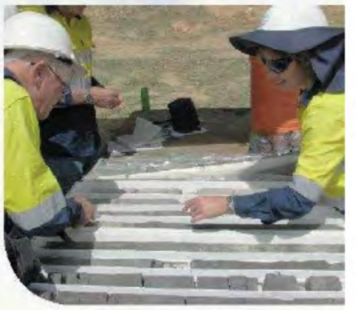
EUNDYNIE GOLD DEPOSIT



SURFACE WATER ASSESSMENT

REPORT FOR RNC MINERALS

JULY 2019

Report No: 497.0/19/02

Rockwater
HYDROGEOLOGICAL AND ENVIRONMENTAL CONSULTANTS

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[redacted]

1 INTRODUCTION

RNC Minerals (RNC) is planning to mine the Eundynie gold deposit, located about 10 km south-east of Higginsville. The proposed pits are situated on high ground at a catchment divide, so are not expected to be impacted by major surface water flows.

Rockwater was commissioned by RNC to undertake a hydrogeological assessment of the proposed Eundynie pits (Hidden Secret, Hidden Secret South and Mouse Hollow) and associated infrastructure, which traverse minor drainages that discharge in northerly and southerly directions into Lake Cowan (Figure 1).

This report includes hydrological and hydraulic analyses to assess the potential impact of flood flows on the pits and associated infrastructure (WRL, ROM, offices and haul roads). The report also provides conceptual designs for flood protection structures, if required.

The layout of the planned Eundynie pits and infrastructure is shown in Figures 1 and 2, together with applicable catchments and topographic contours (1 m interval) derived from the DEM-S version of the 1 second SRTM dataset (Geoscience Australia 2011).

The study was conducted at a level suitable for obtaining regulatory approvals from the Department of Mines, Industry Regulation and Safety.

The scope of work covered in this report includes the following:

- Identification of catchment areas and natural water courses that could impact the pit and infrastructure areas.
- Hydrological analyses to estimate peak flows for 1-in-2, 5, 10, 20, 50 and 100-year ARI rainfalls for the critical storm duration in the relevant catchment areas; and for a 1-in-2000 year rainfall, taken to be the Probable Maximum Precipitation (PMP) event;
- Surface water hydraulic analyses at critical locations and sections in order to examine the impact of the 1-in-100 year ARI peak flow and Probable Maximum Flood; and
- Concept designs and recommendations for any surface water control structures to prevent flooding during a 1-in-100 year ARI flow event.

2 CATCHMENT HYDROLOGY

The proposed pits lie on a small peninsula, about 65 m above Lake Cowan within two small catchments (Catchments A & B, Figure 2) with the potential to impact the pit and infrastructure. These north-westerly and southerly draining catchments would contain water flowing towards Lake Cowan after heavy rainfall.

For this assessment, the methods described in the Australian Rainfall and Runoff 1987 (AR&R, 1987) guideline were used. It should be noted that a revision of the guidelines (AR&R, 2019) was published to replace the 1987 version. However, the new publication uses the Regional Flood Frequency Estimation (RFFE) model which is currently unavailable for the arid regions of WA, so could not be used.

2.1 RAINFALL ANALYSIS

Intensity-Frequency-Duration (IFD) curves for the project area were obtained from the Bureau of Meteorology web-site (Ball et. al., 2019). The IFD tables and curves are included in Appendix A.

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

2.2 CATCHMENT AREAS

The relevant catchments were identified from the 1.0 m interval contour plan (Figures 1 & 2). Catchment areas used in the peak flow estimation analysis are described in Section 2.6 below.

2.3 TIME OF CONCENTRATION

The time of concentration is required to estimate the critical storm duration for peak flows in each catchment. This was estimated using Equation 1 for the Arid Interior Region of Western Australia as recommended by AR&R 1987 and later editions:

$$t_c = 0.76 \cdot A^{0.38}$$ ***Equation 1***

Where:

t_c is the time of concentration (hours)

A is the catchment area (km^2)

2.4 RATIONAL METHOD

The Statistical Rational Method, used in peak-flow estimation, is presented in Equation 2.

$$Q_y = 0.278 \cdot C_y \cdot I_{tcy} \cdot A$$ ***Equation 2***

Where:

Q_y is the peak flow for return period of y years (m^3/s)

0.278 is a dimensionless metric conversion factor

C_y is the runoff coefficient for y years (dimensionless)

I_{tcy} is rainfall intensity (mm/hr)

A is catchment area (km^2)

2.5 FLOOD INDEX METHOD

The Australian Rainfall and Runoff Guideline (1987) does not provide equations for peak flow estimation using the flood index method for the Arid Interior Region. However, the Eundynie area is similar to the Wheatbelt Region with loamy soils, and so the Flood Index Method for that region, presented in Equation 3, was used for comparative purposes. The results from this method may be considered conservative.

$$Q_5 = 3.04 \times 10^{-1} \cdot A^{0.60} \cdot 10^{0.0052 C_L}$$ ***Equation 3***

Where:

Q_5 is the peak discharge for the 5-year ARI flow (m^3/s)
A is the catchment area (km^2)
C_L is the portion of cleared land in the catchment area (%)

2.6 PEAK FLOWS

The characteristics of the catchments which could impact the pit area and haul road are listed in Table 1. The nearest Bureau of Meteorology (BoM) station is Norseman Aero (Stn. 12009), located about 50 km south of the project. Annual Rainfall averages 300 mm at this station.

Table 1: Catchment characteristics

Catchment	Area (km^2)	Length (km)
A	0.44	0.80
B	0.38	0.70

A summary of the design peak flows, as estimated using the Rational and Flood Index Methods, is shown in Table 2. The detailed calculations are presented in Appendix A.

