I

Surface Water Report

Arafura Resources Limited

Nolans Project Environmental Statement

Appendix I: Surface Water

May 2016

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Appendices

1. Introduction

1.1 Purpose of this report

The purpose of this report is to provide a description of the surface water environment at the Nolans Rare Earths Project site. The report will consider baseline data and records that define the physical, climatic and hydrological conditions of the Nolans site and will undertake modelling to infill missing information. This information will be used to support an assessment of Nolans project impacts on the surface water environment which are documented in EIS Chapter 7. This report also assists with the formulation of water management controls that are presented in the Environmental Management Plan (Appendix X).

1.2 Scope and limitations

This report: has been prepared by GHD for Arafura Resources Limited (Arafura) and may only be used and relied on by Arafura Resources Limited for the purpose agreed between GHD and Arafura Resources Limited as set out in Section 1.1 of this report.

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

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

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

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in throughout this report. GHD disclaims liability arising from any of the assumptions being incorrect.

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

1.3 Assumptions

This report makes use of independent studies including the design of tailings and residue storage facilities[1]. Changes to the required material storage capacity and layout of ponds have occurred in response to a longer Life of Mine design. It has been assumed that the original concept design of tailings and residual storage facilities remains valid and required revisions will only involve a pro-rata increase in their capacity.

Two-dimensional hydraulic modelling carried out as part of this study is for the purpose of identifying areas of flood risk and will not be used for design of mine infrastructure.

[1] Nolans Project Infrastructure Engineering Cost Study. Lycopodium. February 2014

2. Project design

2.1 Overview

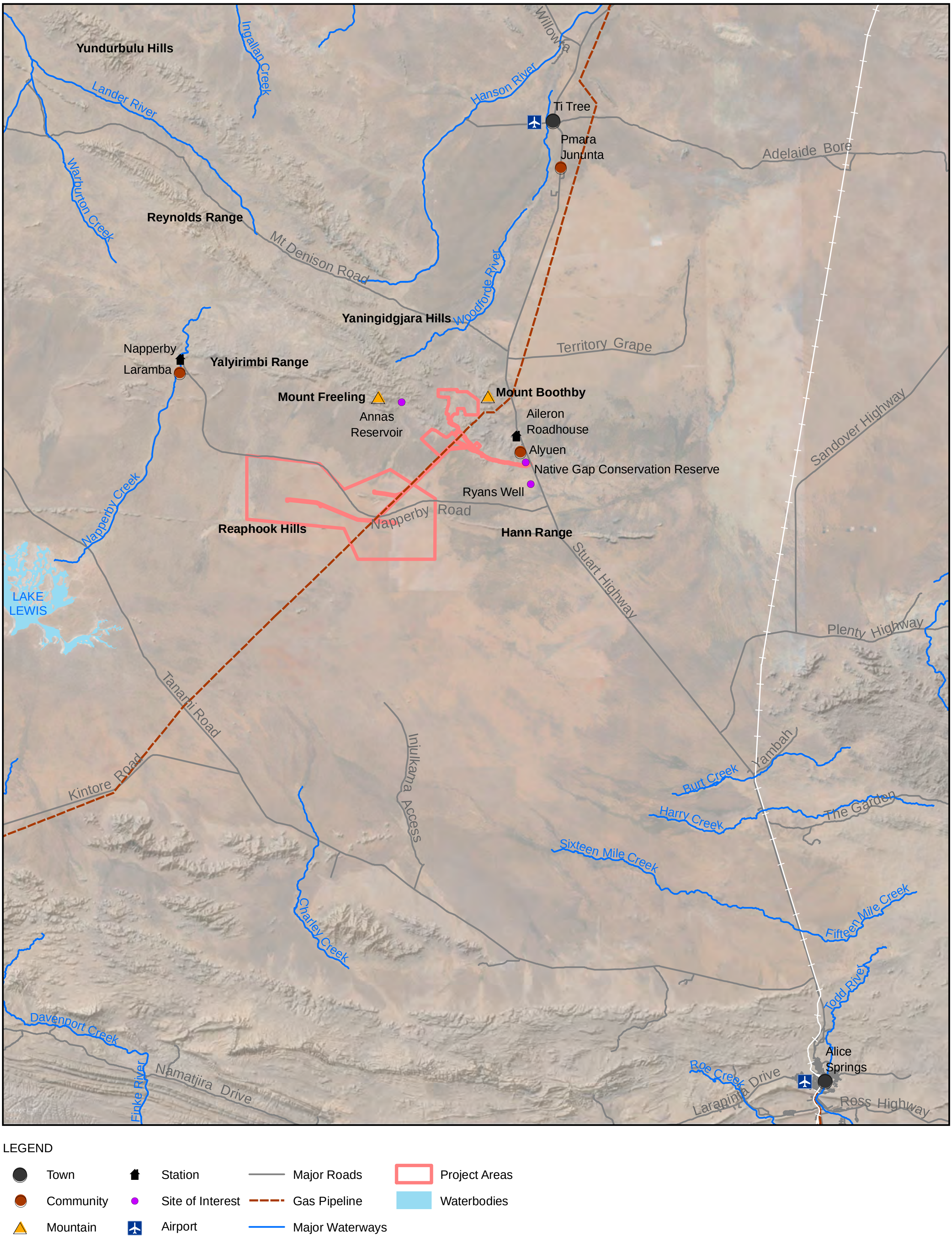
The Nolans project is located 135 kilometres to the north-west of Alice Springs and 10 kilometres west of Aileron community (latitude 22º 33' 55" longitude 133º 14' 20" or 7503560 S 318995 E and Figure 2-1). The Nolans project is currently being designed to produce 20,000 tonnes per annum of rare earths oxide over an operational period of 41 years. The host rock also contains anomalous levels of uranium and thorium.

The open pit is designed to a depth of 225 metres below ground level and is expected to require dewatering to an on-site turkey's nest dam. Overburden and waste material will be deposited in purpose constructed dumps within the mine site. Mining operations will deliver broken rock to a Run-of-Mine pad ("ROM pad") from which a front end loader will feed the crushing circuit. Beneficiation comprises single stage crushing and concentration using a combination of high intensity magnetic separation and froth flotation cells. Flotation tails will be stored within the mine site. The concentrate is pumped to a processing site located 8 km to the south of the mine lease area. The process plant operation will produce four waste streams (water leach residue, neutralisation residue, phosphate residue, excess process liquor) and all will be confined to the site with each stored in a separate facility.

The layout of the project is shown in Figure 2-2 and comprises three principle areas: mine site (14.01 km^2), processing site (15.87 km^2) and worker's village (0.72 km^2) in addition to the water supply borefield (415.69 km^2). Key infrastructure includes:

- Site access roads, comprising:
  - access road from Stuart Highway
  - access road and service corridor between the processing site and concentrator
  - access road and service corridor to the accommodation camp
  - access track and service corridor to the bore fields.
- Accommodation village and associated power, water supply and sewerage treatment.
- Concentrate and filtrate return pipelines and pumps between concentrator and processing site.
- Bore field and raw water supply pipeline to the processing site and concentrator.
- Flotation tailings storage facility (FTSF) at the concentrator site.
- Residue storage facilities (RSFs) at the processing site comprising:
  - Water leach
  - Neutralisation
  - Phosphate
  - Evaporation ponds.
- Waste dumps within the mine site (WD).
- Stormwater management ponds (pit decant water, Waste Dump, ROM pad and processing site runoff)

Further details are given in Chapter 3.



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Job Number 43-22301
Revision 0
Date 18 Mar 2016

Location map

Figure 2-1

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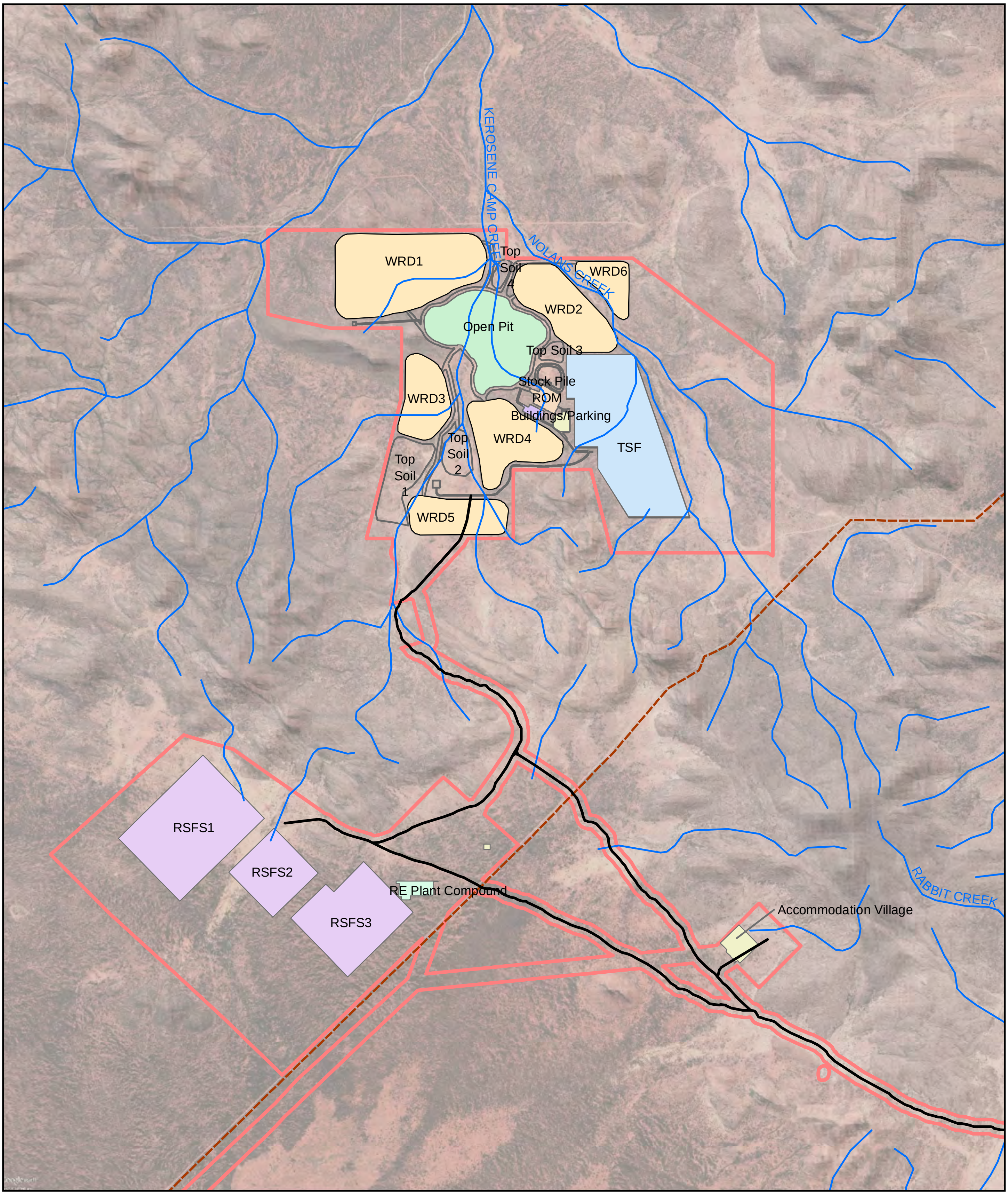
Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/12/2015). ARL - Project Areas (2015). Created by: CM



LEGEND

- Access Road
- Existing Waterways
- Gas Pipeline
- Mine Infrastructure

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0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

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Nolans Project

Job Number	43-22301
Revision	0
Date	29 Apr 2016

Layout of mine site and processing site

Figure 2-2

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 11/02/2016). ARL - Project Areas (2015). GHD - XPRafts Model (2016). Created by: CM

2.2 Accommodation village

The accommodation village is situated on a gently sloping plain at the base of a rocky hill. A small ephemeral watercourse runs at the base of the rocky hill and the proposed layout will make use of the natural grade for drainage, which is relatively flat trending northwest to southwest. Earthworks should generally be restricted to localised building pads; roads and minor grading. The area will also house an additional temporary construction camp.

Potable water will comprise treated water (filtered and chlorinated) pumped from the processing site to the village where it will be stored in a tank sized for two days' storage. A temporary water supply will need to be established as an interim measure for both the construction camp and permanent camp, until the plant supply system is commissioned. Depending on the timing for establishment of bores, it may be necessary to truck potable water to site during construction and the initial operational months.

Sewage will be pumped to a treatment plant located at the processing site.

2.3 Processing site

Concentrate slurry from the concentrator at the mine site would be pumped approximately 8 km to the processing site. The pipeline will run above ground within a bunded corridor. In the event of leaks or pipe failure, slurry will be captured within the bunded corridor and within event ponds located at significant low points along the 8 km alignment. This corridor does not cross creeks with significant upstream catchment area or flood potential

The processing plant and its associated residue storage facilities and storage ponds, namely, Phosphate Residue, Impurity Removal Residue, Water Leach Residue and Sodium Sulphate storage are located west of the gas pipeline and on the south facing slopes in the north eastern headwaters of the Southern Basins. The site is positioned in the head waters of creeks and no established watercourses are present.

2.4 Waste dumps

A combined LOM waste quantity of 159.59 million loose cubic metres (mlcm) will be accommodated in six Waste Dumps (Table 2-1 and Figure 2-3). Waste Dumps will extend over a combined maximum footprint of 590 ha and constructed to a maximum height of about 50 m (to an elevation of RL 730 m) in 10 m lifts.

Material deposited in Waste Dumps is expected to have low sulphur content and low risk of generating acidic, metalliferous or saline leachate (see Appendix L). Should potentially acid forming (PAF) material occur it will be contained and encapsulated within benign waste in designated areas of Waste Dumps.

Table 2-1 Waste dumps and soil storages

Name	Waste Volume (mlcm)	Area (ha)
Waste Dump 1	77.14	212.61
Waste Dump 2	26.87	101.64
Waste Dump 3	14.30	68.22
Waste Dump 4	22.60	99.19
Waste Dump 5	14.57	70.36
Waste Dump 6	4.11	38.04
Top Soil Storage	Not yet known	56.01
Top Soil Storage	Not yet known	22.31
Top Soil Storage	Not yet known	7.61
Top Soil Storage	Not yet known	9.10

Source: Chapter 3 Project Description. Units mlcm = million loose cubic metres

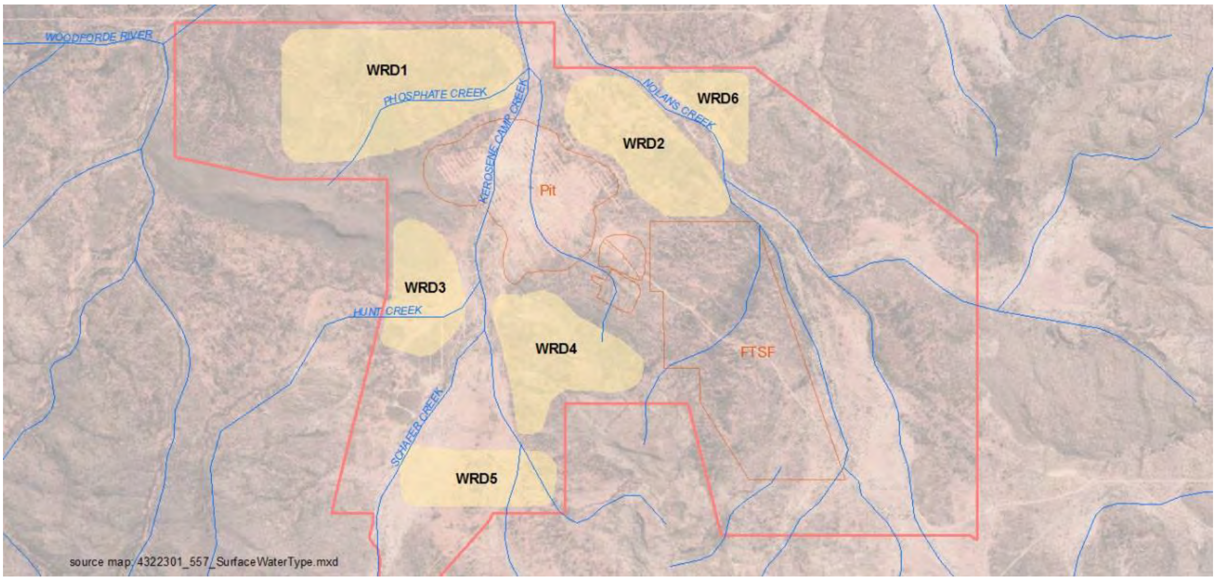


Figure 2-3 Waste dump locations

Waste Dumps will be progressively rehabilitated and closed during the LOM and capped with benign rock.

The overall footprint of topsoil storage requirements has been estimated at 95 ha and areas identified as potential storage locations are located towards the south west of the mine site.

2.5 Tailings and residue storage facilities

Four waste streams will be generated during mining with each waste stream being stored in an individual facility, namely:

1. Flotation tailings from the concentrator at the mine site
2. Phosphate residue from the processing plant
3. Impurity removal residue from the processing plant
4. Water leach residue from the processing plant.

In addition to the above mentioned residue ponds there will be an additional pond which will be designed to concentrate sodium sulfate through evaporation so the liquor can be recycled.

Tailings and residues will be stored in multiple cells. The tailings and residue storage facilities have been recently resized to allow for an increased LOM from 20 years to 43 years. Because a revised design is not currently available, the number of cells in the original design has been increased on a pro-rata basis which increases the footprint as that from the 2012 Ore Reserve design (and that contained in the 2010 Draft BFS)[2]. The combined footprint of the revised tailings and residue storage facilities is approximately 650 hectares.

Flotation Tailings Storage Facility cells will have a soil liner with low permeability over its base and a permanent decant tower to reclaim clarified supernatant for recycle to the processing plant.

Residual Storage Facility cells will incorporate a drainage system over a high density polyethylene (HDPE)/low permeability soil liner system. The purpose of the drainage system is to reduce the water head on the underlying HDPE liner and thus reduce seepage rates. The water from the drainage system will be collected and discharged into the pond within the same facility. Cells have been designed with an emphasis on containment but this may change following chemical characterisation of process residues with an emphasis on recovery of entrained water or seepage. Stored water will evaporate and will not be recycled to the processing plant due to the quality of the water and its detrimental impact on the recovery of rare earths in the processing plant.

The evaporation and sodium sulfate ponds will be lined with an HDPE liner. Excess liquor plus RO plant reject and treated sewage effluent will be directed to one of the evaporation ponds after which the flow will be directed to the next pond in sequence. Over time the liquor will concentrate through evaporation and the remaining brine in the cell will be pumped to the impurity removal RSF to reduce the accumulation of precipitate in the evaporation ponds. The cell will then be available to receive excess liquor for the next cycle

Arafura Resources Limited intends to design and manage Nolans Site as a zero process water discharge operation. Details of a preliminary design for tailings and residue storage facilities are given in Section 4.3 [3] (Knight PiesoldFeb, 2014).

Tailings and residue storage facilities will be covered with a layer of benign stable rock at closure to reduce the potential for radioactive 'shine', limit natural erosion and provide long term protection.

[2] See Appendix E of this EIS for original design drawings

[3] Nolans Project Infrastructure Engineering Cost Study. Lycopodium. February 2014

Table 2-2 Tailings and Residue Storage Facilities

Name	Embankment Height (m)	Number of Cells – LOM 20 years	Number of Cells – LOM 43 years [f]	Area per Cell (ha)	Water Storage Capacity per Cell (ML)	Tailings / Residue Storage per Cell (Mt) [d]
Flotation Tailings	25.1	2	5	20	10.00 [a]	9
Phosphate Residue	24.0	2	5	12	3.73 [b]	2.9
Impurity Removal Residue	24.1	2	5	33	15.58 [b]	11.9
Water Leach Residue	20.9	2	5	35	18.37 [b]	7.2
Evaporation Concentrator	3.1 [e]	6	13	10	660 [c]	0
Sulphate concentrator	3.1 [e]	3	7	10	Not yet known	0

Source: all values taken from Appendix 3.6 of Nolans Project Infrastructure Engineering Cost Study. Lycopodium. February 2014 within: [a] Table 4.3, [b] Table 4.5, [c] Section 5.1. [d] Table 5.1.

Notes: [e] to retain the required PMP freeboard during initial filling Evaporation Ponds will require embankment crest heights of 3.1 m rather than the previously calculated 2.5 m. [f] original number of cells increased pro-rata by relative LOM.

2.6 Open pit

There will be an initial two year period of construction and preparation followed by 41 years of production involving seven open pit stages (Figure 2-4 and Figure 2-5)[4]. The open pit will require dewatering to an on-site turkey's nest pond. Operation of the pit will also require the diversion of Kerosene Camp Creek. The existing creek traverses the area of the proposed pit and it is proposed to divert its course westwards of the mine site and into the upper reaches of a tributary of Kerosene Camp Creek.

Following a risk assessment of alternative options for the diversion of Kerosene Camp Creek a preferred diversion option D was identified. This option comprises a 3.6 kilometre trapezoidal channel with 0.1 percent average gradient and four metre base width diverting Kerosene Camp Creek to the north-west of the mine site. A levee will be required at the upstream extent of the diversion to prevent overbank flows from entering the proposed pit.

Further investigations have been carried out to examine the hydraulic performance of diversion option D in terms of its impact on the flow regime upstream of its inlet and downstream of its outlet (details are provided in Appendix A).

[4] Source: Arafura Resources (NOL sched INF nl37B.08.01 (final).xlsx and nl37B_stg_1_to_7.dxf)

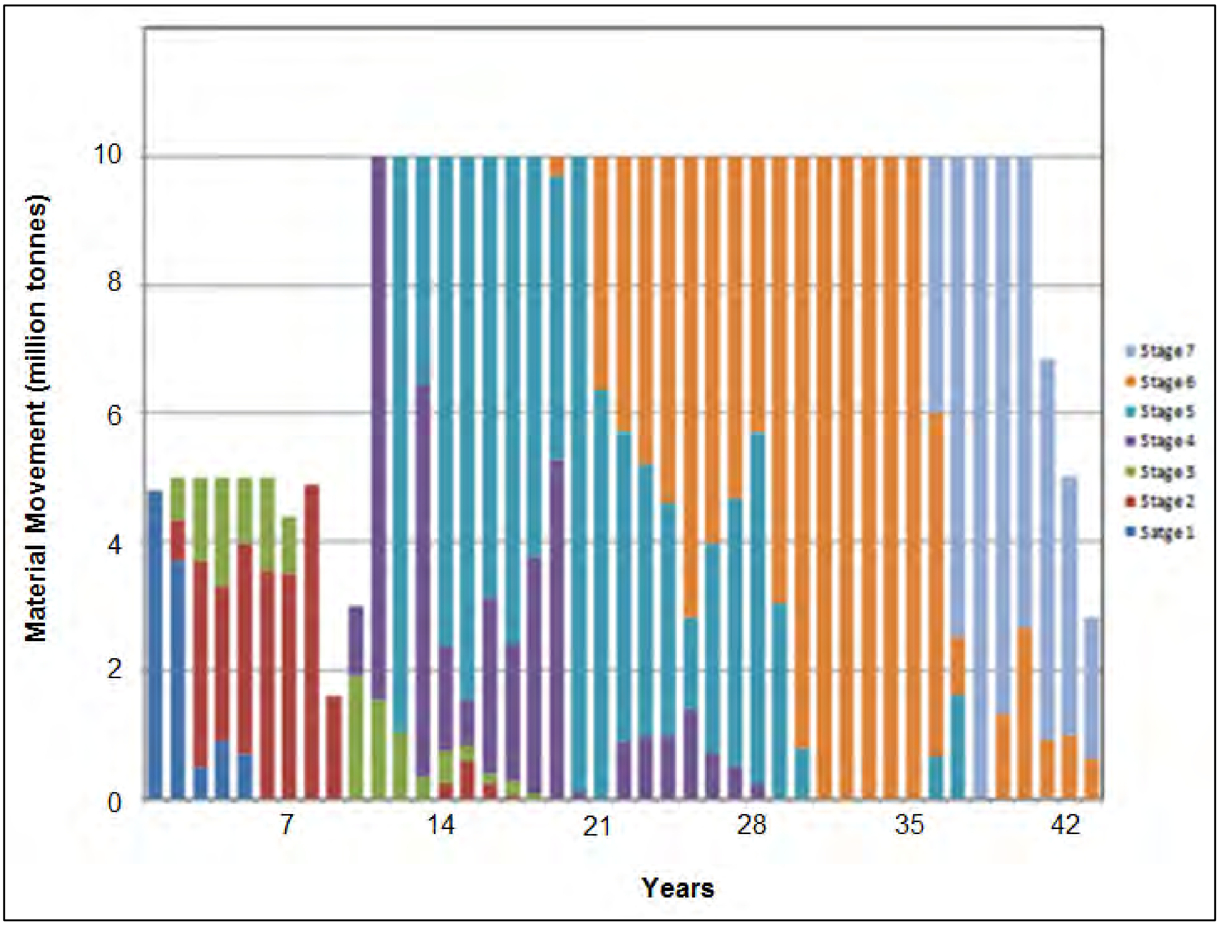


Figure 2-4 Sequence of pit development

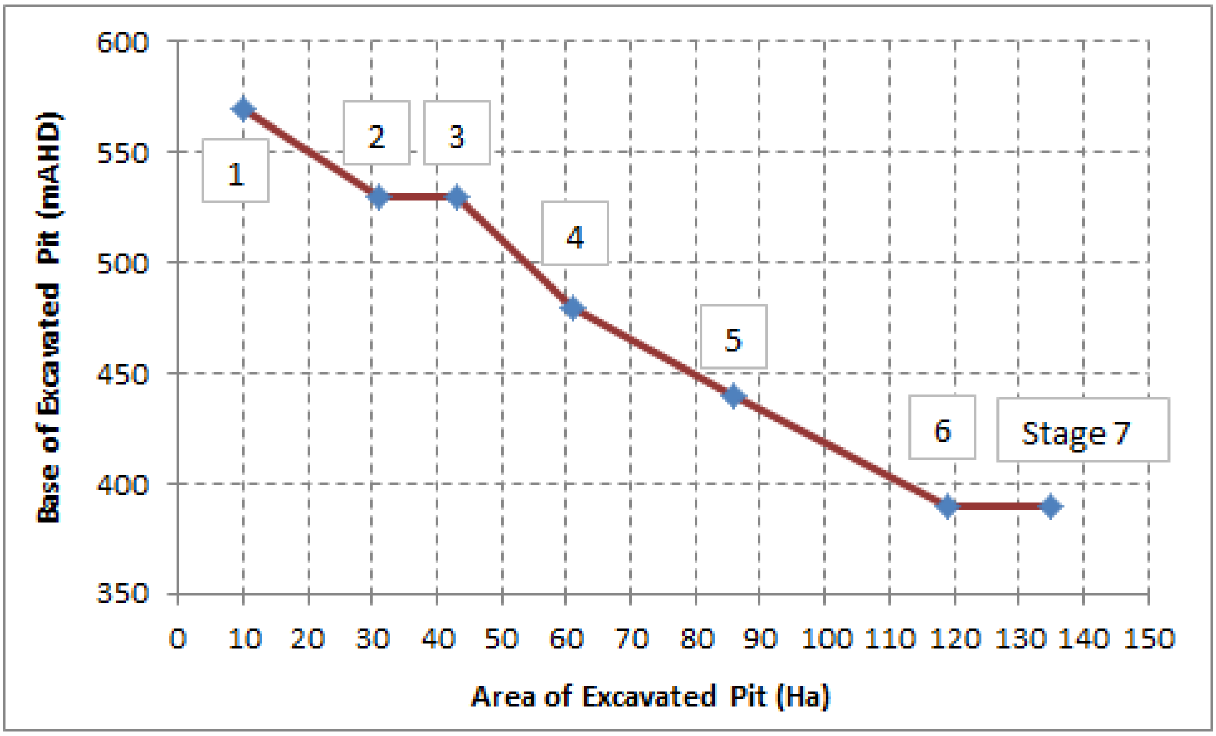


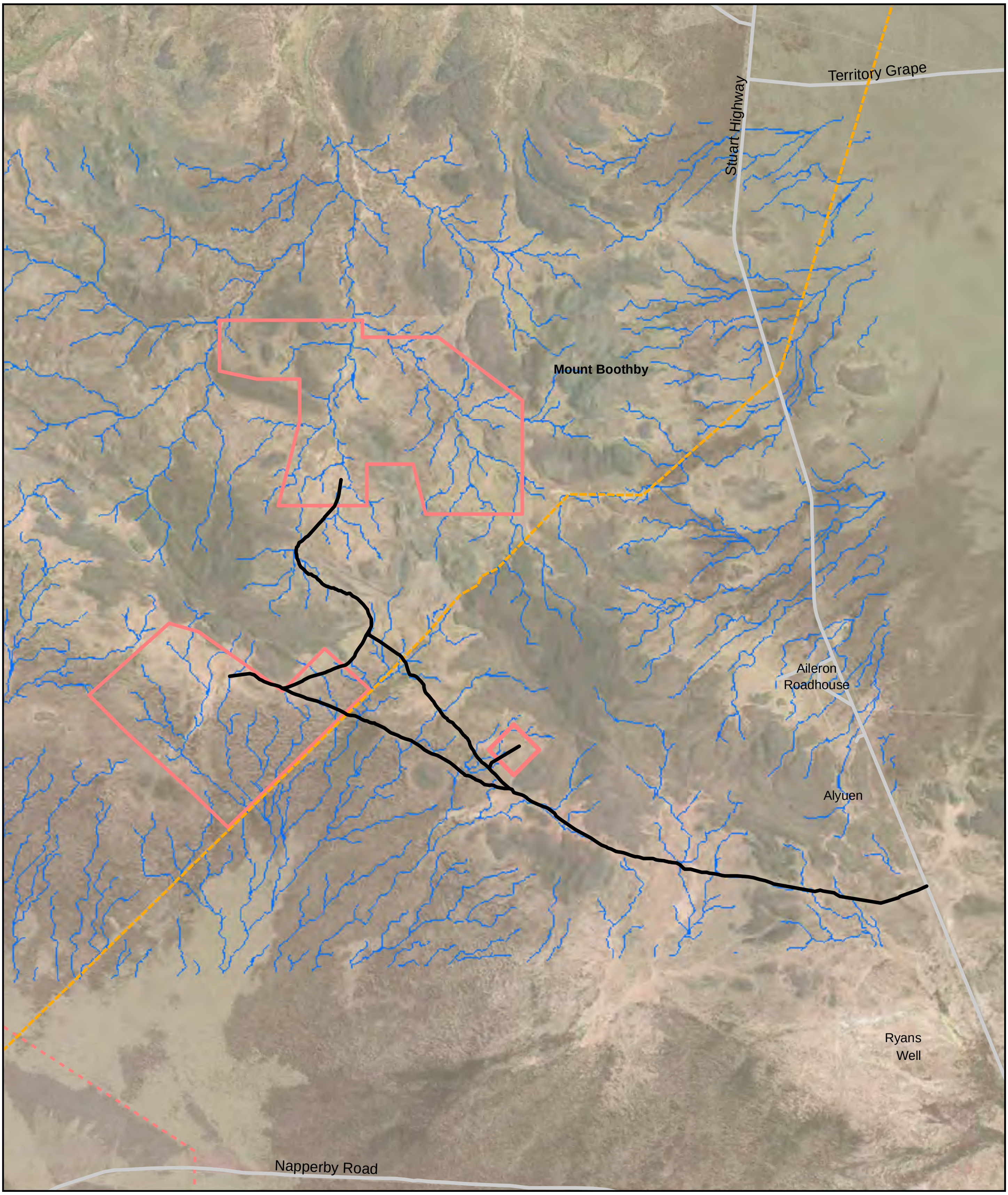
Figure 2-5 Geometry of pit excavation

2.7 Haul roads and access roads

The crossing of creeks is unavoidable and it is envisaged that this will involve floodways or culverts. Access roads/tracks and haul roads will comprise construction of roads (see also Figure 2-2):

- from the Stuart Highway (intersection with Stuart Highway approximately 5 km south of the Aileron Roadhouse access road) to the processing site
- between the processing site and the mine site
- from the processing site to the accommodation village
- from the processing site to the borefield area.

The main access road from the Stuart Highway to the processing site will be a sealed road with signage, road markings, etc. also suitable for anticipated occasional public use. The internal road between the processing site and the mine site will be of gravel construction whilst other project roads, including those to the borefield, will likely be of a lesser quality.



LEGEND

- Major Roads
- Natural drainage
- Existing Access Track
- Site Boundaries
- Gas Pipeline

1:125,000 @ A4

0 1 2 3 4

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Nolans Project

Job Number	43-22301
Revision	0
Date	22 Mar 2016

Access road and natural drainage

Figure 2-6

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Level 5, 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: GA - Roads, Placenames, Placenames, Lakes, Images (2015). ESRI - Shaded Relief (2009). ARL - Project Areas (2015). GHD - Natural drainage (2016). Created by: CM

3. Baseline Description

3.1 Topography, land use and third party infrastructure

The proposed mine site lies at the head of the Kerosene Camp Creek valley on the north facing slopes of an east – west trending ridge of the Reynolds Range, whilst the processing site is situated on the southern slopes of the same ridge. Topographic elevation is 886 m above sea level (m ASL) at Mt Boothby to the east of the mine site, and 1006 m ASL at Mt Freeling to the west. Most of the Kerosene Camp Creek valley floor at the mine site is typically between 650 and 700 m ASL whilst the processing site is at an elevation of about 670 mASL. Longitudinal gradients along local creeks to the north and south of the ridge line are typically less than 0.5 percent with steeper gradients of about 10 percent on isolated hills.

Third party infrastructure in the vicinity of Nolans site includes:

- APA's Amadeus Basin to Darwin gas pipeline which runs south west to north east along the south eastern boundary of the processing site and is buried to a depth of about 1 m
- Stuart Highway which runs north – south about 10 km to the east of Nolans site and does not cross surface watercourses downstream of the site
- Napperby Station/Laramba access road which runs east – west about 12 km to the south of processing site and traverses minor surface watercourses downstream of the processing site.

3.2 Climate

The closest weather station to the mine site that provides a full suite of climate measurements is located at Territory Grape Farm (015643)[5] about 50 km to the north-east at an altitude of 566 m AHD.

Prevailing winds are from the south east and mean monthly minimum and maximum temperatures are likely to range between 5.2 ºC in July and 37.3 ºC in January. Further detail is given in Table 3-1.

Table 3-1 Climate data – Territory grape farm (BoM)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)												
Maximum[1]	**37.3**	36.2	34.3	30.5	25.5	22.2	22.5	25.3	30.5	33.3	35.6	36.3
Minimum[2]	**21.9**	21.6	19.5	14.6	9.5	6.2	5.2	7.1	12.1	15.6	18.8	21.1
Humidity (%)												
Mean 9 am	38	40	37	37	47	**53**	51	38	32	32	34	37
Mean 3 pm	24	**28**	27	25	27	**28**	**28**	22	21	21	22	26
Wind (km/h)												
Mean 9 am	17.0	18.1	**19.7**	18.9	15.2	12.8	14.3	17.3	18.2	19.6	18.2	18.0
Mean 3 pm	15.8	**16.7**	16.6	14.9	14.2	13.5	14.0	16.0	15.5	14.8	14.1	14.5

[5] Bureau of Meteorology: http://www.bom.gov.au/climate/data/stations/

3.2.1 Rainfall records

A rainfall gauge was installed at the proposed mine site in 2008 and has been recording 15-minute rainfall totals. During this period annual rainfall ranged between 173 mm to 1634 mm (mean 629 mm). The recorded rainfall in year 2009 contains some exceptionally high monthly rainfall totals (485 mm and 728 mm) which are not reflected in the records of Bureau of Meteorology gauges in the area and creates uncertainty in the representativeness of the mean annual rainfall estimate.

Bureau of Meteorology rainfall gauges in the area are listed in Table 3-2 and their location relative to the proposed mine site is shown in Figure 3-1. The nearest rainfall gauge to the mine site is located at Aileron approximately 15 km to the east of the site. Unfortunately, the record at Aileron contains a significant proportion of gaps (20 percent).

Data from Bureau of Meteorology stations within 50 km of the mine site, namely Aileron, Pine Hill, Napperby, and Territory Grape Farm (Table 3-2), indicates that long term mean annual rainfall at the proposed mine site is likely to be about 310 mm. Annual rainfall totals are highly variable from year to year and almost 50 percent of annual rainfall can occur within a single month.

Most rainfall tends to occur in summer months although historical maximum daily totals of 94 mm and 142 mm were recorded at Napperby and Pine Hill, respectively, in May 1968.

Previous studies of the proposed mine have relied on the rainfall record at Alice Springs Airport. Whilst the record has few, if any data gaps, it is situated 146 km to the south of the mine site and is unlikely to be representative of climatic conditions at the mine site. Comparison of the long-term average rainfall at Alice Springs Airport with gauges at Aileron, Pine Hill and Napperby suggests its recorded rainfall is 8% lower than that of the gauges further north and closer to the mine site. This difference is most likely due to the influence of nearby hills.

The cause of major rainfall events is the occasional southward extension of the monsoon trough and incursion of north-west cloud bands. In summer, the position of the monsoon trough can deviate far southwards allowing moisture laden north-westerly air flow to penetrate the semi-arid interior. Also, bands of moisture laden air at high altitude, which originate from the Indian Ocean, can move south-east across the interior resulting in late autumn and early winter rainfall. Thunderstorms do occur but are often ‘dry’ storms with most or all rain evaporating before reaching the ground [6].

The seasonal distribution of rainfall from the Napperby rainfall gauge and potential evaporation based on data from Alice Springs Airport is compared in Figure 3-2. This shows that on average monthly rainfall is about one seventh monthly potential evaporation but monthly rainfall can exceed potential evaporation in very wet months.

