Lamb Creek
Mine Closure Plan

MINERAL RESOURCES

Surface Water Assessment Technical Memorandum

Nov 2024

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Revision History

Revision No.	Issue Date	Prepared By	Approved By	Document Purpose
0	30/04/2024	A. Jha & S.Li	A. Jha	Site MCP flooding assessment - Draft
1	06/05/2024	A. Jha & S.Li	A. Jha	Site MCP flooding assessment - Final
2	22/11/2024	S.Li	S.Li	MCP Surface Water Assessment - Final

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1 SCOPE OF WORK

Flood modelling was conducted to assess the Mine Closure Plan (MCP) designs of the Lamb Creek mining area (the Site). The Site is an Iron Ore mine and part of the Mineral Resource Limited (MinRes) Pilbara Project; it is not an active operation.

The Objective of the assessment is to:

- Develop a hydraulic model to evaluate the Site's closure scenario.
- Assess surface water risks from external catchments with an abandonment bund.

The following scenarios were considered for Probable Maximum Flood (PMF) and 1% Annual Exceedance Probability (AEP) events:

- Pre-development condition
- Closure Scenario: Pit backfill to 5m above groundwater level with abandonment bund

1.1 Available Data

- LiDAR-derived 0.25 m Digital Elevation Model (DEM)
- Closure designs, including Pits and Waste Rock Landforms (WRL)
- Shuttle Radar Topography Mission (STRM) 1 sec DEM (ICSM, 2024).

2 SITE HYDROLOGY

Runoff from Catchments A, B, C, D, and E affects The Site. The Site setting and catchments are shown in **Figure 1**.

2.1 Rainfall-Runoff Loss Parameters

The Initial Loss (IL)-Continuous Loss (CL) model as per the ARR 2019 Guidelines (Ball J, 2019) was applied to estimate the rainfall excesses for the modelled events.

In accordance with Book 8, Chapter 6, ARR 2019 Guidelines (Ball J, 2019), the IL of 0 mm and CL of 1.0 mm/hr for the PMF event are adopted.

In accordance with Book 5, Chapter 3, ARR 2019 Guidelines (Ball J, 2019), the Site is within the ARR Loss Prediction Region 2; therefore, a burst IL of 37.5 mm is adopted. The ARR Data Hub (ARR, 2024) storm losses for Tom Price, representative of the Pilbara region where data exists, have been used to advise the CL. The CL of 8 mm/hr for the 1% AEP event has been adopted. Tom Price is approximately 200 km west of the Site.

The Catchments' 1% AEP peak flows from the hydraulic modelling were compared to the Flavell Regional Flood Frequency Procedure (RFFP) 2000 method, which was reported in the existing surface water assessment for the Site (AQ2, 2021).

As summarised in **Table 1**, The Flavell RFFP 2000 method provides peak flow estimates comparable to the hydraulic model. The loss parameters selected are acceptable for estimating the 1% AEP simulated flow.

Table 1 Lamb Creek Catchments 1% AEP Peak Flow Estimates

CATCHMENT	FLAVELL RFFP 2000 (M^3/S)	TUFLOW HYDRAULIC MODEL (M^3/S)
A	390	455
B	62	60
C	18	17

2.2 Design Rainfall

PMF rainfall was estimated for the Site using the Generalised Short-Duration Method (GSDM). The methodology is based on an analysis of convective thunderstorms. It is appropriate for durations up to 6 hours, as detailed in 'The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method' (BOM, 2003).

The Site is located within the 'Intermediate Zone' in the GSDM Zones; a maximum 6-hour duration is adopted, and a Moisture Adjustment Factor (MAF) of 0.952 was selected for the Site. The Catchment was classified as smooth, with an Elevation Adjustment Factor (EAF) of 1.

For the PMF events, temporal patterns have been adopted from the paper 'Growth Curves and Temporal Patterns of Short Duration Design Storms for Extreme Events' (Jordan & Nathan, 2005). A duration-specific temporal pattern ensemble was created from the ten temporal patterns presented in the technical paper. This method aligns with the Australian Rainfall & Runoff (ARR) Guidelines, which recommend using Jordan temporal patterns for extreme event modelling. (Ball J, 2019)

The 1% AEP rainfall was obtained from the ARR data hub, and the Rangelands West temporal patterns have been adopted (ARR, 2024).

The Design Rainfall is detailed in **Table 2**.

Table 2 GSDM PMF and 1% AEP Design Rainfall Values

TIME (HOUR)	PMF VALUE (MM)	1% AEP VALUE (MM)
0.25	158.98	25
0.5	233.24	37.8
0.75	295.12	45.7
1	358.90	51.8
1.5	409.36	61.3
2	461.72	69.3
3	528.36	83.1
6	675.92	125.2

3 HYDRAULIC MODEL

The TUFLOW Heavily Parallelised Compute (HPC) with GPU (2023-03-AB version) hydraulic software was used for flood modelling. TUFLOW HPC GPU is an explicit solver for the full 2D Shallow Water Equations.

3.1 Model Setup

Figure 1 shows the TUFLOW model domain with the locations of flow outlets. The model includes:

- Outflow boundaries north of the Site
- Rain-on-Grid method for the model boundary to simulate flows
- A Print Output (PO) series provides time-series flow hydrograph outputs. These are shown in Figures containing simulated outputs.

A high-resolution DEM was used to generate bathymetry where available. The bathymetry resolution is 30 x 30 m squared grids for upstream catchments, 7.5 x 7.5 m within the Site and a higher resolution grid of 1.875 x 1.875 m on the proposed abandonment bund for high-precision evaluation of the bund performance.

Hydraulic roughness across the model domain was represented using a Manning's n roughness value of 0.07.

The model's simulation period was chosen to allow the peak runoff from the Catchments to drain out of the Site.

3.2 Rainfall Events

As per ARR guidelines (ARR, 2024), Design Rainfall events for all standard durations and Temporal Patterns (TPs) were simulated.

The critical durations and TP that produced the median peak water depth at the locations upstream of the Pit were found to be:

- PMF: 1-hour, TP 06
- 1% AEP: 12-hour, TP 05.

4 HYDRAULIC MODEL RESULTS

The modelling results for each scenario are summarised and discussed in this section.

4.1 Pre-development Condition

Two 'Rain-on-Grid' scenarios for both 1% AEP and the PMF were modelled for the pre-development condition. The design rainfall depths distributed with the adopted temporal pattern were applied to:

- Scenario 1: The whole model domain (results are in **Figure 2** and **Figure 3**)
- Scenario 2: Catchment A extent only (the result is in **Figure 4**).

Figure 2 and **Figure 3** show the flood maps for the 1% AEP and the PMF events, respectively, for the pre-development condition. These figures show that the runoffs from Catchment B & C mainly flow across the location of Pit and WRL 1. The simulated flow patterns shown in **Figure 2** and **Figure 3** suggest that Catchment A runoffs do not enter the footprints of the Pit and WRL 1, which was confirmed by the second 'Rain-on-Grid' scenario results.

For the pre-development condition, The modelled peak flows from Catchment B and C at the PO Lines are summarised in **Table 3**.

Table 3 Catchment Peak Flow Estimation

PO LINE	1% AEP PEAK FLOW (M^3/S)	PMF PEAK FLOW (M^3/S)
B01	60	723
C02	17	246

4.2 Pit Backfill 5 m above Groundwater Level with Abandonment Bund

The simulated flood depth maps for the 1% AEP and the PMF events are presented in **Figure 5** and **Figure 7,** respectively. As expected, the abandonment bund stops flows from Catchment B and C from entering the Pit. The simulated flood velocity maps are presented in **Figure 6** and **Figure 8.**

The simulated maximum water levels upstream of the abandonment bund are:

- 1% AEP: 0.8 m
- PMF: 2.1 m.

The southwest corner of the WRL1 is at erosion risk under both 1% AEP and PMF events. The maximum simulated velocity is 4.5 m/s under the PMF event.

The maximum water level at the southwest corner of WRL1 is 2 m during the 1% AEP event and 4 m during the PMF event.

4.3 Surface Water within the Pit

Table 4 summarises the simulated water depths of the modelled events. Only the surface water reporting to the Pit has been estimated. The pit invert is 679 m AHD;

Table 4 Surface Water Runoff Inflows to the Pit

EVENT	WATER LEVEL (M AHD)	WATER DEPTH IN THE PIT (M)
1% AEP	679.3	0.3
PMF	680.3	1.3

5 PIT LAKE WATER BALANCE MODEL

A pit lake water balance model was developed in GOLDSIM (www.goldsim.com) for the 5m backfilled Pit to assess the likelihood of a permanent pit lake formation.