Table 2: Estimated peak flows

Catchment A	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	0.12	0.36	0.63	0.98	1.54	2.12	
Index	0.13	0.25	0.44	0.76	1.41	2.49	
Adopted	**0.12**	**0.36**	**0.63**	**0.98**	**1.54**	**2.12**	**6.82**

Catchment B	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	0.11	0.33	0.59	0.92	1.45	1.99	
Index	0.11	0.23	0.40	0.70	1.29	2.28	
Adopted	**0.11**	**0.33**	**0.59**	**0.92**	**1.45**	**1.99**	**6.40**

3 HYDRAULIC ANALYSES AND FLOOD PROTECTION STRUCTURES

Peak flows in each catchment were analysed to assess whether they could adversely impact the three pits and associated infrastructure areas, and also to provide data for the conceptual design of flood protection structures.

The locations of the flow paths that could impact the pit and infrastructure areas were identified from aerial photography and the 1 m contour plan (Figures 1 and 2). The width, depth and velocity of flows along the drainages were estimated at selected cross-sections where stage-discharge and stage-velocity relationships were calculated using Manning's equation.

The results of the hydraulic analyses and details of the recommended protective structures are presented below. Cross-sections in the figures are presented looking upstream of the natural creeks.

3.1 FLOOD IMPACT ON HIDDEN SECRET PIT & WASTE DUMP

A hydraulic analysis was not required for the Hidden Secret Pit and waste dump as they are located on high ground at the top of Catchment A and will not be impacted by surface water runoff. Therefore flood protection is not required.

3.2 FLOOD IMPACT ON HIDDEN SECRET HAUL ROAD

Flows in Catchment A were analysed to assess the extent to which the 1-in-100 year ARI and PMF flows will impact the planned haul road, located north-east of the Hidden Secret Pit (Figure 2)

In a 1-in-100 year flood, the natural peak flow from Catchment A, west of the haul road (cross-section 1, XS1), would have an elevation of about 303.29 m AHD and a width of about 53 m (Text-Figure 1). The maximum depth of the flood would be about 0.18 m and its maximum velocity in the order of 0.41 m/s (Table 3).

Text-Figure 1: Cross Section 1 with 100 year ARI flood level and PMF

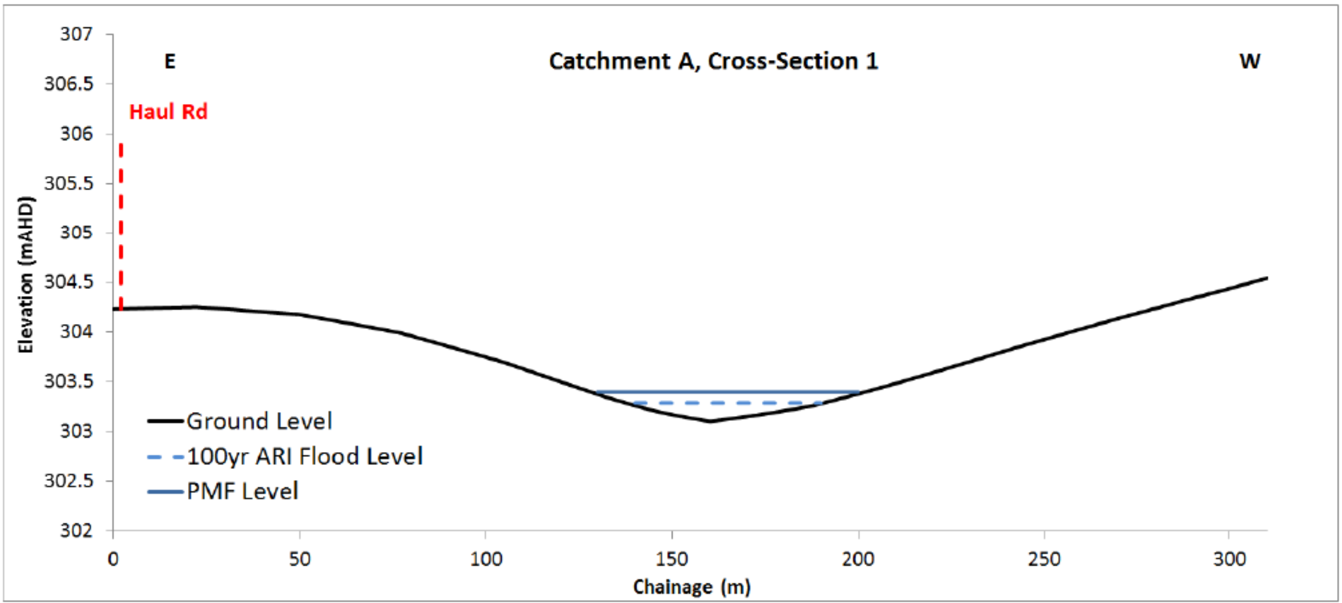


Table 3: Cross-section 1*, flood analysis summary

Flood Analysis	Flow (m^3/s)	Flood Level Elevation (m AHD)	Maximum Depth (mm)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	2.1	303.29	18	0.41	53
PMF	6.8	303.40	29	0.57	74

** Catchment A*

Due to the high elevation of the haul road and shallow depth of the peak floods, no protective measures will be required.

3.3 FLOOD IMPACT ON MOUSE HOLLOW PIT

The southern margin of the proposed Mouse Hollow Pit crosses a minor drainage line from Catchment B (Figure 1). Flows from Catchment B were analysed to assess whether the 1-in-100 year ARI and PMF flow could impact the southern margin of the pit.

In a 1-in-100 year flood, the peak flood from Catchment B at cross-section 2 (XS2) would have an elevation of about 300.10 m AHD and a width of about 58 m (Table 4). The flood level would be about 0.10 m higher in a Probable Maximum Flood (PMF). The maximum depth in the 1-in-100 year flood would be about 0.17 m and the maximum velocity in the order of 0.38 m/s.

