BHP

Orebody 32 below water table: Ophthalmia Dam surplus water impact assessment

August 2022

Authorisation

Version	Description of Version	Position	Date
0	Initial version for Traditional Owner review	Superintendent, Stewardship & Approvals	27 June 2022
0.1	Version for referral of OB32 BWT Proposal to EPA	Superintendent, Stewardship & Approvals	1 August 2022

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1 Introduction

The purpose of this document is to provide an assessment of the impacts on water resources from the proposed discharge of surplus mine dewater from the Orebody 32 Below Water Table Proposal (OB32 BWT Proposal) to Ophthalmia Dam. The *Orebody 32 Below Water Table: Groundwater impact assessment* (BHP 2022) documents the assessment of the impacts of the proposed groundwater abstraction for dewatering for the OB32 BWT Proposal.

2 Existing environment and environmental values

The OB32 above water table (AWT) deposit is part of the existing Eastern Ridge mining operations (Eastern Ridge) which also includes OB 23, 24, 25 and 25 W (Figure 1). The Eastern Ridge mine (Eastern Ridge Iron Ore Revised Proposal) was approved under Part IV of the *Environmental Protection Act 1986* (EP Act) by issue of Ministerial Statement 1037 (MS1037) for below water table mining at OB 24, 25 and 25W and above water table mining at OB32. Below water table mining is also approved at OB23 under MS478 (Figure 1). Backfilling is underway at OB23 and dewatering is scheduled to cease in mid-2023.

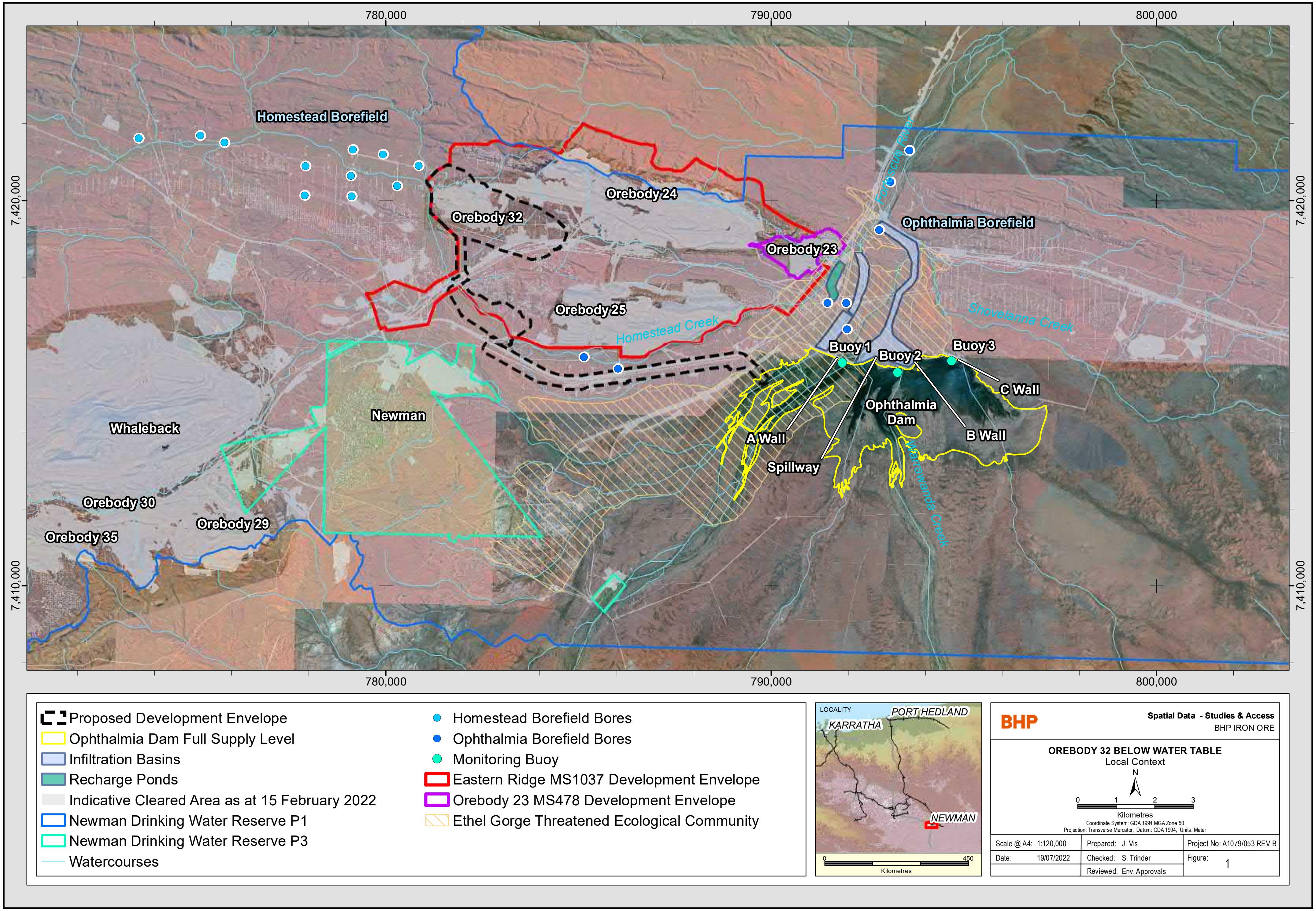
The Ophthalmia Dam system, which comprises the dam, two infiltration basins, three recharge ponds and connecting drainage system is located to the southeast of OB32 (Figure 1). The system was commissioned in 1981 to address declining groundwater levels in the Ethel Gorge aquifer, due to groundwater abstraction from the Ophthalmia Borefield, which supplies drinking water to the Newman town. The dam consists of three main earth-core embankments (Wall A, B and C) (Figure 1). The *Eastern Pilbara Hub Water Balance* report (EMM 2020) describes the Ophthalmia Dam system in detail.

Ophthalmia Dam is located within the Priority 1 Public Drinking Water Source Area of the Newman Water Reserve. Groundwater is currently sourced from the BHP operated Ophthalmia and Homestead borefields for the Newman town water supply. The dam, basins and ponds partially overly the Ethel Gorge aquifer system which supports the Ethel Gorge aquifer Stygobiont community Threatened Ecological Community (Ethel Gorge TEC) (Figure 2).

The Ophthalmia Dam system continues to maintain water levels within the Ethel Gorge aquifer system to support the Ethel Gorge TEC and provides a location for the discharge of surplus water from BHP mines in the Eastern Pilbara Hub (currently Eastern Ridge, Orebody 29/30/35, Jimblebar and Orebody 31) (Figure 2). Discharge of surplus mine dewater to Ophthalmia Dam first commenced in 2006 from Eastern Ridge, followed by Orebody 31 and Orebody 29/30/35 in 2016 and Jimblebar in 2019 (BHP 2019a).

The main water-related environmental values that may be impacted by the addition of surplus water discharge to Ophthalmia Dam from the OB32 BWT Proposal are (Figure 1):

- local groundwater resource in the Newman Water Reserve, used for town water supply
- Fortescue River and tributaries
- Ethel Gorge aquifer (and TEC).



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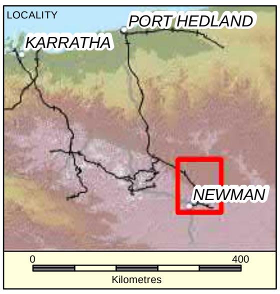
- Stream Gauging
- ! BHP Mine
- Watercourses
- Rail Line
- Highways
- Fortescue Marsh Priority Ecological Community
- Newman Drinking Water Reserve



BHP

Spatial Data - Studies Planning & Access
BHP IRON ORE

OREBODY 32 BELOW WATER TABLE
Regional Context

0 5 10 15
Kilometres

Coordinate System: GCS GDA 1994, Datum: GDA 1994, Units: Degree

Scale @ A4: 1:450,000	Prepared: J.Vis	Project No: A1079/054 Rev A
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3 Surplus water regulation and management

3.1 Environmental regulation

3.1.1 Ophthalmia Dam operation

There are no environmental approvals for the operation of Ophthalmia Dam under the EP Act, as the dam was constructed prior to the EP Act coming into force. A Notice of Intent (NoI) for the Newman Water Resources Development Project (which includes the Ophthalmia Dam system), was submitted in April 1981 (Mt Newman Mining Company 1981). This NoI sets out the justification for the Ophthalmia Dam system, operational parameters, description of the existing environment, potential environmental impacts and environmental monitoring measures. The Newman Water Resources Development Project (including the Ophthalmia Dam system) was approved by the Minister for Resource Development in May 1981. Ophthalmia Dam is not a prescribed premise and is not currently subject to regulation under Part V of the EP Act.

3.1.2 Discharge of surplus water to Ophthalmia Dam

Discharge of surplus mine dewater from BHP mines to the Ophthalmia Dam system is regulated under various Part IV and Part V mine approvals (Table 1):

- Eastern Ridge: MS1037 and L6942/1997/13
- Orebody 29/30/35: MS963 and L4503/1975/14
- Jimblebar: MS1126 and L5415/1988/9
- Orebody 31: MS1021 and L5415/1988/9.

The impacts of discharge were not assessed under Part IV for OB23 (EPA 1998), and as discussed in Section 2, dewatering at OB23 is planned to cease in mid-2023. MS1021 for OB31 contains conditions relating to discharge to Ophthalmia Dam, however, the discharge rate is not specified.

Table 1: Approved discharge to Ophthalmia Dam

Mine	Year approved (Part IV)	Surplus discharge to Ophthalmia Dam (GL/a)	
		Part IV approved	Part V licensed
Eastern Ridge mine (OB24, OB25 Pit 1 and 3, OB25 West)	2016	19[1]	19[1,2]
Orebody 23	1998	Not assessed	
Orebody 29/30/35	2014	8	8
Jimblebar	2011	16.425	32.625[4]
Orebody 31	2015	Not specified[3]	
Total			**59.625**

1. Approvals are for the Ophthalmia Dam system, i.e. include direct discharge of surplus water to recharge ponds and infiltration basins as well as direct discharge to the dam
2. Part V regulated as Eastern Ridge Hub, which includes Eastern Ridge mine and OB23
3. OB31 Part IV assessed up to 16.2 GL/a discharge
4. Part V regulated as Jimblebar Hub, which includes Jimblebar and Orebody 31 mines.

Releases of water from Ophthalmia Dam into the Fortescue River or its tributaries are not regulated under Part IV or Part V of the EP Act.

3.2 Surplus water environmental management

BHP manages the potential impacts to the environment from the discharge of surplus water to the Ophthalmia Dam system primarily through its *Eastern Pilbara Water Resource Management Plan* (EPWRMP) (Revision 6.0, BHP 2018). As a number of environmental approvals regulate the discharge of surplus water to Ophthalmia Dam, the EPWRMP focuses at a regional level on the outcome of maintaining the hydrological conditions (groundwater levels and salinity) in the Ethel Gorge aquifer, to maintain the habitat of the Ethel Gorge TEC. The MS for Eastern Ridge (MS1037), Jimblebar (MS1126) and Orebody 31 (MS1021) all contain conditions requiring the implementation of an environmental management plan (the EPWRMP) to protect the Ethel Gorge TEC. The EPWRMP contains outcomes-based environmental criteria (triggers and thresholds) relating to groundwater level and groundwater salinity change in the Ethel Gorge aquifer that supports the Ethel Gorge TEC, for the Ethel Gorge Primary Habitat Monitoring Zone (Monitoring Zone 1) (Figure 3). Table 2 outlines the relevant triggers and thresholds in the EPWRMP (BHP 2018).

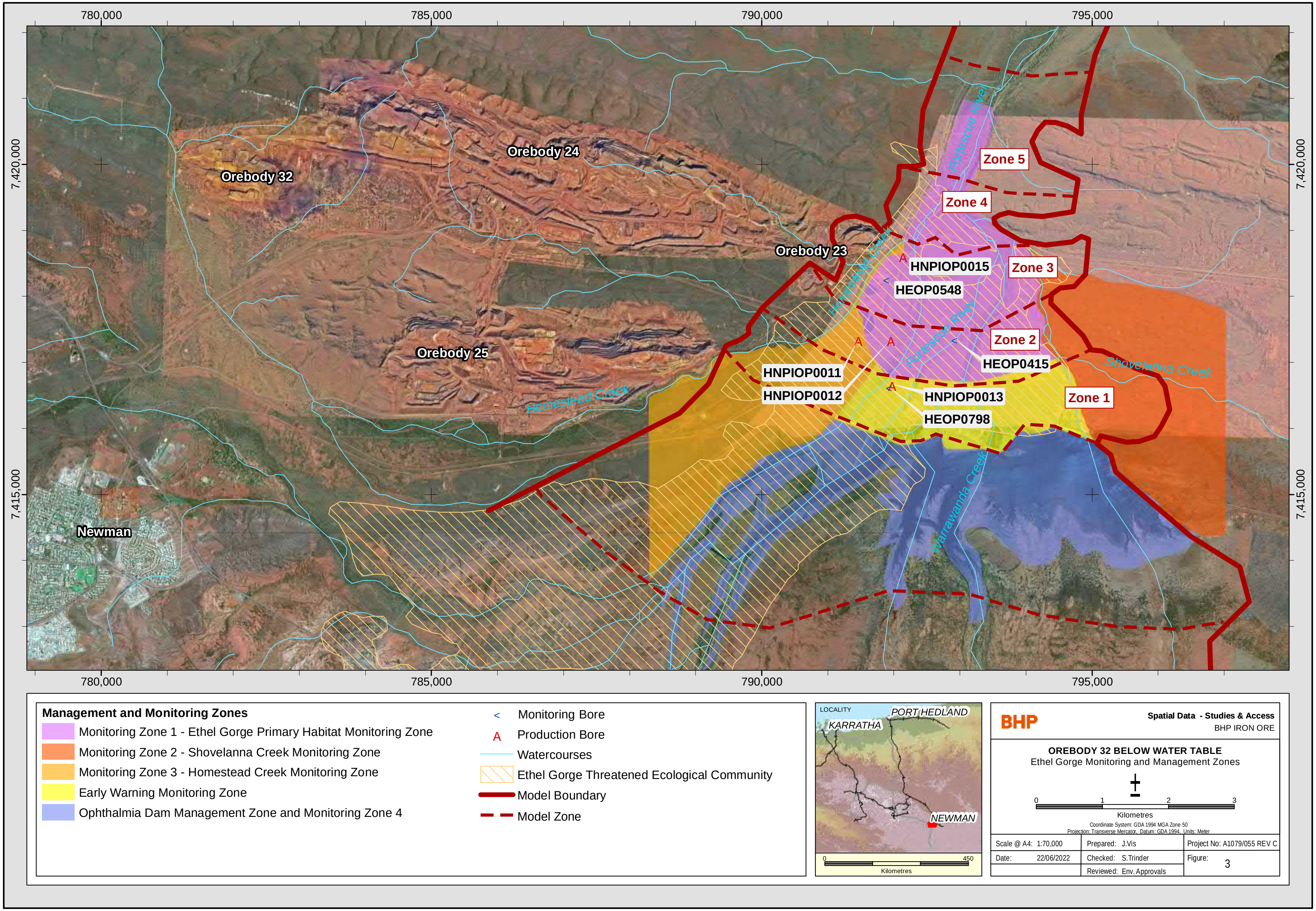
Table 2: EPWRMP triggers and thresholds

Environmental criteria	Trigger	Threshold
Water Quality - Groundwater salinity (in the Ethel Gorge Primary Habitat Monitoring Zone - Monitoring Zone 1)	3,000 mg/L TDS	4,000 mg/L TDS
Water Quantity - Groundwater levels (in the Ethel Gorge Primary Habitat Monitoring Zone - Monitoring Zone 1)	>6 m[1] or a rate of >4 m/year	>12 m[1] or a rate of >8 m/year

1. Interpreted as the statistically significant aquifer response and change to water level in Zone 1 (Figure 3). Water level responses greater than the above thresholds may result from localised bore abstraction and these localised responses shall not bias the overall thresholds.

Response actions in the EPWRMP to manage groundwater levels and/or groundwater salinity include a seasonal (following a wet season (typically December through March)) controlled release from Ophthalmia Dam to upper Fortescue River tributaries. BHP notes in the EPWRMP that three months of controlled release into the Upper Fortescue following the wet season is considered appropriate and unlikely to develop permanent or ponding water downstream in the Fortescue River, or have an impact on riparian vegetation (BHP 2018). In recent correspondence to the EPA Services of the Department of Water and Environmental Regulation (DWER), BHP also noted that discharge from the dam (i.e. releases) of less than three months duration during the dry season (i.e. when there are typically no natural flows) is unlikely to negatively impact riparian vegetation health and considered that biannual releases of water from the dam [total of up to 3 months] may be undertaken (BHP 2019b).

The Part V licences also contain requirements in relation to Ophthalmia Dam, including monitoring of discharge rates into the Ophthalmia Dam system, monitoring of discharge water quality (salinity and other parameters) and annual reporting (of exceedances of trigger values and details of investigations conducted, including outcomes, environmental impacts and remedial actions).



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4 Historical and recent water balance

4.1 Ophthalmia Dam storage and inundation

The maximum operating storage capacity of the dam is estimated to be 25.33 GL at the service spillway elevation (513.5 mRL) covering a total area of approximately 1,476 ha (EMM 2020) (maximum inundation area). The maximum storage capacity is consistent with the approved design, set out in the 1981 NoI which documents the dam full supply level at 513.5 mRL (Minister for Minerals and Energy 1984). When the dam fills from rainfall events and overtops the service spillway (uncontrolled release), water flows into the Fortescue River downstream of the dam. The typical water storage regime consists of dam filling events predominantly during the wet season from large Fortescue River flow events (although the dam does not fill every year), and rapid storage recessions during the dry season, due to seepage and evaporative losses. The dam usually reaches a near empty condition prior to the following wet season. The minimum storage area is 15 ha at the spillway base elevation of 509.0 mRL (EMM 2020).

Figure 4 and Figure 5 provide example plots of Fortescue River flow and dam storage (as the dam water level), and satellite imagery showing the storage inundation area (for high storage and low storage periods) compared to the maximum inundation area, before surplus water discharge from BHP mines commenced in late 2006 and since discharge commenced. The Fortescue River flow is measured at the DWER Newman gauging station (708011) (see Figure 2 for location) as this is the only station that on the Fortescue River that has a long-term gauged record, providing reliable estimates of potential catchment inflows to Ophthalmia Dam (EMM 2020).

Figure 4 shows the pre-mine discharge low storage conditions in June 2005. The plot shows that the dam water level is almost at the minimum (509.2 mRL) in the dry season following a very dry wet season (very little streamflow) and the satellite imagery (although incomplete) shows that the dam is nearly empty with only a small amount of inundation upstream of the dam wall. No imagery was available showing high storage conditions as imagery is usually obtained in the dry season.

Figure 5 shows the recent post-mine discharge low storage conditions in July 2019. The plot shows that the dam water level is low (510.7 mRL) in the dry season following a very dry wet season (very little streamflow) and the satellite imagery shows that the dam is at low storage with inundation areas limited to the areas referred to as Fortescue pool (alluvial area) and Warrawanda pool (EMM 2020).

Appendix 1 provides continuous plots of Fortescue River flow and dam storage for each water year (September - August) since 1982 following construction of the dam in 1981. The dam also receives inflows from Fortescue River tributaries, including Warrawanda Creek. Figure 6 shows the annual (water year) rainfall at the DWER Fortescue River - Newman station 507005 and annual streamflow at DWER Fortescue River - Newman station 708011, highlighting the natural variability in rainfall and streamflow.

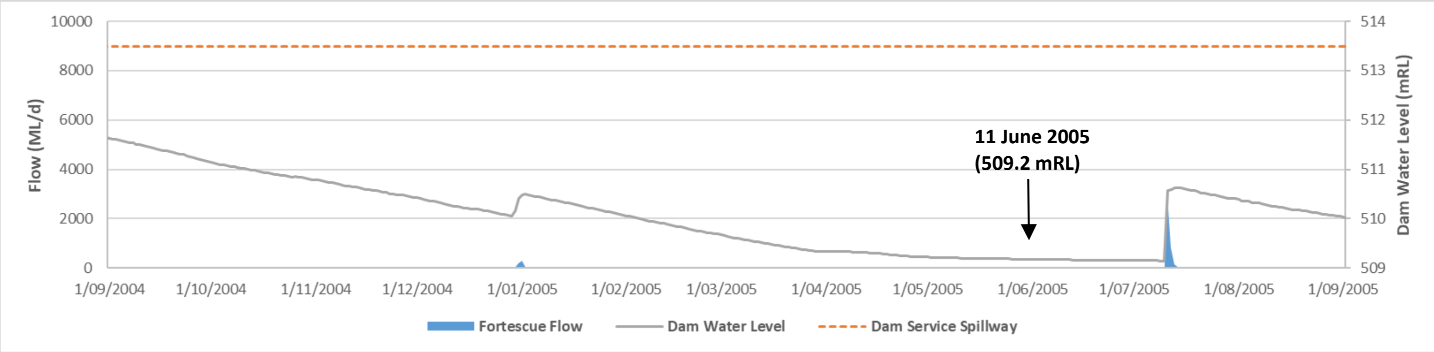
The data in Figure 4, Figure 5 and Appendix 1 show the following:

- Prior to surplus water discharge commencing from BHP mines (2006), the dam storage reached full capacity (maximum inundation extent) at least every two to three years (less frequently in the drier rainfall years in the 1980s and more frequently in the high rainfall years around 2000.
- Prior to surplus water discharge commencing from BHP mines, the duration where the dam remained at full storage ranged between approximately one week and 4.5 months (in 2000).
- The inundation extent shown on the satellite imagery corresponds to the dam storage (as the dam water level) shown on the plots for the relevant date.
- Since the dam has received surplus discharge from BHP mines (2006), the cycle of low storage in the dry season and high storage in the wet season (following sufficient streamflow) has continued. The frequency of the dam reaching full storage and the duration of full storage has remained within the historical variation prior

to the dam receiving discharge. The contribution to dam storage is dominated by creek inflows following large rainfall events, rather than surplus discharge from BHP mines.

