HYDRO ENGINEERING
& CONSULTING PTY LTD

REPORT

Cadia Valley Operations
Modification 13 - Cadia Hill Tailings Completion Modification
Surface Water Assessment for Statement of Environmental Effects

Prepared for: Newcrest Mining Limited

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Revision	Description	Author	Reviewer	Approved	Date
a	Draft	TSM	CW	TSM	11-Dec-2018
b	Draft	TSM	CW	TSM	3-Jan-2019
d	Text added; final void section revised	TSM	Resource Strategies	TSM	20-Mar-2019
e	Revised	TSM	Resource Strategies	TSM	30-Mar-2019
f	Revised	TSM	Resource Strategies	TSM	3-Apr-2019
g	Revised	TSM	Client	TSM	3-May-2019
h	Revised Figure 1	TSM	Resource Strategies	TSM	8-May-2019
i	Revised Section 1.2 and Figure 1	TSM	Resource Strategies	TSM	31-Jul-2019

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 BACKGROUND

Cadia Holdings Pty Limited (CHPL) is the owner and operator of the Cadia Valley Operations (CVO), and is a wholly owned subsidiary of Newcrest Mining Limited. The CVO is located approximately 25 kilometres (km) south-west of Orange, in the Central Tablelands of New South Wales (NSW). Following cessation of open cut mining operations and underground mining of the Ridgeway deposit, the Cadia East underground mine is the sole ore source for CVO and consists of a large-scale mining operation using panel cave mining methods. The site process plant produces gold doré and gold-rich copper concentrates. Doré is transported directly from site, while concentrates are piped to a dewatering facility at nearby Blayney for transport to an overseas shipping port by rail. CHPL has consent to process up to 32 million tonnes per annum (Mtpa).

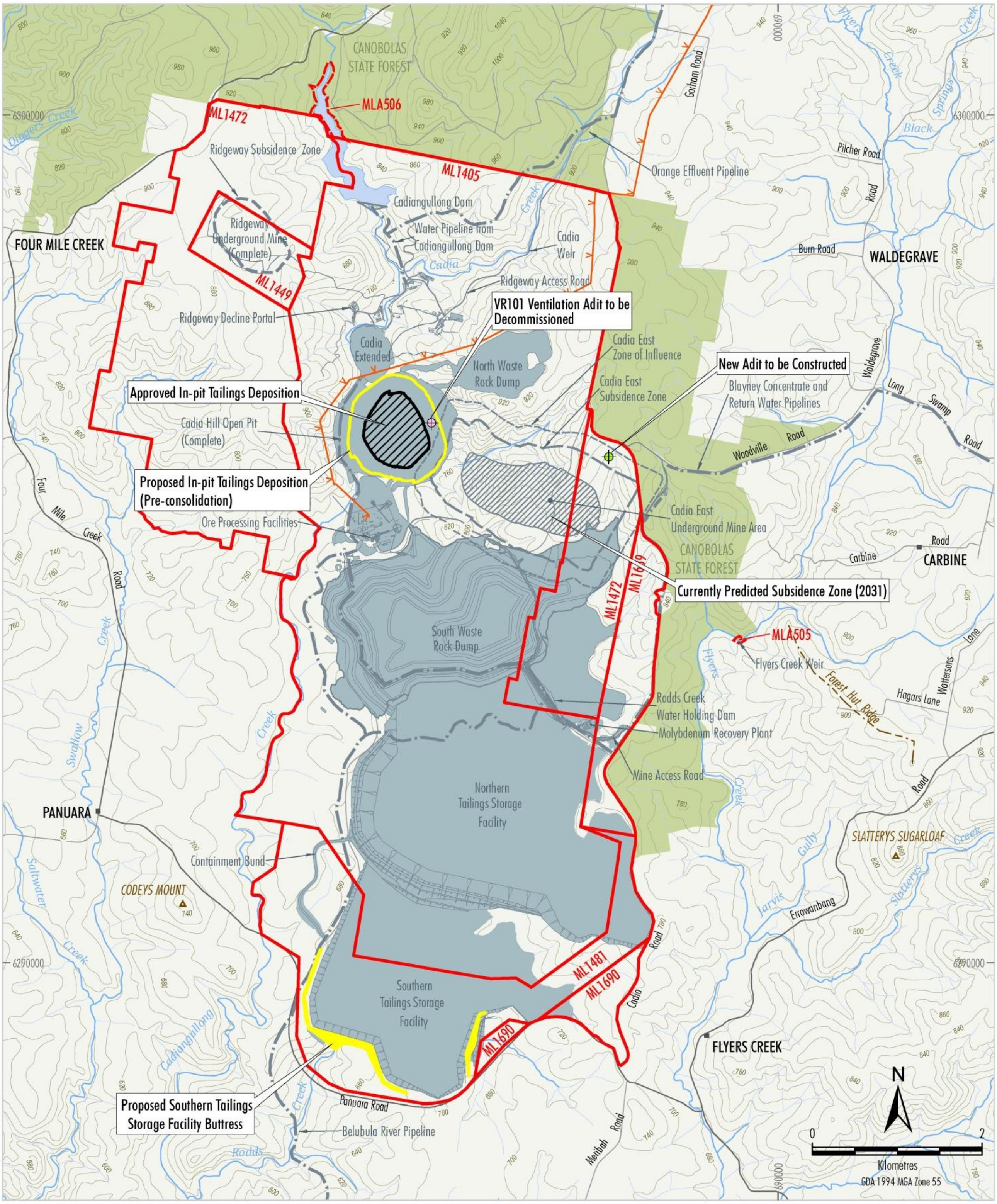
1.2 TAILINGS DISPOSAL

Process tailings are thickened prior to disposal. Tailings are then pumped for disposal to three tailings storage facilities – the northern tailings storage facility (NTSF), the southern tailings storage facility (STSF) and the Cadia Hill Pit tailings storage facility (CHPTSF). The former two are conventional valley-fill storages with confining embankments located towards the south of the CVO area (Figure 1). In March 2018, tailings disposal to the NTSF was suspended following a limited breakthrough of tailings material at the storage embankment. CHPL has undertaken an investigation of the factors that led to the limited breakthrough of tailings material at the embankment of the NTSF and is continuing to explore engineering solutions to repair the embankment. In the interim, CHPL identified the opportunity to deposit tailings within the completed Cadia Hill Open Pit. In May 2018, following approval of Modification 11 to PA 06_0295, tailings discharge to the CHPTSF commenced. In-pit deposition of tailings is currently approved up to a final (consolidated) elevation of 560 metres (m) Australian Height Datum (AHD) – per Modification 12 to PA 06_0295.

CHPL has identified the opportunity to deposit additional tailings within the CHPTSF. On this basis, CHPL proposes a further modification to PA 06_0295 under Section 4.55 of the NSW Environmental Planning and Assessment Act, 1979 (EP&A Act) to increase the tailings level to its full capacity, at a pre-consolidation level of approximately 713 m AHD.

The main activities associated with the Cadia Hill Tailings Completion Modification include:

- increasing the tailings level from 560 m AHD (consolidated tailings level) to 713 m AHD (pre-consolidation tailings level) adding an additional 177 million tonnes (Mt) of capacity, equivalent to approximately seven years of additional deposition to this storage facility;
- decommissioning and closure of the existing ventilation adit VR101, located in the Cadia Hill Open Pit, which would be inundated by tailings;
- installation of a new ventilation adit within the currently approved disturbance footprint of Cadia East (outside of the Cadia Hill Open Pit)
- construction of additional buttressing for the STSF embankment; and
- a pit lake (i.e. a "wet cover") as the final landform of the Cadia Hill Open Pit, consistent with the approved final landform.



LEGEND

- 🟥 Mining Lease Boundary
- ⬚ Mining Lease Application Boundary
- 🟩 State Forest
- Powerline
- ⬛ Existing/Approved Mine Infrastructure and Landforms
- 🟨 Modification Component

Source: Land and Property Information (2017); NSW Planning & Environment Resource & Energy (2017) CHPL (2018)

NEWCREST MINING LIMITED
CADIA VALLEY OPERATIONS

Figure 1 Site Layout

1.3 SCOPE

Hydro Engineering & Consulting Pty Ltd (HEC) has been engaged by CHPL to prepare a surface water assessment (SWA) as part of a Statement of Environmental Effects (SEE) for a Modification to the current approval. The scope of the SWA comprises:

1. water balance modelling of the CVO water management system, with the continuation of in-pit tailings disposal to the CHPTSF and the eventual recommencement of tailings disposal to the NTSF, primarily to assess site processing water supply reliability;
2. water balance modelling of the final void post-filling; and
3. modelling of flow in Cadiangullong Creek to assess the flooding risk to the Cadia Hill Open Pit.

This report addresses each of the above in turn.

2.0 WATER MANAGEMENT SYSTEM

The water management system at CVO involves a number of interlinked on-site storages, their catchments, the process plant, water pumping systems and a number of off-site supply sources. A simplified schematic of the modelled water management system is provided in Figure 2.

The following list details the five main on-site storages (refer Figure 3 for locations):

- Cadiangullong Creek Dam: a 4,200 megalitre (ML) capacity water storage located on Cadiangullong Creek upstream of the site. Runoff to this storage is augmented by gravity transfer via a pipeline from a small weir on nearby Cadia Creek. Controlled release occurs from Cadiangullong Creek Dam to sustain minimum flow requirements in the creek at the southern mining lease boundary.
- Upper Rodds Creek Dam: a 14,500 ML capacity water storage located in the upper reaches of Rodds Creek upstream of the tailings storage facilities.
- The NTSF and STSF: Although designed to store process tailings, these command significant catchment areas and, therefore, can accumulate a significant volume of rainfall runoff plus water liberated from settling tailings. The capacities of the NTSF and STSF to store water vary with tailings volumes discharged and the embankment raising schedule, with water stored within the depression formed by the sloping tailings beach (sloping away from the confining embankment from which tailings are discharged).
- The CHPTSF: the former open cut has an estimated capacity (when empty) of 193,600 ML to a spill level of 721 m AHD.

Catchment rainfall runoff reports to the above storages and forms a key component of site water supply. A number of additional smaller storages capture site runoff and provide transfer pumping to either one of the above storages or to the Process Water Pond – a 62 ML capacity geosynthetically lined storage which directly supplies the process plant.

The system comprises a number of make-up water supply sources, as follows:

- Orange treated effluent supplied at up to 13 megalitres per day (ML/day);
- licensed extraction from the Belubula River at up to 30 ML/day - Newcrest hold a 4,080 ML/annum Belubula River general security Water Access Licence (WAL - 32280) and a 3,125 ML/annum supplementary WAL (32255);
- pumped extraction from a small weir on Flyers Creek to the east of CVO at a rate of up to 10.9 ML/day (extraction is limited in order to sustain minimum flow requirements downstream of the weir);
- water returned from the Blayney concentrate dewatering facility plus Blayney township treated effluent – the dewatering facility reclaim rate varies with production rate and the treated effluent rate is estimated at 0.54 ML/day;
- groundwater bores supplying up to 1 ML/day; and
- groundwater inflow to the CHPTSF, the former Ridgeway underground mine and the Cadia East underground mine.