5.1 Methodology

The water balance of the pit lake can be described as:

Total inflow – Total outflow = Pit Lake storage.

Inflows into the pit lake are from:

- Direct rainfall into the pit void
- Localised runoffs from 0.3 km2 area north of the abandonment bund alignment

Outflows from the pit lake are from:

- Evaporation from the water surface within the pit void
- Evaporation from the top 2 m of the moisture in the backfilled material from the dry pit floor
- Infiltration from the pit lake floor if there is water in the pit void.

The infiltration model is conceptually described in **Figure 9**.

The following assumptions are made in the water balance model:

- Infiltration from the pit lake floor will initially occur vertically towards the recovered regional groundwater table until the moisture content of the backfilled column to the groundwater table is near saturation.
- Once the backfilled void space is near saturation, infiltration losses from the pit floor will be constrained by horizontal flow

5.2 Input Data

5.2.1 Catchment Inflow

A continuous period of record is available from the Department of Water and Environment (DWER) gauging site 708001 (Flat Rocks) on Marillana Creek with an upstream catchment area of 1,369 km^2 (**Figure 10**). The recorded daily time series from the Flat Rocks gauging site is shown in **Figure 11.**

The daily peak value on 10 December 1975 was 1,327.5 m^3/s. The flood frequency curve, based on annual peak discharge timeseries, provided by the Bureau of Meteorology (**Figure 12**), suggests that the daily peak value of 1,327.5 m^3/s on 10 December 1975 has an AEP of 1% or 1 in 100 (WMA Water, 2024).

5.2.2 Rainfall and Evaporation

The daily time series of rainfall and pan evaporation used in the water balance was from the DWER rain gauge 505011 (Flat Rocks), next to the stream gauging site 708001 (**Figure 13**). A pan factor of 0.7 was applied to the pan evaporation to calculate the potential evaporation for the water balance.

5.2.3 Groundwater Hydraulics

The following equations from PC-SUMP model user manual were used to estimate infiltration from the backfilled Pit void floor. The manual is currently maintained by Jdahydro.com.au and used in urban sump design around Perth metropolitan areas.

$$q_0 = K\pi \frac{(H+d)^2}{Log_e(\frac{R}{r})} \qquad \textit{Shallow Water Table (equation 1)}$$

$$q_0 = K\,A \qquad \textit{Deep Water Table (equation 2)}$$

$$R = r + 50(H+d)\left(\frac{K}{24}\right)^{0.5} \qquad \textit{Radius of spread (equation 3)}$$

Where:

q_0= rate of outflow from the pit void floor due to soakage (m^3/day)

K= soil permeability (m/day)

H= Pit Lake water surface area weighted average water depth (m)

d= depth to groundwater table from the base of the basin (m)

R= radius of spread of infiltrated water at the groundwater table (m)

r= equivalent radius of perimeter of the Pit Lake water surface area (m)

A= Pit Lake water surface area at the average depth H

The infiltration rate is controlled by saturated hydraulic conductivity. For this study a conservative value of 0.2 m/day or 8.0 mm/hour has been assumed as the pit void is situated among various fracture zones with limited connectivity with the regional groundwater system. Note that the interpreted saturated hydraulic conductivity values range from 0.3 m/day to 2 m/day for Lamb Creek project area as per the PSM report (PSM, 2021).

The following relationship between backfilled material saturation and void ratio has been used in soil water balance for the top 2 m of the backfilled material.

- Wilting point – volumetric void ratio 0.05 – background moisture content below which evaporation of water will not occur.
- Field capacity – volumetric void ratio 0.30 – background moisture content below which potential evaporation linearly decreases until the wilting point is reached.
- Saturation capacity – volumetric void ratio 0.50 – full potential evaporation and deep percolation occurs towards the groundwater table.

6 PIT LAKE WATER BALANCE RESULTS

The abandonment bund acts like a diversion bund, preventing the runoffs from Catchment B and Catchment C from entering the pit void. **Figure 14** presents inflow time series for this condition.

Figure 15 presents simulated timeseries of pit void water storage from 1970 to 2020. The simulated peak water depth in the backfilled pit void was 2.21 m (or 681.183 m AHD).

Under the simulated shallow water table condition, it would take up to one year for the pit lake to dry up, if the Dec 1975 event were to repeat.

The seepage flow under this condition was simulated based on the shallow water table condition. **Figure 16** presents simulated seepage and evaporation volumes under this condition. Evaporation from the ephemeral pit lake surface is more dominant than the seepage from the pit floor.

7 CONCLUSION

A hydraulic analysis was undertaken to determine the nature of flooding and risks to the modelled closure landforms with and without the required abandonment bund. The key findings of the study are as follows:

- Volumetric reduction of surface water from entering the Pit is minimised.
- Erosion risks at the pit entry locations are minimised.
- Erosion protection required for the southwest corner of the WRL 1 due to a high velocity of 4.5 m/s under the PMF event.
- There is a chance of the backfilled pit void remaining wet for up to one year if the climatic condition of 1975 to 1977 were to repeat in future.

8 REFERENCES

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Figures

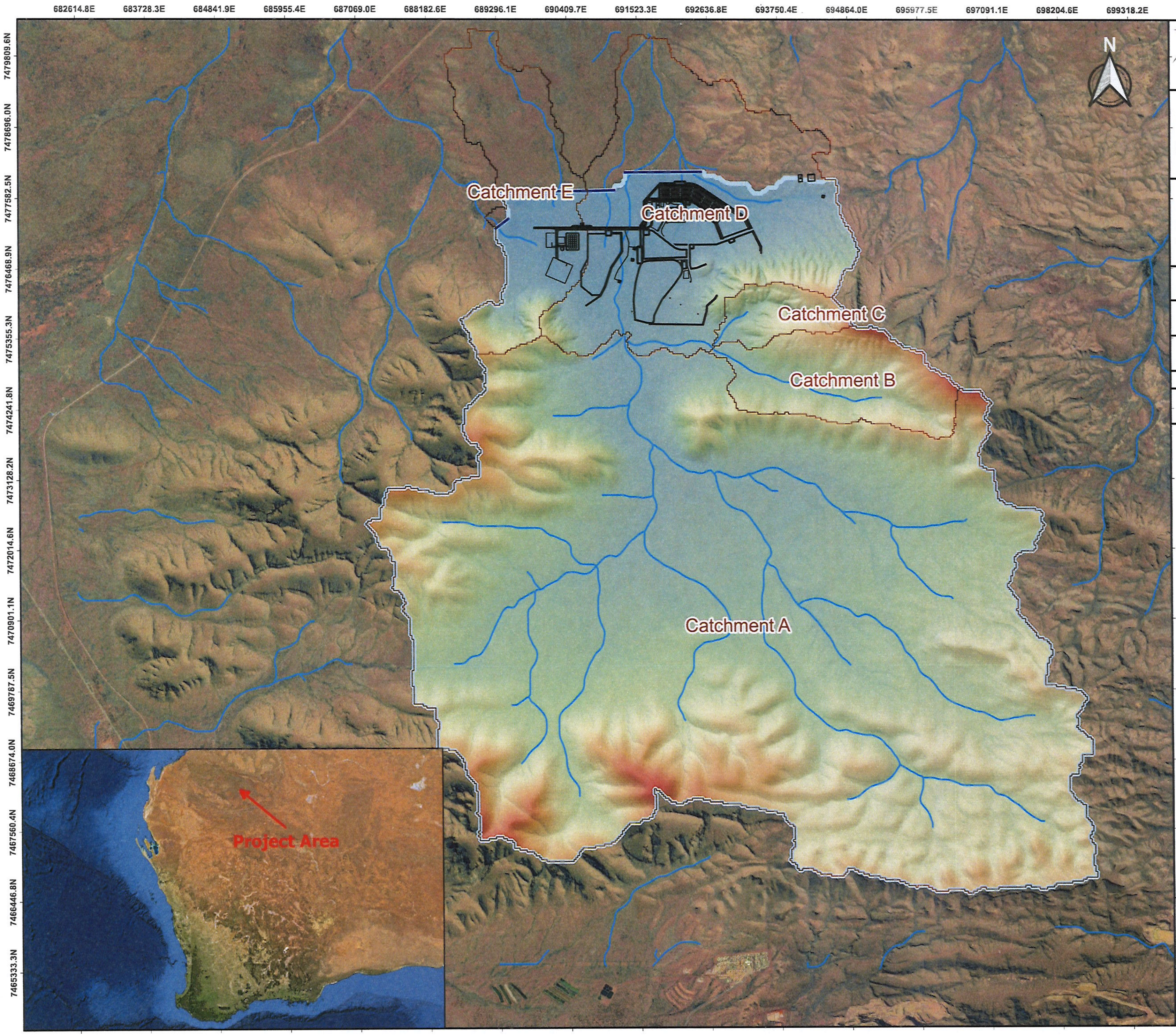

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Figure 1
Site and Model Setting