- Since late 2016, the dam has filled to the spillway capacity (resulting in overtopping over spillway) three times - all in or following the wet season streamflow (April 2017, January 2020 and February 2021).

Dam storage: Low



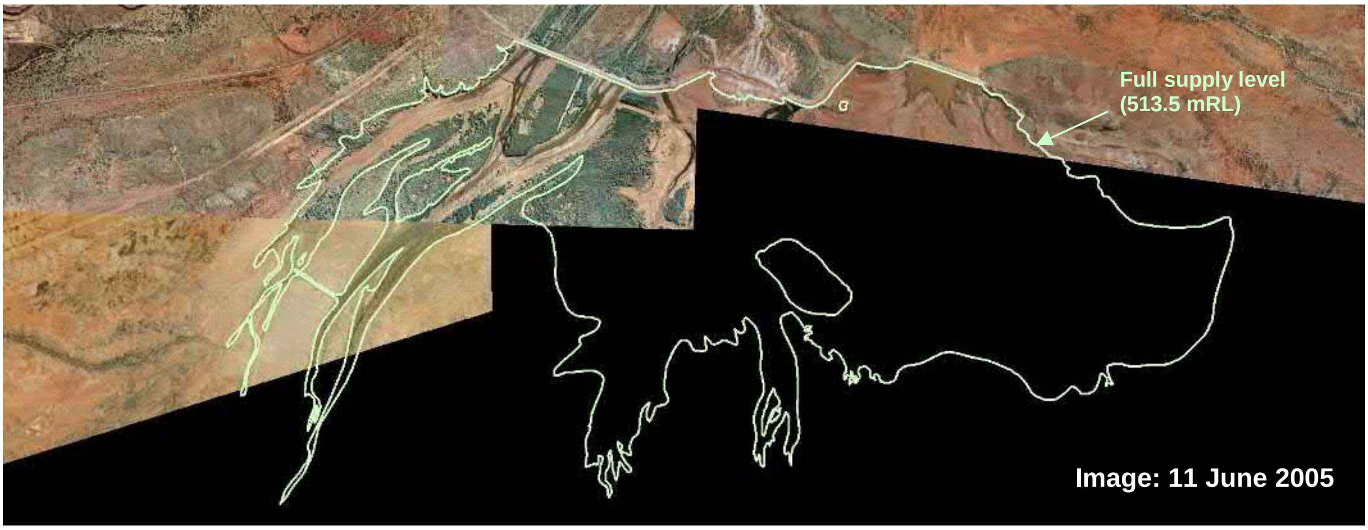
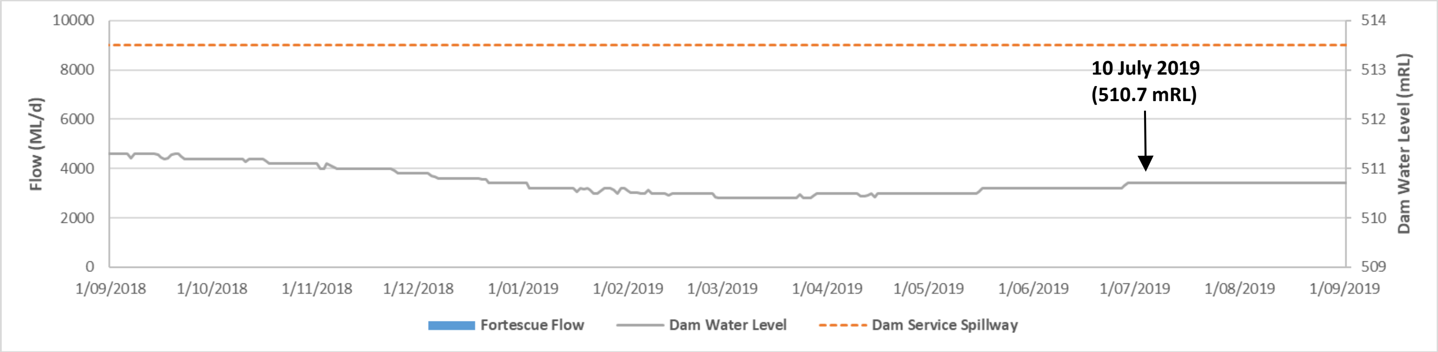


Figure 4: Fortescue River streamflow and Ophthalmia Dam storage - prior to mine discharge

Dam storage: Low



Dam storage: High

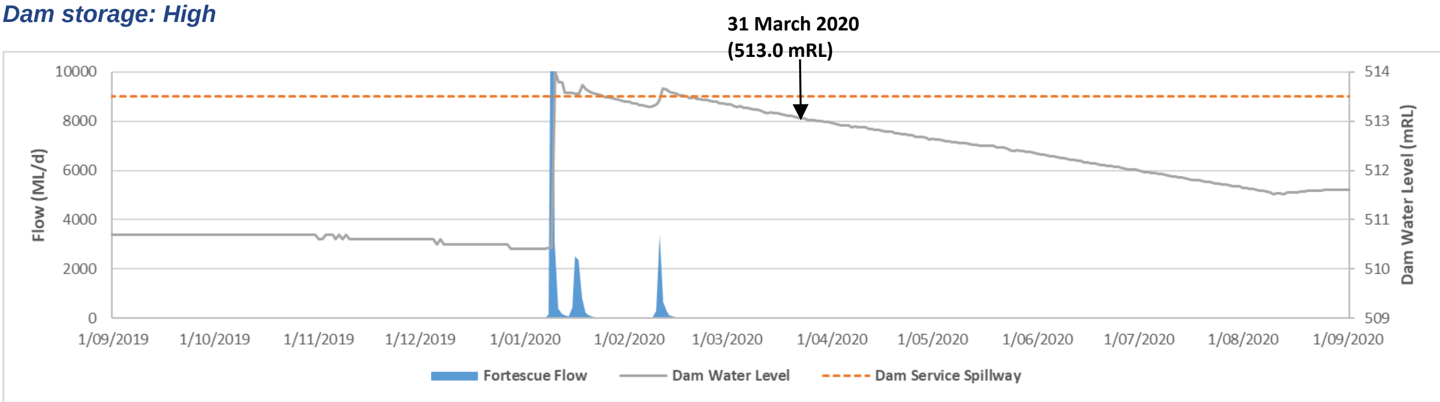


Figure 5: Fortescue River streamflow and Ophthalmia Dam storage - since mine discharge

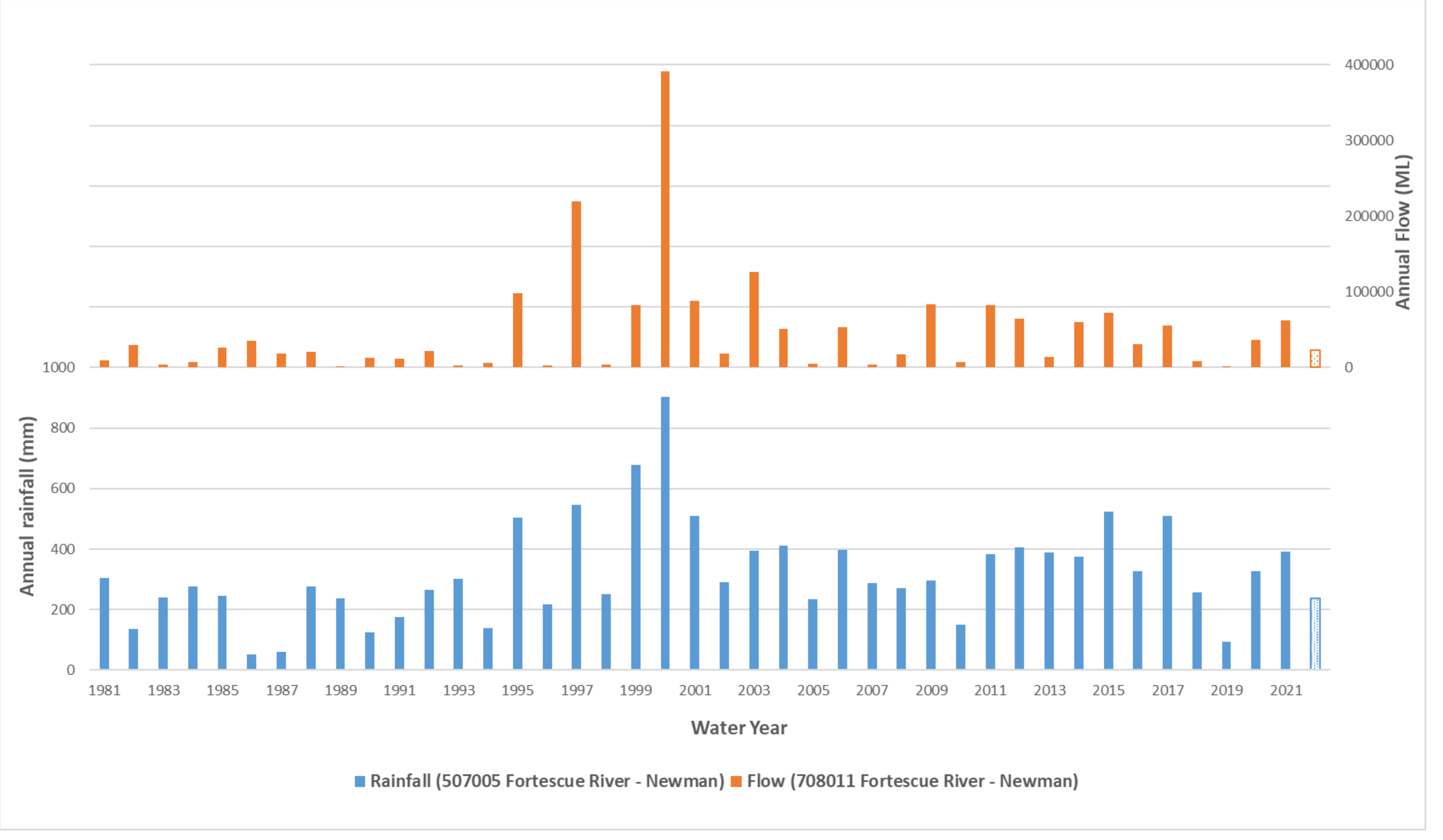


Figure 6: Fortescue River - Newman: Annual rainfall and streamflow

4.2 Ophthalmia Dam salinity

Figure 7 shows the maximum observed salinity in Ophthalmia Dam at three locations (Buoys 1, 2 and 3) (see Figure 1 for buoy locations) and monthly rainfall at Newman since 2013. As shown in Figure 7, the dam salinity is highest following periods of no to low rainfall and decreases following rainfall events. Therefore, the fluctuation in salinity in the dam is driven by rainfall (and natural flow events) rather than the discharge of surplus water to the dam. Salinity increases during the dry season due to evaporation, then decreases to less than 50 mg/L TDS following major rainfall events in the wet season. The data shows that the maximum salinity at the buoys has varied between approximately 1,200 mg/L and 1,800 mg/L TDS.

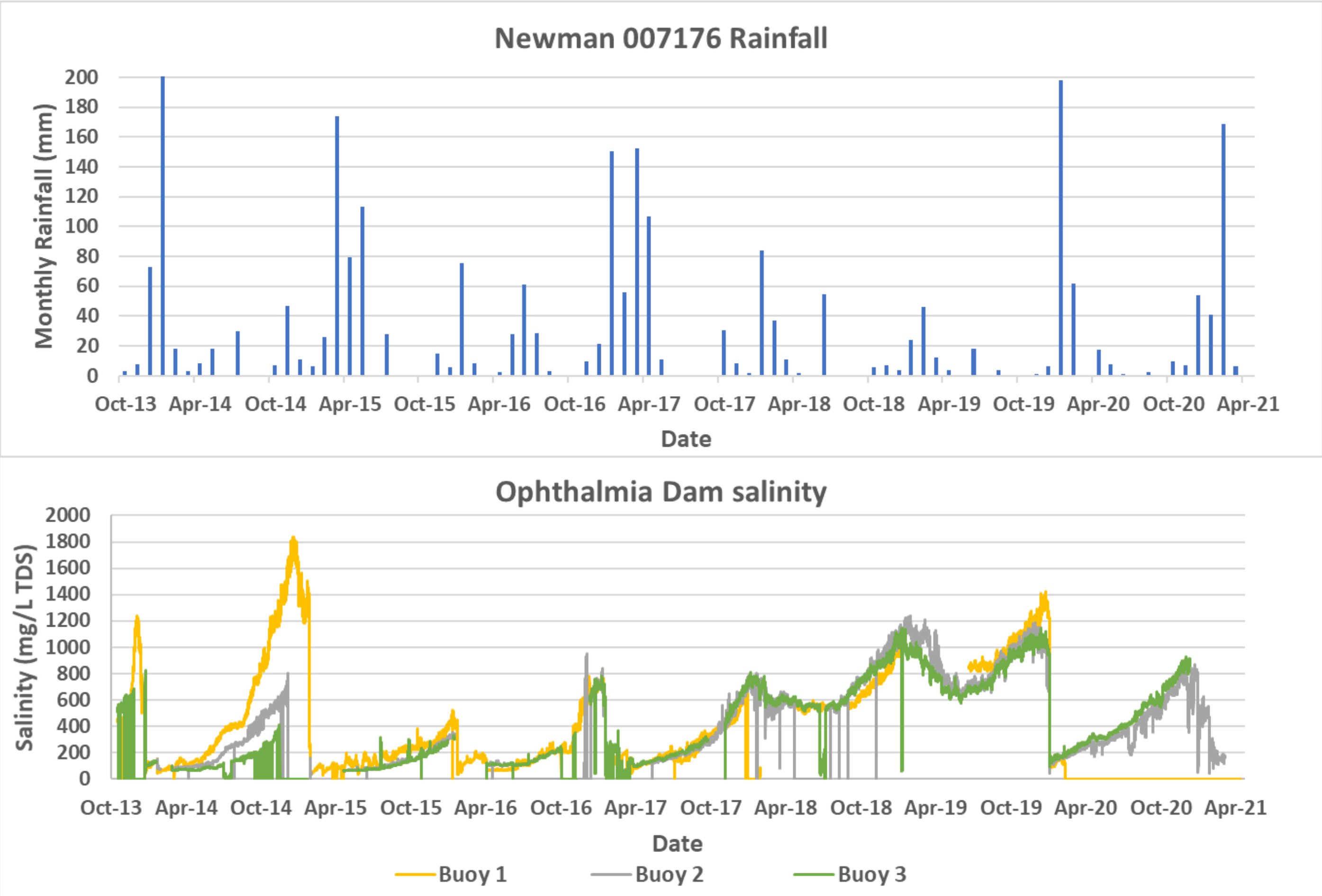


Figure 7: Ophthalmia Dam salinity

4.3 Discharge to Ophthalmia Dam

As discussed in Section 3.1.2, the discharge of surplus water to Ophthalmia Dam is regulated for each mine from where the surplus water originates, rather than the dam itself. Table 3 presents approved and recent actual discharge rates (from financial year (FY) 2021 and 2022) to Ophthalmia Dam from BHP mines. Of the total licensed annual discharge rate (59.625 GL/a), only a portion of this is actually discharged to the Ophthalmia Dam system. This is because the licensed rate is an annual peak rate that allows for fluctuations in dewatering rates according to the individual mine plans (the daily rates shown in Table 3 represent the average daily discharge rates based on the annual rates). The total actual recent discharge rate from FY2021 and FY2022 from all BHP mines is approximately 24.25 GL/a, corresponding to approximately 41% of the approved licensed rate.

Table 3: Recent actual discharge to Ophthalmia Dam

Mine	Surplus discharge to Ophthalmia Dam		
	Part V licensed (GL/a)	Recent actual[1] (GL/a)	Recent actual[1] (ML/d)
Eastern Ridge mine (OB24, OB25 Pit 3)	19[2]	6.35[2]	17.45[2]
OB23			
Orebody 29/30/35	8	2.5	6.9
Jimblebar	32.625	15.6	42.8
Orebody 31			
Total	**59.625**	**24.25**	**67.15**

1. Recent actual from FY2021 and FY2022 (July 2020 to June 2022)
2. Includes surplus water discharge to Ophthalmia Dam system recharge ponds and infiltration basins

4.4 Ophthalmia Dam releases

As discussed in Section 3.2, BHP may undertake controlled releases of water from Ophthalmia Dam to upper Fortescue River tributaries to manage groundwater levels and/or groundwater salinity in the Ethel Gorge aquifer. BHP may also release water from the dam for dam maintenance and safety purposes. The timing of these releases will depend on dam and catchment conditions, to enable the safe operation of the dam. The Outlet Valve 3 at C wall (Figure 1) provides a controlled downstream release of water from the dam to Shovelanna Creek and into the downstream Fortescue River. The estimated maximum discharge (release) rate is approximately 136 ML/d at the service spillway storage capacity (513.5 mRL) (EMM 2020). Table 4 summarises release data since 2016. As shown in Table 4 and Appendix 1, some of the controlled releases coincide with flow events (i.e. during or after the wet season), which is consistent with the response action in the EPWRMP (Section 3.2).

Table 4: Summary of controlled releases from Ophthalmia Dam

Release location	Release dates		Duration (months)	Estimated volume released (GL)	Natural conditions
	Opened	**Closed**			
C wall	28/01/2016	15/03/2016	1.6	5.625	Wet season (natural flows)
C wall	3/06/2016	15/08/2016	2.4	7.9	Dry season (no natural flows and late natural flows)
A wall	13/11/2016	29/01/2017	2.6	3.4	Dry season / start wet season (part natural flows)
C wall	13/03/2017	06/06/2017	2.8	10.5	Wet season (natural flows)
C wall[1]	27/08/2017	16/11/2017	2.7	9.5	Dry season (no natural flows)
C wall	09/02/2018	05/04/2018	1.8	6	Late wet season (part natural flows)

Release location	Release dates		Duration (months)	Estimated volume released (GL)	Natural conditions
	Opened	**Closed**			
C wall[2]	23/01/2020	10/08/2020	6.7	26	Wet season / dry season (part natural flows)
C wall	02/03/2021	19/05/2021	2.6	2.5	Late wet season (part natural flows)
C wall	17/10/2021	20/12/2021	1.5	2.3	Dry season (no natural flow)
C wall[3]	26/01/2022	28/06/2022	5.0	10.5	Wet season / dry season (part natural flows)

1. Discharge (release) trial (BHP 2019b)
2. Release for maintenance to lower water levels to allow remediation works on the dam wall.
3. Release to reduce risk and maintenance requirements for the dam. Commenced during wet season flow and coincides with late wet season (late February and April) flows.

4.5 Groundwater levels

Figure 8 shows observed groundwater levels in the Ethel Gorge aquifer since 1970. The water level measurements are from three bores in the Ethel Gorge TEC (see Figure 3 for locations). The data indicates that groundwater levels are relatively generally lower with increasing distance from the dam. The data shows the decline in groundwater levels during the 1970s due to abstraction from the Ophthalmia Borefield for the Newman town water supply (as discussed in Section 2) and the rapid groundwater level response in the early 1980s following the commissioning of Ophthalmia Dam in 1981. Recent groundwater levels reflect the low rainfall period over 2018/19 (e.g. HEOP0798M and HEOP0415M), however, they are generally within the range of groundwater levels observed since Ophthalmia Dam was commissioned. Groundwater levels recovered near instantaneously, following cyclone Blake in January 2020 and have remained similar since. Since the groundwater level criteria (Table 2) were established in the EPWRMP, monitoring indicates that the overall aquifer response in Monitoring Zone 1 has remained within the groundwater level thresholds.

4.6 Groundwater salinity

Measurements of groundwater salinity in the Ethel Gorge aquifer began in 1978, however, there are very few bores in the monitoring record that have both water level and salinity (Total Dissolved Solids (TDS)/Electrical Conductivity (EC)) measurements to determine potential cause and effect in salinity changes (EMM 2020). Data from three bores in the Ethel Gorge TEC (see Figure 3 for locations) indicate that groundwater salinity has remained at or below 1,500 mg/L TDS since the early 1980s and has remained below the EPWRMP groundwater salinity trigger and threshold (Figure 9).