The main site supply requirement is for make-up water to the process plant to replace water pumped out with thickened process tailings and product concentrate (thickener underflow). At a processing rate of 32 Mtpa, this equates to approximately 60.6 ML/day. A demand of 5.1 ML/day is the estimated requirement for the Cadia East underground mine. A much smaller rate of 0.5 ML/day is the estimated requirement for road dust suppression.

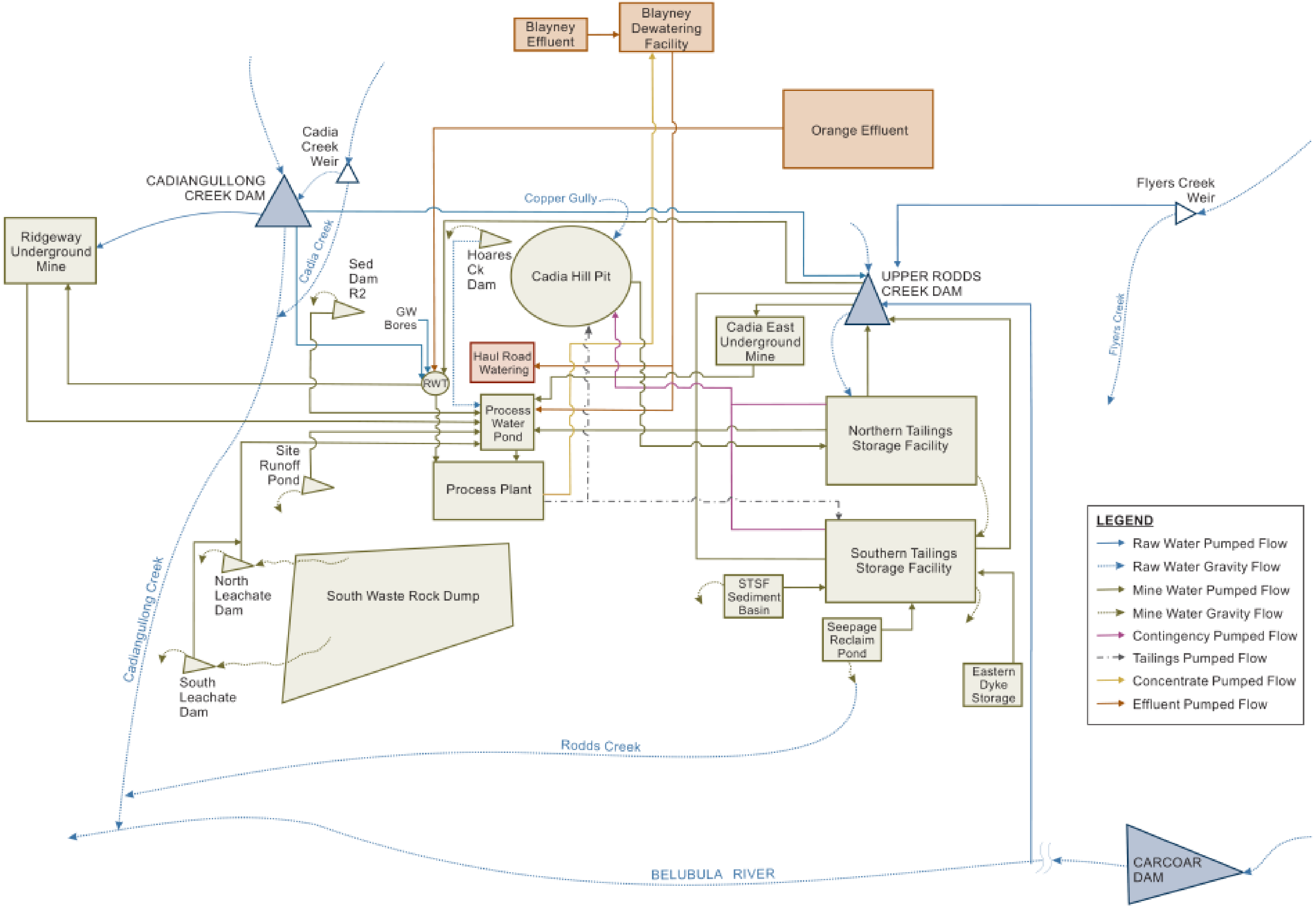


Figure 2 CVO Water Management System Schematic

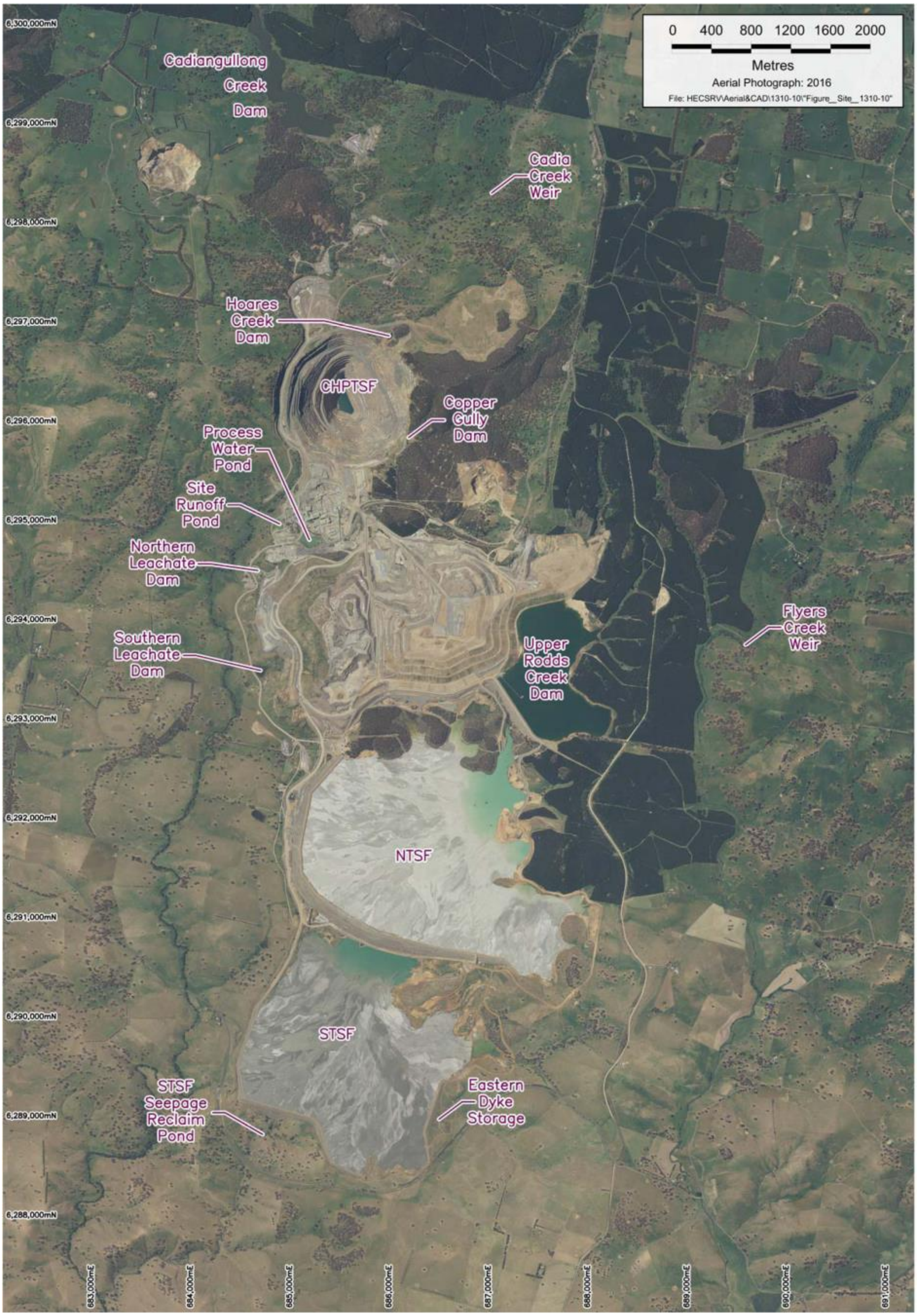


Figure 3 Key Water Storage Locations

Water supplied to the Cadia East underground mine plus underground groundwater inflow (less underground losses) is subsequently recovered to the Process Water Pond.

Water recovery from the CHPTSF is currently directed to the NTSF, with water from the NTSF returned to the Process Water Pond and Upper Rodds Creek Dam. Ultimately, direct reclaim from the CHPTSF to the Process Water Pond is planned.

The southern end of the Cadia Hill Open Pit intersects Copper Gully – a small former tributary of Cadiangullong Creek. A small earthfill dam was constructed across Copper Gully during open cut mining operations to limit runoff into the operational areas, by pumping accumulated water to other storages. Since the completion of open cut mining, water entering Copper Gully has been allowed to flow via a pipeline through the dam embankment into the Cadia Hill Open Pit and this is planned to continue.

The northern end of the Cadia Hill Open Pit intersects another small former tributary of Cadiangullong Creek known as Hoares Creek. A small dam embankment has also been constructed across this creek with an underflow pipeline discharging accumulated water to the Process Water Pond. Extraction from Cadiangullong Creek, Cadia Creek, Copper Gully, Rodds Creek and Flyers Creek is licensed under the *Water Management Act 2000* (WAL 31527).

3.0 WATER BALANCE MODEL DESCRIPTION

The operational water balance model has been developed to simulate the storages and linkages shown in schematic form in Figure 2.

The model simulates the volume of water held in and pumped between all simulated water storages. For each storage, the model simulates:

Change in Storage = Inflow – Outflow

Where:

> *Inflow* includes rainfall runoff, groundwater inflow (for the Cadia East and Ridgeway[1] undergrounds and CHPTSF), tailings supernatant (for the NTSF, STSF and CHPTSF), pumped inflows from other storages and/or water sourced from off-site make-up supply sources (Section 2.0).
>
> *Outflow* includes evaporation, spill, seepage, water entrainment within settled tailings and dewatered concentrate, flow released from Cadiangullong Creek Dam and all pumped inflows to other storages or to a demand (e.g. the process plant).

The water balance model has been set up to forecast the CVO water balance over the period from November 2018 to mid-2031. The model simulates 118 “realizations” derived using the climatic record from 1895 to 2013. The first realization uses climatic data commencing in 1895, the second commences in 1896, the third in 1897 and so on. Data from the start of the record are added to the end of the record to ensure that each year is simulated in the same number of realizations. This method effectively includes all recorded historical climatic events in the water balance model, including high, low and median rainfall periods. The results from all realizations are used to generate water storage volumes and water balance statistics on the performance of the water management system.

The water balance model was linked to output from the Belubula River Integrated Quantity and Quality Model (IQQM). The IQQM is the model that has been used by the NSW Department of Industry - Water (DI - Water) to set available water determinations (AWDs) in the Belubula Valley, in accordance with the *Water Sharing Plan for the Belubula River Regulated Water Source* (the WSP). The IQQM was run using climatic data from 1895 to 2013 to generate predictions of General Security WAL available water determinations, as well as releases from Carcoar Dam and flows at the end of system (Helensholme) for simulation of available water for extraction against supplementary WALs.

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[1] The Ridgeway Underground Mine is under care and maintenance – it has been assumed that dewatering of groundwater inflow would continue into the future.

4.0 OPERATIONAL WATER BALANCE MODEL ASSUMPTIONS AND DATA

A summary of key model assumptions and supplied data are provided in the sub-sections below.