Lamb Creek Mine Closure Plan
Surface Water Assessment
Technical Memorandum

Date:03/05/2024

Prepared by: SL

Approved by: AJ

Projection: GDA 94/MGA Zone 50 EPSG:28350

1 0 1 2 km

Legend

- Site Layout
- Catchments
- Model Outflow Boundary
- Model Domain
- Streams

Terrain (m AHD)

1,062.57

679

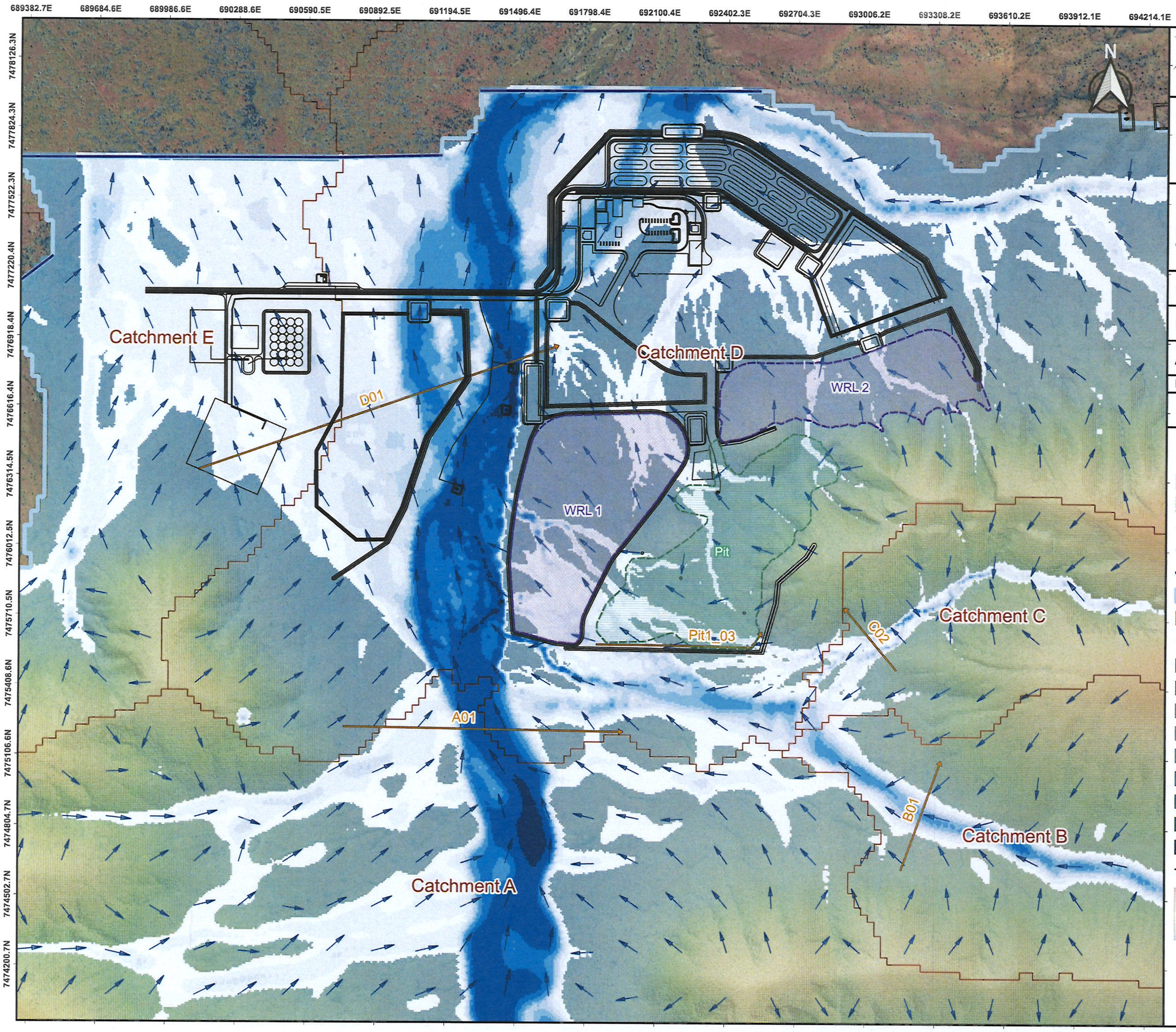

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Figure 2
1% AEP Flood Depth Map - Pre-development

Lamb Creek Mine Closure Plan Surface Water Assessment Technical Memorandum

Date:03/05/2024

Prepared by: SL

Approved by: AJ

Projection: GDA 94/MGA Zone 50 EPSG:28350

0.3 0 0.3 0.6 km

Legend

- Waste Rock Landform Footprint
- Pit Footprint
- Site Layout
- Print Output (PO) Lines
- Model Outflow Boundary
- Model Domain
- Catchments

Water Depth (m)

- <= 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.40
- 0.40 - 0.50
- 0.50 - 0.70
- 0.70 - 1.00
- 1.00 - 2.00
- > 2.00

Terrain (m AHD)

1,062.57

679

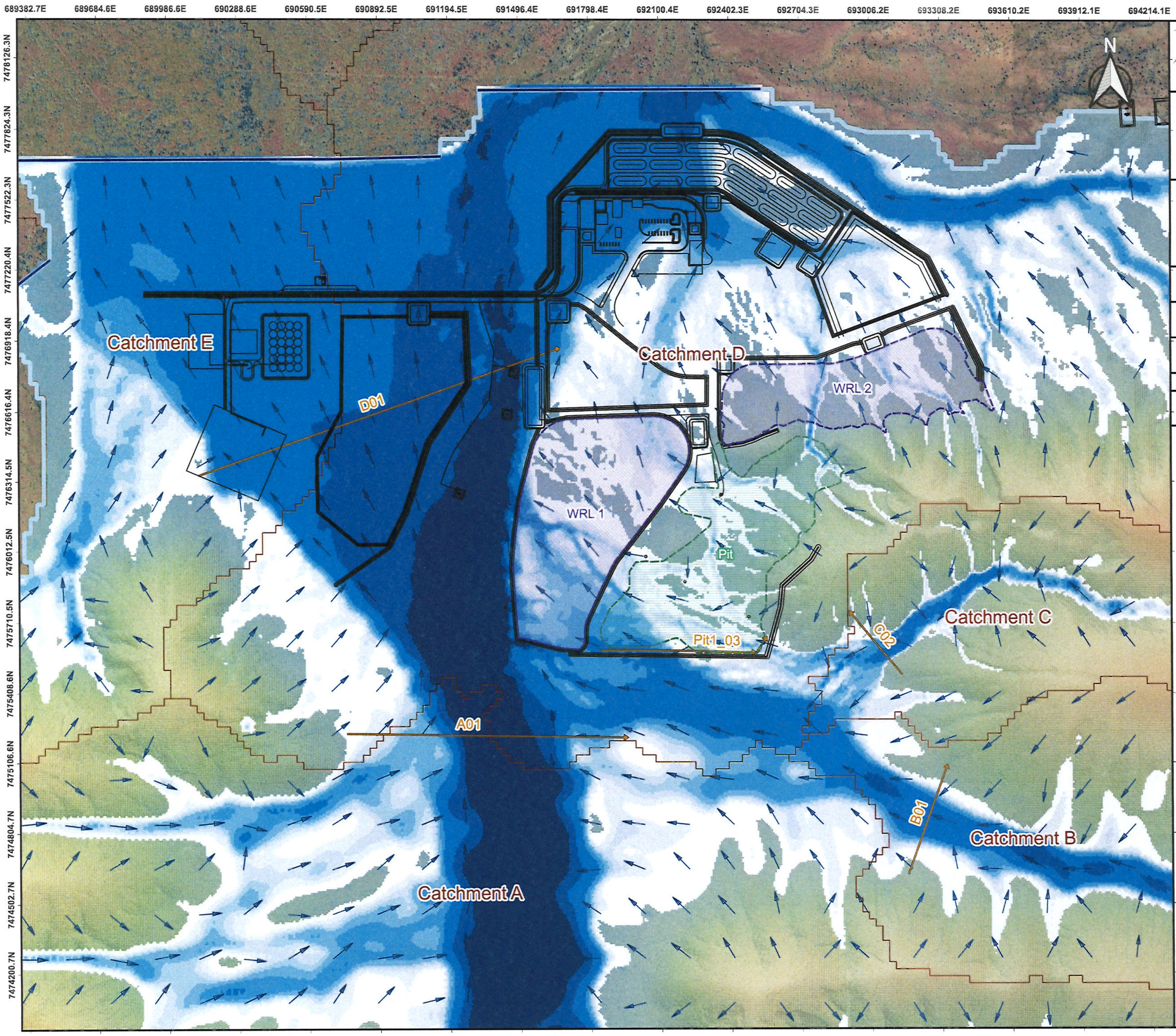

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Figure 3
PMF Flood Depth Map - Pre-development