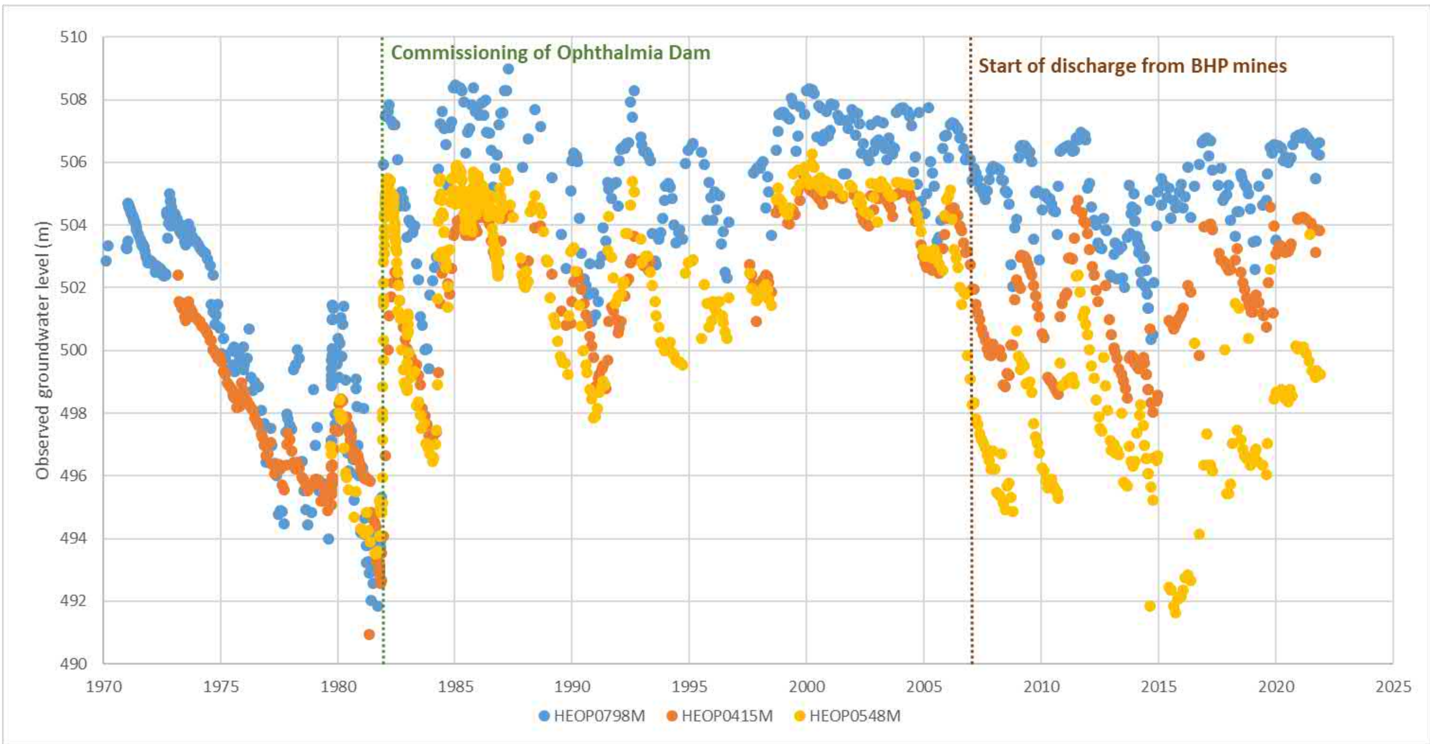


Figure 8: Ethel Gorge aquifer observed groundwater levels

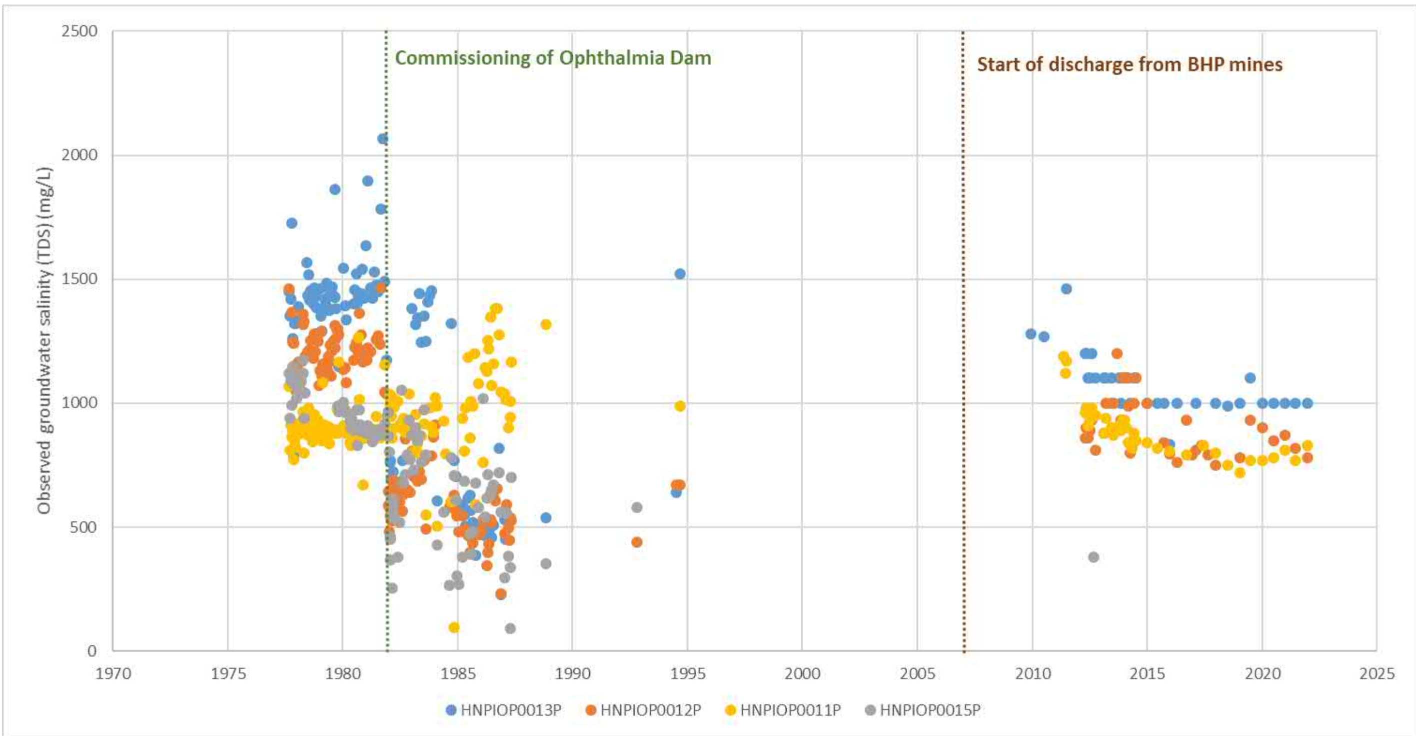


Figure 9: Ethel gorge aquifer observed groundwater salinity

5 Forecast water balance

Figure 10 shows the estimate of forecast surplus water discharge rates to Ophthalmia Dam from the OB32 BWT Proposal, assuming the peak (uncertainty) dewatering scenario from the 2020 groundwater model (BHP 2022). At the time the 2020 model was developed, a peak dewatering rate of 60 ML/d was predicted and it was conservatively assumed that the additional water demand was 0 ML/d. The 2022 groundwater modelling for the OB32 BWT Proposal predicts a peak dewatering rate of 70.4 ML/d (BHP 2022). Recent mine planning has indicated that up to 10 ML/d of dewatered groundwater from OB32 will be used at Eastern Ridge, including the OB32 AWT mine. Therefore, the proposed maximum discharge rate remains at 60 ML/d (equivalent to 21.9 GL/a). The 2022 forecast discharge from OB32 (based on the 2022 groundwater modelling) is lower than the 2020 forecast discharge (see Figure 10). Therefore, the 2020 water balance assessment (which used the 2020 forecast discharge) (see Section 6) was not updated with the 2022 forecast. The actual discharge rates will depend on the mine plan and the variability in dewatering rates, and the forecast rates presented in Figure 10 are for assessment purposes only.

Table 5 summarises the approved and proposed (OB32 BWT) discharge rates to Ophthalmia Dam.

Table 5: Approved and proposed discharge to Ophthalmia Dam

Mine	Surplus discharge to Ophthalmia Dam (GL/a)	Approved or proposed
Eastern Ridge operations (OB23, OB24, OB25, OB25 West)	19	Approved
OB32 BWT	21.9	Proposed
Orebody 29/30/35	8	Approved
Jimblebar	32.625	Approved
Orebody 31		
Total	**81.525**	

Figure 11 shows the 2020 estimate of the total forecast surplus water discharge rate to the Ophthalmia Dam system from all BHP mines that are approved to discharge surplus water into Ophthalmia Dam (including discharge to the recharge ponds): Eastern Ridge operations (Eastern Ridge mine and OB23), Whaleback operations (Orebody 29/30/35) and Jimblebar operations (Jimblebar and Orebody 31), and the proposed discharge from OB32 BWT. The discharge rates are presented at the operations level as surplus water is managed at the operations level. The forecast indicates that the highest surplus is skewed towards the first 10 years and discharge rates reduce after 2030. The highest forecast years are between 2022 and 2026 and are the only years where the forecast is predicted to be higher than recent historical discharge. The forecast also assumes that surplus discharge to the dam from the Jimblebar operations decreases in the mid to late 2020s. The Caramulla surplus scheme (managed aquifer recharge and creek discharge) was approved under Part IV of the EP Act in March 2020 as part of the Jimblebar Iron Ore project - revised proposal (MS1126) and is now operating, and an alternative surplus water management option for OB31 is also planned.

The estimated peak total discharge rate (155 ML/d) shown on Figure 11 is lower than the equivalent average daily total rate for all approved and proposed projects (223 ML/d) based on 81.525 GL/a Table 5. As discussed in Section 4.3, only a portion of the approved rate is discharged to the Ophthalmia Dam system because the licensed rate is an annual peak rate that allows for fluctuations in dewatering rates according to the individual mine plans. The total forecast average daily rate (155 ML/d) as a percentage of the total average approved and proposed rate (223 ML/d) is 69%, which is higher than the total actual recent discharge rate as a percentage of the approved rate (41%). The total recent discharge rates (Section 4.3) and estimated forecast discharge rates to Ophthalmia Dam are used in the current water balance modelling (Section 6.2).

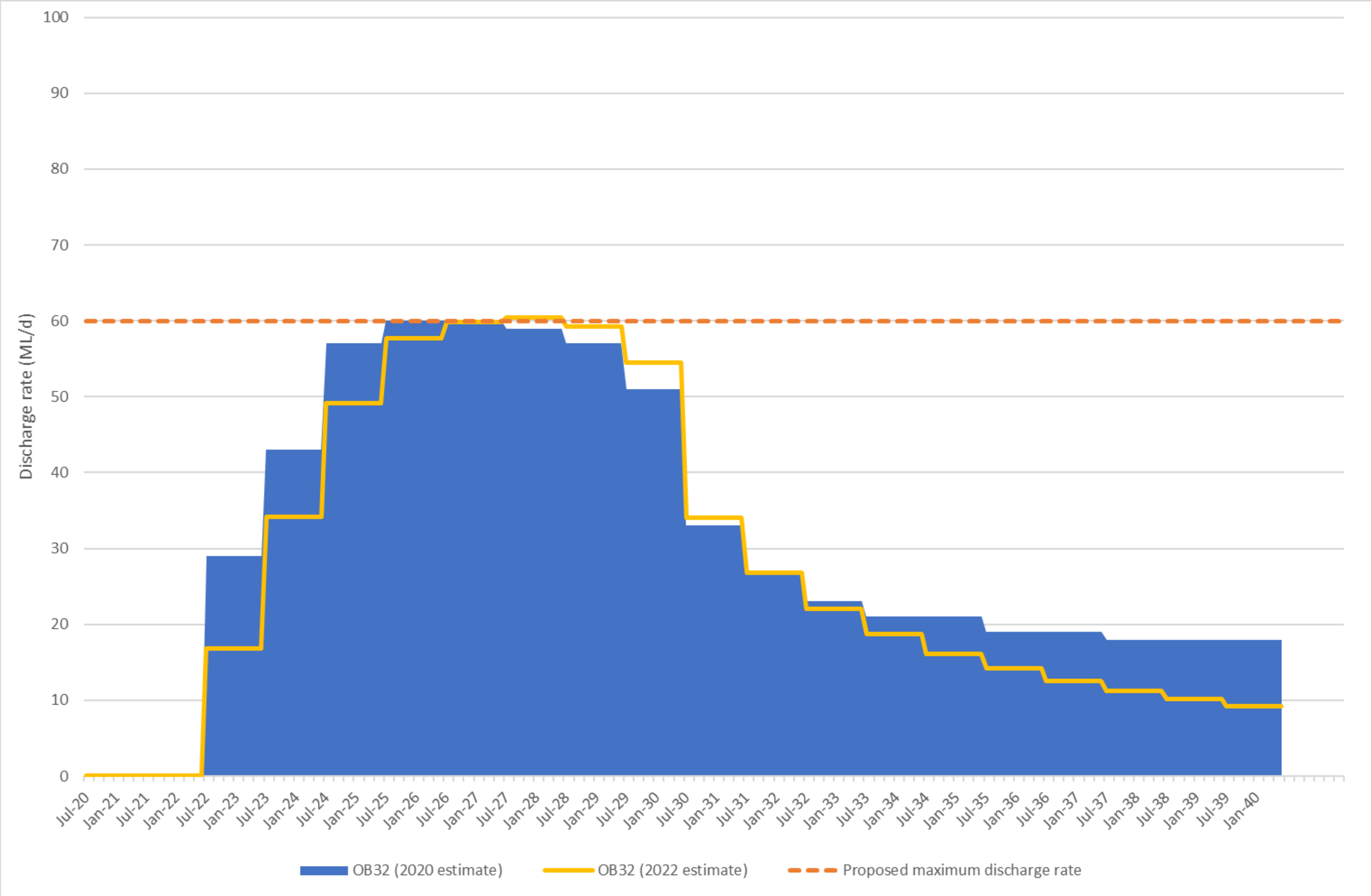


Figure 10: Forecast OB32 BWT discharge rates to Ophthalmia Dam

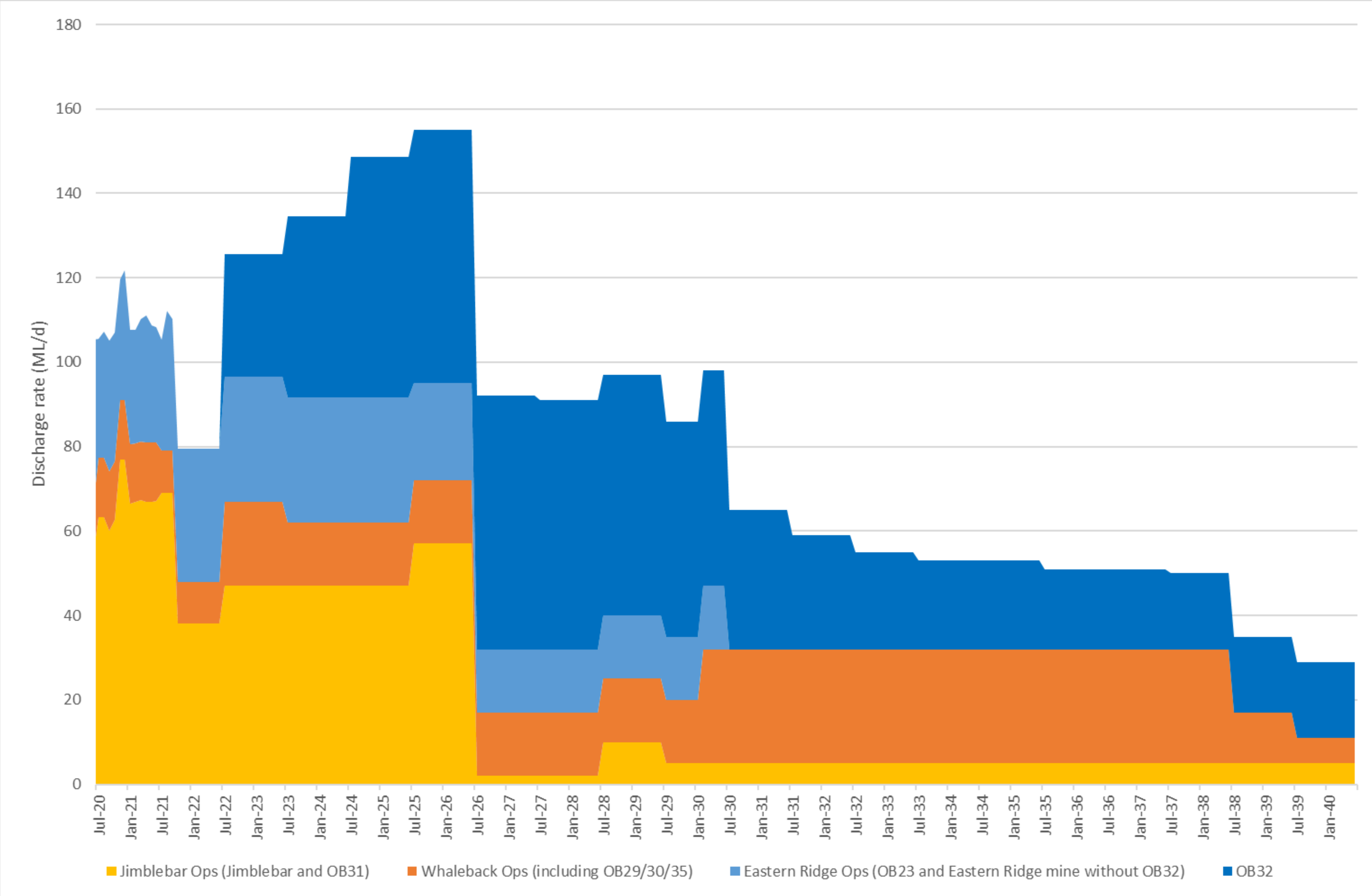


Figure 11: Forecast discharge rates to Ophthalmia Dam system - All BHP mines

6 Water balance model and scenarios

6.1 Eastern Pilbara Hub integrated water balance model

Since Ophthalmia Dam was commissioned, BHP has conducted numerous water balance assessments for the Eastern Pilbara Hub, to understand changes in the Ethel Gorge aquifer system (groundwater levels and quality) from the interactions from groundwater abstraction (water supply and dewatering) and surplus water management at Ophthalmia Dam.

The integrated water balance model for the Ophthalmia Dam and Ethel Gorge aquifer system was developed for BHP by Golder Associates in 2016 and was based on earlier assessments and conceptual model developments undertaken by RPS in 2014 (EMM 2020). The integrated water balance model uses Goldsim, an industry standard simulation software used for analysing the risk of water resource management options. The existing Eastern Pilbara Hub (EPH) integrated water balance model provides a tool to support the mine planning process. The integrated model links to mine forecasts, includes surplus water management options (including Ophthalmia Dam), and has the functionality to assess the potential sensitivity and impacts on Ophthalmia Dam and the Ethel Gorge aquifer in response to surplus water discharge scenarios (Golder Associates 2019).

6.2 Current modelling (2020)

6.2.1 Study overview and objective

BHP commissioned EMM to undertake a water balance review and hydrological assessment of the Ophthalmia Dam and downstream Ethel Gorge aquifer system. The current water balance modelling (2020) updates the modelling undertaken for the 2019 study, which reviewed, updated and modified the EPH integrated water balance model (Golder Associates 2019).

The key objective of the 2020 study was to investigate the sustainable capacity of the Ophthalmia Dam under different operating scenarios (surplus water discharge, climate, water releases from the dam), specifically:

- Groundwater criteria assessment: whether the hydrological parameters in the Ethel Gorge aquifer remain within the criteria set out in the EPWRMP.
- Ophthalmia Dam capacity assessment: the capacity of the dam to accept proposed volumes of surplus water without overtopping the spillway.

The report on the current modelling: *Eastern Pilbara Hub Water Balance: Integrated water balance model review and Ophthalmia Dam water management capacity* (EMM 2020; Appendix 2) details the water balance structure and the conceptual model, model assumptions and limitations, model updates and the surplus water discharge scenarios.

Figure 3 shows the model domain (boundary). The EPWRMP Ethel Gorge Primary Habitat Monitoring Zone (Monitoring Zone 1) presented in Figure 3 extends across the model zones 2 to 5.

6.2.2 Model scenarios

Surplus water discharge scenarios

EMM (2020) assessed three scenarios of surplus water discharge to Ophthalmia Dam (Figure 12):

- Scenario 1: Continue total recent surplus discharge rate (50 ML/d - see Section 4.3) over 20-year period. Scenario defined to assess reliability of results.
- Scenario 2: Apply total forecast surplus discharge rate from approved operations (i.e. excluding OB32).

- Scenario 3: Apply total forecast surplus discharge rate from approved operations and OB32. Scenario 3 shows the incremental influence of OB32 surplus water contributions.

