HUMECOAL PROJECT

VOLUME 2B

Hume Coal Project and Berrima Rail Project

Response to Submissions

Appendix 2

Prepared for Hume Coal Pty Limited
June 2018

EMM

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HUME COAL

HUME COAL PROJECT

RESPONSE TO SUBMISSIONS - REVISED SURFACE WATER ASSESSMENT

JUNE 2018

Hume Coal Project
Response to submissions - revised surface water assessment

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REV	DATE	DETAILS
001	14/2/2018	Draft for EMM and Hume Coal review
002	15/2/2018	Revised draft for EMM and Hume Coal review
003	14/3/2018	Revised draft incorporating EMM and Hume Coal review comments
004	15/3/2018	Revised draft incorporating EMM and Hume Coal review comments
005	8/5/2018	Revised draft for updated groundwater modelling data
006	25/5/2018	Revised draft incorporating EMM and Hume Coal review comments
007	29/5/2018	Revised draft
008	12/6/2018	Final draft
009	21/6/2018	Final

	NAME	DATE	SIGNATURE
Prepared by:	L Doeleman	21/6/2018	
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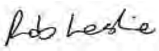
Approved by:	R Leslie	21/6/2018	

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1 INTRODUCTION

1.1 BACKGROUND

WSP Australia Pty Ltd (formerly Parsons Brinckerhoff) prepared the surface water assessments for the Hume Coal Project Environmental Impact Statement (EIS) (EMM 2017a) and the related Berrima Rail Project EIS (EMM 2017b). The Hume Coal Project and the Berrima Rail Project EIS were publicly exhibited between March and June 2017 and submissions have been received from government agencies and stakeholders. WSP has now been engaged to assist Hume Coal in preparing surface water inputs to the Response to Submissions (RTS) report.

The surface water modelling undertaken for the EIS has been revised to address matters raised in the submissions from government agencies and stakeholders. The surface water modelling has also been revised to reflect post-EIS numerical groundwater modelling, including uncertainty analysis and climate sensitivity analysis, as described in HydroSimulations (2018). The groundwater inflow and baseflow reduction estimates predicted by the numerical groundwater modelling are key inputs to the surface water modelling.

The purpose of this report is to present the findings of the revised surface water modelling, including descriptions of the modelling methodology and assumptions (where they differ from the EIS) and modelling results. The specific analyses revised in order to address key submissions received from government agencies and other stakeholders relating to the EIS surface water assessment are the water balance modelling, water quality modelling and flow/yield calculations. Additional analyses have been undertaken for baseflow reduction and dust deposition.

All other components of the surface water assessment for the EIS not revised and presented in this report remain relevant. The surface water assessment reports prepared for the EIS are included as appendices for reference (Appendix A to Appendix E).

1.2 AVAILABLE DATA

The following information has been utilised for the RTS surface water modelling:

- Hume Coal Project EIS and Berrima Rail Project EIS surface water assessments, including:
  - Hume Coal Project Water Balance Assessment report (Parsons Brinckerhoff, 2016a) (ref: 2200539A-WAT-REP-001 Rev10) and supporting GoldSim water balance model.
  - Hume Coal Project Surface Water Quality Assessment report (Parsons Brinckerhoff, 2016b) (ref: 2200540A-WAT-REP-004 RevE) and supporting MUSIC water quality models.
  - Hume Coal Project Surface Water Flow and Geomorphology Assessment report (Parsons Brinckerhoff, 2017a) (ref: 2200540A-SFW-REP-001 RevI).
  - Berrima Rail Project Surface Water Assessment report (Parsons Brinckerhoff, 2017b) (ref: 2200569A-WAT-REP-001 RevP) and supporting MUSIC water quality model.
- Revised groundwater inflow and baseflow reduction estimates obtained from post-EIS numerical groundwater modelling (HydroSimulations, 2018), including the results used for the impact assessment (utilising a static average climate scenario) and results from climate sensitivity analysis.
- Using MUSIC in Sydney’s Drinking Water Catchment standard (Sydney Catchment Authority (SCA), 2012).
- Neutral or Beneficial Effect (NorBE) on Water Quality Assessment Guideline (SCA, 2015).
- Developments in Sydney’s Drinking Water Catchment - Water Quality Information Requirements guidelines (WaterNSW, 2015).

1.3 SUMMARY OF REVISIONS TO SURFACE WATER MODELLING

A summary of the revisions made to the surface water modelling methodology and assumptions is provided in Table 1.1.

Table 1.1 Summary of revisions to surface water modelling

STUDY COMPONENT		REVISIONS ADOPTED FOR THE RTS
Water balance assessment		- The water balance model base case adopted revised groundwater inflow estimates from the Mean K Groundwater Model (which utilised static average climate). - The water balance model climate sensitivity analysis adopted revised groundwater inflow estimates from the Modified EIS Groundwater Model (which utilised static average climate, wet climate scenario and dry climate scenario).
Surface water flow assessment		- The base case flow assessment adopted revised baseflow reduction estimates from the Mean K Groundwater Model (which utilised static average climate). - Revised predicted SB03 and SB04 releases to Oldbury Creek following first flush (output of revised base case water balance modelling adopting Mean K Groundwater Model inflows (which utilised static average climate)). - Flow assessment climate sensitivity analysis adopted revised baseflow reduction estimates from the Modified EIS Groundwater Model (which utilised static average climate, wet climate scenario and dry climate scenario).
Surface water quality assessment	NorBE assessment of releases from stormwater basins to Oldbury Creek	- Revised predicted SB03 and SB04 releases to Oldbury Creek following first flush (output of revised base case water balance modelling adopting Mean K Groundwater Model inflows (which utilised static average climate)). - Modelled existing flows as mix of base flow and storm flow in MUSIC. - Changed MUSIC model timestep from daily to 6-min. - MUSIC modelling has been undertaken for total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN).
	NorBE assessment of mine access roads	- Changes to MUSIC model parameters (swale exfiltration rate set to zero, swale vegetation height set to 0.25 m, industrial land use type adopted for road cut/fill embankments). - Proposed swale lengths increased. Constructed wetlands proposed downstream of swales as an additional management measure.
	NorBE assessment of railway line	- Changes to MUSIC model parameters (swale exfiltration rate set to zero, swale side slopes set to 1:3.33, swale vegetation height set to 0.25 m, industrial land use type adopted for road and rail cut/fill embankments). - Proposed swale lengths increased. Constructed wetlands proposed downstream of swales as an additional management measure.

STUDY COMPONENT		REVISIONS ADOPTED FOR THE RTS
	Baseflow reduction	- Impacts associated with baseflow reduction for Medway Rivulet Management Zone assessed using daily mass balance model developed in GoldSim. Modelling has been undertaken for nitrate, nitrite, calcium, sodium, sulfate and aluminium. - Adopted revised baseflow reduction estimates from the Mean K Groundwater Model (which utilised static average climate). - Riparian protection zones on Evandale and Mereworth properties (total protection area of 42.5 ha) proposed as a new management measure.
	Dust deposition	- Impacts associated with coal dust deposition for Oldbury Creek and Wells Creek catchments assessed by applying the results of water extract testing of coal samples to predicted catchment average dust deposition rates and runoff volumes.

2 REVISED GROUNDWATER MODELLING DATA

Revised groundwater inflow and baseflow reduction estimates from post-EIS numerical groundwater modelling, including uncertainty analysis and climate sensitivity analysis, undertaken by HydroSimulations were supplied by Hume Coal. The following data were supplied:

— Revised groundwater inflow and baseflow reduction estimates from the Mean K Groundwater Model for impact assessment (utilising static average climate).

— Revised groundwater inflow and baseflow reduction estimates from the Modified EIS Groundwater Model for climate sensitivity analysis (utilising static average climate, wet climate, and dry climate scenarios).

For the climate sensitivity analysis, the Modified EIS Groundwater Model wet climate scenario used the wettest 19-year rainfall sequence on the historical record, and the Modified EIS Groundwater Model dry climate scenario used the driest 19-year rainfall sequence on the historical record.

2.1 GROUNDWATER INFLOW DATA

Groundwater inflow estimates to the mine sump and mine void from the Mean K Groundwater Model are summarised in Table 2.2 for the 19-year period of mining. Groundwater inflow estimates from the Modified EIS Groundwater Model static average climate, wet climate scenario and dry climate scenario are summarised in Table 2.2 for the 19-year period of mining and demonstrate that the model is insensitive to climate.

Table 2.1 Groundwater inflow estimates – revised groundwater model (static average climate), for impact assessment

MINING YEAR	GROUNDWATER INFLOWS (MEAN K GROUNDWATER MODEL - FOR IMPACT ASSESSMENT)		
	STATIC AVERAGE CLIMATE		
	TO MINE SUMP	TO MINE VOID	TOTAL
1	31.3	168.8	200.1
2	193.2	977.8	1,171.1
3	263.2	1,180.2	1,443.4
4	273.8	1,138.9	1,412.7
5	278.4	959.4	1,237.8
6	301.3	921.5	1,222.8
7	350.8	900.6	1,251.4
8	448.9	1,075.1	1,523.9
9	546.4	1,202.6	1,749.0
10	637.2	1,175.2	1,812.3
11	707.0	1,131.2	1,838.2

MINING YEAR	GROUNDWATER INFLOWS (MEAN K GROUNDWATER MODEL - FOR IMPACT ASSESSMENT)		
	STATIC AVERAGE CLIMATE		
	TO MINE SUMP	TO MINE VOID	TOTAL
12	739.1	1,114.8	1,853.9
13	792.3	1,001.5	1,793.8
14	845.8	895.4	1,741.2
15	921.5	784.4	1,705.9
16	992.7	839.4	1,832.1
17	1,009.5	1,056.2	2,065.7
18	945.6	1,116.9	2,062.5
19	728.5	938.2	1,666.8
Total	**11,007**	**18,578**	**29,585**

Source: HydroSimulations, 2018

Table 2.2 Groundwater inflow estimates – revised groundwater model results for sensitivity analysis, using static average climate, wet climate scenario and dry climate scenario

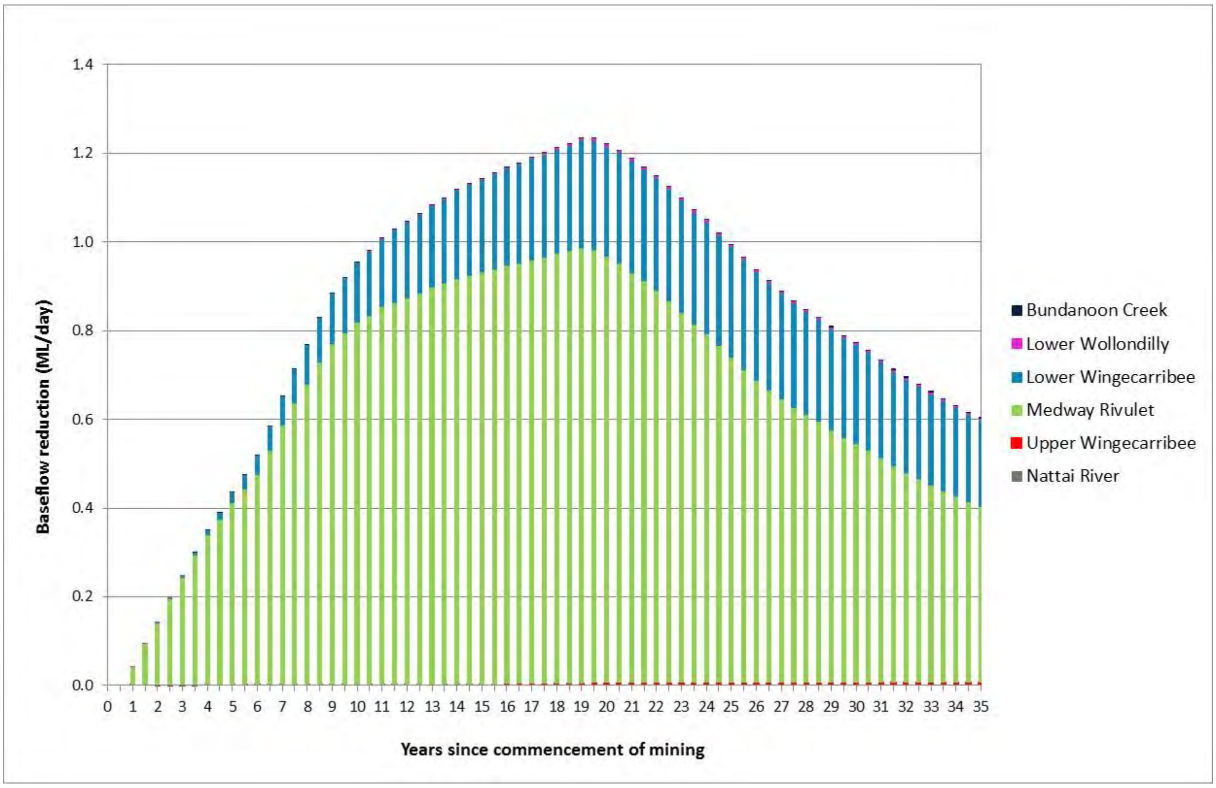
MINING YEAR	GROUNDWATER INFLOWS (MODIFIED EIS GROUNWATER MODEL - FOR CLIMATE SENSITIVITY ANALYSIS) (ML/YR)								
	STATIC AVERAGE CLIMATE			WET CLIMATE SCENARIO			DRY CLIMATE SCENARIO		
	TO MINE SUMP	TO MINE VOID	TOTAL	TO MINE SUMP	TO MINE VOID	TOTAL	TO MINE SUMP	TO MINE VOID	TOTAL
1	4.8	126.4	131.2	4.8	126.6	131.4	4.8	126.4	131.2
2	67.1	721.4	788.5	67.5	723.9	791.4	66.9	722.3	789.2
3	132.1	973.1	1,105.2	133.1	976.4	1,109.5	131.6	974.3	1,106.0
4	188.5	1,080.1	1,268.6	190.1	1,082.7	1,272.7	187.5	1,080.6	1,268.1
5	236.4	1,092.5	1,328.9	238.4	1,093.1	1,331.4	234.7	1,092.1	1,326.8
6	276.0	1,126.1	1,402.1	278.2	1,125.1	1,403.3	273.2	1,124.7	1,398.0
7	304.0	1,143.8	1,447.7	306.2	1,141.3	1,447.5	300.2	1,141.7	1,441.9
8	334.4	1,174.1	1,508.5	336.8	1,172.0	1,508.8	329.4	1,173.2	1,502.6
9	397.6	1,163.9	1,561.6	399.7	1,162.0	1,561.7	390.9	1,164.0	1,554.9
10	501.6	1,138.5	1,640.1	502.8	1,139.2	1,642.0	492.7	1,138.5	1,631.2
11	593.6	1,117.8	1,711.3	594.2	1,117.7	1,711.8	582.8	1,117.5	1,700.4
12	642.8	1,159.3	1,802.1	643.8	1,159.1	1,802.9	630.2	1,158.7	1,788.9
13	720.3	1,177.8	1,898.1	722.3	1,177.9	1,900.3	704.4	1,177.4	1,881.8
14	845.7	1,042.0	1,887.6	849.6	1,041.5	1,891.1	824.6	1,042.4	1,867.1

MINING YEAR	GROUNDWATER INFLOWS (MODIFIED EIS GROUNWATER MODEL - FOR CLIMATE SENSITIVITY ANALYSIS) (ML/YR)								
	STATIC AVERAGE CLIMATE			WET CLIMATE SCENARIO			DRY CLIMATE SCENARIO		
	TO MINE SUMP	TO MINE VOID	TOTAL	TO MINE SUMP	TO MINE VOID	TOTAL	TO MINE SUMP	TO MINE VOID	TOTAL
15	967.5	707.4	1,674.9	973.9	706.4	1,680.3	942.1	708.1	1,650.2
16	1,026.8	691.1	1,717.9	1,034.5	692.0	1,726.4	999.9	692.1	1,692.0
17	997.2	1,029.0	2,026.2	1,003.5	1,030.5	2,034.0	970.8	1,029.3	2,000.0
18	911.5	1,046.0	1,957.5	915.1	1,045.2	1,960.3	884.7	1,046.0	1,930.8
19	696.3	691.2	1,387.5	698.2	688.1	1,386.3	673.4	690.4	1,363.9
Total	**9,844**	**18,401**	**28,246**	**9,893**	**18,401**	**28,293**	**9,625**	**18,400**	**28,025**