These flood waters would have an impact on the southern edge of the planned pit; as shown in Text-Figure 2. A low levee is therefore recommended to protect the southern margin of the pit from flood flows (see below).

Text-Figure 2: Cross-Section 2 with 100 year ARI flood level and PMF

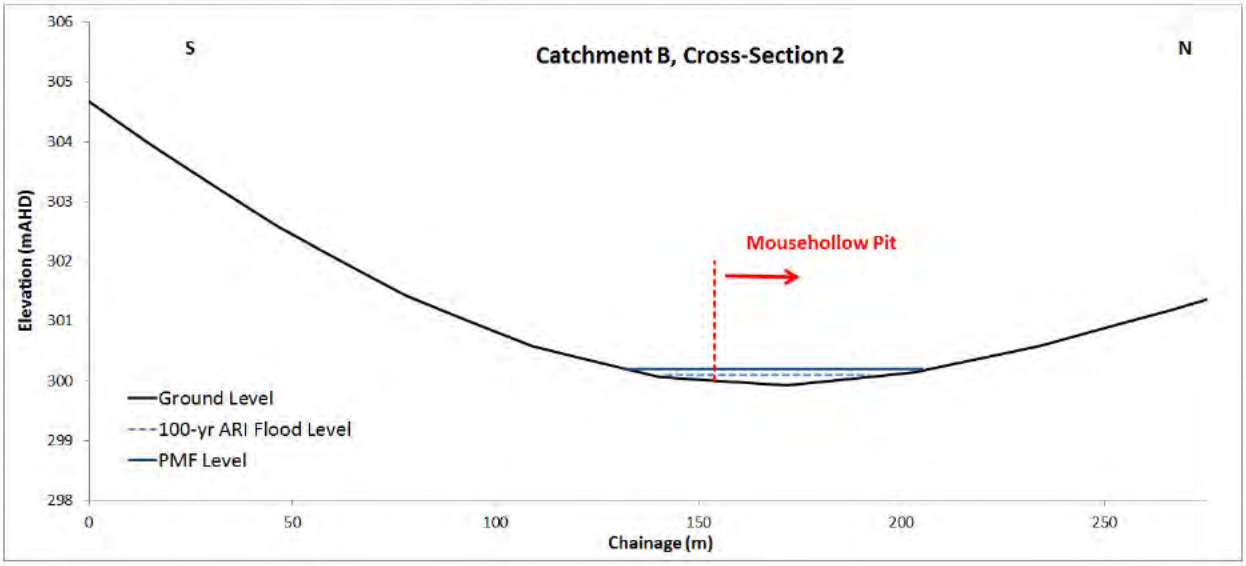


Table 4: Cross-section 2*, 100 year ARI flood summary

Cross Section	100 Year ARI Flow (m^3/s)	Flood Level Elevation (m AHD)	Depth (mm)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	2.0	300.10	17	0.38	58
PMF	6.4	300.20	27	0.55	75

** Catchment B*

3.4 FLOOD IMPACT ON MOUSE HOLLOW WASTE DUMP

In a 1-in-100 year flood, the natural peak flow from Catchment B, at the southern margin of the Mouse Hollow waste dump (cross-section 3, XS3) would have an elevation of about 297.25 m AHD and a width of about 91 m (Table 5). The level would be about 0.07 m higher in a Probable Maximum Flood (PMF) (Text-Figure 3).

The maximum depth of the 1-in-100 year flood at XS3 would be about 0.10 m and its maximum velocity would be about 0.35 m/s (Table 5). The flow waters would not extend to the southern margin of the Waste Dump; as shown in Text-Figure 3.

Text-Figure 3: Cross-Section 3 with 100 year ARI flood level and PMF

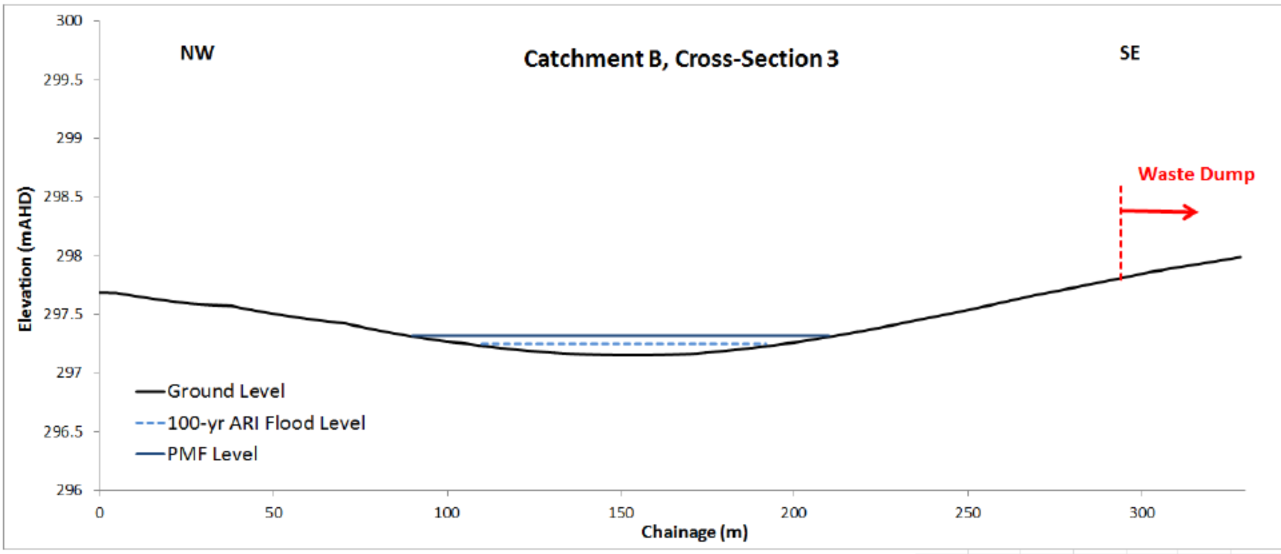


Table 5: Cross-section 3*, 100 year ARI flood summary

Cross Section	100 Year ARI Flow (m^3/s)	Flood Level Elevation (m AHD)	Depth (mm)	Velocity (m/s)	Extent of Flood Level (m)
100-yr	2.0	297.25	10	0.35	91
PMF	6.4	297.32	17	0.50	124

** Catchment B*

3.5 RECOMMENDATIONS

It is recommended that a low levee be constructed along the southern margin of the Mouse Hollow Pit to prevent flood waters from flowing into the pit.