4.1 RAINFALL AND EVAPORATION DATA

Daily climatic data used in model forecast simulations, as outlined in Section 3.0, was sourced from the SILO Data Drill. The Data Drill is a system which provides synthetic data sets for a specified point by interpolation between surrounding point records held by the Bureau of Meteorology[2]. Both rainfall and pan evaporation data were obtained from this source. Different rainfall data sets were obtained for different storage catchments – e.g. the mine site itself, Cadiangullong Creek Dam and Flyers Creek Weir.

4.2 RAINFALL RUNOFF SIMULATION

AWBM simulation of flow from six different sub-catchment types was undertaken, namely: undisturbed (natural) areas, hardstand (for example, roads and infrastructure areas), open cut pit, waste rock, rehabilitated waste rock and tailings. Each mine site storage catchment area was divided into these sub-catchment areas, which were estimated from available aerial photography and mine contour plans. For the undisturbed sub-catchment type, model parameters were derived from AWBM calibration to a recorded flow at streamflow gauging stations maintained by CHPL. AWBM parameters for other sub-catchment types were initially taken from literature-based guideline values or experience with similar projects and then adjusted as part of model calibration.

4.3 CATCHMENT AREAS

Surface and sub-surface catchment areas were used to calculate the surface runoff reporting to site storages. It was assumed that there would be no change to these in the future, with the exception of:

- the NTSF and STSF where the tailings area would grow with time, with tailings discharge to the NTSF to recommence at the start of 2022 and tailings discharge to the STSF to be completed in 2030; and
- the CHPTSF where the tailings area would also increase with time and the catchment area reporting to Copper Gully would reduce with time as the Cadia East mine subsidence area increases.

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[2] Refer https://legacy.longpaddock.qld.gov.au/silo/

4.4 EVAPORATION FROM STORED WATER AREAS

Storage volumes calculated by the model are used to calculate stored water area based on storage level-volume-area relationships (storage characteristics) for each storage, that were either supplied by CHPL or derived from available topographic information. For the NTSF and STSF tailings surfaces, these were obtained from surveys commissioned by CHPL (with the most recent in March 2018) combined with projected tailings beach profiles at the end of processing supplied by ATC Williams[3] – refer also Section 4.5. For dates between March 2018 and the end date of processing, water surface areas were interpolated between the two dates based on modelled water volume.

For modelling purposes, the CHPTSF tailings surface was assumed to be flat. Any ponded water would therefore be modelled as occupying the entire tailings surface area plus a marginal area above this around the pit perimeter. In the longer term, it is anticipated that the tailings surface will slope (similar to the STSF and NTSF tailings surfaces) from the eastern (deposition) side to the west, however the slope is presently unknown. The tailings surface area was calculated from storage characteristics for the empty open cut (developed from supplied topographic information), the cumulative mass of accumulated tailings and an assumed in-pit tailings density[4] of 1.2 t/m^3. These assumptions are likely to somewhat over-estimate evaporation and therefore, are conservative in terms of predicting water supply reliability.

Daily pan evaporation was multiplied by a pan factor in the calculation of storage evaporation losses for water storages. Monthly pan factors were taken from McMahon et al. (2013) data for a nearby location and varied from 0.77 to 0.88.

A pan factor of 0.7 was assumed for estimation of evaporation from the CHPTSF when the water surface was more than 40 m below spill level (to allow for shading effects and lower wind speed at depth). A pan factor of 1.2 was used in the estimation of evaporation from wet tailings surfaces within the NTSF and STSF (due to the darker and more exposed tailings surface).

4.5 PROCESSING AND TAILINGS RATES

Annual planned processing and tailings rates have been advised by CHPL and are summarised in Table 1.

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[3] Email G.New 29 November 2017.

[4] Per Golder Associates Memorandum 17 October 2018 (Document No. 086-1657358 Rev 1).

Table 1 Modelled Annual Production

Year	Million Tonnes per Annum					
	Total Plant Feed	Concentrate	Total Tailings	To NTSF	To STSF	To CHPTSF
2018	29.67	0.37	29.3	0	8	21.3
2019	29.67	0.37	29.3	0	8	21.3
2020	29.67	0.37	29.3	0	8	21.3
2021	30.68	0.38	30.3	0	8	22.3
2022	32	0.40	31.6	8	8	15.6
2023	32	0.40	31.6	9.2	8	14.4
2024	32	0.40	31.6	9.3	8	14.3
2025	32	0.40	31.6	9.3	8	14.3
2026	32	0.40	31.6	9.3	8	14.3
2027	32	0.40	31.6	9.3	8	14.3
2028	32	0.40	31.6	9.3	8	14.3
2029	32	0.40	31.6	9.3	8	14.3
2030	32	0.40	31.6	10.3	7	14.3
2031	15.85	0.20	15.65	9.65	0	6

4.6 PROCESS PLANT DEMAND

The process plant demand is calculated as the sum of the water pumped out with tailings and product concentrate. Relevant concentrate and tailings properties (current and planned) that affect process plant water demand are summarised as follows (based on information supplied by CHPL):

- ore moisture: 2% (w/w);
- concentrate solids concentration: 65%;
- tailings (thickener underflow) solids concentration for NTSF and STSF: 57%; and
- tailings solids concentration for CHPTSF: 60%.

Process plant demand simulated in the model is plotted in Figure 4.

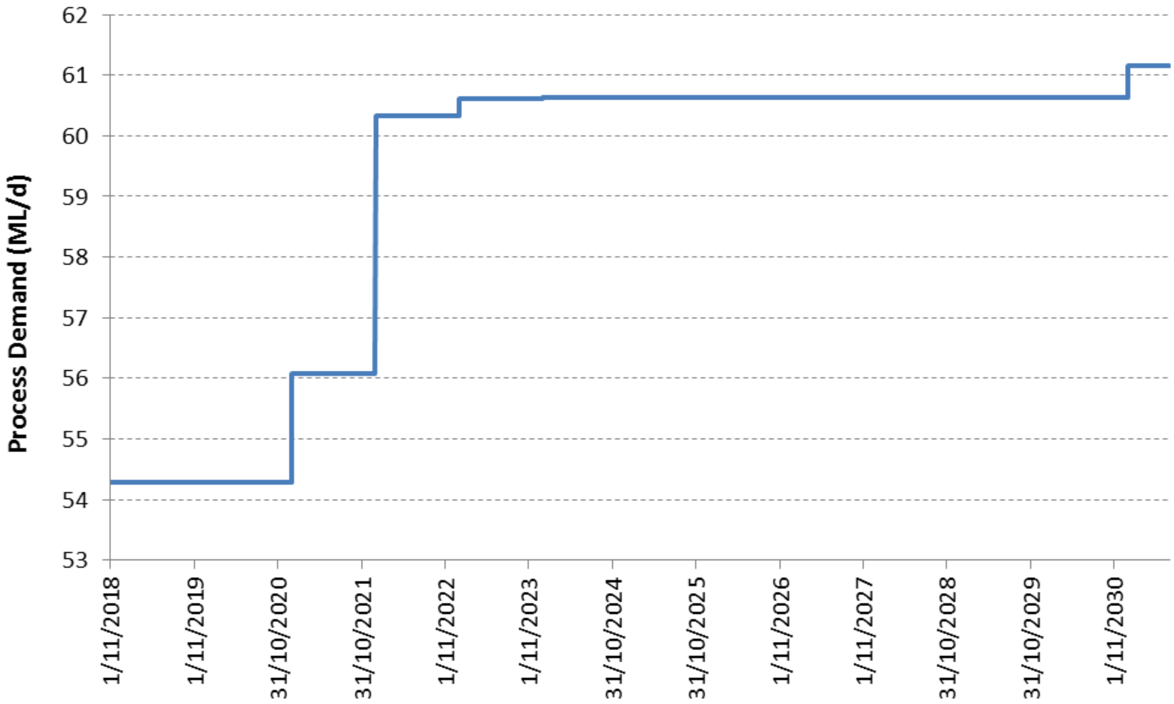

Figure 4 Modelled Process Plant Demand

A portion of the process plant demand needs to be supplied by “raw” water – sourced from Orange treated effluent, groundwater bores, Upper Rodds Creek Dam or Cadiangullong Creek Dam (in that order of priority). This is modelled as 13.9 ML/day (for a 27 Mtpa processing rate as advised by CHPL) and has been assumed to increase in proportion to the processing rate.

4.7 TAILINGS STORAGE OPERATION

The STSF will operate concurrently with tailings discharge to the CHPTSF, with discharge to the STSF to cease in 2030 (refer Section 4.3). CHPL has advised that tailings deposition to the NTSF is planned to recommence in 2022 pending required external environmental approvals.

The model calculates water liberated as tailings settle (“bleed” water) – which reports to the tailings supernatant pond in tailings storages and is available for reclaim. Conventionally thickened tailings discharged to the NTSF and STSF have been assumed to settle initially in the tailings beach to 1.2 t/m^3 dry density (as advised by tailings specialists) with a tailings particle density[5] of 2.76 t/m^3 - this data is used to calculate the bleed water rate. For the tailings discharged to the CHPTSF, an initial settled density of 1.13 t/m^3 was adopted[6]. Based on column settling test results, a 1.13 t/m^3 initial settled density corresponds to a 5-day settled density for tailings with an initial solids concentration of 57% w/w. From commissioning of the CHPTSF until 1 April 2019, records indicate an average tailings solids concentration of 60% w/w for tailings discharged to the CHPTSF. A higher initial solids concentration will result in a higher settled density – therefore the adoption of a 1.13 t/m^3 initial settled density to calculate the bleed water rate is likely to be an underestimate of both initial settled density and the bleed water rate.

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[5] Per Golder Associates Memorandum 2 February 2018 (Document No. 048-1657358 Rev 1).

[6] Per Golder Associates Memoranda 29 March 2018 (Document No. 061-1657358 Rev 0) and 17 October 2018 (Document No. 086-1657358 Rev 1).

In the NTSF and STSF bleed water is subject to evaporation from the "active" tailings beach area. Supernatant water that ponds within each storage is also subject to evaporation.

Seepage has been simulated from the NTSF to the STSF and from the STSF to a small seepage reclaim pond located downstream of the STSF (Figure 3). Reclaim from the STSF seepage reclaim pond to the STSF occurs at a rate of up to 2.78 ML/day (the seepage reclaim pond has a small surface catchment area, which also contributes to inflow). Pumping into the STSF also occurs periodically from runoff that accumulates against an STSF confining embankment on the south-eastern side of the storage (known as the Eastern Dyke storage – see Figure 3).

4.8 OTHER DEMANDS

Other system demands comprise water for road dust suppression and supply to the Cadia East underground mine. These have been assumed at rates of 0.5 ML/day and 4.9 ML/day respectively as advised by CHPL. The underground demand has been assumed to change in proportion to increases in the future processing rate (relative to a 27 Mtpa rate). No haul road water was assumed to be required on days with more than 10 mm rainfall.

4.9 GROUNDWATER INFLOWS AND UNDERGROUND DEWATERING

A time-varying groundwater inflow rate for the Cadia East underground mine was simulated from information supplied by CHPL (Figure 5).