Source: HydroSimulations, 2018

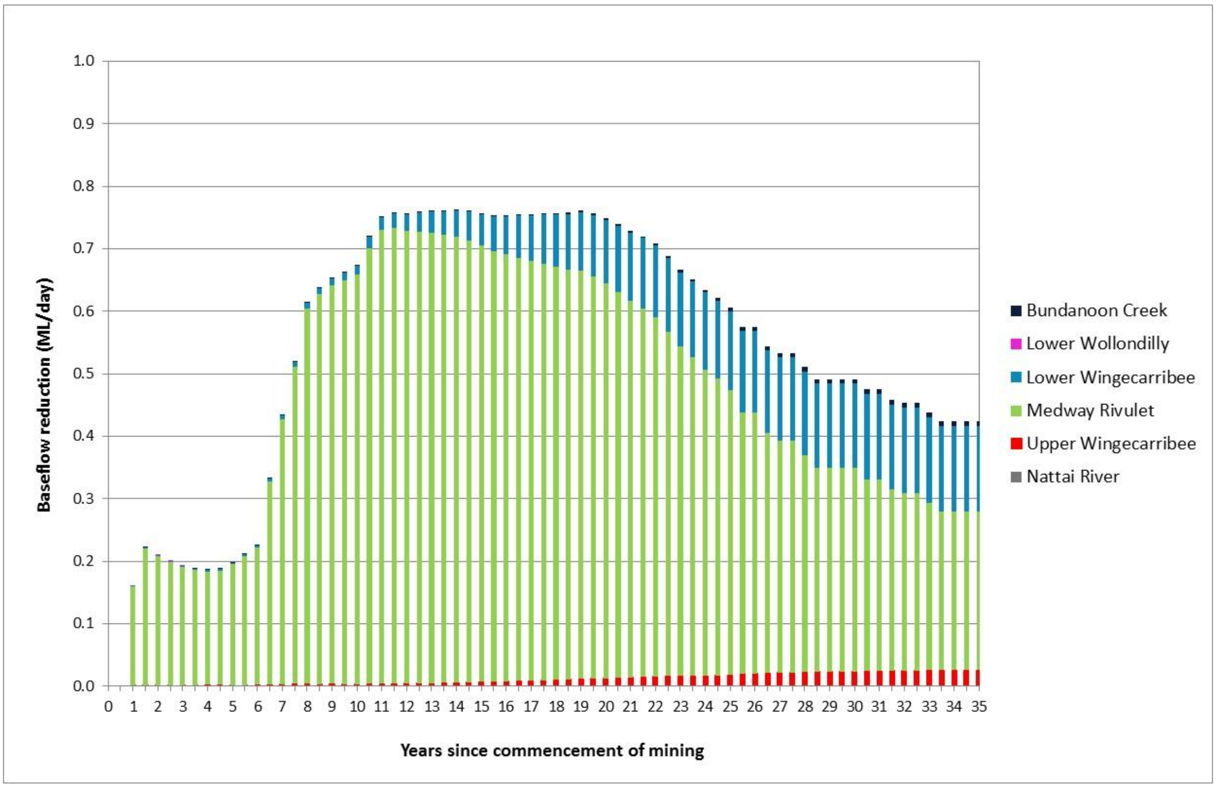
2.2 BASEFLOW REDUCTION DATA

Baseflow reduction estimates from the Mean K Groundwater Model are summarised in Figure 2.1 for the 35-year period from the commencement of mining. Baseflow reduction estimates from the Modified EIS Groundwater Model static average climate, wet climate scenario and dry climate scenario are summarised in Figure 2.2, Figure 2.3 and Figure 2.4, respectively, for the 35-year period from the commencement of mining.



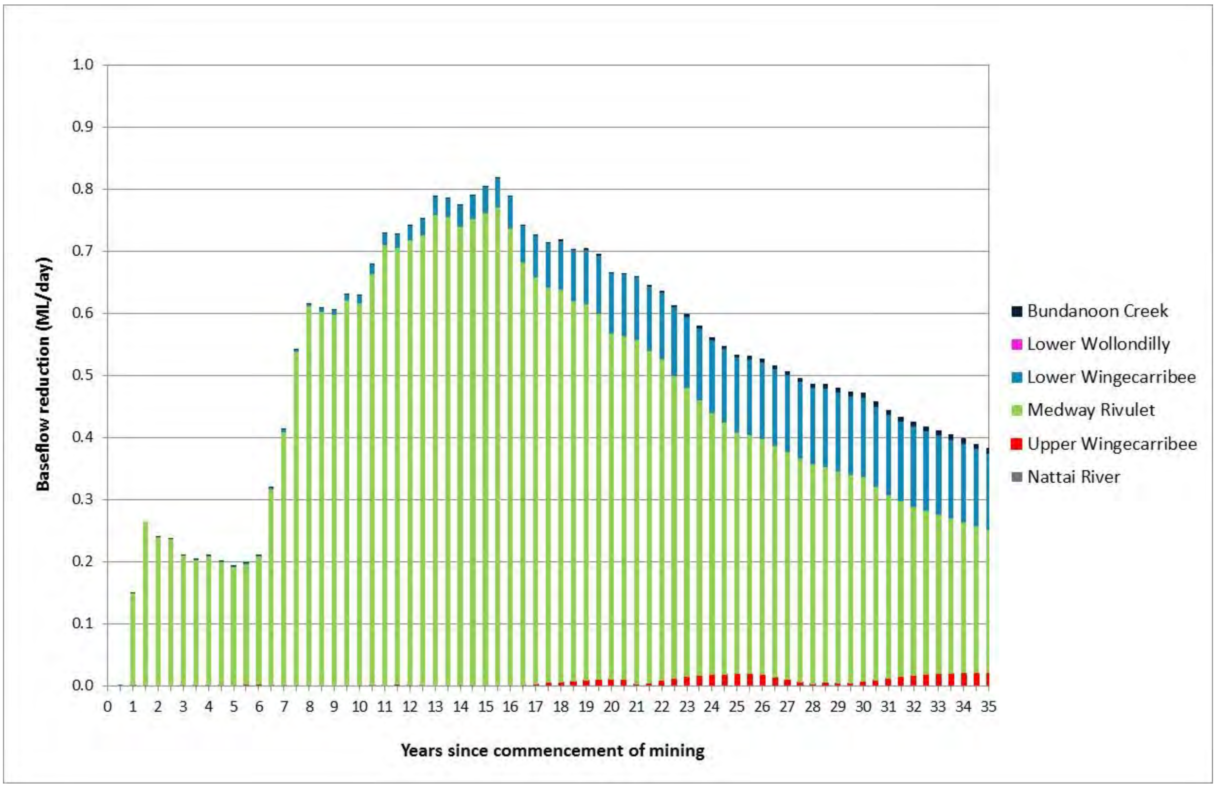
Source: HydroSimulations, 2018

Figure 2.1 Baseflow reduction estimates – Mean K Groundwater Model



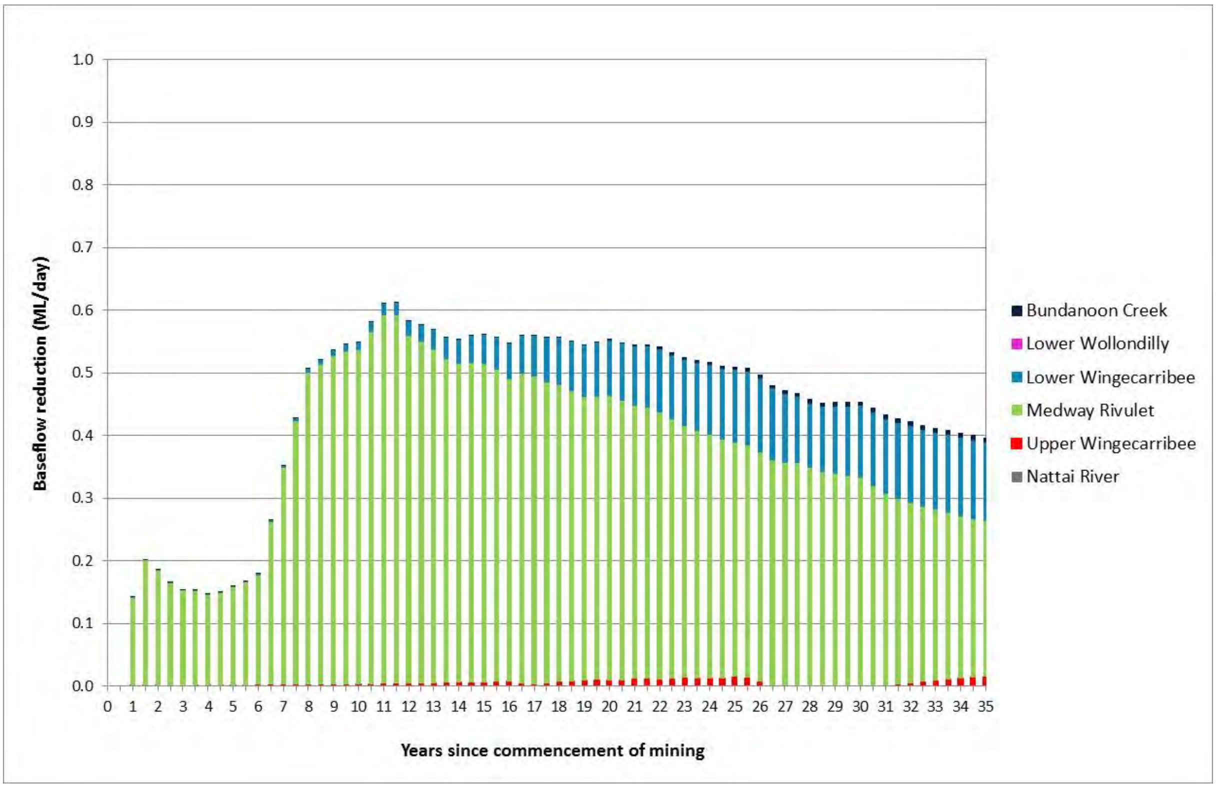
Source: HydroSimulations, 2018

Figure 2.2 Baseflow reduction estimates – Modified EIS Groundwater Model static average climate



Source: HydroSimulations, 2018

Figure 2.3 Baseflow reduction estimates – Modified EIS Groundwater Model wet climate scenario



Source: HydroSimulations, 2018

Figure 2.4 Baseflow reduction estimates – Modified EIS Groundwater Model dry climate scenario

3 WATER BALANCE ASSESSMENT

3.1 METHOD

The water balance model developed for the Hume Coal Project EIS has been revised to include the revised groundwater inflow estimates from post-EIS numerical groundwater modelling undertaken by HydroSimulations (refer to Section 2). No other changes have been made to the water balance model developed for the Hume Coal Project EIS. Full details of the water balance model data, model assumptions and operating rules are outlined in the Hume Coal Project Water Balance Assessment report (Parsons Brinckerhoff, 2016a).

The water balance model base case adopts groundwater inflow estimates from the Mean K Groundwater Model. The results of the water balance model base case are provided in Section 3.2.

A water balance model climate sensitivity analysis has been undertaken adopting groundwater inflow estimates from the Modified EIS Groundwater Model static average climate, wet climate scenario and dry climate scenario. The results of the water balance climate sensitivity analysis are provided in Section 3.3. The water balance model climate sensitivity analysis has been undertaken to address matters raised in the submissions from government agencies.

A summary of the RTS water balance model scenarios is provided in Table 3.1.

Table 3.1 Summary of RTS water balance model scenarios

WATER BALANCE MODEL SCENARIO	GROUNDWATER INFLOW DATA	REPORT REFERENCE
Base case	Mean K Groundwater Model static average climate (refer Section 2.1 Table 2.1)	Section 3.2
Climate sensitivity analysis static average climate	Modified EIS Groundwater Model static average climate (refer Section 2.1 Table 2.2)	Section 3.3
Climate sensitivity analysis wet climate scenario	Modified EIS Groundwater Model wet climate (refer Section 2.1 Table 2.2)	
Climate sensitivity analysis dry climate scenario	Modified EIS Groundwater Model dry climate (refer Section 2.1 Table 2.2)	

For all water balance model scenarios in Table 3.1, the water balance model has been simulated at a daily time step for a 19-year duration (assumed to be from 2021 to 2039) for 107 realisations (or sequences) of rainfall and evaporation data. The 107 realisations were developed by 'stepping through' the Data Drill sourced historical rainfall and evaporation data from 1 January 1889 to 1 January 2014. The first realisation started on 1 January 1889, the second realisation on 1 January 1890 and so on. Probability distributions were then developed using the daily and annual results from all of the 107 realisations.

For each scenario in Table 3.1, the corresponding groundwater inflow data in Table 3.1 was adopted for all 107 water balance realisations to determine the system behaviour under a range of historical climate conditions, including periods of prolonged wet and dry conditions.

3.2 WATER BALANCE MODEL BASE CASE

3.2.1 GROUNDWATER INFLOWS ADOPTED IN WATER BALANCE MODEL BASE CASE

As discussed in Section 3.1, the water balance model base case adopts groundwater inflow estimates from the Mean K Groundwater Model. Groundwater inflow estimates adopted for the water balance model base case are provided in Table 3.2. The revised total groundwater inflow (including inflows to the mine sump and mine void) over the 19-year mining period adopted for the RTS assessment is 29,585 ML, compared to 30,342 ML adopted for the EIS assessment. This is a 2.5% reduction in the total groundwater inflows adopted for the RTS compared to the EIS.

A comparison of the revised annual groundwater inflows to the annual net project demand is provided in Table 3.2. The total net project demand over the 19-year mining period has not changed from the EIS and is expected to be 12,837 ML. The revised 19-year total groundwater volume for the mine sump is 11,007 ML.

Table 3.2 Comparison of net annual demands to annual groundwater inflows to sump – water balance model base case (replaces Table 4.3 of the EIS Water Balance Assessment (PB 2016a))

MINING YEAR	GROUNDWATER INFLOW TO MINE SUMP (ML/YR)	GROUNDWATER INFLOW TO MINE VOID (ML/YR)	TOTAL NET DEMAND (ML/YR)	COMPARISON OF GROUNDWATER INFLOW TO SUMP AND TOTAL NET DEMAND (%)
1	31.3	168.8	216.1	14%
2	193.2	977.8	467.5	41%
3	263.2	1,180.2	640.0	41%
4	273.8	1,138.9	625.0	44%
5	278.4	959.4	721.6	39%
6	301.3	921.5	781.6	39%
7	350.8	900.6	758.2	46%
8	448.9	1,075.1	776.1	58%
9	546.4	1,202.6	794.9	69%
10	637.2	1,175.2	683.1	93%
11	707.0	1,131.2	684.5	103%
12	739.1	1,114.8	715.8	103%
13	792.3	1,001.5	804.4	98%
14	845.8	895.4	871.2	97%
15	921.5	784.4	886.2	104%
16	992.7	839.4	686.9	145%
17	1,009.5	1,056.2	709.4	142%
18	945.6	1,116.9	626.2	151%
19	728.5	938.2	387.9	188%
Total	**11,007**	**18,578**	**12,837**	**86%***

A discussion on how the project demands will be met, with consideration to groundwater inflow and rainfall-runoff capture, is provided in Section 3.2.2.2.

The mine void space availability for water (including natural groundwater inflow and surplus water pumped to voids from the sump) has not changed from the EIS and was calculated by accumulating total void space available behind the bulkheads after deducting the volume of co-disposed reject that will be placed behind the bulkheads. The annual net void space available for surplus water pumped from the sump after the natural groundwater inflow has been revised to reflect the Mean K Groundwater Model groundwater inflows and is provided below in Table 3.3.

Table 3.3 Mine void capacity available for surplus water pumped from the sump – water balance model base case (replaces Table 4.13 of the EIS Water Balance Assessment (PB 2016a))

MINING YEAR	TOTAL VOID VOLUME (ML)	CO-DISPOSED REJECT EMPLACED (ML)	NET VOID SPACE AVAILABLE AFTER PLACEMENT OF CO-DISPOSED REJECT (ML)	GROUNDWATER INFLOW TO VOID (ML/YR)	NET VOID SPACE AVAILABLE FOR SURPLUS WATER (ML) CUMULATIVE
1	0.0	0.0	0.0	168.8	0.0
2	384.5	138.3	246.2	977.8	0.0
3	1,628.7	585.6	1,043.1	1,180.2	0.0
4	1,764.9	634.6	1,130.3	1,138.9	0.0
5	940.6	338.2	602.4	959.4	0.0
6	1,734.1	623.6	1,110.5	921.5	189.0
7	2,367.1	851.1	1,516.0	900.6	804.4
8	2,165.5	778.7	1,386.8	1,075.1	1,116.1
9	2,348.7	844.6	1,504.1	1,202.6	1,417.6
10	2,054.4	738.7	1,315.7	1,175.2	1,558.1
11	1,430.9	514.5	916.4	1,131.2	1,343.3
12	1,990.4	715.7	1,274.7	1,114.8	1,503.2
13	1,209.2	434.8	774.4	1,001.5	1,276.1
14	2,463.9	886.0	1,577.9	895.4	1,958.6
15	2,058.5	740.2	1,318.3	784.4	2,492.5
16	282.2	101.5	180.7	839.4	1,833.8
17	2,954.9	1,062.6	1,892.3	1,056.2	2,669.9
18	2,336.5	840.2	1,496.3	1,116.9	3,049.3
19	2,443.3	878.6	1,564.7	938.2	3,675.8

For water balance modelling, the net void space availability for surplus water was calculated at a daily time step by subtracting the natural groundwater inflows to the void from the available void space. If the predicted daily inflow of groundwater to the void exceeded the available void space then the inflow was reduced to match the available void space.