Lamb Creek Mine Closure Plan
Surface Water Assessment
Technical Memorandum

Date:03/05/2024

Prepared by: SL

Approved by: AJ

Projection: GDA 94/MGA Zone 50 EPSG:28350

0.3 0 0.3 0.6 km

Legend

- Waste Rock Landform Footprint
- Pit Footprint
- Site Layout
- Print Output (PO) Lines
- Model Outflow Boundary
- Model Domain
- Catchments

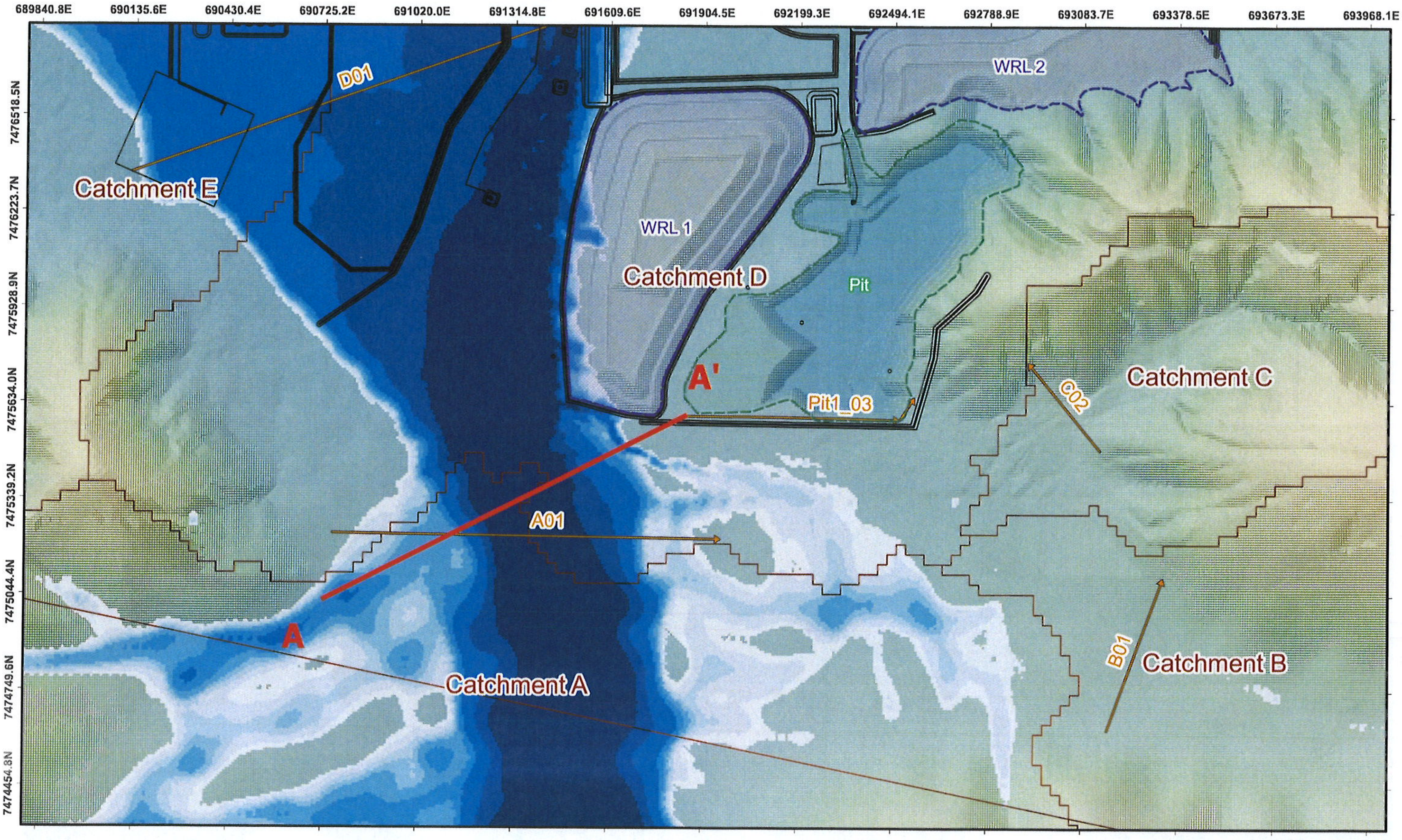
Water Depth (m)

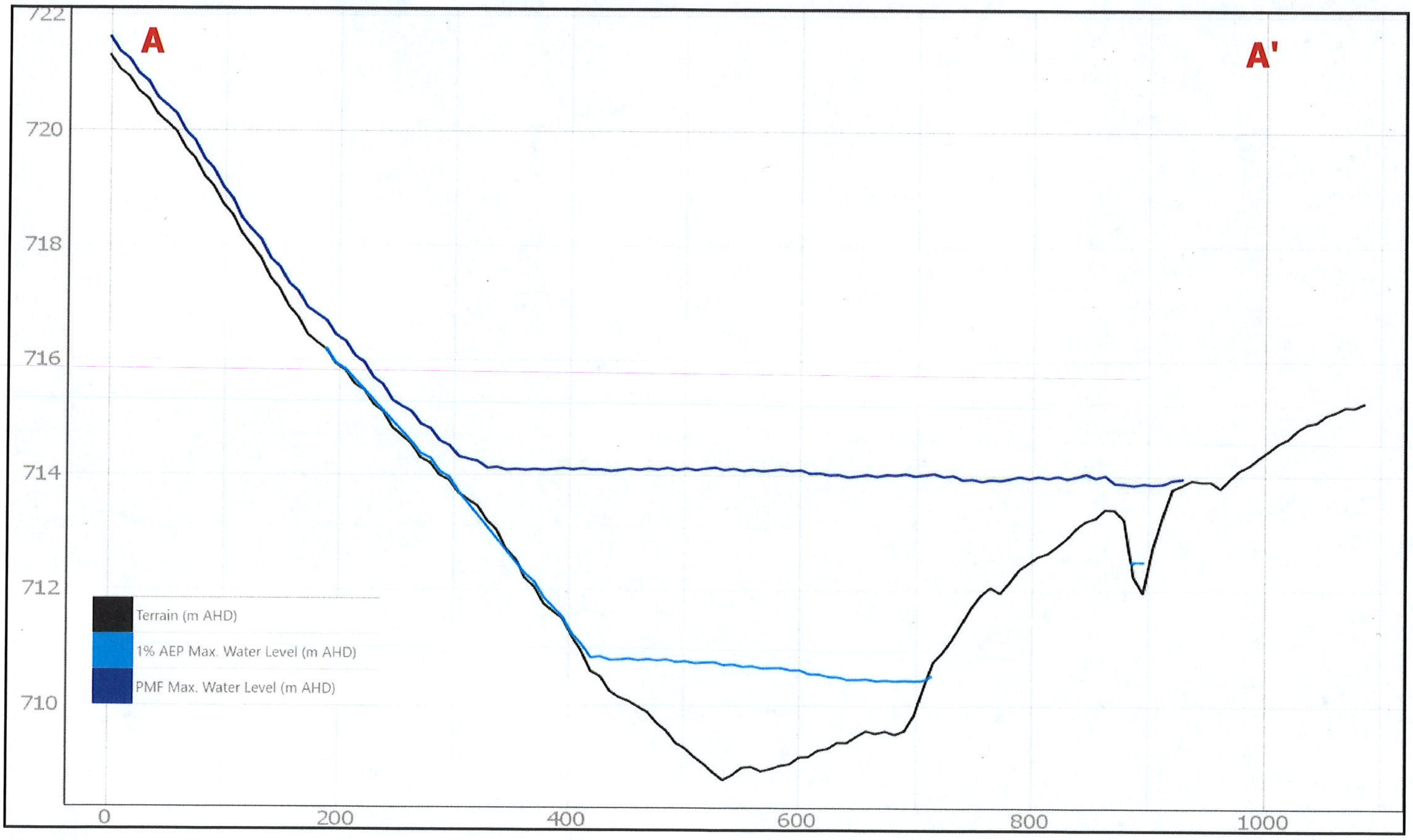
- <= 0.20
- 0.20 - 0.30
- 0.30 - 0.40
- 0.40 - 0.50
- 0.50 - 0.70
- 0.70 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3.00