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[6] Australian Bureau of Statistics. http://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/1301.0Feature%20Article22006?open

Table 3-2 Rainfall gauges

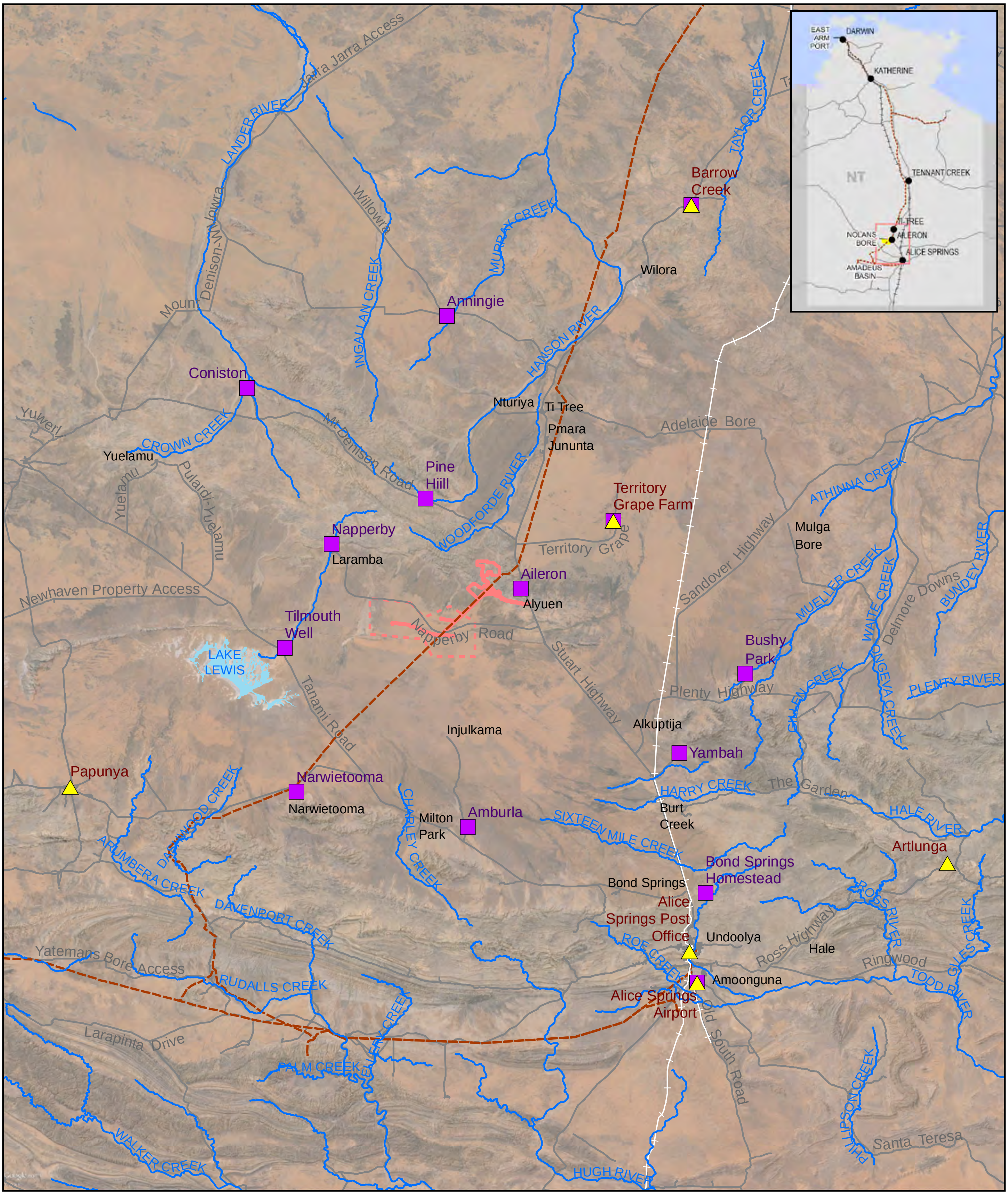
Gauge Number	Name	Lat	Long	Record Start	Record End	Record Length (years)	Distance from Mine Site	Mean Annual Rainfall (mm)
-	Nolans Mine	22.56	133.24	Sep 2008	open	8	0	314
015543	Aileron	22.646	133.346	1949	2009	60	15 km	301
015507	Pine Hill	22.380	133.050	1967	open	48	32 km	348
015518	Napperby	22.509	132.752	1955	2014	59	48 km	309
015643	Territory Grape Farm	22.452	133.638	1987	Open	28	49 km	319
015658	Tilmouth Well	22.81	132.60	1991	Open	24	64 km	nc
015515	Amburla	23.34	133.17	1968	Open	47	78 km	nc
015501	Yambah	23.13	133.84	1968	Open	47	84 km	nc
015650	Narwietooma	23.23	132.63	1989	Open	26	88 km	nc
015542	Anningie	21.848	133.123	1941	Open	74	88 km	nc
015596	Bushy Park	22.90	134.05	1954	Open	61	91 km	nc
015553	Hamilton Downs	22.90	134.05	1958	Open	57	96 km	nc
015535	Coniston	22.050	132.495	1948	Open	77	97 km	nc
015631	Bond Springs Homestead	23.54	133.92	1901	Open	114	124 km	nc
015525	Barrow Creek	21.532	133.890	1874	2014	140	142 km	nc
015590	Alice Springs Airport	23.800	133.890	1940	Open	75	146 km	nc

Notes: nc = not calculated for gauges over 50 km from mine site.

Table 3-3 Mean monthly rainfall

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Napperby (years 1955 to 2014) mm												
55	55	39	22	21	11	14	6	7	19	30	40	309
Alice Springs (years 1942 to 2015) mm												
41	43	31	17	18	13	15	9	8	21	29	37	282
Mine Site (years 2011 to 2014) mm [a]												
48	73	68	30	11	5	6	1	1	3	35	32	314

Source: Bureau of Meteorology and Arafura Resources Ltd. Notes: [a] excludes uncertain values in years 2009 and 2010.



LEGEND

- BOM Evaporation Gauge
- BOM Rain Gauge
- Major Waterways
- Gas Pipeline
- Major Roads
- Borefield Area
- Project Areas
- Waterbodies

1:1,700,000 @ A4

0 10 20 30 40 50

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Location of rainfall, evaporation and flow gauges

Job Number	43-22301
Revision	0
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Figure 3-1

G:\43\22301\GIS\Maps\4322301_564_RainEvapGauges.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 01/02/2016). ARL - Project Areas (2015). BOM - Gauges (2015). Created by: CM

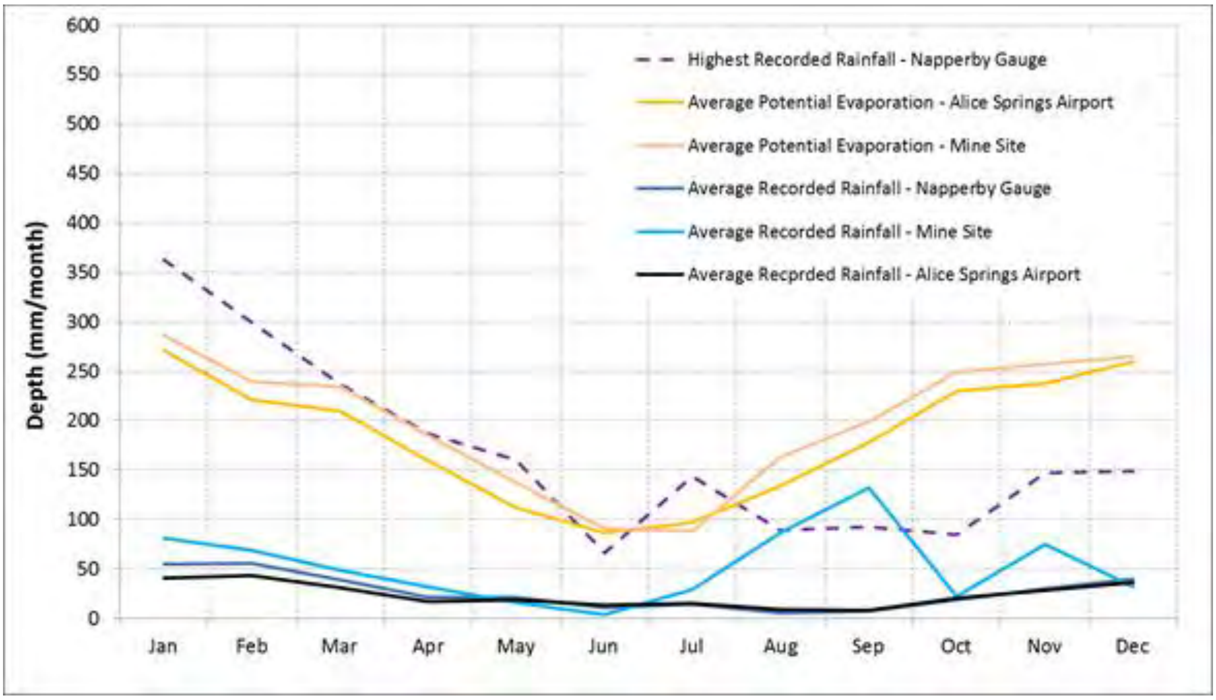


Figure 3-2 Seasonal distribution of rainfall and evaporation

Table 3-4 shows predicted rainfall intensities for a range of storm durations and average recurrence intervals as determined by the Bureau of Meteorology. For example, a 100-year ARI 24-hour rainfall intensity (9.53 mm/hr) is almost twice the 10-year ARI 24-hour rainfall intensity (5.03 mm/hr) and one eighth the 100-year ARI 1-hour rainfall intensity. In general, higher rainfall intensity occurs over short durations, also higher rainfall intensity events are a less frequent occurrence than lower intensity rainfall events.

Table 3-4 Rainfall intensity – duration – frequency data

Units mm/hr	Frequency as an Average Recurrence Interval						
Duration	**1 year**	**2 year**	**5 year**	**10 year**	**20 year**	**50 year**	**100 year**
5 mins	56.0	74.3	104	123	147	180	205
6 mins	52.2	69.4	97.5	115	138	168	192
10 mins	43.5	58.0	81.9	97.0	116	142	163
20 mins	33.5	44.7	63.4	75.4	90.5	111	128
30 mins	27.9	37.2	53.0	63.2	76.0	93.5	107
1 hr	18.9	25.4	36.6	43.8	52.9	65.5	75.5
2 hrs	11.8	15.9	23.4	28.3	34.4	42.9	49.7
3 hrs	8.72	11.8	17.6	21.4	26.2	32.8	38.2
6 hrs	5.11	6.98	10.6	13.1	16.1	20.5	24.0
12 hrs	3.04	4.19	6.47	8.04	10.0	12.8	15.1
24 hrs	1.87	2.59	4.03	5.03	6.28	8.07	9.53
48 hrs	1.15	1.59	2.48	3.09	3.85	4.95	5.85
72 hrs	0.827	1.14	1.78	2.22	2.78	3.57	4.23

3.2.1 Evaporation records

Evaporation gauges in the area are listed in Table 3-5 and their location relative to the proposed mine site is shown in Figure 3-1. The nearest evaporation gauge to the mine site is located at Territory Grape Farm 50 km to the north east but this record is of limited length (7 years).

An evaporation pan has been recording potential evaporation at the proposed mine site since September 2008. During this period annual potential evaporation rates ranged between 2111 mm to 3162 mm (average 2396 mm). It is unclear if the reported data represents evaporation as measured by the pan or whether it has been adjusted by pan factors to account for the scale effects of the instrument.

The nearest evaporation pan gauge with a long-term record is located at Alice Springs Airport. This 75-year record exhibits a mean annual potential evaporation rate of 2196 mm (assuming monthly pan factors ranging between 0.67 to 0.78). Evaporation is less spatially variable than rainfall and despite the distance from the mine site recorded evaporation at Alice Springs can be expected to be similar to conditions at the site.

Actual evaporation is constrained by available water and rates are much lower than potential rates. Therefore, actual evaporation will closely match rainfall throughout the year and virtually all the rain that does fall will evaporate.

Table 3-5 Evaporation gauges

Gauge Number	Name	Lat	Long	Record Start	Record End	Record Length (years)	Distance from Mine Site	Mean Annual Potential Evaporation (mm) b
-	Nolans Mine	22.56	133.24	Sep 2008	open	8	0	2396 [b]
015643	Territory Grape Farm	22.452	133.638	1987	2003	7	50 km	-
015540	Alice Springs Post Office	23.71	133.868	1890	1953	54	136 km	-
015525	Barrow Creek	21.532	133.890	1967	1988	21	142 km	-
015612	Papunya	23.204	131.916	2000	open	15	145 km	-
015590	Alice Springs Airport	23.800	133.890	1940	open	75	146 km	2196 [a]
015594	Arltunga	23.456	134.685	2000	open	15	176 km	-

Notes: [a] adjusted by pan factors (0.67 to 0.78) [b] it is unclear whether the reported evaporation record has been adjusted by pan factors or whether it represents the raw pan evaporation values.

Table 3-6 Mean monthly potential evaporation

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Alice Springs (years 1959 to 2015) mm												
271	221	210	159	112	87	97	134	178	230	238	259	2196
Mine Site (years 2009 to 2014) mm												
286	240	235	185	137	91	89	163	200	249	257	265	2396

Source: Bureau of Meteorology and Arafura Resources Ltd.

3.3 Surface runoff

3.3.1 Watercourses

Semi-arid regions such as the area in which the mine is located are typically characterised by conditions in which actual evaporation closely matches rainfall and virtually all rainfall evaporates resulting in almost no surface runoff. This general situation will alter if intense rainfall occurs. Therefore, the occurrence of surface runoff and flows within local creeks is likely to be infrequent and only occur during exceptional rainfall events, such as those associated with the occasional southward extension of a monsoon trough or periodic incursion of north-west cloud bands over the interior of the continent.

Creek beds tend to be mobile with deep sand deposition and banks that show signs of active erosion. Channels are typically a metre deep with a base width of five metres. During infrequent, intense rainfall events out-of-bank flow can be expected leading to temporary and short-term flooding of adjacent lands.

Kerosene Camp Creek is an ephemeral creek and flows through the centre of the mine site before joining with a major tributary three kilometres further to the north where after it eventually flows into Woodforde River. Minor tributaries of Kerosene Camp Creek occur upstream of the mine site between the processing site and mine site and have a combined catchment area of about 16 km^2 and includes two unnamed creeks (Figure 3-3).

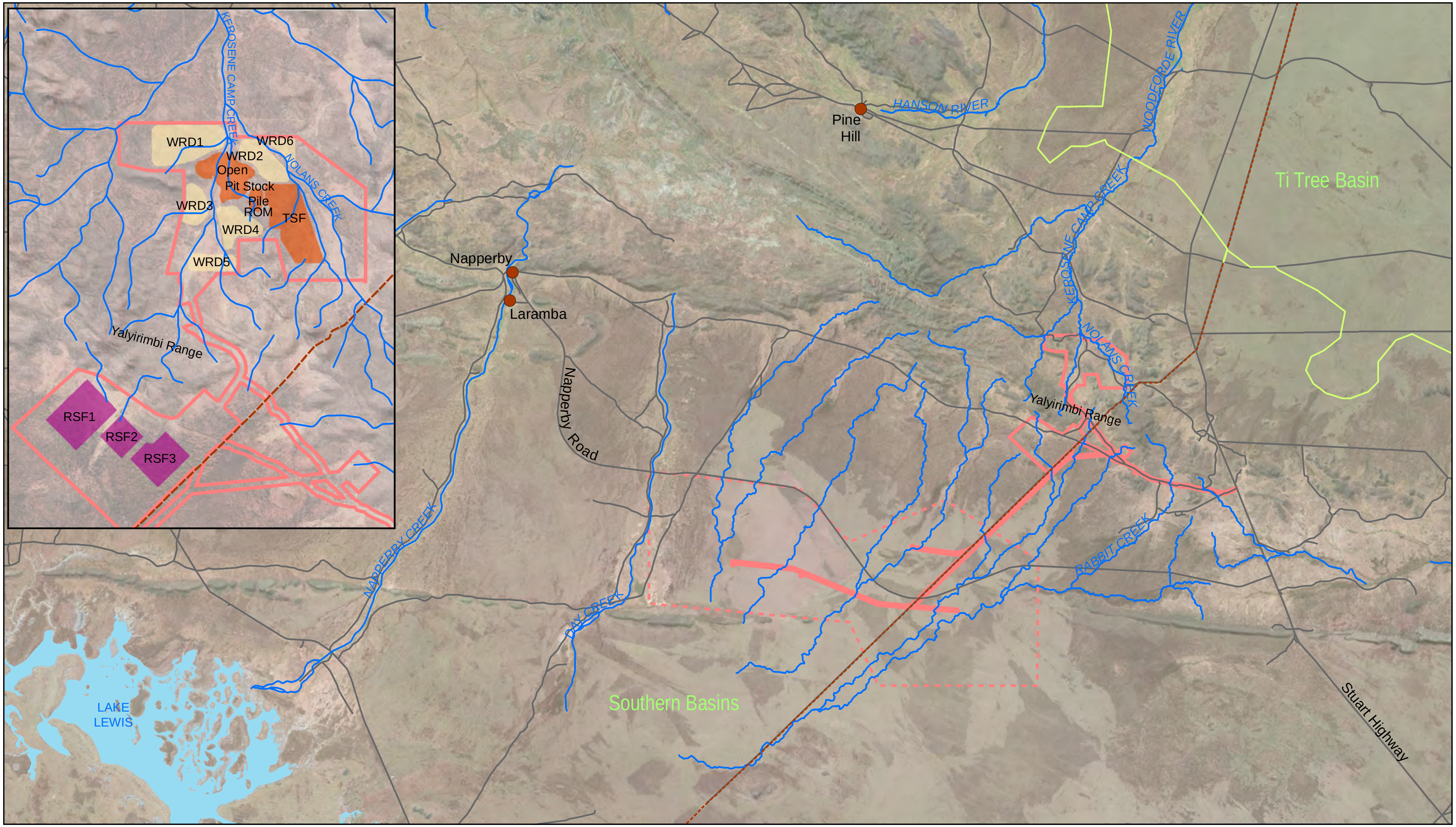
Nolans Creek is a major tributary of Kerosene Camp Creek and has a catchment area of about 26 km^2 upstream of the mine site. It flows adjacent to the eastern boundary of the proposed Flotation Tailings Storage Facility and will pass between Waste Rock Dumps 2 and 6 where after it joins Kerosene Camp Creek (Figure 3-3).

The mine site is located on the south western fringe of the Ti Tree Water Allocation Area. The Woodforde River, into which Kerosene Camp Creek flows, passes through the western margins of the Ti Tree Basin aquifer and is about 20 km downstream of the mine site. The aquifer at this location along the Woodforde River is about 60 m below ground level (~550 m ASL)[7] and is down gradient of the mine site (Figure 3-3).

The access road from the Stuart Highway crosses the drainage paths from catchments on the upper slopes of the Yalyirimbi Range. Drainage continues to flow towards the Southern Basins and Lake Lewis 70 km to the west. Catchments upstream of the access road are relatively small, typically less than 3 km^2 with one catchment of about 12 km^2 located towards the eastern end of the access road (Figure 3-3).

The processing site also receives drainage from the upper slopes of the Yalyirimbi Range. Due to their small catchment area channels tend to be ill-defined with runoff likely to be dispersed across the south facing hillslope before combining into distinct creeks which eventually drain into the Southern Basins and Lake Lewis 70 km to the west. Catchments upstream of the processing plant are typically less than 1 km^2 in extent (Figure 3-3).

[7] Map of The Ti-Tree Basin Aquifer, Department of Natural Resources, Environment and Arts. Sept 2007.



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0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Outstations and Communities
- Water Resource Basins
- Gas Pipelines
- Major Waterways
- Roads
- Borefield Area
- Project Areas
- Waterbodies

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Surface drainage network

Figure 3-3

G:\43\22301\GIS\Maps\4322301_560_SurfaceDrainageNetwork.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: Geoscience Australia, GeoTOPO 250K, v3/2006; Department of Mines and Energy, Mineral Titles, Strike Download/10/03/2015; DPLE, Tenure/Cadastre, 2015. Created by:cmacgregor

3.3.2 Flow records

Long-term gauging of flow in watercourses (Table 3-7) that traverse or connect with drainage from the mine site is, or has been, carried out at only one location, namely Arden Soak Bore on the Woodforde River (Figure 3-1). This gauge is located 26 km downstream of the proposed mine and comprises a water level gauge board in a sandy river bed. A second gauge at Allungra Waterhole is located about 42 km to the east and is outside the catchment of the proposed mine site and its infrastructure. The Arden Soak Bore and Allungra gauges both provide records of water level from which discharge can be calculated. Gauging of water levels is also carried out at a third location, Pine Hill on the Hanson River, which is situated 33 km to the west and is also outside the catchment of the mine site and its infrastructure. No flow records are available for this latter gauge.

Arden Soak Bore on the Woodforde River measures runoff from a catchment area (393 km^2) that is an order of magnitude greater than that subtended by the mine site (54 km^2). However, given the similarity of catchment conditions the recorded time series of water levels and discharge are likely to be indicative of the pattern of runoff (but not the magnitude) from catchments at the mine site.

An analysis of the flow record at Arden Soak Bore (Figure 3-4) confirms that flow events are relatively infrequent with only 25 percent of days during the 41 year record having a total daily flow greater than 3 Ml (arbitrarily selected threshold discharge of 0.03 m^3/s). Runoff is most likely in months during the summer season, December to March (Figure 3-5). The low frequency of flow events suggests that only one or two flow events can be expected in most years (Figure 3-6).

The maximum recorded flow at Arden Soak Bore on Woodforde River is 206 m^3/s and occurred in January 2010 (Figure 3-7) with a measured water depth of 3.7 m. Whilst this flow was recorded 26 km downstream of the proposed mine site it serves to show the relatively 'flashy' response and short duration of flow events for drainage systems in this region.

Both the flow frequency curve (Figure 3-4) and hydrograph of the maximum recorded flow event (Figure 3-7) at Arden Soak Bore on Woodforde River illustrate the absence of baseflow (surface flow sustained by groundwater). However, anecdotal evidence[8] states that during 2010 and 2011 (wet years) water drained out of the local hills for months and a 'soak' upstream of the mine site was wet most of the year. This suggests that surface runoff infiltrates to the alluvium of creek channels where after it will form shallow groundwater flow moving down gradient along the creek channel.

The volume of surface runoff relative to locally recorded rainfall for the January 2010 event at Arden Soak Bore is estimated to be nine percent and indicates relatively high rainfall losses of over 90 percent. What proportion of this 'loss' infiltrates to a shallow aquifer and what proportion is lost to the atmosphere through evapotranspiration is uncertain but serves to confirm the typically low rate of surface runoff in the area.

It is understood that surface water monitoring has been carried out at the mine site during recent years. Given the infrequency of rainfall – runoff events and lack of stage – discharge rating curves for the gauged sites, it is unlikely this data provides a continuous record of runoff during storm events.

.

[8] Nolans Feasibility Study – Preliminary Studies Site Drainage and Land Tenure, AMC Consultants, February 2015. Comments on report by K Hussey.

Table 3-7 Hydrometric gauges

Type	Gauge Number	Name	Lat	Long	Record Start	Record End	Record Length (years)	Location Relative to Mine Site
River Flow	0280010	Woodforde River - Arden Soak	22.367	133.324	1974	open	41	same river system 26 km downstream
River Flow	0280004	Allungra Creek - Allungra Waterhole	22.689	133.631	1996	open	19	different river system 42 km to east
River Height	0280010	Woodforde River - Arden Soak Bore	22.367	133.324	1974	open	41	same river system 26 km downstream
River Height	0280004	Allungra Creek - Allungra Waterhole	22.689	133.631	1996	open	19	different river system 42 km to east
River Height	0280021	Hanson River At Pine Hill	22.367	133.025	1968	1977	9	different river system 33 km to west
Surface Water Quality	0280010	Woodforde River - Arden Soak Bore	22.367	133.324	1974	open	41	same river system 26 km downstream
Surface Water Quality	0280004	Allungra Creek - Allungra Waterhole	22.689	133.631	1996	open	19	different river system 42 km to east

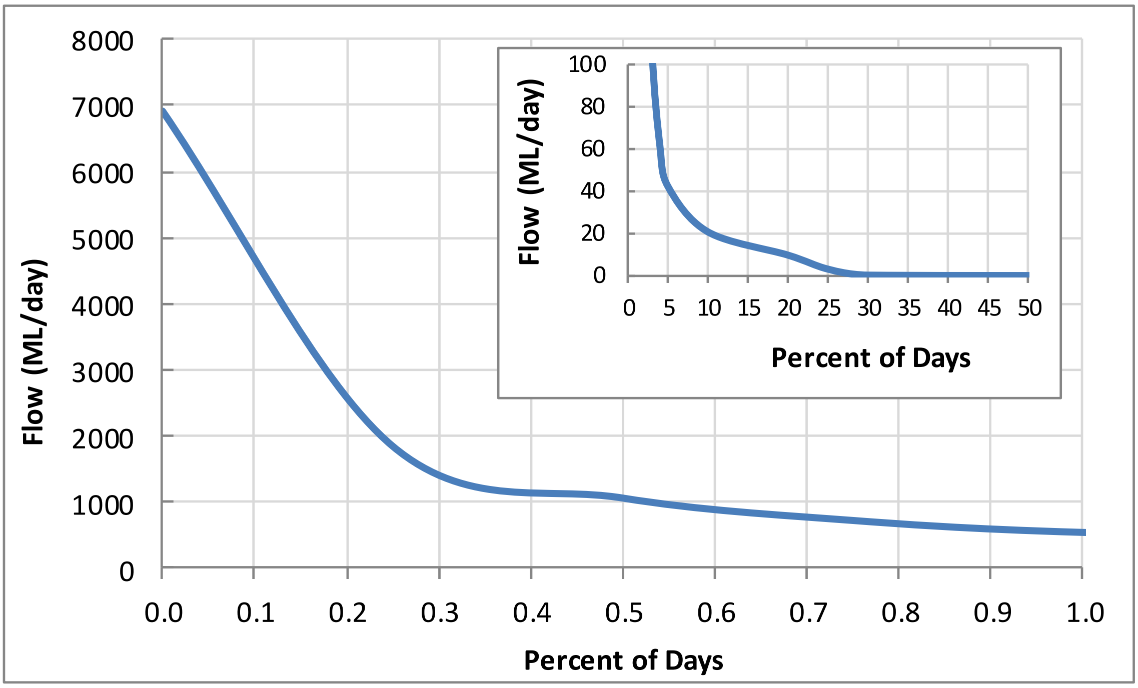


Figure 3-4 Flow frequency curve for Woodforde River at Arden Soak Bore

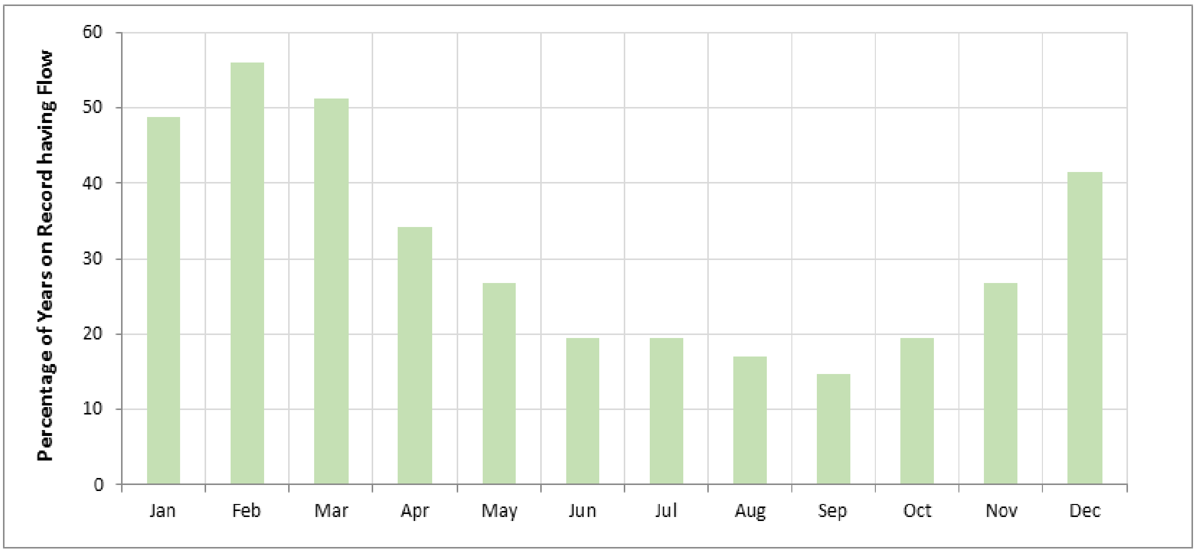


Figure 3-5 Occurrence of flow at Arden Soak Bore on Woodforde River

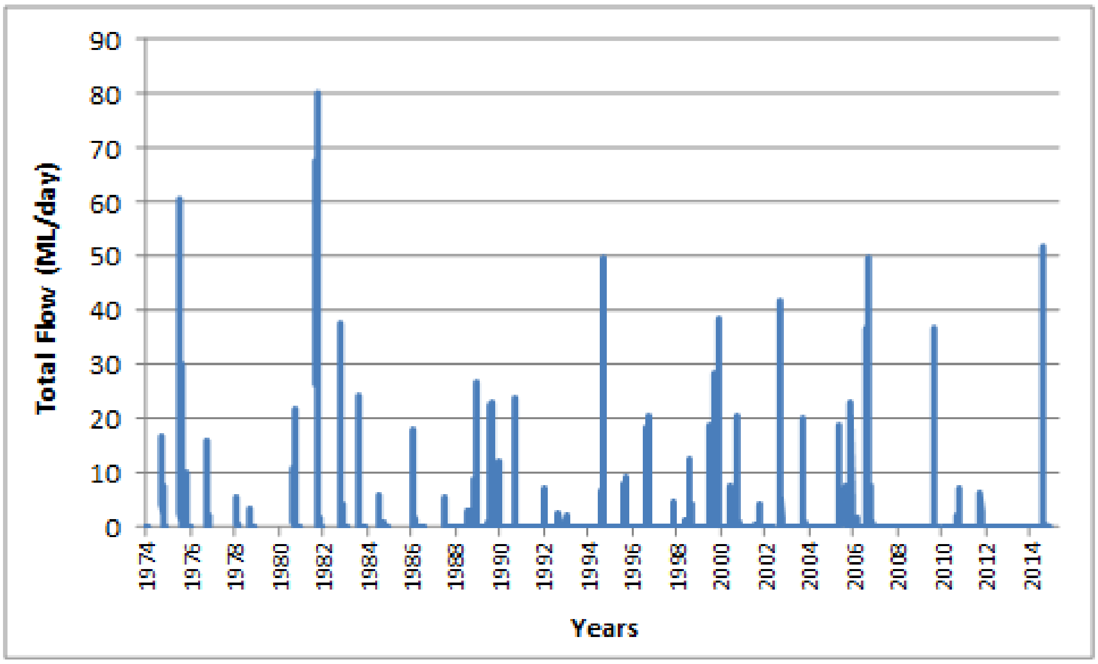


Figure 3-6 Time series of recorded flow at Arden Soak Bore on Woodforde River

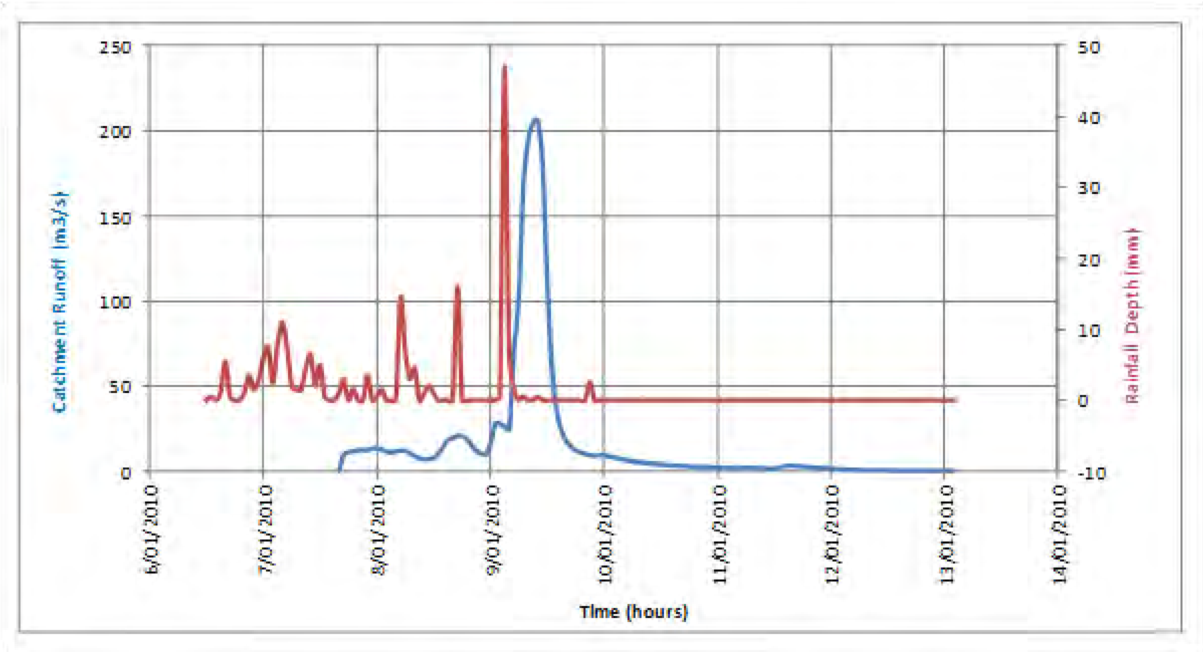


Figure 3-7 Maximum recorded flow at Arden Soak Bore on Woodforde River

3.4 Flood risk

Recorded flow events are infrequent and the probability of the mine site experiencing flood events with annual recurrence intervals of between 10 and 100 years during the 43-year LOM can be summarised as follows[9]:

- 10-year ARI flood event has a 99 percent probability of occurring during the LOM
- 50-year ARI flood event has a 58 percent probability of occurring during the LOM
- 100-year ARI flood event has a 35 percent probability of occurring during the LOM
- 1000-year ARI flood event has a 4 percent probability of occurring during the LOM.

It is assumed that mine infrastructure will be protected against the effects of flooding with an average recurrence interval (ARI) of 1 in 1000-years. The extent and depth of flooding across the existing Nolans site during a 1000-year ARI event together with an indication of flow velocity have been obtained by 2-D rain-on-grid flood modelling. Due to the limited extent of detailed topographic data and the preliminary stage of mine infrastructure design this was considered an expedient method to obtain an initial measure of existing flood risk across the entire site against which the impacts of the mine site can be compared. Details of model implementation are given in Appendix B.

The lateral extent, depth, and velocity of flooding for existing site conditions (pre-mining) is shown in Figure 3-8 and a summary of indicative flood depth and velocity at significant locations is given in Table 3-8. Flood peak discharge along the two creeks flowing through the proposed mine site (Kerosene Camp Creek and Nolans Creek) has been obtained from hydrological modelling details of which can be found in Appendix C. Estimates of flood peak discharge assume a 4.5-hour storm rainfall event which is equivalent to the time of concentration for catchments draining to the downstream boundary of the proposed mine site. It is recognised that the critical storm duration will vary across the site and therefore more detailed modelling will be required during the design stage.

Preliminary modelling shows the extent of flooding along Kerosene Camp Creek and Nolans Creek and it would be preferable for mine infrastructure to be located outside these areas. If this proves impractical then flood protection measures commensurate with the depth and velocity of flooding will be required.

Modelling predicts that flood depths and flood velocities during a 1000-year ARI event assuming existing pre-mining conditions are not expected to exceed 1.5 m and 1 m/s, respectively, along creeks within the proposed mine site. Whilst flood depths and flood velocities are expected to be less than 1 m and 0.5 m/s, respectively, along watercourses within the proposed treatment site and accommodation village.

The 1000-year ARI flood extent and depth following development of the mine is reported in Section 5.4.3

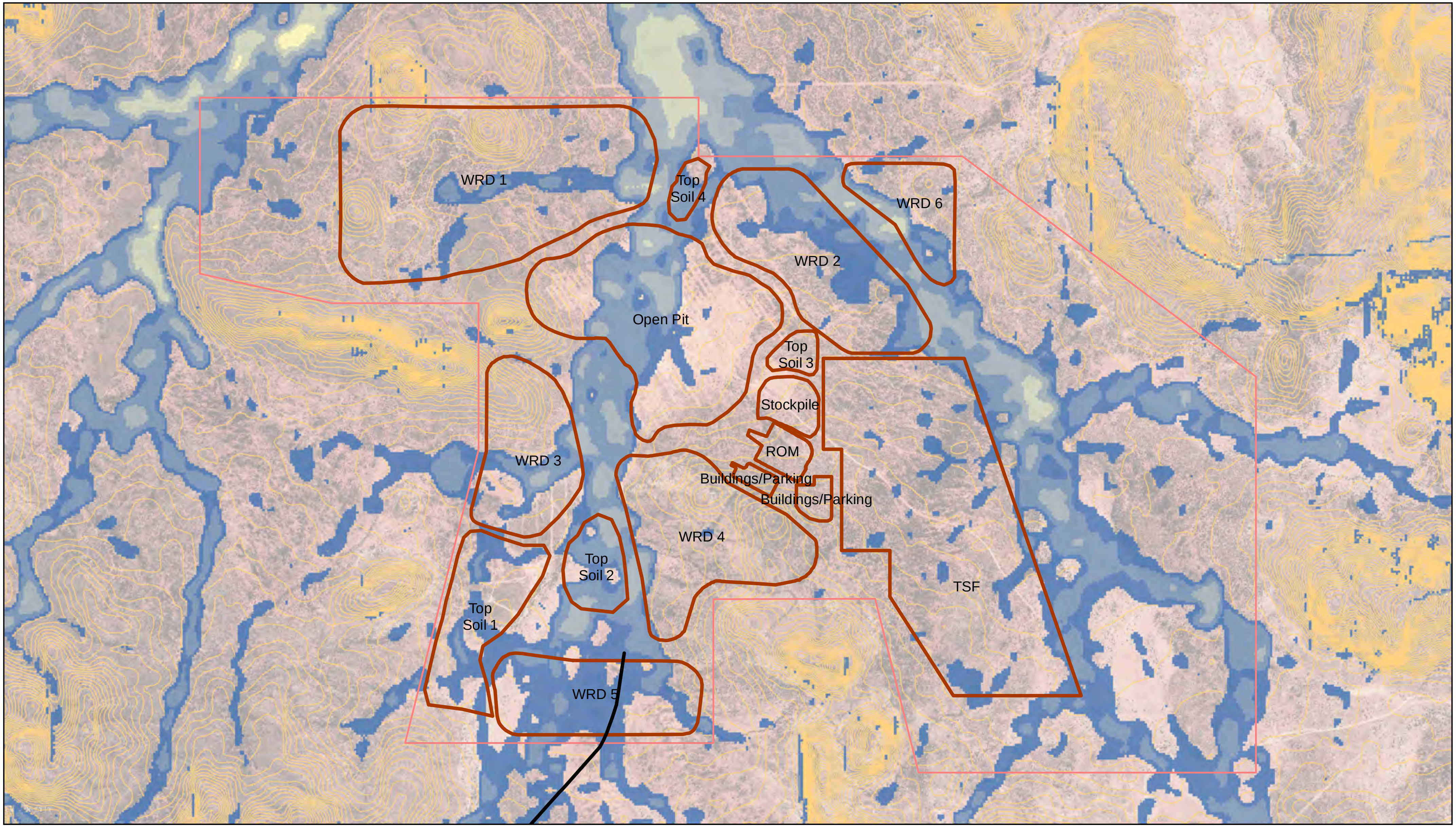
Table 3-8 Design flood characteristics – pre-mining

Creek	Location	Upstream Area (km2)	1 in 1000-year ARI – 4.5 hr flood event [a]	
			Velocity (m/s)	Depth (m)
Nolans	upstream mine site boundary	26.3	0.9	1.3
Nolans	downstream mine site boundary	28.2	0.6	1.3

[9] Pr = 1 – ((1-(1/ARI))^LOM) where ARI is average recurrence interval and LOM is life of mine

Creek	Location	Upstream Area (km2)	1 in 1000-year ARI – 4.5 hr flood event [a]	
			Velocity (m/s)	Depth (m)
Kerosene Camp	upstream mine site boundary	12.3	0.3	0.2
Kerosene Camp	proposed diversion inlet	20.4	0.8	1.0
Kerosene Camp	downstream mine site boundary	25.8	0.7	1.6
Kerosene Camp	downstream of confluence of Kerosene Camp Creek and Nolans Creek	58.7	0.7	1.7
Tributary of Kerosene Camp	proposed diversion outlet	46.0	0.7	1.8

Notes: [a] storm duration corresponds to the time of concentration at mine site boundary.