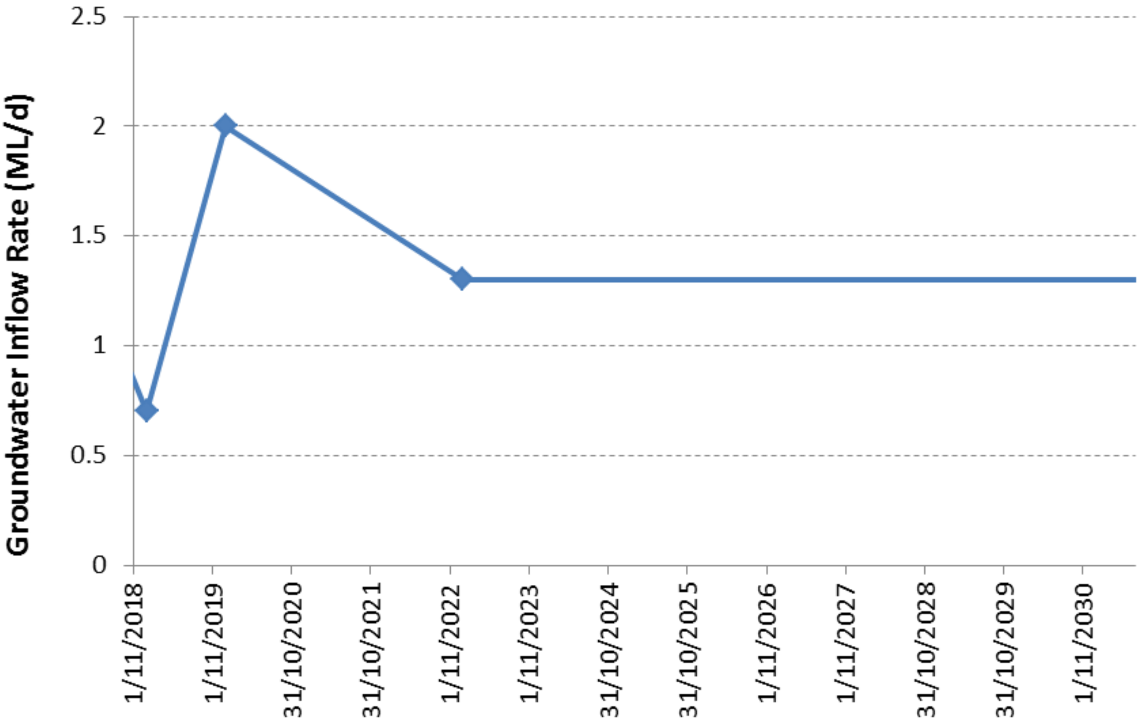

Figure 5 Modelled Cadia East Groundwater Inflow

Losses from the Cadia East underground comprise a ventilation loss of 1.86 ML/d (based on records supplied by CHPL), which is assumed to increase in proportion to increases in processing rate, plus loss in wetting up mined ore to 2% moisture from an in-situ moisture of 1.8%. The underground balance was calculated as the inflows from groundwater and water supplied (Section 4.8) less ventilation loss and loss to ore moisture increase. The remaining water calculated from this balance was assumed available for pumping to the Process Water Pond.

The Ridgeway underground mine is now under care and maintenance and it has been assumed to remain so for the duration of the forecast simulations undertaken herein. It is assumed that dewatering of groundwater inflows to the Process Water Pond will continue during this period. An inflow rate of 1.08 ML/d was estimated based on recorded mine inflow data supplied by Newcrest.

An initial groundwater inflow rate to the Cadia Hill Open Pit of 0.69 ML/day was assumed as advised by CHPL. This rate was assumed to reduce in proportion to the water and tailings level in the open cut, with zero groundwater inflow at a pond level equal to the spill level (721 m AHD).

4.10 BELUBULA RIVER SUPPLY

Licensed extraction from the Belubula River was assumed to continue into the future, with no change to the WAL volumes held by CHPL (Section 2.0). Simulated extraction occurs in response to site storage trigger levels (Section 4.16). As advised by CHPL, no access to uncontrolled flow events was assumed to occur in the future (this is considered to be a conservative assumption).

4.11 EFFLUENT SUPPLY AND BLAYNEY DEWATERING FACILITY RETURN

Supply of treated effluent from the Orange wastewater treatment plant (WWTP) was assumed to continue unchanged into the future at a rate of up to 13 ML/day. Recorded effluent flows from the Orange WWTP were used to develop monthly correlations between flow and rainfall, with flow increasing in higher rainfall months. Orange treated effluent was assumed used to firstly satisfy “raw” water demand (Section 4.6) and then any process plant requirement as a priority over other water sources. No storage of effluent occurs at either the Orange WWTP or on site. Once the volume stored in the Upper Rodds Creek Dam rises above a certain trigger level (refer Section 4.16), sourcing of treated effluent was assumed to be suspended.

A constant rate of 0.54 ML/day of treated effluent was assumed available from the Blayney WWTP (average of recorded data supplied by Newcrest). This was added to the volume of water returned from the Blayney Concentrate Dewatering Facility (CDF), where the concentrate slurry pumped from the site is dewatered to produce a filter cake, which is loaded onto trains. Dewatering was simulated at all processing rates at a rate of 555 L/tonne of concentrate (based on records supplied by CHPL) and therefore this volume increases with higher processing rates. The combined Blayney treated effluent and CDF return was assumed to be used to firstly satisfy road dust suppression requirements (Section 4.8), with excess transferred to the Process Water Pond.

4.12 BOREFIELD SUPPLY

Based on information supplied by CHPL, supply from site groundwater bores has not been included in future forecasts.

4.13 SUPPLY FROM CADIANGULLONG CREEK DAM, CADIA CREEK AND FLYERS CREEK WEIRS

Extraction from Cadiangullong Creek Dam occurs to supply “raw” water demand (last priority, after supply from Upper Rodds Creek Dam) as well as to transfer to Upper Rodds Creek Dam via the ‘backbone’ pipeline. Transfer to Upper Rodds Creek Dam is subject to operating volume triggers (Section 4.16).

Release from Cadiangullong Creek Dam occurs, whenever there is sufficient stored water, in order to maintain a minimum flow rate in downstream Cadiangullong Creek at the southern lease boundary (Oaky Creek gauging station). A release protocol has been incorporated into the model as follows:

- When inflows to the dam (measured at a gauging station upstream) are less than 0.4 ML/day, water is released from the dam to maintain a flow rate of at least 0.4 ML/day at the Oaky Creek gauging station.
- When inflows to the dam are between 0.4 ML/day and 3.4 ML/day, water is released from the dam to maintain an equivalent flow rate at the Oaky Creek gauging station.
- When inflows are greater than 3.4 ML/day, water is released from the dam to maintain a flow rate of at least 3.4 ML/day at the Oaky Creek gauging station.

Losses occur between the dam release point and the Oaky Creek gauging station and allowance for these losses has been made in the model.

Inflow to Cadiangullong Creek Dam is supplemented by piped (gravity) flow from a small overtopping weir on nearby Cadia Creek at a maximum rate of 7.92 ML/day.

Extraction from a small overtopping weir on Flyers Creek occurs to Upper Rodds Creek Dam. Extraction is only simulated when creek flow exceeds 3.6 ML/day (as advised by CHPL) at a rate of up to 10.92 ML/day, with extraction managed to allow at least 3.6 ML/day to pass the weir[7]. “Medium” creek flow rates are defined as less than 14.52 ML/day or less than the sum of the minimum flow at the weir (3.6 ML/day) and the maximum flow extraction (10.92 ML/day). At “medium” creek flow rates an additional 10% of the inflow rate is allowed to pass the weir extraction point (as a “safety” margin). Extraction ceases if the stored water volume in Upper Rodds Creek Dam exceeds a given trigger volume (Section 4.16).

The extraction or harvesting of water from the local creeks at CVO is approved under a licensed maximum annual volumetric allocation scheme. This requires that extraction of water from the above storages ceases should extraction from those storages plus inflow to Upper Rodds Creek Dam exceed 4,200 ML in any water (financial) year (consistent with WAL 31527). This provision has been included in the model.

4.14 FORECAST PERIOD AND INITIAL STORAGE VOLUMES

Model simulations occur from 1 November 2018 to the end of June 2031 (just over 12½ years). The model’s starting stored water volumes for the five main storages (as advised by CHPL) were as follows:

- Cadiangullong Creek Dam: 665 ML;
- Upper Rodds Creek Dam: 2,804 ML;

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[7] This condition allows for extraction when creek flow exceeds 3.5 ML/day in accordance with Condition 29, Schedule 3 of the Project Approval.

- NTSF: 20 ML;
- STSF: 99 ML;
- CHPTSF: 4,376 ML.

An initial volume of 592 ML was available in Belubula River WAL sub-account A and zero in sub-account B[8].

4.15 TRANSFER RATES

Modelled transfer rates between storages are summarised in Table 2 (as advised by CHPL). Pumped transfer rates from the NTSF, STSF and Upper Rodds Creek Dam were assumed to increase in proportion to the ratio of future increases in processing rate relative to 27 Mtpa (upon which the model was originally based)[9], so that the pump rates did not limit supply.

Table 2 Modelled Transfer Rates

From	To	Transfer Rate (ML/day)
Cadiangullong Creek Dam	Upper Rodds Creek Dam	19.6
	Raw Water Supply	20.2
STSF	NTSF or Upper Rodds Creek Dam	19.2
	Process Water Pond	30.24
NTSF	Process Water Pond (w/o transfer to Upper Rodds Creek)	40.8
	Process Water Pond (with concurrent transfer to Upper Rodds Creek)	31.2
	Upper Rodds Creek Dam	34
Upper Rodds Creek Dam	Raw Water Supply	18
	Process Water Pond	33.6
Flyers Creek Weir	Upper Rodds Creek Dam	10.92
Belubula River	Upper Rodds Creek Dam	29
Cadia Creek Weir	Cadiangullong Creek Dam	7.92
Northern Leachate Dam	Process Water Pond	11.2
Southern Leachate Dam	Process Water Pond	7.9
H19	NTSF	4.2
Site Runoff Pond	Process Water Pond	5.6
Cadia Hill Open Pit (CHPTSF)	NTSF*	1/11/2018 – 11/12/2018:13.8 12/12/2018 – 30/6/2019:46.7 1/7/2019 onwards: 70
	Process Water Pond**	When >25% water storage capacity remaining: 12.96; otherwise: 38.88
Hoares Creek Dam	Process Water Pond	Up to 24.6 (head-dependent)
STSF Seepage Reclaim Pond	STSF	2.78
Cobadah Dam	Process Water Pond	7.2
Eastern Dyke Storage	STSF	13.68

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[8] WALs are split into two accounts: Sub-account A is available for use in the current water year, while sub-account B is used to facilitate 'carry-over' between water years (per "*Water Sharing Plan for the Belubula Regulated River Water Source 2012*" Part 9, Division 1, Clause 45).

[9] In accordance with Condition 6, Schedule 2 of the Project Approval, CHPL may process up to 32 Mt in a calendar year.

* Prior to recommissioning of tailings disposal to the NTSF.

** Post-recommissioning of tailings disposal to the NTSF.

Dewatering rates from the CHPTSF were assumed to be increased by a factor of three if the stored water volume in the open cut exceeded 75% of its remaining water storage capacity (in order to limit spill risk towards the end of its operational life).

4.16 STORAGE TRIGGER LEVELS

Supply from off-site sources, as well as certain internal transfers, are dictated by trigger levels for stored water in Upper Rodds Creek Dam. The simulated trigger levels and consequences are summarised in Table 3.