3.2.2 WATER BALANCE MODEL BASE CASE RESULTS

This section provides a summary of results for the water balance model base case.

An average of simulated results from 107 sets of 19-year climate sequences was calculated and is summarised in Table 3.4 and Table 3.5. The project water supply will be provided from rainfall-runoff and groundwater from the underground mine, and if necessary during construction, bore water from existing groundwater licences owned by Hume Coal. Note that the water balance model assumes an initial storage volume of 100 ML in the PWD at the start of the water balance simulation.

Table 3.4 Average project water balance summary for surface storages PWD, SB01-04 and MWD05-06 – water balance model base case (replaces Table 5.1 of the EIS Water Balance Assessment (PB 2016a))

SURFACE STORAGES		ML	ML/YR	% OF SUBTOTAL
Inflows	Rainfall	2,107	111	7.8%
	Runoff	3,591	189	13.3%
	CPP wash and dust suppression return	2,799	147	10.4%
	Supplied from the underground mine sump	16,395	863	60.7%
	Supplied from void space groundwater	2,116	111	7.8%
	Total	**27,009**	**1,422**	**100.0%**
Outflows	Dam evaporation	2,928	154	10.9%
	Releases from SB03 and SB04 to Oldbury Creek after first flush	361	19	1.3%
	Treat before release to Oldbury Creek	0.0	0.0	0.0%
	Underground mine equipment water supply	9,120	480	33.8%
	Product coal handling water supply	2,587	136	9.6%
	CPP process water supply	5,644	297	20.9%
	ROM stockpile water supply	559	29	2.1%
	Co-disposed reject water supply	5,199	274	19.3%
	Administration and Workshop Area fire water supply	560	29	2.1%
	Total	**26,957**	**1,419**	**100.0%**
Storage	Initial dam storage	100		
	Final dam storage	152		

Notes: MWD07 is excluded from the surface storages as it transfers water to the underground system (see Table 3.5). MWD08 is excluded from the water balance.

Table 3.5 Average project water balance summary for underground mine – water balance model base case (replaces Table 5.2 of the EIS Water Balance Assessment (PB 2016a))

UNDERGROUND SUMP WATER BALANCE		ML	ML/YR	%
Inflows	Co-disposed reject decant	2,333	123	12.1%
	Groundwater in to the sump	11,006	579	57.0%
	Rainfall-runoff transfer from MWD07 to the sump	118	6	0.6%
	Return water from underground processes less losses in underground mine	5,837	307	30.3%
	Total	**19,294**	**1,015**	**100.0%**
Outflows	Supplied from the sump to the PWD	16,395	863	85.0%
	Pumping from the sump to the void	2,899	153	15.0%
	Total	**19,294**	**1,015**	**100.0%**
Balance	Inflows minus outflows	0	0	
VOID SPACE WATER BALANCE		**ML**	**ML/YR**	**%**
Inflows	Groundwater in to the void	18,577	978	65.1%
	Pumping from the sump to the void	2,899	153	10.2%
	Water contained in reject codisposal	7,071	372	24.8%
	Total	**28,547**	**1,502**	**100.0%**
Outflows	Supplied from the void to the PWD	2,116	111	47.6%
	Co-disposed reject decant	2,333	123	52.4%
	Total	**4,449**	**234**	**100.0%**
Balance	Inflows minus outflows	24,097	1,268	

3.2.2.1 WATER MANAGEMENT SYSTEM RAINFALL-RUNOFF

The variability of available water supply from harvestable rainfall-runoff within the SB and MWD catchments are presented in Table 3.6. The total simulated harvestable rainfall-runoff volume (allowing for evaporation loss) over the 19-year mining operation was found to range from 1,388 ML to 4,829 ML based on the 107 water balance realisations. The maximum annual net rainfall-runoff was 707 ML/yr. The net rainfall-runoff volumes in Table 3.6 are dependent on the volume of water stored in dams on site as the direct rainfall and evaporation calculations in the water balance model depend on the stored water surface area. The rainfall-runoff volumes have therefore changed slightly compared to the EIS as the revised groundwater inflows have changed the volume of water stored on site.

Table 3.6 Simulated 19-year sum of rainfall-runoff (net of evaporation) based on 107 water balance realisations – water balance model base case (replaces Table 5.3 of the EIS Water Balance Assessment (PB 2016a))

19-YEAR SUM OF NET RAINFALL-RUNOFF (ML/YR)									
AVERAGE	MINIMUM (DRIEST)	5TH %ILE (VERY DRY)	10TH %ILE	25TH %ILE	50TH %ILE (MEDIAN)	75TH %ILE	90TH %ILE	95TH %ILE (VERY WET)	MAXIMUM (WETTEST)
2,889	1,388	1,644	1,826	2,321	2,798	3,474	4,026	4,430	4,829

3.2.2.2 PROJECT DEMAND AND GROUNDWATER SUPPLY

Annual water volume that will be supplied from the PWD each year is presented in the column 2 of Table 3.7. The net annual volume consumed during the mining operation is listed in column 3 of Table 3.7, which ranges from 215 ML/yr in the first year to a maximum of 878 ML/yr in the 15th year of mining. Net annual rainfall-runoff volumes for the wettest rainfall sequence (1950 to 1969) and the driest rainfall sequence (1991 to 2010) are presented in column 6 and column 7 of Table 3.7 respectively. The net water consumption cannot be fully supplied for all years of the mine life by using the net harvestable annual rainfall-runoff from the SBs and MWDs only. Groundwater that would be collected at the underground mine sump and in the void spaces behind the bulkheads will be required in supplying the rest of the annual water demands.

The data presented in Table 3.7 suggests that all of the groundwater that would arrive at the underground sump is likely to be utilised to meet net demands in Years 2021 to 2030 of the project. Additional water would be pumped from the void spaces to meet the demands fully for Years 2021 to 2030. In Years 2031 to 2039 of the project, the groundwater inflows to the underground sump are generally able to meet net demands (the exception is Years 2033 and 2034 when groundwater inflows to the underground sump are slightly lower than net demands).

Comparisons of the sums of net annual harvestable rainfall-runoff volumes over the 19-year mining period with the required potential supply (column 5 of Table 3.7) provide an indication of the likely range of utilisation of natural groundwater from the void spaces for meeting the project demands, in addition to the groundwater that would be collected in the underground mine sump.

The likely range of utilisation of the natural groundwater from void spaces over the 19-year mining period is expected to be from zero in the wettest climate sequence up to 1,707 ML in the driest climate sequence (obtained by subtracting the total of column 7 from the total of column 5). It should be noted that this is the ‘groundwater to void’ abstraction required, which differs from the total amount of water abstracted from the void to the PWD as the water balance model indicates there will be water pumped to voids from the sump in all climate sequences.

The exact volume of water utilisation from the underground mine will depend on the complex interaction between basin and dam storage, climate, rainfall-runoff, water transfer volumes and mode of operation. For example, the rainfall-runoff volume from MWD07 is transferred directly to the sump, which may get pumped to voids rather than being transferred to the PWD for water supply. The results from daily simulation for the mean annual rainfall-runoff condition are presented in Section 3.2.2.3.

Table 3.7 Summary of the annual project water demand and supply – water balance model base case (replaces Table 5.4 of the EIS Water Balance Assessment (PB 2016a))

MINING YEAR (COLUMN 1)	TOTAL DEMAND (ML) (COLUMN 2)	NET DEMAND (ML) (COLUMN 3)	ANNUAL GROUNDWATER TO THE MINE SUMP (ML) (COLUMN 4)	POTENTIAL SUPPLY FROM THE MINED OUT PANEL GROUNDWATER WITHOUT SURFACE WATER (ML) (COLUMN 5)	NET ANNUAL RAINFALL - RUNOFF FOR WET CLIMATE SEQUENCE (1950 TO 1969) (ML) (COLUMN 6) *	NET ANNUAL RAINFALL - RUNOFF FOR DRY CLIMATE SEQUENCE (1991 TO 2010) (ML) (COLUMN 7) *
1	275	215	31	184	269	123
2	727	465	193	272	691	90
3	1,116	636	263	373	355	30
4	1,054	618	274	343	422	26
5	1,312	713	278	435	49	121
6	1,524	774	301	473	78	76
7	1,596	749	351	399	187	42

MINING YEAR (COLUMN 1)	TOTAL DEMAND (ML) (COLUMN 2)	NET DEMAND (ML) (COLUMN 3)	ANNUAL GROUNDWATER TO THE MINE SUMP (ML) (COLUMN 4)	POTENTIAL SUPPLY FROM THE MINED OUT PANEL GROUNDWATER WITHOUT SURFACE WATER (ML) (COLUMN 5)	NET ANNUAL RAINFALL - RUNOFF FOR WET CLIMATE SEQUENCE (1950 TO 1969) (ML) (COLUMN 6) *	NET ANNUAL RAINFALL - RUNOFF FOR DRY CLIMATE SEQUENCE (1991 TO 2010) (ML) (COLUMN 7) *
8	1,670	768	450	318	542	299
9	1,648	786	546	240	-3	84
10	1,337	674	637	37	123	75
11	1,242	675	707	0	272	80
12	1,369	707	741	0	119	-29
13	1,468	795	792	4	440	43
14	1,567	862	845	17	265	-21
15	1,652	878	921	0	486	138
16	1,228	679	995	0	292	-12
17	1,297	701	1,009	0	22	239
18	1,055	619	945	0	108	13
19	532	384	728	0	112	-30
Total	**23,668**	**12,698**	**11,006**	**3,095**	**4,829**	**1,388**

Note: * Negative values indicate water evaporated from PWD water surface that would be maintained between 83 ML and 124 ML with water supplied from mined out panels or CPP washing return in SB02.

3.2.2.3 SUMMARY OF MEAN ANNUAL WATER BALANCE

The water balance model was run at a daily timestep for 107 sets of climatic sequences for the 19-year mining period to estimate surpluses and deficits in meeting total annual project demands. The mean values calculated from 107 likely sets of climatic sequences for annual project inflows and outflows are presented in Table 3.8.

Project water demands over the period of the 19-year mine life are expected to be fully met by the use of the net harvestable rainfall-runoff from the SBs and MWDs, the groundwater collected by the underground mine sump and the groundwater within the mined out void spaces behind the bulkheads. Note that the water balance model assumes an initial storage volume of 100 ML in the PWD at the start of the water balance simulation and this water will be available in the initial year of mining when net demands exceed groundwater inflows to the sump and void.

The PWD will receive all transferred rainfall-runoff and any water returns from mining operation. On average 22% of the total demand over the 19-year mining period could be supplied from the simulated net rainfall-runoff (column 2 of Table 3.8) that is transferrable from the dam catchments to the PWD, including the CPP return from SB02. The remainder of water supply to the PWD will come from the underground sump (69%) and the void spaces (9%) (Table 3.8). Note that the void spaces will receive natural groundwater and water used to pump the coal reject material, as well as any surplus water pumped to voids from the underground sump, and therefore the water pumped from the void to the PWD will be a mixture of these water sources. On average, 85% of the water collected in the sump will be returned to the PWD.

The simulated net rainfall-runoff sequence volume was the lowest for the climate sequence 103 from 1991 to 2010 (refer to column 7 of Table 3.7 for annual volumes). For this sequence the simulated daily volume and supply deficit report for the PWD confirms that the project demands can be fully met by the net rainfall-runoff and groundwater from the underground mine and there is no deficit (assuming an initial storage volume of 100 ML in the PWD at the start of the water balance simulation). For this climate sequence, the majority of simulated water supply for the project demand came from the groundwater from the underground mine (refer to Figure 3.1 for daily distribution of supply). Over the 19-year simulation for this sequence a total volume of 2,436 ML was supplied from the void representing about 13% of total groundwater inflow volume to the void over that period.

Figure 3.2 shows the 19-year sum of net rainfall-runoff, water transferred from the void to the PWD and water pumped from the sump to the void for all climate realisations. The peak volume stored in the PWD is also shown on the figure. The figure shows the correlation between net rainfall-runoff and pumping of surplus water to the void. The transfer of water from the void to the PWD is inversely correlated to net rainfall-runoff volumes in the dry climate sequences when the PWD needs to be maintained at volumes > 83 ML more regularly within the 19-year mining period for operations and to meet project demands including evaporation.

Results presented in Table 3.8 are subject to modelled pumping rules applied at the underground sump. The mean of annual results for the groundwater balance is presented in Table 3.9. The underground sump is expected to receive water from:

— local groundwater (column 2 of Table 3.9)

— MWD07 (column 3 of Table 3.9)

— decant from the co-disposed reject emplaced underground in each mine panel prior to bulkheads being installed

— the remainder of the water supplied for the underground mining equipment and operation from the PWD.

If the volume in the PWD is less than 124 ML, water will be pumped from the underground sump back to the PWD, to maintain a volume of between 83 ML and 124 ML in the PWD. Pumping from the underground sump into mine voids only occurs when the volume in the PWD exceeds 124 ML. If the volume of water reporting to the sump is insufficient to maintain the PWD level, then it will be supplemented with groundwater abstracted from mine voids.

Natural groundwater and surplus water that will be stored in the void spaces over the 19-year mining operation will be pumped to the PWD to meet project demands as required. During the 19-year mine life it is expected that 784 ML net may be pumped into the void spaces in excess of water pumped out to meet demands (refer to the last column of Table 3.9).

Simulations undertaken for the 107 sets of 19-year climate sequences suggest that the water volume in the PWD and all SBs and MWDs will not exceed their capacities during the mining operation. Refer to Section 3.2.2.4 for discussion of results for all basins and dams.

Statistics for the simulated 19-year sum of releases to creeks from SB03 and SB04 are presented in Table 3.10 based on the 107 water balance realisations. The total simulated release to creeks from SB03 over the 19-year mining operation was found to range from 112 ML to 277 ML. The maximum annual release from SB03 was 30.6 ML/yr. The total simulated release to creeks from SB04 over the 19-year mining operation was found to range from 87 ML to 302 ML. The maximum annual release from SB04 was 41.1 ML/yr.

Table 3.8 Simulated mean annual PWD water balance based on 107 water balance realisations – water balance model base case (replaces Table 5.5 of the EIS Water Balance Assessment (PB 2016a))

MINING YEAR	NET WATER TRANSFER FROM SBS AND MWDS * TO PWD (ML)	WATER TRANSFER FROM UNDER GROUND SUMP TO PWD (ML)	GROUNDWATER FROM THE VOID SPACES SUPPLIED TO PWD (ML)	RAINFALL AND RUNOFF IN EXCESS OF EVAP AT PWD (ML)	TOTAL ANNUAL PROJECT DEMAND (ML)	WATER STORED IN PWD AT THE START OF A YEAR (ML)	ANNUAL OVERFLOW FROM PWD (ML)
1	164.3	54.7	95.8	4.0	274.7	87.4	0.0
2	236.4	336.9	138.8	3.5	726.7	137.8	0.0
3	285.2	547.8	239.9	5.4	1,116.4	122.1	0.0
4	270.9	530.4	240.6	6.4	1,053.9	91.2	0.0
5	283.6	700.8	321.1	6.4	1,311.7	88.3	0.0
6	293.5	860.3	362.8	6.3	1,523.8	88.1	0.0
7	295.9	996.5	298.0	6.0	1,595.6	88.4	0.0
8	296.4	1142.0	227.0	5.5	1,670.0	89.6	0.0
9	302.8	1180.8	160.2	5.3	1,647.9	90.3	0.0
10	281.0	1042.6	21.5	3.6	1,337.2	93.6	0.0
11	273.7	976.2	2.8	2.1	1,242.2	103.6	0.0
12	282.0	1085.9	0.0	0.9	1,369.0	112.9	0.0
13	295.0	1165.2	1.1	0.8	1,468.0	111.1	0.0
14	295.1	1262.3	5.3	1.3	1,567.0	105.7	0.0
15	282.9	1376.9	1.5	0.4	1,652.2	106.7	0.0
16	262.3	973.8	0.0	-1.0	1,227.6	122.8	0.0
17	283.0	1015.5	0.0	-1.3	1,297.2	123.0	0.0
18	259.6	797.2	0.0	-1.2	1,055.0	123.3	0.0
19	195.0	349.6	0.0	-2.3	532.0	125.3	0.0
Total	**5,138.6**	**16,395.4**	**2,116.4**	**52.0**	**23,668.1**	**105.9 ****	**0.0**

Note: * MWD07 is excluded from the surface storages as it transfers water to the underground system. MWD08 is excluded from the water balance as it is a small storage associated with the WTP. ** Mean stored volume in PWD at the start of year is 105.9 ML.