3.5.1 MOUSE HOLLOW PIT LEVEE

The location of the levee recommended to protect the southern margin of the Mouse Hollow Pit is shown in Figure 3.

Table 6 shows the recommended design dimensions of the levee and a conceptual cross-section design of the levee at cross-section 2 (XS2) is shown in Text-Figure 4.

Text-Figure 4: Recommended Levee Design at Cross-Section 2

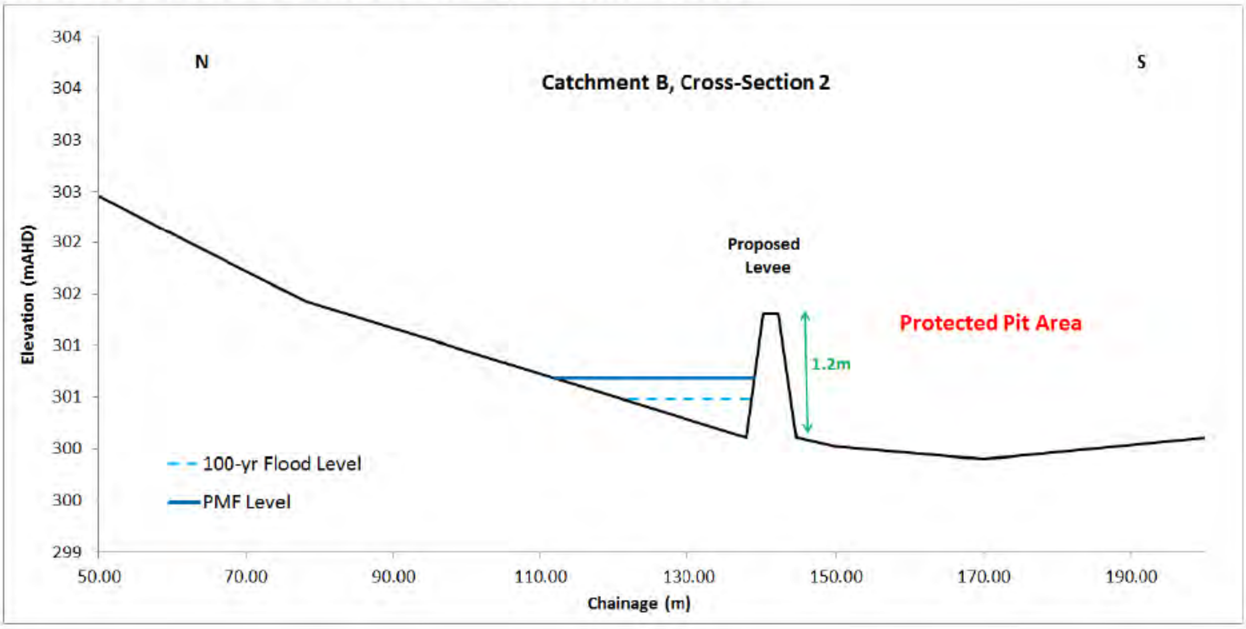


Table 6: Mouse Hollow Levee Design

Parameter	Entire Section
Catchment	B
Design peak discharge (m^3/s)	6.4
Levee Height (m)	1.2
Side slopes v:h (m/m)	1:2

The dimensions presented above should be considered as minimum requirements. Adjustments should be made depending on the site conditions.

Dated: 16 July 2019

[redacted]