As discussed in Section 5, the discharge rates used for Scenarios 2 and 3 (Figure 12) are based on the best current estimate of forecast surplus water discharge rates from 2020 shown in Figure 11, but exclude the forecast discharge rate to the recharge ponds (assumed constant 15 ML/d) from Eastern Ridge. Scenario 3 also assumes that when dewatering from the approved Eastern Ridge operations ceases that surplus water from OB32 will be discharged to the recharge ponds at the same rate. The updated model structure defines the recharge ponds separately from the Ophthalmia Dam water balance, with discharge to the ponds defined as a stand-alone water management option for the Eastern Ridge operations only (EMM 2020). Scenarios 2 and 3 use forecast rates rather than current approved and proposed surplus water rates (Table 5) because as discussed in Sections 4.3 and 5, only a portion of the approved licensed rate will be discharged into Ophthalmia Dam as the approved rate is a peak rate that allows for fluctuations in dewatering rates according to the individual mine plans.

The above scenarios were run for 20-year future periods starting at 2020, representing 'dry', 'average', and 'wet' hydrological (climate) scenarios to review the potential sensitivity of the water balance assessment. All scenarios include a controlled release of water from the dam from the C Wall valve (Outlet 3) for a 3-month release period (from August to October) (EMM 2020).

Ophthalmia Dam discharge capacity scenarios

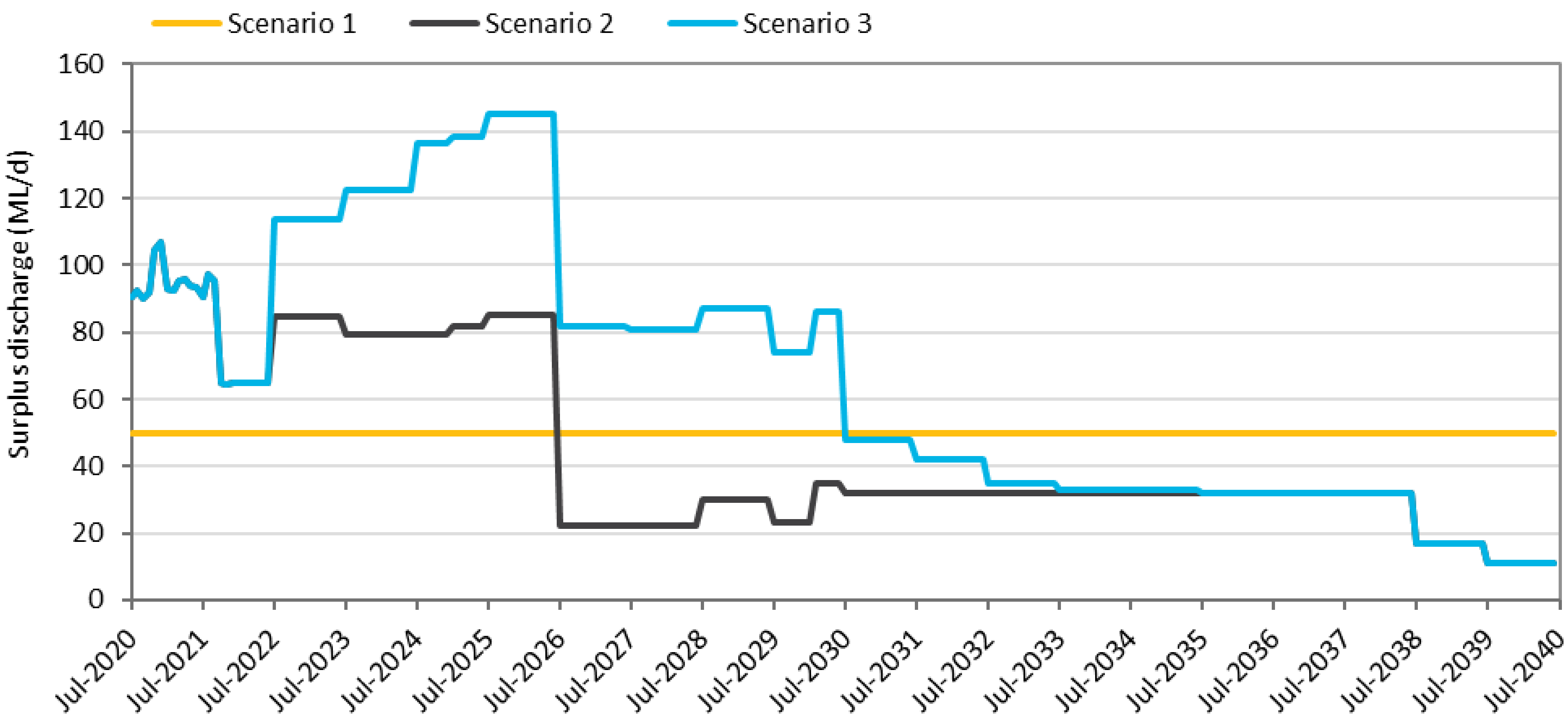
Modelling scenarios were also run to provide an assessment of the maximum ‘physical’ capacity of the dam. This scenario was undertaken to determine the potential capacity of the dam to manage surplus water through evaporation and infiltration losses, with and without a 3-month controlled release. The scenarios are theoretical only as the only inflow to the dam is surplus mine water discharge and creek inflow and direct rainfall contributions are excluded (i.e. set to zero). This aims to represent a ‘theoretical’ perpetual dry season for a 20-year simulation period, where an incrementally increasing surplus discharge rate is applied up to the point at which the dam storage capacity is exceeded and overflow is predicted to occur (EMM 2020).

The dam capacity assessment was undertaken for the following two scenarios:

- Capacity Assessment 1: No controlled release
- Capacity Assessment 2: 3-month controlled release.

The following modifications and adaptions were applied to the water balance model for the dam capacity assessment:

- There is no catchment inflow or direct rainfall input.
- Surplus water discharge represents the only water input to the dam, applied at a constant rate starting at 50 ML/d ramping up to 240 ML/d in 10 ML/d increments.
- Open water evaporation and seepage are included as losses.
- Controlled release of water from the dam is included as an option (Capacity Assessment 2) based on a 3-month release duration from August each year (at an average release rate of 100 ML/d = 9,100 ML over the 3-month period, or 25 ML/d annualised over 12 months).
- The assumed ‘criteria’ for the assessment is the estimation of the maximum surplus water discharge rate where the dam storage does not overtop the spillway.



Source: EMM (2020), Figure 5.1

Figure 12: Surplus water discharge scenarios

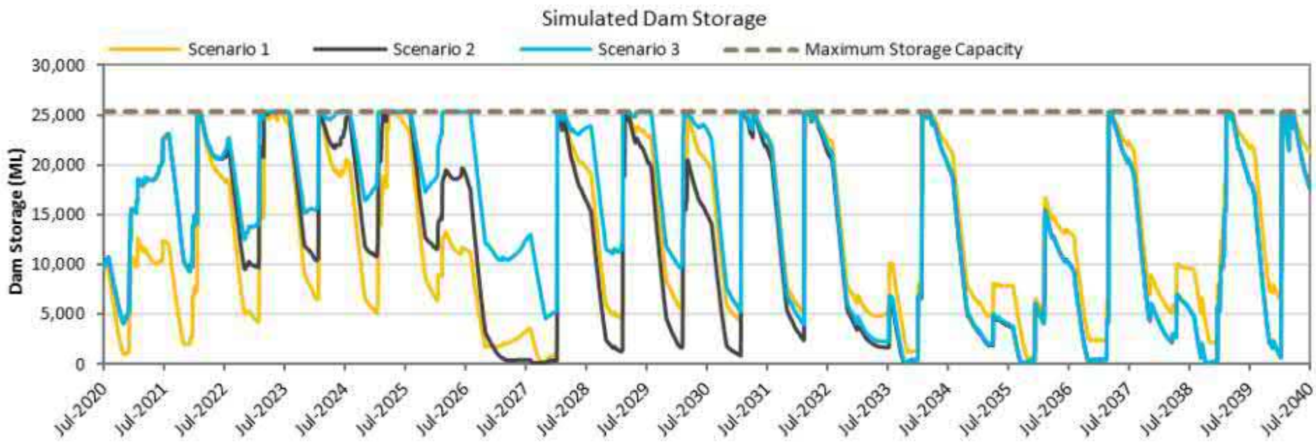
7 OB32 BWT assessment

The water balance assessment for OB32 BWT focuses on the modelled contribution of OB32 surplus water discharge to Ophthalmia Dam (Scenario 3 predictions as described in Section 6). The results of the modelling (EMM 2020) are summarised in Sections 7.1 and 7.3. Section 7.1.1 discusses changes in discharge to the dam and dam inundation. Because the modelling was undertaken in 2020 and assumed that discharge from OB32 starts in 2022 (see Figure 12), the dates discussed in the following assessment are for comparative purposes only.

7.1 Ophthalmia Dam water balance

7.1.1 Dam storage and inundation

Figure 13 shows the simulated (predicted) dam storage for the model run for the 'average' hydrology scenario, with a 3-month controlled release each year (model run 13). Figure 13 shows that dam storage is predicted to be higher with the contribution of surplus water from OB32 (Scenario 3 compared to Scenario 2) for longer periods (particularly due to the higher discharge rates between 2022 and 2026), but the predicted dam storage for Scenarios 2 and 3 is similar from 2032 onwards.



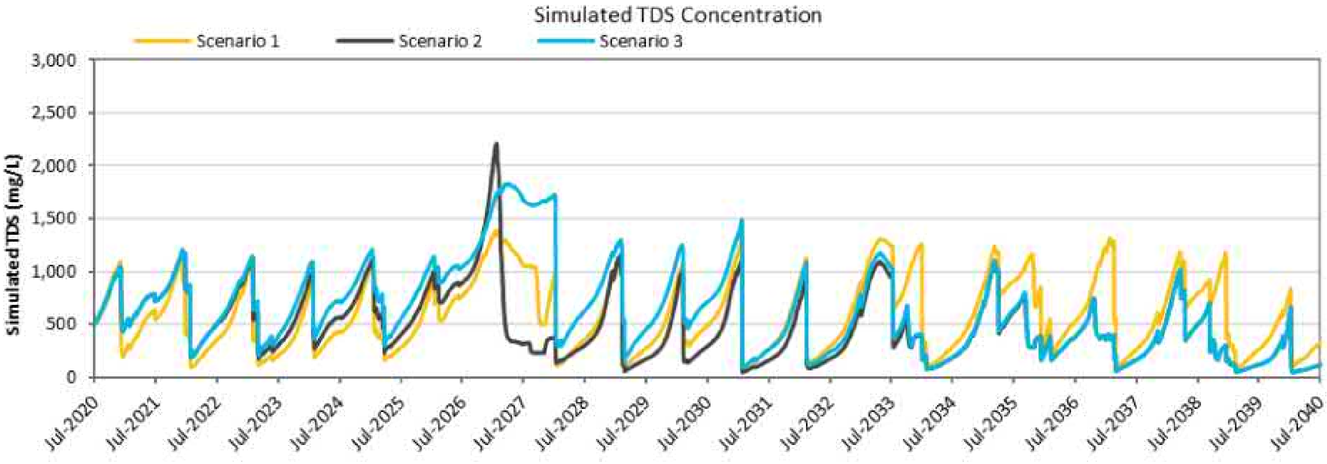
Source: EMM (2020), Figure 5.6

Figure 13: Predicted dam storage

As discussed in Section 4.1, the maximum inundation area is controlled by the maximum operating storage capacity of the dam at the service spillway elevation (513.5 mRL). The OB32 BWT Proposal will not result in a change to the storage capacity so there will be no change to the maximum inundation area. Figure 13 shows that there will still be the seasonal change in storage, however, dam storage will be relatively higher for longer periods during the higher forecast discharge years. During the periods where the dam storage is predicted to be higher from the contribution of surplus water from OB32 (Scenario 3 compared to Scenario 2), the inundation extent is similar to historical inundation in wet years (see Section 4.1). As discussed above, the predictions are for the 'average' hydrology scenario. BHP also notes that the calibration shows that the model simulation has over-estimated the volume of water in the dam compared to the measured volume of water in the dam (EMM 2020; Figure 4.6). The actual dam storage will depend on the catchment and climate conditions and actual discharge rates to the dam. Figure 11 shows that forecast discharge including discharge from OB32 will be lower than recent historical discharge except for the four peak discharge years (shown as late 2022 to 2026). Therefore, when the discharge is similar or lower than recent historical discharge rates, the pattern of inundation (change in extent and duration) is not expected to change compared to recent historical inundation.

7.1.2 Dam salinity

There is the potential for the salt load in the dam to increase from increased discharge as the salinity of the discharge water from all BHP mines is higher than the rainfall salinity. Figure 14 shows the predicted Ophthalmia Dam salinity for model run 13. The plot shows that the seasonal freshening will still occur. The predicted peak salinity (TDS) for the contribution of surplus water from OB32 (Scenario 3) is generally less than 1,100 mg/L for most years but is as high as approximately 1,800 mg/L during the peak discharge years around 2026. The predicted dam salinity for Scenario 3 remains within the range of observed dam salinity shown in Figure 9.



Source: EMM (2020), Figure 5.6

Figure 14: Predicted dam salinity

7.2 Groundwater criteria assessment

Figure 15 to Figure 18 show the predicted groundwater levels and groundwater salinity in the Ethel Gorge aquifer for model run 13. The model outputs are shown for model zones (2 to 5), as the EPWRMP Ethel Gorge Primary Habitat Monitoring Zone (Monitoring Zone 1) extends across these four zones of the model (as discussed in Section 6.2.1).

7.2.1 Groundwater levels

Figure 15 to Figure 18 indicate that predicted groundwater levels in the Ethel Gorge aquifer are higher with the contribution of surplus water from OB32 (Scenario 3 compared to Scenario 2) due to the higher discharge rates between 2022 and 2026 (up to approximately 0.75 m higher within any of the model zones), but the predicted groundwater levels for Scenarios 2 and 3 are similar from 2030 onwards. The modelled groundwater levels for Scenario 3 (representing the cumulative discharge scenario) remain within the range of observed groundwater levels shown in Figure 8.

The cumulative increase in average groundwater levels as a result of surplus water discharge is predicted to be in the order of less than 0.5 to 1 m. This is within the predicted natural range of groundwater variability and is within the EPWRMP criteria (EMM 2020), i.e. below the groundwater level change trigger of less than 4 m/year or total change of 6 m (Table 2). Historical groundwater monitoring indicates that more significant variations in groundwater levels are associated with varying abstraction rates and dewatering activities rather than responses to shifts in more distributed and consistent fluxes such as seepage from the dam (EMM 2020).

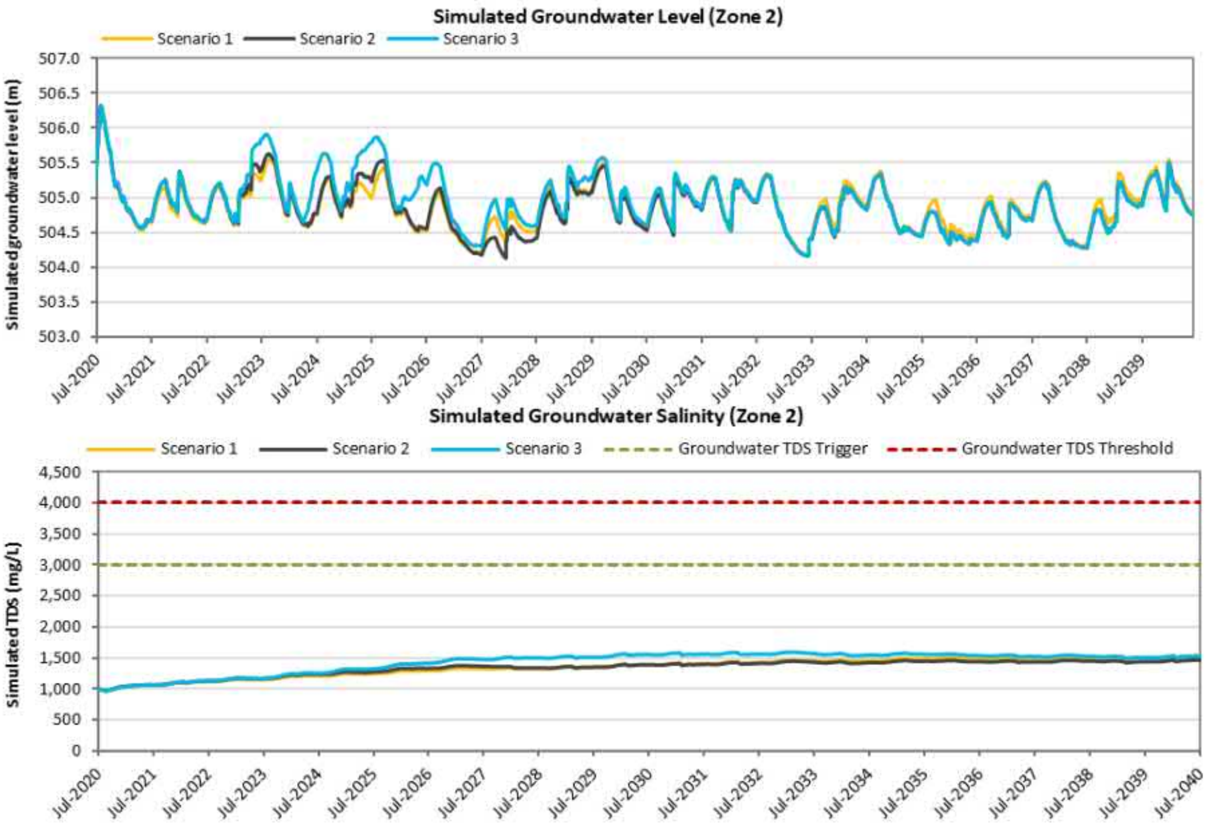
7.2.2 Groundwater salinity

The main mechanism for increasing salinity in the Ethel Gorge aquifer is increasing groundwater levels, driven largely by enhanced dam seepage from increased discharge to the dam. As groundwater levels rise, groundwater is removed via evapotranspiration, which increases the concentration of salt and the model predicts a higher salinity in the aquifer

(EMM 2020). Modelling indicates that increasing groundwater levels in the Ethel Gorge aquifer, driven largely by enhanced dam seepage, has the potential to lead to increasing groundwater salinity (TDS) over the 20-year simulation period. Figure 15 to Figure 18 indicate that groundwater salinity in the Ethel Gorge aquifer is higher for Scenario 3 compared to Scenario 2 from the mid-2020s, ranging from up to 250 mg/L higher in model zone 2 to up to 500 mg/L higher in model zone 5. This difference reduces by the end of the simulation period except for model zone 5 (Figure 18). All simulations show a stabilisation of the salinity increase by the end of the simulation period. The modelled groundwater salinity for Scenario 3 remains at or below approximately 2,000 mg/L, within the range of observed groundwater salinity shown in Figure 9.

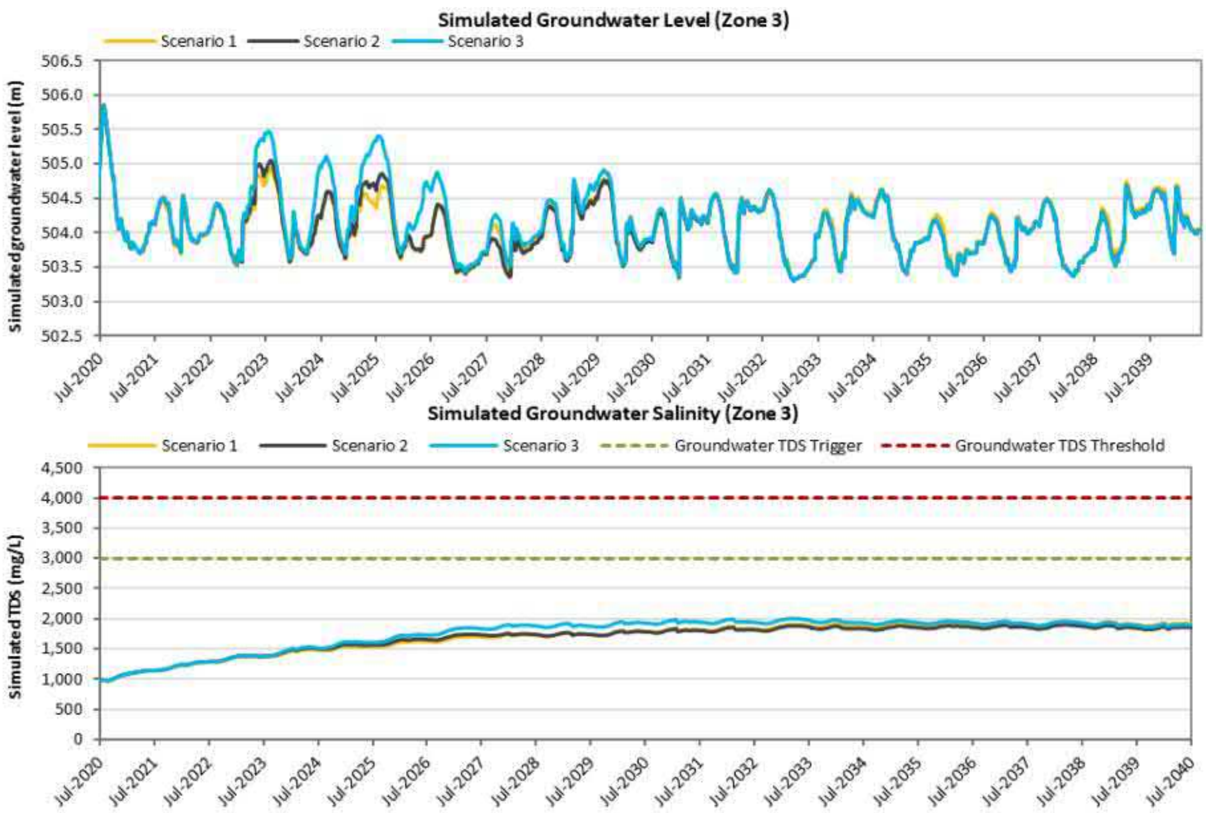
EMM (2020) noted that here is a high level of uncertainty relating to these predictions with considerable natural variable (spatially and temporally) in groundwater quality. However, the predicted maximum groundwater salinity (TDS) is within the range that has been measured elsewhere through the Ethel Gorge aquifer system and is within the EPWRMP criteria, i.e. below the groundwater salinity trigger of less than 3,000 mg/L TDS (Table 2).