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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Proposed Haul Roads
- 2m Contours
- Proposed Infrastructure
- Mine Site Boundary

Pre-Mining Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 4.0 - 4.5

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Revision 0
Date 29 Apr 2016

Flood depth for 1000 year
ARI design storm event - pre-mining Figure **3-8**

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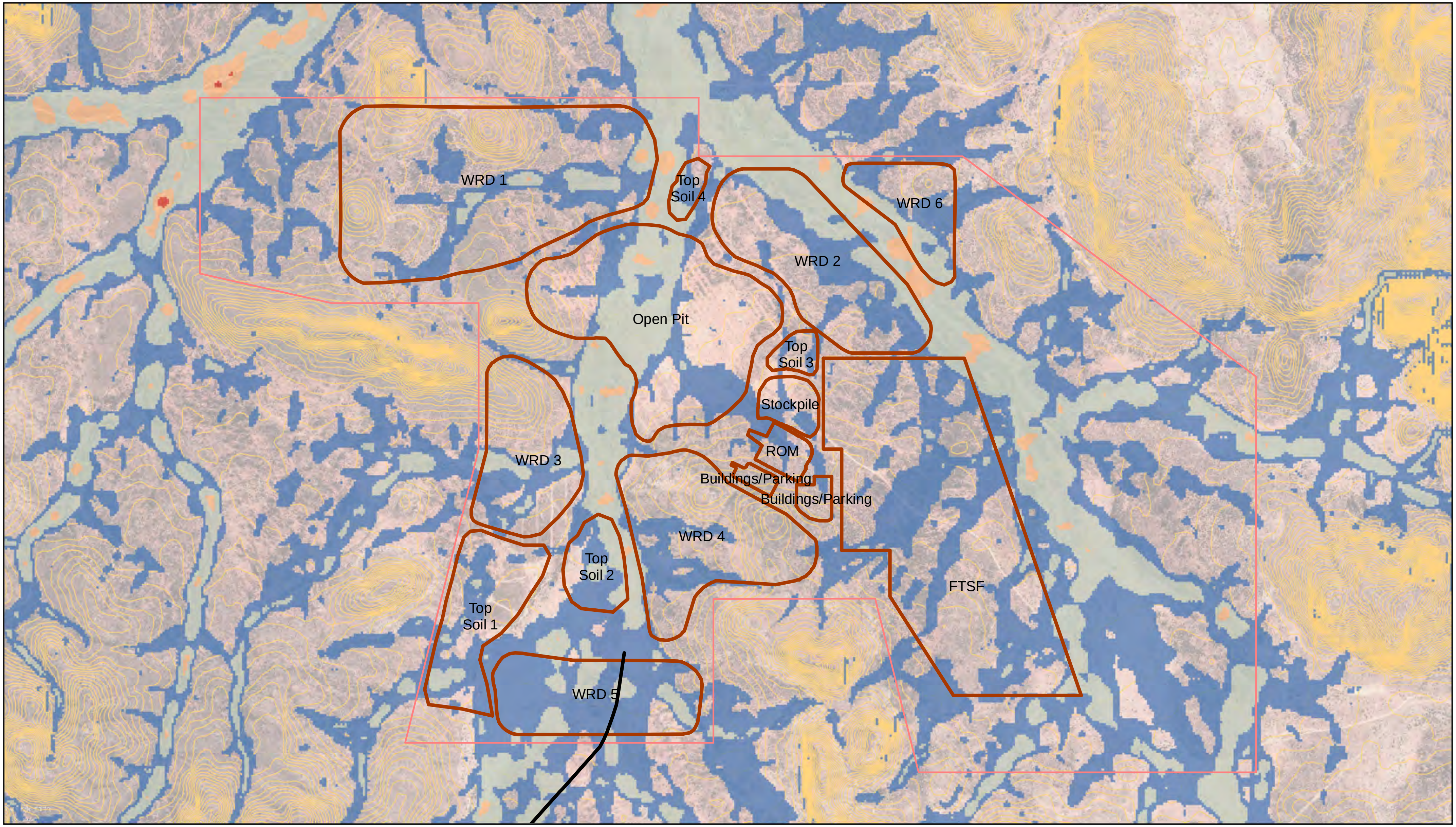
Level 5 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Haul Roads, Existing Creek Channels, Proposed Infrastructure (2015). CSIRO - 2m Contours (derived from SRTM) (2015). GHD - Flood Data (2016). Created by: CM



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0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

Proposed Haul Roads

2m Contours

Proposed Infrastructure

Proposed Mine Site Boundary

Pre-Mining Flood Velocity (m/s)

0.0 - 0.5

0.5 - 1.0

1.0 - 1.5

1.5 - 2.0

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Flood velocity for 1000 year ARI event - pre-mining

Figure 3-9

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Level 5 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Haul Roads, Existing Creek Channels, Proposed Infrastructure (2015). CSIRO - 2m Contours (derived from SRTM) (2015). GHD - Flood Data (2016). Created by: CM

3.5 Water quality

The character of surface water quality is influenced by land use and the mineral composition of soils and near-surface geology. The absence of a sustained baseflow contribution to watercourses is likely to limit the influence of deeper bedrock geology on surface water quality.

The geology of the area comprises greenschist to granulite facies metamorphic rocks with granitic intrusions overlain by alluvial sediments in the west and central parts and sheetflow fan sediments in the east. Land use is rangeland cattle grazing. Bloodwood open woodland predominates with minor riparian red gum woodland along Kerosene Camp Creek and Mulga or Acacia woodlands on flood plains, hills and rises.

Baseline ambient water quality of surface water systems (when they flow) has been determined from the results of water monitoring. Surface water quality records are available from the Department of Land Resource Management water data portal. This data is limited to just two locations in the vicinity of the mine site, namely Arden Soak Bore (G0280010) which is on the Woodforde River 26 km downstream of the mine site, and Allungra Waterhole (G0280004) which is on a different river system 42 km to the east of the mine site. These records are limited to just a few individual samples taken in February and March 2011 (Table 3-9).

Table 3-9 Surface water quality recorded data

Gauge	Date	Conductivity µS/cm)	Turbidity field (NTU)	Temperature (ºC)	pH	Dissolved oxygen (mg/l)
Arden Soak Bore on Woodforde River	8/2/2011	77	119	29.62	6.48	6.99
Arden Soak Bore on Woodforde River	14/3/2011	68	631	25.24	6.36	8.05
Allungra Waterhole on Allungra Creek	5/2/2011	76	369	29.66	6.51	4.8
Allungra Waterhole on Allungra Creek	8/2/2011	56	88	28.35	6.41	4.66
Allungra Waterhole on Allungra Creek	16/3/2011	79	170	26.66	6.9	-

The available records include physical and chemical stressors that describe water quality conditions that are potentially directly toxic to biota (salinity, pH, DO and temperature) and stressors that are non-toxic but can directly affect ecosystems and biota (turbidity).

Salinity, pH and temperature are naturally variable both seasonally and spatially among and within ecosystem types causing natural biological communities to adapt to site-specific conditions. Therefore, trigger values for these three stressors may need to be based on site-specific biological effects data.

Stressors can indirectly affect biota by affecting other stressors. Dissolved oxygen can influence redox conditions and influence the uptake or release of nutrients by sediments. pH and suspended particulate matter can have a major effect on the bioavailable concentrations of most heavy metals.

ANZECC guidelines state the following:

- Based on aesthetic considerations, turbidity should not exceed 5 NTU
- Temperature is primarily an aesthetic criterion for drinking water. No guideline is set due to the impracticality of controlling water temperature
- No health-based guideline value for pH
- Should dissolved oxygen concentration fall below 5 mg/l then aquatic life is put under stress. No health-based guideline value has been set for dissolved oxygen
- An electrical conductivity value of less than 0.5 ppt (50 mg/l ~ 83 µS/cm) is essentially indicative of fresh water.

The water sampled in Woodforde River was fresh but very turbid, neutral in pH and with sufficient dissolved oxygen to support aquatic life. Conditions at the mine site may exhibit higher salinity and turbidity due to the lower volume of flow and thus a smaller dilution capacity.

3.6 Geomorphology of watercourses

Creeks flowing through the mine site are characterised by low sinuosity channels (i.e. generally straight with gentle bends) with a grade of approximately 1 in 400 (0.25%).

The existing channel of Kerosene Camp Creek has bankfull widths in the order of 10 to 15 metres and depths in the range of 1 to 2 metres. The channel invert typically consists of a relatively featureless bed of sand with some gravel. In cross-section, the channel is symmetrical and relatively simplistic in form with limited evidence of features such as pools, bars or benches. Banks are composed of alluvially deposited sand and silt and are vegetated with low grasses and scattered shrubs and trees. Bedrock occasionally outcrops in the banks and bed providing some control on channel form and bed levels.

Nolans Creek is set within a terraced valley with the contemporary valley floor extending up to approximately 100 metres. The inset floodplains typically bound either side of the channel, with the surrounding terrace surfaces rising 1 to 2 metres above the floodplains. Based on bank exposures the floodplains are likely to be dominantly composed of silty sand. The floodplain surfaces are largely vegetated and low shrubs and are dissected by shallow flood channels.

3.7 Surface – groundwater interaction

The geology of the mine site and processing site comprises greenschist to granulite facies metamorphic rocks with granitic intrusions overlain by alluvial sediments in the west and central parts and sheetflow fan sediments in the east. The ore body is known, from exploration drilling, to be bounded in all directions by the Proterozoic Arunta Block gneissic granite host rock.

Local aquifers are thought to approximately correspond to the geographical extent of the mine site ore body which is surrounded by much lower permeability rocks that act as an aquitard[10]. The areal extent of the aquifer based on the mineralisation zone and pumping test analyses is expected to be in the order of one hundred metres to the north, west and south and five hundred metres to the east of abstraction bore NBGW819[11]. It is also expected that due to the porous nature of soils in the area and the surface outcropping of the apatite, that the aquifer will be recharged directly from surface infiltration during infrequent rainfall events, and by leakage through the overlying creek bed when Kerosene Camp Creek is flowing.

[10] Environmental Earth Sciences (June 2010) Work progress report for open pit dewatering investigation at Nolan's Bore, via Aileron, NT. Letter report to Arafura Resources Ltd.
[11] Hydrogeological Open Pit Dewatering Investigation, Nolan's Bore, Via Aileron, NT. Environmental Earth Sciences. (July 2011)

Regionally, the mine site rests on the southern margin of the Ti Tree Basin which is located 20 kilometres downstream and to the north of the mine site. The aquifer is about 60 metres below the ground surface.

The processing plant is located on the northern margin of the Whitcherry Basin which is part of what is termed the Southern Basins; parts of which drain towards Lake Lewis 70 kilometres downstream of the processing site. Whilst the two basins are considered to be connected, the ridge line between the mine site and processing site is considered to be a subtle groundwater divide with water flowing north of the divide to the Ti-Tree Basin and south of the divide to the Southern Basins.[12].

The ephemeral nature of the creeks indicates no sustained support of surface flow from groundwater. Also, the large disparity between evaporation and rainfall throughout the year suggests that recharge of aquifers is limited to periods of intense rainfall which are infrequent (once or twice a year) and relatively short lived. The duration of aquifer recharge from smaller creeks in the vicinity of the mine site is therefore likely to be in the order of days.

A detailed description of the hydrogeological setting is given in Chapter 8.

3.8 Water users

3.8.1 Environment

Environmental water use is constrained by the sporadic nature of rainfall and surface runoff. Vegetation and fauna are either capable of surviving in between rainfall events or are able to access shallow groundwater. Depth to groundwater is generally greater than the reach of root systems except along watercourses where the channel alluvium provides access to shallow groundwater particularly along the Woodforde River downstream of the proposed mine site. Riparian vegetation is dominated by red gum (*Eucalyptus camaldulensis*) with localised occurrences of bean tree (*Erythrina vespertilio*) and ghost gum (*Corymbia aparrerinja*) along Kerosene Camp Creek and Nolans Creek with *Acacia aneura* (Mulga) woodland in flood out areas in the lower reaches of catchments particularly the South Basins (Figure 3-10).

Rock pools occur along drainage lines or in depressions in outcropping rock across the study area and surrounding hills. These features are filled by rainfall and or surface runoff and provide a source of water for environmental use until depleted by evaporation.

Lake Lewis and its surrounds is a site of conservation significance with a rating of National Significance. The processing site is located in the headwaters of the Southern Basins, parts of which drain towards Lake Lewis, 70 km to the north east of the lake.

3.8.2 Agriculture

The area of the mine and processing site is currently being used for rangeland cattle grazing and stockwater is extracted from groundwater throughout the region (Figure 3-10). About 45 km to the north east irrigation water for agriculture is extracted from the Ti-Tree Basin aquifer.

Drinking water is supplied from groundwater to a number of communities in the wider region including Ti-Tree (60 km to north), Pmara Jutunta (55 km to north), Laramba (Napperby) (50 km to north-west), Alyuen (15 km to the east) and Aileron Roadhouse (13 km to the east).

According to the DLRM database there are 66 registered bores within a 10 km radius of the mine lease area of which many are abandoned or not in use, whilst some appear to be in use.

[12] Hydrogeological Study Preliminary Background and Model Geometry Report for Internal (Project) Comment. GHD (November 2015)

Of the operational bores, the following are located in close proximity to surface water channels downstream of the mine site:

- Bore RN010759 - Kerosene Well (Pine Hill Station) is located close the confluence of Kerosene Camp Creek and a major tributary about 8 km downstream of the mine lease area and was completed in 1974 to a depth of 52 m; the bore has been used for stock water purposes and has a yield of 2.3 l/s with Total Dissolved Solids of 2,290 mg/L.
- Bore RN012624 - Kerosene Well (Pine Hill Station) is located close the confluence of Kerosene Camp Creek and a major tributary about 8 km downstream of the mine lease area and was completed in 1980 to a depth of 58 m; the bore has been used for stock water purposes and has a yield of 1.1 l/s with Total Dissolved Solids of 2,510 mg/L.

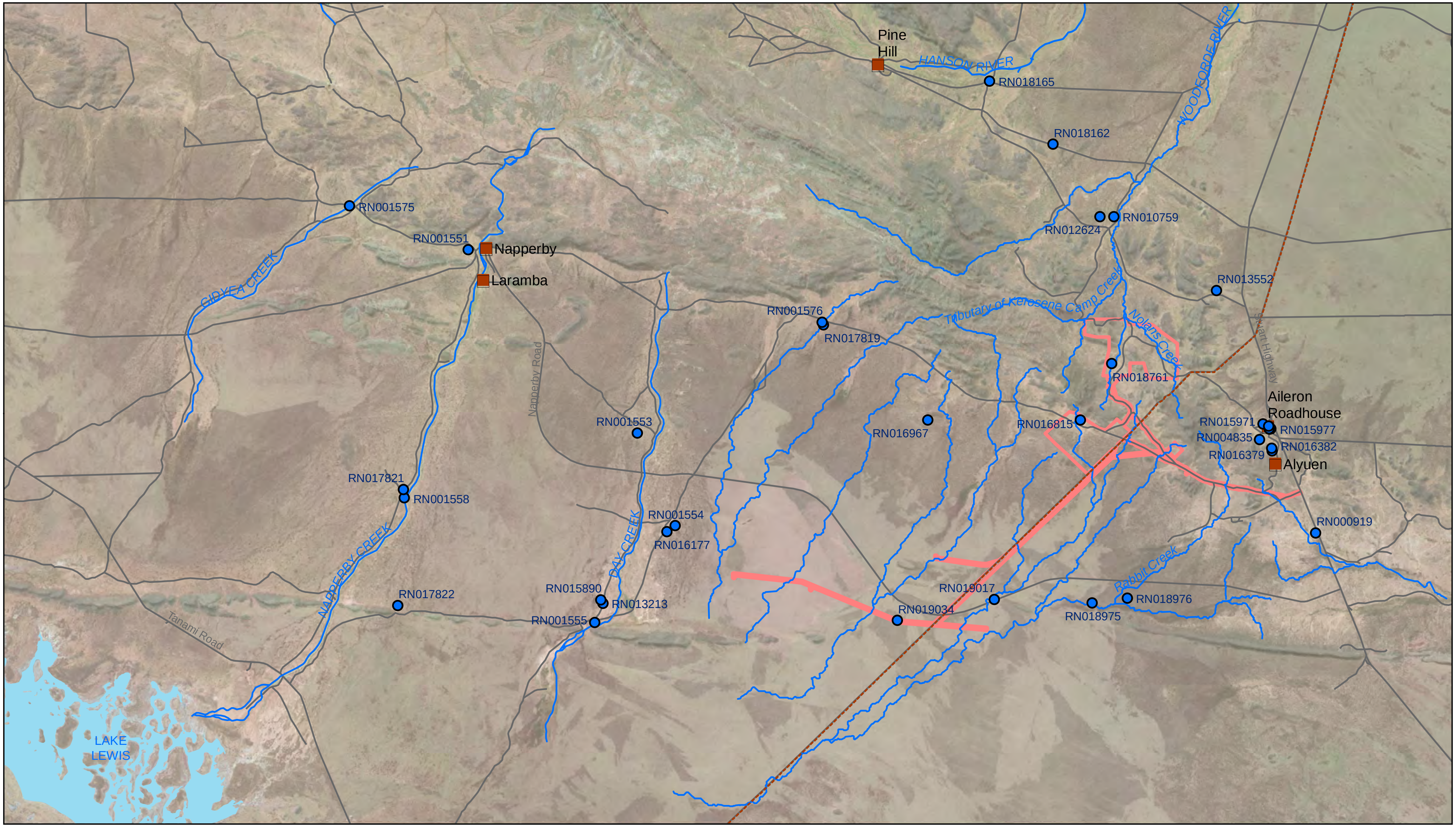
And downstream of the processing site:

- Bore RN018975 – Alyuen Outstation, Aileron Station is located close to the Napperby Station road about 10 km south of the processing site. The bore was completed in 2013 to a depth of 102 m; the DLRM database reports that the bore has been used for stock water supply and has a yield of 2 l/s with Total Dissolved Solids 2,890 mg/L. It is uncertain if the bore is still being used.
- Bore RN018976 – Alyuen Outstation, Aileron Station is located close to the Napperby Station road about 10 km south of the processing site. The bore was completed in 2013 to a depth of 75 m; the bore has been used for irrigation and has a yield of 4 l/s with Total Dissolved Solids unknown. Anecdotal evidence suggests the bore yield is unreliable and an alternative source is being used.
- Bore RN019017 – Aileron Station is located close to the Napperby Station road about 10 km south of the processing site. The bore was completed in 2014 to a depth of 48.5 m; the bore has been used for stock water supply and has a yield of 5 l/s with Total Dissolved Solids 2,540 mg/L. Anecdotal evidence suggests the bore yield may be unreliable.

Whilst the following bores are located between the mine site and processing site and possibly up-gradient:

- Bore RN018761 - Aileron Station is located close to the southern boundary of the mine site and was completed in 2011 to a depth of 59.5 m; the bore has been used for stock water purposes and has a yield of 6 l/s with Total Dissolved Solids of about 2,000 mg/L. It is understood that this bore replaces the old Nolans bore.

Bore RN016815 - Aileron Station is located towards the ridge between the processing plant and mine site and was completed in 1999 to a depth of 53 m; the bore has been used for stock water purposes and has a yield of 0.8 l/s with Total Dissolved Solids of 2,570 mg/L. Anecdotal evidence suggests this bore has high Uranium levels and might no longer be in use.



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0 2.5 5 7.5 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Water Supply Bores
- Outstations and Communities
- Gas Pipelines
- Major Waterways
- Roads
- Project Areas
- Waterbodies

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Nolans Project

Job Number	4322301
Revision	0
Date	22 Mar 2016

Water users

Figure 3-10

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Level 5 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: Geoscience Australia, GeoTOPO 250K, v3/2006; Department of Mines and Energy, Mineral Titles, Strike Download/10/03/2015; DPLE, Tenure/Cadastre, 2015. Created by:cmacgregor

4. Mine site water balance

4.1 Approach

Water storage facilities should be designed to handle and control required inflows and outflows including unpredictable fluctuations due to exceptional storm inflow. Consideration of such inflows and outflows in a water balance will help identify storage requirements and minimise the risk of uncontrolled overflow and thus structural failure.

A water balance previously carried out by Knight Piesold[13] estimated the design capacity of tailings and residue storage facilities that is required to contain storm rainfall. The water balance also quantified the volume of tailings supernatant water that can be reclaimed from the Flotation Tailings Storage Facility for transfer to the processing site to augment the mine site water supply. It is understood that water will not be recycled for water supply from the Water Leach Residue Facility, Phosphate Residue Facility, Impurity Removal Residue Facility and Evaporation Ponds.

A monthly water balance has been carried out to identify whether the Nolans project is likely to be in water deficit or surplus regarding its water supply requirements. The underlying assumptions in the Knight Piesold water balance of the tailings and residue storage facilities have been reviewed (Appendix D) and its conclusions, together with estimates of open pit dewatering rates and mine site water demands, have been incorporated into a mine site water balance (Appendix E).

Open pit dewatering rates have been estimated by groundwater modelling which is reported in Chapter 8.

Mine site water demands comprise the requirements of ore processing (RE intermediate plant, beneficiation and crushing plant), dust suppression along haul roads and at the crusher, together with potable water demands in both the processing site and accommodation village (Section 3.8).

Available water resources will include pit dewatering which, due to the limited spatial extent and highly porous and transmissive nature of the ore body, is likely to be achieved through pumping from in-pit sumps. Also available is the recycled tailings supernatant water that will collect in the Flotation Tailings Storage Facility. Additional water may be available from stormwater management ponds but this is likely to be restricted to infrequent and short-lived periods when intense rainfall exceeds evaporation and infiltration. At other times rainfall is unlikely to result in surface runoff and will therefore not be an available resource.

Water balance calculations to assess monthly water deficits or surpluses represent the following components:

Flotation tailings storage facility

Inflows:

- Incident rainfall – runoff over pond and from ‘dry’ areas
- Slurry water
- Seepage return flows.

Outflows:

- Evaporation from ponded and ‘dry’ areas

[13] Nolans Project Tailings Storage Facilities Engineering Cost Study, Lycopodium, February 2014.

- Decant of ponded water to the processing site
- Seepage.

Open pit

Inflows:

- Incident rainfall – runoff from walls and floor (surrounding mine areas will be isolated by perimeter flood protection bund)
- Groundwater inflow.

Outflows:

- Evaporation
- Seepage loss
- Dewatering by pumping from in-pit sumps.

Residue Facilities

Water balances previously carried out by Knight Piesold to check the performance of the containment capacity of the Water Leach Residue Facility, Phosphate Residue Facility and Impurity Removal Residue Facility are basically the same and are based on the following representation (note there is no recycling of water for water supply):

Inflows:

- Incident rainfall – runoff over pond and from 'dry' areas
- Slurry water
- Seepage return flows.

Outflows:

- Evaporation from ponded and 'dry' areas
- Seepage.

Evaporation Ponds

Water balances previously carried out by Knight Piesold suggest that Evaporation Ponds will be operated by pumping water into successive evaporation cells over a period of 4 months, thereafter inflow is stopped and the stored water in the cell allowed to evaporate over a period of up to 20 months before the cycle is repeated. Water in the cell at the end of 20 months or sooner if its SG has reached 1.3 is pumped to the Impurity Removal Residue facility. This procedure has the objective of minimising salinity effects on evaporation and preventing a loss of storage capacity by the build-up of precipitated salts in the ponds. Thus the water balance for Evaporation Ponds comprises (note there is recycling of sodium sulphate):

Inflows:

- Incident rainfall
- Liquor stream from processing plant, RO reject and treated effluent water.

Outflows:

- Evaporation from ponded areas
- Precipitate.

Sediment basins

Sediment ponds will be located downstream of disturbed areas such as Waste Dumps, mine service buildings, process site, power plant and accommodation village. Runoff events will be sporadic and short in duration; thus the volume of captured water will be relatively small compared to process water demands. High rates of evaporation and seepage will also limit the residence time of stored water. Therefore, it is likely that this water would be used opportunistically for dust suppression and is not included in the mine site water balance.

4.2 Mine site water use

The overall site raw water demand is projected to peak at 4,777 ML/y [14]. This includes a demand for process water of 4,418 ML/y, potable water 91.5 ML/y and dust suppression 267 ML/y. A schematic layout of water demands is shown in and an estimate of the change in water demand over the life of mine is given in Table 4-4 . This pattern of water demand is pro-rated from the peak demand of 4,777 ML/y using the annual estimates of material excavation in Figure 2-4.

The raw water supply to the processing site and the concentrator will be sourced from a borefield located in the Southern Basins approximately 13 km to the south of Nolans site (Figure 2-1) and possibly from dewatering operations in the open pit. It is also understood that work is on-going to reduce the designed water demand.

Table 4-1 Process water demand

Location	Requirement (ML/y)
Beneficiation make-up water	667
RE intermediate plant	2990
RO Plant reject surplus	761
Total	4418

Table 4-2 Potable water demand

Location	No of People	Usage (l/person/d)	Requirement (ML/y)
Accommodation camp	400	400	58
MSA/concentrator	205	180	13.5
RE intermediate plant	300	180	20
Total	-	-	91.5

Table 4-3 Dust suppression water demand

Type	Dry days per year	Indicative haul road width (m)	Haul road length (km)	Spray depth (mm/day)	Water Requirement (ML/yr)
Haul road	336	12 [a]	30	2	242
Crusher	-	-	-	-	25
Total	-	-	-	-	267

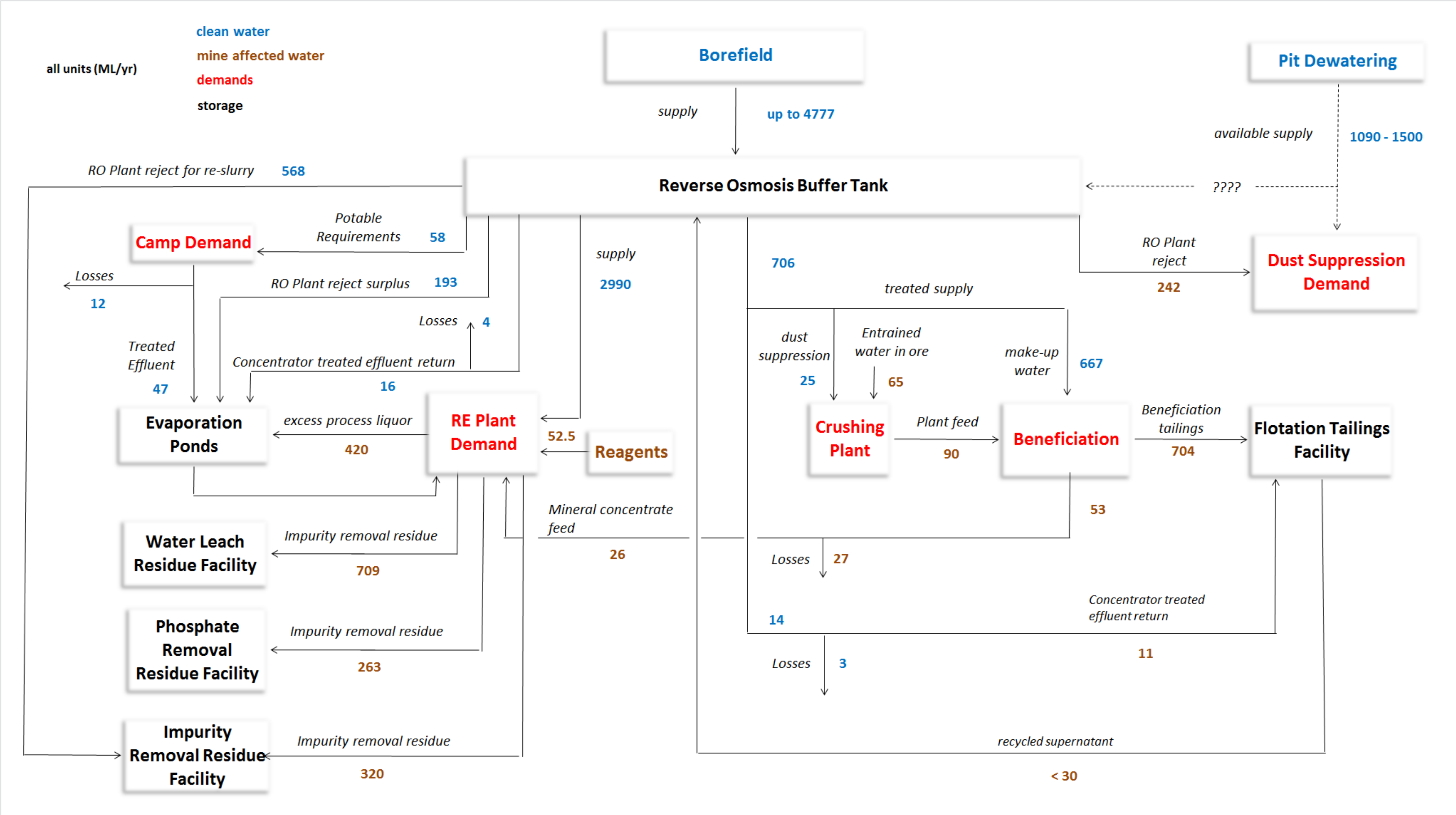
Note: [a] sections of pit ramps will be 30 m wide.

[14] Overall Nolans Site Water Balance Summary Rev C. November 2013.

Table 4-4 Total water demand over the LOM

	Mine Development Stage						
	1	2	3	4	5	6	7
Excavation (mtpa)	11	24	13	38	103	120	50
Water demand (ML/yr)	424	967	519	1500	4099	4777	1973

Source: pro-rated from peak demand using material excavation totals for each mine development stage.



source: Nolans Project Infrastructure Engineering Cost Study. Lycopodium, February 2014. {Figure - Overall Nolans Site Water Balance Summary Rev C 5/11/2013}

Figure 4-1 Schematic of mine site water demands

4.3 Results - tailings and residue storage requirements

Knight Piesold made a preliminary assessment of the hazard category for the tailings and residue storage facilities in terms of the ANCOLD guidelines[15]. Their assessment identified the facilities as having a High C consequence category classification requiring a spillway or freeboard equivalent to a 1 in 100,000 ARI or Probable Maximum Flood (PMF) event. It is assumed the same criteria was applied to the design of evaporation ponds.

Knight Piesold carried out a water balance to establish the design capacity for tailings, residue and evaporation ponds based on an ability to contain inflows during a year with average rainfall whilst retaining a freeboard equivalent to the PMP – 72-hour storm event depth (1100 mm). The Knight Piesold design capacity and pond configuration was based on a 20 year LOM and it is assumed the number of cells will be increased by a pro-rata amount to accommodate the tailings and residue from a 43-year LOM as indicated in Table 4-5.

A review of the design storage capacities has been carried out and is summarised in Appendix D. The review was affected by a lack of information regarding the expected profile of deposited tailings and residue and thus its influence on available 'head room' for water containment and rate of evaporation from the ponded surface. The review suggests that the design should be revisited in more detail to obtain a more robust check of storage areas and embankment heights.

Table 4-5 Design Capacity of Storage Facilities

Name	Embankment Height (m)	Number of Cells – LOM 20 years	Number of Cells – LOM 43 years	Area per Cell (ha)	Water Storage Capacity per Cell (ML)	Tailings / Residue Storage per Cell (Mt) [d]
Flotation Tailings Storage	25.1	2	5	20	10.00 [a]	9
Phosphate Residue	24.0	2	5	12	3.73 [b]	2.9
Impurity Removal Residue	24.1	2	5	33	15.58 [b]	11.9
Water Leach Residue	20.9	2	5	35	18.37 [b]	7.2
Evaporation Concentrator Pond	3.1 [e]	6	13	10	660 [c]	0
Na2 SO4 concentrator	3.1 [e]	3	7	10	Not yet known	0

Source: all values taken from Appendix 3.6 of Nolans Project Infrastructure Engineering Cost Study. Lycopodium. February 2014 - [a] Table 4.3, [b] Table 4.5, [c] Section 5.1. [d] Table 5.1.

Notes: [e] to retain the required PMP freeboard during initial filling Evaporation Ponds will require embankment crest heights of 3.1 m rather than the previously calculated 2.5 m.

4.4 Results - mine site water balance

A water balance for the Nolans mine site has been used to determine whether the project will experience a water surplus or deficit. Should the water balance indicate a water surplus then an acceptable means of disposal will need to be identified, whereas if the site is in deficit then an external water source is required.

[15] Nolans Project Infrastructure Engineering Cost Study 1683.25-STY-001. Lycopodium. February 2014

The results of a mine site water balance are summarised in Table 4-6 and is based on the following (note the water balance for the processing site would comprise rainfall 314 mm/yr and evaporation 2196 mm/yr, only, and no transfer of water to the mine site):

- Seven mine development stages corresponding to the open pit development stages reported in Section 2.6.
- Monthly rainfall and evaporation comparable to conditions during an average year.
- Estimation of recycled supernatant water from the Tailings Flotation Storage Facility based on a slurry inflow of 0.45 mtpa, which is assumed to correspond with mine development Stage 6 when the maximum quantity of material is mined. Quantities of recycled water for other mine development stages have been pro-rated from this maximum value by means of the relative quantity of mined material (Appendix D).
- Estimation of runoff within the open pit assumes a rainfall loss of 90 percent from evaporation and seepage.
- Groundwater inflow of up to 46 l/s depending on the pit water level (Appendix E).
- Pro-rating of the peak processing water demand (4,510 ML/year) to provide estimates of water demand during other mine development stages. This has been achieved using estimates of the quantity of material mined in each development stage.
- De-watering maintains a dry pit floor throughout the year.
- Recycling of the water captured in sediment ponds at Waste Dumps is assumed to be impractical due to the infrequent nature of surface runoff events.

Table 4-6 Water balance of mine site for average rainfall year

Component	Stage 1 (ML/y)	Stage 2 (ML/y)	Stage 3 (ML/y)	Stage 4 (ML/y)	Stage 5 (ML/y)	Stage 6 (ML/y)	Stage 7 (ML/y)
Open pit rainfall Inflow	32	101	139	191	262	335	385
Open pit groundwater Inflow	1088	1243	1243	1391	1451	1461	1461
Open pit rainfall losses	-28	-91	-125	-172	-236	-301	-346
Open pit de-watering Requirement [B]	-1091	-1253	-1257	-1410	-1477	-1495	-1500
Recycling of the flotation tailings storage facility supernatant water[A]	2.7	6.1	3.3	9.4	25.7	30.0	12.4
Process water demand (excluding dust suppression)[C]	405	884	479	1399	3792	4418	1841
Dewater plus recycle minus process demand	689	376	782	20	-2289	-2893	-328
Water deficit (excluding dust suppression)	0	0	0	0	2289	2893	328
Water surplus (excluding dust suppression)	689	376	782	20	0	0	0

Notes: source: [A] pro-rated and based on % reclaim from 'Nolans Project Tailings Storage Facilities Engineering Cost Study, Lycopodium, February 2014' [B] Appendix E [C] Section 4.2.

A comparison of the mine site process water demand with available on-site water resources indicates a potential surplus of water due to pit dewatering during the first four stages of mine development and a potential deficit in the supply of water demands thereafter. Surplus water will be pumped to a turkey nest pond located within the mine site from where it will be recycled to augment mine water supply, whilst deficits in demand will be met by groundwater supply from a nearby borefield.

Surplus water

A turkey nest pond capacity of 12 ML will be required to provide contingency storage should abstraction from the pond cease for a period of 3 days. This assumes inflow during a maximum expected dewatering rate of 46 l/s (Appendix E).

At this stage it is unclear if water from pit dewatering will be used to meet part of the water demand requirements of the processing site or whether it will be used only for dust suppression. Water in excess of mine site processing demands would represent a dust suppression spray rate of up to 6.5 mm/day depending on the development stage (Table 4-7) which is significantly greater than an expected requirement of 2 mm/day (). Should surplus water from dewatering be used solely for dust suppression then an application rate of 12.4 mm/day would be required to dispose of this surplus water (Table 4-7).