S Underwood
Hydrologist/Hydrogeologist

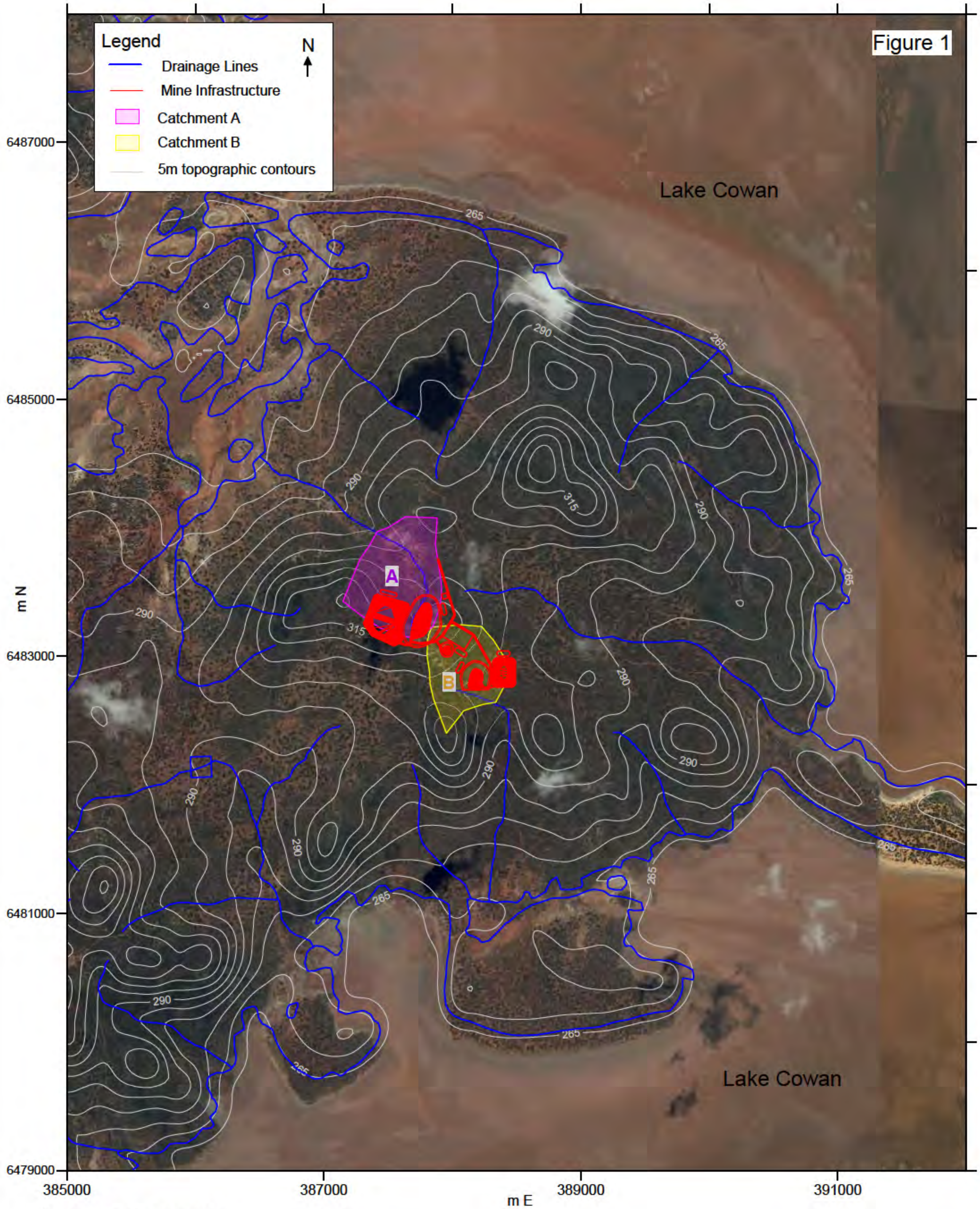
REFERENCES

AR&R, 1987, Australian Rainfall and Runoff, 1987, The Institution of Engineers, Australia.

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 1987, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

FIGURES

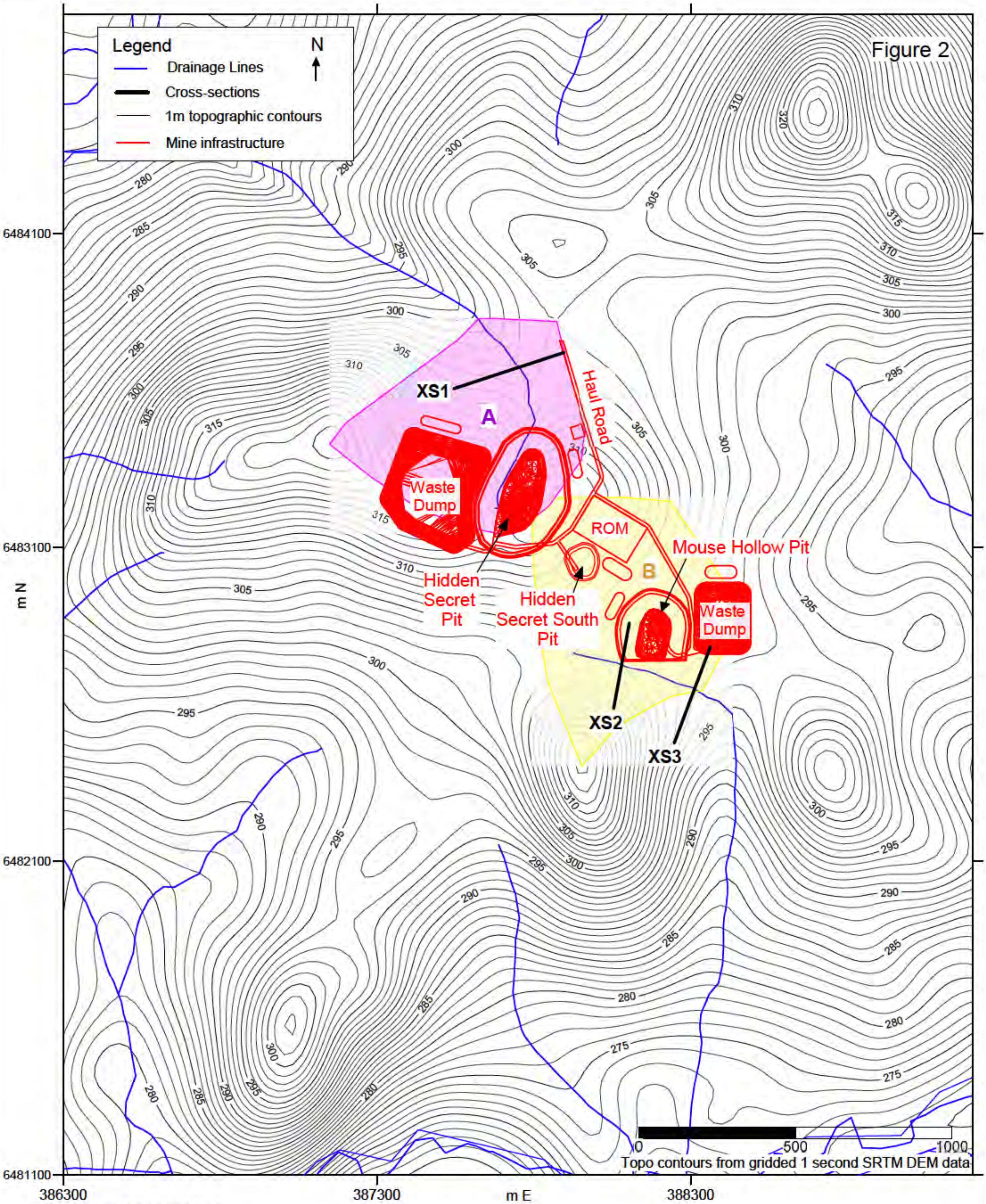


I:/497-0/Surfer/Figure 1 - Catchments.srf

CLIENT:	RNC Minerals
PROJECT:	Eundynie - Surface Water Assessment
DATE:	July 2019
DWG NO:	497-0/19/2-1