Table 3 Modelled Upper Rodds Creek Dam Trigger Levels

Upper Rodds Creek Dam Water Level		Upper Rodds Creek Dam Stored Volume (ML)	Triggered Response (if modelled level greater than trigger level)
Depth below spillway (m)	RL (m)		
2	5778	12,511	Suspend transfer from Cadiangullong Creek Dam
1.75	5778.25	12,745	Suspend extraction from Flyers Creek Weir
1.5	5778.5	12,978	Suspend extraction from Belubula River
1	5779	13,446	Suspend supply of Orange treated effluent
0.5	5779.5	13,973	Suspend pumping from NTSF

5.0 OPERATIONAL WATER BALANCE MODEL FORECAST RESULTS

Forecast results obtained from the water balance modelling for the period of simulation comprised:

- an overall site water balance showing system inflows and outflows;
- predicted stored water volumes on-site as a whole and within the CHPTSF;
- the reliability of supply for processing; and
- the risk of off-site spills.

These results are provided in the following sub-sections.

5.1 OVERALL WATER BALANCE

Average system inflows and outflows (averaged over all simulated 118 realizations and the full forecast period) are shown in Figure 6. Model results indicate that, on average, rainfall runoff provides the highest system inflow, with supply from Belubula licensed extraction and Orange effluent also providing significant inputs. The majority of outflow comprises water lost to tailings entrainment, while losses from Cadiangullong Creek Dam (spills and release) comprise approximately one quarter of outflows.

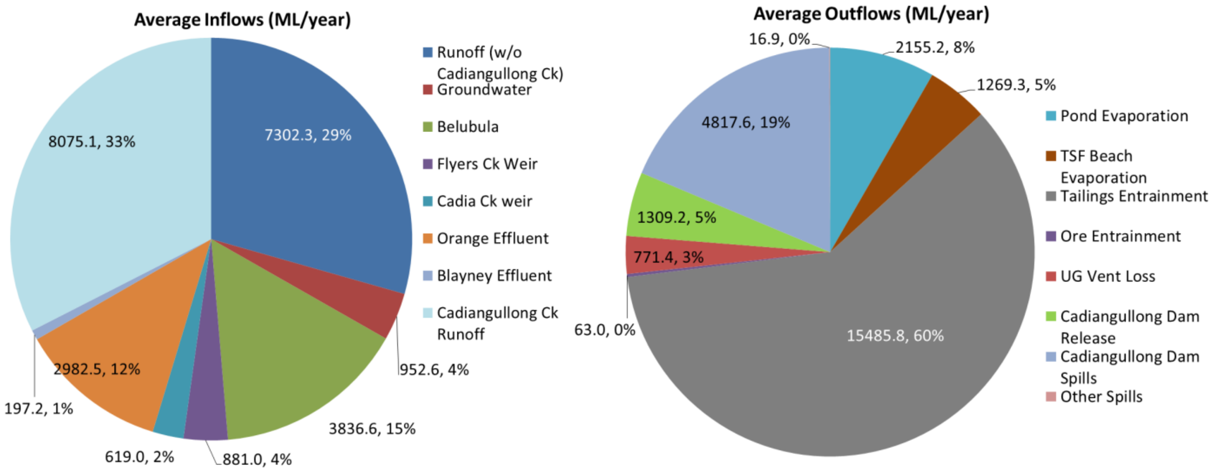

Figure 6 Modelled Average Predicted System Water Balance

5.2 STORED WATER VOLUMES

Predicted total stored water volumes (in all site storages, including TSFs) are shown in Figure 7. These graphs are shown as probability plots over the simulation period, compiled from all 118 climatic realizations. These probability plots show the range of likely total stored water volumes with the solid central plot representing the median volumes or depths and the broken upper and lower lines representing the 10th/90th percentile volumes or depths. It is important to note that none of these plots represents a single climatic realization; these probability plots are compiled from all 118 realizations, e.g. the median volume or depth plot does not represent model forecast volume or depth for median climatic conditions.

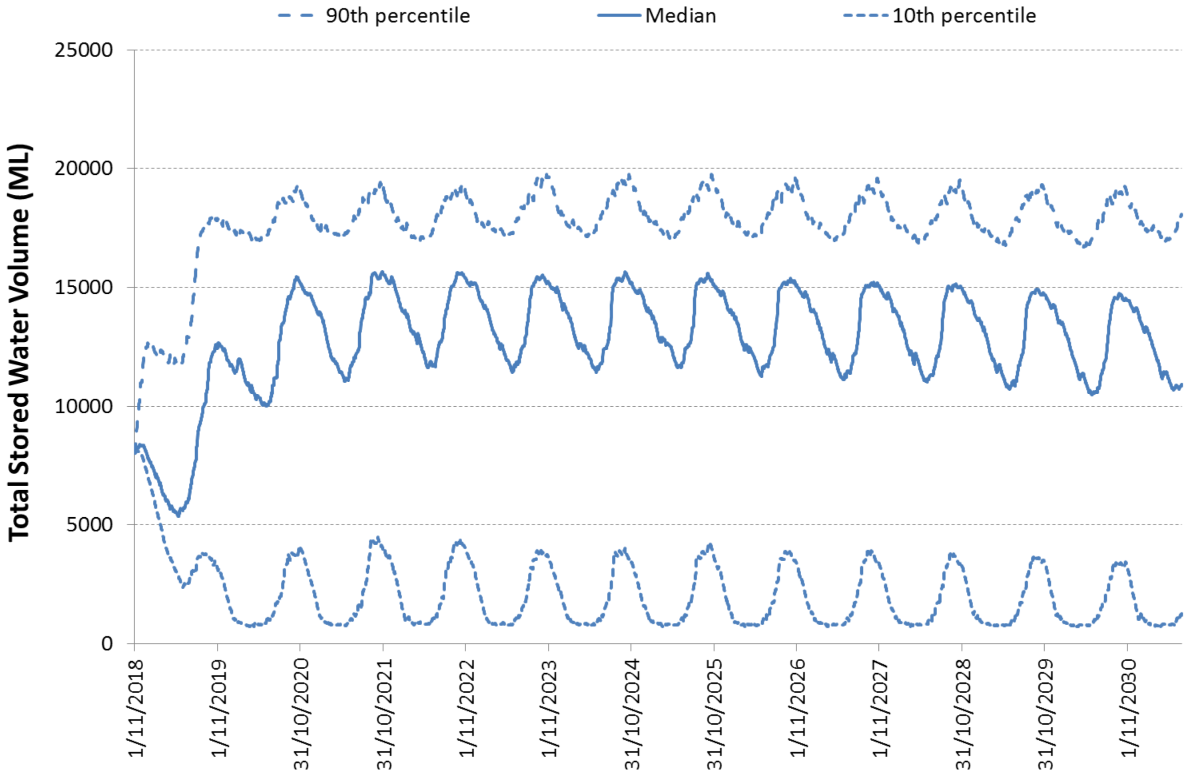

Figure 7 **Modelled Total Site Water Inventory**

Predicted stored water volumes within the CHPTSF are shown in Figure 8 also as probability plots over time. This plot indicates a low risk of accumulation of significant volumes of water within the CHPTSF.

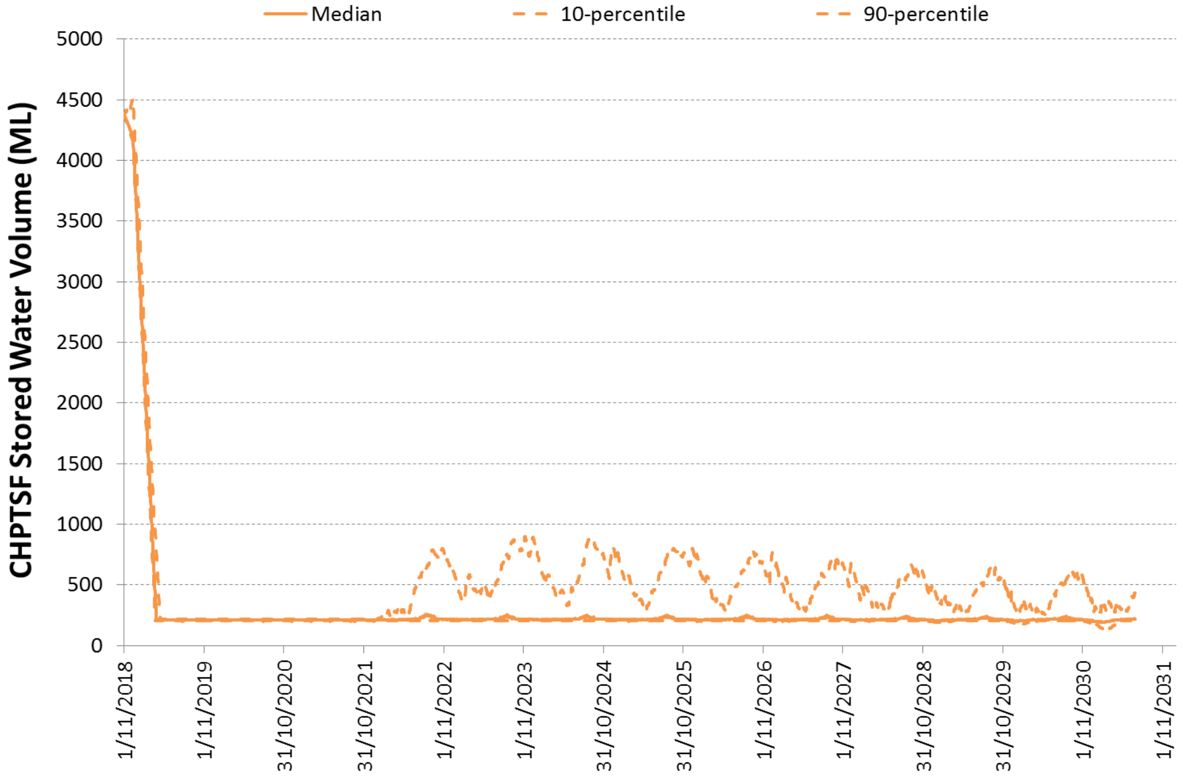

Figure 8 **Modelled CHPTSF Water Volume**

5.3 PROCESS PLANT SUPPLY RELIABILITY

For process plant supply reliability, the following forecast results are provided:

- the percentage of the 118 climatic realizations (refer Section 3.0) in which some (non-negligible) volume of shortfall is simulated, i.e. the risk of some shortfall occurring at some point in the simulation period;
- the average volumetric reliability, i.e. volume of water supplied divided by demand volume, averaged over the full simulation period; and
- the forecast future pattern and magnitude of annual shortfalls.

The model forecast indicates that 70% of climatic realizations are predicted to experience some (non-negligible) shortfall volume during the simulation period. The average volumetric reliability (averaged over all 118 climatic realizations) is 96.4%, while the lowest in any of the 118 climatic realizations is 85.4%.

The pattern of forecast annual shortfall is illustrated in Figure 9 at different probability or risk levels, again compiled from all 118 climatic realizations. Forecast 90th and 95th percentile shortfalls increase with time as the future process demand increases (Figure 4).