Table 4-7 Surplus water disposal by dust suppression

Scenario	Surplus water (ML/y)	Dry days per year	Haul road width (m)	Haul road length (km)	Available spray depth (mm/day)
Dewatering in excess of RE plant demand	376 to 782	336	12	30	3.1 to 6.5
Total dewatering	1500	336	12	30	12.4

Water deficit

Investigative work in the Southern Basins area south-west of the processing site has defined a sizeable, high-yielding, slightly brackish groundwater system. The Southern Basins borefield is planned to be operated at up to 13,000 m^3/day (150 L/s or 4,700 ML/year) and therefore has the capacity to service the deficit in process water supply as well as the dust suppression demand, if required. Groundwater from the Southern Basins will be supplied from a number of active bores within the borefield area and pumped to a centrally located collection point. Thereafter, water will be pumped to an intermediate pond before reaching the processing site.

It is anticipated that the raw water demand for potable uses can be supplied from the northern part of the borefield area via a dedicated transfer pipeline to a treatment facility at the processing site. An alternative option of using the main raw water supply is also available. The raw water will be treated by a filtration and treatment system.

5. Potential impacts and management

5.1 Impact assessment

The risk that an impact will occur if all three elements of a ‘source – pathway – receptor’ are present. In this instance the source of impact is:

- mine affected runoff from the mine site or processing site
- upstream catchment flood water on the mine site or processing site
- influence of the mine site or processing site on normal flows or flood flows in downstream creeks and waterways (due to ‘removal’ of catchment area of the mine from the normal/natural catchments).

In terms of surface runoff the pathway can be:

- sheet flow
- channel flow
- near-surface flow within the channel bed (groundwater pathways are dealt with in Appendix K of the EIS).

Receptors include:

- third party infrastructure
- water supplies
- locations with environmental or heritage value
- Nolans site in the case of flood impact on the site.

A further description of the source-pathway-receptor and project impacts in terms of the surface water system is discussed below and contributes to the overall assessment of project impacts detailed in Chapter 5.

The elimination of risk is achieved by removing a source, pathway or receptor. If this proves impractical then a risk is managed by the implementation of project controls which are outlined below and dealt with in more detail in the Environmental Management Plan (Appendix X).

5.2 Potential receptors

Receptors are considered to comprise third party infrastructure, water supplies and locations with environmental or heritage value which occur within 10 km of the mine lease area and along potential surface or near-surface flow paths. Potential receptors have been scoped as follows:

- There are no known places of historical or cultural value on watercourses downstream of the mine site and processing site. RWA 8 is located between the mine site and processing site and is potentially downstream of potential spills from an access road. However, this road will carry mainly innocuous reagents to the flotation plant.
- Third party infrastructure consists of the Amadeus Basin to Darwin gas pipeline, which is buried to a depth of about 1 m and runs along the south eastern boundary of the processing site. The Napperby Station access track is located 12 km to the south of the processing site whilst the Stuart Highway is 15 km to the east. All third party infrastructure is located a sufficient distance from drainage paths not to be susceptible to surface water impacts from the mine development.

- Potable water supply to communities in the region is supplied from bores the nearest of which is in excess of 20 km from the mine lease area and unlikely to be susceptible to surface water impacts from the mine development.
- Irrigation water use occurs within the Ti Tree Basin. The Woodforde River, in to which runoff from the mine site and Kerosene Camp Creek drains, passes over the western fringe of the Ti Tree Basin aquifer about 20 km downstream of the mine site. The aquifer is about 60 m below the ground surface and unlikely to be susceptible to surface water impacts from the mine development.
- Riparian vegetation occurs along Kerosene Camp Creek, downstream of the mine site, and could be affected by the diversion of surface runoff due to mine development. Riparian vegetation also occurs in flood out areas on the lower reaches of catchments draining the processing site and is unlikely to be susceptible to surface water impacts from the mine development.
- Stock water supplies within a 10 km radius of the mine site potentially comprise 19 bores of which, anecdotally, only 3-4 are in use. It is unclear how many are in regular use but it is thought the majority may have been abandoned. Two of these bores are located down gradient of the mine site close to Kerosene Camp Creek near its confluence with a major tributary, and three are positioned in areas down gradient of the processing site. It is conceivable that these five sources of water could be susceptible to surface water quality impacts from mine development. The remaining bores are located outside of surface water flow paths and are therefore unlikely to be susceptible to surface water impacts from mine development.
- The mine operations in the case of flood.

5.3 Approach to mine water management

Various types of water will be encountered across the Nolans site (Figure 5-1).

Clean water

This would include water which originates outside of the mine or upstream of access roads and has not been in contact with any activities on the mine site, or water which originates from groundwater sources and meets at least livestock drinking water standards. This water would, where appropriate, be released to the environment without any treatment or be used as process water, including water for dust suppression on internal roads.

Water containing mine operations generated sediment and other diffuse source pollutants

This category would include surface water originating on the disturbed area of the site, but not being in contact with pollutants or contaminants. This water would comprise drainage from Waste Dumps containing uncontaminated material or drainage from administrative areas. Water can overflow/seep to the environment or it could be utilised as process water after the sediment load has been reduced.

Water in contact with ore

Water which has been in contact with ore or the ore preparation/movement areas should, as a precaution, not be allowed to leave the site and should be directed to a dedicated event pond. This would include surface water collecting within the pit, dewatering of the ore body and runoff from the ROM pad and crushing area. This water could be used for plant process water.

Process water

Water which has been in contact with or used in the process would include water from the Floatation cell and Reagent mixing area, drainage from the residue storage facilities, also Reverse Osmosis waste water. Process water from the Flotation Tailings Facility could be recycled whilst the remaining process water will be contained in residue storage facilities or allowed to evaporate.

Water potentially in contact with radioactive material.

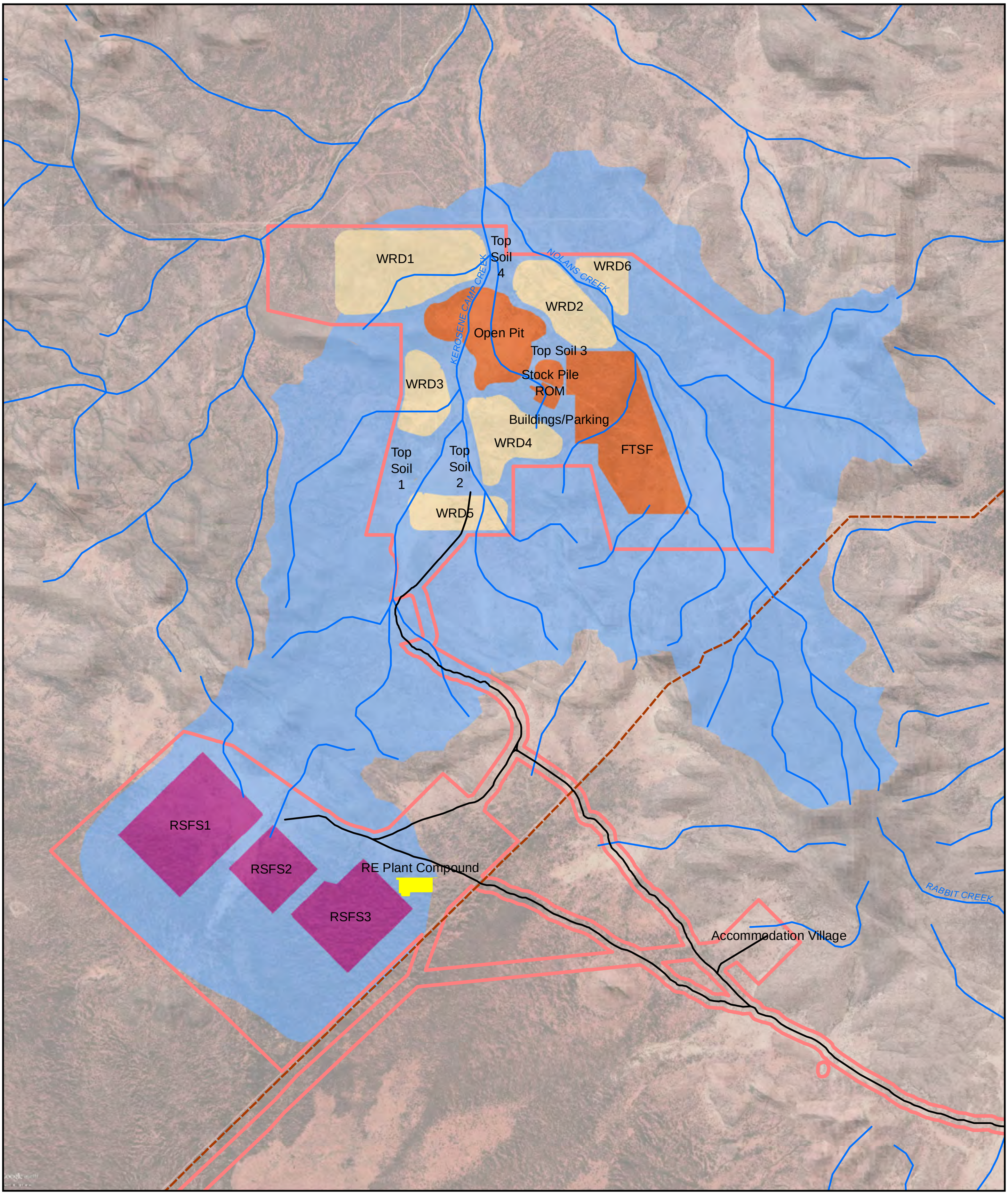
This category of water would apply to any water which has potentially been in contact with process residues. This water will be contained within these areas and allowed to evaporate.

A mine site water balance has shown that a positive water balance will occur during early development stages and a negative water balance during later stages. A positive water balance is when inflow from rainfall, groundwater seepage and entrained water in tailings exceeds rates of evaporation and mine site water demand and leads to a surplus of water. The opposite is true for a negative water balance.

Water balances by Knight Piesold have demonstrated that the design capacity of tailings and residue storage facilities can manage incoming process water liquor streams and incident rainfall by natural evaporation without a need to discharge excess water to the downstream environment.

The approach to mine water management will therefore involve implementation of the following controls to manage project impacts which are considered in more detail in the following sections:

- Maintenance of natural overland flow paths where practical through construction of culverts and/or floodways along linear infrastructure
- Separation of 'clean' surface runoff from mine affected areas by diversion channels/bunds to reduce the volume of contaminated water thus reducing the required capacity of water containment structures and to reduce the volume of contaminated water in the pit resulting from surface water inflow
- Appropriate siting of infrastructure and the construction of bunds to provide immunity from flooding
- Provision in the design for appropriate operational phase erosion and sediment control to mitigate sediment laden runoff and protect the works
- Implementation of a construction phase Erosion and Sediment Control Plan to minimise runoff quality impacts due to disturbance through vegetation clearance and land forming
- Containment of contaminated water (tailings, mine waste liquors and residues) to preserve downstream environments
- Recycling, where appropriate, of water from pit dewatering and the Flotation Tailings Storage Facility to meet water demands for dust suppression and possibly part of the processing site demand to reduce the magnitude of external water supply.



LEGEND

Access Road
Waterways
Gas Pipeline
Project Areas

Water Type

Clean
Ore Contact
Process
Sediment
RE plant compound

1:75,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

Arafura Resources Limited
Nolans Project

Job Number	43-22301
Revision	0
Date	29 Apr 2016

Surface water type

Figure 5-1

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Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 11/02/2016). ARL - Project Areas (2015). GHD - XPRafts Model (2016). Created by: CM

5.4 Discussion of surface water impacts and controls

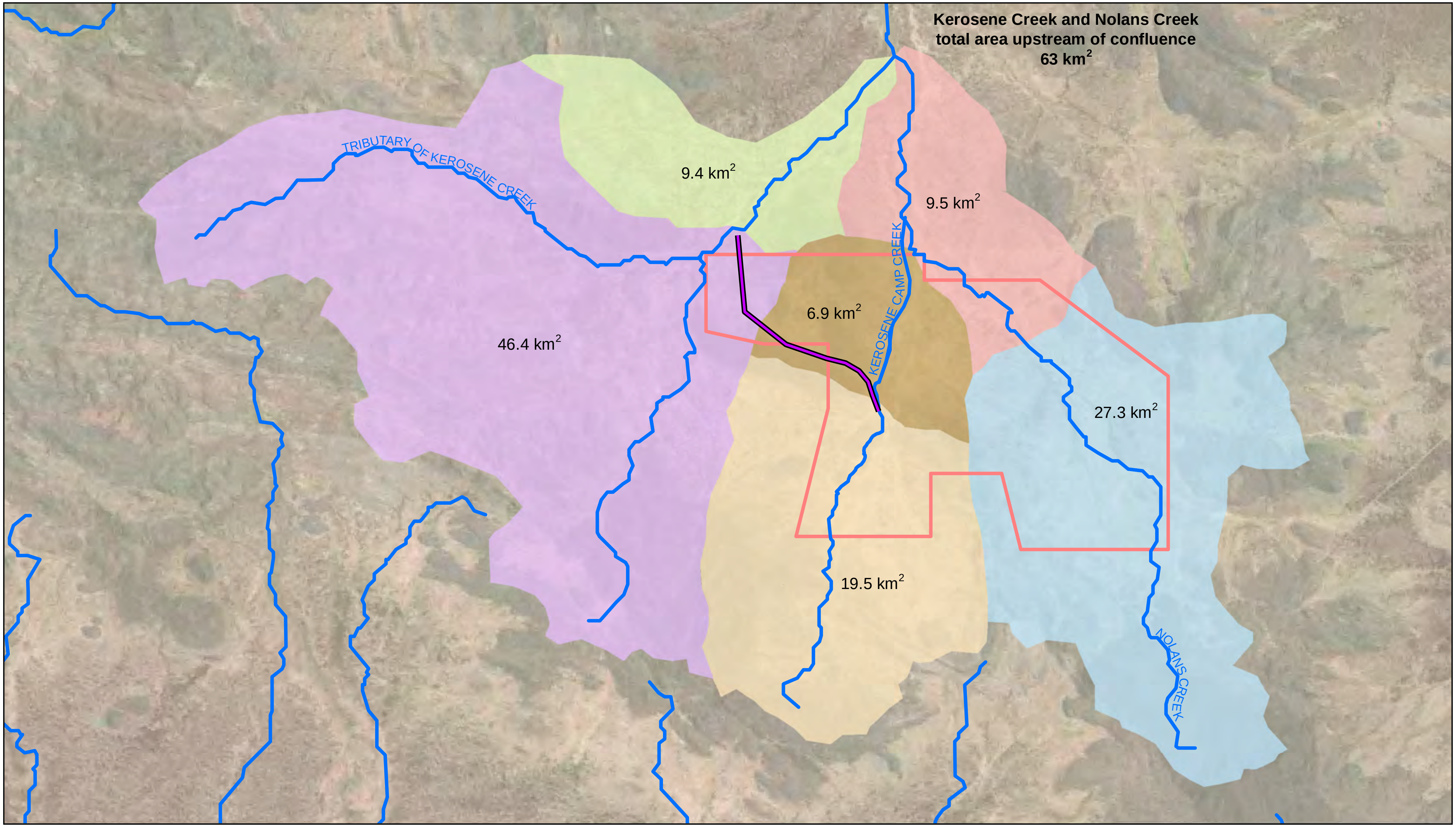
5.4.1 Separation of clean and mine affected water

Potential impacts

The mine site is located within the headwaters of Kerosene Camp Creek, Nolans Creek and minor catchments of the Southern Basins but significant areas of catchment occur upstream of the mine lease boundary comprising 16 km^2, 26 km^2 and 16 km^2, respectively (Figure 5-2). Due to natural flow paths runoff that originates from upstream catchments will pass through the mine site and processing site and could therefore increase the volume of mine affected water.

The open pit has the potential to capture 31 percent of the runoff in Kerosene Camp Creek that currently reaches Kerosene Camp Creek in a reach between the mine site boundary and its confluence with a major tributary. This proportion is based on relative catchment areas upstream of the pit (19.5 km^2) and at the confluence of Kerosene Camp Creek with a major tributary of Kerosene Camp Creek (63 km^2) (Figure 5-2).

Catchment areas upstream of the processing site are relatively small (typically less than 1 km^2). Therefore, the magnitude of surface runoff will be relatively small but will have the potential to mobilise contaminants, if they occur, albeit over limited distances due to the sporadic nature of rainfall events in this area.



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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

Diversion Channel

Waterways

Mine Site Boundary

Arafura Resources Limited
Nolans Project

Job Number 4322301
Revision A
Date 23 Mar 2016

Kerosene Camp Creek diversion catchments

Figure 5-2

G:\43\22301\GIS\Maps\4322301_567_NolansDiversion.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Pipelines, Proposed Mine Site, Proposed Diversion Channel Options, Tailings Storage Facility (2015). Created by: CM

A proposed diversion of Kerosene Camp Creek (Figure 5-2) will cause a change in the direction of flow within Kerosene Camp Creek. A design study (Appendix A) suggests that this will cause an increase in water depth during a 100-year ARI flow event of 1.5 m immediately upstream of the diversion inlet and reduce the flow velocity and shear stress. Additional preliminary modelling suggests the water level upstream of the diversion inlet would increase by a further 0.2 m during a 1000-year ARI flow event.

The Kerosene Camp Creek diversion outlet will also cause an increase of 30 percent in the catchment area contributing flow to a major tributary of Kerosene Camp Creek which will cause flows in this receiving watercourse to increase by a similar amount. The design study also suggests that the diverted flow will have flow energies and erosion and sediment transport potential similar to existing conditions in the receiving channel with an afflux during a 100-year ARI flow event of 0.2 m. As a result, the additional flow discharge from the diversion is not expected to have a significant impact on the morphology of the receiving channel (Appendix A).

Water management controls

Runoff that originates from catchments upstream of mine infrastructure is essentially clean and it is desirable that this water remains isolated from mine areas otherwise it will increase on-site requirements for containment and/or treatment. This can be achieved by the construction of diversion channels and flood protection levees.

Due to the proposed location of the open pit on the natural flow path of Kerosene Camp Creek it will be necessary to divert Kerosene Camp Creek to the west of the mine site to discharge into a major tributary of Kerosene Camp Creek (Figure 5-2). It will be necessary to protect adjacent areas of the mine site against over-bank flow by means of a flood protection levee along the approach channel. Also, it will be necessary to obtain a longitudinal profile for the diversion channel that achieves flow conveyance and sediment transport in the approaches to the diversion that are closer to existing conditions within Kerosene Camp Creek.

The diversion of clean water runoff around the processing site will be achieved by means of flood protection bunds and shallow drainage ditches. Conceptual designs are included in the Environmental Management Plan (Appendix X).

5.4.2 Cross-drainage structures

Potential impacts

Haul roads and access roads will need to cross a relatively large number of minor creeks the majority of which have small upstream catchments ranging between 0.09 and 3.9 km^2.

Should the construction of roads cause a reduction in the existing capacity of channels or an increase in channel bed gradient this could lead to a localised increase in flow velocity leading to the potential for erosion of creek beds. Conversely, if channel widths are increased or channel bed gradients reduced this could result in a reduction in the velocity of flow and an increased potential for the deposition of sediment.

Water management controls

To prevent problems associated with erosion or sedimentation at road crossings it is desirable that changes to the drainage path and flow conveyance capacity of creeks is kept to a minimum.

Preliminary rain-on-grid 2-D flood modelling of catchments upstream of proposed haul roads suggests that flood depths and velocities during a 1000-year ARI event will not exceed 0.5 m and 1.0 m/s, respectively. Flood depths and flood velocities during more frequent storm events such as a 20-year ARI event would be significantly less.

Given the limited depth and likely duration of flood flows at haul roads it is likely that floodways will be the preferred method of ‘bridging’ creeks. Floodways consist of a localised depression in the elevation of the road formation and reinforcement of the road verge to facilitate the spillage of flow across the depressed section of road. Depending on the depth of flow this could cause temporary closure of the road but due to the small extent of catchments the duration of flooding is likely to be measured in minutes rather than hours.

Where creeks are wide or the gradient of creek banks is steep or roads are susceptible to erosion it may be necessary to use culverts instead of floodways.

5.4.3 Flood immunity

Potential impacts

Preliminary rain-on-grid 2-D flood modelling of the Nolans site and its upstream catchments has been undertaken to provide an estimate of flood levels (Figure 5-3) and velocity (Figure 5-4) during a 1000-year 4.5 hr ARI storm event. This has assumed that the majority of rainfall over Waste Dumps and soil stores will be retained through infiltration and seepage or attenuated by perimeter drains and sediment ponds. Rainfall over the open pit will be contained within the pit.

Indicative changes in flood levels and flood velocities as a result of mine development are shown in Figure 5-5 and Figure 5-6 and are summarised for significant locations across the mine site in Table 5-1. An assessment of the Kerosene Camp Creek diversion design and flood conditions immediately upstream and downstream of the proposed creek re-alignment has been investigated by a separate study using a detailed 1-D flood routing model (Appendix A). This study has only considered conditions during a 100-year ARI event. A preliminary indication of potential impacts during a 1000-year ARI event has been obtained from the 2-D model. Further refinement of modelling will be required at a later stage of project development for the purpose of designing mine infrastructure and water management controls.

Nolans Creek flows along what will be the eastern boundary of the Flotation Tailings Storage Facility and between the proposed locations for Waste Rock Dumps 2 and 6. The location of Nolans Creek in close proximity to mine infrastructure creates the potential for flooding and erosion. However, due to the shallow gradient of the creek a narrowing of the Nolans Creek floodplain due the Waste Rock Dumps modelling suggests only a small flood level afflux of 0.1 m and no significant increase in flood flow velocity.

Kerosene Camp Creek enters the mine site adjacent to the proposed Waste Dump 5 and proposed top soil stores in this area also further impinge on the Kerosene Camp Creek. However, gradients in this area are relatively shallow and mine development is predicted to cause only a small flood level afflux upstream of the mine site boundary of 0.1 m and an insignificant decrease in flood velocity of 0.1 m/s. Also, the proposed creek diversion will cause an abrupt change in the direction of Kerosene Camp Creek which will result in flow depth immediately upstream of the diversion inlet of about 1.7 m and a slowing of flood flows by about 0.5 m/s during a 1000-year ARI event. Unless mitigated this would lead to localised over-bank flooding and spillage into the open pit and possibly sedimentation problems upstream of the diversion inlet.

Runoff generated from areas between the open pit, processing site and Waste Dumps represents an additional potential source of water ingress to the open pit with typical flood depths of up to 0.2 m and small localised areas where flood depths reach 0.75 m, also velocities of up to 0.5 m/s.

Table 5-1 Design flood characteristics – post-mining

Creek	Location	1 in 1000-year ARI – 4.5 hr flood event [a]			
		Velocity (m/s)	Depth (m)	Velocity Change [b] (m/s)	Afflux [b] (m)
Nolans	upstream of mine lease boundary	0.9	1.4	0.0	+0.1
Nolans	downstream of mine lease boundary	0.6	1.4	0.0	+0.1
Kerosene Camp	upstream of mine lease boundary	0.2	0.4	-0.1	+0.1
Kerosene Camp	Upstream of proposed diversion inlet	0.3	1.7	-0.5	+0.7
Kerosene Camp	downstream of mine lease boundary	0.5	1.1	-0.2	-0.5
Kerosene Camp	downstream of confluence of Kerosene Camp Creek and Nolans Creek	0.6	1.3	-0.1	-0.4

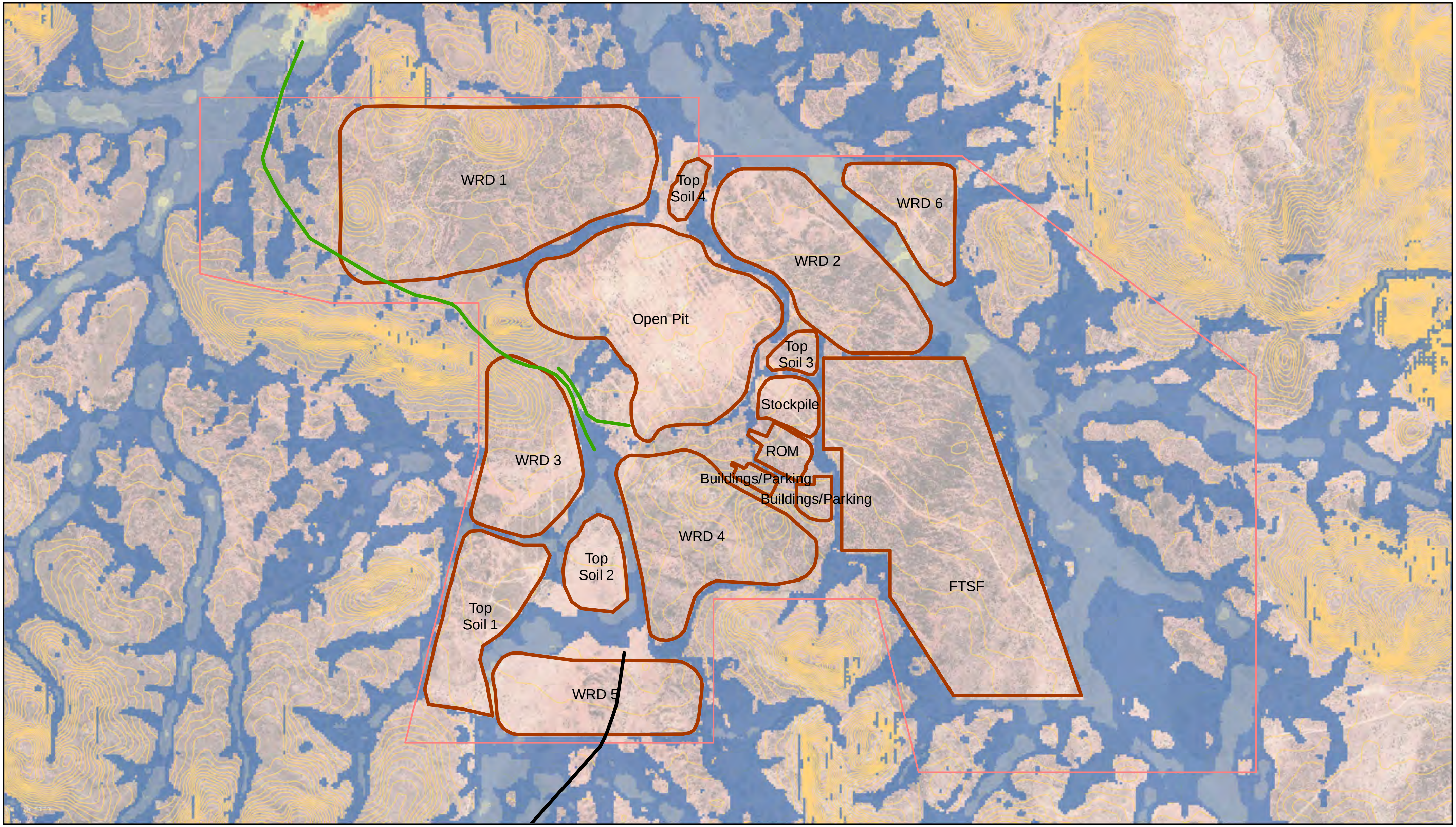
Notes: [a] storm duration corresponds to the time of concentration at mine site boundary [b] change from pre-mining conditions.

Water management controls

The positioning and design of mine infrastructure will need to take cognisance of the risk of flooding and erosion along existing watercourses, particularly Kerosene Camp Creek and Nolans Creek which pass through or adjacent to mine infrastructure. It is preferable that the footprint of infrastructure is positioned outside the 1000-year ARI flood extent and thus the existing mine layout may require amendment, especially Waste Dumps 3 and 5. Where the mine footprint encroaches on flood prone areas it will require flood protection measures and preliminary modelling suggests this would include:

- Flood runoff from areas surrounding the open pit will be diverted away by a flood protection levee constructed around the perimeter of the pit rim to height of 1 m
- A flood protection levee in the approaches to the Kerosene Camp Creek would need to be constructed to a minimum height of about 2 m and a re-profiling of the diversion inlet to equalise its velocity with that of the existing upstream natural channel
- Due to the proximity of Kerosene Camp Creek and Nolans Creek to proposed mine infrastructure it will be necessary to provide rock protection to the eastern external embankment of the Flotation Tailings Storage Facility where flood velocities of to 0.5 m/s can be expected, and along the toe of Waste Dumps 2 and 6 adjacent to Nolans Creek (velocities of up to 1.5 m/s), also along the toe of Waste Dumps 3 and 4 (velocities of up to 1 m/s) and Waste Dump 5 and the neighbouring soil store (velocities of up to 2 m/s)
- Drains will be required along the western toe of Waste Dump 3, also along the southern toe of Waste Dumps 4 and 5 and around the northern, western and southern sides of the Flotation Tailings Storage Facility to prevent ingress of runoff from adjacent catchments.

Conceptual designs of water management controls are included in the Environmental Management Plan (Appendix X).



1:35,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Proposed Diversion
- Proposed Haul Roads
- 2m Contours
- Proposed Infrastructure
- Mine Site Boundary

Post-Mining Flood Velocity (m/s)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0

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Job Number	4322301
Revision	0
Date	18 Mar 2016

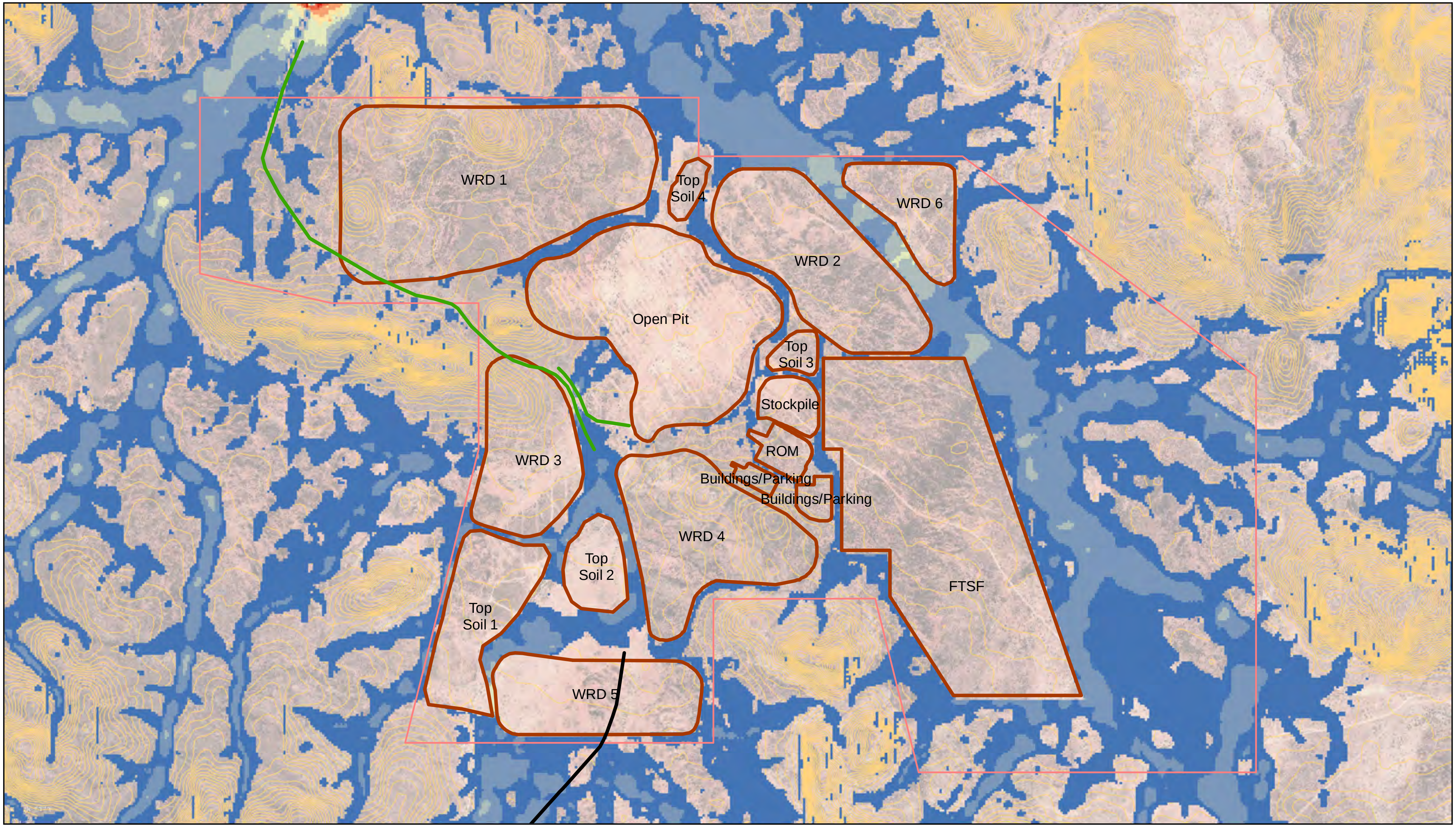
Flood depth for 1000 year ARI event - post-mining

Figure 5-3

G:\43\22301\GIS\Maps\4322301_568_FloodDepthPostMine.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Haul Roads, Existing Creek Channels, Proposed Infrastructure (2015). CSIRO - 2m Contours (derived from SRTM) (2015). GHD - Flood Data (2016). Created by: CM



1:35,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

Proposed Diversion
Proposed Haul Roads
2m Contours
Mine Site Boundary
Proposed Infrastructure

Post-Mining Flood Velocity (m/s)

0.0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5
3.5 - 4.0

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Revision 0
Date 18 Mar 2016

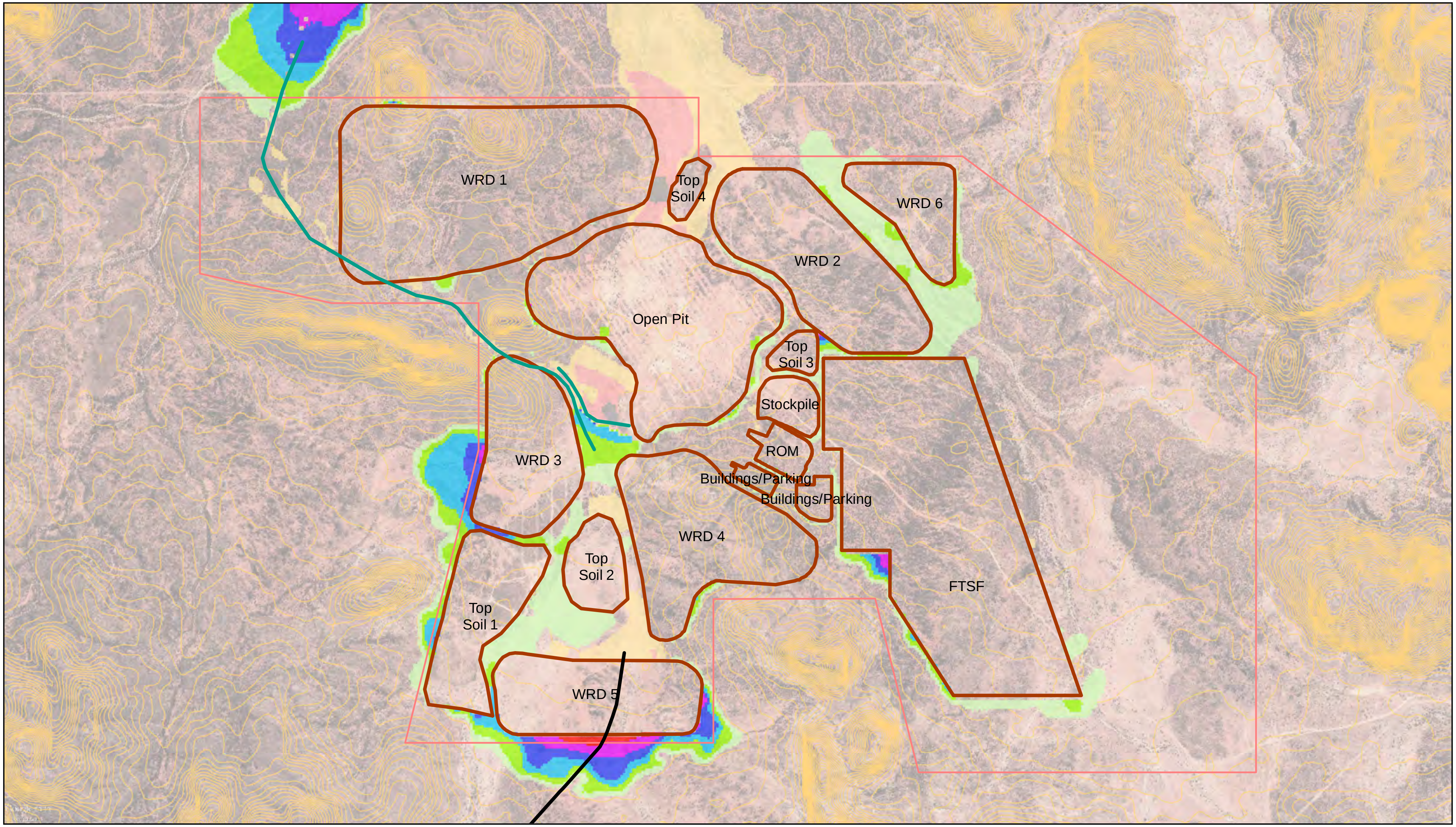
Flood velocity for 1000 year ARI event - post-mining

Figure 5-4

G:\43\22301\GIS\Maps\4322301_571_FloodVelPostMine.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Haul Roads, Existing Creek Channels, Proposed Infrastructure (2015). CSIRO - 2m Contours (derived from SRTM) (2015). Created by: CM



1:35,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

Proposed Diversion
Proposed Haul Roads
2m Contours
Proposed Infrastructure
Mine Site Boundary

Post-Mining Flood Afflux (m)

-1.5 - -1.0
-1.0 - -0.5
-0.5 - 0.0
0.0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0

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Date	18 Mar 2016

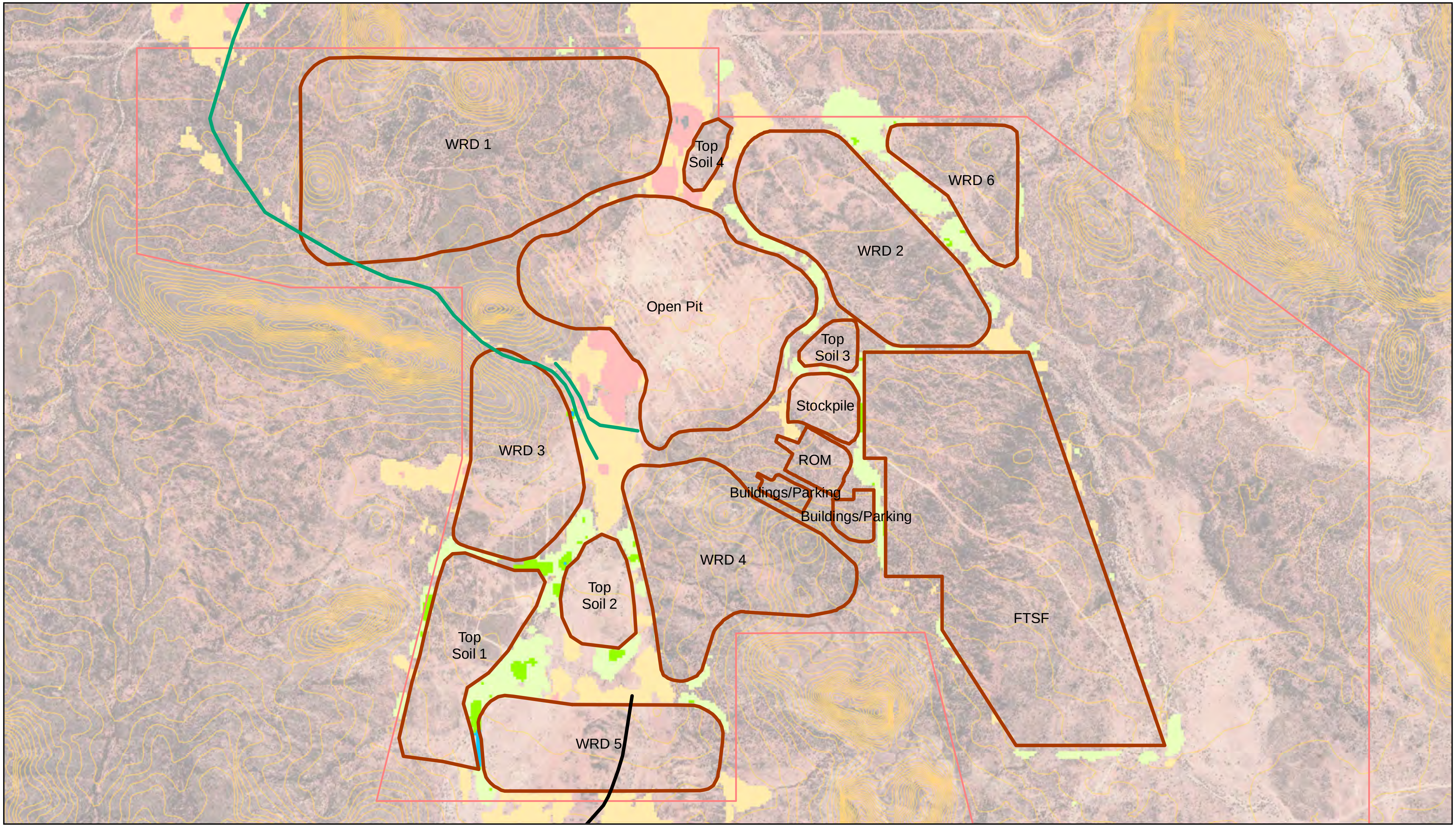
Change in flood depth (afflux) for 1000 year ARI event - post-mining

Figure 5.5

G:\43\22301\GIS\Maps\4322301_570_FloodAfflux.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Haul Roads, Existing Creek Channels, Proposed Infrastructure (2015). CSIRO - 2m Contours (derived from SRTM) (2015). GHD - Flood Data (2016). Created by: CM



1:35,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Proposed Diversion
- Proposed Haul Roads
- 2m Contours
- Proposed Infrastructure
- Mine Site Boundary

Post-Mining Change in Flood Velocity (m/s)

- -1.5 - -1.0
- -1.0 - -0.5
- -0.5 - 0.0
- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0

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Job Number	4322301
Revision	0
Date	18 Mar 2016

Change in flood velocity for 1000-year ARI event - post-mining

Figure 5-6

G:\43\22301\GIS\Maps\4322301_569_FloodChVel.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Haul Roads, Existing Creek Channels, Proposed Infrastructure (2015). CSIRO - 2m Contours (derived from SRTM) (2015). Created by: CM

5.4.4 Erosion and sediment control

Potential impacts

Depending on the carrying capacity of the stream, sediments may be deposited or bank erosion may occur to increase the sediment load in the water to its "carrying capacity". Whilst creek beds are generally mobile due to the unconsolidated nature of bed material the relatively shallow gradient of longitudinal profiles limits creek flow velocities to generally less than 1.5 m/s during a 1000-yr ARI event (Figure 5-4). This limits the potential for erosion during extreme flood events. Small areas between mine infrastructure have larger gradients and there is therefore greater potential for erosion.