CATCHMENTS

Rockwater



I:/497-0/Surfer/Figure 2 - Layout Plan.srf

CLIENT: RNC Minerals

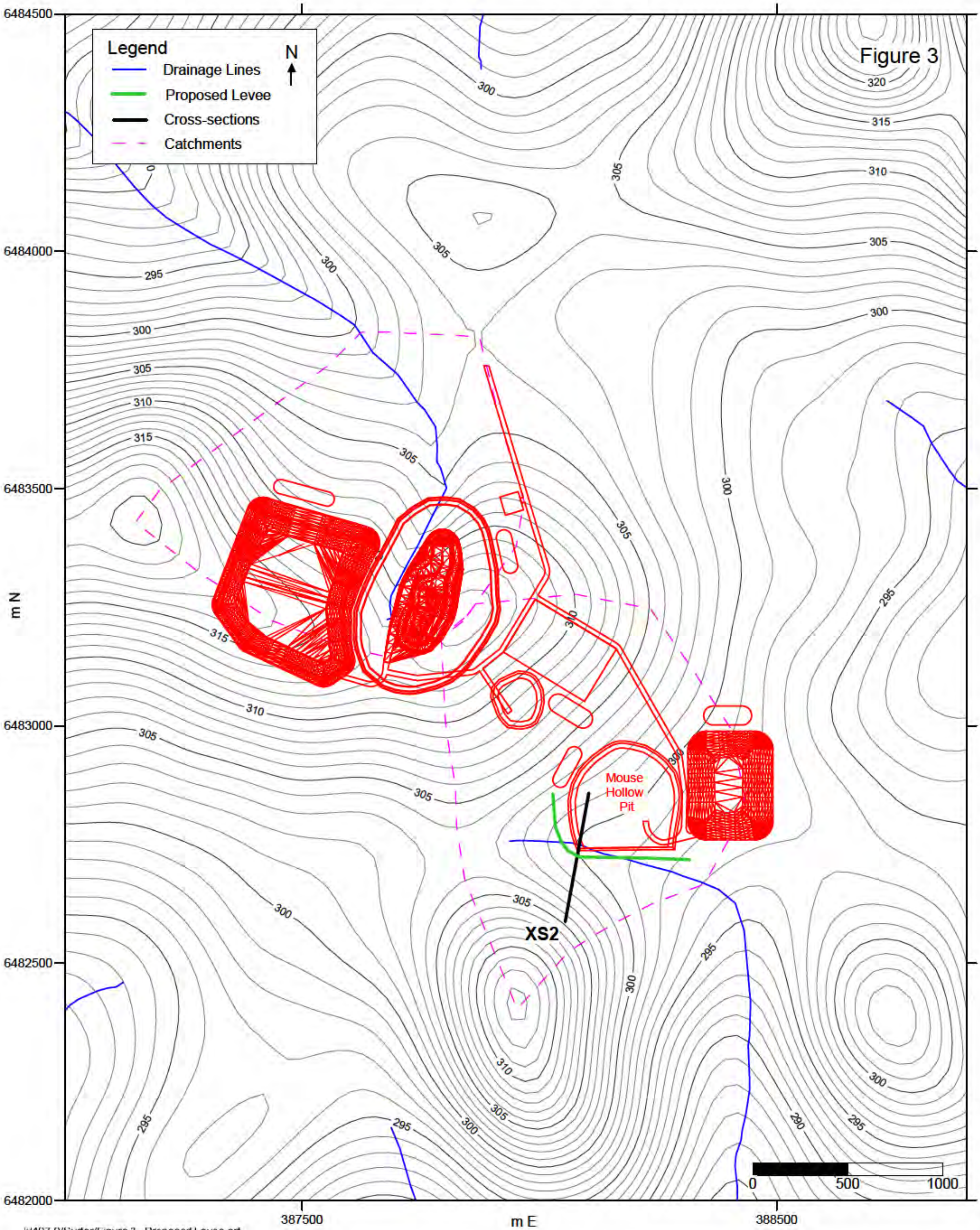
PROJECT: Eundynie - Surface Water Assessment

DATE: July 2019

DWG NO: 497-0/19/2-2

LAYOUT PLAN & CROSS SECTIONS

Rockwater



I:/497-0/Surfer/Figure 3 - Proposed Levee.srf

CLIENT:	RNC Minerals	PROPOSED LEVEE
PROJECT:	Eundynie - Surface Water Assessment	
DATE:	July 2019	
DWG NO:	497-0/19/2-3	Rockwater