EMM (2020) also noted the modelling results show that high dam storage conditions and related increases in controlled releases and spillway flows may result in an increase in river recharge fluxes to the downstream groundwater system, which may act to freshen the groundwater system and buffer potential increases in salinity.



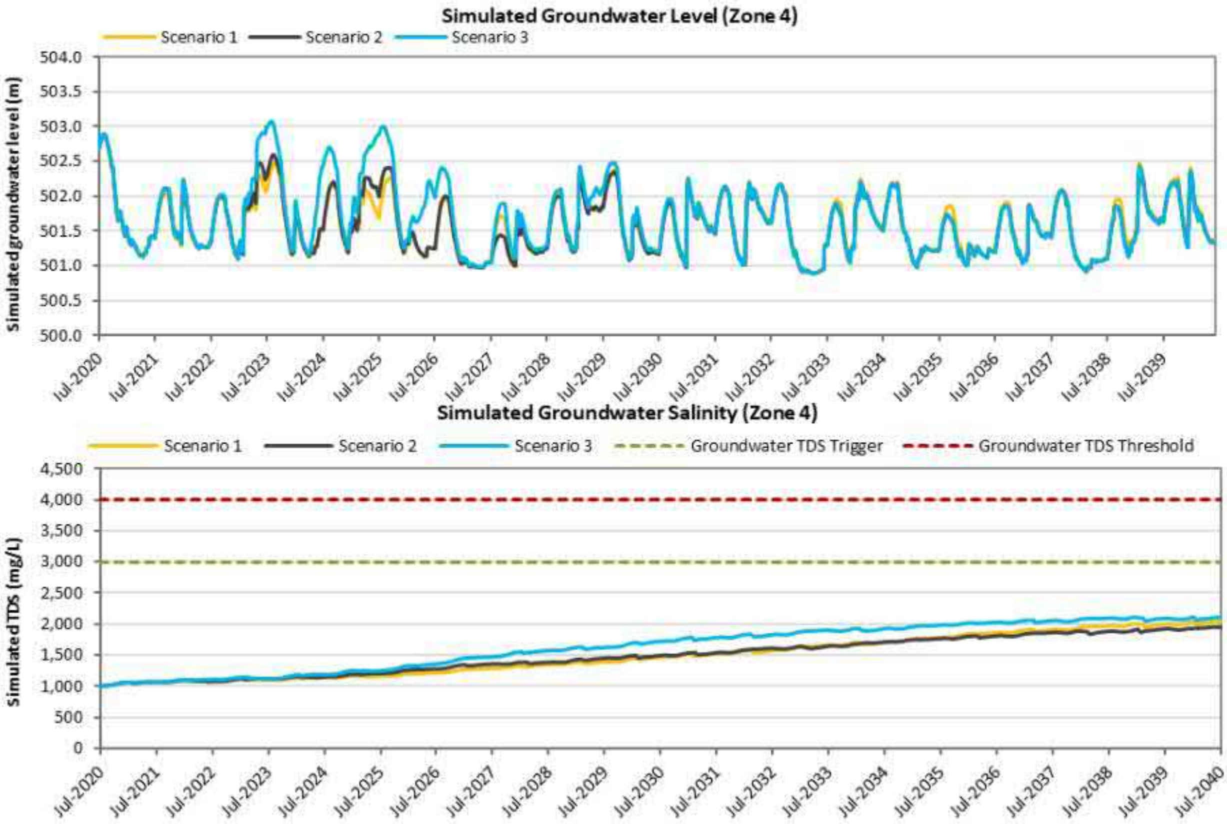
Source: EMM (2020), Figure 5.9

Figure 15: Predicted Ethel Gorge aquifer groundwater levels and salinity - Model zone 2



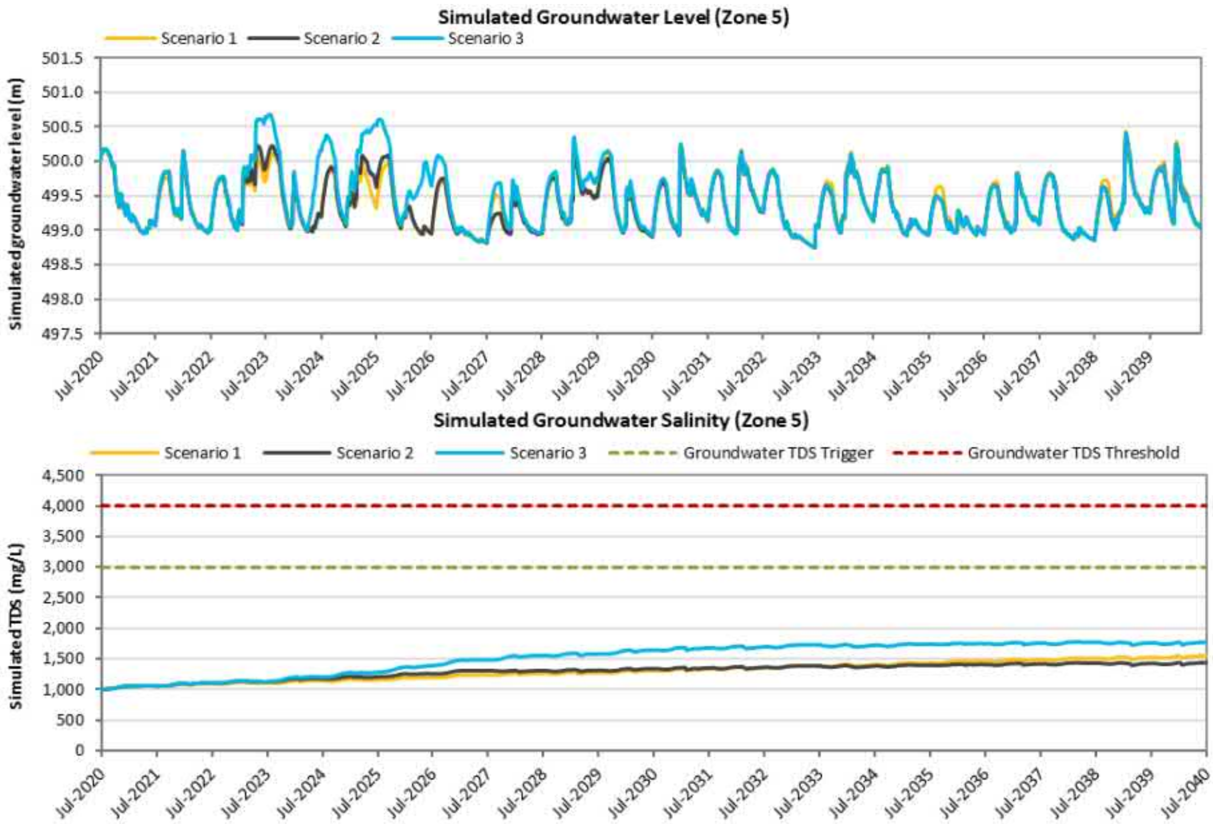
Source: EMM (2020), Figure 5.10

Figure 16: Predicted Ethel Gorge aquifer groundwater levels and salinity - Model zone 3



Source: EMM (2020), Figure 5.11

Figure 17: Predicted Ethel Gorge aquifer groundwater levels and salinity - Model zone 4



Source: EMM (2020), Figure 5.12

Figure 18: Predicted Ethel Gorge aquifer groundwater levels and salinity - Model zone 5

7.3 Ophthalmia Dam capacity assessment

As discussed in Section 6.2, the objective of the current modelling was to investigate the sustainable capacity of Ophthalmia Dam. Additional theoretical scenarios were run to assess the 'physical' capacity of the dam, i.e. to determine the maximum surplus discharge rate when the dam reaches the maximum storage capacity (storage of 25.33 GL) and does not overtop the spillway. The 'theoretical' capacity assessment predicted the following:

- Capacity Assessment 1 (no controlled release): Ophthalmia Dam storage reaches a spilling condition at approximately 115 ML/d surplus water discharge.
- Capacity Assessment 2 (3-month controlled release): Ophthalmia Dam storage reaches a spilling condition at approximately 135 ML/d.

Therefore, the potential yield benefit of the 3-month controlled release is equivalent to approximately 20 ML/d of additional constant surplus water discharge.

Figure 19 shows the estimated theoretical capacity of Ophthalmia Dam for the two capacity assessment scenarios against the estimated forecast surplus water discharge rates to Ophthalmia Dam only (i.e. excludes discharge to the recharge ponds as discussed in Section 6.2.2. Although the above scenarios are theoretical only as they exclude catchment inflows and rainfall, they indicate that Ophthalmia Dam is likely to have sufficient capacity to receive the total surplus discharge from approved operations (i.e. Scenario 2) with or without the 3-month controlled release (Figure 19). However, the dam may reach capacity during the estimated peak discharge years (2024 to 2026) from the total surplus discharge from approved operations and OB32 (i.e. Scenario 3) even with the 3-month controlled release.

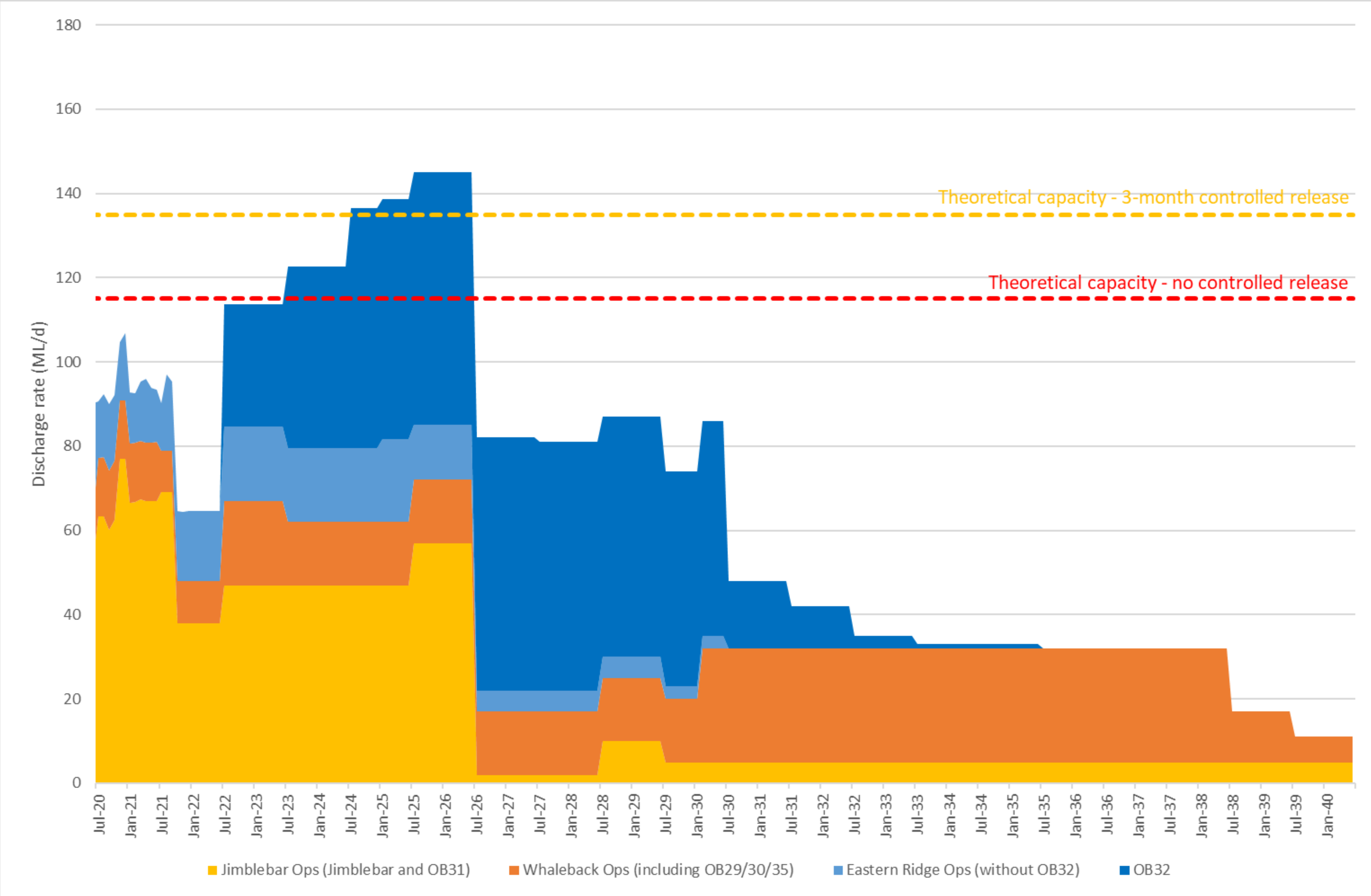


Figure 19: Theoretical Ophthalmia Dam capacity

7.4 Conclusions

The review and updates to the integrated water balance model showed that simulated dam water balance results closely match historical Ophthalmia Dam water level and quality (TDS concentration) observations. Therefore, there is a high level of confidence in the Ophthalmia Dam water balance predictions based on future surplus water discharge scenarios (EMM 2020).

The groundwater component of the model (representing the Ethel Gorge aquifer system downstream of the dam) provides reasonable simulations of long-term observed groundwater level and salinity variability and trends. However, it is acknowledged that the modelling approach has a number of limitations with respect to accuracy and reliability of groundwater balance simulations owing to the inherent spatial and temporal variability in groundwater levels and salinity, in conjunction with model assumptions and numerical algorithms used to approximate (and simplify) the complex hydrological processes influencing the Ethel Gorge aquifer system. Therefore, predictions should be used to identify trends and magnitude of change, particularly for comparing relative changes between scenarios, rather than be considered accurate predictions of future groundwater conditions at a specific location. (EMM 2020).

Evaluation of the potential hydrological changes from the discharge of surplus water from the OB32 BWT Proposal to Ophthalmia Dam (up to 60 ML/d or 21.9 GL) indicates that groundwater and salinity will remain within the range of observed levels. Predictions show that none of the EPWRMP groundwater level or groundwater salinity triggers or thresholds are exceeded for any of the hydrological scenarios over the 20-year simulation period, assuming a 3-month controlled release period. A controlled release of up to 3 months total in the dry season is consistent with the response actions outlined in the EPWRMP.

Modelling scenarios undertaken to assess the theoretical capacity of Ophthalmia Dam indicate that the potential maximum capacity of the dam to manage surplus water via infiltration, evaporation and controlled discharge, without overtopping of the dam during the dry season, is approximately 115 ML/d without any controlled discharge and potentially up to 135 ML/d with a 3-month annual controlled discharge (EMM 2020). This is lower than the estimated peak discharge rate from all approved operations and OB32 (145 ML/d). Therefore, it is possible that the capacity of Ophthalmia Dam may be reached during the estimated peak discharge years (for approximately 2 years). Potential management options are discussed in Section 8.

There is no change to the storage capacity so there will be no change to the maximum inundation area. The pattern of inundation (change in extent and duration) is expected to be within historical variation and during peak discharge years, the inundation extent and duration may be more similar to historical wet years.

8 Surplus water management requirements

As discussed in Section 7, model predictions indicate that the groundwater level and salinity criteria in the EPWRMP will continue to be met if surplus water discharge to Ophthalmia Dam is increased due to the contribution from the OB32 BWT Proposal. Therefore, BHP proposes to manage the additional surplus water discharge from the OB32 BWT Proposal in accordance with current groundwater level and groundwater salinity criteria (triggers and thresholds) in the EPWRMP.

If future detailed surplus water forecasts indicate that the capacity of Ophthalmia Dam could be reached, BHP will manage the surplus discharge volumes from its operations and the operation of the dam to avoid overtopping of the dam spillway and uncontrolled surface flows to the Fortescue River in the dry season. Management options to limit releases to the Fortescue River in the dry season include the management measures and controls outlined in the EPWRMP, e.g. release water from the dam during wet season flow events or alter the surplus water discharge regime (amount of water discharged) from its eastern mines to the Ophthalmia Dam system.

As communicated to the DWER-EPA Services, BHP is also implementing and investigating alternative surplus water management options for its Eastern Pilbara mines, including managed aquifer recharge (MAR) and creek discharge in the catchment, to minimise risk to operations and alleviate dependency on the dam (BHP 2019b). This includes implementing the Caramulla surplus water scheme (MAR and creek discharge) and investigating alternative surplus water options as part of its Eastern Pilbara Regional Surplus Water study.

Future surplus water management may also depend on future climate and the management of the dam itself. A wetter or drier climate may require regular more frequent or longer duration releases from the dam, to maintain groundwater levels and salinity in the Ethel Gorge TEC and/or seasonal flows to the Fortescue River. Changes may also be required to meet contemporary dam engineering and safety standards (noting that Ophthalmia Dam was constructed in the 1980s). BHP will assess the potential environmental impacts of any proposed major changes, including if changes are required to the EPWRMP.

9 References

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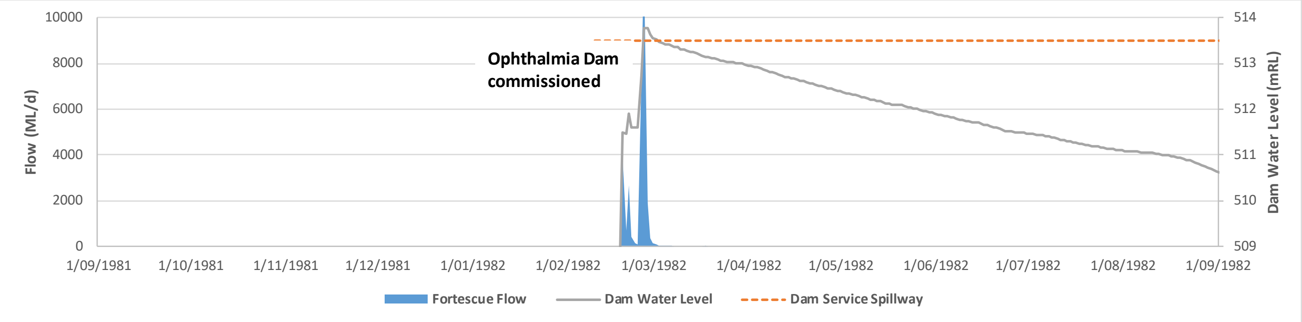
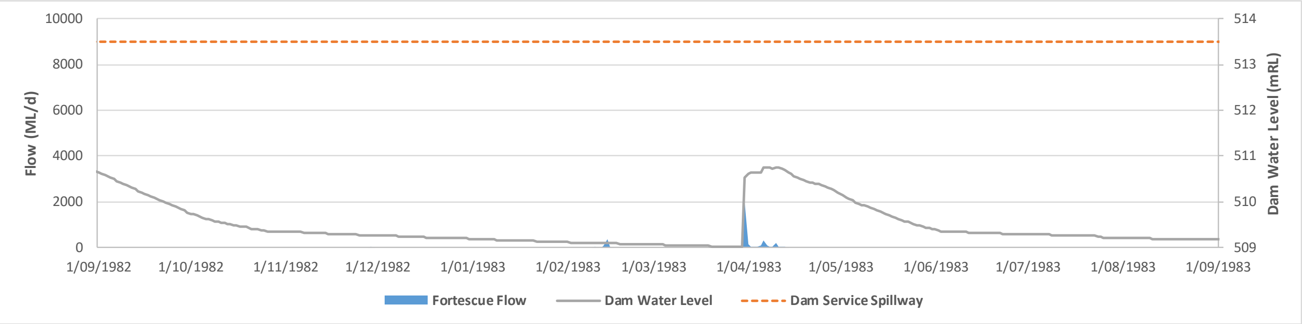
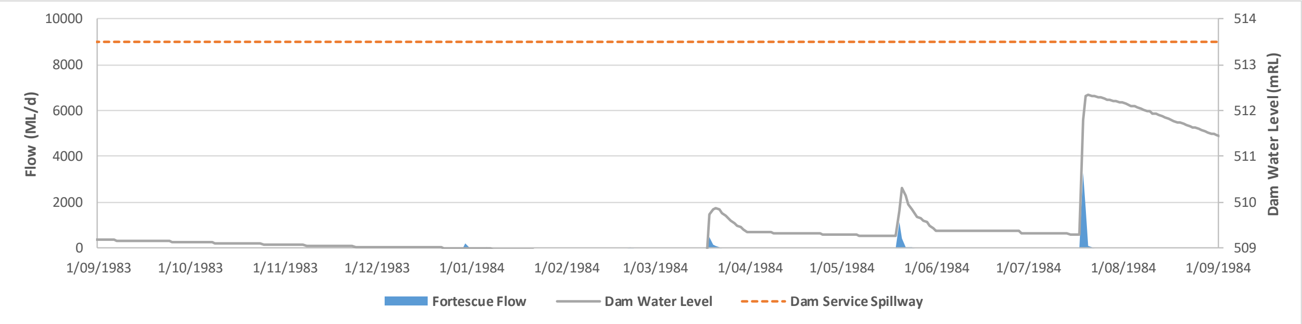
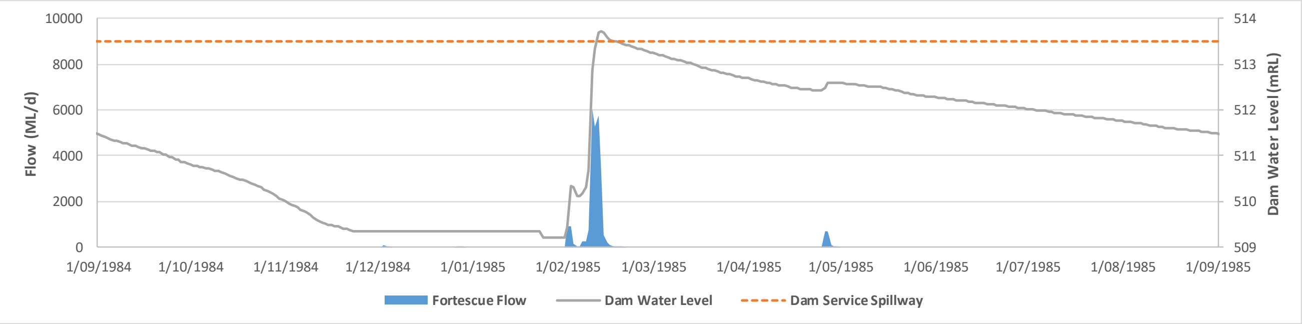
Appendices