Terrain (m AHD)

1,062.57

679





Legend

- Waste Rock Landform Footprint
- Pit Footprint
- Site Layout
- Print Output (PO) Lines
- Model Domain
- Catchments

PMF Water Depth (m)

- 0.15 - 0.20
- 0.20 - 0.30
- 0.30 - 0.40
- 0.40 - 0.50
- 0.50 - 0.70
- 0.70 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3.00

Terrain (m AHD)

1,062.57

679

Date:03/05/2024

Prepared by: SL

Approved by: AJ

Projection: GDA 94/MGA Zone 50 EPSG:28350

0 0.25 0.5 0.75 km

N

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Figure 4
Cross-section Profile - Catchment A Rainfall Only

Lamb Creek Mine Closure Plan Surface Water Assessment Technical Memorandum

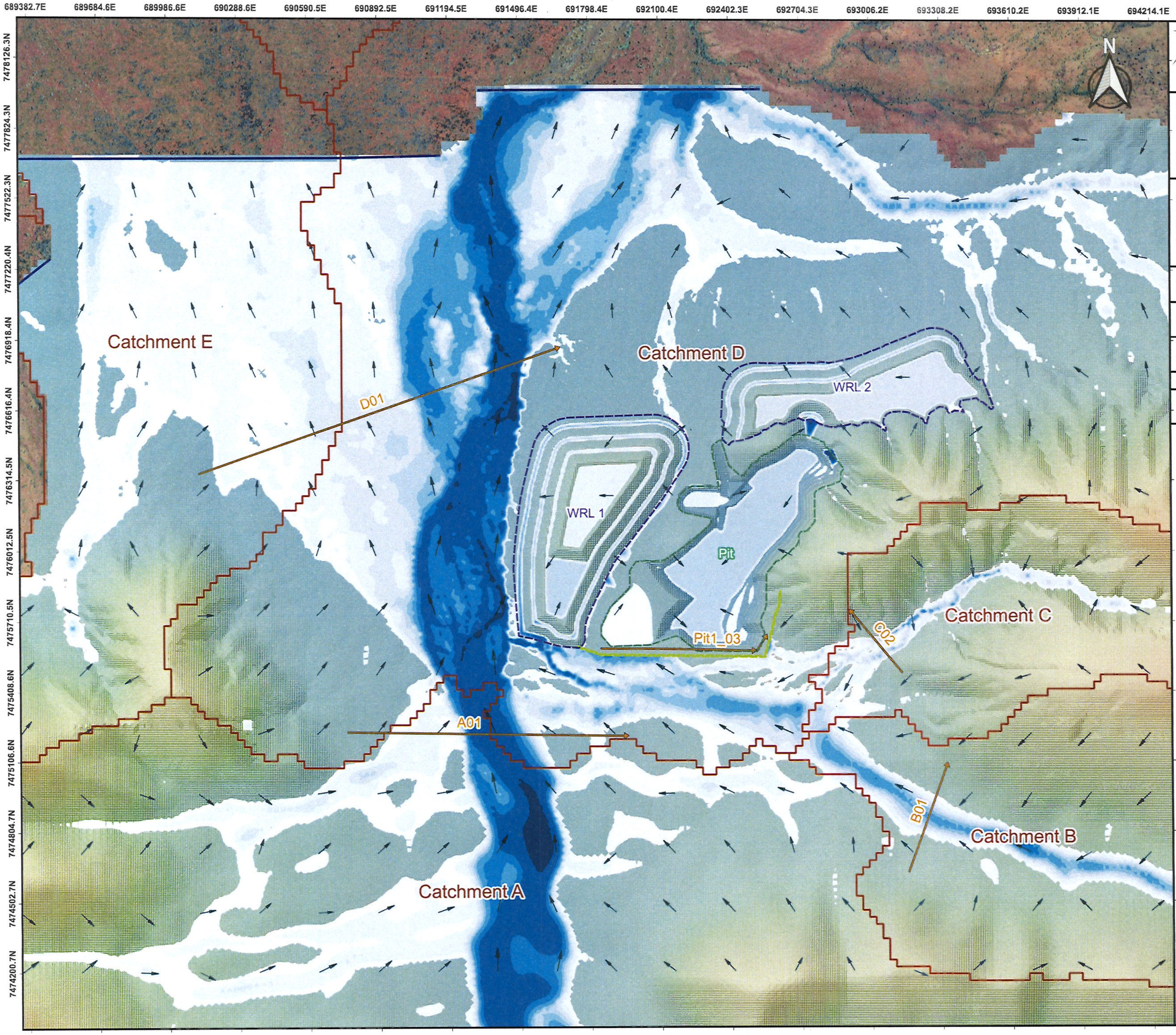

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Figure 5
1% AEP Flood Depth Map - Closure Scenario

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Prepared by: SL

Approved by: AJ

Projection: GDA 94/MGA Zone 50 EPSG:28350

0.3 0 0.3 0.6 km

Legend
- Waste Rock Landform Footprint
- Pit Footprint
- Indicative Abandonment Bund
- Print Output (PO) Lines
- Model Outflow Boundary
- Catchments

Water Depth (m)
- <= 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.40
- 0.40 - 0.50
- 0.50 - 0.70
- 0.70 - 1.00
- 1.00 - 2.00
- > 2.00

Terrain (m AHD)
- 1,062.57
- 679

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Figure 6
1% AEP Flood Velocity - Closure Scenario

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Surface Water Assessment
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Prepared by: SL

Approved by: AJ

Projection: GDA 94/MGA Zone 50 EPSG:28350

0.1 0 0.1 0.2 km

Legend

Waste Rock Landform Footprint

Pit Footprint

Indicative Abandonment Bund

Catchments

Water Velocity (m2/s)

<= 0.50

0.50 - 1.00

1.00 - 1.50

1.50 - 2.00

> 2.00

Terrain (m AHD)