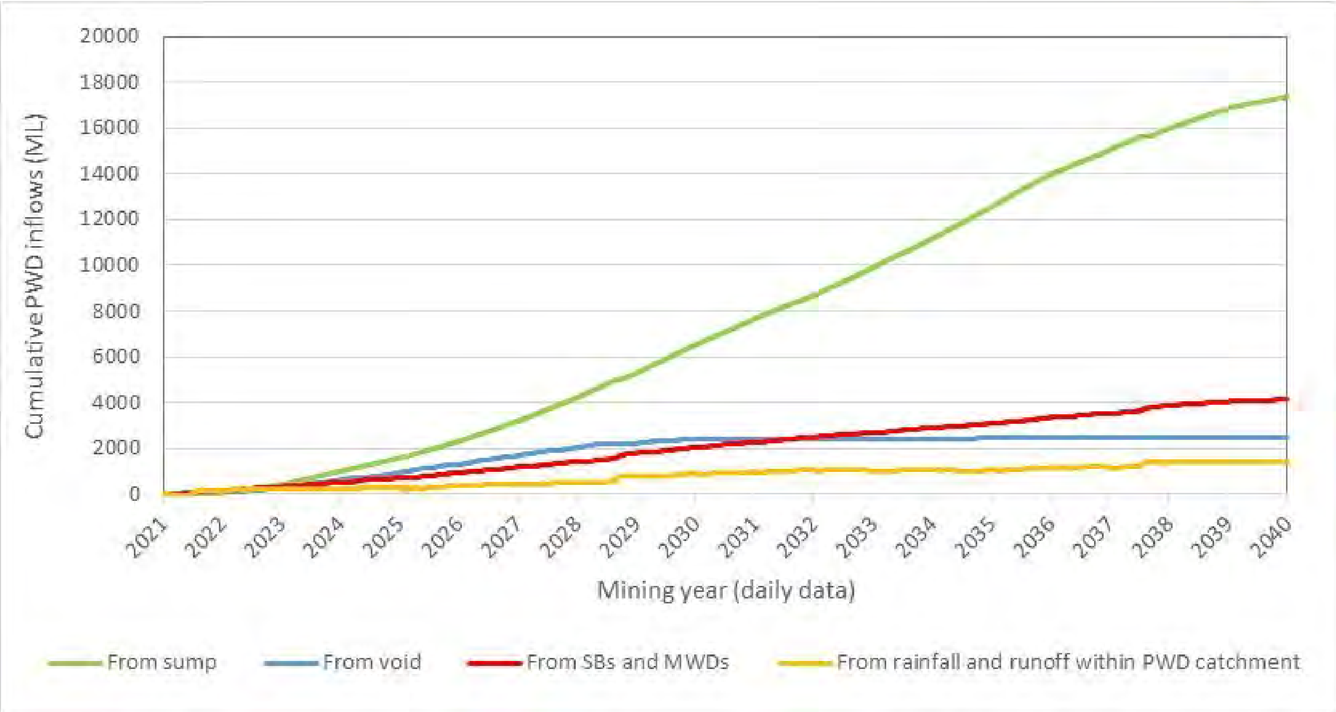


Figure 3.1 Simulated daily inflows to the PWD from sump, void, SBs and MWDs and the PWD local catchment for dry climate sequence 103 (1991 to 2010) – water balance model base case (replaces Figure 5.1 of the EIS Water Balance Assessment (PB 2016a))

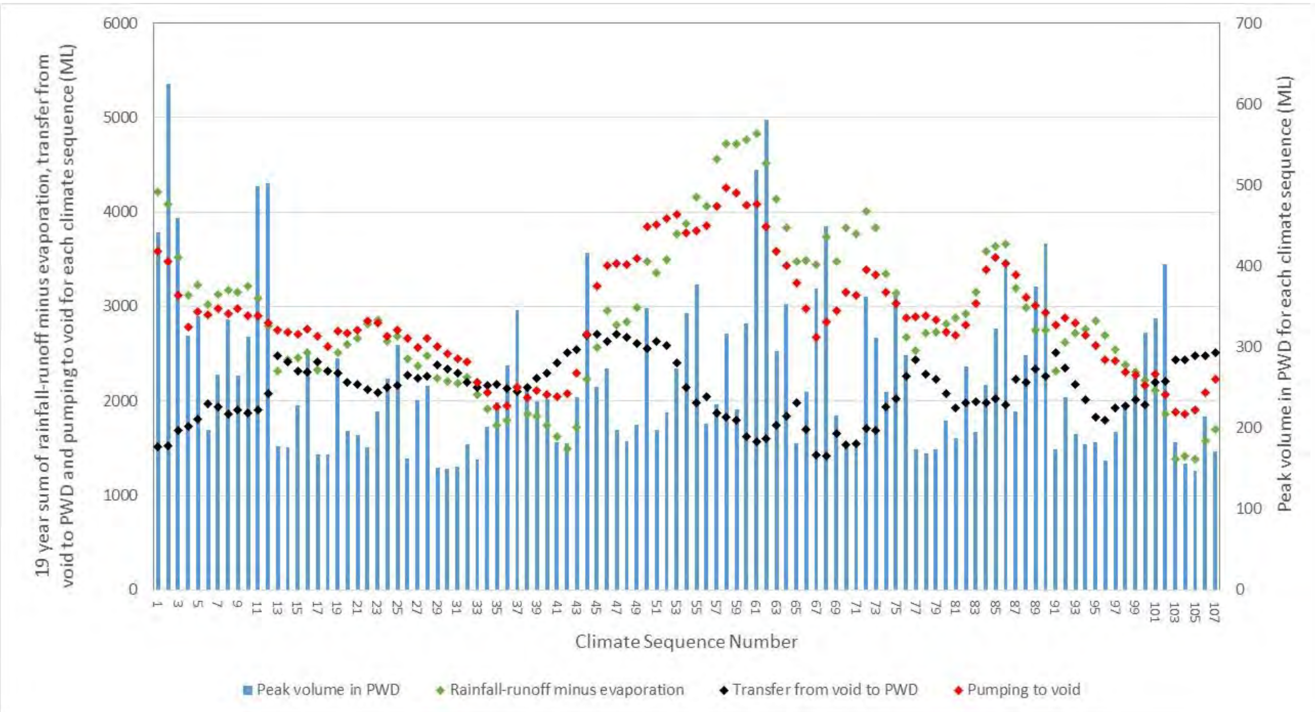


Figure 3.2 Simulated 19-year sum of rainfall runoff, transfer from void to PWD and pumping to void, with peak volume in PWD for all 107 water balance realisations – water balance model base case (replaces Figure 5.2 of the EIS Water Balance Assessment (PB 2016a))

Table 3.9 Simulated mean annual underground mine balance based on 107 water balance realisations – water balance model base case (replaces Table 5.6 of the EIS Water Balance Assessment (PB 2016a))

MINING YEAR	ANNUAL GROUNDWATER VOLUME TO SUMP (ML) COLUMN 2	ANNUAL TRANSFER FROM MWD07 TO SUMP (ML) COLUMN 3	ANNUAL PUMPING TO THE VOID SPACES (ML) COLUMN 4	ANNUAL NATURAL GROUNDWATER TO THE VOID SPACES (ML) COLUMN 5	SUPPLY FROM THE VOID SPACES BEHIND THE BULKHEADS (ML) COLUMN 6	NET SUPPLY FROM VOID (ML) * COLUMN 7
1	31.3	6.0	0.2	168.7	95.8	95.6
2	193.1	6.6	22.3	977.2	138.8	116.5
3	263.0	6.5	47.0	1,179.4	239.9	193.0
4	274.4	6.4	44.9	1,141.3	240.6	195.6
5	278.2	6.4	27.4	958.7	321.1	293.6
6	301.1	6.4	29.9	920.9	362.8	332.8
7	350.6	6.3	36.5	900.0	298.0	261.4
8	449.8	6.3	45.8	1,077.3	227.0	181.1
9	546.0	6.3	55.5	1,201.8	160.2	104.7
10	636.7	6.2	106.4	1,174.4	21.5	-85.0
11	706.5	6.2	152.9	1,130.4	2.8	-150.0
12	740.6	6.1	162.0	1,117.1	0.0	-161.9
13	791.7	6.0	129.1	1,000.8	1.1	-127.8
14	845.2	6.0	117.3	894.8	5.3	-112.0
15	920.9	6.0	159.3	783.9	1.5	-157.8
16	994.8	6.0	431.4	841.1	0.0	-431.4
17	1,008.8	5.9	428.9	1,055.5	0.0	-428.9
18	944.9	6.0	448.0	1,116.2	0.0	-448.0
19	728.0	6.0	455.3	937.6	0.0	-455.3
Total	**11,005.6**	**117.6**	**2,899.9**	**18,577.1**	**2,116.4**	**-783.7**

*Note: Negative values indicate a surplus of water pumped to voids that is not needed to meet demand (column 4 minus column 7).

Table 3.10 Simulated 19-year sum of releases from SB03 and SB04 to Oldbury Creek subject to meeting the first flush criteria based on 107 water balance realisations – water balance model base case (replaces Table 5.7 of the EIS Water Balance Assessment (PB 2016a))

19-YEAR SUM OF RELEASES (ML)							
AVERAGE	MINIMUM	25TH %ILE	50TH %ILE (MEDIAN)	75TH %ILE	90TH %ILE	95TH %ILE	MAXIMUM
SB03 releases							
183	112	161	175	205	238	263	277
SB04 releases							
178	87	148	173	208	253	285	302

3.2.2.4 UNCONTROLLED SPILL RISK

Water storage capacity and pumping rates for the project basins and dams were tested in the water balance modelling to ascertain that no uncontrolled overflows occur from any of the storages, for the assumed AWBM estimated rainfall-runoff volumes. The capacities and peak simulated stored volume in each basin and dam from the 107 water balance model realisations are provided in Table 3.11, demonstrating that none of the basins or dams spill in any of the 107 realisations.

Figure 3.3 shows the peak simulated stored volume in the PWD over the 19-year mining period for the 107 water balance model realisations. The peak stored volume in the PWD is 625 ML compared to 665 ML for the EIS (the difference is due to reduced groundwater inflow rates to the mine sump in Year 1 of mining (HydroSimulations, 2018)). Stored volumes in the PWD are highest in the initial years of mining when demand is low and there is less void space available to receive excess water. Figure 3.3 shows the probability envelope of all simulated results for stored volume within the PWD.

Table 3.11 Capacities and simulated peak water volumes in stormwater basins, mine water dams, the PWD and the underground mine sump based on 107 water balance realisations – water balance model base case (replaces Table 5.8 of the EIS Water Balance Assessment (PB 2016a))

DAM	MODELLED CAPACITY (ML)	PEAK SIMULATED VOLUME (ML)
SB01	106.40	82.9
SB02	91.10	51.8
SB03	19.44	17.5
SB04	140.24	57.8
MWD05	5.95	2.1
MWD06	14.80	8.0
MWD07	5.73	5.0
PWD	730.00	624.6
Sump	6.00	6.0

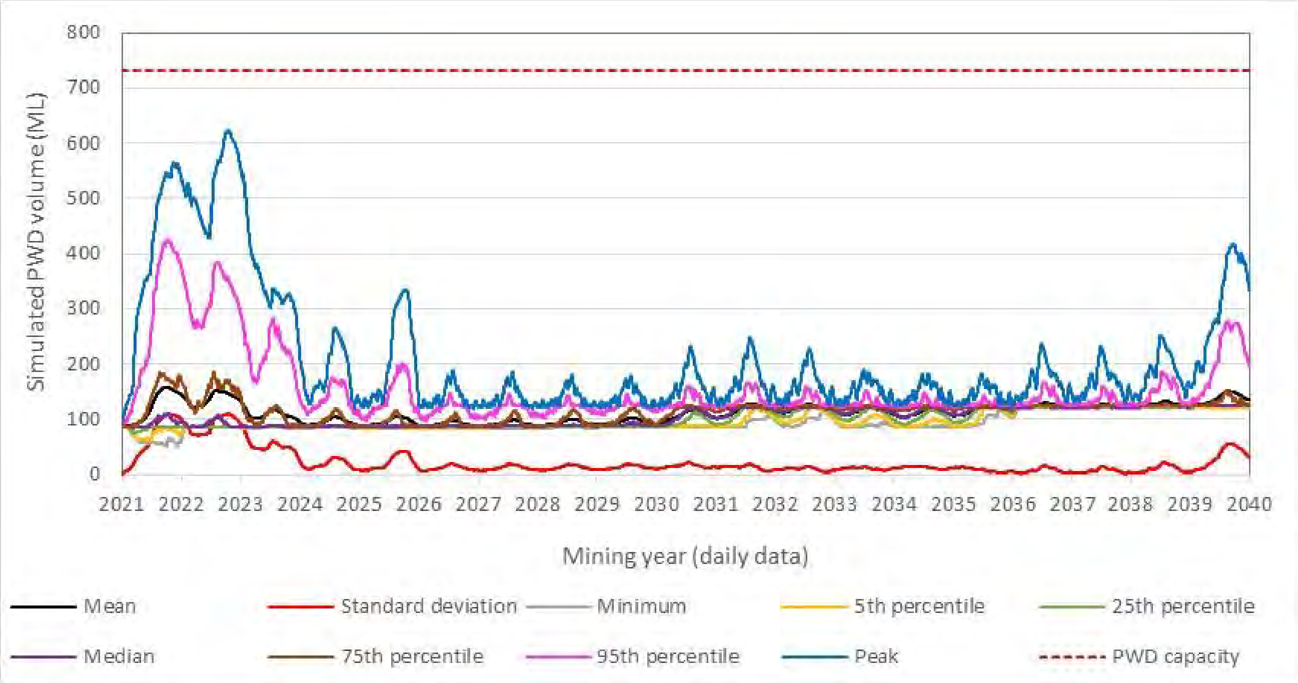


Figure 3.3 Daily statistics of simulated stored volume in the PWD over life of project based on 107 sets of climate sequences – water balance model base case (replaces Figure 5.3 of the EIS Water Balance Assessment (PB 2016a))

3.2.2.5 PUMPING TO MINE VOID

The mine void space available to accommodate surplus water pumped from the sump will depend on the volume of co-disposed reject placed in the void and the natural groundwater ingress into the void. The data presented in Table 3.3 provides the physically available storage space created each year, however, the actual availability may increase during the mining operation due to pumping from the void for supply of project water demands if/when the PWD storage reduces to less than 83 ML.

Figure 3.4 shows the annually available net void space with co-disposed reject, cumulative groundwater inflows to the void, and cumulative volumes of water pumped from the sump to behind the bulkheads for the wet climate sequence 62. Total groundwater inflow to the panels in the early years of the mine life was limited by the available net void space for the wet climate sequence 62. The void space limitation is evident from 2021 to 2026 in Figure 3.4.

Statistics for the simulated 19-year sum of pumping to the void are presented in Table 3.12 based on the 107 water balance realisations. The total simulated pumping to the void over the 19-year mining operation was found to range from 1,865 ML to 4,255 ML. The minimum annual pumping to the void was 0 ML/yr. The maximum annual pumping to the void was 959 ML/yr occurring in Year 18 of mining.