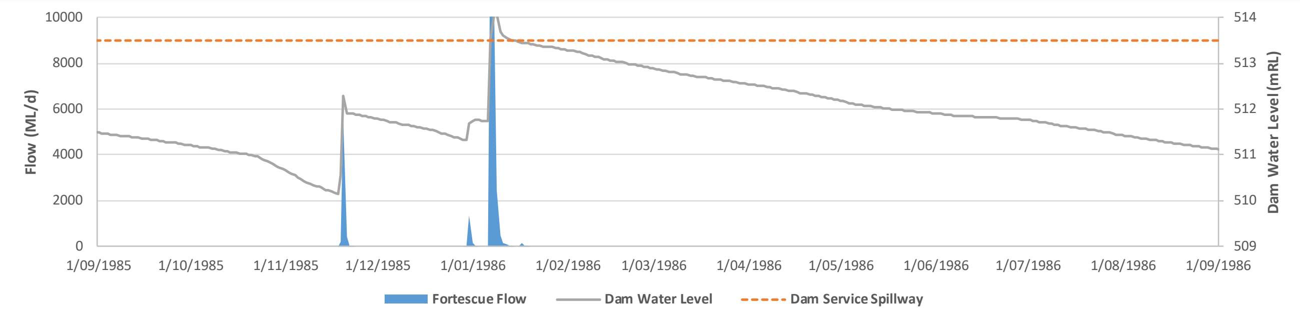
Appendix 1 Fortescue River flow and Ophthalmia Dam storage







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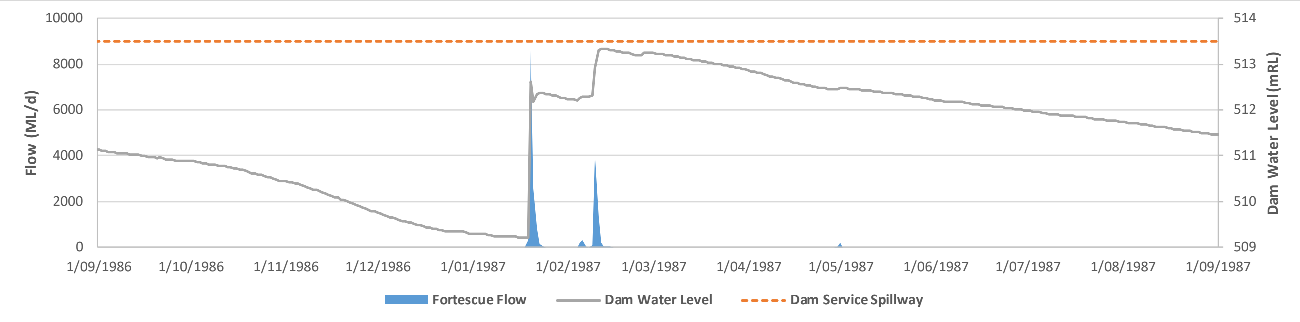
Fortescue Flow
Dam Water Level
Dam Service Spillway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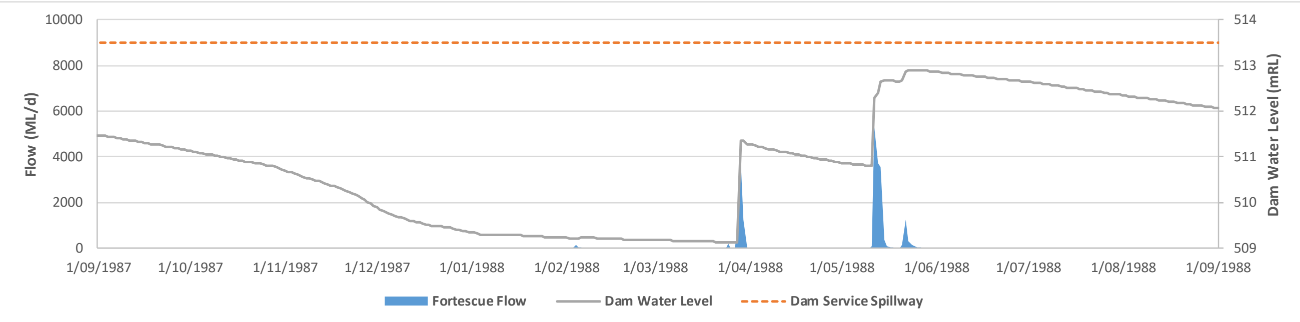
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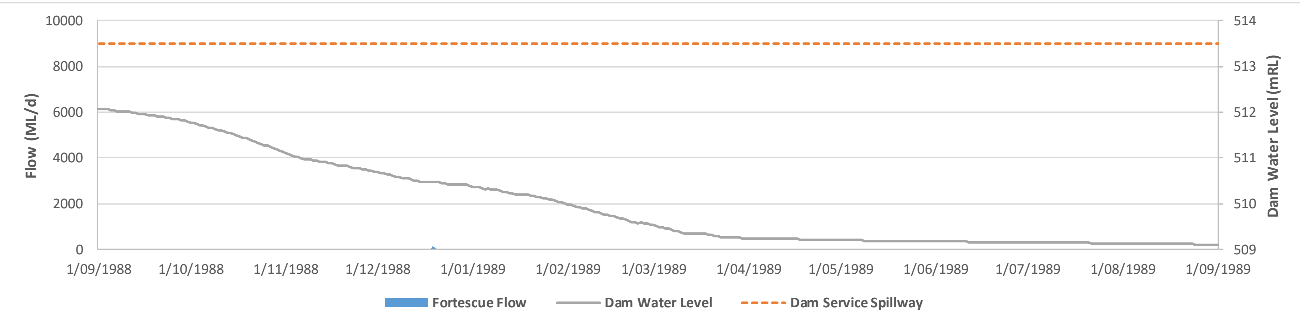
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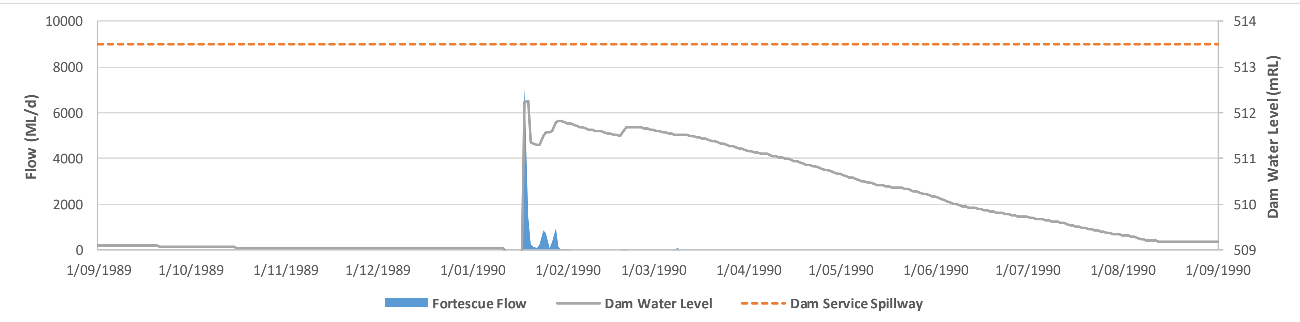
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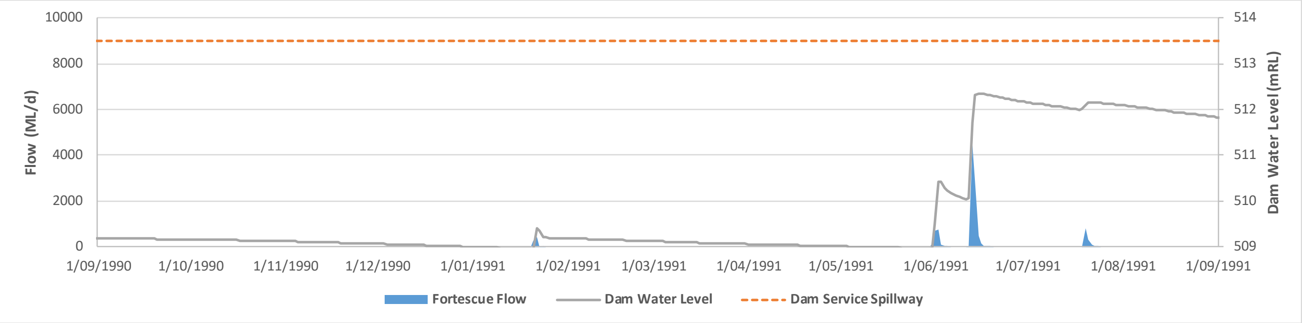
Dam Service Spillway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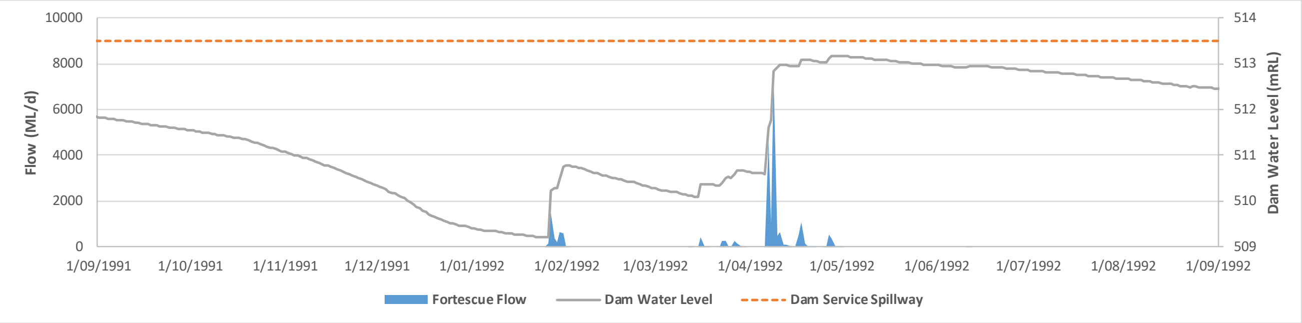
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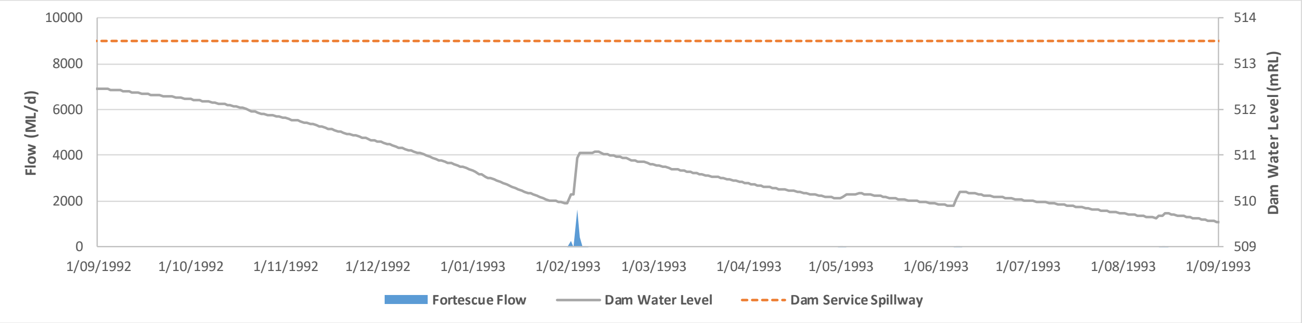
Dam Water Level
Dam Service Spillway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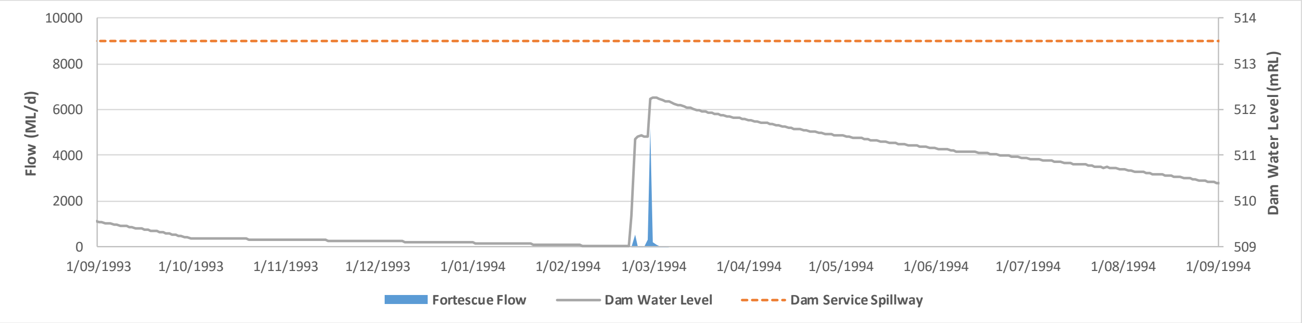
Dam Water Level
Dam Service Spillway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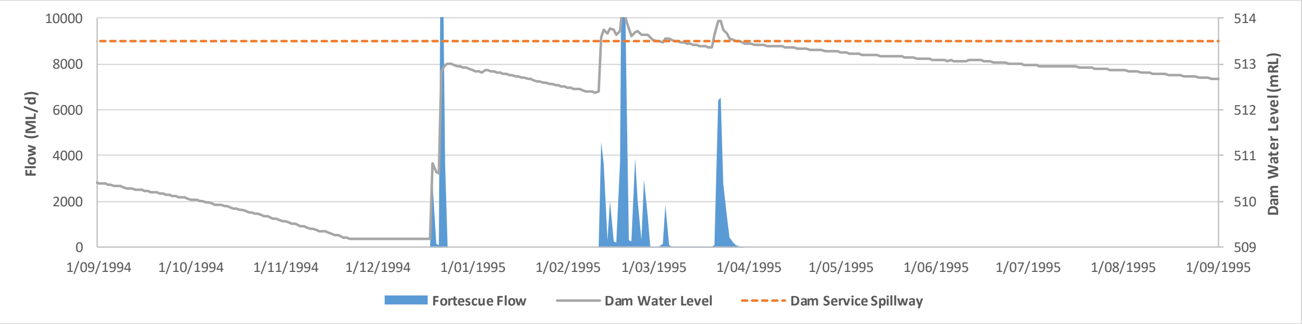
Dam Water Level
Dam Service Spillway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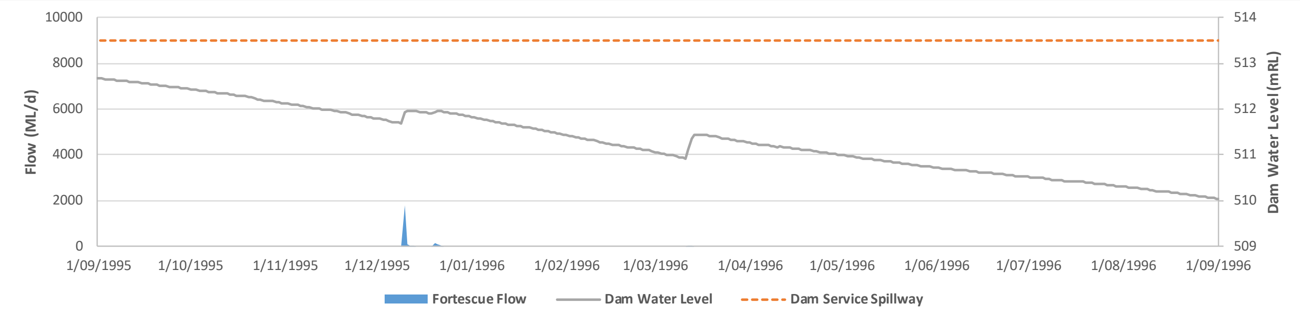
Fortescue Flow
Dam Water Level
Dam Service Spillway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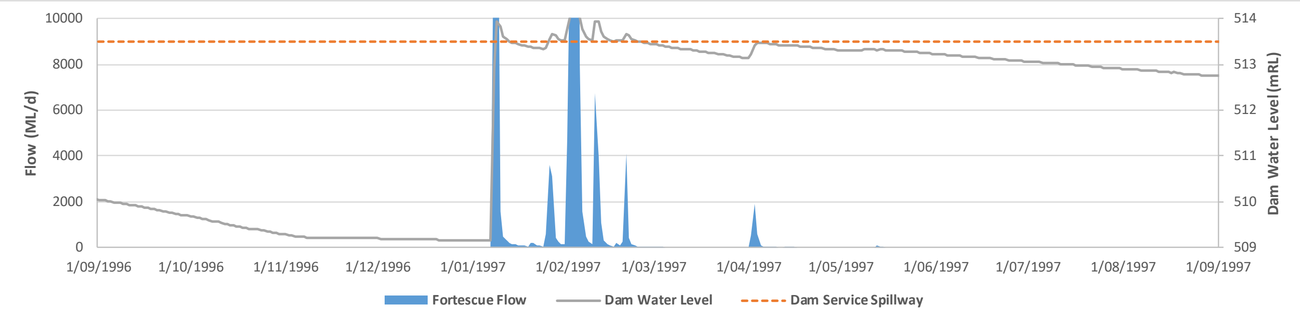
Dam Water Level
Dam Service Spillway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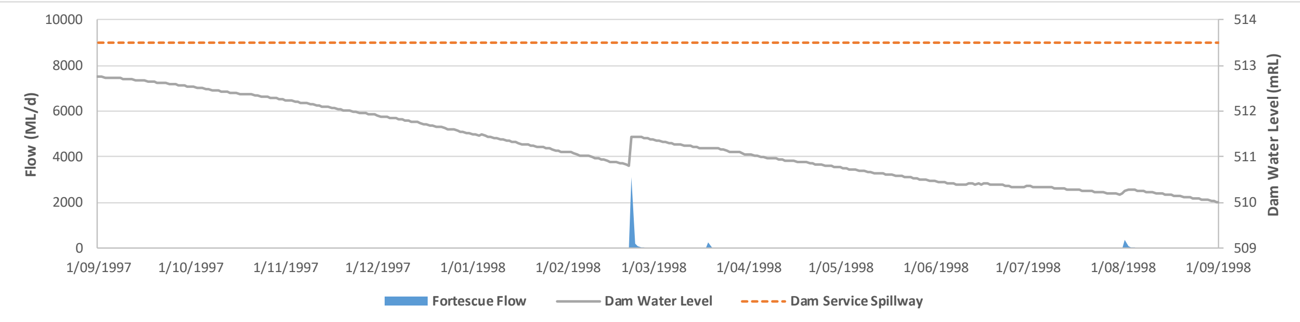
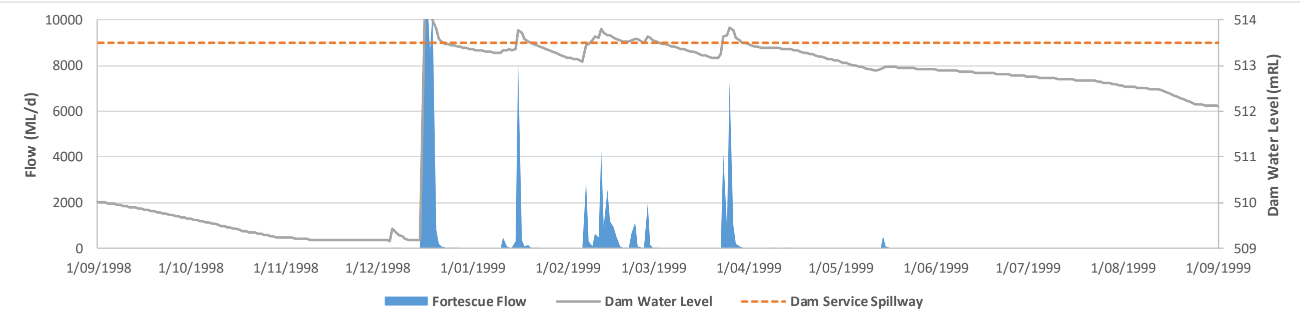
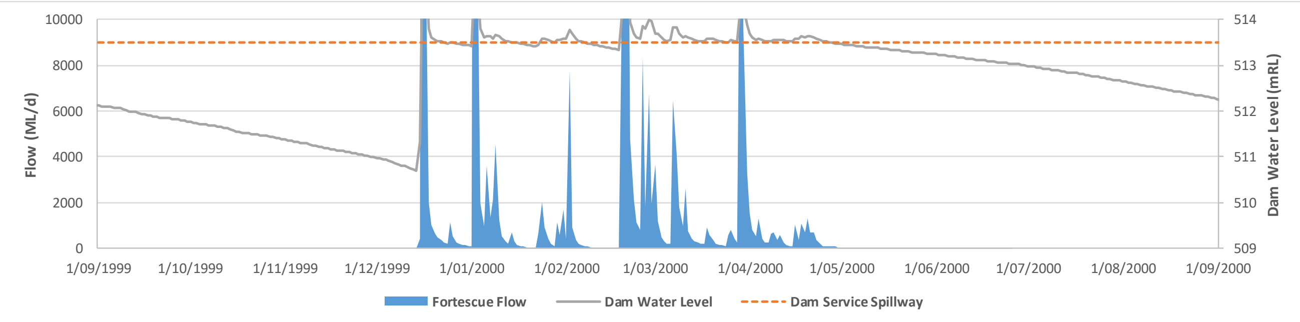
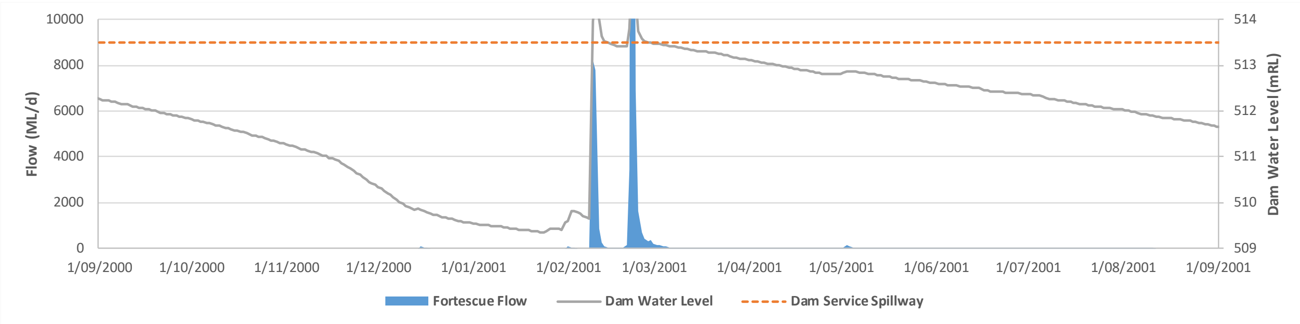
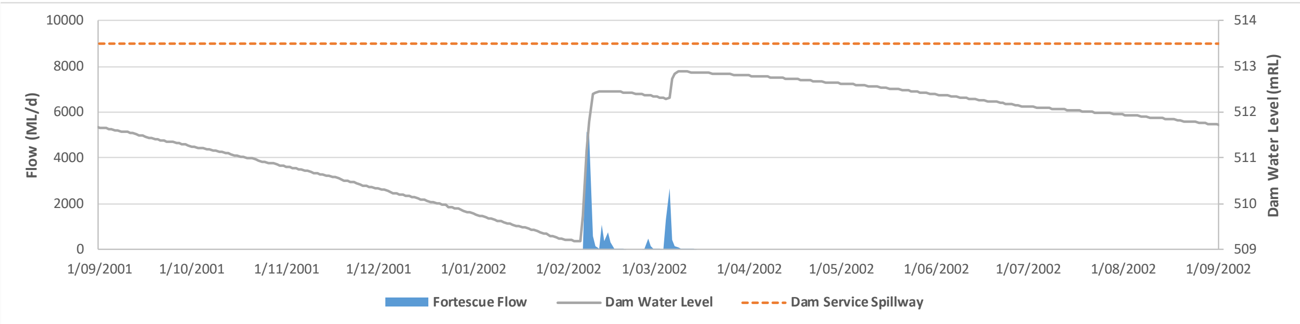
Dam Water Level (mRL)
1/09/1996
1/10/1996
1/11/1996
1/12/1996
1/01/1997
1/02/1997
1/03/1997
1/04/1997
1/05/1997
1/06/1997
1/07/1997
1/08/1997
1/09/1997
Fortescue Flow
Dam Water Level
Dam Service Spillway