Water management controls

Controls to reduce overland flow-induced erosion are set out in Environmental Management Plan (Appendix X) and include:

- Contouring, such as the creation of a series of benches, swales, furrows or irregularities that cause the precipitation to pond, and infiltrate or evaporate rather than translate into runoff
- Vegetation once established is probably the most cost-effective and aesthetically pleasing erosion control measure.

5.4.5 Contaminated water

General

Contaminated water (by contact with ore) will be generated by activities involving the extraction of ore (pit dewatering), its subsequent processing both within the mine (tailings from crushing) and processing site (residue streams) and possibly during the disposal of material to Waste Dumps (Figure 5-1).

Potential impacts - tailings and residue storage facilities

Due to the prevailing topography of the mine site uncontrolled overflow from the tailings storage facility, should it occur, would discharge contaminated water into Nolans Creek where after, depending on the rate of overflow and the presence of water within Nolans Creek, it could potentially reach the downstream Woodforde River system and the Ti Tree Basin.

Uncontrolled overflow from the residue storage facility at the processing site, should it occur, would enter multiple small watercourses that flow southwards towards the Southern Basins and eventually the mine’s borefield water supply.

Climatic conditions that could cause overflow conditions to occur are also likely to result in the generation of flow within downstream creeks. Flow records for Woodforde River (Figure 3-7) suggest that during exceptional rainfall events surface flow can persist for at least one day. Due to the smaller extent of headwater catchments upstream of the mine and processing sites the duration of flow in local creeks is likely to be much shorter. Even so, it is likely to provide sufficient time for contaminated water to reach the tributary of Kerosene Camp Creek (11 km and 6 hours travel time) downstream of the mine site. It would also provide sufficient time for flows to reach the edge of the Southern Basins area (10 km and 5.5 hours travel time) downstream of the treatment site. These travel times assume a moderate flood flow velocity of 0.5 m/s. The migration of contaminated water to the Ti Tree Basin and borefield areas, which are over 50 km from the Nolans site, would take over a day and experience high levels of dilution by the ever increasing runoff volume from surrounding catchments. Should overflow from tailings and residue storage facilities occur during dry conditions then contaminated outflow would seep into the shallow alluvium of local creeks. Anecdotal evidence suggests that subsurface flow occurs within the alluvium of creeks and this could provide a path for the dispersion of contaminants. Topographic gradients to the north of the mine site are about 0.2 percent whilst those to the south of the processing site are slightly steeper at 0.3 percent. Thus, an approximate estimate of subsurface flow velocity within the sandy creek beds (hydraulic conductivity 0.001 m/s) will be in the region of 100 metres per year and the travel time to reach the tributary of Kerosene Camp Creek and Southern Basins is therefore in excess of 100 years.

Potential impacts - open pit

The open pit will receive groundwater flow during excavation along with incident rainfall and pit dewatering will be required to maintain dry working conditions. During the first development stage the pit void is at its smallest and the risk of pit overflow is highest should dewatering activities cease. A void space in excess of 4 million m^3 will be achieved relatively quickly towards the end of stage one and would exceed the average annual volume of inflow from groundwater and incident rainfall.

A water balance also shows that water levels within the pit will achieve an equilibrium level well below the pit perimeter (Appendix E). This assumes that the Kerosene Camp Creek diversion continues to function as designed.

In addition to the low risk of pit overflow the low sulphur content, generally low metal toxicant content and low metal and salt leachability further limits the risk of acid mine drainage from the open pit (reference Appendix L of this EIS).

Potential impacts - waste dumps

Waste Dumps occupy a large proportion (590 ha) of the mine site (1401 ha) and will rise to a height of around 50 m. The material to be stored is generally non-acid forming. Detail of the likely water retention capacity of dumps is not available, however, given the height and potential void space of stored material the water retention is likely to be comparable with extreme (100-year ARI) storm rainfall events (depth of 295 mm) and annual average rainfall (depth of 310 mm). Therefore, the majority of incident rainfall over Waste Dumps will infiltrate and result in negligible surface runoff or return of seepage to the ground surface.

Depending on the properties of material used in the base of the Waste Dumps infiltrating water within the dumps will eventually seep into the underlying ground where it will follow prevailing hydraulic gradients. Following excavation of the pit void and implementation of dewatering activities hydraulic gradients within the mine site are likely to be directed towards the open pit thereby reducing the potential for migration of mine affected water to groundwater systems beyond the mine site.

Water management controls

The mine site lies in the headwaters of the Woodforde River drainage system that flows across the western extension of the Ti Tree Basin whilst the processing site lies in the headwaters of the Southern Basins and the mine water supply borefield. For this reason, the storage capacity of tailings and residue storage facilities must be sufficient to maintain a negative water balance (evaporation exceeds water inputs).

Tailings and residue storage facilities will have a design storage capacity that is sized according to industry compatible standards whereby storage is able to contain a 100-year ARI average annual rainfall whilst retaining sufficient additional freeboard to accommodate a PMP 72-hour storm rainfall event. Water balances have shown that the accumulation of supernatant water can be controlled by natural evaporation given this design storage capacity. Storage facilities will also have maximum reporting levels above which water levels will invoke emergency measures to prevent overflow. In addition to evaporation the supernatant water accumulating in the Flotation Tailings Storage Facility will be controlled by recycling to the processing site. Due to adverse water quality the recycling of supernatant water is not permissible from the Water Leach Residue Facility, Phosphate Residue Facility and Impurity Removal Residue Facility. It is understood that all storage facilities will have low permeability liners and leakage collection systems to reduce the risk of seepage to groundwater.

Waste Dumps are expected to be constructed with a perimeter bund and then a series of irregular cells will be created with this outer bund. The cells store rainfall and encourage vegetation. An inward sloping mid-slope bench to trap incident rainfall and promote seepage to internal water storage is also in the dump design concept. Given the relatively high height (50 m) of Waste Dumps and low annual rainfall it is unlikely that internal pore spaces of the dump will become fully saturated where seepage emerging from its base would match infiltration at its surface.

Sediment ponds will be used to capture surface runoff from all mine affected areas to promote evaporation and seepage to ground. This includes areas of:

- Surface water draining from Waste Dumps and soil stores
- Surface runoff from the administration and camp areas
- Surface water collected in the pit
- Dewatering from the ore body
- Runoff from the ROM pad
- Runoff from the road between pit and ROM pad
- Runoff from the crushing area.

The open pit will require dewatering to ensure dry working conditions although pumping will be staged to ensure the ore remains damp to reduce potential dust emission throughout the year. Inflow from groundwater, and to a lesser degree incident rainfall, will need to be decanted to an on-site storage pond for recycling to the processing site and/or dust suppression. Dewatering of the open pit will cause a local drawdown of groundwater levels in surrounding areas. This will cause seepage of surface water from Waste Dumps and other areas of the mine site to migrate towards the pit, thereby reducing the risk of potential impact on the surface or groundwater of areas beyond the zone of groundwater drawdown (more or less coincident with mine site boundary).

HDPE piping has been adopted for the transfer pipeline between the mine site and processing site. The pipeline will run above ground within a bunded corridor. In the event of leaks or pipe failure, slurry will be captured within the bunded corridor and within event ponds located at significant low points along the eight kilometre alignment. Specific details of event pond sizing and tiered bund levels will need to be assessed during detailed design.

Appendices

Appendix A – Nolans Bore EIS Kerosene Camp Creek Diversion – Concept

Arafura Resources

Nolans Bore EIS

Kerosene Camp Creek Diversion - Concept

March 2016

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Figure index

Appendices

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

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD as described in this report where relevant. GHD disclaims liability arising from any of the assumptions being incorrect.

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The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

1. Introduction

Arafura Resources (AR) are proposing to develop and operate an open cut rare earth minerals mine at Nolans Rare Earths Mine (the project), located approximately 140 km north- west of Alice Springs. The project will include an open cut pit, waste rock dumps, topsoil storage, a tailings storage facility and mine facilities (refer to Figure 1-1).

Some project components are proposed to be located within Kerosene Camp Creek and its tributaries (refer to Figure 1-1). To allow for the development of the project to occur in a safe manner, it is proposed that a diversion be constructed to manage upstream flows to be safely conveyed around the project with minimal interaction with the proposed mining activities.

For the Nolans Feasibility Study, AMC Consultants (AMC 2015, Appendix A) identified seven diversion options to convey flows within Kerosene Camp Creek around (or through) the project. Of these seven options, three were not considered to be viable by AMC (2015).

A risk assessment was undertaken by AMC (2015) for the remaining four diversion options. Following the risk assessment the preferred diversion options was identified by AR (option D: refer to Figure 1-1) as it represents the lowest risk with respect to safety, environment and community. In particular, by diverting Kerosene Camp Creek around most of the project option D reduces the risk of contamination of the surrounding water resources.

This report provides a hydraulic assessment of a conceptual design for the Option D diversion. The assessment included:

- Refinement of the location of the Option D diversion alignment based on additional survey information
- Development of a channel cross-section for the realignment
- Hydraulic modelling of the concept realignment to assess its performance.

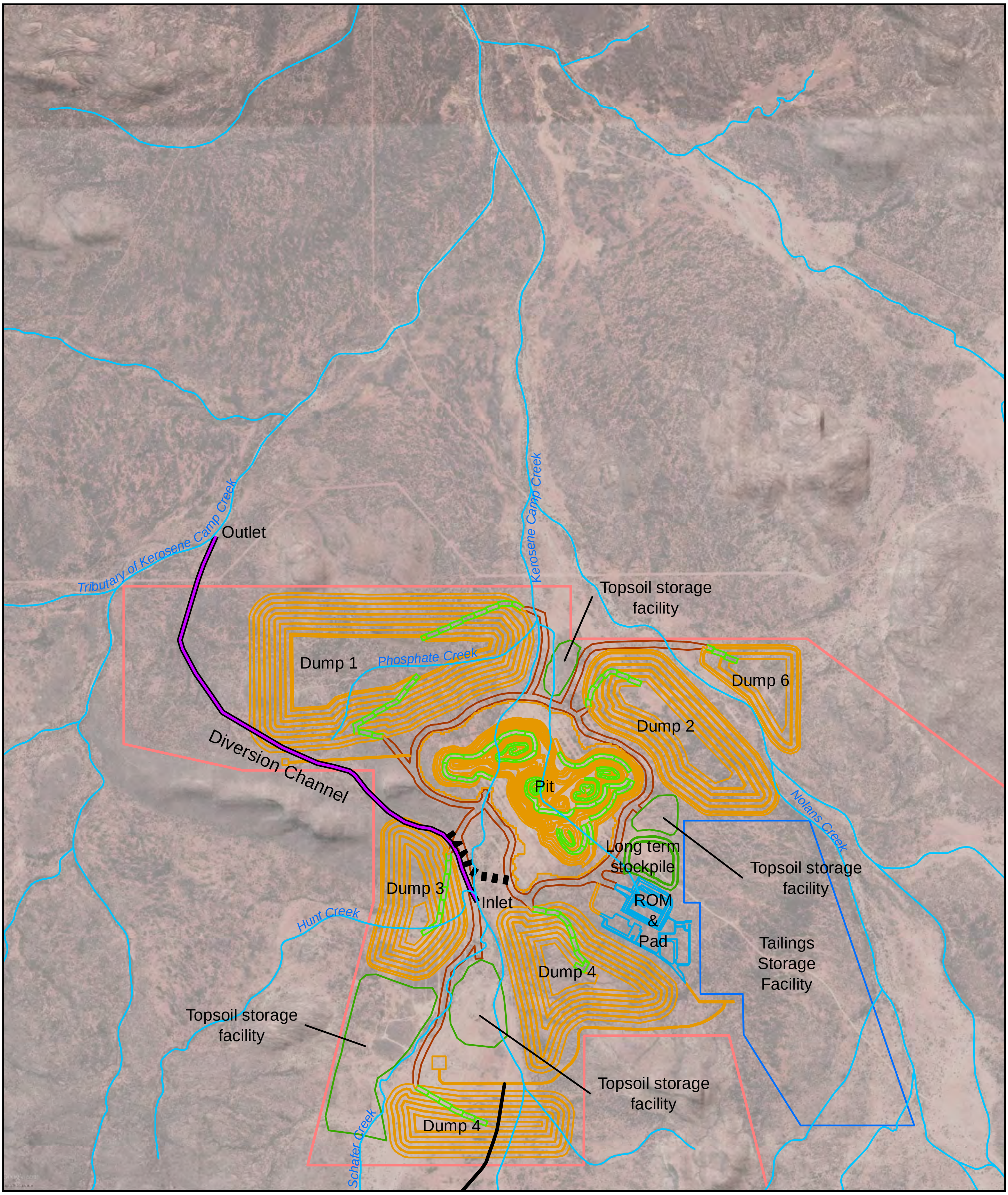
1.1 Option D alignment overview

As shown in Figure 1-1, Option D includes a channel approximately 4 km in length, diverting Kerosene Camp Creek to the north-west following existing drainage lines and a saddle in the hills to the west of the mine. The downstream extent of the alignment joins an unnamed tributary of Kerosene Camp Creek, approximately 4 kilometres upstream of the confluence with the main channel of Kerosene Creek. A levee will be required at the upstream extent of the diversion to prevent overbank flows from entering the proposed pit (refer to Figure 1-1).

1.2 Assumptions and limitations

The following key limitations and assumptions have been made in the preparation of this report:

- There is limited information regarding soils and sub-surface ground conditions along the realignment route. GHD has assumed that realignment will primarily be set within bedrock of a moderate to high strength.
- GHD have developed the diversion route based on information provided by AR. It is assumed that this information is accurate and the diversion route does not impinge on threatened ecological species or communities, cultural heritage sites and existing or future mine infrastructure.



LEGEND

Waterways
Proposed Mine Site Boundary
Diversion
Levee

1:40,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

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Nolans Project

Kerosene Camp Creek
Diversion Channel - Option D Alignment

Job Number	43-22301
Revision	0
Date	30 Mar 2016

Figure 1-1

G:\43\22301\GIS\Maps\4322301_019_DiversionOptionD.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 05/11/2015). ARL - Project Areas (2015). Created by: CM

2. Existing environment

2.1 Site description

The total catchment area of Kerosene Camp Creek upstream of the proposed realignment is approximately 20 km^2. The catchment area of the tributary into which the realignment will flow to is approximately 46 km^2 upstream of the diversion entry point. Both creeks are ephemeral with stream flow limited to short periods following rainfall events.

The Strahler Order of the section to be realigned was derived using the 1:250,000 Geoscience Australia's Geofabric Watercourse lines dataset. Kerosene Camp Creek is a 3rd order watercourse at the point where the proposed diversion starts, and the tributary into which the realignment will flow to is also a 3rd order watercourse.

The existing morphology of Kerosene Camp Creek and the tributary was identified based on a site inspection undertaken over the 28 and 29 of April 2015 and a review of aerial imagery and topographic data. Neither flow nor any ponded water was observed at the time of the inspection.

The creeks are characterised by low sinuosity channels (i.e. generally straight with gentle bends) with a grade of approximately 1 in 400 (0.25%). The existing channel of Kerosene Creek has bankfull widths of approximately 10 metres to 15 metres and depths of approximately 1 metres to 2 metres. The tributary has a wider channel, typically between approximately 25 metres and 35 metres, reflecting the larger catchment area of the tributary upstream of the diversion.

The bed of both creeks is relatively featureless, with sand with some gravel (Figure 2-1 and Figure 2-2). In cross-section, the channel is symmetrical and relatively simplistic in form with limited evidence of features such as pools, bars or benches. Banks are composed of alluvial sand and silt deposits and are vegetated with low grasses and scattered shrubs and trees. Bedrock occasionally outcrops in the banks and bed of both creek channels (Figure 2-3), providing some control on channel form and bed levels.

The channel of Nolans Creek is set within a terraced valley with the contemporary valley floor extending up to approximately 100 metres. The inset floodplains typically bound either side of the channel, with the surrounding terrace surfaces rising approximately 1 metre to 2 metres above the floodplains. The exposed banks indicate that the floodplains are likely to be dominantly composed of silty sand. The floodplain surfaces are largely vegetated and low shrubs (Figure 2-4) and are dissected by shallow flood channels.

Figure 2-1 View of typical channel morphology in the vicinity of the start of Option D diversion alignment

Figure 2-2 Upstream view of tributary near point of entry of the diversion

Figure 2-3 Bedrock outcrops in channel bed of the tributary

Figure 2-4 View across western floodplain to Kerosene Camp Creek channel

2.2 Option D alignment – existing conditions

The initial section of the proposed diversion traverses gently upwards sloping land (Figure 2-5) until the diversion meets an existing drainage line (Figure 2-6). The proposed diversion then follows the drainage line up the range to a saddle area between hill tops. The saddle area typically slopes to the north and exhibits several rock outcrops (Figure 2-7). On the western flank of the range, the proposed diversion alignment follows an existing drainage line that flows in a north-westerly direction (Figure 2-8) before joining with the unnamed tributary of Kerosene Camp Creek.

The general terrain traversed by the proposed diversion means that the bulk of the diversion channel will be set in rock. However, it expected alluvial and weathered bedrock materials will be encountered within the upstream and downstream extents of the proposed diversion alignment.

Figure 2-5 View along the initial section of the alignment

Figure 2-6 Drainage line on eastern flank of the hills

Figure 2-7 Bedrock outcrops through the saddle section

Figure 2-8 The incised drainage line on the western flank of the hills

2.3 Hydrology

The occurrence of surface runoff and flows within local creeks is likely to be infrequent and only occur during exceptional rainfall events associated with the occasional southward extension of the monsoon trough or periodic incursion of north-west cloud bands over the interior.

The magnitude of flood events in response to design rainfall events within the Kerosene Camp Creek and tributary catchments were modelled using a rainfall-runoff model (XP-RAFTS) and are summarised in Table 2-1. From Table 2-1 it can be seen that the 100 year ARI flows within Kerosene Camp Creek at the diversion location are less than half those within the unnamed tributary where the diversion will discharge.

Table 2-1 Design flood peak runoff for Kerosene Camp Creek

Catchment and Location	Upstream Area (km^2)	1 in 2-year ARI flood	1 in 10-year ARI flood	1 in 100-year ARI flood
		Peak (m^3/s)	Peak (m^3/s)	Peak (m^3/s)
Kerosene Camp Creek Existing Case (Upstream of Proposed Diversion)	20.4	3.0	28.8	86.4
Kerosene Camp Creek Tributary Existing Case (Downstream of Proposed Diversion)	46.0	6.2	64.3	184.1

3. Concept design and evaluation

3.1 Concept design

The hydraulic concept design for the proposed diversion of the Kerosene Camp Creek is considerably constrained by the terrain along the Option D alignment:

- Limited longitudinal grade, with an average gradient of approximately 0.1% (compared to approximately 0.25% within the existing reaches of Kerosene Camp Creek)
- Deep excavation into largely fractured but competent rock, with excavation depths exceeding 6 metre for approximately 2,000 metres and maximum excavation depths of approximately 12 metres to 16 metres for approximately 800 metres across the saddle.

A preliminary concept cross-section for the proposed diversion was developed, with consideration of these site constraints, as follows:

- A steep sided channel with 3V to 1H batters to minimise both excavation volumes and the top footprint width of the diversion
- An inset channel with 1V to 1.5H banks, approximately of 2 metres deep with a 4 metre base width that mimics the dimensions of the existing channel
- Benches, each approximately 2 metres wide, on either side of the inset channel to provide an opportunity for vegetation to establish in proximity the channel.

This conceptual channel section is displayed in Figure 3-1 for an excavation depth of 6 metres.

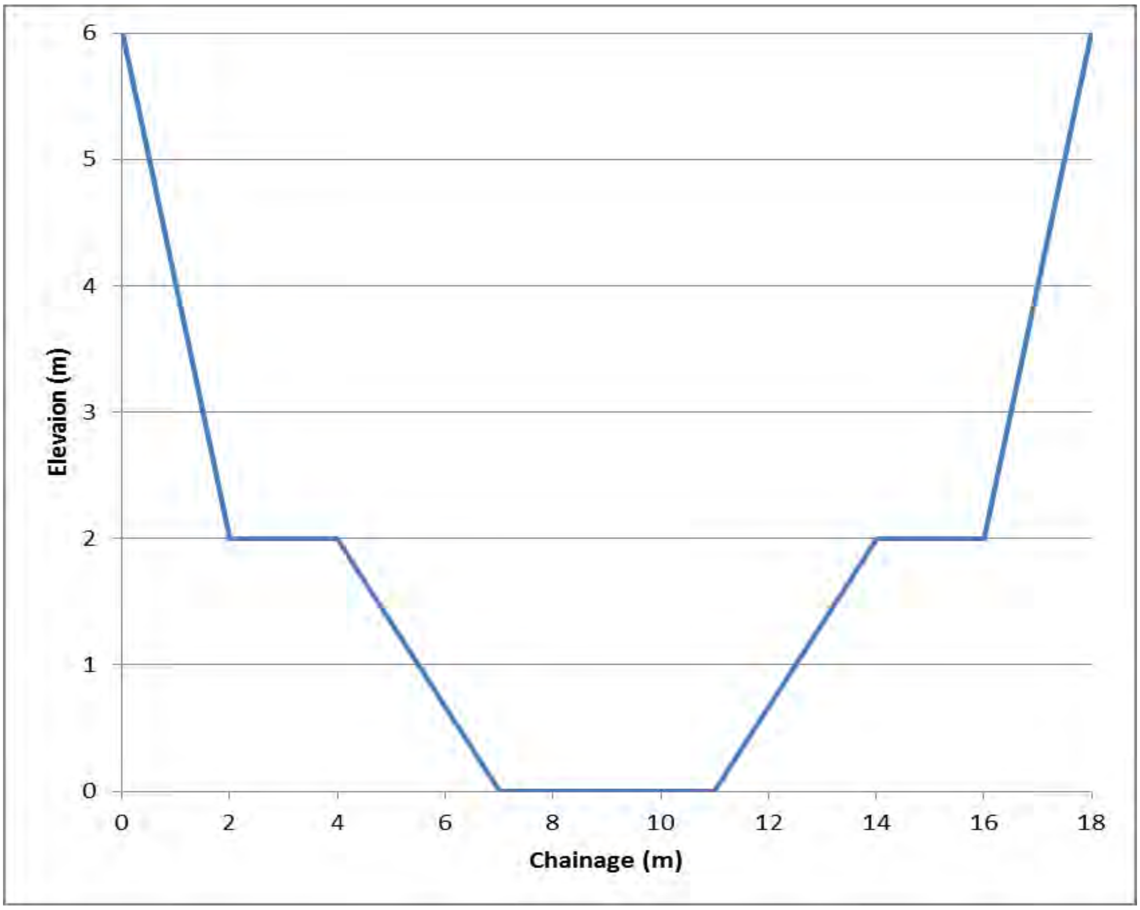

Figure 3-1 Conceptual diversion channel cross-section

The concept batter slopes and channel shape will be updated during future design phases as additional geotechnical and constructability investigations are undertaken. It is expected that the final diversion design will incorporate a number of cross section geometries that are tailored to the local geotechnical, geomorphic and hydraulic requirements.

3.2 Hydraulic evaluation

The concept design was used to develop a hydraulic model using the one dimensional HEC-RAS model (USACE 2010). The model also incorporated the effect of the proposed flood protection bund at the upstream extent of the realignment to direct overbank flows down the diversion channel. The model was used to estimate flow conditions for the 2-year, 10-year and 100 year ARI peak flow events (refer to Table 2-1).

The modelling included Manning's n values of:

- 0.04 for the existing channel, to account for vegetated conditions
- 0.03 for the diversion channel, to account for rough bedrock
- 0.05 for the overbank areas, to account for long grasses with scattered trees.

The maximum modelled water level and shear stresses for the 2-year, 10-year and 100-year ARI flood events are included in Figure 3-2, Figure 3-3 and Figure 3-4 respectively. The modelled water levels for existing conditions within Kerosene Camp Creek and the tributary are also included.

The modelling indicates that the proposed diversion is likely to increase flow depths within the section immediately upstream of the start of the diversion by up 1.5 metres under the 100 year ARI event (refer to Figure 3-4). The modelled water level increase is considered to be the result of the lower gradient of the proposed diversion, resulting in a back-up effect which in turn results in a marked reduction in shear stress values at the upstream extent of the diversion (refer to Figure 3-4).

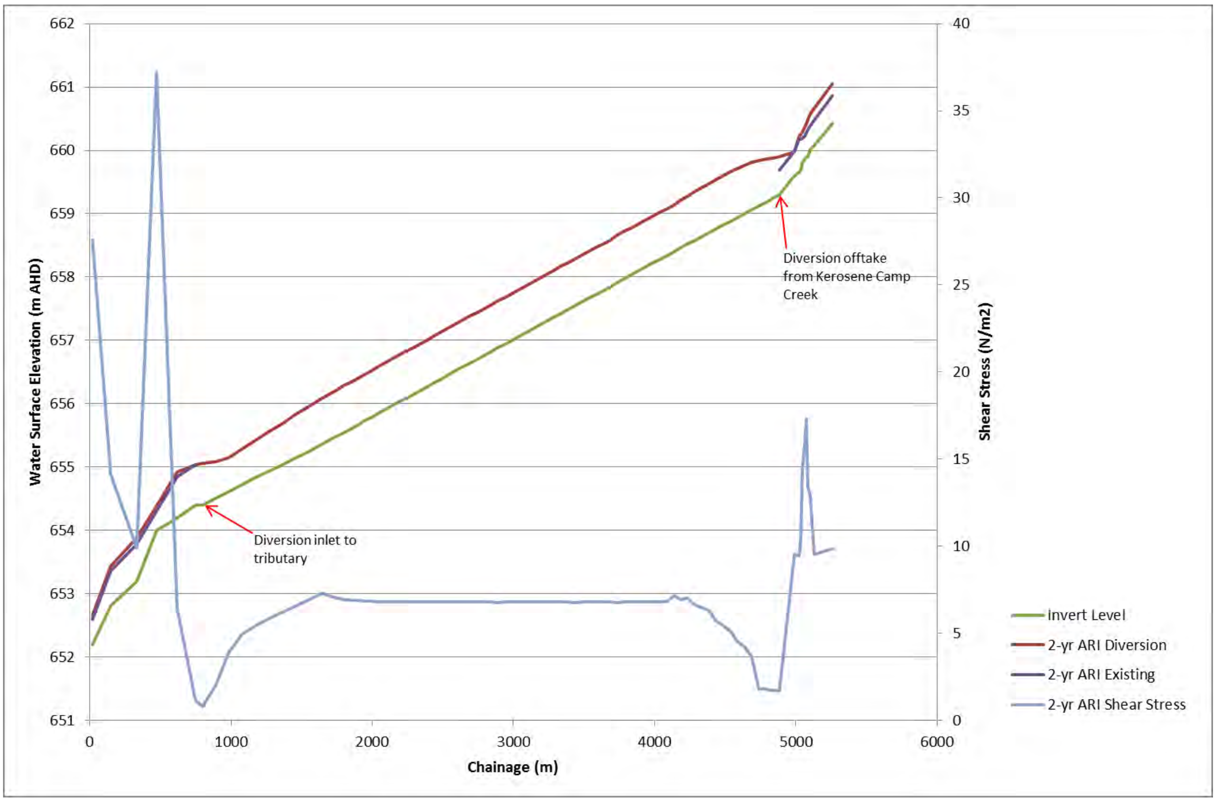

Figure 3-2 Modelled water level and shear stress for the 2 Year ARI

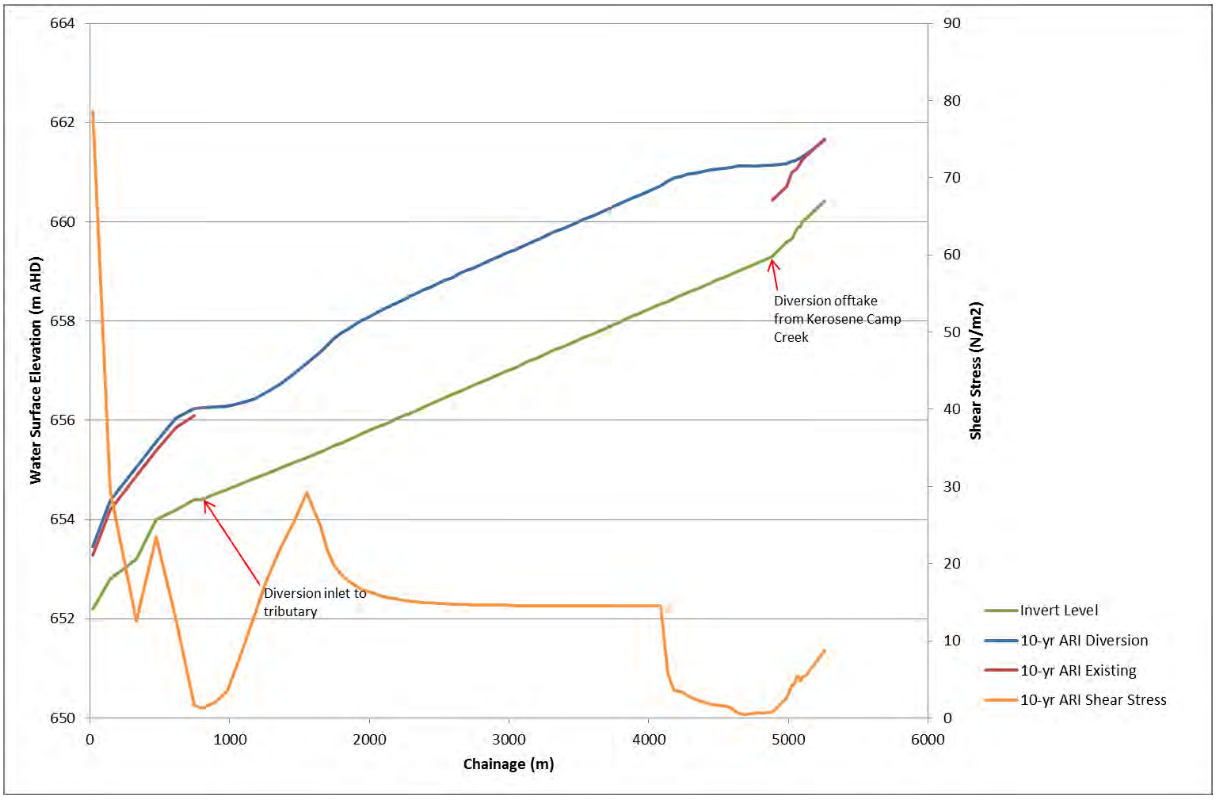

Figure 3-3 Modelled water level and shear stress for the 10 Year ARI

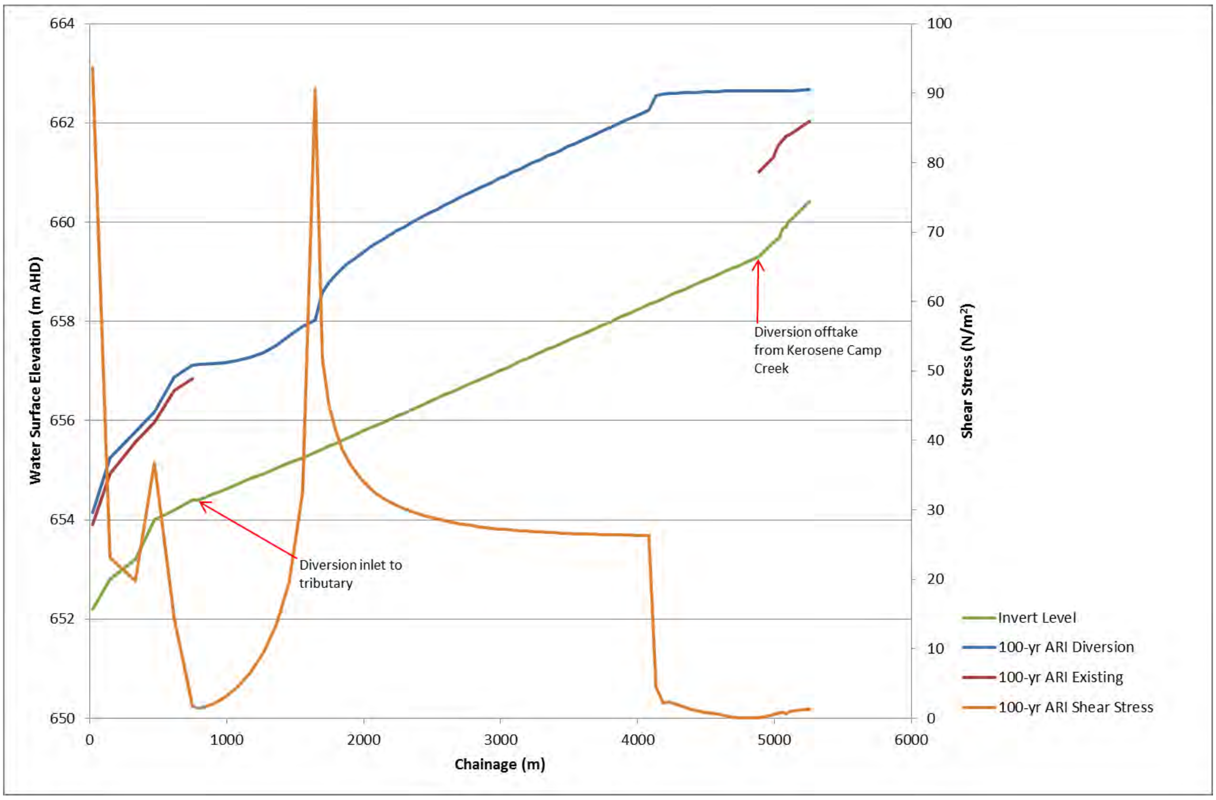

Figure 3-4 Modelled water level and shear stress for the 100 Year ARI

Shear stress is an indicator of the capacity of a flow to entrain and transport sediment, with reductions in shear stresses indicating a potential decrease in sediment transport capacity.