1,062.57

679

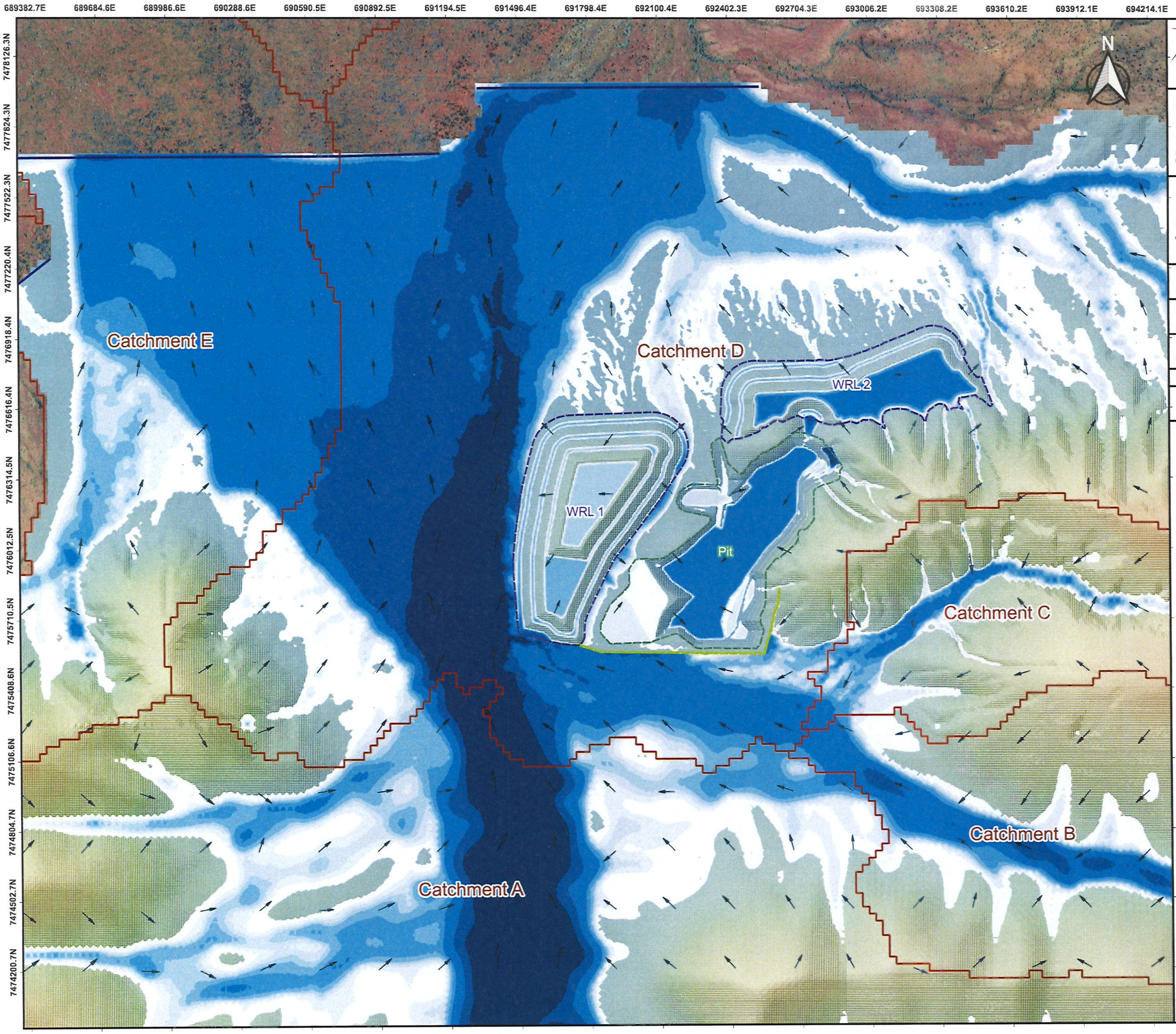

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Figure 7
PMF Flood Map - Closure Scenario

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Prepared by: SL

Approved by: AJ

Projection: GDA 94/MGA Zone 50 EPSG:28350

0.3 0 0.3 0.6 km

Legend

- Waste Rock Landform Footprint
- Pit Footprint
- Indicative Abandonment Bund
- Model Outflow Boundary
- Catchments

Water Depth (m)

- <= 0.20
- 0.20 - 0.30
- 0.30 - 0.40
- 0.40 - 0.50
- 0.50 - 0.70
- 0.70 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3.00

Terrain (m AHD)

1,062.57

679

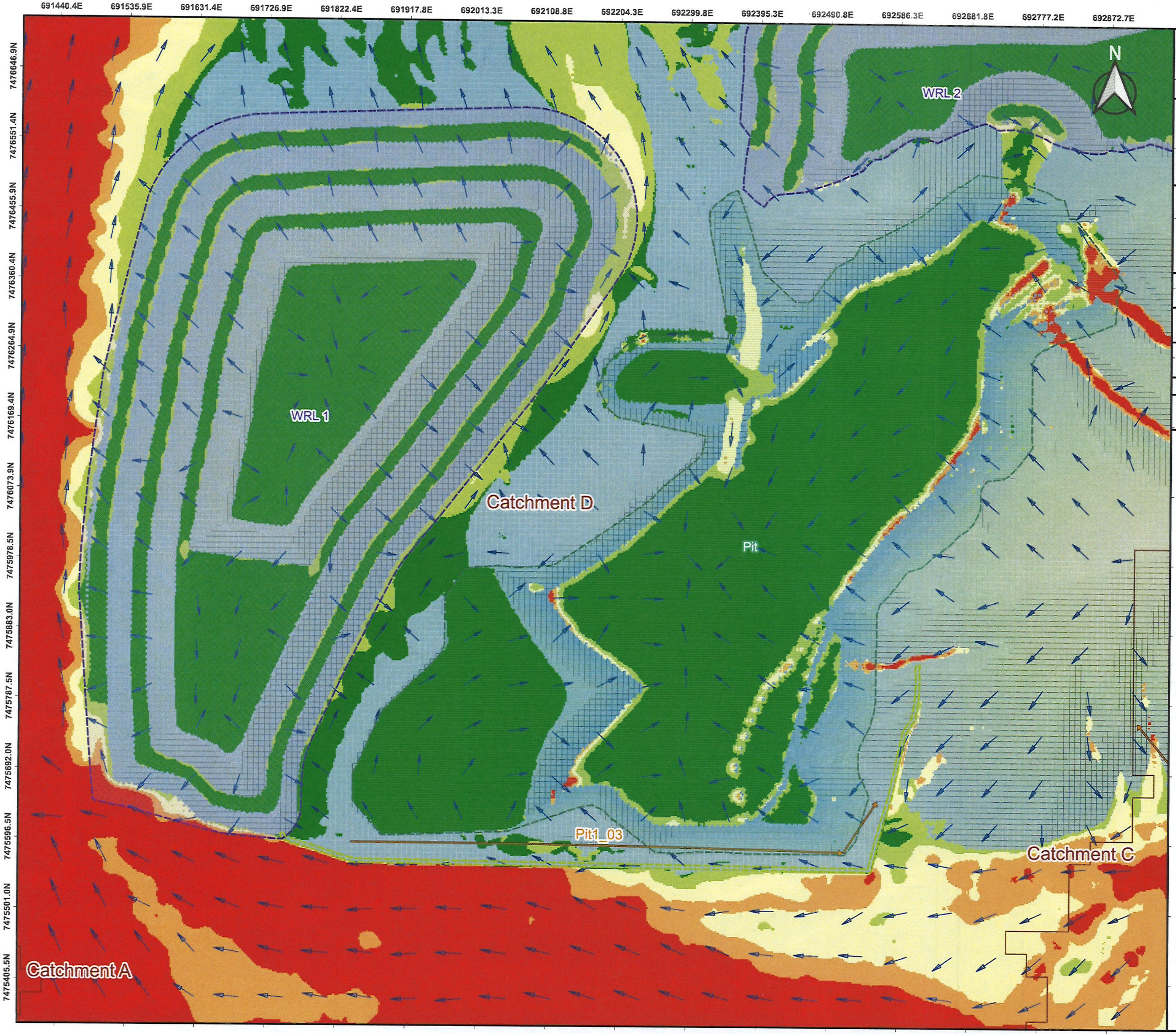

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Figure 8
PMF Flood Velocity - Closure Scenario

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Surface Water Assessment
Technical Memorandum

Date:27/11/2024

Prepared by: SL

Approved by: AJ

Projection: GDA 94/MGA Zone 50 EPSG:28350

0.1 0 0.1 0.2 km

Legend

- Waste Rock Landform Footprint
- Pit Footprint
- Indicative Abandonment Bund
- Print Output (PO) Lines
- Model Domain
- Catchments

Water Velocity (m/s)

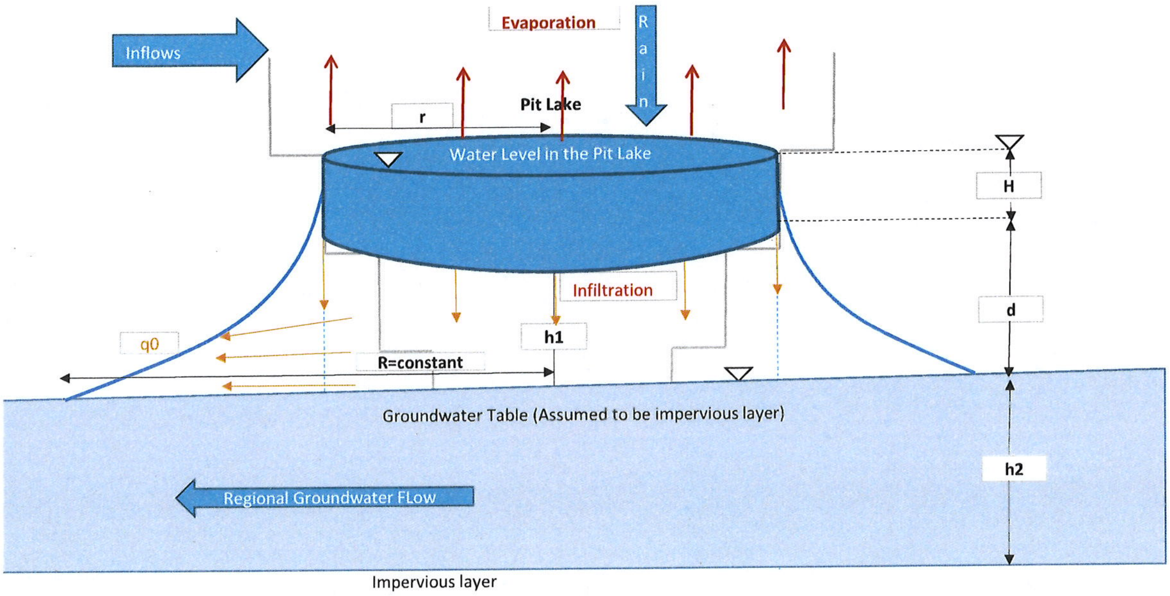
- <= 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00