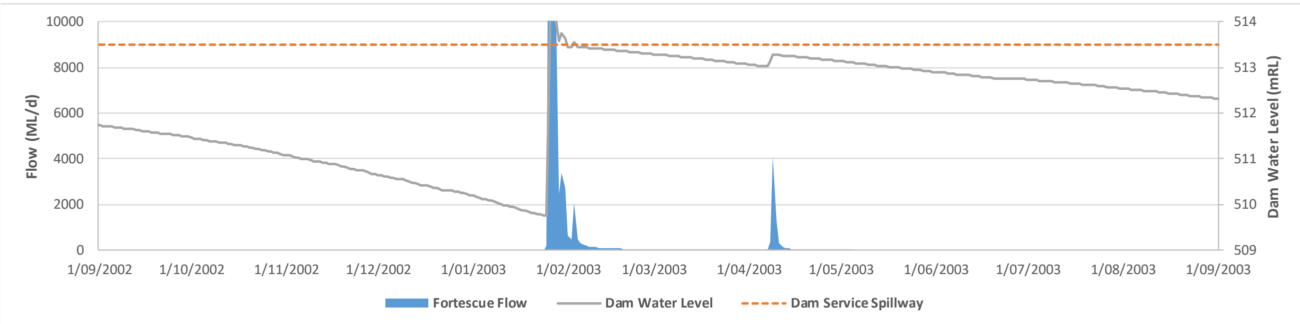

Flow (ML/d)
Dam Water Level (mRL)
1/09/1997
1/10/1997
1/11/1997
1/12/1997
1/01/1998
1/02/1998
1/03/1998
1/04/1998
1/05/1998
1/06/1998
1/07/1998
1/08/1998
1/09/1998
Fortescue Flow
Dam Water Level
Dam Service Spillway

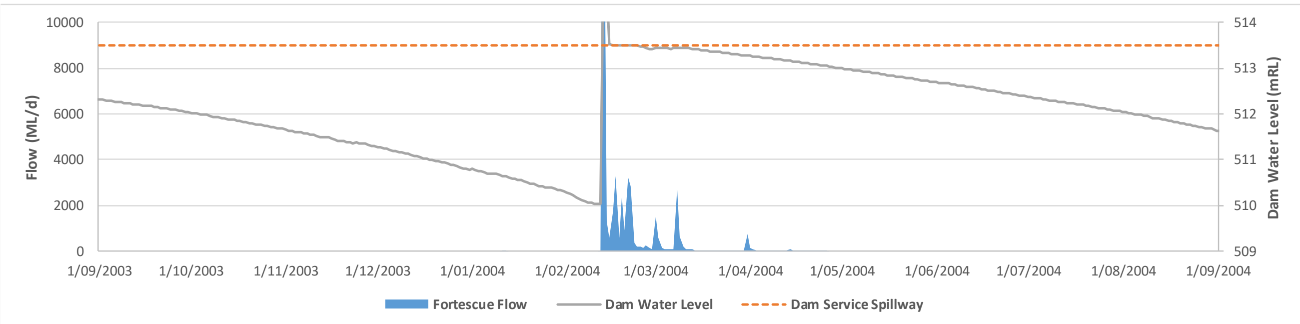

Flow (ML/d)
Dam Water Level (mRL)
1/09/1998
1/10/1998
1/11/1998
1/12/1998
1/01/1999
1/02/1999
1/03/1999
1/04/1999
1/05/1999
1/06/1999
1/07/1999
1/08/1999
1/09/1999
Fortescue Flow
Dam Water Level
Dam Service Spillway

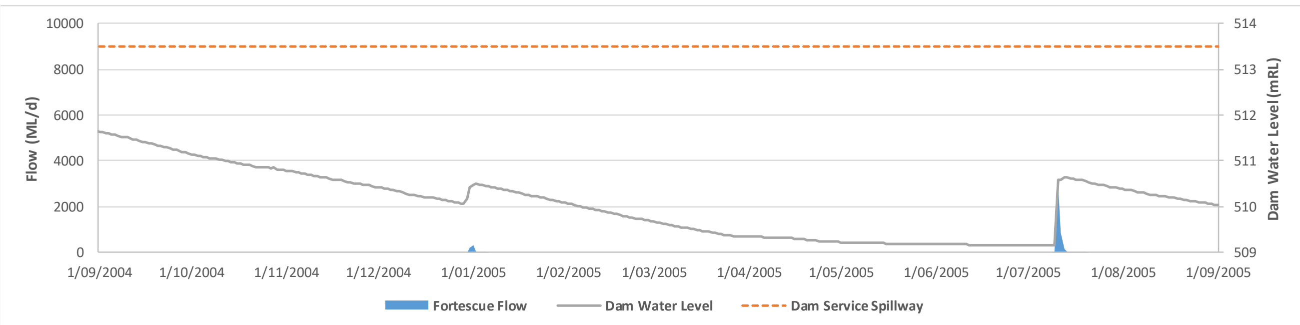

Flow (ML/d)
Dam Water Level (mRL)
1/09/1999
1/10/1999
1/11/1999
1/12/1999
1/01/2000
1/02/2000
1/03/2000
1/04/2000
1/05/2000
1/06/2000
1/07/2000
1/08/2000
1/09/2000
Fortescue Flow
Dam Water Level
Dam Service Spillway

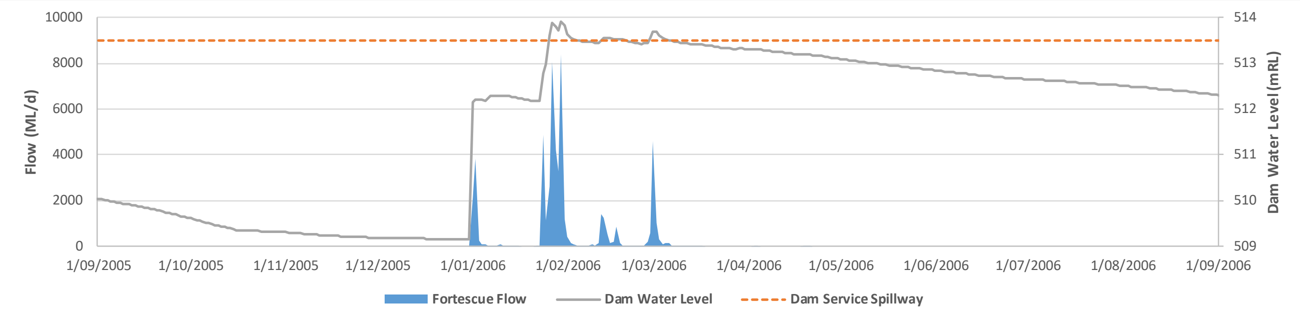

Flow (ML/d)
10000
8000
6000
4000
2000
0
Dam Water Level (mRL)
514
513
512
511
510
509
1/09/2000
1/10/2000
1/11/2000
1/12/2000
1/01/2001
1/02/2001
1/03/2001
1/04/2001
1/05/2001
1/06/2001
1/07/2001
1/08/2001
1/09/2001
Fortescue Flow
Dam Water Level
Dam Service Spillway

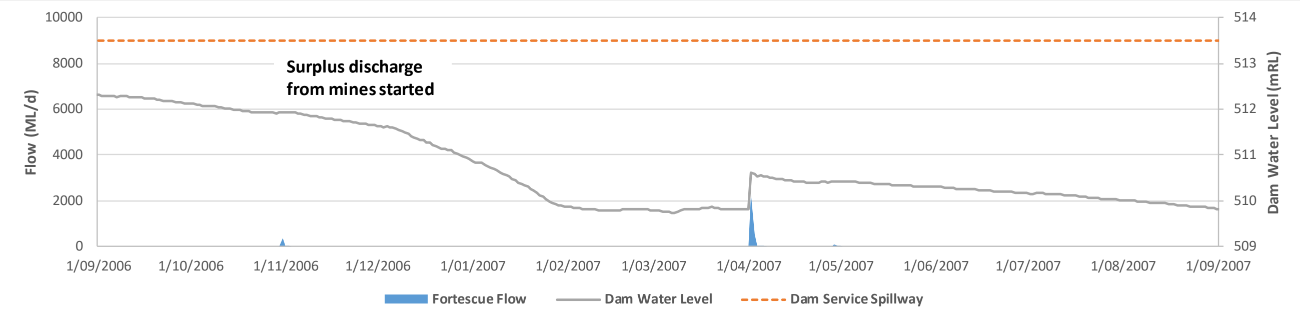

Flow (ML/d)
10000
8000
6000
4000
2000
0
Dam Water Level (mRL)
514
513
512
511
510
509
1/09/2001
1/10/2001
1/11/2001
1/12/2001
1/01/2002
1/02/2002
1/03/2002
1/04/2002
1/05/2002
1/06/2002
1/07/2002
1/08/2002
1/09/2002
Fortescue Flow
Dam Water Level
Dam Service Spillway

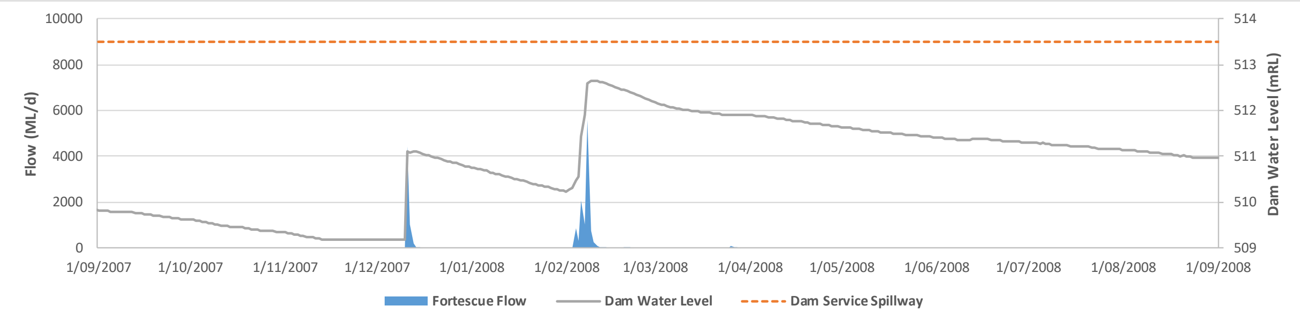

Flow (ML/d)
10000
8000
6000
4000
2000
0
Dam Water Level (mRL)
514
513
512
511
510
509
1/09/2002
1/10/2002
1/11/2002
1/12/2002
1/01/2003
1/02/2003
1/03/2003
1/04/2003
1/05/2003
1/06/2003
1/07/2003
1/08/2003
1/09/2003
Fortescue Flow
Dam Water Level
Dam Service Spillway

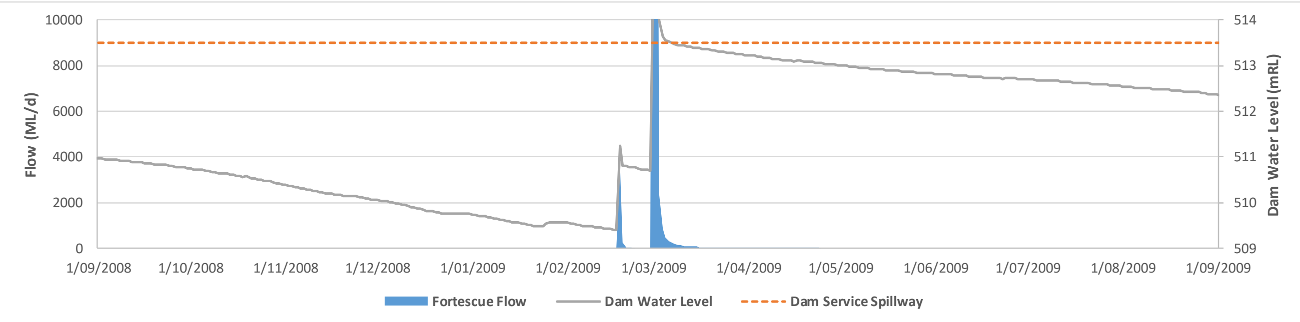

Flow (ML/d)
10000
8000
6000
4000
2000
0
Dam Water Level (mRL)
514
513
512
511
510
509
1/09/2003
1/10/2003
1/11/2003
1/12/2003
1/01/2004
1/02/2004
1/03/2004
1/04/2004
1/05/2004
1/06/2004
1/07/2004
1/08/2004
1/09/2004
Fortescue Flow
Dam Water Level
Dam Service Spillway

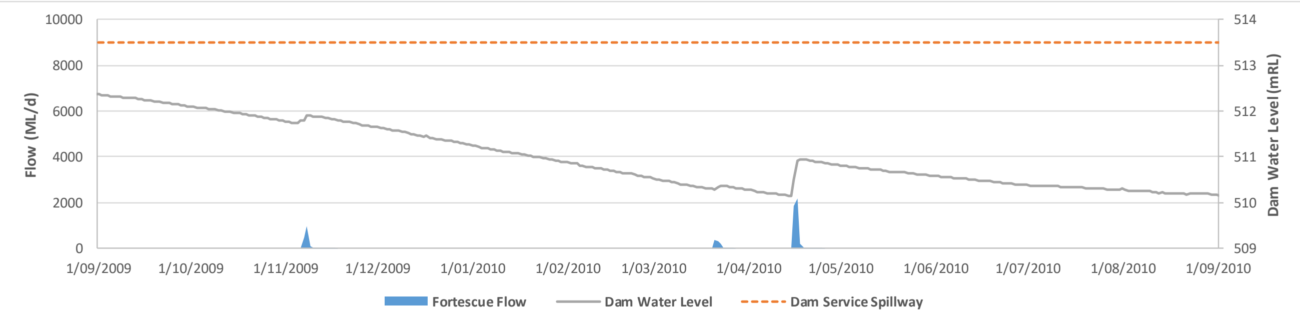

Flow (ML/d)
10000
8000
6000
4000
2000
0
Dam Water Level (mRL)
514
513
512
511
510
509
1/09/2004
1/10/2004
1/11/2004
1/12/2004
1/01/2005
1/02/2005
1/03/2005
1/04/2005
1/05/2005
1/06/2005
1/07/2005
1/08/2005
1/09/2005
Fortescue Flow
Dam Water Level
Dam Service Spillway

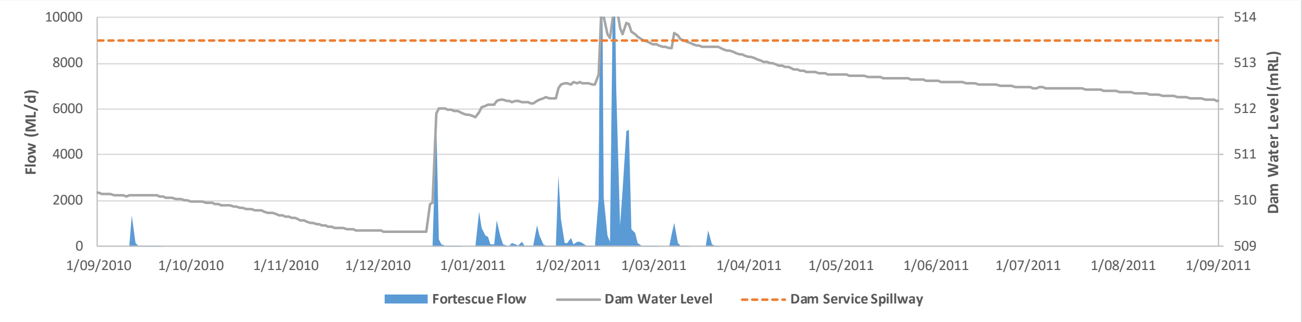

10000
8000
6000
4000
2000
0
Flow (ML/d)
514
513
512
511
510
509
Dam Water Level (mRL)
1/09/2005
1/10/2005
1/11/2005
1/12/2005
1/01/2006
1/02/2006
1/03/2006
1/04/2006
1/05/2006
1/06/2006
1/07/2006
1/08/2006
1/09/2006
Fortescue Flow
Dam Water Level
Dam Service Spillway