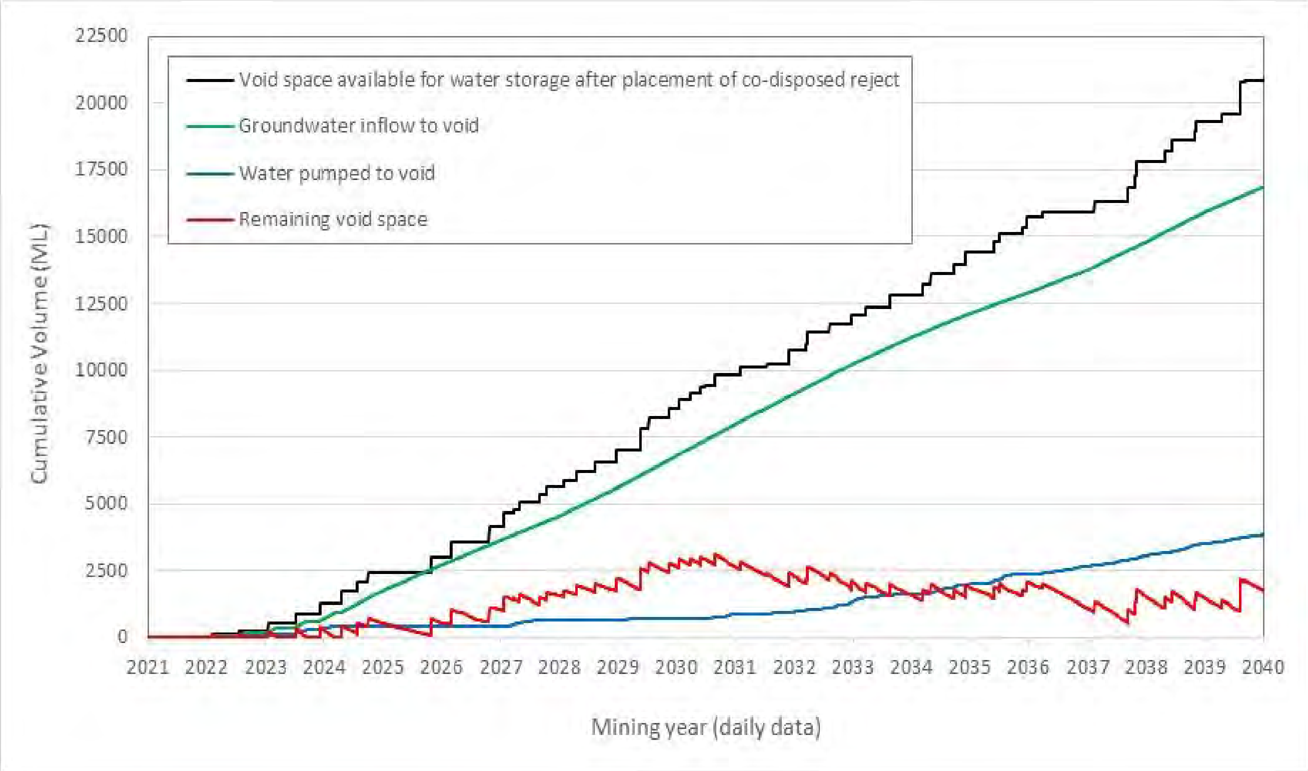


Figure 3.4 Simulated annual volumes of available void space, groundwater inflows to void, water pumped to void and remaining void space for wet climate sequence 62 (1950 to 1969) – water balance model base case (replaces Figure 5.4 of the EIS Water Balance Assessment (PB 2016a))

Table 3.12 Simulated 19 year sum of pumping to mine void based on 107 water balance realisations – water balance model base case (replaces Table 5.9 the EIS Water Balance Assessment (PB 2016a))

19-YEAR SUM OF PUMPING TO MINE VOID (ML)							
AVERAGE	**MINIMUM**	**25TH %ILE**	**50TH %ILE (MEDIAN)**	**75TH %ILE**	**90TH %ILE**	**95TH %ILE**	**MAXIMUM**
2,899	1,865	2,567	2,842	3,289	3,820	3,966	4,255

3.2.2.6 CONSIDERATION OF EXCESS WATER DISPOSAL REQUIREMENTS

Simulations undertaken for 107 climate sequences showed that the excess water can be managed by pumping into the void and PWD, and there is no requirement for disposing of excess water by treatment and release to Oldbury Creek. The water balance operating rules assumed that rainfall-runoff arriving at SB03 and SB04 after the first flush would be released to Oldbury Creek subject to water quality being acceptable.

Table 3.13 presents simulated peak annual volumes in the PWD for the 10 wettest climate sequences out of 107. The peak volume in PWD is 625 ML. For all 107 water balance realisations, the peak volume in the PWD was less than the peak volume presented in the EIS (665 ML) and far less than the maximum capacity of the dam (730 ML). This demonstrates that no disposal of excess water (via treatment in the WTP and release to Oldbury Creek) would be required for the simulated combination of climates and operating rules.

Figure 3.5 shows the daily distribution of the volumes of water in the PWD if the wet climate sequence from 1950 to 1969 (sequence number 62) repeats during mining.

Table 3.13 Simulated annual peak volume (ML) in PWD – water balance model base case (replaces Table 5.10 of the EIS Water Balance Assessment (PB 2016a)))

MINING YEAR	CLIMATE SEQUENCE NUMBER									
	2	**62**	**61**	**12**	**11**	**3**	**68**	**1**	**90**	**44**
1	506.8	564.9	257.7	502.0	327.7	460.0	449.6	180.4	428.4	110.8
2	624.6	581.3	519.2	471.9	499.1	415.3	371.5	441.1	381.8	92.7
3	556.8	497.5	479.1	158.9	454.4	284.4	124.2	329.4	92.9	110.7
4	157.1	212.9	190.8	110.7	125.6	131.8	125.3	177.4	95.1	98.3
5	128.2	101.5	106.2	166.1	111.5	119.5	102.2	162.7	94.1	96.5
6	117.5	129.3	100.0	93.2	153.4	124.7	132.1	127.9	102.6	96.6
7	125.4	136.5	130.9	119.7	95.8	125.3	134.2	120.1	114.8	127.1
8	126.0	103.1	136.0	111.3	124.5	126.8	129.7	126.4	100.1	92.3
9	128.8	125.1	105.8	126.5	116.8	154.9	159.8	127.6	134.5	95.6
10	168.2	134.2	128.0	117.4	130.6	232.7	124.4	131.7	126.7	110.2
11	248.3	132.2	139.0	147.9	125.0	132.5	136.1	172.3	172.0	133.6
12	131.3	159.3	129.8	138.4	145.2	139.0	134.5	230.1	143.6	206.5
13	128.9	135.7	153.5	142.0	137.3	129.8	124.4	130.4	171.7	126.0
14	128.4	141.8	135.2	148.2	137.7	181.3	132.3	128.2	130.3	131.2
15	173.0	165.5	136.7	127.8	140.6	127.4	127.6	128.7	129.7	126.5
16	128.2	132.8	183.4	138.8	140.5	139.2	128.0	199.3	126.5	127.2
17	138.4	135.2	133.2	168.3	137.9	128.7	128.3	128.0	133.3	127.9
18	131.8	140.9	140.7	128.8	177.0	150.0	127.9	143.8	139.1	178.4
19	169.2	138.6	164.4	140.3	135.3	133.8	305.1	143.2	141.5	416.0

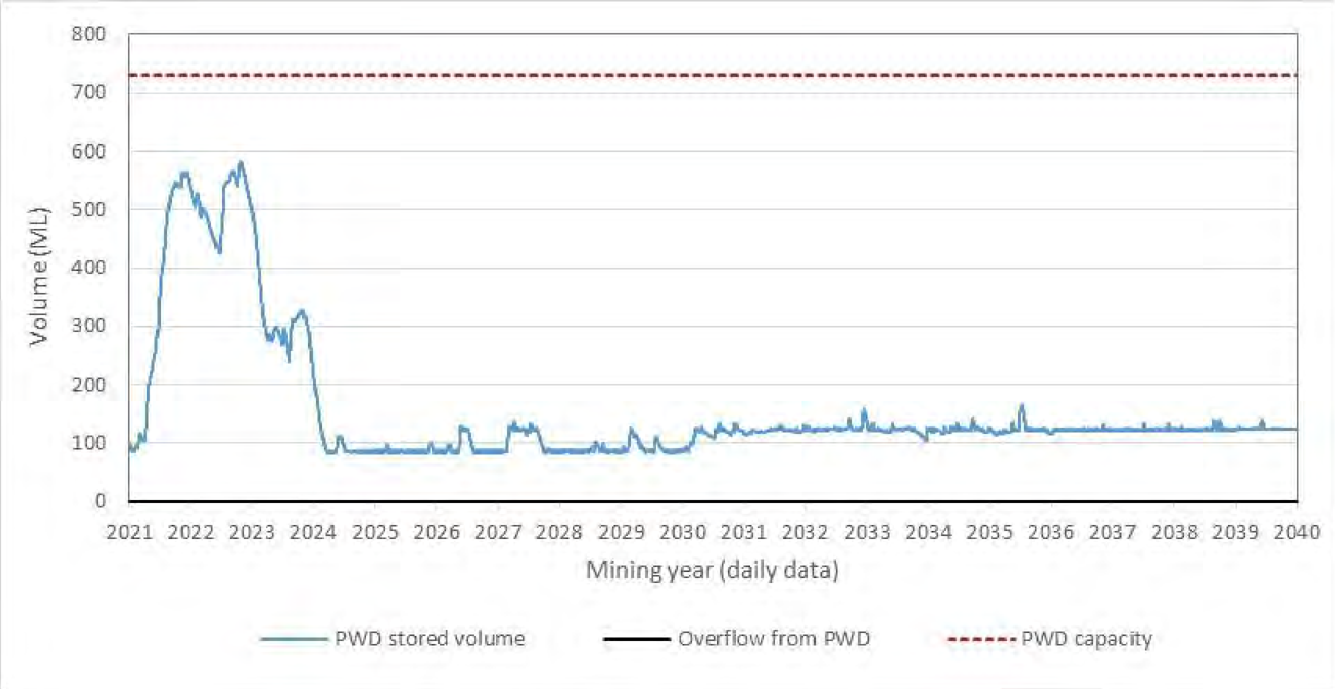


Figure 3.5 Simulated daily volumes in the PWD for wet climate sequence 62 (1950 to 1969) – water balance model base case (replaces Figure 5.5 of the EIS Water Balance Assessment (PB 2016a)))

3.3 WATER BALANCE MODEL CLIMATE SENSITIVITY ANALYSIS

A water balance model climate sensitivity analysis has been undertaken to assess the impact of changes to the groundwater inflow estimates from the Modified EIS Groundwater Model wet and dry climate scenarios compared to the Modified EIS Groundwater Model static average climate.

The only change to the water balance model for the climate sensitivity analysis is the groundwater inflow estimates adopted in the model. All other model data and operating rules are the same as for the water balance model base case in Section 3.2.

3.3.1 GROUNDWATER INFLOWS ADOPTED IN WATER BALANCE MODEL CLIMATE SENSITIVITY ANALYSIS

Groundwater inflow estimates adopted in the water balance model climate sensitivity analysis are provided in Table 3.14. The total groundwater inflow, including inflows to the mine sump and mine void, over the 19-year mining period is 28,246 ML for the climate sensitivity analysis static average climate. The total groundwater inflow is 28,293 ML for the climate sensitivity analysis wet climate scenario, which is 0.2% higher than the climate sensitivity analysis static average climate. The total groundwater inflow is 28,025 ML for the climate sensitivity analysis dry climate scenario, which is 0.8% lower than the climate sensitivity analysis static average climate.

Table 3.14 Groundwater inflow estimates adopted for water balance model climate sensitivity analysis

MINING YEAR	GROUNDWATER INFLOWS ESTIMATES FROM MODIFIED EIS GROUNDWATER MODEL (ML/YR)								
	STATIC AVERAGE CLIMATE			WET CLIMATE SCENARIO			DRY CLIMATE SCENARIO		
	TO MINE SUMP	TO MINE VOID	TOTAL	TO MINE SUMP	TO MINE VOID	TOTAL	TO MINE SUMP	TO MINE VOID	TOTAL
1	4.8	126.4	131.2	4.8	126.6	131.4	4.8	126.4	131.2
2	67.1	721.4	788.5	67.5	723.9	791.4	66.9	722.3	789.2
3	132.1	973.1	1,105.2	133.1	976.4	1,109.5	131.6	974.3	1,106.0
4	188.5	1,080.1	1,268.6	190.1	1,082.7	1,272.7	187.5	1,080.6	1,268.1
5	236.4	1,092.5	1,328.9	238.4	1,093.1	1,331.4	234.7	1,092.1	1,326.8
6	276.0	1,126.1	1,402.1	278.2	1,125.1	1,403.3	273.2	1,124.7	1,398.0
7	304.0	1,143.8	1,447.7	306.2	1,141.3	1,447.5	300.2	1,141.7	1,441.9
8	334.4	1,174.1	1,508.5	336.8	1,172.0	1,508.8	329.4	1,173.2	1,502.6
9	397.6	1,163.9	1,561.6	399.7	1,162.0	1,561.7	390.9	1,164.0	1,554.9
10	501.6	1,138.5	1,640.1	502.8	1,139.2	1,642.0	492.7	1,138.5	1,631.2
11	593.6	1,117.8	1,711.3	594.2	1,117.7	1,711.8	582.8	1,117.5	1,700.4
12	642.8	1,159.3	1,802.1	643.8	1,159.1	1,802.9	630.2	1,158.7	1,788.9
13	720.3	1,177.8	1,898.1	722.3	1,177.9	1,900.3	704.4	1,177.4	1,881.8
14	845.7	1,042.0	1,887.6	849.6	1,041.5	1,891.1	824.6	1,042.4	1,867.1
15	967.5	707.4	1,674.9	973.9	706.4	1,680.3	942.1	708.1	1,650.2
16	1,026.8	691.1	1,717.9	1,034.5	692.0	1,726.4	999.9	692.1	1,692.0
17	997.2	1,029.0	2,026.2	1,003.5	1,030.5	2,034.0	970.8	1,029.3	2,000.0
18	911.5	1,046.0	1,957.5	915.1	1,045.2	1,960.3	884.7	1,046.0	1,930.8
19	696.3	691.2	1,387.5	698.2	688.1	1,386.3	673.4	690.4	1,363.9
Total	**9,844**	**18,401**	**28,246**	**9,893**	**18,401**	**28,293**	**9,625**	**18,400**	**28,025**

Source: HydroSimulations, 2018

3.3.2 WATER BALANCE MODEL CLIMATE SENSITIVITY ANALYSIS RESULTS

This section provides a comparison of key results for the water balance model climate sensitivity analysis wet and dry climate scenarios compared to the climate sensitivity analysis static average climate. The focus is on the predicted risk of overflows from SBs and MWDs, peak stored volumes in SBs and MWDs, and releases from SB03 and SB04 subject to meeting the first flush criteria.

No uncontrolled overflows occurred from any of the SBs or MWDs over the 19-year mine life based on the 107 water balance model realisations for the climate sensitivity analysis static average climate or the climate sensitivity analysis wet and dry climate scenarios. The percentage change to the simulated peak water volume in SBs and MWDs based on the 107 water balance model realisations for the climate sensitivity analysis wet and dry climate scenarios compared to the climate sensitivity analysis static average climate is provided in Table 3.15. There was no change to the simulated peak stored volume in SB01, SB02, SB03, SB04, MWD05 and MWD06 between the climate sensitivity analysis wet and dry climate scenarios compared to the climate sensitivity analysis static average climate. This is because these SBs and MWDs transfer water to the PWD, and the stored volume in the PWD does not exceed the volume at which water transfer into the PWD is stopped for any of the realisations or scenarios modelled. The only change in the simulated peak stored volumes between the climate sensitivity analysis wet and dry climate scenarios compared to the climate sensitivity analysis static average climate is a slight difference in the stored volume in the PWD. The peak stored volume in the PWD is +0.01% higher (equivalent to less than 1 ML higher) for the climate sensitivity analysis wet climate scenario compared to the climate sensitivity analysis static average climate. The results from the climate sensitivity analysis dry climate scenario are similar to those from the climate sensitivity static average climate.

Table 3.15 Change in simulated peak water volumes in stormwater basins, mine water dams, the PWD and the underground mine sump based on 107 water balance realisations – water balance model climate sensitivity analysis

DAM	% CHANGE TO PEAK WATER VOLUME COMPARED TO CLIMATE SENSITIVITY ANALYSIS STATIC AVERAGE CLIMATE	
	CLIMATE SENSITIVITY ANALYSIS WET CLIMATE SCENARIO	CLIMATE SENSITIVITY ANALYSIS DRY CLIMATE SCENARIO
SB01	0.00%	0.00%
SB02	0.00%	0.00%
SB03	0.00%	0.00%
SB04	0.00%	0.00%
MWD05	0.00%	0.00%
MWD06	0.00%	0.00%
MWD07	0.00%	0.00%
PWD	+0.01%	0.00%
Sump	0.00%	0.00%

There was no change to the simulated 19-year sum of releases from SB03 and SB04 to Oldbury Creek (subject to meeting the first flush criteria) based on the 107 water balance model realisations for the climate sensitivity analysis wet and dry climate scenarios compared to the climate sensitivity analysis static average climate. This is because the PWD is able to accept pumped inflows from SB03 and SB04 over the 19-year life of the mine for all of the realisations and scenarios modelled.