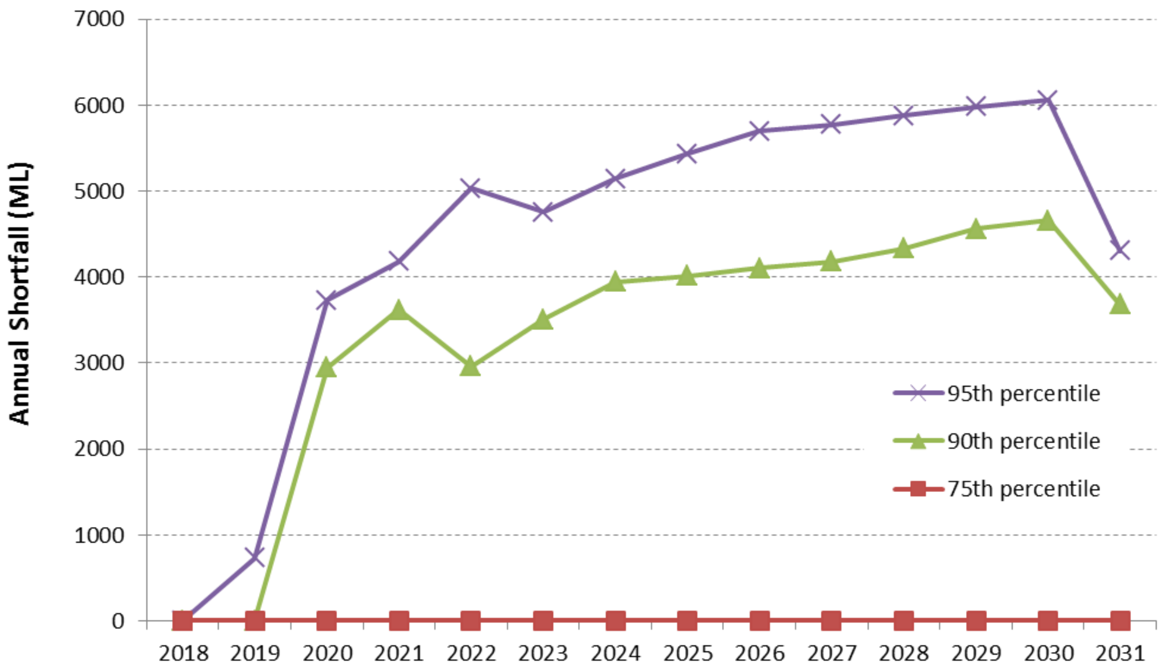

Figure 9 Modelled Annual Shortfall

The operational water balance model would continue to be used by CHPL to provide on-going forecasts of water supply reliability for the CVO. Such forecasts will allow CHPL to plan for contingency measures as required, including acquisition of additional WALs/temporary transfers or implementation of water use reduction measures.

5.4 RISK OF SPILL

No spills were predicted from any of the TSFs. Spills were simulated from the following storages:

- Site Runoff Pond;
- Southern Leachate Dam; and
- STSF Seepage Reclaim Pond.

In order to avoid these predicted spills, CHPL plans to review the catchment, capacity and pumping capacity of the above storages in order to ensure consistency with the hydrologic design criteria given in CHPL (2009) and the requirements of Environment Protection Licence (EPL) 5590. Note that EPL 5590 allows for spills from these storages under high rainfall conditions.

6.0 FINAL VOID WATER BALANCE MODELLING

Following completion of tailings deposition into the Cadia Hill Open Pit, tailings settling would occur over a period of years. Final void closure is envisaged as “wet” closure consistent with approved concepts (Gilbert & Associates, 2009). A final void water balance model has been set up to simulate the volumetric balance of the final void and forecast long-term water levels.

The model simulates inflow from catchment rainfall runoff (including direct rainfall) and groundwater recovery and outflow due to evaporation. Key model assumptions included the following:

- A final void catchment area of 153 hectares (ha). This excludes the catchment area of Copper Gully, which is assumed to report to the Cadia East cave zone and assumes that the residual catchment area of Copper Gully between the cave zone and the Cadia Hill Open Pit is also directed away from the final void. It also excludes a portion of the “go line” and other disturbance areas to the south of the Cadia Hill Open Pit, which it is assumed, would be diverted around the final void. A plan of the modelled final void catchment is shown in Figure 10.
- Time-varying final void level-volume-area relationships developed from predicted depth-volume data provided by Golder Associates (2018) and developed from tailings consolidation modelling. These were combined with level-volume-area relationships for the Cadia Hill Open Pit between the perimeter tailings level and the spill level at 721 m AHD. Final void capacities of 9,023 ML and 58,845 ML were calculated as at the end of tailings deposition and after 500 years of settlement, respectively.
- No interaction between, or intersection with, the Cadia Hill Open Pit and the Cadia East cave zone (as advised by CHPL).
- A 130-year climatic data set obtained from the SILO Data Drill for a location near the Cadia Hill Open Pit. The data set was repeated several times over to generate an extended period of data (500 years in length) for final void simulation – to ensure that equilibrium water levels were reached during the simulation period. SILO Data Drill pan evaporation data was adjusted (increased) on the basis of comparison with site recorded (calculated) pan evaporation over a period of more than 12 years.
- Monthly evaporation pan factors taken from a literature reference - varying from 0.77 to 0.88.
- Rainfall runoff from the final void catchment was estimated using the AWBM applied to the final void sub-catchments (in a manner similar to the operational water balance model – refer Section 4.2).
- Groundwater inflow rates to the final void (reducing with increasing void water level) provided by specialist groundwater consultants[10].

The model forecast water level is shown in Figure 11. Modelling predicts that the final void water levels would take more than 150 years to reach equilibrium. In the long term, the water level is predicted to rise no closer than within 21 m of the 721 m AHD spill level. No spills were forecast to occur.

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[10] Australasian Groundwater and Environmental Consultants Pty Ltd.

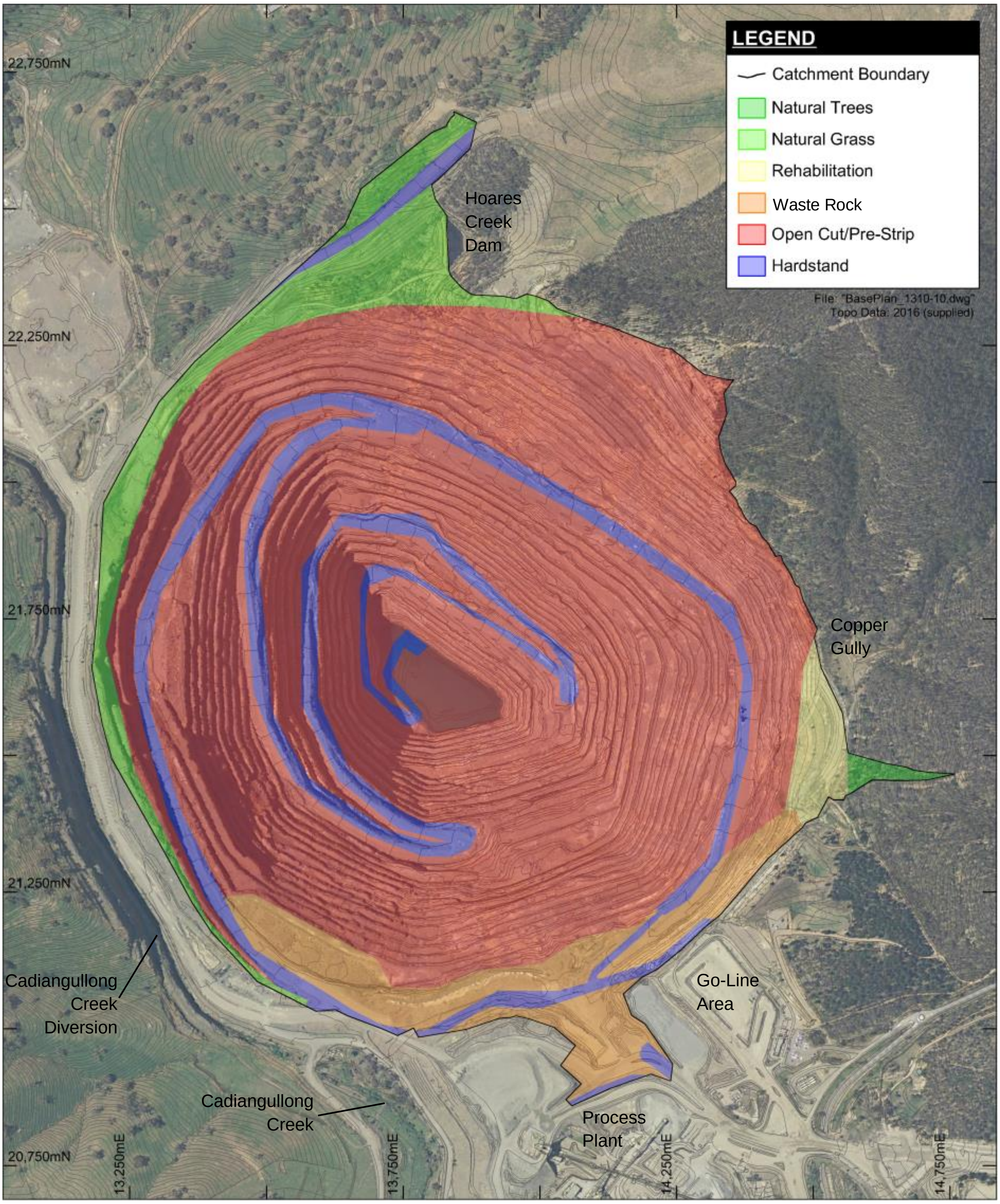


Figure 10 Modelled Final Void Catchment

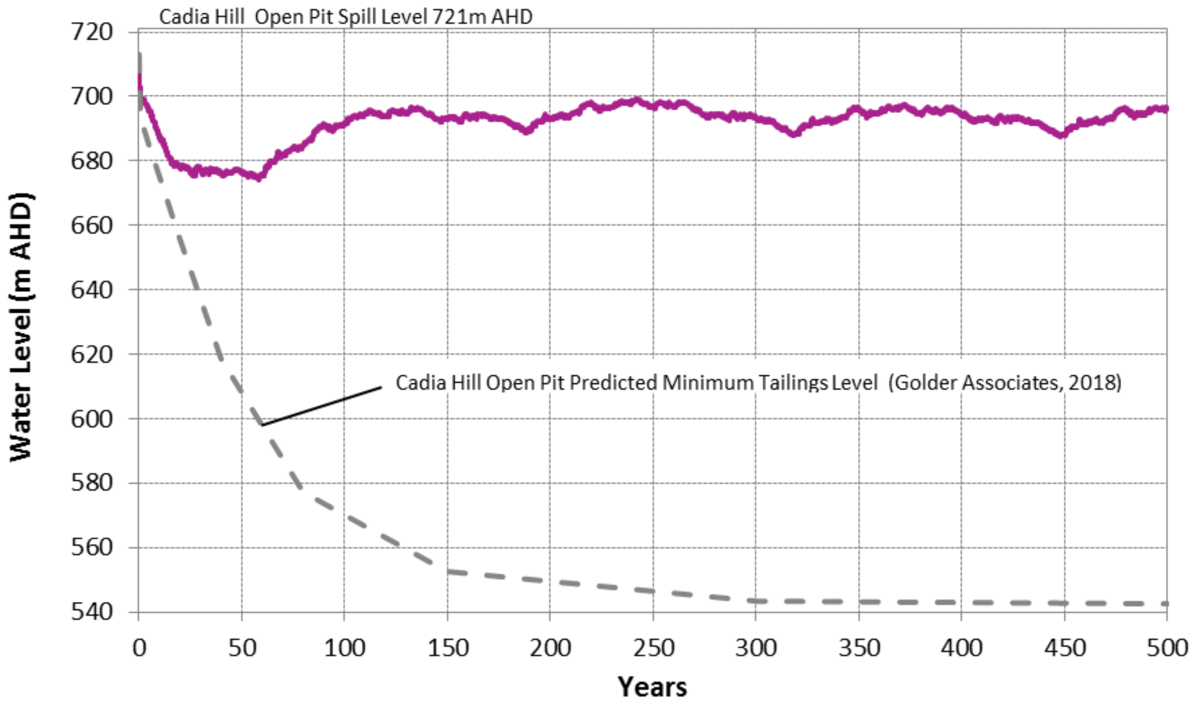


Figure 11 Modelled Final Void Water Level

7.0 CADIANGULLONG CREEK FLOOD MODELLING

Cadiangullong Creek has been diverted around the western margin of the Cadia Hill Open Pit by construction of an excavated diversion channel. The diversion comprises a main channel, designed with capacity to pass a 1% (1:100) annual exceedance probability (AEP) flow event, plus a high-flow channel to the east of the main channel (former haul road) which, in combination with the main channel, was designed with the capacity to pass a 0.01% (1:10,000) AEP peak flow (Gilbert & Associates, 2001).