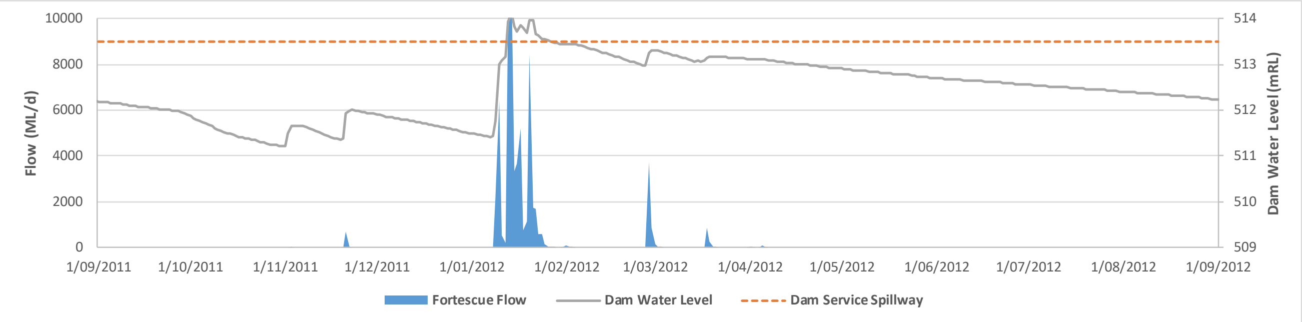

10000
8000
6000
4000
2000
0
Flow (ML/d)
514
513
512
511
510
509
Dam Water Level (mRL)
Surplus discharge from mines started
1/09/2006
1/10/2006
1/11/2006
1/12/2006
1/01/2007
1/02/2007
1/03/2007
1/04/2007
1/05/2007
1/06/2007
1/07/2007
1/08/2007
1/09/2007
Fortescue Flow
Dam Water Level
Dam Service Spillway

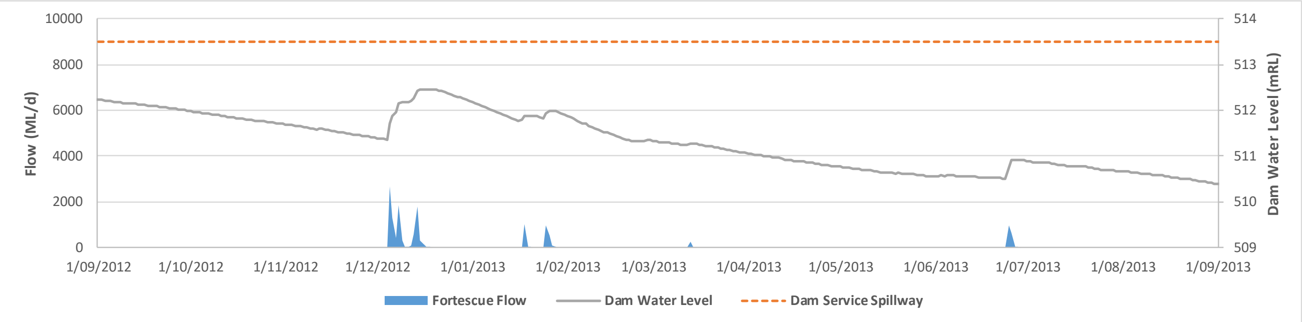

10000
8000
6000
4000
2000
0
Flow (ML/d)
514
513
512
511
510
509
Dam Water Level (mRL)
1/09/2007
1/10/2007
1/11/2007
1/12/2007
1/01/2008
1/02/2008
1/03/2008
1/04/2008
1/05/2008
1/06/2008
1/07/2008
1/08/2008
1/09/2008
Fortescue Flow
Dam Water Level
Dam Service Spillway

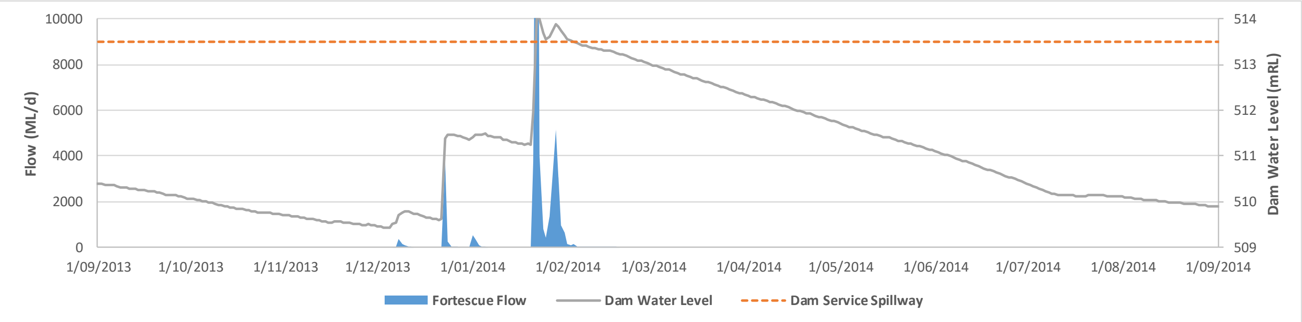

10000
8000
6000
4000
2000
0
Flow (ML/d)
514
513
512
511
510
509
Dam Water Level (mRL)
1/09/2008
1/10/2008
1/11/2008
1/12/2008
1/01/2009
1/02/2009
1/03/2009
1/04/2009
1/05/2009
1/06/2009
1/07/2009
1/08/2009
1/09/2009
Fortescue Flow
Dam Water Level
Dam Service Spillway

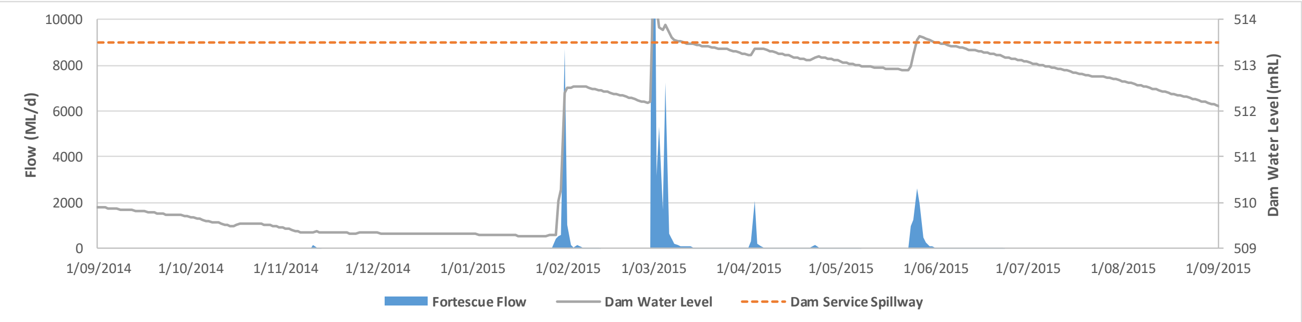

10000
8000
6000
4000
2000
0
Flow (ML/d)
514
513
512
511
510
509
Dam Water Level (mRL)
1/09/2009
1/10/2009
1/11/2009
1/12/2009
1/01/2010
1/02/2010
1/03/2010
1/04/2010
1/05/2010
1/06/2010
1/07/2010
1/08/2010
1/09/2010
Fortescue Flow
Dam Water Level
Dam Service Spillway

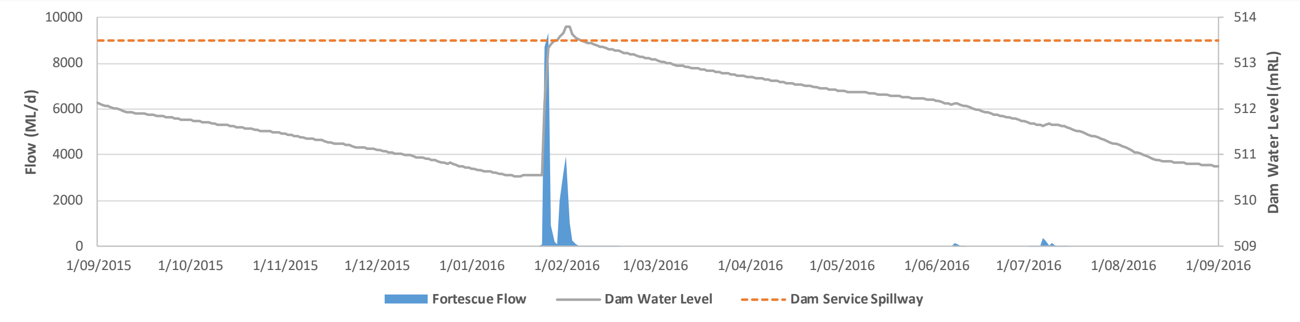

10000
8000
6000
4000
2000
0
Flow (ML/d)
514
513
512
511
510
509
Dam Water Level (mRL)
1/09/2010
1/10/2010
1/11/2010
1/12/2010
1/01/2011
1/02/2011
1/03/2011
1/04/2011
1/05/2011
1/06/2011
1/07/2011
1/08/2011
1/09/2011
Fortescue Flow
Dam Water Level
Dam Service Spillway

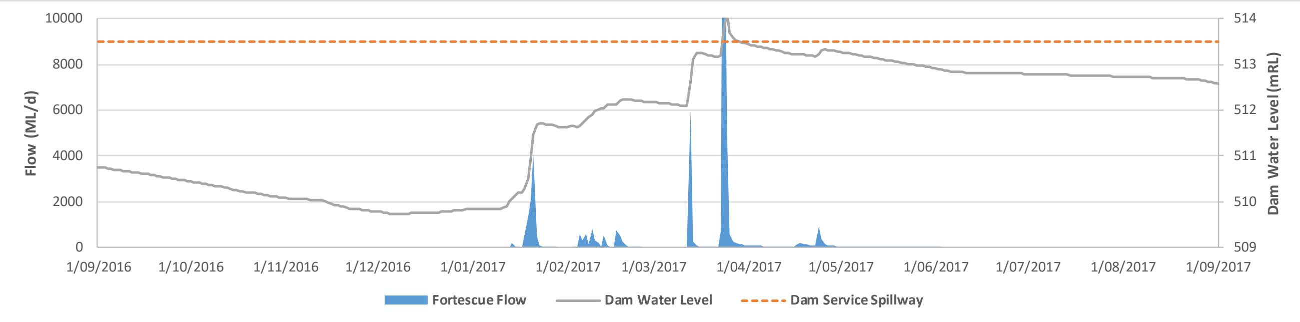

10000
8000
6000
4000
2000
0
Flow (ML/d)
514
513
512
511
510
509
Dam Water Level (mRL)
1/09/2011
1/10/2011
1/11/2011
1/12/2011
1/01/2012
1/02/2012
1/03/2012
1/04/2012
1/05/2012
1/06/2012
1/07/2012
1/08/2012
1/09/2012
Fortescue Flow
Dam Water Level
Dam Service Spillway

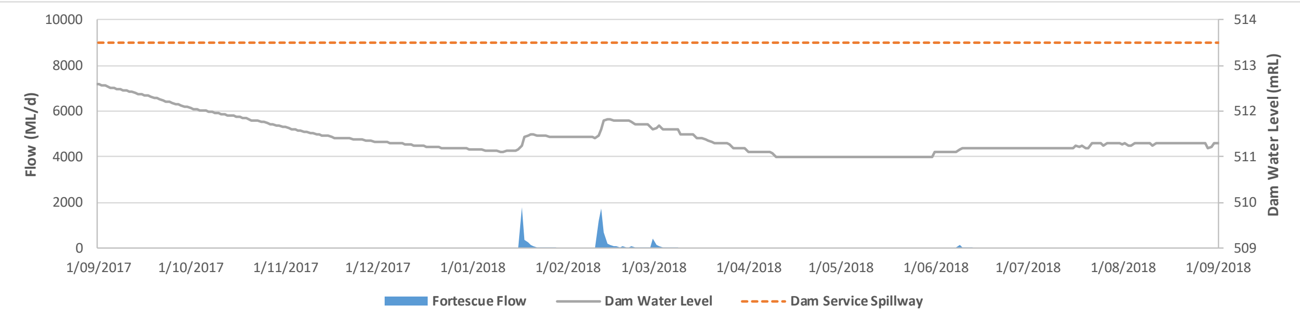

10000
8000
6000
4000
2000
0
Flow (ML/d)
514
513
512
511
510
509
Dam Water Level (mRL)
1/09/2012
1/10/2012
1/11/2012
1/12/2012
1/01/2013
1/02/2013
1/03/2013
1/04/2013
1/05/2013
1/06/2013
1/07/2013
1/08/2013
1/09/2013
Fortescue Flow
Dam Water Level
Dam Service Spillway

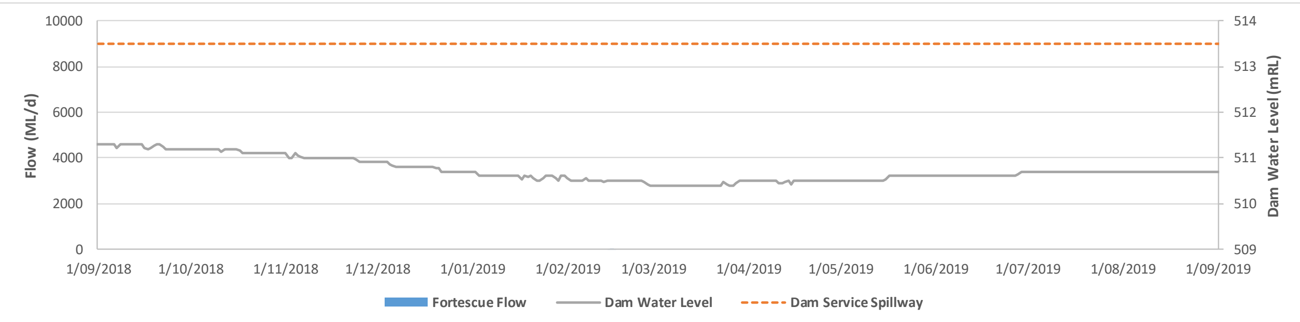

10000
8000
6000
4000
2000
0
Flow (ML/d)
514
513
512
511
510
509
Dam Water Level (mRL)
1/09/2013
1/10/2013
1/11/2013
1/12/2013
1/01/2014
1/02/2014
1/03/2014
1/04/2014
1/05/2014
1/06/2014
1/07/2014
1/08/2014
1/09/2014
Fortescue Flow
Dam Water Level
Dam Service Spillway

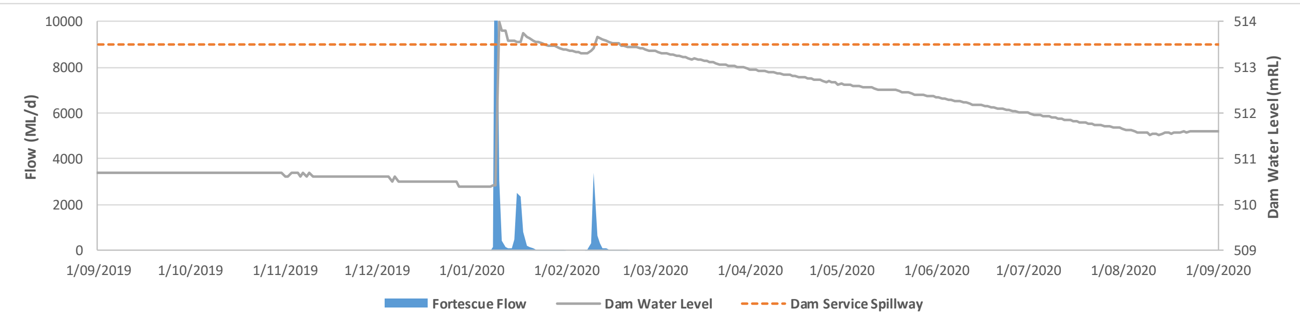

10000
8000
6000
4000
2000
0
Flow (ML/d)
514
513
512
511
510
509
Dam Water Level (mRL)
1/09/2014
1/10/2014
1/11/2014
1/12/2014
1/01/2015
1/02/2015
1/03/2015
1/04/2015
1/05/2015
1/06/2015
1/07/2015
1/08/2015
1/09/2015
Fortescue Flow
Dam Water Level
Dam Service Spillway

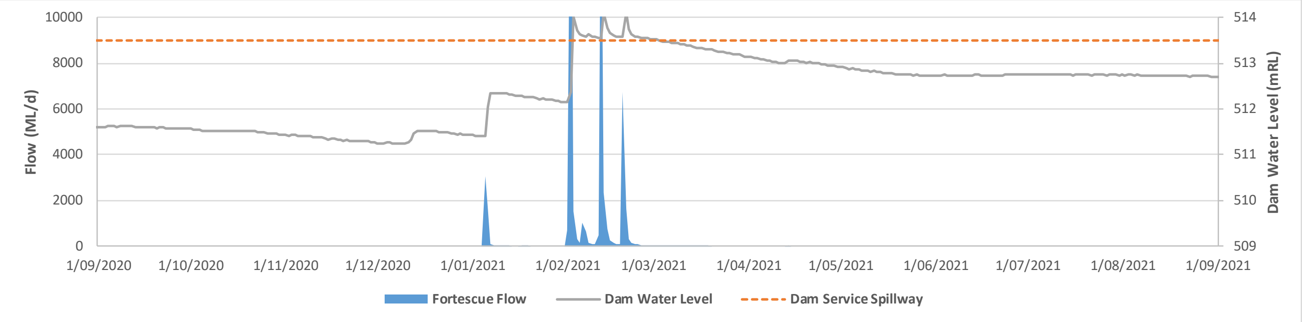

Flow (ML/d)
Dam Water Level (mRL)
10000
8000
6000
4000
2000
0
514
513
512
511
510
509
1/09/2015
1/10/2015
1/11/2015
1/12/2015
1/01/2016
1/02/2016
1/03/2016
1/04/2016
1/05/2016
1/06/2016
1/07/2016
1/08/2016
1/09/2016
Fortescue Flow
Dam Water Level
Dam Service Spillway

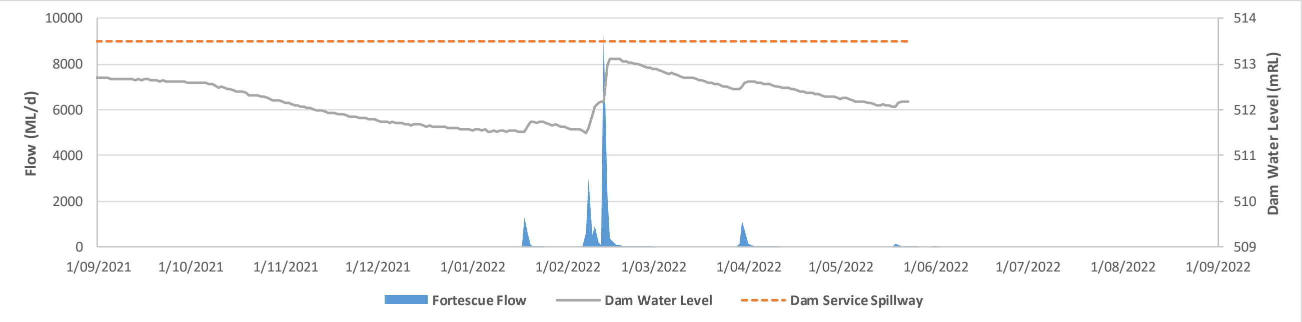

Flow (ML/d)
Dam Water Level (mRL)
10000
8000
6000
4000
2000
0
514
513
512
511
510
509
1/09/2016
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017
Fortescue Flow
Dam Water Level
Dam Service Spillway


Flow (ML/d)
Dam Water Level (mRL)
10000
8000
6000
4000
2000
0
514
513
512
511
510
509
1/09/2017
1/10/2017
1/11/2017
1/12/2017
1/01/2018
1/02/2018
1/03/2018
1/04/2018
1/05/2018
1/06/2018
1/07/2018
1/08/2018
1/09/2018
Fortescue Flow
Dam Water Level
Dam Service Spillway


Flow (ML/d)
Dam Water Level (mRL)
10000
8000
6000
4000
2000
0
514
513
512
511
510
509
1/09/2018
1/10/2018
1/11/2018
1/12/2018
1/01/2019
1/02/2019
1/03/2019
1/04/2019
1/05/2019
1/06/2019
1/07/2019
1/08/2019
1/09/2019
Fortescue Flow
Dam Water Level
Dam Service Spillway


Flow (ML/d)
Dam Water Level (mRL)
10000
8000
6000
4000
2000
0
514
513
512
511
510
509
1/09/2019
1/10/2019
1/11/2019
1/12/2019
1/01/2020
1/02/2020
1/03/2020
1/04/2020
1/05/2020
1/06/2020
1/07/2020
1/08/2020
1/09/2020
Fortescue Flow
Dam Water Level
Dam Service Spillway


Flow (ML/d)
Dam Water Level (mRL)
10000
8000
6000
4000
2000
0
514
513
512
511
510
509
1/09/2020
1/10/2020
1/11/2020
1/12/2020
1/01/2021
1/02/2021
1/03/2021
1/04/2021
1/05/2021
1/06/2021
1/07/2021
1/08/2021
1/09/2021
Fortescue Flow
Dam Water Level
Dam Service Spillway


Flow (ML/d)
Dam Water Level (mRL)
10000
8000
6000
4000
2000
0
514
513
512
511
510
509
1/09/2021
1/10/2021
1/11/2021
1/12/2021
1/01/2022
1/02/2022
1/03/2022
1/04/2022
1/05/2022
1/06/2022
1/07/2022
1/08/2022
1/09/2022
Fortescue Flow
Dam Water Level
Dam Service Spillway

Appendix 2 Eastern Pilbara Hub Water Balance: Integrated water balance model review and Ophthalmia Dam water management capacity

Separate document