The results of the water balance model climate sensitivity analysis demonstrate that the Modified EIS Groundwater Model wet and dry climate scenario groundwater inflows are not sufficiently different to make any significant change to the predicted overflows from SBs and MWDs, peak stored volumes in SBs and MWDs, and releases from SB03 and SB04 compared to the Modified EIS Groundwater Model static average climate groundwater inflows.

4 SURFACE WATER FLOW ASSESSMENT

4.1 METHOD

The flow impact assessment undertaken for the Hume Coal Project EIS has been revised to include the revised baseflow reduction estimates from post-EIS numerical groundwater modelling undertaken by HydroSimulations (refer to Section 2). The flow impact assessment has also been revised to include the revised estimates of releases from SB03 and SB04 to Oldbury Creek as predicted by the revised water balance model. Details of the flow assessment undertaken for the EIS are provided in the Hume Coal Project Surface Water Flow and Geomorphology Assessment report (Parsons Brinckerhoff, 2017a).

The base case flow assessment adopts baseflow reduction estimates from the Mean K Groundwater Model. The results of the base case flow assessment are provided in Section 4.2.

A flow assessment climate sensitivity analysis has been undertaken adopting baseflow reduction estimates from the Modified EIS Groundwater Model static average climate, wet climate scenario and dry climate scenario. The results of the flow assessment sensitivity analysis are provided in Section 4.3. The flow assessment sensitivity analysis has been undertaken to address matters raised in the submissions from government agencies.

A summary of the RTS flow assessment scenarios is provided in Table 4.1.

Table 4.1 Summary of RTS flow assessment scenarios

FLOW ASSESSMENT SCENARIO	BASEFLOW REDUCTION DATA	REPORT REFERENCE
Base case	Mean K Groundwater Model static average climate (refer Section 2.2 Figure 2.1)	Section 4.2
Climate sensitivity analysis static average climate	Modified EIS Groundwater Model static average climate (refer Section 2.2 Figure 2.2)	Section 4.3
Climate sensitivity analysis wet climate scenario	Modified EIS Groundwater Model wet climate (refer Section 2.2 Figure 2.3)	
Climate sensitivity analysis dry climate scenario	Modified EIS Groundwater Model dry climate (refer Section 2.2 Figure 2.4)	

Flow impacts have been assessed for:

— The Medway Rivulet and Oldbury Creek catchments where the surface and underground infrastructure for the mine is located.

— The Lower Wingecarribee River, Upper Wingecarribee River, Lower Wollondilly River, Bundanoon Creek and Nattai River management zones. These catchments are located outside the project area, however, small reductions of natural baseflow contributions to surface water systems in these catchments are predicted to occur as a result of the project.

Further details of the flow impact assessment methodology are provided in Section 4.1.1 and Section 4.1.2 below.

4.1.1 MEDWAY RIVULET AND OLDBURY CREEK CATCHMENTS

Existing flow conditions for Medway Rivulet and Oldbury Creek were established using the AWBM rainfall-runoff model as outlined in the Hume Coal Project Water Balance Assessment report (Section 2.6 and Appendix A) (Parsons Brinckerhoff, 2016a). The flow conditions during operation of the mine were assessed and the resulting changes in flow were analysed by comparing flow duration curves for existing conditions and operational mining conditions.

Flow impacts were assessed due to the following operational impacts:

— The reduction in catchment area associated with project storages. Note that there has been no change in catchment areas compared to the EIS.

— The release of water from SB03 and SB04 to Oldbury Creek. This was estimated using the revised GoldSim water balance model (refer to Section 3).

— The reduction of natural baseflow to streams associated with lowering of groundwater phreatic zones during underground mining. This was provided by Hume Coal and was an output of post-EIS numerical groundwater modelling undertaken by HydroSimulations.

4.1.2 OTHER CATCHMENTS

Existing case (pre-mining) flows for the Lower Wingecarribee River, Upper Wingecarribee River, Lower Wollondilly River, Bundanoon Creek and Nattai River management zones were approximated using the AWBM runoff for the Medway Rivulet management zone scaled to the subject catchment area. These pre-mining flows were then compared against the baseflow reduction volumes estimated by the revised numerical groundwater model to assess the potential change in yield for these catchments.

The flow impact assessment undertaken for the EIS has been extended to include the Upper Wingecarribee River and Nattai River management zones as the revised numerical groundwater modelling now predicts negligible amounts of baseflow reduction in these management zones (whereas no baseflow reduction was predicted in these management zones for the EIS). The maximum baseflow reduction for the Upper Wingecarribee River and Nattai River management zones was predicted to be 0.008 ML/day and 0.0002 ML/day, respectively, for the base case using baseflow reduction estimates from the Mean K Groundwater Model (refer to Section 2.2, Figure 2.1).

The above approach was considered reasonable given that the AWBM model was calibrated to observed flows at the WaterNSW stream gauging station No. 212009 on the Wingecarribee River at Greenstead, which receives runoff from a total catchment area of 58,700 ha and is therefore representative of regional scale flows. Stream gauging data is available at gauging station No. 212009 for the period October 1989 to December 2015. A comparison of the gauged flows to the AWBM scaled flows for gauging station No. 212009 (catchment area 587 km^2) indicates that the predicted total flow over the period of record is 16.6% higher than the observed flow, which is considered a reasonable calibration.

Calibration of separate AWBM models for the Lower Wollondilly River, Bundanoon Creek and Nattai River management zones was not considered necessary for the assessment of yield impacts given the low predicted baseflow reduction for these management zones. The maximum baseflow reduction for the Lower Wollondilly River, Bundanoon Creek and Nattai River management zones was predicted to be 0.006 ML/day, 0.007 ML/day and 0.0002 ML/day, respectively, for the base case using baseflow reduction estimates from the Mean K Groundwater Model (refer to Section 2.2, Figure 2.1).

4.2 FLOW ASSESSMENT BASE CASE

Impact assessment results are presented for two climate sequences:

— Climate sequence 61 (1949 to 1968), which is the climate sequence with the maximum volume of water released to Oldbury Creek from SB03 and SB04 of the 107 realisations simulated in GoldSim.

— Climate sequence 103 (1991 to 2010), which is the climate sequence with the lowest simulated rainfall-runoff volume of the 107 realisations simulated in GoldSim.

4.2.1 FLOW ASSESSMENT BASE CASE RESULTS

4.2.1.1 MEDWAY RIVULET AND OLDBURY CREEK CATCHMENTS

Flow duration curves for the wet and dry climate sequences in the Medway Rivulet catchment (excluding the Oldbury Creek catchment) are presented in Figure 4.1 and Figure 4.2. The flow duration curves for the operation case include the impacts of a reduction in catchment area associated with project storages and baseflow reduction to Medway Rivulet and its tributaries associated with lowering of groundwater phreatic zones during underground mining. The flow duration curves in Figure 4.2 include low flow discharges from the Moss Vale sewage treatment plant (STP) located on Whites Creek for both the existing and operation cases, which are approximated at 2.3 ML/day based on effluent data provided by Wingecarribee Shire Council for the EIS (refer to Hume Coal Project Surface Water Flow and Geomorphology Assessment report (Section 5.4.1.1) (Parsons Brinckerhoff, 2017a)).

The results show that with constant low flow discharges from the Moss Vale STP, the flow regimes in Medway Rivulet for the existing and operation cases are similar, as was also the results presented in the EIS. With constant discharges from Moss Vale STP, flow in Medway Rivulet exceeds 1 ML/day and there are zero no flow days for the existing and operation cases. If the constant discharges from the Moss Vale STP are excluded, changes in the low flow regime below approximately 5 ML/day may occur and the number of no flow days may increase by approximately 25% under the wet climatic scenario and by approximately 35% under the dry climatic scenario. The potential impacts to the low flow regime are mainly attributable to baseflow reduction associated with the lowering of groundwater phreatic zones during underground mining. The peak baseflow reduction in the Medway Rivulet catchment is 0.982 ML/day occurring in Year 19 of mining based on the Mean K Groundwater Model. Baseflow reduction in the Medway Rivulet catchment will decrease to less than 0.1 ML/day 66 years after the commencement of mining (refer Section 2.2 Figure 2.1). In comparison, peak baseflow reduction in the Medway Rivulet catchment presented in the EIS was very similar, at 0.925 ML/day occurring in Year 11 of mining (refer to Hume Coal Project Surface Water Flow and Geomorphology Assessment report (Section 5.1.4) (Parsons Brinckerhoff, 2017a)).

Flow duration curves for the wet and dry climate sequences in Oldbury Creek are presented in Figure 4.3. The flow duration curves for the operation case include the impacts of a reduction in catchment area associated with project storages, release of water from SB03 and SB04 after the first flush, and the reduction of natural baseflow to Oldbury Creek during underground mining. The flow duration curves for Oldbury Creek with and without constant low flow discharges from the Berrima STP are approximately the same. This is because discharges from the Berrima STP to Oldbury Creek are low, at approximately 0.2 ML/day which is the same as the EIS (refer to Hume Coal Project Surface Water Flow and Geomorphology Assessment report (Section 5.4.1.2) (Parsons Brinckerhoff, 2017a)).

The results show that alteration of the flow regime in Oldbury Creek during operation of the mine will be minor compared to pre-mining conditions, with releases from SB03 and SB04 to some extent offsetting impacts to flow associated with a reduction in catchment for project storages and slight baseflow reduction associated with a lowering of groundwater phreatic zones during underground mining. The peak baseflow reduction in the Oldbury Creek catchment is 0.021 ML/day occurring 20.5 years after the commencement of mining based on the Mean K Groundwater Model (refer Section 2.2 Figure 2.1). In comparison, peak baseflow reduction in the Oldbury Creek catchment presented in the EIS was slightly lower at 0.0021 ML/day occurring in Year 11.5 of mining (refer to Hume Coal Project Surface Water Flow and Geomorphology Assessment report (Section 5.1.4) (Parsons Brinckerhoff, 2017a)).

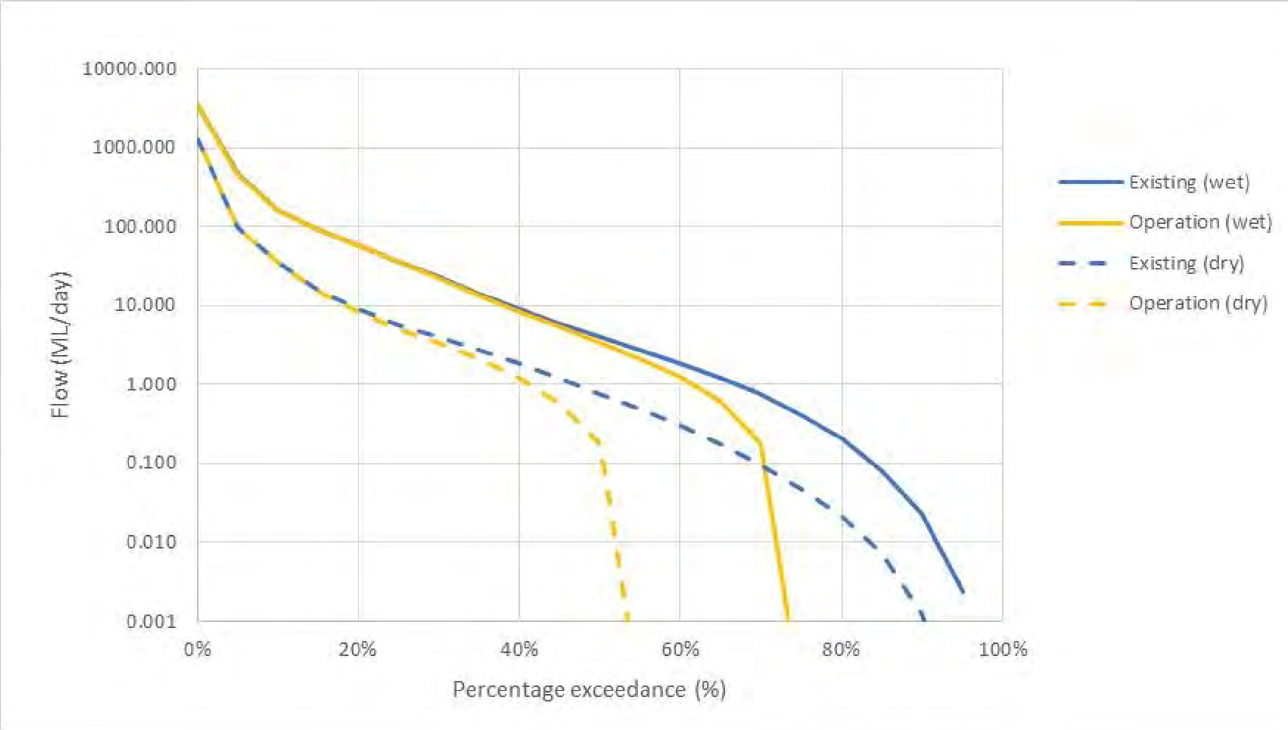


Figure 4.1 Flow duration curves for Medway Rivulet excluding Moss Vale STP discharges (wet and dry climate sequences) – flow assessment base case (replaces Figure 5.3 of the EIS Surface Water Flow and Geomorphology Report (PB 2017a))

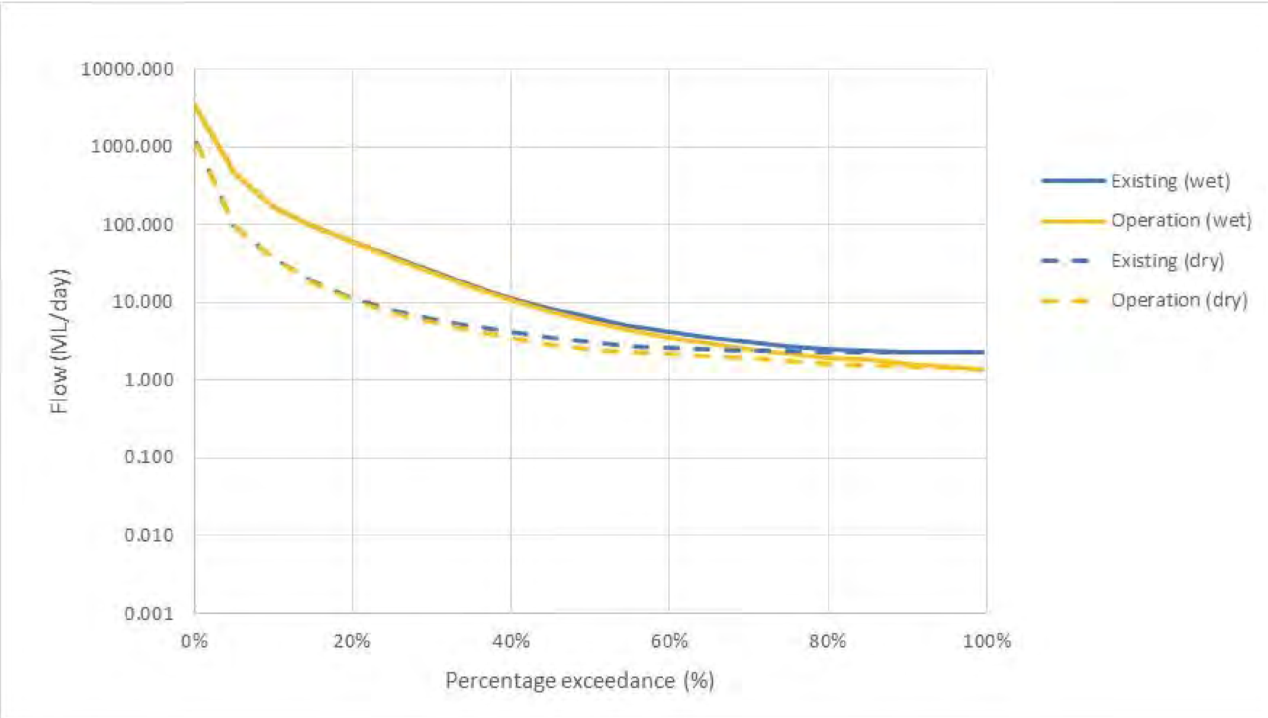


Figure 4.2 Flow duration curves for Medway Rivulet including Moss Vale STP discharges (wet and dry climate sequences) – flow assessment base case (replaces Figure 5.4 of the EIS Surface Water Flow and Geomorphology Report (PB 2017a))