Updated hydrologic and hydraulic flood modelling has been undertaken to confirm the existing predicted flooding risk of the Cadia Hill Open Pit, using as-built digital terrain data of the diversion and updated hydrologic guidelines – ARR2016 (Ball et al., 2016). Modelling was undertaken of 1%, 0.1% and 0.01% AEP flow events as well as the probable maximum flood (PMF).

7.1 HYDROLOGIC MODELLING

A hydrologic model of the catchment of Cadiangullong Creek upstream of the Cadia Hill Open Pit was set up to simulate creek flow from rainfall. Modelling was undertaken using the RORB runoff routing model (Laurenson et al., 2010). RORB is a general runoff and streamflow routing program used to calculate flood hydrographs (flow rate versus time) from rainfall and estimated catchment losses. The model initially calculates rainfall excess using estimates of storm catchment loss. This rainfall excess is then used to calculate streamflow at any point within a defined stream channel network, incorporating the effects of “routing” or reduction in flow peak (in the absence of inputs) with distance along a channel. The model uses four key parameters (for rural catchments):

IL – initial loss (millimetres [mm])

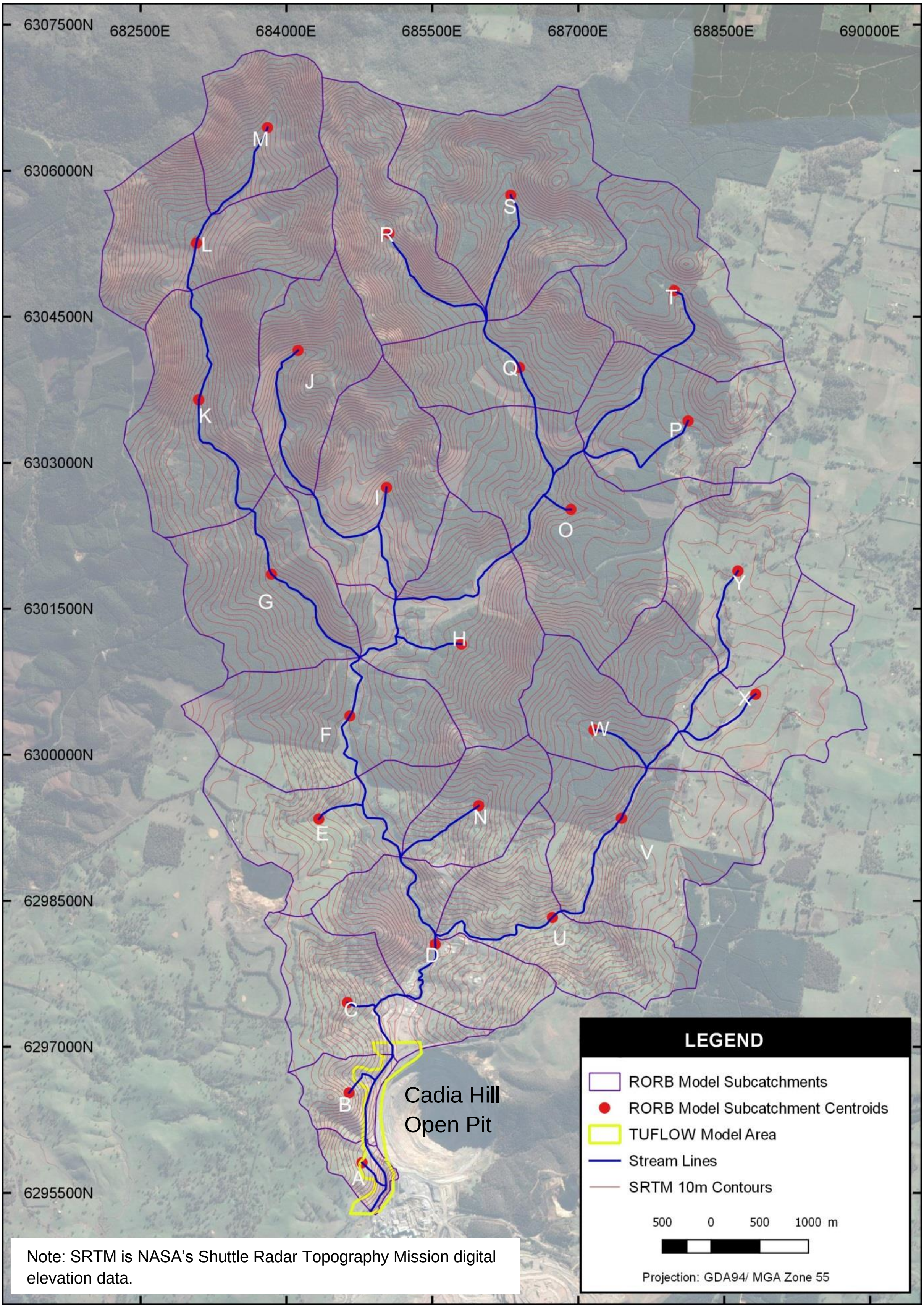
CL – continuing loss (millimetres per hour [mm/hr])

k_c – main routing parameter

m – exponential routing parameter

Losses were estimated from recommendations in ARR2016 (Ball et al., 2016) and based on experience. Values of IL and CL were varied from 20 mm and 2 mm/h (1% AEP) to 0 mm and 1 mm/h (for the PMF), respectively. The routing parameters directly affect the shape of the flood hydrograph (i.e. whether the flow response is sharp and quick or slow and long), hence the magnitude of the peak flow rate. RORB model calibration was undertaken previously (Gilbert & Associates, 2000) using recorded streamflow in Cadiangullong Creek, resulting in the following calibrated parameters: k_c = 14.1 and m = 0.71. The value of k_c is lower than the recommended value from ARR2016 (Ball et al., 2016), which results in a higher peak flow and is therefore conservative.

RORB modelling was undertaken by subdividing the creek catchment into 25 sub-catchments as shown in Figure 12, with a total catchment area of approximately 57.6 km^2 to the downstream end of the diversion. The model included flow routing through the Cadiangullong Creek Dam with the dimensions of its multi-level spillway, obtained from as-built drawings, included in the model. The Cadiangullong Creek Dam was conservatively assumed to be full at the start of each design event.



Note: SRTM is NASA's Shuttle Radar Topography Mission digital elevation data.

Figure 12 RORB Model Sub-catchments and TUFLOW Model Area

Culverts located within Cadiangullong Creek were conservatively ignored in the analysis (flow through culverts will tend to attenuate flood peaks). The effects of flow through the Cadia Creek Weir were also conservatively neglected.

Design storm rainfall totals, areal reduction factors and temporal patterns for the various design events were derived using standard methods as outlined in ARR2016 (Ball et al., 2016) and used as input to the model. Simulated rainfall durations were varied until the peak flow rate was identified for a particular design event (i.e. the "critical" duration). The calculated peak flow rates at the downstream end of the modelled catchment and critical duration for the different design events are summarised in Table 4.

Table 4 Predicted Peak Flood Flow Rates – Cadiangullong Creek Diversion

Design Event	Critical Duration (hours)	Peak Flow Rate (m^3/s)
1% AEP (1:100)	6	150.2
0.1% AEP (1:1,000)	6	289.3
0.01% AEP (1:10,000)	6	457.3

7.2 HYDRAULIC MODELLING

A hydraulic model was set up to simulate peak water levels and depths within and just downstream of the diversion for the design events listed in Table 4. Modelling was undertaken using the 2-dimensional hydrodynamic model TUFLOW™. TUFLOW (BMT, 2017) is a widely-used 2-dimensional numerical, finite difference model. The modelled surface topography was taken from digital terrain data supplied by Newcrest. The model was set up using a 3 m by 3 m horizontal grid, spanning the reach indicated in Figure 12. A set of culverts is located in Cadiangullong Creek just downstream of the diversion (at a light vehicle crossing) near the downstream end of the modelled reach. These were conservatively neglected in the modelling (i.e. equivalent to assuming that these culverts were completely blocked during the event).

The modelled upstream boundary conditions were set to design flow hydrographs derived from hydrologic modelling (Section 7.1). The downstream boundary condition was set to "normal" depth, i.e. depth calculated for uniform flow conditions at the estimated downstream longitudinal gradient using Manning's equation[11]. Modelled stream roughness (Manning's "n" values) were set using a combination of aerial and terrestrial photographs, literature guidelines and experience. Adopted values are summarised in Table 5.

Table 5 TUFLOW Model Roughness Values

Description	Roughness (Manning's "n") values
Creek without trees	0.035
Creek with scattered trees	0.04
Creek with trees	0.05
Road surface	0.02
Waterbody	0.025
Floodplain	0.04

Model results are given in Figure 13 to Figure 15 as predicted peak water depths for the four design flow events simulated.