Terrain (m AHD)

1,062.57

679

Figure 9 Conceptual Water Balance Model



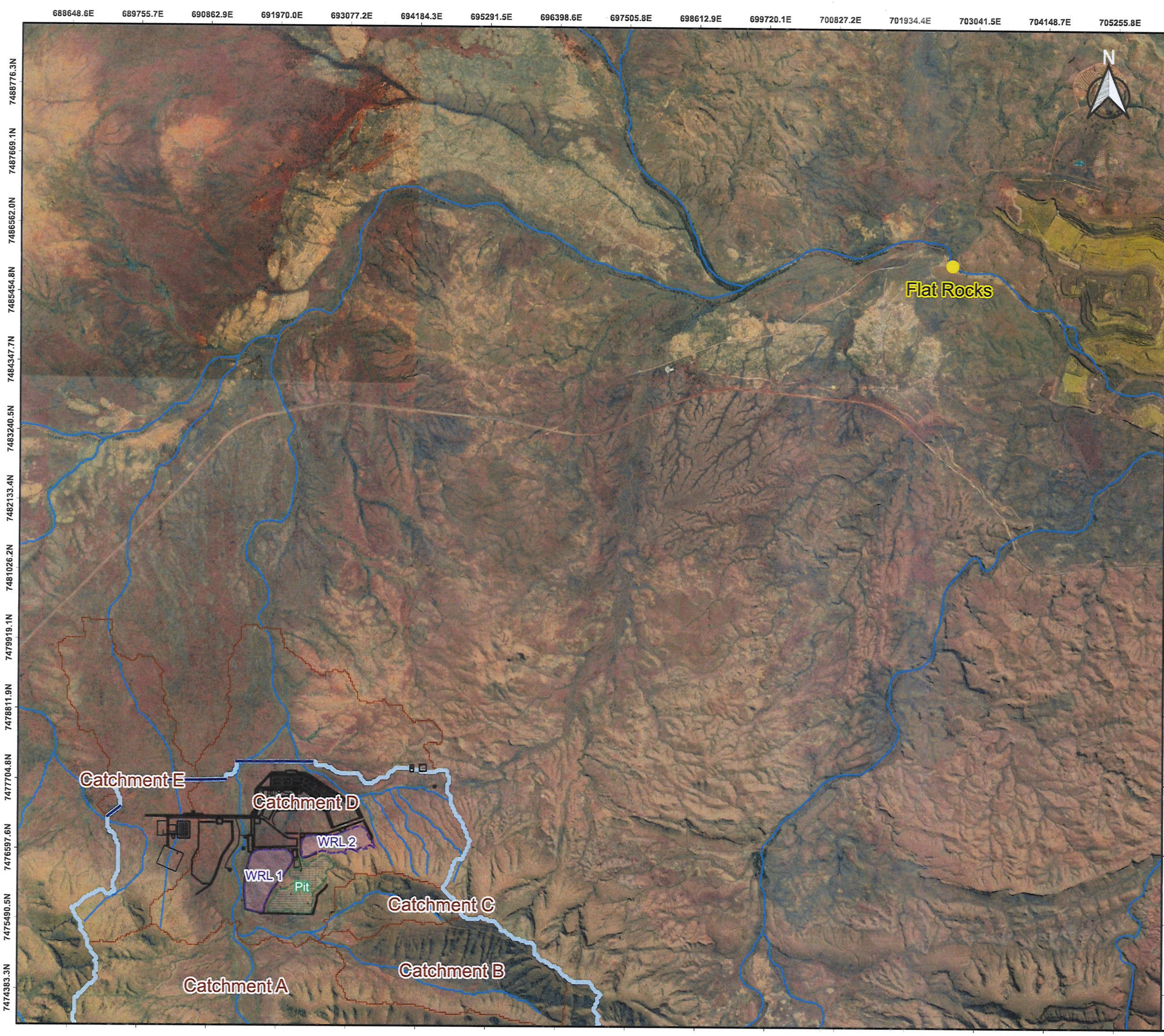


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Figure 10
Stream Gauge Location

Lamb Creek Mine Closure Plan
Surface Water Assessment
Technical Memorandum

Date:27/11/2024

Prepared by: SL

Approved by: AJ

Projection: GDA 94/MGA Zone 50 EPSG:28350

1 0 1 2 km

Legend

- Waste Rock Landform Footprint
- Pit Footprint
- Site Layout
- DWER Stream Gauge 708001 (Flat Rocks)
- Model Outflow Boundary
- Model Domain
- Catchments
- Streams