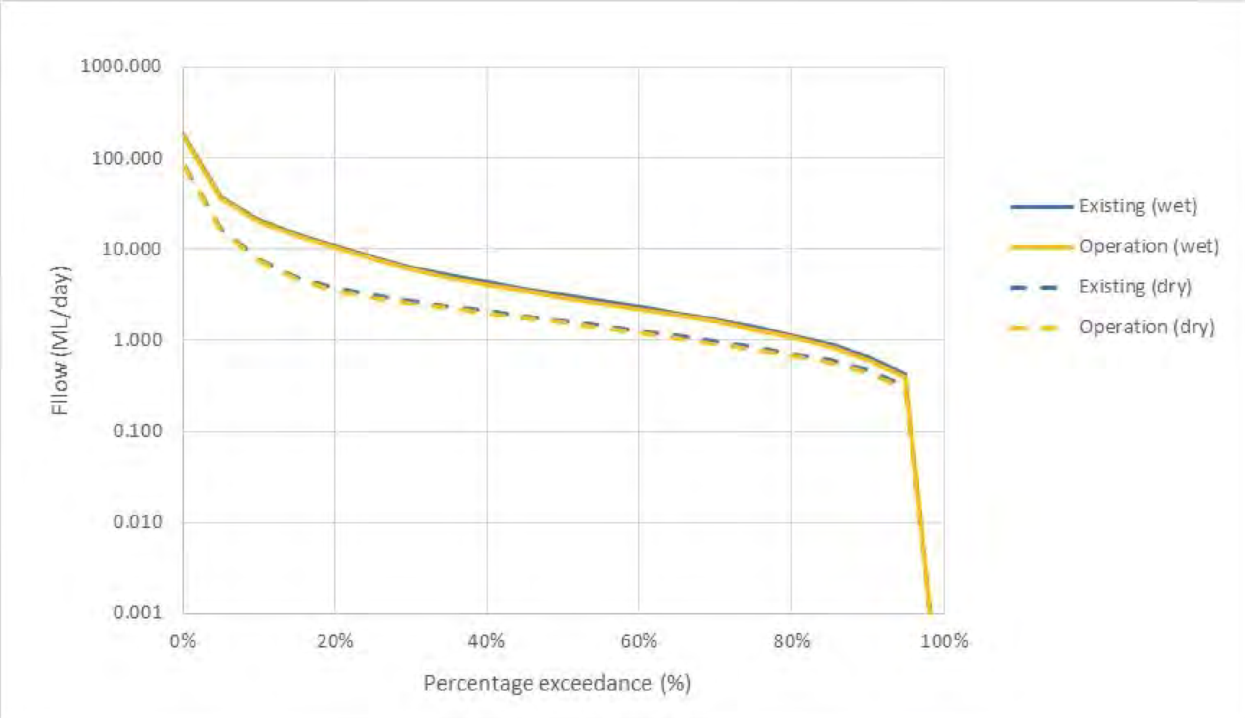


Figure 4.3 Flow duration curves for Oldbury Creek excluding STP discharges (wet and dry climatic sequences) – flow assessment base case (replaces Figure 5.5 of the EIS Surface Water Flow and Geomorphology Report (PB 2017a))

4.2.2 YIELD IMPACT ASSESSMENT RESULTS

4.2.2.1 MEDWAY RIVULET AND OLDBURY CREEK CATCHMENTS

The yield impact assessment results for the Medway Rivulet Management Zone and Medway Dam are presented in Table 4.2. Results are provided as a percentage change in yield and as an annual average and annual maximum volumetric loss over the 19-year mining period. The maximum volumetric loss estimates have been provided to address matters raised in the submissions from government agencies. The results indicate that under wet conditions, the project will result in a 0.9% reduction in yield for the Medway Rivulet management zone, and under dry conditions the project will result in a 1.6% reduction in yield. Locally, impacts to yield in the Oldbury Creek sub-catchment will be about a 4.3% reduction in yield under wet conditions and a 4.5% reduction in yield under dry conditions. There are no known or probable stream water users in the Oldbury Creek sub-catchment except for the farming operation affiliated with Hume Coal.

Table 4.2 Yield impacts for Medway Rivulet and Oldbury Creek – flow assessment base case (replaces Table 5.2 of the EIS Surface Water Flow and Geomorphology Report (PB 2017a).

CATCHMENT	INCLUDED SUB-CATCHMENTS	IMPACT DUE TO	YIELD IMPACT (% REDUCTION) / ANNUAL VOLUMETRIC LOSS OVER 19-YEAR MINING PERIOD (ML/YR)	
			WET CLIMATE SEQUENCE	DRY CLIMATE SEQUENCE
Medway Dam	Medway Rivulet Wells Creek	- Reduction in catchment area due to project storages (SB03, SB04, MWD05, MWD06 and MWD07) - Baseflow reduction for Medway Rivulet and Wells Creek	0.3% Max 278.1 ML/yr Mean 100.6 ML/yr	0.3% Max 120.9 ML/yr Mean 30.2 ML/yr
Medway Rivulet at the confluence with Wingecarribee River (excluding Oldbury Creek)	Medway Rivulet Wells Creek Belanglo Creek	- Reduction in catchment area due to project storages (SB03, SB04, MWD05, MWD06 and MWD07) - Baseflow reduction for Medway Rivulet, Wells Creek and Belanglo Creek	0.6% Max 505.5 ML/yr Mean 274.7 ML/yr	1.2% Max 294.9 ML/yr Mean 167.2 ML/yr
Oldbury Creek	Oldbury Creek	- Reduction in catchment area due to project storages (SB01, SB02, MWD08 and PWD) - Releases from SB03 and SB04 after a first flush - Baseflow reduction for Oldbury Creek	4.3% Max 424.1 ML/yr Mean 159.1 ML/yr	4.5% Max 208.0 ML/yr Mean 71.9 ML/yr
Medway Rivulet Management Zone		- Reduction in catchment area due to project storages (SB01, SB02, SB03, SB04, MWD05, MWD06, MWD07, MWD08 and PWD) - Releases from SB03 and SB04 to Oldbury Creek after a first flush - Baseflow reduction for Medway Rivulet, Wells Creek, Belanglo Creek and Oldbury Creek	0.9% Max 762.9 ML/yr Mean 433.9 ML/yr	1.6% Max 494.5 ML/yr Mean 239.1 ML/yr

4.2.2.2 OTHER CATCHMENTS

Existing case (pre-mining) flows in the Lower Wingecarribee River, Upper Wingecarribee River, Lower Wollondilly River, Bundanoon Creek and Nattai River management zones were approximated using the AWBM runoff for the Medway Rivulet catchment scaled to the area of each catchment.

Baseflow reduction associated with lowering of groundwater phreatic zones during underground mining was estimated for each water management zone using the Mean K Groundwater Model. The resulting changes in flow were applied to the existing case flow duration curves to assess the change in surface water yield for the catchments. The yield impact assessment results are presented in Table 4.3. Results are provided as a percentage change in yield and as an annual average and annual maximum volumetric loss over the 19-year mining period.

Table 4.3 Reduction in yield due to baseflow reduction for other catchments – flow assessment base case (replaces Table 5.3 of the EIS Surface Water Flow and Geomorphology Report (PB 2017a))

WATER MANAGEMENT ZONE	CATCHMENT AREA (HA)	LOCAL YIELD IMPACT (% REDUCTION) / ANNUAL VOLUMETRIC LOSS OVER 19-YEAR MINING PERIOD (ML/YR)	
		WET CLIMATE SEQUENCE	DRY CLIMATE SEQUENCE
Lower Wingecarribee River	50,546	0.02% Max 77.5 ML/yr Mean 38.0 ML/yr	0.05% Max 72.2 ML/yr Mean 34.1 ML/yr
Upper Wingecarribee River	13,419	0.0009% Max 1.5 ML/yr Mean 0.4 ML/yr	0.002% Max 1.4 ML/yr Mean 0.4 ML/yr
Bundanoon Creek	31,947	0.00009% Max 0.4 ML/yr Mean 0.1 ML/yr	0.0002% Max 0.4 ML/yr Mean 0.1 ML/yr
Nattai River	44,697	0.000008% Max 0.07 ML/yr Mean 0.02 ML/yr	0.00003% Max 0.06 ML/yr Mean 0.02 ML/yr
Lower Wollondilly River	265,763	0.00004% Max 1.6 ML/yr Mean 0.5 ML/yr	0.0001% Max 1.5 ML/yr Mean 0.4 ML/yr

4.3 FLOW ASSESSMENT CLIMATE SENSITIVITY ANALYSIS

A flow assessment climate sensitivity analysis has been undertaken to assess the impact of changes to the baseflow reduction estimates from the Modified EIS Groundwater Model wet and dry climate scenarios compared to the Modified EIS Groundwater Model static average climate.

The flow assessment climate sensitivity analysis has adopted the predicted releases from SB03 and SB04 from the corresponding scenario from the water balance model climate sensitivity analysis (note that the water balance sensitivity analysis in Section 3.3 demonstrated that predicted releases are the same for the climate sensitivity static average climate, wet climate scenario and dry climate scenario).

4.3.1 YIELD IMPACT ASSESSMENT RESULTS

This section provides a comparison of results for the flow assessment climate sensitivity analysis static average climate and climate sensitivity analysis wet and dry climate scenarios.

The percentage change to yield impact for the Medway Rivulet and Oldbury Creek catchments for the climate sensitivity analysis wet and dry climate scenarios compared to the climate sensitivity analysis static average climate is provided in Table 4.4. The results indicate that yield impacts for the climate sensitivity analysis wet and dry climate scenarios are generally similar to the climate sensitivity analysis static average climate.

There is a slight increase in yield impact (i.e. a negative value in Table 4.4) for the Medway Rivulet and Oldbury Creek catchments under wet conditions when using the climate sensitivity analysis wet climate scenario baseflow reduction estimates compared to the static average climate baseflow reduction estimates. This is expected as baseflow reduction for the Modified EIS Groundwater Model wet climate scenario are generally higher than for the Modified EIS Groundwater Model average static climate. The peak baseflow reductions for the Medway Rivulet Management Zone predicted by the Modified EIS Groundwater Model climate sensitivity analysis were 0.729 ML/day for the static average climate and 0.771 ML/day for the wet climate scenario (refer to Section 2.2 Figure 2.2 and Figure 2.3).

There is a slight improvement in yield impact (i.e. a positive value in Table 4.4) for the Medway Rivulet and Oldbury Creek catchments under dry conditions when using the climate sensitivity analysis dry climate scenario baseflow reduction estimates compared to the static average climate baseflow reduction estimates. This is expected as baseflow reduction for the Modified EIS Groundwater Model dry climate scenario is generally lower than for the Modified EIS Groundwater Model average static climate. The peak baseflow reductions for the Medway Rivulet Management Zone predicted by the Modified EIS Groundwater Model climate sensitivity analysis were 0.729 ML/day for the static average climate and 0.589 ML/day for the dry climate scenario (refer to Section 2.2 Figure 2.2 and Figure 2.4).

Table 4.4 Change in yield impacts for Medway Rivulet and Oldbury Creek – flow assessment climate sensitivity analysis

CATCHMENT	INCLUDED SUB-CATCHMENTS	CHANGE TO YIELD IMPACT % REDUCTION COMPARED TO CLIMATE SENSITIVITY ANALYSIS STATIC AVERAGE CLIMATE	
		WET CLIMATE SEQUENCE USING MODIFIED EIS GROUNDWATER MODEL WET CLIMATE SCENARIO BASEFLOW REDUCTION	DRY CLIMATE SEQUENCE USING MODIFIED EIS GROUNDWATER MODEL DRY CLIMATE SCENARIO BASEFLOW REDUCTION
Medway Dam	Medway Rivulet Wells Creek	-0.004%	+0.08%
Medway Rivulet at the confluence with Wingecarribee River (excluding Oldbury Creek)	Medway Rivulet Wells Creek Belanglo Creek	-0.008%	+0.2%
Oldbury Creek	Oldbury Creek	-0.0004%	+0.03%
Medway Rivulet Management Zone		-0.007%	+0.2%

5 SURFACE WATER QUALITY ASSESSMENT

5.1 WATER QUALITY ASSESSMENT CRITERIA

To assess whether the project and its associated treatment measures will have a Neutral or Beneficial Effect (NorBE) on water quality, existing conditions (pre-development) and operational phase (post-development) pollutant loads and concentrations predicted by the MUSIC model have been assessed against the following criteria outlined in the SCA standard (2012):

- The mean annual pollutant loads for the post-development case (including mitigation measures) must be 10% less than the pre-development case for TSS, TP and TN. For gross pollutants, the post-development load only needs to be equal to or less than pre-development load.
- Pollutant concentrations for TP and TN for the post-development case (including mitigation measures) must be equal to or better compared to the pre-development case for between the 50th and 98th percentiles over the five-year modelling period when runoff occurs. Periods of zero flow are not accounted for in the statistical analysis as there is no downstream water quality impact. To demonstrate this, comparative cumulative frequency graphs, which use the Flow-Based Sub-Sample Threshold for both the pre- and post-development cases, must be provided. As meeting the pollutant percentile concentrations for TP generally also meets the requirements for TSS, cumulative frequency analysis is not required for TSS. Cumulative frequency is also not applied to gross pollutants.

A Neutral or Beneficial Effect (NorBE) assessment has been undertaken using the MUSIC model for releases from stormwater basins to Oldbury Creek (refer Section 5.2), mine access roads (refer Section 5.3), and the Berrima Railway Line (refer Section 5.4). Additional water quality assessments have been undertaken for impacts in the wider study area associated with baseflow reduction (Section 5.5) and dust deposition (refer Section 5.6).

5.2 RELEASES FROM STORMWATER BASINS TO OLDBURY CREEK

MUSIC modelling was undertaken for the Hume Coal Project EIS to assess potential impacts of releases from SB03 and SB04 following the first flush on TSS and nutrient loads and concentrations in Oldbury Creek and to assess compliance with the NorBE criteria. Details of the MUSIC modelling undertaken for the EIS are provided in the Hume Coal Project Surface Water Quality Assessment report (Section 5.2.2) (Parsons Brinckerhoff, 2016b).

The following revisions have been made to the MUSIC modelling undertaken for the EIS:

- The predicted time series for releases from SB03 and SB04 to Oldbury Creek has been revised to reflect the results of the revised water balance modelling (refer to Section 3). Revised water balance modelling was undertaken to reflect the post-EIS numerical groundwater modelling undertaken by HydroSimulations.
- Existing flows have been modelled as a mix of base flow and storm flow. This revision was made to address matters raised in submissions from government agencies.
- The MUSIC model timestep has been changed from daily to 6-minute. This revision was made to address matters raised in submissions from government agencies.

5.2.1 *MUSIC MODELLING METHODOLOGY*

5.2.1.1 MUSIC MODEL SET UP

MUSIC model nodes were set up for SB03 and SB04 which will release to Oldbury Creek and SB01, SB02, PWD and MWD08 which are sub-catchments of Oldbury Creek that will be removed from its catchment during mining operation. The sub-catchment areas and land use breakdown modelled in MUSIC have not changed from the EIS.

The MUSIC model nodes were set up to represent the following:

— The existing conditions within the catchments. The catchments were assumed to be fully pervious with the land use assumed to be ‘agricultural’.

— The proposed conditions within the catchments of SB03 and SB04 under operation. The catchments were a mix of pervious and impervious areas (refer Table 5.1) and the land use was assumed to be ‘industrial’. For the operational phase, the sub-catchments of SB01, SB02, PWD and MWD08 will not contribute any runoff to Oldbury Creek, and therefore these nodes were not included in the proposed conditions model.

Table 5.1 Catchment areas and imperviousness for SB03 and SB04 operational catchments

	SB03	**SB04**
Catchment area (ha)	5.91	14.73
Impervious (%)	57%	44%
Pervious (%)	43%	56%

For the EIS, MUSIC modelling was undertaken at a daily timestep to match the timestep of the GoldSim water balance model. For the revised modelling, a 6-minute timestep has been adopted as it is recommended in the SCA standard (2012).

5.2.1.2 CLIMATE DATA

The climate data used in the MUSIC model was the zone 3 meteorological template file obtained from the WaterNSW website, as described in the Hume Coal Project Surface Water Quality Assessment report (Section 5.2.2.1) (Parsons Brinckerhoff, 2016b). The rainfall data were at a 6-minute timestep over a 5-year period from 1997 to 2001.