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[11] http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Manning_s_Equation.htm

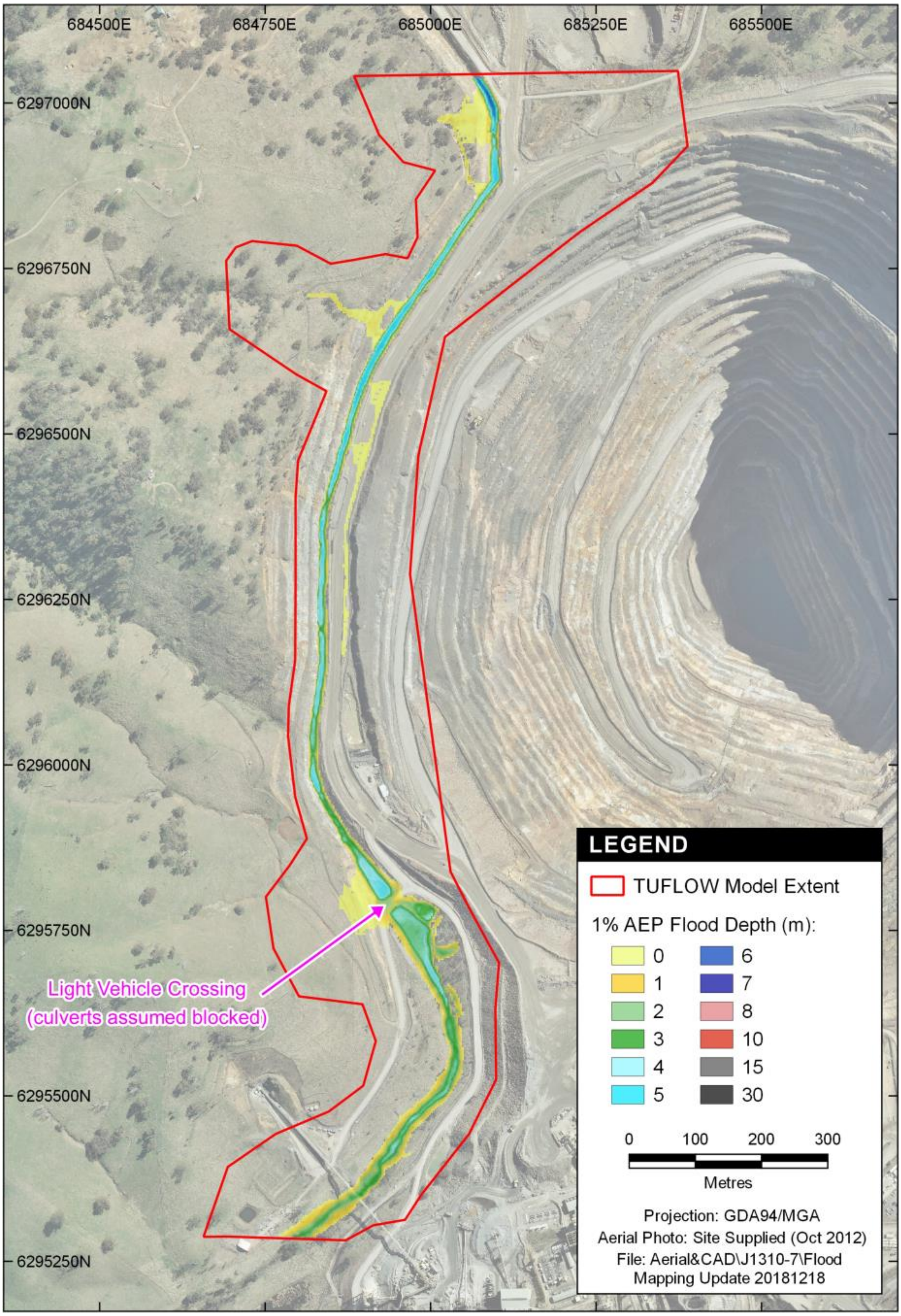

Figure 13 Predicted Peak Flow Depths – 1% (1:100) AEP Event

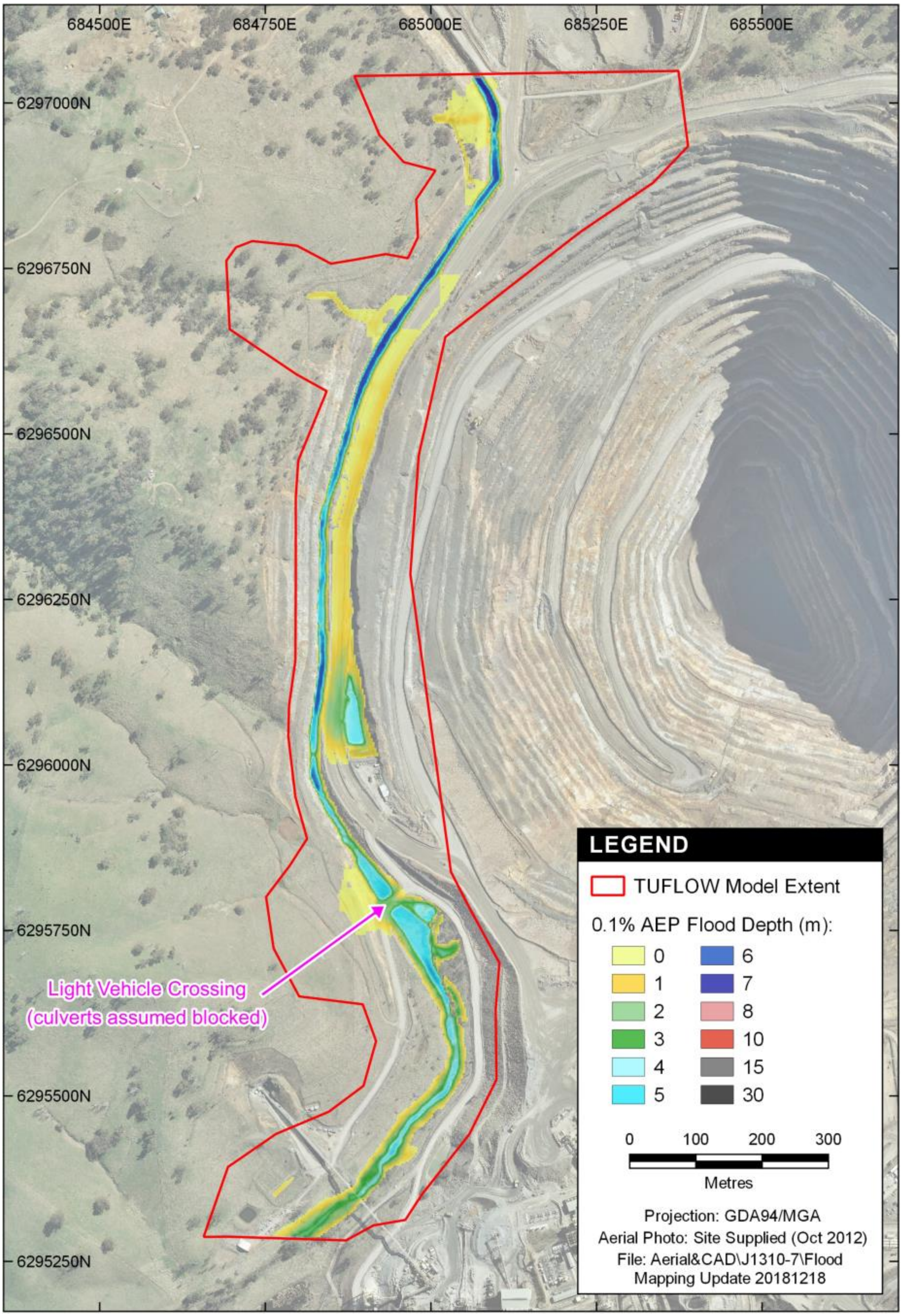

Figure 14 **Predicted Peak Flow Depths – 0.1% (1:1,000) AEP Event**

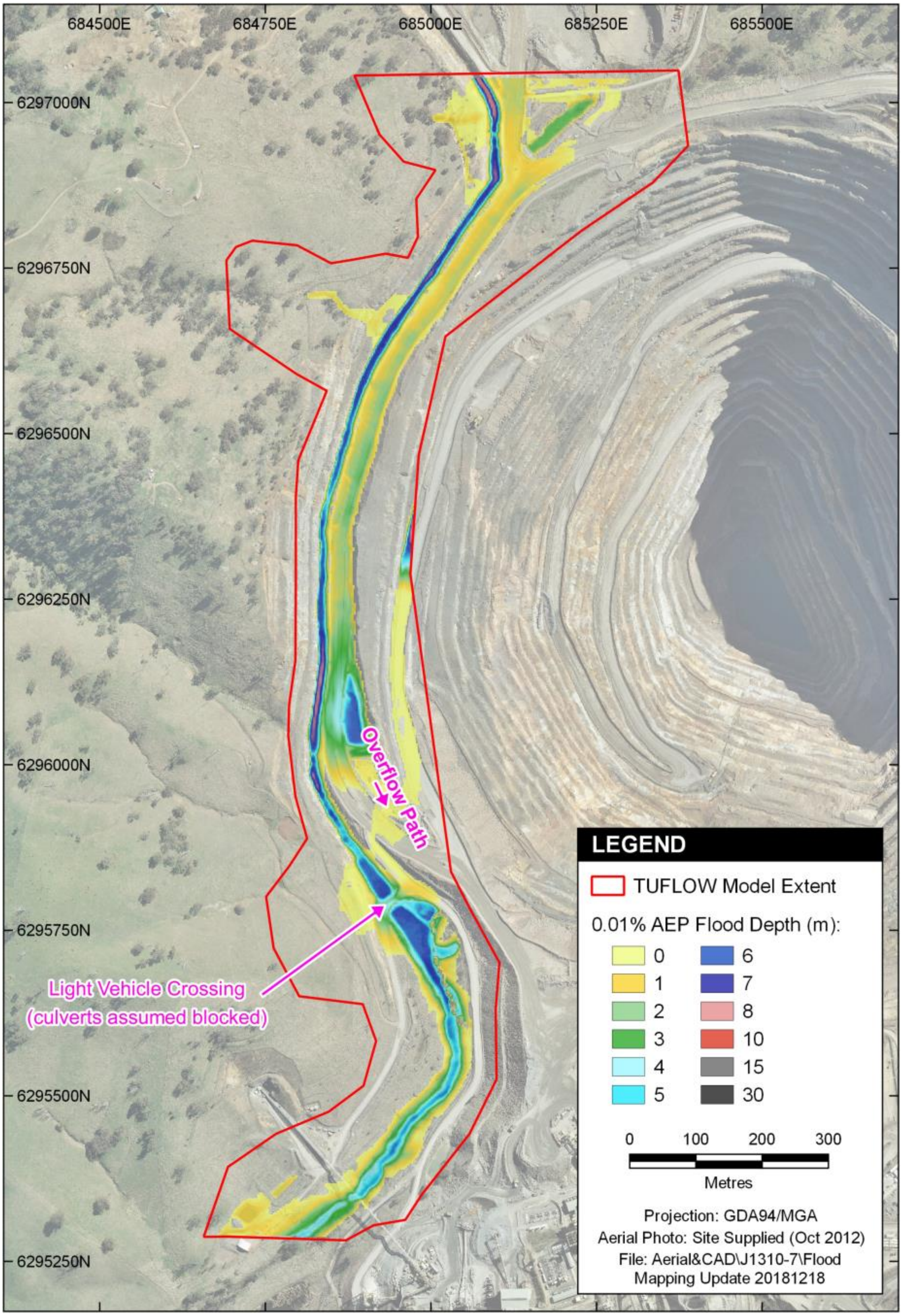

Figure 15 Predicted Peak Flow Depths – 0.01% (1:10,000) AEP Event

Figure 15 indicates that the diversion would just overtop into the Cadia Hill Open Pit in a 1:10,000 AEP peak flow, near the south-west corner of the open cut, based on the predicted peak water depth.

It is apparent from the peak flow depths in Figure 15 that the overtopping flow in a 1:10,000 AEP peak flow predominantly occurs from the north – from overtopping of the roadside sediment dam and as indicated by the arrow – rather than from backwater from the light vehicle crossing. The predicted peak flow depths at the overtopping location (indicated by the arrow) are approximately 0.2 m. Localised raising of the surface in this area by a small amount should therefore prevent inflows to the open cut in 1:10,000 AEP peak flow.

8.0 REFERENCES

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