APPENDIX A

HYDROLOGY CHARTS AND CALCULATIONS

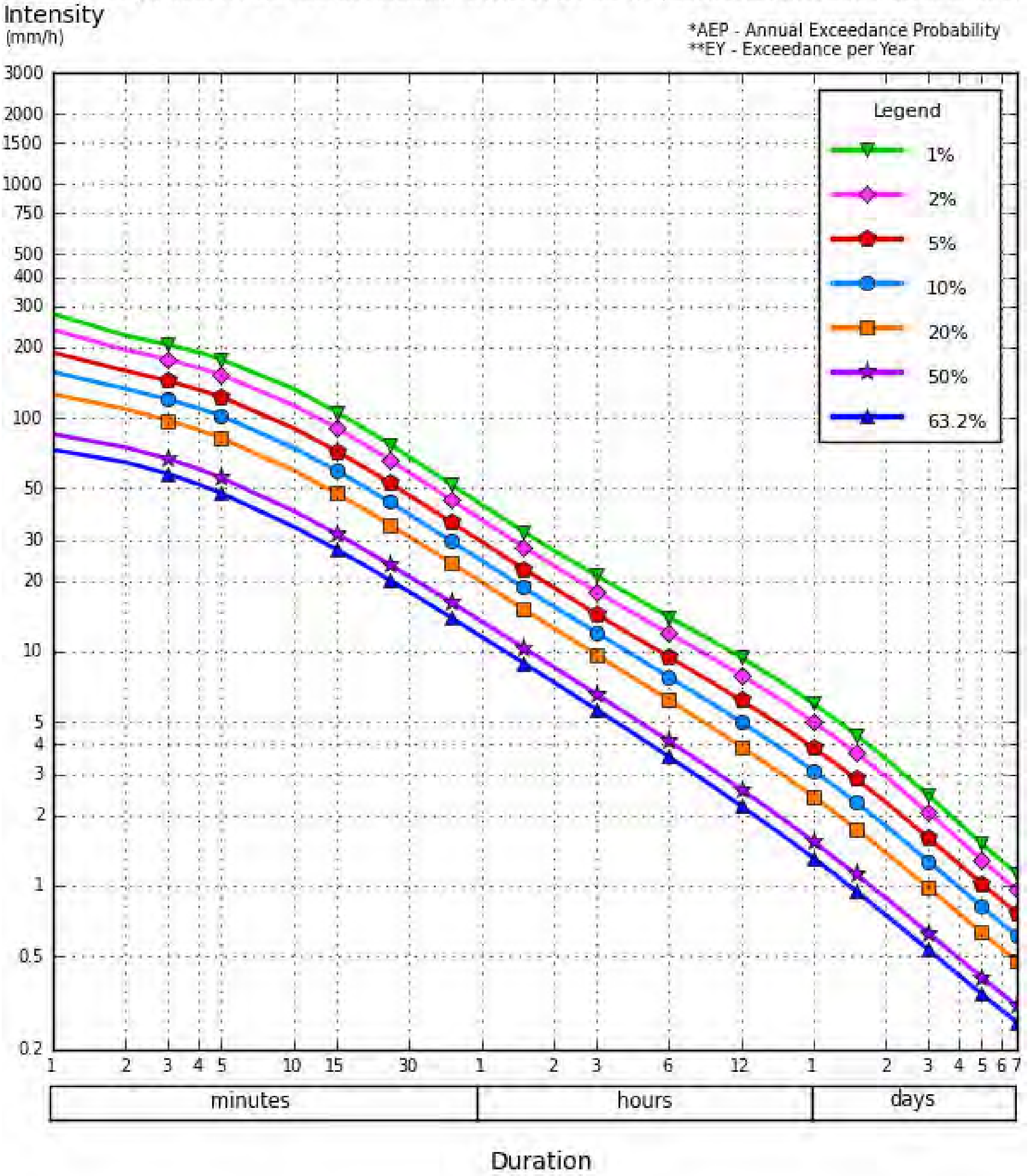
Label:Eundynie

Requested coordinate Latitude: -31.7790 Longitude: 121.8200
Nearest grid cell Latitude: 31.7875 (S) Longitude: 121.8125 (E)

IFD Design Rainfall Intensity (mm/h)

Issued: 19 June 2019

Rainfall intensity in millimetres per hour for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).



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

REGION: **ARID INTERIOR**

LOCATION: Eundynie, Higginsville

CATCHMENT: A

Arid Interior Region

	A (km^2)	L (km)	C_L (%)	P (mm)
Catchment Characteristics	0.44	0.8	25	298

RATIONAL METHOD:

Please note that the Rational Method has been based on the following catchment characteristics:

A =	59.0	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

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

$t_c = 0.76A^{0.38}$ ………… **(1.29)**

t_c = 0.56 Hrs

$C_{10} = 1.06x10^{-1}L^{-0.32}10^{0.0042C_L}$ ………… **(1.30)**

C_{10} = 0.15

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year and 2000 year ARI extrapolated using the logarithmic trend-line

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.05	0.10	0.14	0.19	0.23	0.28

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

REGION: **ARID INTERIOR**

LOCATION: Eundynie, Higginsville

CATCHMENT: A

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.56 hours

Use IFD curves

Duration (hours)	ARI (Years) [mm/hr]					
	2	5	10	20	50	100
0.56	19.4	28.7	35.7	43.1	53.8	62.8

Calculate peak discharge using equation (1.1)

Discharge (m^3/s)	ARI (Years)					
	2	5	10	20	50	*100*
Q	0.12	0.36	0.63	0.98	1.54	*2.12*

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

REGION: **ARID INTERIOR**

LOCATION: Eundynie, Higginsville

CATCHMENT: A

INDEX FLOOD METHOD:

The Australian Rainfall and Runoff Guideline (1987) does not provide equations for peak flow estimation using the Index Flood method for the Arid Interior Region. The Index Flood method was however used for the Wheatbelt Region with loamy soils (similar to Eundynie study area) for comparative purposes only. The results from this method are to be considered conservative.