The average modelled shear stresses for existing and diverted conditions within Kerosene Camp Creek upstream of the proposed diversion are included in Table 3-1. Similarly, Table 3-2 provides the average shear stress values in the tributary downstream of the diversion.

Table 3-1 Average channel shear stress values for existing and diverted conditions upstream of the diversion

Flow Event ARI	Existing Average Shear Stress Values (N/m2)	Diversion Average Shear Stress Values (N/m2)
2 Year	7.6	7.2
10 Year	25.4	11.5
100 Year	26.5	1.3

Table 3-2 Average channel shear stress values for existing and diverted conditions in the tributary downstream of the diversion

Flow Event ARI	Existing Average Shear Stress Values (N/m^2)	Diversion Average Shear Stress Values (N/m^2)
2 Year	13.8	13.7
10 Year	44.5	26.4
100 Year	73.4	69.7

The modelling indicates that upstream of the proposed diversion, average shear stresses for the 100-year ARI flood event are reduced from 26.5 N/m^2 to 1.3 N/m^2 (refer to Table 3-1). Low shear stress values (<5 N/m^2) indicate that the reach of Kerosene Camp Creek upstream of the proposed diversion and the upper reaches of the proposed diversion are likely to be subject to sediment deposition.

The deposition of sediments will result in the progressive reduction in the level of flood protection provided by the proposed flood protection bund, increasing the risk of pit flooding and/or the capture of Kerosene Camp Creek into the pit. To mitigate these risks, it is recommended that the initial 200 metres to 400 metres of the diversion be steepened to improve flow conveyance and sediment transport at the start of the diversion. The steepening of the start of the proposed diversion will reduce the available grade for the remaining section of the proposed diversion. This will likely reduce shear stresses and sediment transport potential in the downstream section of the diversion. Further hydraulic modelling is recommended to optimise the longitudinal gradient and cross sectional geometry required to optimise sediment transport along the length of the proposed diversion. It is also recommended that the flood protection bund be designed to provide flood protection for design storm events well in excess of the 100-year ARI flood event modelling. This will reduce the risk of future creek capture by the pit from progressive sediment accumulation at the start of the diversion and/or from design event exceedance.

The modelling indicates no significant change in the modelled shear stresses downstream of the proposed diversion (refer to Table 3-2). This is consistent with the minimal change in the modelled flood levels at this location, with an average afflux of approximately 0.2 metres (refer to Figure 3-4). As a result, the additional flow discharge from the diversion is not expected to have any significant impact on the morphology or flood behaviour of the tributary.

3.3 Channel stabilisation and treatments

As the diversion will predominantly be set in hard bedrock, the need for channel stabilisation measures will be limited to the upstream and downstream extents of the proposed diversion where alluvial and/or weathered bedrock materials are expected to be encountered. The extent of the stabilisation treatments will be identified more accurately during future investigation and design phases, including outputs from geotechnical investigations.

Rock lining is recommended where additional bed and bank stabilisation may be required. Any topsoil won from construction of the diversion may be incorporated into the voids of the rock lining to provide an improved media for the establishment of vegetation within the rock lining.

4. Summary and recommendations

The hydraulic performance of a concept design for the proposed diversion of Kerosene Camp Creek to permit mining at the proposed Nolans Bore Mine has been assessed. The proposed diversion design assessed was based on the preferred (option D) diversion alignment as AR considered it to have the lowest risks with respect to safety, environment and community. In particular, option D involves diverting the creek well away from mining operations thereby reducing the risk of contamination of creek flows through contact with mined materials.

From a hydraulic design perspective, the proposed diversion alignment poses some significant design constraints, including:

- Limited longitudinal grade, with an average gradient of approximately 0.1% (compared to approximately 0.25% within the existing reaches of Kerosene Camp Creek)
- Deep excavation into largely fractured but competent rock, with excavation depths exceeding 6 metre for approximately 2,000 metres and maximum excavation depths of approximately 12 metres to 16 metres for approximately 800 metres across the saddle.

With consideration to these constraints, a preliminary concept cross-section for the proposed diversion was developed as follows:

- A steep sided channel with 3V to 1H batters to minimise both excavation volumes and the top footprint width of the diversion
- An inset channel with 1V to 1.5H banks, approximately of 2 metres deep with a 4 metre base width that mimics the dimensions of the existing channel
- Benches, each approximately 2 metres wide, on either side of the inset channel to provide an opportunity for vegetation to establish in proximity the channel.

Hydraulic modelling of the proposed diversion indicates that the reduced gradient is likely to result in a back-up effect within the upstream reaches of the proposed diversion, with upstream flow depths increasing by up to 1.5 metre in the 100 year ARI event (refer to Figure 3-4). In addition, shear stresses are expected to reduce upstream of the proposed diversion. It is therefore expected that reach upstream of the proposed diversion, including the upper reaches of the proposed diversion itself, will be subject to sediment deposition. With deposition over time, the flood immunity level provided by the proposed flood protection bund will progressively lessen, increasing the risk of pit flooding and/or the capture of Kerosene Camp Creek into the pit.

To mitigate these risks, it is recommended that the initial 200 metres to 400 metres of the proposed diversion be steepened to improve flow conveyance and sediment transport at the start of the proposed diversion. This steepening at the start of the proposed diversion will reduce the available grade with the rest of the proposed diversion downstream. This will likely reduce shear stresses and sediment transport potential within the downstream sections of the proposed diversion. The potential increase in sediment deposition within the downstream reaches of the proposed diversion may be further managed by local changes to the channel slope and cross sectional geometry. Further hydraulic modelling is recommended to optimise the slope and cross sectional geometry of the proposed diversion to balance sediment transport throughout the proposed diversion and within the upstream and downstream reaches of Kerosene Camp Creek and its tributary.

It is also recommended that the flood protection bund be designed to manage flood flows well in excess of the design capacity of the diversion channel. This will reduce the risk of future creek capture by the pit from progressive sediment accumulation at the start of the diversion and/or from design event exceedance.

Modelled average shear stress values within the tributary downstream of the proposed diversion remain comparable between the existing and proposed conditions. This indicates the additional flow discharge from the diversion is not expected to have a significant impact on the morphology of the tributary downstream of the proposed diversion.

As the proposed diversion will predominantly be set in hard bedrock, the need for channel stabilisation measures will be limited to the upstream and downstream extents of the alignment where alluvial and/or weathered bedrock materials are expected to be encountered. The extent of the stabilisation treatments will require additional investigation and consideration as part of future design phases, including outputs from geotechnical investigations.

4.1 Considerations for detailed design

The following investigations and refinements are recommended to be implemented during the detailed design phase of the diversion:

- Optimisation of the proposed diversion alignment with consideration of any environmental or heritage constraints
- Geotechnical investigation of sub-surface conditions along the proposed diversion route.
- Refinement of the channel cross-section based on results from the geotechnical investigation and consideration of efficient construction methods
- Hydraulic analysis to evaluate any required alignment or cross-sectional form changes and to define the degree of steepening required at the upstream extent of the diversion to mitigate sediment deposition risks
- Levee design including the provision to pass flows in excess of the design event into the pit void with limited risk of breaching
- Determination of material quantities and channel stabilisation requirements based on design refinements
- Requirements for erosion and sediment control during construction
- Determination of access routes and the location and volume of both temporary stockpiles and any permanent storage of excavated materials.

Appendices

Appendix A – Nolans Feasibility Study – Preliminary Studies Site Drainage and Land Tenure

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Report

Nolans Feasibility Study – Preliminary Studies
Site Drainage and Land Tenure
Arafura Resources Limited

AMC Project 215004B_2
7 April 2015

7 April 2015

Mr Peter Llewellyn
Independent Mining Consultant
Arafura Resources Limited
Level 5, 16 St Georges Terrace
PERTH WA 6000

Dear Peter,

RE: Nolans Feasibility Study – Preliminary Studies
Site Drainage and Land Tenure

Arafura Resources Ltd (Arafura) commissioned AMC Consultants Pty Ltd (AMC) to conduct preliminary studies relating to the diversion of the Kerosene Camp Creek, the current land tenure in respect to life-of-mine (LOM) waste storage capacity and the impact of increasing the surface footprint of the tailings storage facility (TSF). A risk review of Kerosene Camp Creek diversion scenarios was also completed by Arafura and AMC.

The major outcomes of this work were:

- Two options, Options D and E, for the Kerosene Camp Creek diversion will be further assessed as part of the definitive feasibility study (DFS).
- Three other options, Options A, B and C, were initially considered viable but when assessed as part of the risk review, their residual ratings remained extreme from an environmental perspective and may therefore be considered too risky by Arafura to pursue further.
- Option D diversion channel will require acquisition of an Access Authority.
- Mine infrastructure upgrades to suit the LOM pit limits have been completed.
- There is appropriate storage capacity for the total LOM waste quantity on the existing Nolans 1 mineral lease (MLA 26659).
- Doubling of the TSF footprint will require the acquisition of the proposed Nolans 3 mineral lease.

AMC recommends Arafura:

- Assess Options D and E as part of the DFS Surface Water Management Plan.
- Engage a civil engineer to assess the technical requirements for Option E.
- Engage a civil engineer for detailed diversion channel design, if Option D is selected, to confirm the gradient and cross sectional area is sufficient to achieve the target flow rate. The natural topography did not allow for a gradient of 0.5% as recommended by Knight Piesold.
- Develop waste dumps as presented in this option (to be refined as required for the DFS).
- Reconfigure the mine surface layout during the DFS to ensure buildings are located upwind of the ROM pad and process plant, taking account of the prevailing wind, to minimize dust exposure for personnel.

AMC is available to discuss any queries that you may have.

Yours sincerely

Alex Biggs
Mining Engineer

Quality control

The signing of this statement confirms this report has been prepared and checked in accordance with the AMC Peer Review Process. AMC's Peer Review Policy can be viewed at www.amcconsultants.com.

Author

Alex Biggs	7 April 2015 **Date**

Peer Reviewer

Jonathan Dray	7 April 2015 **Date**

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1 e-copy to AMC Perth office

1 Introduction

1.1 Background and scope

AMC Consultants Pty Ltd (AMC) was engaged by Arafura Resources (Arafura) to undertake preliminary studies and reviews (Preliminary Studies) for the Nolans Rare Earths project (Nolans), in preparation for the 2015 Definitive Feasibility Study (DFS). The status of the Preliminary Studies work packages are summarized in Table 1.1. This report (the Study) summarizes the findings for the Site Drainage and Creek Investigations and Land Tenure components of the Preliminary Studies.

In addition to the original scope of the Preliminary Studies, Arafura and AMC also completed a risk review in relation to the Site Drainage and Creek Investigations component.

Table 1.1 Status of Preliminary Studies

Preliminary Mining Studies Component	Completion Date	Status
Strategic Schedules	January 2015	Complete
Site Drainage and Creek Investigations	February 2015	This report
Land Tenure	February 2015	This report
Waste Rock Model	June 2015	Yet to commence

Previous relevant work completed by AMC, referenced within this report, is:

- 2012 Nolans Bore Ore Reserve[1] (2012 Ore Reserve) - pit designs and surface layout.
- 2014 Study Update[2] (2014 Update). Aspects of the 2012 Ore Reserve mine planning were updated for the Nolans Development Report (NDR) which was completed by Arafura in September 2014. For this work, two scenarios were considered:
  - Measured and Indicated Mineral Resources (M&I Case), and
  - Measured, Indicated and Inferred Mineral Resources (LOM Case).

The objective of the Site Drainage and Creek Investigations work package was to identify possible relocation options for the Kerosene Camp Creek diversion channel (Diversion Channel). The original Diversion Channel recommended by Knight Piesold as part of the 2010 Draft Feasibility Study (Draft FS) is now largely redundant because current pit sizes (as defined in the 2014 Update) and waste dump sizes from the Preliminary Studies (as defined in the this report) have increased, for both the M&I and LOM Cases. This increased mining footprint now encroaches on the Draft FS Diversion Channel. Arafura requires updated surface layout information as input to the Nolans Environmental Impact Statement (EIS).

The objective of the Land Tenure work package was to consider waste dumping options for the LOM Case, using new waste dump designs to identify and quantify additional land areas outside the existing tenure to be targeted. The target areas would account for heritage sites, drainage considerations and an increased tailings storage facility (TSF) footprint, whilst minimizing haulage distance.

This report summarizes the waste dump designs required to accommodate the life-of-mine (LOM) waste quantities and the impact that the Diversion Channel may have on:

- Existing infrastructure design and layout.
- Waste dump design and capacity.
- Creek diversion scenarios and associated works.
- Diversion Channel bulk earthworks costs.

The Study was completed at a scoping study level of accuracy, as requested by Arafura.

[1] AMC Consultants Pty Ltd report, Nolans Project Feasibility Study Mine Planning, 2012 Ore Reserve – Supporting Documentation, dated 3 May 2013 (AMC report AMC212079E).
[2] AMC Consultants Pty Ltd report, Nolans Project Mine Planning – Mining Update, dated 7 March 2014 (AMC report AMC212079G_2)

1.2 Client supplied information

Arafura provided AMC with mining exclusion zone data, topography file a91901mPT (in points format), mining lease data and aerial photography of the relevant leases.

Arafura advised AMC to assume the LOM TSF footprint would be twice the size of the Draft FS TSF and other waste materials footprint. This footprint included DMS waste, flotation and slimes tailings and thorium and water leach residues returned from the then envisaged chemical processing plant at Whyalla.

1.3 Other supplied information

Additional information regarding hydrology, Kerosene Camp Creek, and the document PE801-00140 EMEM-KP008 Surface Water Management were supplied by Knight Piesold. Previous information and work completed by AMC was also referenced where appropriate in the compilation of this work.

2 Approach

The following approach was applied in the Study:

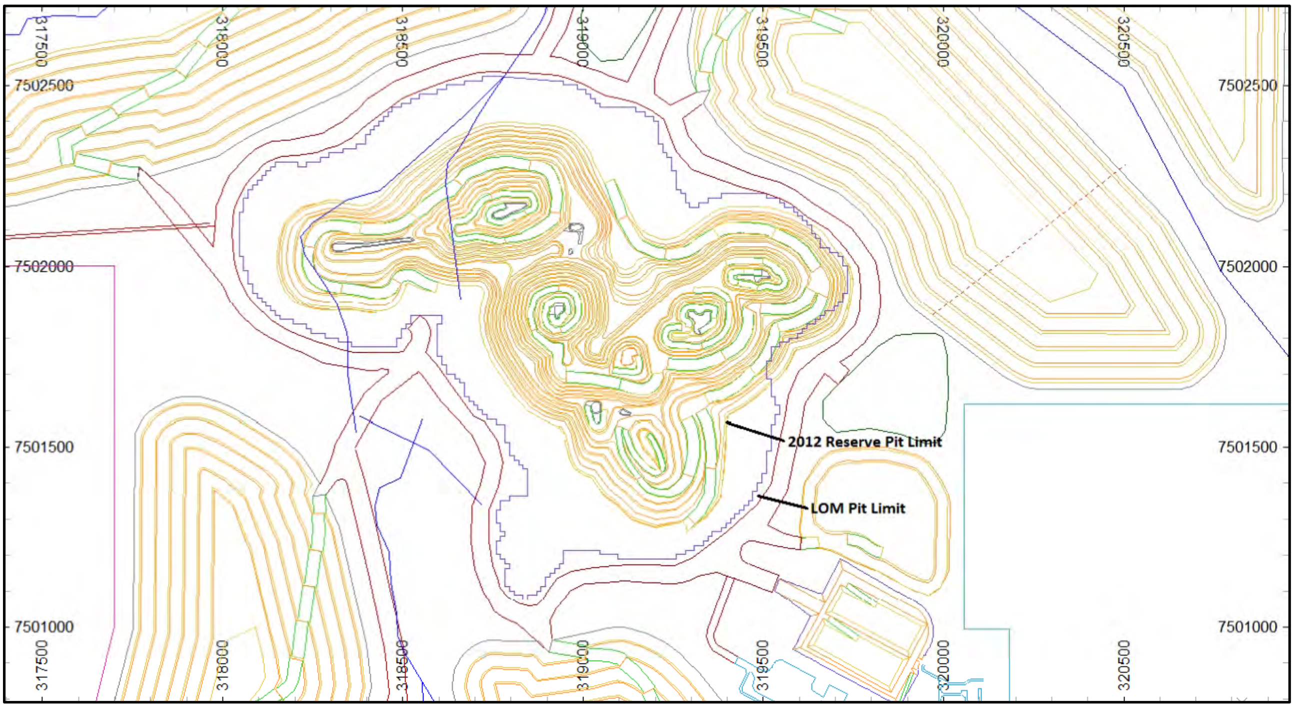
- Review the LOM pit limits.
- Review the exclusion zones.
- Develop options for the diversion of Kerosene Camp Creek and associated costing.
- Adjust the haul roads and infrastructure layout to accommodate the LOM pit limits.
- Identify the most appropriate Kerosene Camp Creek diversion route.
- Redesign waste dumps to allow for both the M&I Case and LOM Case.

All design work was completed using Datamine Studio 3 software.

2.1 LOM pit limit

The LOM pit limit is shown in Figure 2.1 by the purple line and has a significantly larger footprint compared to the 2012 Ore Reserve pit limit. The haul roads were relocated accordingly to accommodate the larger LOM pit limit.

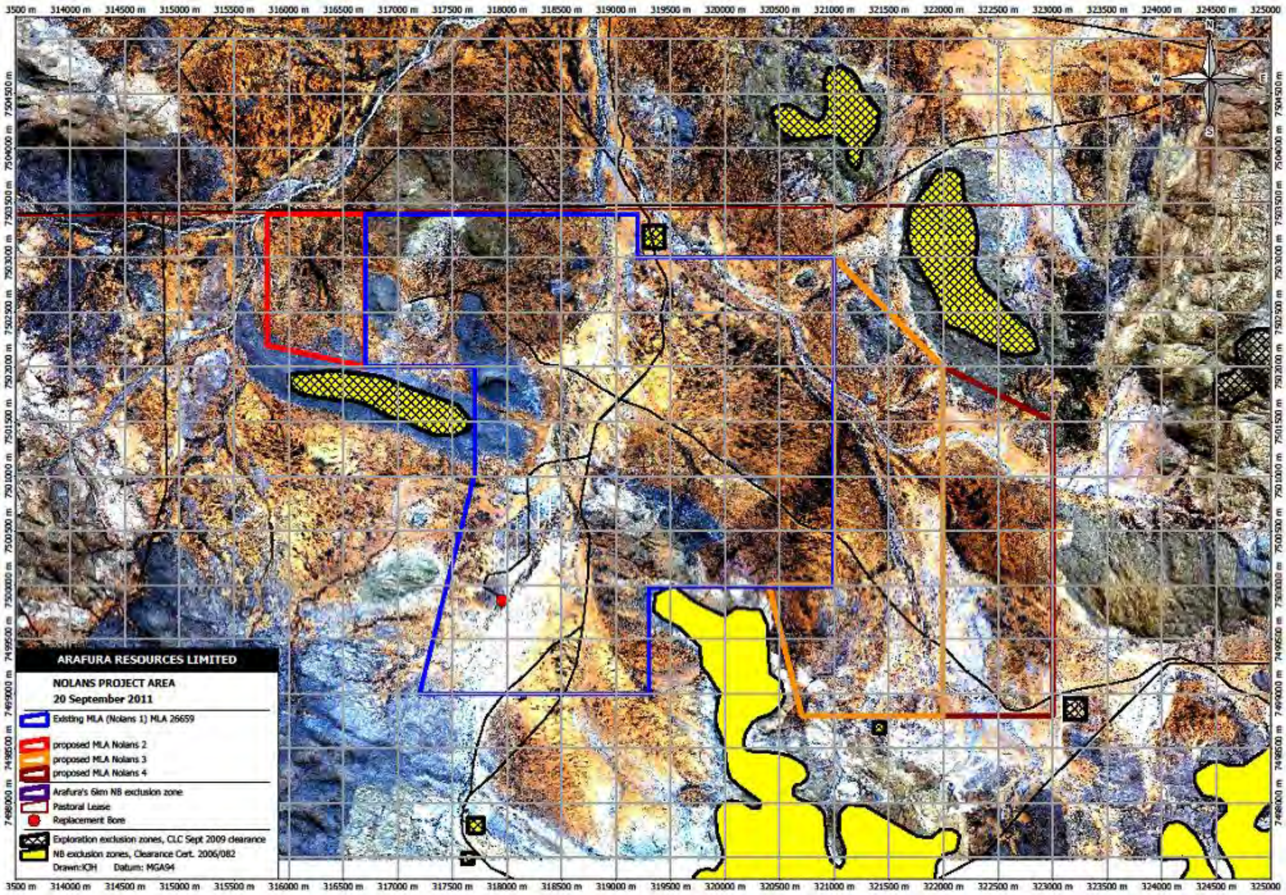
Figure 2.1 Pit limits - LOM and 2012 Ore Reserve



2.2 Exclusion zones

Arafura provided AMC with exclusion zones as shown in Figure 2.2. AMC determined that these exclusion zones do not interfere significantly with the planned mining activities and infrastructure on the lease as they are outside the current and proposed mining lease applications.

Figure 2.2 Mining lease applications and exclusion areas



2.3 Kerosene Camp Creek diversion scenarios

Four of the seven Kerosene Camp Creek diversion options initially considered were further evaluated as part of the Study – Options A, B, C and D, as shown in Table 2.1. The Diversion Channel locations for Options A, B, C and D are shown graphically in Figure 2.3.

Options E, F and G were not further evaluated because AMC considers the disadvantages outweigh the advantages.

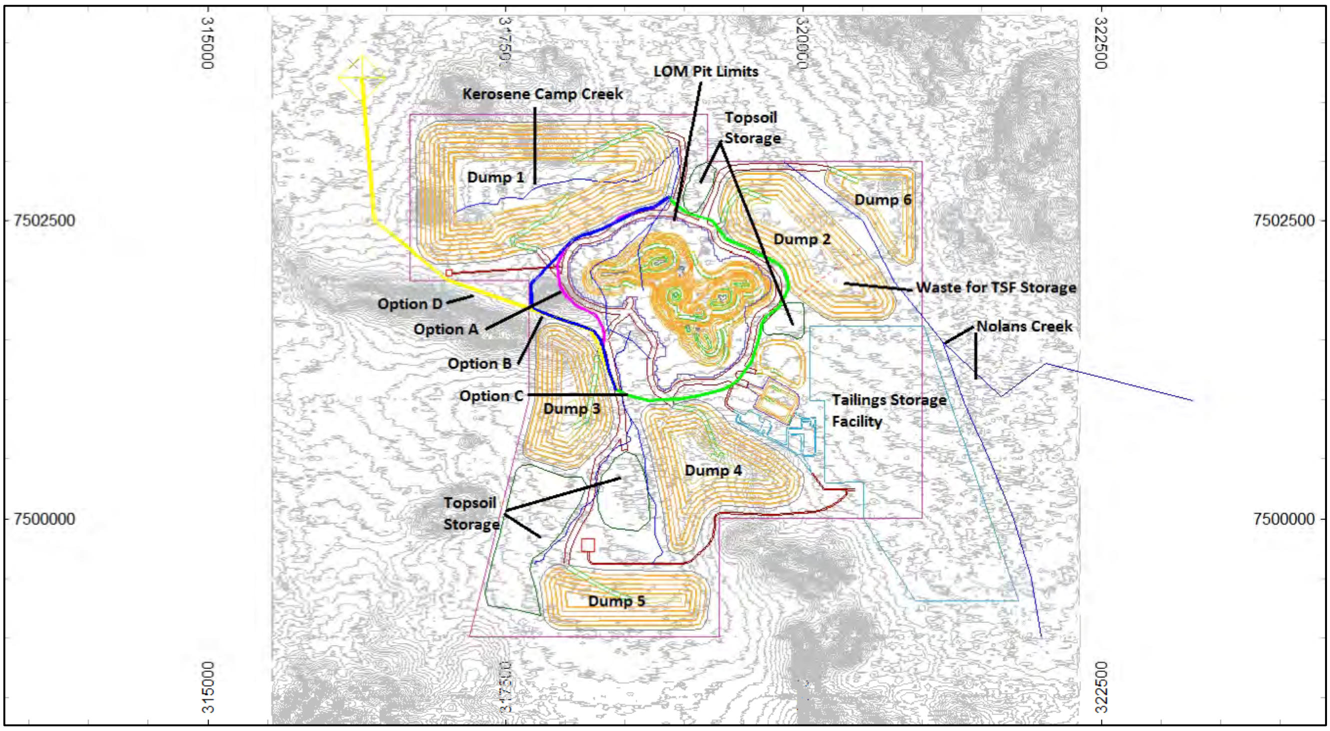
Table 2.1 Kerosene Camp Creek diversion scenarios

Option	Solution	Plot Key (refer to Figure 2.3)	Advantages	Disadvantages	Approximate Length (m)
A	Divert the creek around the western nose of the pit under the main haul road and also under the access road to the waste dump 1 before joining the creek on the north western side of the pit.	Pink	Most direct route. Can follow haul road path on waste dump side.	Will interact will access ramp to waste dump 1. Minimal space between the south western corner of the pit and the adjacent hill therefore requiring additional material removal.Will require further modification, relocation should pit expansions through additional resources be defined or prices increase. The potential for dust/rock contamination or spills/slumps into the diversions means that downstream contamination is likely which would be costly to remedy and manage from a technical and community perspective.	2,400
B	Divert the creek between the two hills to the west of the pit and swing back around 180 degrees and follow between the hill and waste dump.	Blue	Away from mine infrastructure and pit, reducing interaction potential from an environmental point of view and ensuring potential floodwaters are diverted and kept away from working areas.	Long route. Interaction with hill located in the western edge of the lease. Will require further modification, relocation should pit expansions through additional resources be defined or prices increase. The potential for dust/rock contamination or spills/slumps into the diversions means that downstream contamination is likely which would be costly to remedy and manage from a technical and community perspective.,	3,200
C	Divert the creek to the east and back around the pit to re-join the creek on the north west side of the pit	Green	Least undulating terrain. Technically easy to excavate. Least drill and blast required.	Interaction with mining activity around the south, east and north of the pit including a number of access roads to waste dumps. Likely to be least consistent with EIS guidelines pertaining to surface hydrology. Long route. Will require further modification, relocation should pit expansions through additional resources be defined or prices increase. The potential for dust/rock contamination or spills/slumps into the diversions means that downstream contamination is likely which would be costly to remedy and manage from a technical and community perspective.	3,300

Table 2.2 Kerosene Camp Creek diversion scenarios (continued)

Option	Solution	Plot Key (refer to Figure 2.3)	Advantages	Disadvantages	Approximate Length (m)
D	Divert creek to the north west and join to another water course.	Yellow	Furthest away from mining activity and therefore more likely to be consistent with EIS guidelines pertaining to surface hydrology. Most favourable option from environmental management persepctive. Least disruptive to operations during construction.	Longest route. Elevation in the north west of the leases is generally higher than the source or at best slightly lower. This means that the proposed route is relatively flat and will require a greater cross sectional area and therefore a larger amount or earth movement.	3,800
E	Divert the creek close to its source to an event pond directly to the east from where the water may be pumped back on to the land. This would meet Category 1 water standards. If it is required that the water be pumped back to its original downstream destination this can be achieved by running polyethylene pipe fron the event pond, around the western crest of the pit to the downstream location. Upon completion of mining the creek may be reconstructed along its length if required, once there is no requirement for haul roads and infrastructure which is currently preventing the development of a more direct route.	Same as Option A	Least capital intensive. Least time consuming. Event pond can be placed anywhere that is appropriate (closer to source is better to minimise capital costs).	This methodology may possibly breach EPA requirements, although should be investigated further.	100 (creek diversion channel) 2,300 (polyethylene pipe)
F	Allow intersection of creek by pit development, build bund and apply additional in pit pumping capacity as is required when creek is flowing.	N/A	Short term this is the easiest and cheapest option. Minimal excavation required.	Long term this may be probelematic depending on the amount of rainfall. Likely production delays. Safety issues. Potential geotechnical problems in the pit wall due to potential increased pore pressure.	n/a
G	Don't mine the western side of the pit where Kerosene Camp Creek intersects.	N/A	No additional works required.	Reduction in reserve ore.	n/a

Figure 2.3 Potential Diversion Channels for Kerosene Camp Creek



2.4 Impact of Diversion Channel scenarios on operations

A review of potential impact on mining operations of Options A, B, C and D is as follows:

In summary, Options A, B and C all impact the mining and operation with Option C also impacting mining, infrastructure and processing facilities. Option D could be completed as a standalone project completed entirely by a civil contractor with minimal impact on mining activities.

2.4.1 Option A

Interaction with the access road to waste dump 1 should be considered. The Diversion Channel may be excavated on the western side of the haul road on the western side of the pit between the haul road and the waste dump.

There will be a requirement to blast a significant amount of material related to the hill to the south west of the pit which, depending on the timing of construction, may require resources, such as drill-and-blast, to be diverted from pit mining activities.

The channel will be remote from most mining activity, which is beneficial from an interaction and environmental viewpoint.

2.4.2 Option B

This option is also remote from mining infrastructure and activity. The channel may need to cross one haul road and will follow the route of Option A, once it has passed between the hill and back around near waste dump 1. There will be a requirement to move a significant amount of material related to the hill to the south west of the pit. As with Option A, this may impact mining operations depending on the timing of the channel construction, as it will divert resources from the mining operation.

2.4.3 Option C

By diverting the channel to the east and around the pit the Diversion Channel comes into contact with infrastructure and mining activity. There may be the requirement for a number of floodways to account for interaction with access roads to waste dumps and the plant if this option is utilized. However, AMC does not anticipate that the development of this option will be resource intensive or technically demanding because the topography is relatively flat in comparison to the routes taken by Options A, B and D.

2.4.4 Option D

Diverting the channel away from active mining areas and activities is preferable when considering the EIS guidelines that pertain to surface hydrology. This option is the best in terms of reducing interaction with active mining areas although it is the longest route. It also requires more drill-and-blast and is potentially a more technically challenging option.

2.5 Design parameters and assumptions

The design parameters in Table 2.3 were advised by Knight Piesold. These parameters provide a channel cross sectional area adequate to channel the surface flow for catchment C2 (from the surface water management report PE801-00140 EMEM-KP008 Surface Water Management prepared by Knight Piesold for a 1 in 100 year storm event.

Table 2.3 First pass design criteria

Design Input		Unit	Quantity		Quantity
Top of channel (width)	For Options A,B and C	m	18.59	For Option D**	25
Bottom of channel (width)		m	3.00		4.00
Depth of channel (centre)		m	2.60		3.00
Wall angle		degrees	18.40		18.40
Gradient		degrees	-0.29*		0.04

*Equivalent to -1:200

**Option D parameters evaluated individually due to shallow slope but being a preferred option due to location

2.6 Kerosene Camp Creek Diversion Channel costing

The unit mining costs used to determine drill-and-blast excavation costs are shown in Table 2.4.

Table 2.4 Costing criteria for excavation of Kerosene Camp Creek

Item	Unit	Value
Drill and blast (unweathered)	$/bcm	3.35
Excavation	$/bcm	1.22

The combined drill-and-blast and excavation costs for the various options are shown in Table 2.5. AMC assumed all material between 655 mRL and 660 mRL would be free dig.

All other material below and above these RLs was considered as blasted material. An adjustment factor of 0.7 was applied to blasted material between 660 mRL – 670 mRL to allow for the natural topography change, i.e. 70% of this material is considered to require blasting and 30% will be free dig.

Table 2.5 Drill-and-blast versus free dig mining quantities

Option	Drill and Blast Material (bcm)	Free Dig Material (bcm)*	Total Material (bcm)	Diversion Channel Length (m)	Cost (AU$)
A	499,945	145,498	645,443	2,400	2,252,466
B	334,242	178,727	512,968	2,700	1,497,586
C	181,013	180,470	361,483	3,300	898,238
D	798,578	160,781	959,359	3,800	3,221,312

* No haulage requirement as material will be side cast along the length of the excavation.

2.7 Waste dump design parameters

Waste dumps were designed to accommodate both the M&I and LOM waste volumes, as shown in Table 2.6. The ore and waste densities are shown in Table 2.7.

Waste dump designs were completed based on the parameters set out in Table 2.8. These parameters are the same as the 2012 Ore Reserve design parameters.

Table 2.6 Nolans Bore total pit inventory

Item	Unit	M&I	LOM
Ore volume	Mbcm	10.67	20.24
Waste volume	Mbcm	64.14	121.82
Total volume	Mbcm	74.80	142.06
Ore tonnes	Mt	28.63	54.64
Waste tonnes	Mt	158.85	304.33
Total tonnes	Mt	187.49	358.97
Waste dump requirements	Mlcm*	83.38	158.36

*Loose cubic metres

Table 2.7 Nolans Bore total pit inventory densities (t/m3)

Item	Unit	M&I	LOM
Ore	t/m^3	2.68	2.70
Waste	t/m^3	2.48	2.50
Average	t/m^3	2.51	2.53

Table 2.8 Waste dump design parameters

Dump Design Parameter	Unit	Quantity
Lift	m	10
Overall face angle	deg	16
Berm width	m	5
Road gradient	%	10
Road width	m	35
Stand off from pit crest	m	50
Maximum dump height (to maximum RL)	mRL	734*
Stand off from infrastructure	m	35-50
Swell factor	%	30

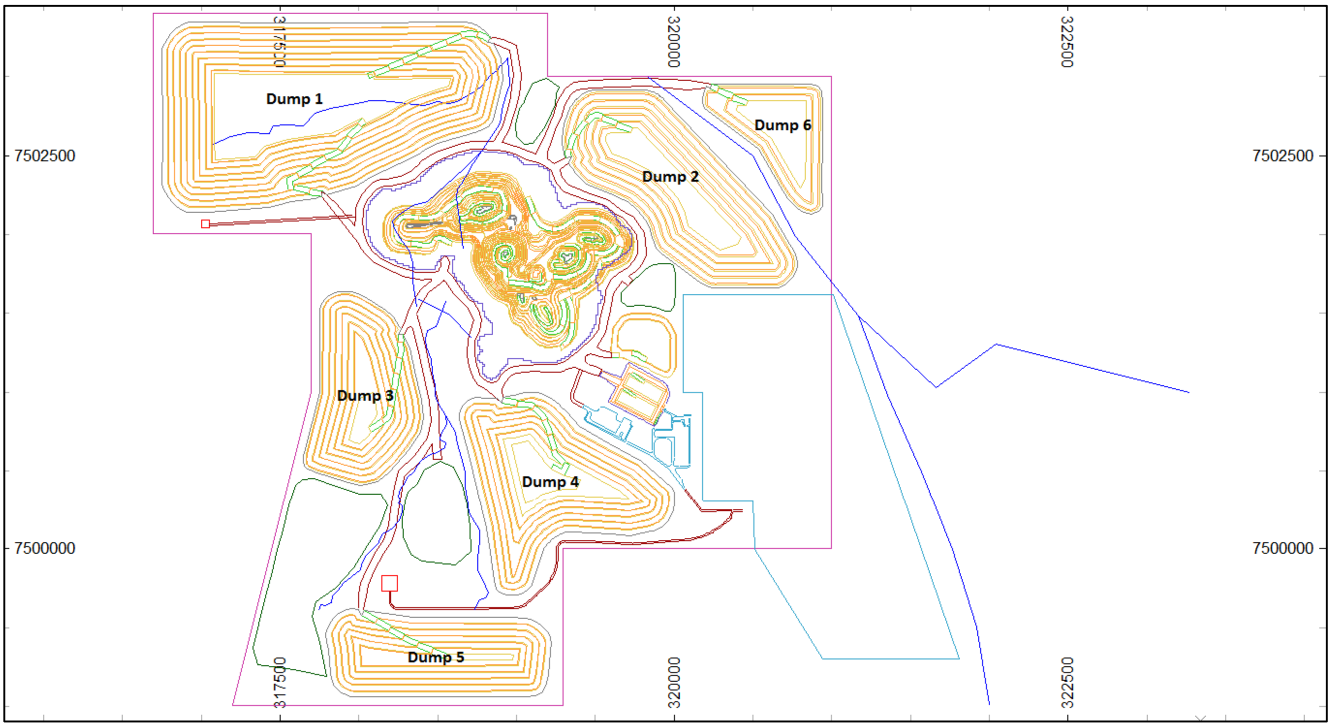
*Maximum height of surrounding topography

The required LOM dump capacity is 158.4 million loose cubic metres (Mlcm). AMC redesigned waste dumps which allowed for a storage capacity of 159.6 Mlcm. Dump capacities are shown in Table 2.9 and the designs are presented in Figure 2.4. A swell factor of 30% was applied to designs, but with traffic compaction and consolidation over time, this may actually be closer to 25% in operations. Therefore AMC expects a swell factor of 30% to be at the upper limit and to provide a safety margin in waste dump design capacities.