Figure 11 Gauged Streamflow at Flat Rocks

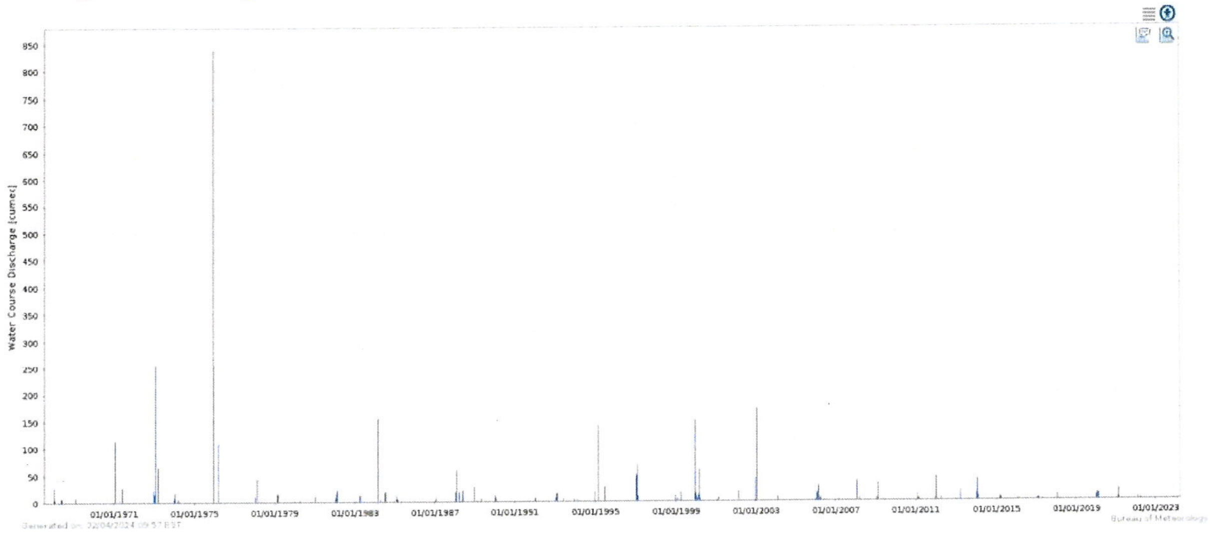

Figure 12 Flood Frequency of Gauged Streamflow at Flat Rocks

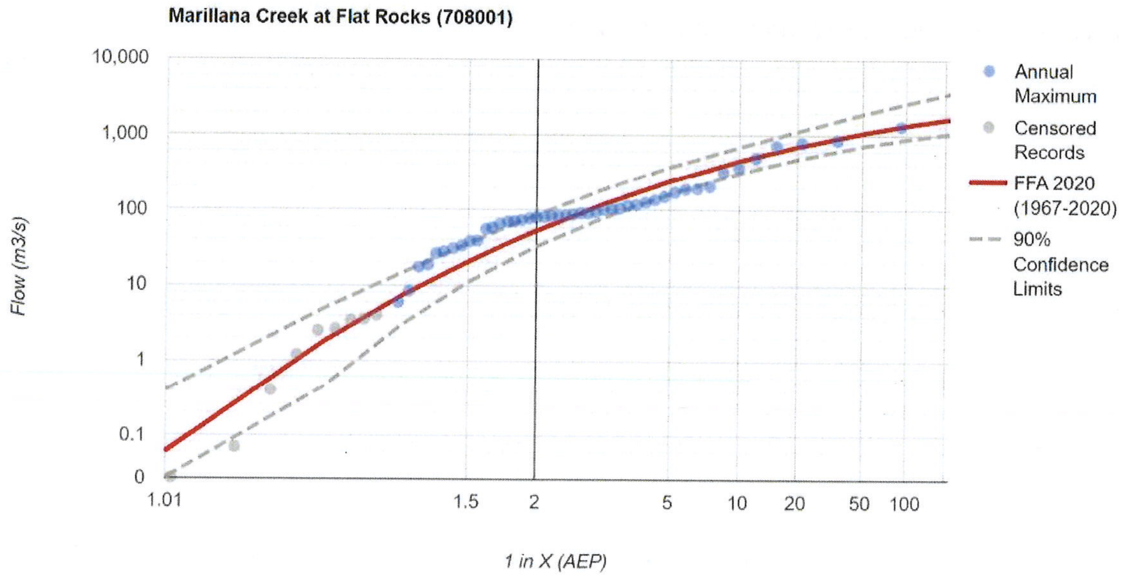

Figure 13 Rainfall and Pan Evaporation Time Series

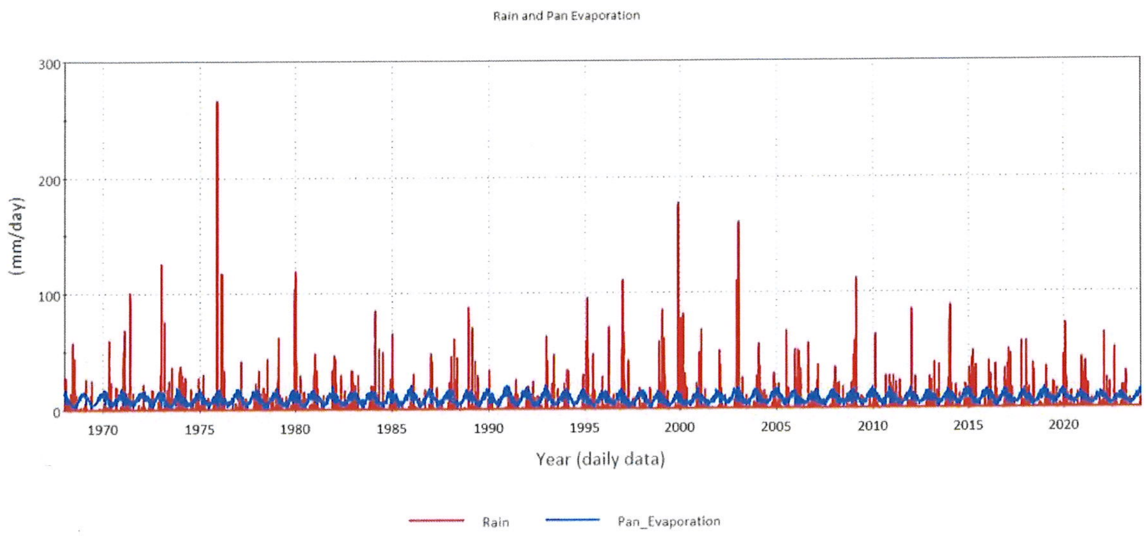

Figure 14 Scaled Pit Inflows with the Abandonment Bund in Place for Flow Diversion

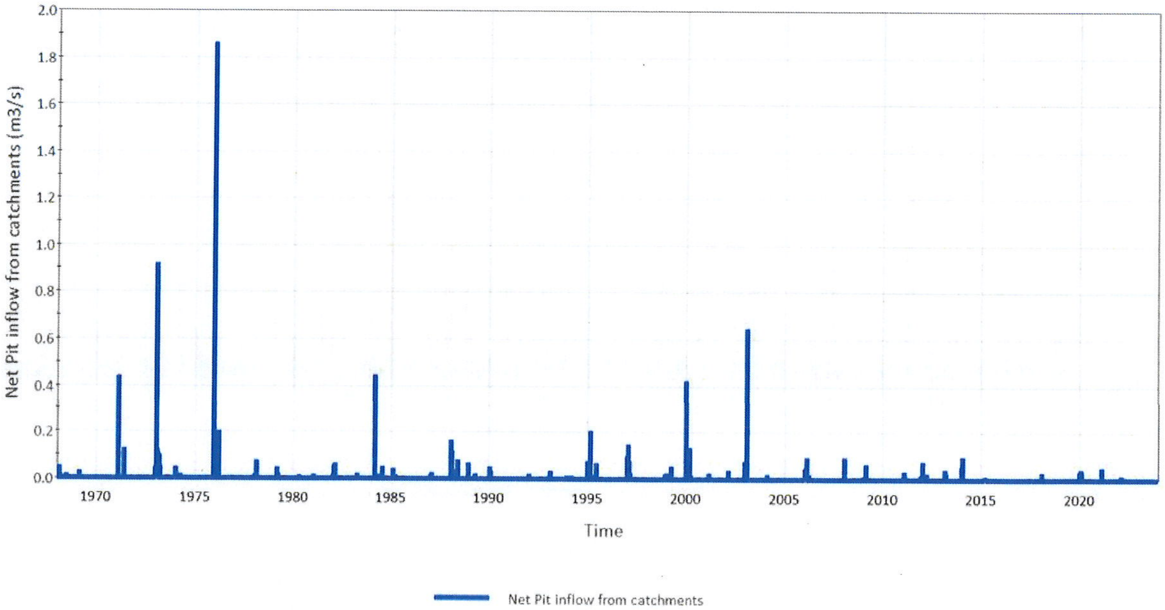

Figure 15 Simulated Pit Water Volume and Depth for the Backfilled Pit Floor 5m above Groundwater Table with an Abandonment Bund

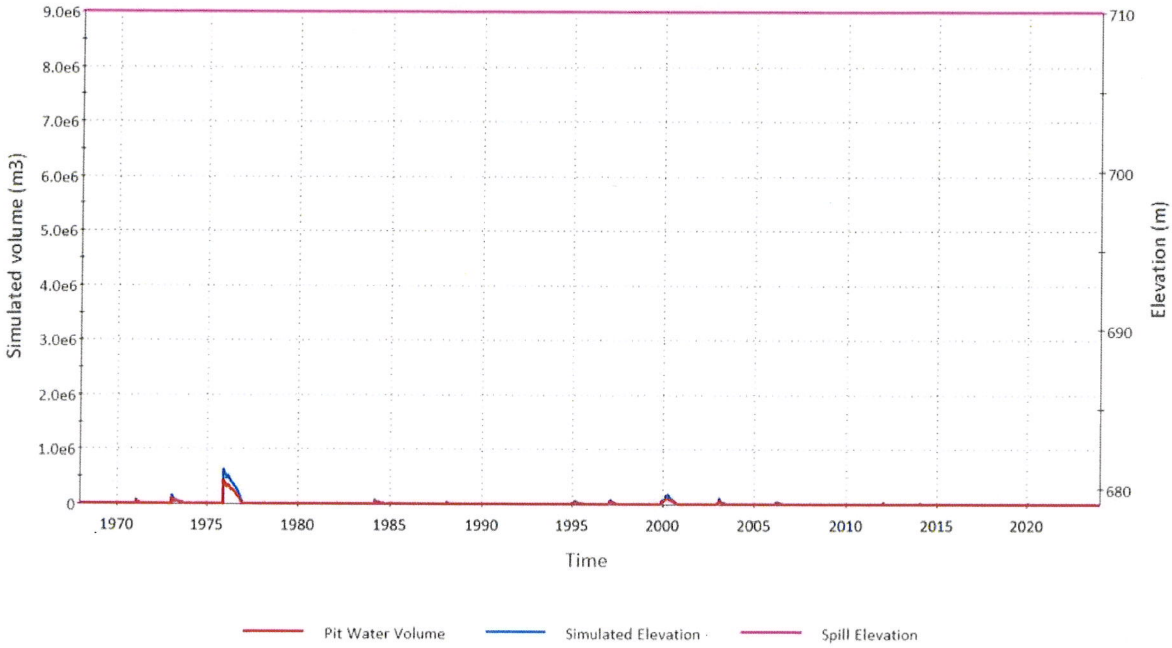

Figure 16 Simulated Pit Water Seepage and Evaporation for the Backfilled Pit Floor 5m above Groundwater Table with an Abandonment Bund