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

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

$Q_5 = 3.04 \times 10^{-1} A^{0.60} 10^{0.0052 C_L}$ .... **(1.31)**

$Q_5 =$ 0.25 m^3/s

Frequency Factors (Q_Y/Q_5)

	ARI (years)					
	2	5	10	20	50	*100*
Q_Y/Q_5	0.50	1.00	1.76	3.05	5.65	*9.94*

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge

Discharge (m^3/s)	ARI (Years) 2	5	10	20	50	100
Q	0.13	0.25	0.44	0.76	1.41	2.49

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

REGION: **ARID INTERIOR**

LOCATION: Eundynie, Higginsville

CATCHMENT: A

SUMMARY OF RATIONAL AND INDEX METHODS:

Arid Interior Region

Catchment A	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	0.12	0.36	0.63	0.98	1.54	2.12	
Index	0.13	0.25	0.44	0.76	1.41	2.49	
Adopted	**0.12**	**0.36**	**0.63**	**0.98**	**1.54**	**2.12**	**6.82**

*PMF estimated using 1 in 2000 year ARI

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

REGION: **ARID INTERIOR**

LOCATION: Eundynie, Higginsville

CATCHMENT: B

Arid Interior Region

Catchment Characteristics	A (km^2)	L (km)	C_L (%)	P (mm)
	13.9	8.7	25	298

RATIONAL METHOD:

Please note that the Rational Method has been based on the following catchment characteristics:

A =	59.0	km^2
L =	11.5	km
S_e =	5.71	m/km
P =	255	mm

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

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

$t_c =$ 0.53 Hrs

$C_{10} = 1.06 \times 10^{-1} L^{-0.32} 10^{0.0042 C_L}$ .... **(1.30)**

$C_{10} =$ 0.151

Frequency Factors (C_Y/C_{10})

	ARI (years)					
	2	5	10	20	50	*100*
C_Y/C_{10}	0.34	0.70	1.00	1.28	1.62	*1.91*

100 year ARI extrapolated using the logarithmic trend-line

Therefore:

	ARI (years)					
	2	5	10	20	50	100
C_Y	0.05	0.11	0.15	0.19	0.25	0.29

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

REGION: **ARID INTERIOR**

LOCATION: Eundynie, Higginsville

CATCHMENT: B

RATIONAL METHOD:
CONTINUES

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.53 hours

Use IFD curves

Duration (hours)	ARI (Years) [mm/hr]					
	2	5	10	20	50	100
2.07	20.2	29.9	37.2	44.9	56.1	65.4

Calculate peak discharge using equation (1.1)

Discharge (m^3/s)	ARI (Years)					
	2	5	10	20	50	*100*
Q	0.11	0.33	0.59	0.92	1.45	1.99

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

REGION: **ARID INTERIOR**

LOCATION: Eundynie, Higginsville

CATCHMENT: B

INDEX FLOOD METHOD:

The Australian Rainfall and Runoff Guideline (1987) does not provide equations for peak flow estimation using the Index Flood method for the Arid Interior Region. The Index Flood method was however used for the Wheatbelt Region with loamy soils (similar to Eundynie study area) for comparative purposes only. The results from this method are to be considered conservative.

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

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

$Q_5 = 3.04 \times 10^{-1} A^{0.60} 10^{0.0052C_L}$ .... **(1.31)**

$Q_5 =$ 0.23 m^3/s

Frequency Factors (Q_Y/Q_5)

	ARI (years)					
	2	5	10	20	50	*100*
Q_Y/Q_5	0.50	1.00	1.76	3.05	5.65	*9.94*

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge

Discharge (m^3/s)	ARI (Years) 2	5	10	20	50	100
Q	0.11	0.23	0.40	0.70	1.29	2.28

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

REGION: **ARID INTERIOR**

LOCATION: Eundynie, Higginsville

CATCHMENT: B

SUMMARY OF RATIONAL AND INDEX METHODS:

Arid Interior Region

Catchment A	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF*
Rational	0.11	0.33	0.59	0.92	1.45	1.99	
Index	0.11	0.23	0.40	0.70	1.29	2.28	
Adopted	**0.11**	**0.33**	**0.59**	**0.92**	**1.45**	**1.99**	**6.40**

*PMF estimated using 1 in 2000 year ARI

APPENDIX B

HYDRAULIC ANALYSES

Manning's Formula: $$Q = \frac{1}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2}$$

Cross-section 1 (Catchment A)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
303.11	0.0	0.0	0.0	0.06	0.012	0.00	0.00
303.15	16.5	0.4	16.5	0.06	0.012	0.15	0.06
303.2	31.9	1.6	31.9	0.06	0.012	0.25	0.40
303.3	55.2	6.0	55.2	0.06	0.012	0.42	2.55
303.4	73.6	12.5	73.6	0.06	0.012	0.57	7.08

Cross-section 2 (Catchment B)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m3/s)
299.93	0.0	0.0	0.0	0.06	0.012	0.00	0.00
300	27.1	1.0	27.1	0.06	0.012	0.20	0.19
300.1	58.2	5.4	58.2	0.06	0.012	0.38	2.05
300.2	74.7	12.1	74.7	0.06	0.012	0.55	6.69

Cross-section 3 (Catchment B)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m^3/s)
297.15	0.0	0.0	0.0	0.06	0.017	0.00	0.00
297.2	63.2	2.1	63.2	0.06	0.017	0.22	0.45
297.3	115.5	11.2	115.5	0.06	0.017	0.46	5.08
297.4	152.3	24.6	152.3	0.06	0.017	0.64	15.80

Cross-section 2 with Levee (Catchment B)

Stage	Top Length (m)	A (m2)	P (m)	Manning's n	Slope (m/m)	V (m/s)	Q (m^3/s)
300.11	0.0	0.0	0.0	0.06	0.012	0.00	0.00
300.2	4.3	0.2	4.3	0.06	0.012	0.24	0.0
300.4	13.8	2.0	13.9	0.06	0.012	0.51	1.0
300.6	23.3	5.7	23.4	0.06	0.012	0.72	4.1
300.8	32.7	11.3	32.9	0.06	0.012	0.91	10.3