Table 2.9 Waste dumps and capacities

Waste Dump	Unit	Quantity
1	Mlcm	77.14
2	Mlcm	26.87
3	Mlcm	14.30
4	Mlcm	22.60
5	Mlcm	14.57
6	Mlcm	4.11
Total	**Mlcm**	**159.59**

Figure 2.4 Surface infrastructure with revised waste dump designs



2.8 Resizing of tailings storage facility

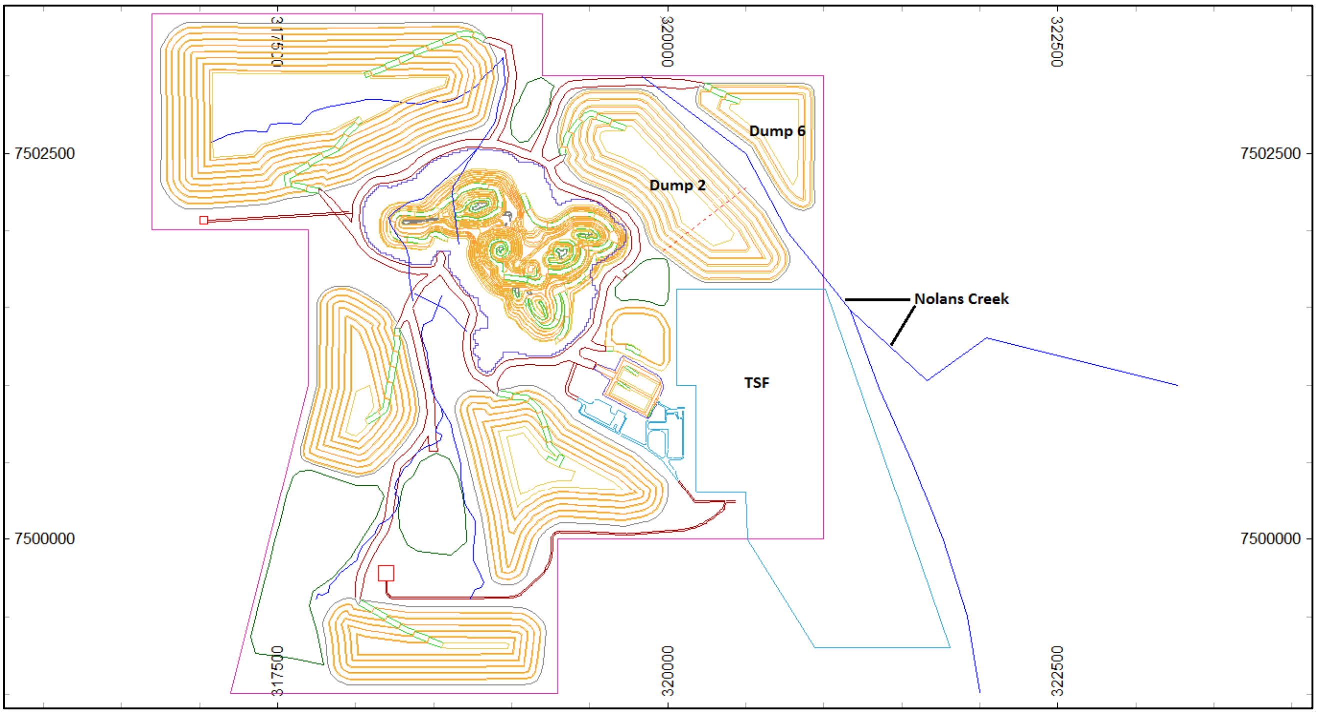
The tailings storage facility (TSF) will be resized by others to allow for LOM tailings quantities. Because a revised TSF design is not currently available, a surface area of twice the footprint as that from the 2012 Ore Reserve design (and that contained in the 2010 Draft BFS) was assumed, as requested by Arafura. The 2010 Draft BFS footprint included DMS rejects, flotation and slimes tailings as well as chemical plant residues storage. The current extent of MLA 26659 (the existing Nolans 1 mineral lease) is too small to accommodate this expansion and the LOM waste storage requirements.

The TSF footprint for the 2012 Ore Reserve scenario is 120 hectares while the proposed TSF footprint for the LOM tailings storage is 245 hectares. This will require the acquisition of proposed Nolans 3 mineral lease.

The most viable option for expansion of the TSF is to the east and the south of the existing MLA 26659. It should be noted that the resizing of the TSF will not impact on the proposed development of the Kerosene Camp Creek Diversion Channel in the options presented in this document.

AMC also notes that the eastern boundary of the TSF is affected by Nolans Creek as shown in Figure 2.5. The two waste dumps located on the north east of the lease (Dump 2 and Dump 6) also take into account the existing path of Nolans Creek and are designed with this as the primary consideration.

Figure 2.5 Surface layout showing extended TSF footprint and revised waste dumps



Upon completion of mining, part of the mine closure activities will involve the coverage of the TSF with suitable waste rock material. The suggested coverage is two meters to allow appropriate encapsulation of radioactive tailings. The approximate requirement for this will be 5 million bcm of clean waste rock material which can be sourced from the southern end of Dump 2, as denoted by red dotted line in Figure 2.6.

Table 2.10 TSF footprints and waste capping volumes

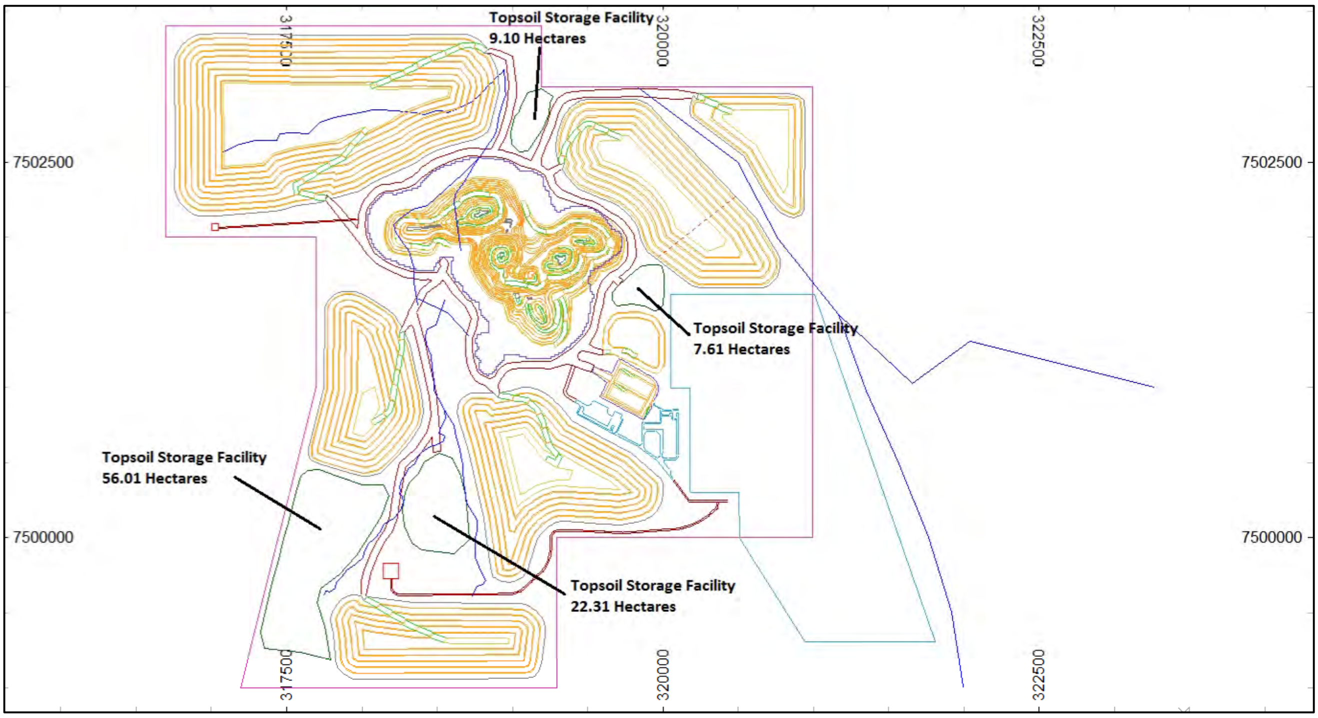
Option	Unit	Quantity
2012 Ore Reserve TSF footprint	hectares	120
Associated waste volume for TSF capping (2 metre thickness)	m^3	2,393,066
LOM TSF footprint	hectares	245
Associated waste volume for TSF capping (2 metre thickness)	m^3	4,891,264

2.9 Topsoil storage areas

A review of the topsoil storage areas was undertaken to evaluate whether there is the opportunity to reduce the amount of surface area reserved for these areas.

Based on high level scheduling it was determined that the maximum requirement at any point in time for topsoil storage will be approximately 50 hectares. The areas highlighted in Figure 2.6 exceed this requirement and give a total storage area of 95 hectares. To ensure that topsoil storage is kept to a minimum progressive rehabilitation will be required.

Figure 2.6 Topsoil storage capacity



3 Risk review

Arafura hosted a risk review on 13 March 2015 to assess the risks associated with all the options contained in Table 2.1. The review was attended by Arafura and AMC. The detailed risk management plan is contained in Appendix A. The risks are summarized in Table 3.1. The risk map is shown in Table 3.2 and the risk ranking calculator is shown in Table 3.3.

The following categories were applied to the risks in Table 3.1:

- Safety (S).
- Operational (O).
- Environmental (E).
- Community reputation (C).

Table 3.1 Risk summary

Category	Rank	No.	Description	Before		After
O	2	1	Option G - Don't mine the western side of the pit where Kerosene Camp Creek intersects.	25E		19E
SCE	4	2	Option F - Allow intersection of creek by pit development, build bund and apply additional in pit pumping capacity as is required when creek is flowing.	22E		13H
O	4	3	Option F - Allow intersection of creek by pit development, build bund and apply additional in pit pumping capacity as is required when creek is flowing.	22E		13H
SCE	7	4	Option E - Divert the creek close to its source to an event pond directly to the east from where the water may be pumped back to the creek downstream from the pit.	15H		8M
O	7	5	Option E - Divert the creek close to its source to an event pond directly to the east from where the water may be pumped back to the creek downstream from the pit.	8M		8M
SCE	3	6	Option A - Divert the creek around the western side of the pit under the main haul road and also under the access road to the waste dump 1 before joining the creek on the north western side of the pit. Option B is a variant of this option.	23E		18E
O	10	7	Option A - Divert the creek around the western side of the pit under the main haul road and also under the access road to the waste dump 1 before joining the creek on the north western side of the pit. Option B is a variant of this option.	12H		2L
SCE	1	8	Option C - Divert the creek to the east and back around the pit to re-join the creek on the north west side of the pit.	23E		21E
O	10	9	Option C - Divert the creek to the east and back around the pit to re-join the creek on the north west side of the pit.	12H		2L
SCE	6	10	Option D -Divert creek to the north west and join to another water course.	14H		9M
O	9	11	Option D -Divert creek to the north west and join to another water course.	7M		3L

Source: Arafura

Table 3.2 Risk map

		Consequence				
		Minor	Moderate	Significant	Major	Catastrophic
Likelihood	Almost Certain	High	Extreme	Extreme	Extreme	Extreme
	Likely	Medium	High	Extreme	Extreme	Extreme
	Possible	Low	Medium	High	Extreme	Extreme
	Unlikely	Low	Low	Medium	High	Extreme
	Rare	Low	Low	Medium	High	High

Source: Arafura

Table 3.3 Risk ranking calculator

RISK RANKING CALCULATOR					
Likelihood	Consequence				
	Minor	Moderate	Significant	Major	Catastrophic
Almost Certain	11	16	20	23	25
Likely	7	12	17	21	24
Possible	4	8	13	18	22
Unlikely	2	5	9	14	19
Rare	1	3	6	10	15

1 – 5 Low	6 – 9 Medium	10 – 17 High	16 – 25 Extreme

RISK RANKING					
	Consequence				
	Minor	Moderate	Significant	Major	Catastrophic
Safety	First Aid treatment	Medical treatment, disabling injury = < 4 days	Lost time injury, disabling injury => 4 days	Single Fatality	Multiple fatalities
Operational	**Production Loss :** < 1 Day **Property Damage:** Potential cost < $50,000	**Production Loss:** > 1 Day **Property Damage** Potential cost >$50,000	**Production Loss:** 1 Week **Property Damage** Potential cost >$200,000 $<1,000,000	**Production Loss:** 2-3 Wks **Property Damage** Potential cost >$1,000,000 $<500,000	**Production Loss:** = >Month **Property Damage** Potential cost >$5,000,000
Environment	Loss of containment of substance (remains on premises) <500 litre	Loss of containment of substance (remains on premises) >500 litre	Record of health effects, impact on Containment on site >1,000 litres	Severe health effects, **Death or severe impact of a protected flora, fauna, wildlife, long term, Prosecution /**	Multiple deaths Destruction of protected wildlife or plants or their habitat Devastation to large area of land
Community Reputation	Local complaint resolved	Local complaint resolved with future impact	Community complaint, impact at council level	Community complaint state level, prosecution, cessation of ops > 1 week	Community complaint national level, prosecution, cessation of ops > 1
Theft		Theft on site, no police involvement		Theft on site requires police involvement	

Likelihood				
Almost Certain	Likely	Possible	Unlikely	Rare
Event is expected to occur in most occasions. Frequency – weekly.	Event is expected to occur on many Frequency - monthly.	Event is expected to occur on some Frequency - yearly.	Event is expected to occur infrequently. Frequency – 5 years.	Event is not expected to occur, but may occur under exceptional circumstances.

Source: Arafura

Conclusions from the risk review are:

- Option D is the least risky of all options.
- Option E requires further evaluation in a technical sense, to assess things such as size and location of the event pond.
- Option C is the most risky from an S, C and E perspective.
- Option G is discounted as it erodes project value and project life.
- Options A and B are low risk operationally but very high risk environmentally and socially.
- Option F is high risk also and is unlikely to be approved by safety regulators.

4 Summary

4.1 Selection of the most appropriate Diversion Channel scenarios

AMC considers Option C is the best route for the Kerosene Camp Creek Diversion Channel, from a bulk earthworks cost perspective (it is the lowest cost option). However, after completion of the risk review, which took into account potential safety, operational, environmental, and community reputation considerations, AMC understands Arafura will further pursue only the following two options as part of the Surface Water Management Plan for the DFS:

- Option D. Divert Kerosene Camp Creek to the north west of operations and join another water course. Arafura would require an Access Authority for this option.
- Option E. Divert Kerosene Camp Creek to an event pond and discharge as required. Further investigations are needed to determine whether this is permissible from an environmental perspective and also whether the original water course needs to be re-established upon cessation of mining, which AMC recommends is completed by Arafura or an environmental consultant. Also, design work will be required, which AMC recommends is completed by a civil engineering consultant, such as Knight Piesold, as part of the update of the DFS Surface Water Management Plan.

The Option C Diversion Channel is the third longest (3.3 km) and is in close proximity to major site infrastructure. It is the lowest cost option with respect to bulk earthworks establishment cost, at $1.4M. This is due to the relatively flat topography compared to Options A, B and D which directly results in an overall lower material extraction quantity (0.4 Mbcm) and a less technically challenging route. There is no requirement for additional lease acquisitions for this option. There is increased environmental risk compared to all other options because the Diversion Channel is closer to the plant and is therefore more susceptible to contamination from radioactive dust resulting from ore handling activities and crushing.

AMC considers Options A and B are also viable, although they are less favourable primarily due to their higher construction costs, compared to Option C. Options A and B also have an increased environmental risk compared to Option D, because the respective Diversion Channels are located within the mine area.

Options A, B and C have suitable overall down slope gradients, (-0.25%, -0.25% and -0.18% respectively) based on their natural topographical start and finish elevations. However, Option D is marginal in this regard, with an overall slope of –0.08%.

AMC suggests further consideration of Option D based on its location away from mining activity and the low environmental impact because of this. Due to the shallow gradient of this option, a cross sectional area of 43 m^2 is required for the Diversion Channel. Due to the large excavation required the cost for this option is the greatest of the four options at $3.2M, with the greatest material movement of approximately 1.0 Mbcm.

AMC recommends that the final engineering design of the proposed Diversion Channel be completed by a civil engineer for detailed Diversion Channel design and to confirm the gradient of the recommended option is sufficient to achieve the target flow rate. The natural topography did not allow for a gradient of 0.5% as recommended by Knight Piesold. Further works should also be based on a full detailed survey of the proposed route.

4.2 Resizing of the TSF (LOM)

AMC recommends that Arafura acquires the proposed Nolans 3 mineral lease to provide additional land space to accommodate the LOM TSF. For the Study it was assumed the LOM TSF footprint was approximately twice the size of the 2012 Ore Reserve TSF footprint, increasing from 120 hectares to 245 hectares. The waste dump locations for the LOM scenario TSF accommodate this reconfiguration, as shown in Figure 2.6.

Due to the tight space restrictions on MLA 26659 (Nolans 1) lease there is limited opportunity to increase the size of the TSF and still keep it within the boundaries of this lease. In determining the boundary limits of the resized TSF, the location of the adjacent Nolans Creek was considered. The positioning of waste dumps 2 and 6 (refer Figure 2.5) in the north east corner of MLA 26659 accommodates Nolans Creek, and as such no diversion of the creek is required. Allocation of approximately 5 Mbcm of clean, non-radioactive waste in waste dump 2 will allow for rehabilitation and coverage of the TSF upon mine closure.

4.3 Waste dumps and site infrastructure

The LOM waste quantity is 158 Mlcm. The LOM waste dump designs have sufficient capacity to accommodate these LOM mine waste quantities, at a design capacity of 159 Mlcm. All waste dumps are within the original MLA 26659 lease.

Topsoil storage facilities have a total surface area for storage of 93 hectares. Based on high level scheduling, the required surface area should not exceed 50 hectares. However, this assumes progressive rehabilitation of waste dumps and shows there is limited space available for additional infrastructure if required.

AMC recommends that the mine surface layout is reconfigured during the DFS to ensure buildings are located upwind of ROM pad process plant, taking account of the prevailing wind, to minimize dust exposure for personnel.

4.4 Critical path

The critical path for the development of the LOM plan is the acquisition of proposed Nolans 3 mineral lease due to the anticipated requirement to double the size of the current TSF to accommodate LOM tailings quantities. There is limited additional space on MLA 26659 (Nolans 1) for a size increase of this magnitude. Obtaining an Access Authority may also fall on the critical path if Option D is selected.

Appendix A
Detailed risk management plan

Desktop Risk Assessment

Category	Number	Rank	Risk Description	Event/Impact	Risk Severity before Treatment			Risk Treatment Plan	Preventative Controls	Mitigating Controls	Risk Severity after Treatment			COMMENTS
					Likelihood	Consequence	Before Treatment				Likelihood	Consequence	After Treatment	
O	1	2	Option G - Don't mine the western side of the pit where Kerosene Camp Creek intersects.	Reduction in mineralisation available for mining. Loss of mine life.	Almost Certain	Catastrophic	25E	Reduce Consequence of Occurrence	None available	Drilling and Exploration to replace lost ore.	Unlikely	Catastrophic	19E	Not a viable option for further consideration. Only possible replacement ore is at depth with increased stripping etc.
SCE	2	4	Option F - Allow intersection of creek by pit development, build bund and apply additional in pit pumping capacity as is required when creek is flowing.	Safety - Potential loss of life, equipment with in-rush of water. Potential geotechnical problems in the pit wall due to increased pore pressure. Erosion of pit walls during flood events. Environment - Water released into pit will become contaminated by the very act and when pumped out of pit will have to be contained on site for evaporation or use in beneficiation plant due to zero release conditions.	Possible	Catastrophic	22E	Reduce Consequence of Occurrence	Construct high bunds. Remove personnel and equipment from pit prior to wet season. Requires construction of a large containment structure as an evaporation pond or pump into TSF.	Bunds to be constructed at very high factors of safety to minimise failure risk. Mechanisms to be constructed to allow controlled release of water into pit. Pit evacuation planning. Construct large evaporation pond on site or design TSF to manage additional water flows.	Possible	Significant	13H	Water in-rushes into open pits have occurred in the past and this option unlikely to be allowed by Mines Department and Work Health. Barely enough land for current project proposed. More land would be required for evaporation ponds. TSF design and management would increase - cost and operational.
O	3	4	Option F - Allow intersection of creek by pit development, build bund and apply additional in pit pumping capacity as is required when creek is flowing.	Loss of production in wet season and storm events. Higher costs for in-pit pumping.	Possible	Catastrophic	22E	Reduce Consequence of Occurrence	Construct high bunds. Remove personnel and equipment from pit prior to wet season or storm event.	Mine at higher rates in dry season and construct large ROM stockpiles. Pit staging to always provide deeper un-used pit stages.	Possible	Significant	13H	Water in-rushes into open pits have occurred in the past and this option unlikely to be allowed by Mines Department.
SCE	4	7	Option E - Divert the creek close to its source to an event pond directly to the east from where the water may be pumped back to the creek downstream from the pit.	Event pond overflows in major storm event. Possible in-rush into pits. Potential loss of life, equipment., loss of production. At closure, full creek diversion will still be required unless creek is allowed to flow into mined out pit.	Rare	Catastrophic	15H	Reduce Consequence of Occurrence	Construct event pond to manages 1:1,000 year event.	Careful management of equipment interaction etc with event pond. Double redundancies in pumps, pipes. Evacuation plans for storm events.	Possible	Moderate	8M	High cost of construction of event pond, relies on Mitigating plans (eg Evacuation). Action: This Option needs further evaluation - how big is event pond, where will it be located, what cost and what final cost at closure?
O	5	7	Option E - Divert the creek close to its source to an event pond directly to the east from where the water may be pumped back to the creek downstream from the pit.	At closure, full creek diversion will still be required unless creek is allowed to flow into mined out pit.	Possible	Moderate	8M	Reduce Consequence of Occurrence	Construct event pond to manages 1:200 year event.	Double redundancies in pumps, pipes. Sediment control in event pond.	Possible	Minor	8M	High cost option. Means construction of event pond, built-in redundancies in equipment and may still require full diversion at closure.
SCE	6	3	Option A - Divert the creek around the western side of the pit under the main haul road and also under the access road to the waste dump 1 before joining the creek on the north western side of the pit. Option B is a variant of this option.	Safety - possible injury during flood event. Environment - contaminants accumulate in the channel reducing water quality. Wind direction downwind from mining operation. Community - bad publicity due to downstream users - Ti Tree basin.	Almost Certain	Major	23E	Reduce Likelihood of Occurrence	Construct channel crossings. Increased dust suppression, watering of shots during excavation where required. Waste characterisation to identify waste rock which is radioactive and requiring additional dust suppression.	Dust (radioactivity etc) modelling. Monitoring of water flows, water quality and dust levels. Community management plan. Dumping strategy depending on wind direction.	Possible	Major	18E	
O	7	10	Option A - Divert the creek around the western side of the pit under the main haul road and also under the access road to the waste dump 1 before joining the creek on the north western side of the pit. Option B is a variant of this option.	Operation disruptions during construction. Loss of access over floodways during storm events - short term. Sediment control during operation.	Likely	Moderate	12H	Reduce Likelihood and Consequence of Occurrence	Staged construction with surplus equipoment prior to requirement. Construct culverts in lieu of floodways.	Use surplus equipment to regularly clean channel.	Unlikely	Minor	2L	Depends on installation of channel crossings and culverts. Cost impost.
SCE	8	1	Option C - Divert the creek to the east and back around the pit to re-join the creek on the north west side of the pit.	Safety - possible injury during flood event. Environment - highly radioactive contaminants from ROM pad, crushing, TSF, stockpiling etc accumulate in the channel reducing water quality. Wind direction downwind from ROM and beneficiation operation. Community - bad publicity due to downstream users - Ti Tree basin.	Almost Certain	Major	23E	Reduce Likelihood of Occurrence	Construct channel crossings. Increased dust suppression, watering of stockpiling rehandling. Wet crushing, covered stockpiles.	Dust (radioactivity etc) modelling. Monitoring of water flows, water quality and dust levels. Community management plan.	Likely	Major	21E	Review layout plan particularly location of admin, crib rooms and workshops - dust from ROM, crushing, TSF's.
O	9	10	Option C - Divert the creek to the east and back around the pit to re-join the creek on the north west side of the pit.	Operation disruptions during construction. Loss of access over floodways during storm events - short term. Sediment control during operation.	Likely	Moderate	12H	Reduce Likelihood and Consequence of Occurrence	Staged construction with surplus equipoment prior to requirement. Construct culverts in lieu of floodways.	Use surplus equipment to regularly clean channel.	Unlikely	Minor	2L	Depends on installation of channel crossings and culverts. More culverts and therefore higher cost impost than Option A,B..

Desktop Risk Assessment

Category	Number	Rank	Risk Description	Event/Impact	Risk Severity before Treatment			Risk Treatment Plan	Preventative Controls	Mitigating Controls	Risk Severity after Treatment			COMMENTS
					Likelihood	Consequence	Before Treatment				Likelihood	Consequence	After Treatment	
SCE	10	6	Option D -Divert creek to the north west and join to another water course.	Safety - possible injury during flood event. Environment - contaminants accumulate in the channel reducing water quality. Wind direction downwind from parts of the mining operation. Permanent impact on KC Creek from NW of pit to confluence with Nolans Creek. Community - bad publicity due to downstream users - Ti Tree basin.	Unlikely	Major	***14H***	Reduce Likelihood and Consequence of Occurrence	Construct channel crossings. Increased dust suppression, watering of shots during excavation where required. Waste characterisation to identify waste rock which is radioactive and requiring additional dust suppression.	Dust (radioactivity etc) modelling. Regular cleaning of channels of contaminated materials. Monitoring of water flows, water quality and dust levels. Community management plan. Dumping strategy depending on wind direction.	Unlikely	Significant	***9M***	Reconsider location of Dump 3 and joining Dumps 1,2.
O	11	9	Option D -Divert creek to the north west and join to another water course.	Loss of access over floodways to Dump 3 during storm events - short term. Sediment control during operation.	Likely	Minor	***7M***	Reduce Likelihood and Consequence of Occurrence	Construction during pre-strip, pre-production period.	Use surplus equipment to regularly clean channel.	Rare	Moderate	***3L***	

S = Safety
O= Operational
E = Environment
C = Community Reputation

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		Name	Signature	Name	Signature	Date
0	G. Lampert	A. Wyatt		N. Conroy		30/03/2016

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Appendix B – Flood routing model

Model extent

The extent of flooding in and around the mine site has been represented by a 2-D rain-on-grid model implemented by TUFLOW software. This approach was deemed appropriate given the preliminary phase of mine design and the need to highlight potential flood issues across the mine site.

Due to limitations in the resolution and extent of available topographic data results from the rain-on-grid model are only indicative of flood risk conditions and are not suitable for design purposes.

The 2-D model is 21 km by 18 km in extent and represents the entire catchment area of Kerosene Camp Creek and Nolans Creek and the upper reaches of catchments draining into the Southern Basins from the processing site and accommodation village.

Input data

Topographic data has been obtained from a regional digital elevation model which has a horizontal resolution of 30 m and which dictated the TUFLOW model grid size. The proposed Kerosene Camp Creek diversion has been represented by a linked 1-D model of the diversion channel.

The critical duration of flood peak runoff will vary across the mine site due to the topography, land use, size of the upstream catchment and nature of the drainage systems. The ideal approach would be to model a wide range of durations but this was not considered to be warranted at this stage of the project. Areas of most importance were towards the lower end of creeks passing through the mine site and therefore a single storm rainfall duration of 4.5 hours was selected for all model runs to ensure consistency and comparability of results across the Nolans site. This duration equals the critical duration of a catchment at the downstream mine boundary.

The TUFLOW model uses design storm rainfall characteristics established by a hydrologic model of the mine site. A summary of the model is given in Appendix C and its design storm rainfall characteristics are as follows:

- Critical storm duration across the Nolans site equivalent to 4.5 hours
- Rainfall intensity - 28 mm/hr and 43 mm/hr for 100-year ARI and 1000-year ARI storm events, respectively
- Rainfall losses of initial 43.5 mm and continuing 1 mm
- Storm rainfall pattern compatible with a recommended profile in the Australian Rainfall and Runoff manual for this region (storm rainfall hyetograph is given in Table B1).

Table B1   Design storm hyetograph

Time (hrs)	100-year ARI Net Rainfall (mm)	1000-year ARI Net Rainfall (mm)
0.0	0.0	0.0
0.5	0.0	11.8
1	20.5	42.8
1.5	14.3	22.2
2	15.0	23.3
2.5	8.7	13.6
3	8.1	12.7

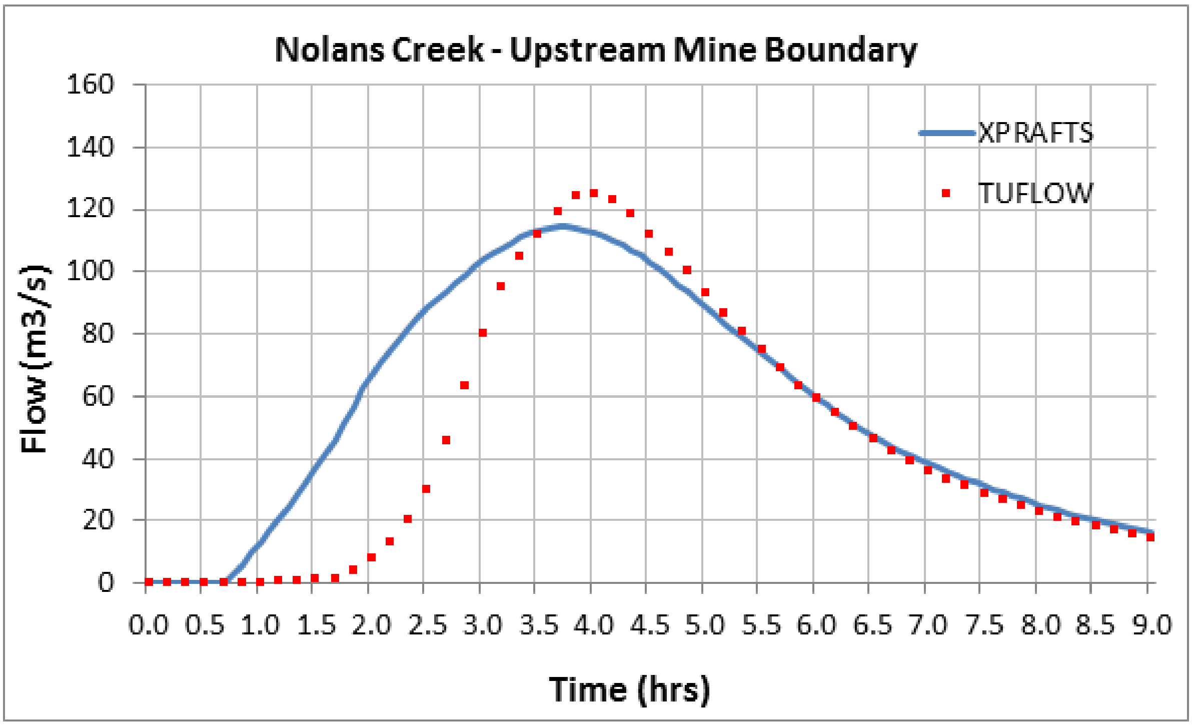
Time (hrs)	100-year ARI Net Rainfall (mm)	1000-year ARI Net Rainfall (mm)
3.5	6.2	9.7
4	3.8	6.1
4.5	1.8	3.0
5	0.0	0.0

Model calibration

Surface hydraulic roughness across the mine site and surrounding catchments has been adjusted to achieve agreement with the flood peak magnitude of the calibrated XPRAFTS hydrological model at locations across the mine site (Table B2). This requires a Manning's value of 0.07. The disagreement between the two models in terms of the rising limb of the hydrograph is due to differences in the way in which the two models represent the filling of temporary storage (surface depressions) prior to the onset of runoff (Figure B1 to Figure B3).

Table B2 Comparison of flows from TUFLOW 2-D model and XPRAFTS hydrological model

Time (hrs)	Nolans Creek mine site upstream boundary	Nolans Creek mine site downstream boundary	Kerosene Camp Creek mine site upstream boundary	Kerosene Camp Creek mine site downstream boundary
XPRAFTS	114	120	35	95
TUFLOW	125	143	33	110



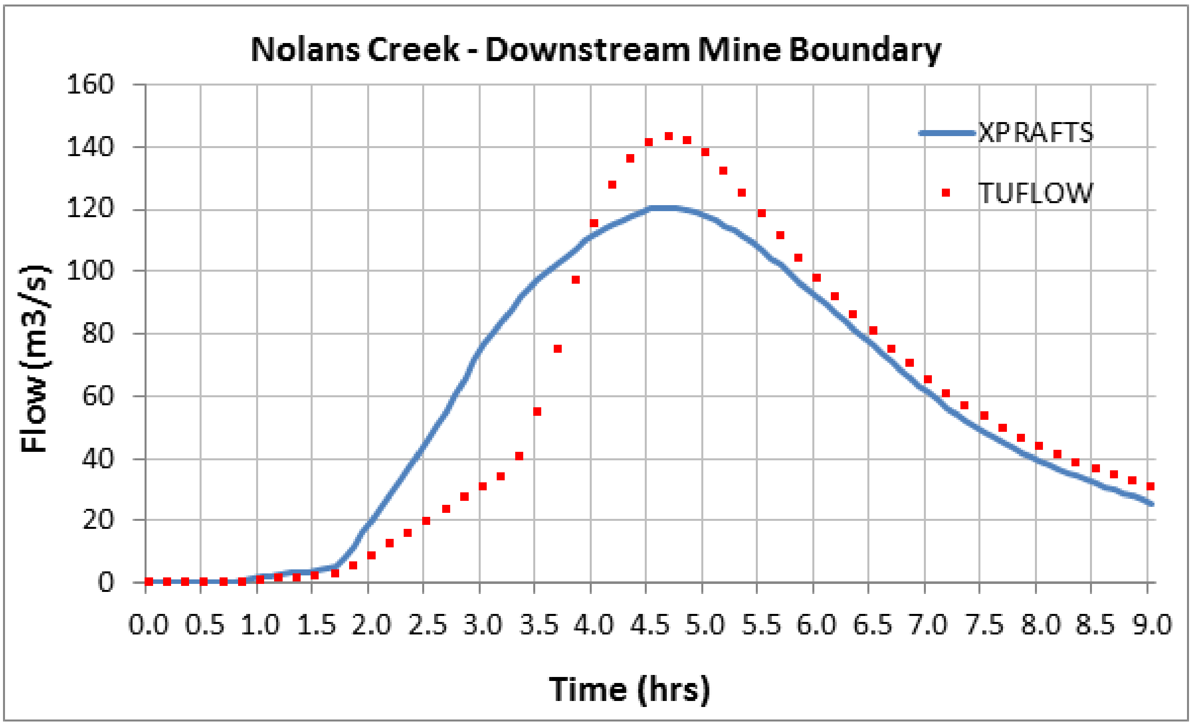
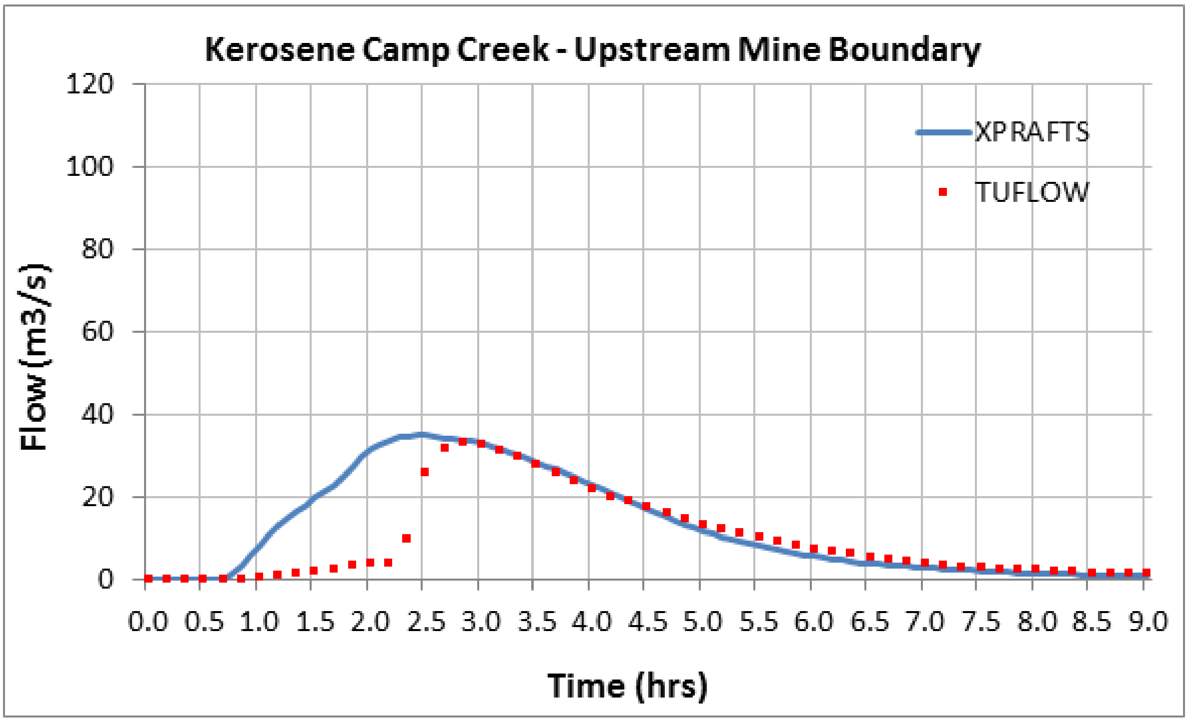


Figure B1 Comparison of 2D model flows with XPRafts model flows



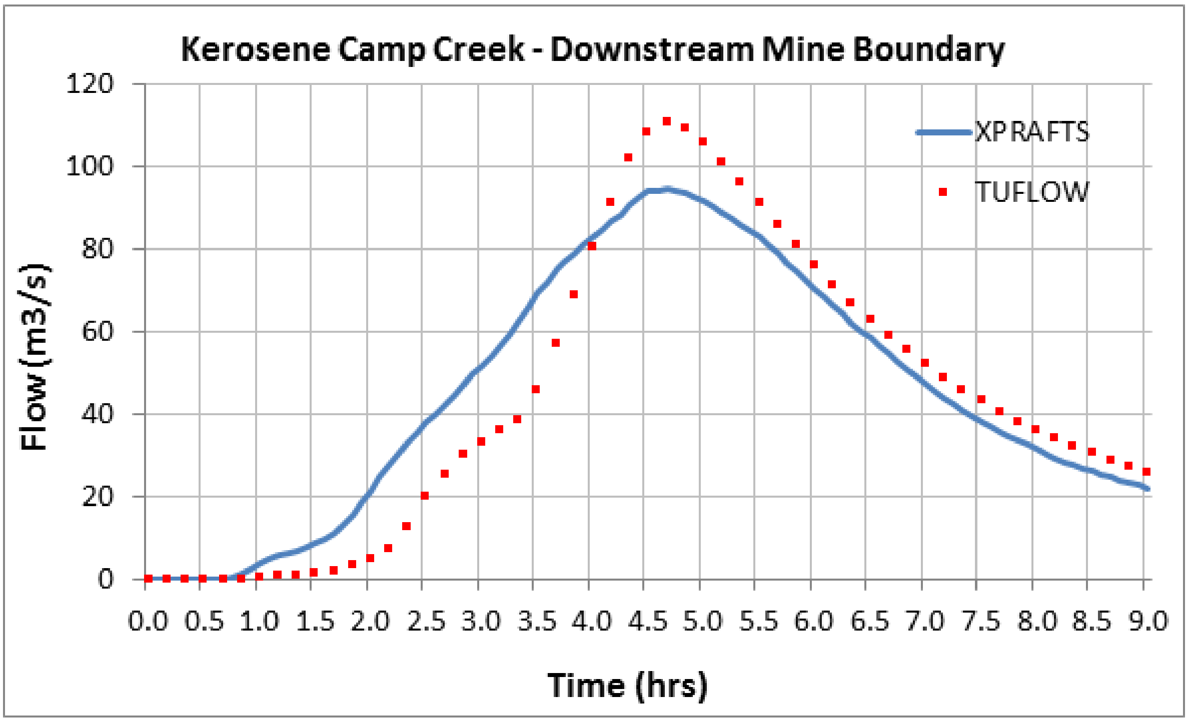
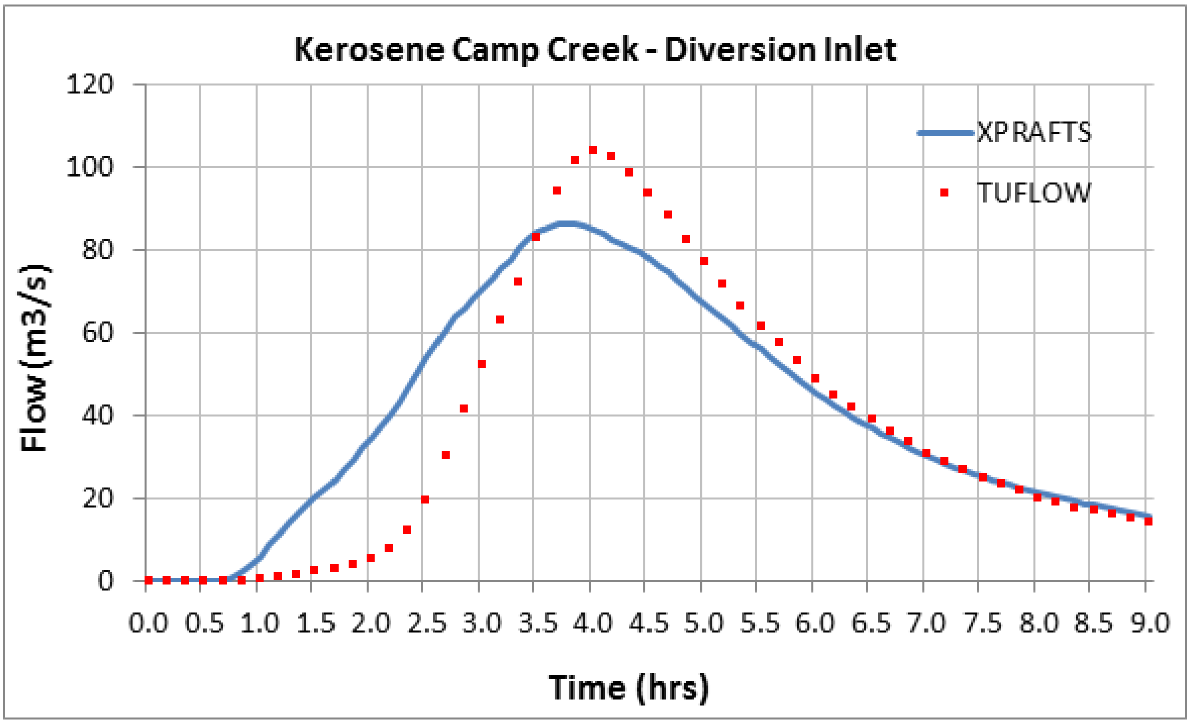


Figure B2 Comparison of 2D model flows with XPRafts model flows



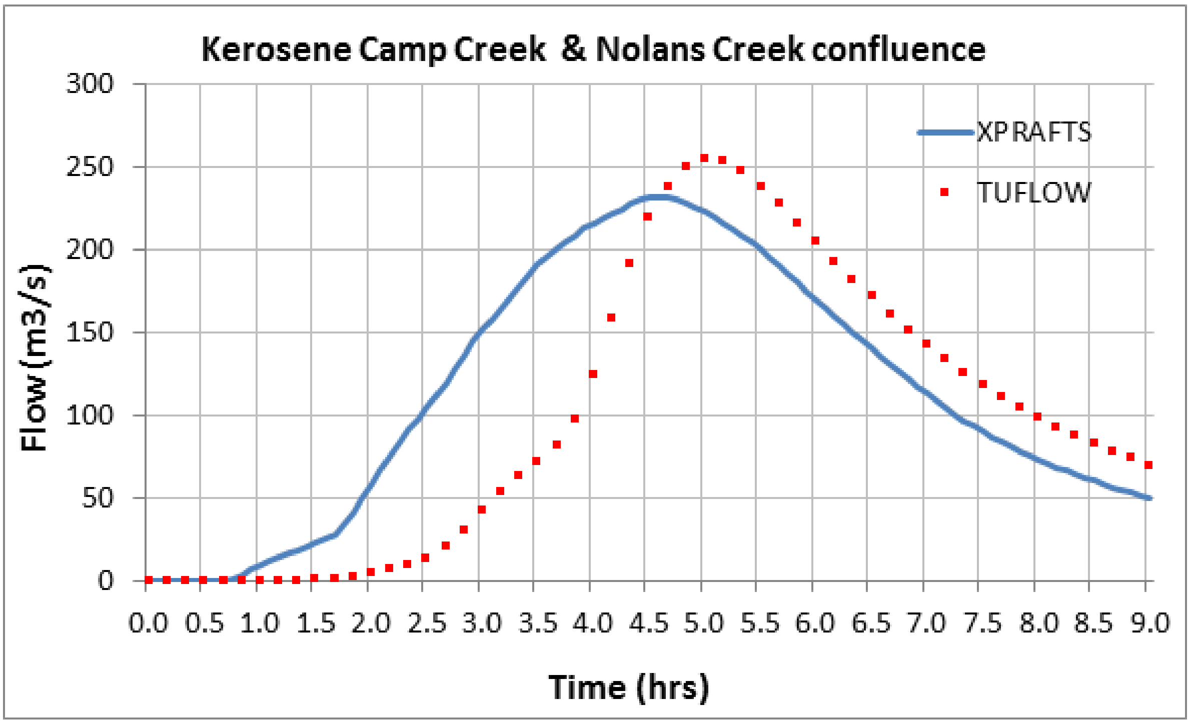


Figure B3 Comparison of 2D model flows with XPRafts model flows

Results

Despite the disparity between the TUFLOW 2-D and XPRAFTS model results the TUFLOW 2-D results have been accepted for the purpose of obtaining an indication of flood depth and velocity across the Nolans site. These flood characteristics are more closely allied to flood peak discharge, which has acceptable agreement between models, rather than the volume of the flood hydrograph.

The 1000-year ARI design flood extent generated by the TUFLOW 2-D rain-on-grid model is shown in Figure 3-8 for pre-mining conditions and in Figure 5-3 for post-mining conditions. Maps of flood afflux and changes in velocity between pre and post mining conditions are given in Figure 5-5 and Figure 5-6. The cumulative error for model runs was less than +/- 5% for a majority of the simulation.

Appendix C - Hydrological model

Introduction

Design flood hydrographs across the mine site have been created by hydrologic model (XPRAFTS) in a separate study which looked at the design of a proposed creek diversion on Kerosene Camp Creek (Appendix A. The modelled flood hydrographs from the creek diversion study have been used to calibrate a 2-D flood routing model which has been used to establish flood risk across the Nolans site (Appendix B).

The estimation of design flood hydrographs was undertaken with XP-RAFTS software which uses the Laurenson non-linear runoff routing procedure to produce a stormwater runoff hydrograph from rainfall Intensity-Frequency-Duration data and catchment characteristics.

The XP-RAFTS hydrologic model[16] encompasses the catchment upstream of the flow gauging station at Arden Soak Bore (G0280010) on the Woodeford River which contains the mine site located 26 km upstream of the gauge. The model includes the sub-catchments of Kerosene Camp Creek and Nolans Creek, which flow through the mine site, and the upper reaches of a tributary to Kerosene Camp Creek in to which a proposed diversion of Kerosene Camp Creek will discharge (Figure C2).

Modelled areas consist mostly of arid desert with rocky outcrops towards the upper reaches of catchments. Topography is relatively flat with slopes ranging from 0.2 to 1 % with sparse vegetation cover. Creeks are characterised by mobile sandy beds and floodplains.

A summary of the hydrological model in terms of its inputs and the calibration of model parameters is given below.

Data input

The parameters used in the XP-RAFTS hydrologic model were derived from industry standard sources with guidance from information specific to the study area. These sources are as follows:

- Sub-catchment areas and land surface gradients were derived from Shuttle Radar Topographic Mission (SRTM) 10 m contour data.
- Catchment impervious fraction (5 percent) was derived from inspection of current, publically available aerial photography.
- Catchment Manning's 'n' roughness values (0.02-0.04) based on Australian Rainfall and Runoff (AR&R 1987) guidance and industry accepted values.
- Initial (20-40 mm) and continuing rainfall losses (3-5 mm/h) were based on Australian Rainfall and Runoff (AR&R, 1987) guidance and adjusted by a subsequent calibration using observed storm rainfall and runoff data to obtain values of initial and continuing losses of 43.5 mm and 1 mm, respectively.
- Catchment lag times were used to represent the natural delay in catchment response due to storage effects and were based on an assumed flood flow velocity of 0.5 m/s.
- Observed storm rainfall and river flow records for the purposes of model calibration were obtained from the Bureau of Meteorology and Northern Territory Department of Land Resources and Management online data portal.
  - Arden Soak Bore (G280010) – This gauge is located on the Woodforde River downstream of the Kerosene Camp Creek. The location is around 26 km downstream

[16] N:\AU\Sydney\Projects\43\22301\Technical\Waterways\Hydrology\RAFTS\nolans_bore_HECRAS.xp

of the study area. The flow gauging station was established in 1974 and has reasonable quality data with some periods of missing data. Rainfall records are also available at this gauge and were assumed representative of conditions over the lower reaches of catchments within the model.

  – Aileron (015543) – This rainfall gauge is located approximately 13 km to the east of the mine site and is able to provide data from 1949 up until 2009 with some periods of missing data. The rainfall record was considered to be representative of the upper reaches of catchments within the model.

- Design storm rainfall Intensity – Duration – Frequency data was obtained from the Bureau of Meteorology data portal for a range of storm frequency and durations (Table 3-4).

XP-RAFTS model calibration

Based on a review of the available storm events recorded by rainfall and flow records the storm event from January 2010 was chosen for use in calibration of the hydrologic model parameters. From a comparison with other events on record the selected event is considered to be in the order of a 10-year to 20-year ARI.

Recorded rainfall data from Aileron and Arden Soak Bore gauges were applied to the model's representation of the upper and lower sub-catchments, respectively, to capture the spatial variation in rainfall. Modelled flows for the January 2010 storm event were compared to the flow record at Arden Soak Bore and parameters adjusted and the model re-run until an acceptable agreement between the modelled and recorded flows was achieved.

Figure C1 shows the graph of the modelled hydrograph plotted against the gauged hydrograph for the January 2010 storm event. From this plot it can be seen that the calibrated modelled produced a comparable peak flow rate to that recorded by the Arden Soak Bore gauge. Also, the timing of the peak was able to be matched relatively well compared to the gauge as well as the rate of increase on the rising limb of the hydrograph. The receding limb of the hydrograph is seen to be slightly less accurate compared to the gauged hydrograph which recedes quickly after the rainfall event finishes. This latter discrepancy could be attributed to a number of factors including the model over predicting the storage within the river system and an over simplification of rainfall losses by the use of initial and continuing factors. However, the calibration was considered acceptable for the purposes of the study.

The calibration determined an initial rainfall loss of 43.5 mm and continuing rainfall loss 1 mm/h.

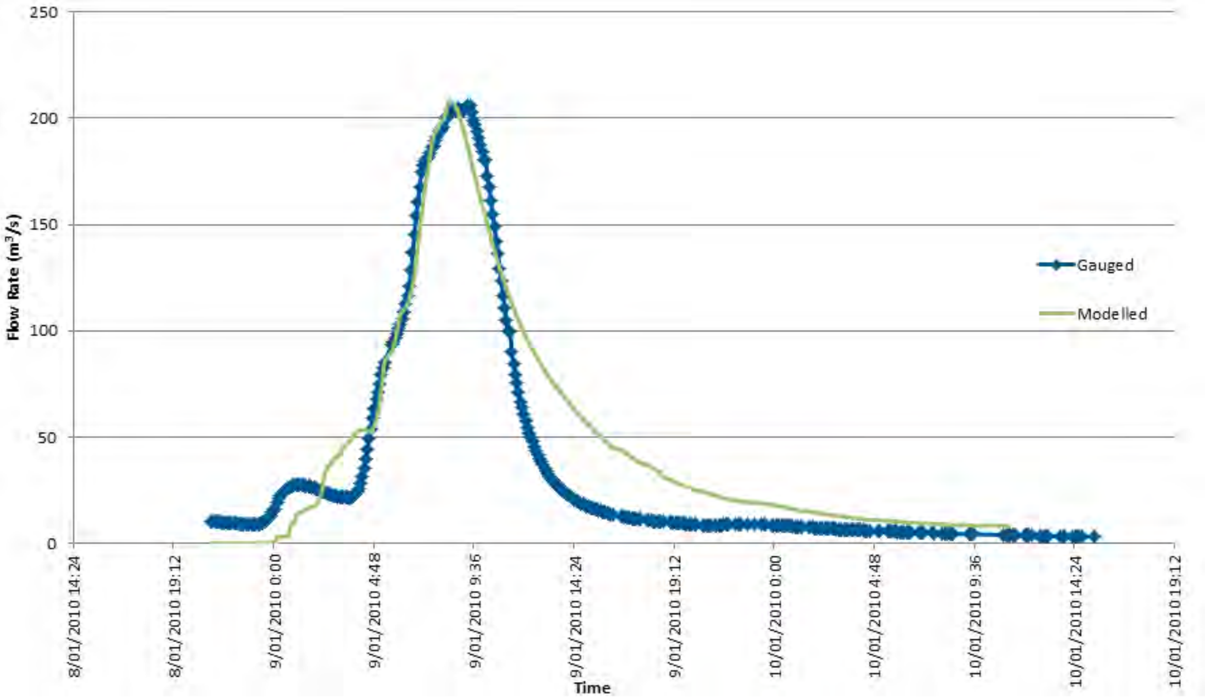
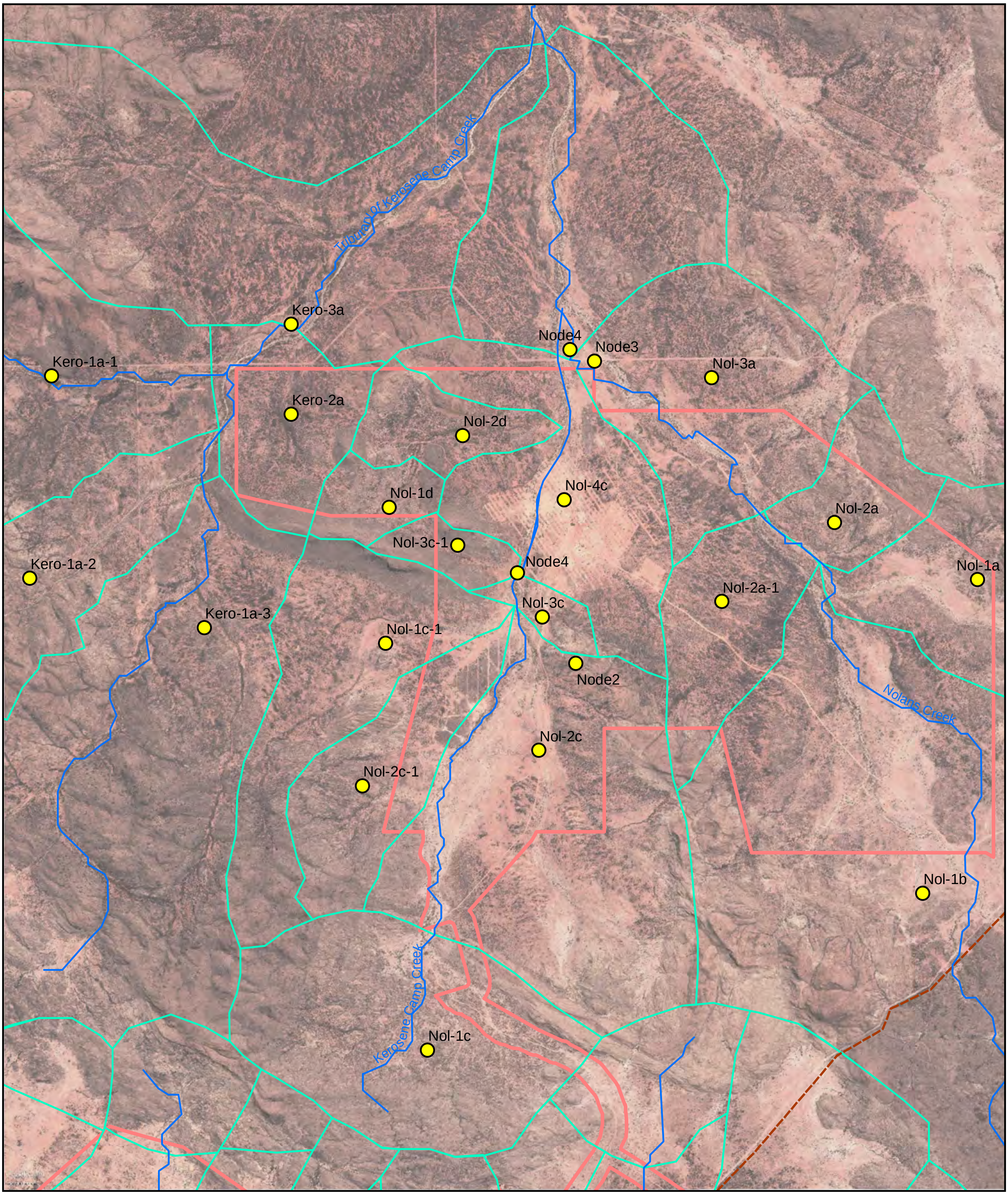


Figure C1 XP-RAFTS model calibration result



LEGEND

- XPRafts Model Nodes
- Gas Pipeline
- Major Waterways
- Project Areas
- Model Sub-catchments

1:50,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

Arafura Resources Limited
Nolans Project
Environmental Impact Statement

Job Number	43-22301
Revision	0
Date	30 Mar 2016

XPRAFTS model extent

Figure C2

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Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 11/02/2016). ARL - Project Areas (2015). GHD - XPRafts Model (2016). Created by: CM

XPRAFTS model comparison with Knight Piesold study results

The calibrated rainfall-runoff model has been compared to the results of a previous study by Knight Piesold[17] for a catchment on Kerosene Camp Creek with (Table C1). This reveals a large discrepancy in estimates for lower intensity more frequent storm events and is due to differences in model complexity (representation of catchment response) and assumptions regarding rainfall losses.

Flood peak estimates from the Knight Piesold study are based on the SCS method which is a simple empirical model that represents the catchment response by a single lumped value. Rainfall losses are represented as an initial amount based on a curve number that relates to soil conditions and land use. No evidence of model parameter calibration for local conditions is reported and rainfall losses appear to be in the order of 27 mm for a curve number of 65.

Flood peak estimates from the GHD study are based on a XP-RAFTS model which provides a semi-distributed non-linear representation of catchment response. Rainfall losses are represented as initial and continuing amounts totalling 44 mm as determined from a calibration against data from a recorded storm event.

Table C1 Comparison with Knight Piesold flood peak estimates

Study	Location	2-year ARI	10-year ARI	100-year ARI
Knight Piesold (2010)	Kerosene Camp – catchment C2	20.0	34.7	61.6
GHD (2015)	Kerosene Camp – catchment C2	3.0	29	86

Notes: C2 = Knight Piesold catchment with an area = 18.05 km^2.

Both studies have assumed rainfall losses are independent of storm frequency whereas rainfall losses during more frequent storm rainfall events (1 in 2-year ARI and 1 in 10-year ARI) are likely to be higher than those during more extreme events (1 in 100-year ARI).

The GHD flood peak estimates benefit from a calibration of catchment response parameters against an observed event and it uses a distributed sub-catchment configuration, whereas the Knight Piesold estimates are based on uncalibrated model parameters and a lumped catchment configuration.

GHD's calibrated XPRAFTS model has been used to estimate design flood peaks for pre-mining conditions at a number of significant locations across the mine site (Table C2).

Table C2 Design flood peak estimates – pre-mining

Model Node	Creek	Location	Upstream Area (km^2)	100-yr ARI Peak (m^3/s)	1000-yr ARI Peak (m^3/s)
Nol-2a	Nolans	upstream mine lease boundary	26.3	114	234
Node 3	Nolans	downstream mine lease boundary	28.2	120	246
Node 2 (part)	Kerosene Camp	upstream mine lease boundary (at extent of topographic data)	12.3	50	131
Node 1	Kerosene Camp	proposed diversion inlet	20.4	86	173
Node 4	Kerosene Camp	downstream mine lease boundary	25.8	95	188

[17] Table 2.4 Surface Water Management Plan, Knight Piesold. PE801-00140/05. November 2010

Model Node	Creek	Location	Upstream Area (km^2)	100-yr ARI Peak (m^3/s)	1000-yr ARI Peak (m^3/s)
Nol-3a	Kerosene Camp	downstream of confluence of Kerosene Camp Creek and Nolans Creek	58.7	232	462
Kero-3a	Tributary of Kerosene Camp Creek	Upstream of proposed diversion outlet	46.0	184	381
Node 19	Tributary of Kerosene Camp Creek	Downstream of confluence with Kerosene Camp Creek	105	413	837

Appendix D - Validation of previous water balance for the residue and tailings storage facilities

A previous tailings and residue storage water balance carried out by Knight Piesold adopted 12-month rainfall sequences representative of a 1 in 100-year ARI 'wet' year (annual rainfall of 985 mm/yr), average year (281 mm/yr) and 1 in 100-year ARI 'dry' year (55 mm/yr) to test both the required storage capacity of residue and tailings facilities and to provide estimates of recycled water volume from the Flotation Tailings Storage Facility. This rainfall data appears to be based on the record at Alice Springs Airport whose mean annual rainfall is lower than that recorded by gauges at or near to the mine site. However, the annual totals for the wet and dry scenarios appear to be compatible with rainfall statistics derived from the record at Napperby which is much closer to the proposed mine site (48 km) than Alice Springs (146 km). The use of a monthly time step for the water balance is considered appropriate given the low frequency and sporadic nature of rainfall events.

The water balance has used a mean annual pan evaporation rate of 3041 mm which differs slightly from the mean annual rate of 3151 mm obtained from the nearest suitable record at Alice Springs Airport. This is due to an error in the reported value for March which according to the record should be 319 mm rather than 222 mm as used in the water balance. Whilst evaporation estimates for ponded water in the Flotation Tailings Storage Facility have not been adjusted to reflect the impact of an elevated temperature in tailings slurry evaporation has been adjusted to account for the reduction due to the increased salinity of stored water. This reduction ranges between a maximum 80 percent reduction for a salinity level of 1.35 specific gravity and 10 percent reduction for 1.1 specific gravity. A pan factor also has been applied to account for the difference in scale of measurement and ponded area.

Estimates of supernatant runoff are based on the difference between the design parameters describing the solids density of the slurry entering the facilities and of the tailings or residue settled within the facility. This results in a supernatant release of between 11 and 28 percent depending on the facility (Table D1).

Table D1 Water balance modelling assumptions

Facility	Slurry Throughput (Mtpa)	Slurry Input (Percentage Solids)	Salinity (Specific Gravity)	Supernatant Release	Evaporation Factors	Permeability of base (m/s)
Flotation Tailings	0.450	38.6	1.000	28	0.75	5E-08
Water Leach	0.357	33.5	1.007	26	0.73	8E-08
Phosphate Removal	0.141	34.9	1.068	11	0.63	5.8E-08
Impurity Removal	0.592	40.0	1.025	19	0.69	1E-07
Evaporation	0	0	1.042	(0.676)[a]	0.75	Not known

Notes: [a] Mtpa of inflow from the Excess Process Liquor generated within the process plant (0.420 Mtpa) plus the RO reject stream and treated effluent from the sewage plant (0.256 Mtpa).

Surface runoff has been determined as a relatively high and fixed proportion (0.8) of rainfall. Runoff is only likely during intense rainfall events when the infiltration capacity of tailings is likely to be exceeded and runoff will be a relatively high proportion of rainfall. However, these events are relatively infrequent and of short duration (Section 3.3.2).

The storage capacity of residue and tailings storage facilities is reported in Table 4-5. The capacity represents a storage volume that will contain water inflows during an average rainfall year whilst maintaining a freeboard equivalent to the PMP depth (Section 4.3). The reported PMP 72-hour depth is 1009 mm which appears slightly lower than a recently estimated value of 1100 mm but is within an acceptable margin of error given the uncertainties associated with estimates of PMP.

It should be noted that the Knight Piesold water balance assumes that evaporation ponds are initially filled to a depth of about 1.8 m to 2.0 m where after water levels are reduced by evaporation. If the embankment crest of evaporation ponds has a height of 2.5 m, then a required freeboard of 1.1 m (equivalent to PMP 72-hour rainfall) would not be available during this initial period. i.e. embankment crests will need to be 3.1 m or the maximum filling level reduced to 1.4 m.

Appendix E – Open pit water balance

Introduction

A simple monthly water balance for a period of one year has been carried out to assess likely rates of pit dewatering through pumping from within pit sumps[18] and assumes no constraints on pump capacity or duration of pumping.

Seven phases of pit development have been examined as summarised in Table E1 and the following inputs have been used.

A similar water balance has been used to determine the likely pit water levels following mine closure and assuming the pit geometry for phase 7.

Input data

Open pit geometry:

Table E1 Open pit geometry

Phase	Base of Pit (m ASL)	Perimeter Area (Ha)
1	570	10
2	530	31
3	530	43
4	480	61
5	440	86
6	390	119
7	390	135

Source: NOL sched INF nl37B.08.01 (final).xlsx and nl37B_stg_1_to_7.dxf

Rainfall scenarios – 1 in 100-year ARI dry year (55 mm), average (281 mm) and 1 in 100-year ARI wet year (985 mm) derived from Alice Springs gauge record;

Pit runoff – 90 percent rainfall losses through seepage into pit walls and pit floor. It is assumed that surface runoff from areas surrounding the pit is diverted away by a flood protection bund. To obtain a pessimistic representation of pit water levels after mine closure zero rainfall losses were assumed for the mine closure water balance;

Evaporation – evaporation from ponded water on the pit floor assuming average monthly potential evaporation from Alice Springs gauge record (3140 mm/yr) and a pan factor of 0.75;

Groundwater seepage inflow is determined from groundwater modelling (Chapter 8) where an average inflow for the entire pit has been determined for different elevations (Figure E1) corresponding to either the pit floor or ponded water elevation within the pit.

[18] N:\AU\Darwin\Projects\43\22301\06 Specialist Studies\Surface Water\Water Balance

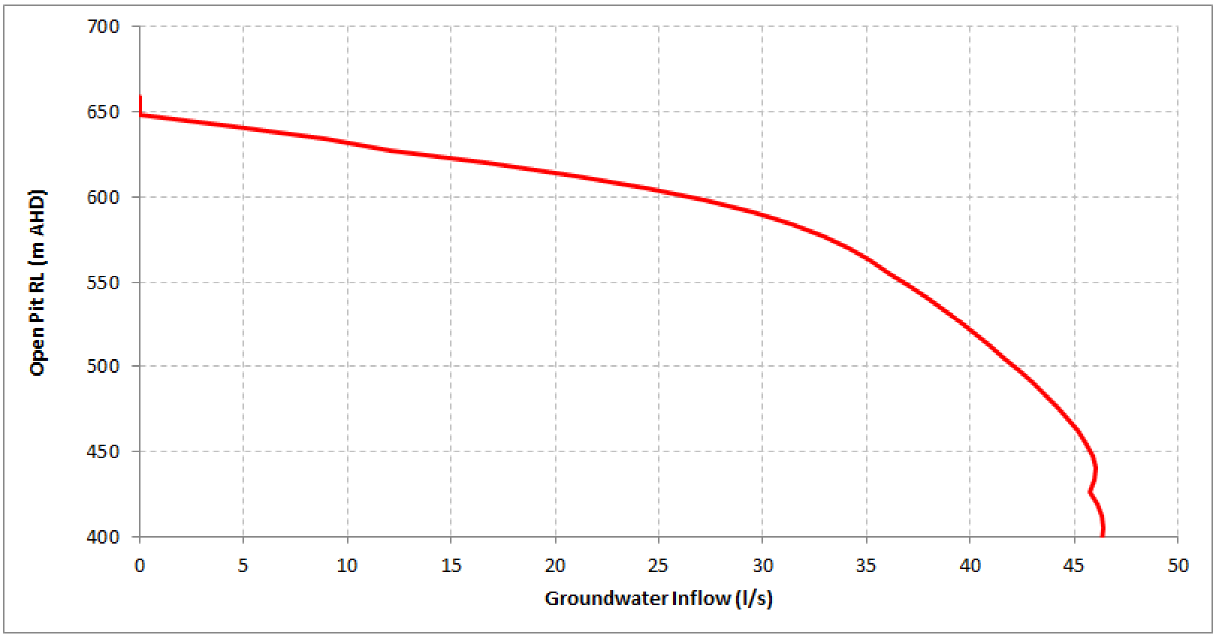

Figure E1 Predicted groundwater inflow to the open pit

Water balance results - operations

A summary of the monthly water balance results for each operational stage of mine development is summarised in Tables E2 to E4. Results are reported in terms of annual totals for inflow and outflow components during average, wet and dry year rainfall scenarios.

The water balance shows that open pit de-watering requirement ranges between 35 l/s in stage 1 and 51 l/s in stage 7 with small variations depending on the rainfall scenario. This reflects an increasing groundwater seepage inflow as the pit deepens.

Table E2 Open pit water balance for average annual rainfall conditions

Component	Stage 1 (ML/y)	Stage 2 (ML/y)	Stage 3 (ML/y)	Stage 4 (ML/y)	Stage 5 (ML/y)	Stage 6 (ML/y)	Stage 7 (ML/y)
Rainfall Inflow	32	101	139	191	262	335	385
Groundwater Inflow	1088	1243	1243	1391	1451	1461	1461
Rainfall Losses	-28	-91	-125	-172	-236	-301	-346
Open pit de-watering Requirement	-1091	-1253	-1257	-1410	-1477	-1495	-1500

Table E3 Open pit water balance for 1 in 100-yr (wet) annual rainfall conditions

Component	Stage 1 (ML/y)	Stage 2 (ML/y)	Stage 3 (ML/y)	Stage 4 (ML/y)	Stage 5 (ML/y)	Stage 6 (ML/y)	Stage 7 (ML/y)
Rainfall Inflow	111	354	488	669	918	1173	1349
Groundwater Inflow	1088	1243	1243	1391	1461	1461	1461
Rainfall Losses	-100	-319	-439	-602	-826	-1055	-1215
Open pit de-watering Requirement	-1099	-1278	-1292	-1458	-1543	-1578	-1596

Table E4 Open pit water balance for 1 in 100-yr (dry) annual rainfall conditions

Component	Stage 1 (ML/y)	Stage 2 (ML/y)	Stage 3 (ML/y)	Stage 4 (ML/y)	Stage 5 (ML/y)	Stage 6 (ML/y)	Stage 7 (ML/y)
Rainfall Inflow	6.2	20	27	37	51	65	75
Groundwater Inflow	1088	1243	1243	1391	1451	1461	1461
Rainfall Losses	-5.6	-18	-25	-34	-46	-59	-68
Open pit de-watering Requirement	-1088	-1245	-1245	-1395	-1456	-1468	-1469

Water Balance Results – mine closure

A summary of the monthly water balance results for the mine closure stage is summarised in Figures E2 and E3. This shows predicted pit water levels assuming average and wet year rainfall scenarios and no dewatering of the pit. It assumes losses through evaporation, only, and that the Kerosene Camp Creek diversion continues to function as designed.

The water balance suggests that pit water levels will reach an equilibrium level after 150 years where after pit inflow from groundwater seepage and incident rainfall is matched by evaporation. It also shows that pit water levels are not expected to exceed RL 620 m compared to a pit perimeter level of RL 690 m.

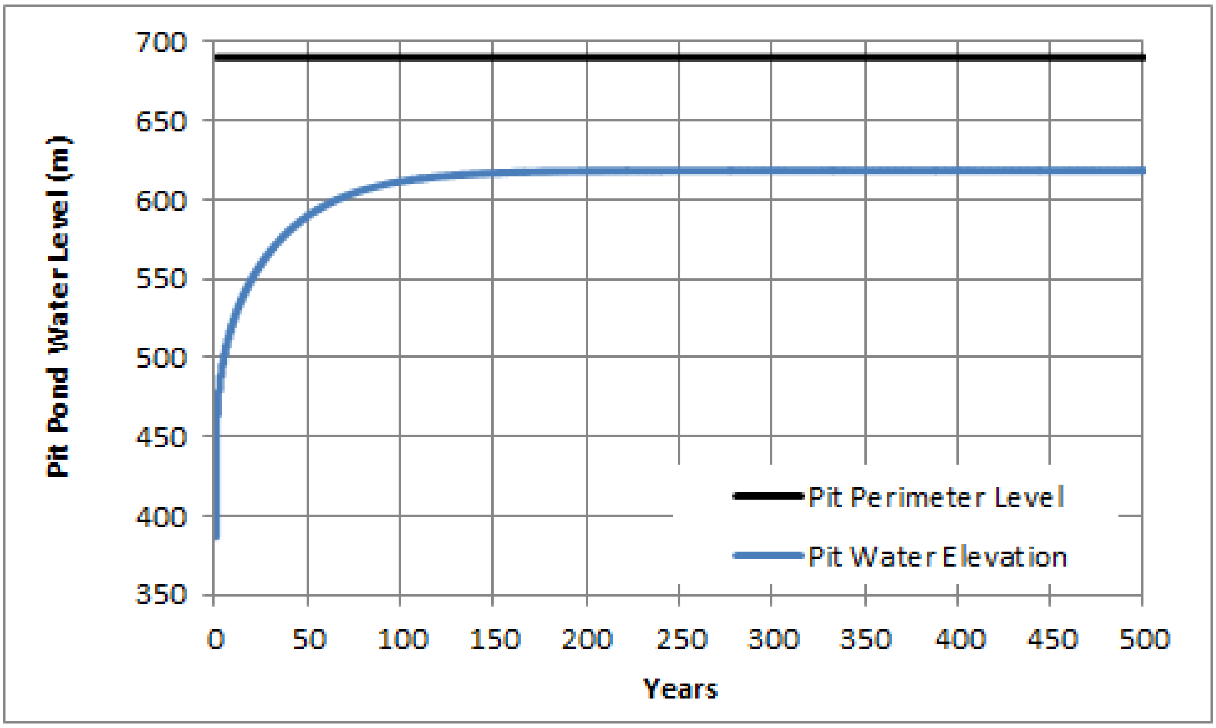

Figure E2 Mine closure water balance – wet year rainfall scenario

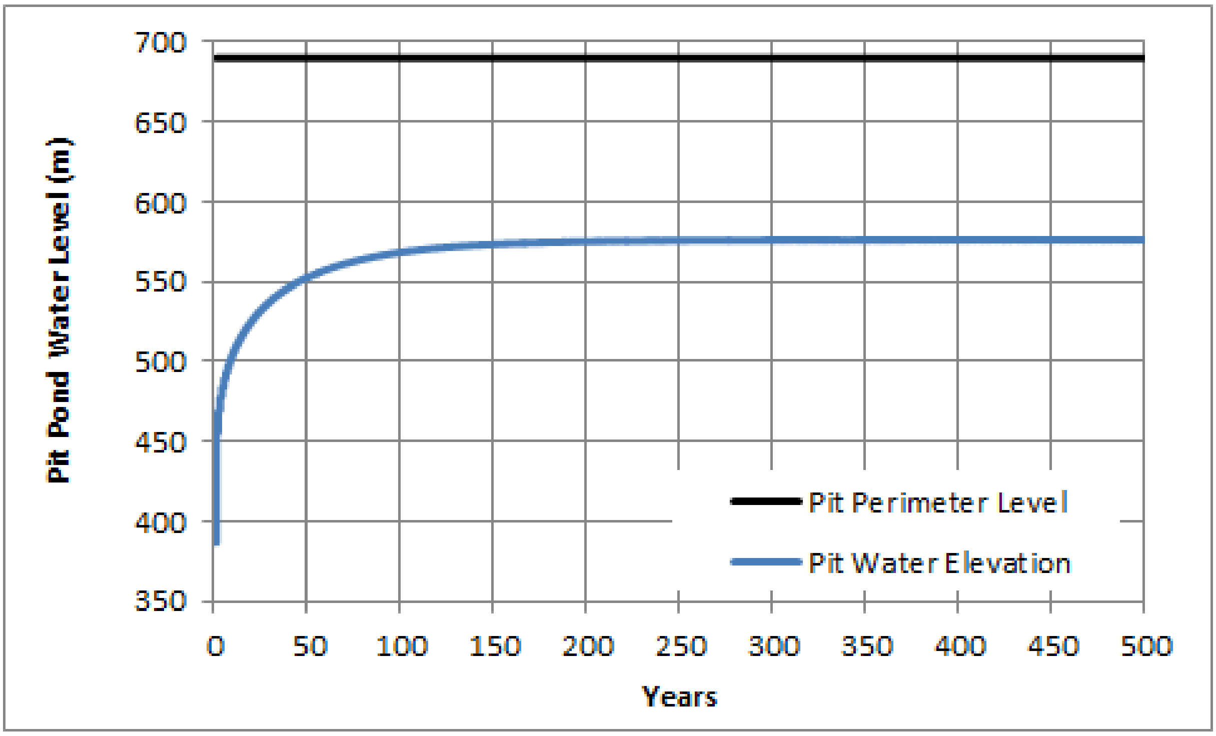

Figure E3 Mine closure water balance – average year rainfall scenario

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Document Status

Revision	Author	Reviewer		Approved for Issue		
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