5.2.1.3 RELEASE VOLUMES

The climate data for the 5-year simulation period was input into the revised GoldSim water balance model (refer to Section 3). The GoldSim model was used to generate a daily outflow time series for the SB01, SB02, PWD and MWD08 catchments in their existing states, and for SB03 and SB04 in their operational states. For the operational phase, the model simulated pumping of the first flush to the PWD as per the design criteria for these dams so that the outflow time series generated for the operational phase represented the volumes that would be released to Oldbury Creek after the first flush has been captured and pumped to the PWD.

For the revised modelling, the daily outflow time series from GoldSim was converted to a 6-minute timestep (by averaging the daily outflows) for input into MUSIC. It was not considered appropriate to run the water balance model at a 6-minute timestep as the AWBM rainfall-runoff model incorporated into GoldSim was calibrated to a daily timestep and a change in timestep would affect the AWBM model calibration.

The outflow time series predicted by the water balance model base case was adopted in MUSIC. The water balance model base case adopts groundwater inflows from the Mean K Groundwater Model. The water balance model sensitivity analysis for wet and dry climate scenario groundwater inflows predicted the same releases from SB03 and SB04 to

Oldbury Creek as the static average climate (refer to Section 3.3.2). The water balance model base case releases from SB03 and SB04 have therefore been adopted for MUSIC modelling and a sensitivity analysis for wet and dry climate groundwater inflows is not required.

5.2.1.4 INFLOW DATA

MUSIC inflows are required to be separated into baseflow, pervious flow and impervious flow.

For the EIS, existing flows were assumed to be pervious flow, with no baseflow or impervious flow assumed. For the revised MUSIC modelling, existing flows were assumed to be a mix of pervious flow and baseflow. The breakdown between pervious flow and baseflow was estimated by the AWBM rainfall-runoff model which simulates surface flow and baseflow.

For the EIS, the operational flows were assumed to be a mix of pervious flow and impervious flow as identified for the catchment areas given in Table 5.1, with no baseflow. The same assumption was made for operational flows for the revised MUSIC modelling.

5.2.1.5 MODELLED SCENARIOS

The existing conditions scenario was set up for the SB01, SB02, PWD, MWD08, SB03 and SB04 catchments using the ‘agricultural’ MUSIC source node. The operational scenario was set up for the SB03 and SB04 catchments using the ‘industrial’ MUSIC source node. The stormwater pollutant parameters used for the source nodes are provided in Table 5.2 and are in accordance with the SCA standard (2012).

Table 5.2 Source node mean pollutant inputs into MUSIC for SB03 and SB04 assessment (replaces Table 5.5 of the EIS Surface Water Quality Assessment Report (PB 2016b))

LAND USE	TSS		TP		TN	
	MEAN LOG (MG/L)	SD LOG (MG/L)	MEAN LOG (MG/L)	SD LOG (MG/L)	MEAN LOG (MG/L)	SD LOG (MG/L)
Baseflow						
Agricultural	1.3	0.13	-1.05	0.13	0.04	0.13
Industrial	1.2	0.17	-0.85	0.19	0.11	0.12
Storm flow						
Agricultural	2.15	0.31	-0.22	0.3	0.48	0.26
Industrial	2.15	0.32	-0.60	0.25	0.3	0.19

SD - standard deviation

5.2.2 MUSIC MODELLING RESULTS

5.2.2.1 COMPARISON OF MEAN ANNUAL POLLUTANT LOADS

Table 5.3 provides a summary of existing and operational scenario mean annual pollutant loads for TSS, TP and TN. The results show that mean annual pollutant loads for these parameters are reduced by significantly more than 10%, and therefore meet this NorBE criterion. This is achieved due to the significant reduction in agricultural catchment draining to Oldbury Creek during operation.

Table 5.3 Mean annual pollutant loads in Oldbury Creek due to runoff from SB01, SB02, PWD, MWD08, SB03 and SB04 catchments (replaces Table 5.6 of the EIS Surface Water Quality Assessment Report (PB 2016b))

PARAMETER	MEAN ANNUAL LOAD		
	EXISTING (FROM SB01, SB02, MWD08 AND PWD)	OPERATION (FROM SB03 AND SB04)	DIFFERENCE TO EXISTING
TSS (kg/yr)	15,000	3,900	-74%
TP (kg/yr)	63.7	6.19	-90%
TN (kg/yr)	347	45.9	-87%
Flow (ML/yr)	146	20.9	-86%

5.2.2.2 COMPARISON OF POLLUTANT CONCENTRATIONS BETWEEN THE 50TH AND 98TH PERCENTILES

Cumulative frequency graphs of TN and TP concentrations in runoff to Oldbury Creek from SB01, SB02, PWD, MWD08, SB03 and SB04 for the existing and operational scenarios are provided in Figure 5.1 and Figure 5.2. The figures demonstrate that pollutant concentrations for the operational scenario are equal to or lower than the existing scenario between the 50th and 98th percentiles, and therefore compliance with this NorBE criterion is achieved.

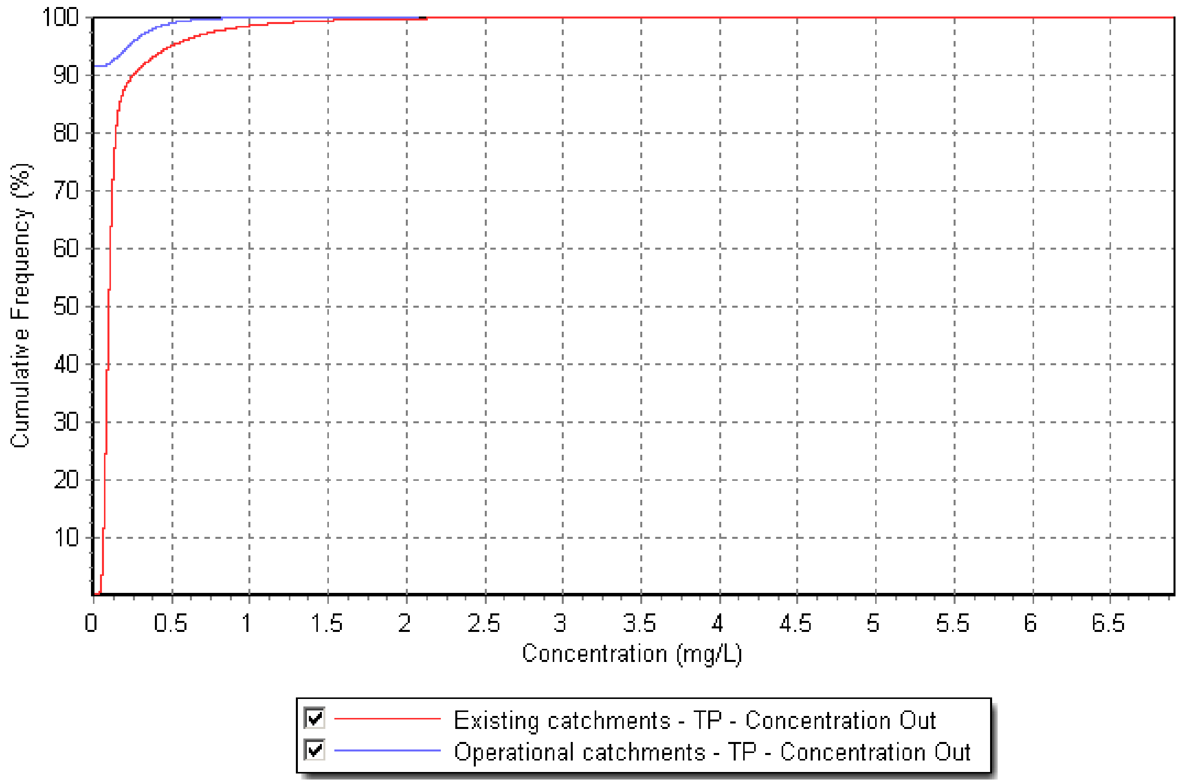


Figure 5.1 Total Phosphorus cumulative frequency graph for SB03 and SB04 release assessment (replaces Figure 5.4 of the EIS Surface Water Quality Assessment Report (PB 2016b))

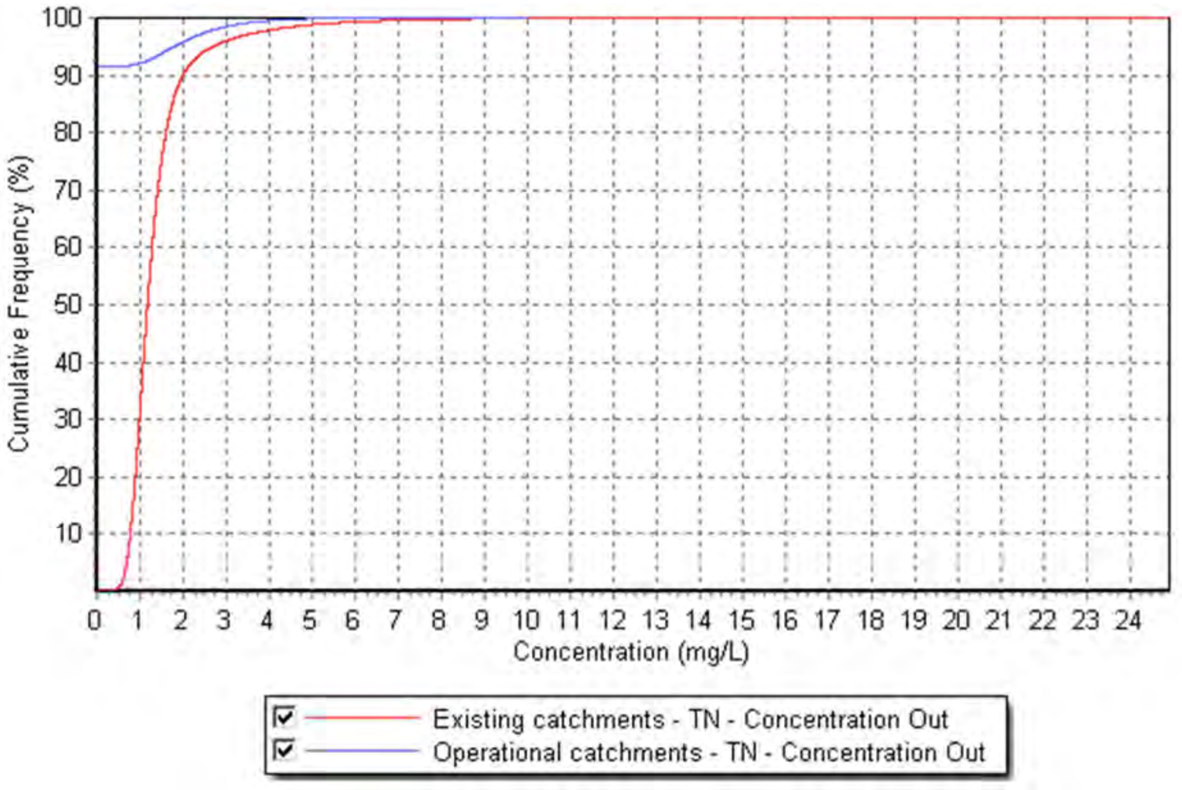


Figure 5.2 Total Nitrogen cumulative frequency graph for SB03 and SB04 release assessment (replaces Figure 5.5 of the EIS Surface Water Quality Assessment Report (PB 2016b))

5.2.2.3 CONCLUSION

Operational phase releases from SB03 and SB04 to Oldbury Creek were simulated in GoldSim and MUSIC and found to meet the NorBE criteria for TSS, TP and TN.

5.3 MINE ACCESS ROADS

There are two mine access roads located outside the water management system:

— the main mine access road from Mereworth Road to the administration and workshop area, which follows existing sealed and unsealed roads for most of its length

— the access road between the personnel and materials portal, the conveyor portal and the ventilation shaft, which follows existing unsealed tracks.

MUSIC modelling was undertaken for the Hume Coal Project EIS to assess the potential impacts of runoff from these roads on TSS and nutrient loads and concentrations in the receiving environment and to assess compliance with the NorBE criteria. Details of the MUSIC modelling undertaken for the EIS are provided in the Hume Coal Project Surface Water Quality Assessment report (Section 5.2.3) (Parsons Brinckerhoff, 2016b).

The following revisions have been made to the MUSIC modelling undertaken for the EIS:

— Changes to MUSIC model parameters:

    — swale exfiltration rate set to 0 mm/hr

    — swale vegetation height set to 0.25 m

    — industrial land use type adopted for road cut/fill embankments.

These changes to modelling parameters were made to address matters raised in submissions from government agencies.

— Changes to proposed water quality treatment measures:

  — proposed swale lengths increased

  — constructed wetlands proposed downstream of swales.

  These changes to treatment measures were made in order to achieve NorBE following the changes to the MUSIC modelling parameters.

5.3.1 MUSIC MODELLING METHODOLOGY

Existing and operational scenarios were modelled using MUSIC by representing the sub-catchments of the road corridors in their existing conditions as a mix of existing sealed and unsealed roads and agricultural land and proposed conditions as sealed / unsealed roads and industrial land for road cut/fill embankments. The operational phase scenarios included simulation of stormwater quality treatment measures to achieve the NorBE criteria. Modelling has been undertaken in accordance with the SCA standard (2012).

5.3.1.1 MUSIC MODEL SET UP

Model nodes were established for the two mine access roads. The main mine access road follows a ridge line between Medway Rivulet and Oldbury Creek, and is a sealed road with a total road corridor area (including embankments) of 5.02 ha. The other access road is located within the Medway Rivulet catchment and is an unsealed road with a total area (not including embankments) of 1.32 ha. The assessment of the sealed road included the road embankments, as it warranted a more detailed assessment and sub-catchment breakdown due to the relatively higher potential impact of a sealed road on the local catchments. The unsealed road was assessed more simplistically by modelling the impact of the area of the trafficked surface only.

The main mine access road was split into three sub catchments (northern, middle and southern) and represented in the MUSIC model as follows:

— The catchment taken up by the proposed road corridor including cut/fill embankments.

  — Within this catchment there is an existing sealed road and unsealed road. Under existing conditions these areas were represented as ‘sealed roads’ and ‘unsealed roads’. The remaining land use under existing conditions within the footprint of the proposed road corridor is assumed to be ‘agricultural’.

— The catchment taken up by the proposed road corridor.

  — In the operational conditions this area was modelled to contain a mix of ‘sealed roads’ for the road surface and ‘industrial’ for the cut/fill embankments. This is different to the EIS, where cut/fill embankments were modelled as ‘revegetated land’.

The other access road was represented in the MUSIC model as follows:

— The part of the catchment taken up by the proposed road corridor (excluding cut/fill embankments) under existing conditions. The land use under existing conditions is assumed to be ‘agricultural’.

— The part of the catchment taken up by the proposed road corridor (excluding cut/fill embankments) in the operational condition. The land use under the operational scenario is ‘unsealed roads’.

MUSIC modelling was undertaken at a 6-minute timestep, which is the same timestep adopted for the EIS.

5.3.1.2 CLIMATE DATA

The climate data used in the MUSIC model was the zone 3 meteorological template file obtained from the WaterNSW website, as described in the Hume Coal Project Surface Water Quality Assessment report (Section 5.2.2.1) (Parsons Brinckerhoff, 2016b). This is the same climate data modelled for the EIS.

5.3.1.3 MODELLED SCENARIOS

The existing conditions scenario was set up for each of the sub-catchments using a combination of the 'agricultural', 'sealed roads' and 'unsealed roads' MUSIC source nodes and assumed to be 100% pervious for agricultural land, 100% impervious for sealed roads, and 50% pervious and 50% impervious for unsealed roads. The operational scenario was set up for each of the sub-catchments using the 'sealed roads', 'unsealed roads' and 'industrial' MUSIC source nodes and assumed to be 100% impervious for sealed roads, 50% pervious and 50% impervious for unsealed roads, and 100% pervious for embankments. For the EIS, the 'revegetated land' MUSIC source node was adopted for mine access road cut/fill embankments. For the revised modelling, the 'industrial' source node was adopted for mine access road cut/fill embankments because it is considered more conservative for cut embankments which may be partially vegetated. The stormwater pollutant parameters used for the source nodes are given in Table 5.4 and are in accordance with the SCA standard (2012).

Table 5.4 Source node mean pollutant inputs into MUSIC for mine access roads assessment (replaces Table 5.9 of the EIS Surface Water Quality Assessment Report (PB 2016b))

LAND USE	TSS		TP		TN	
	MEAN LOG (MG/L)	SD LOG (MG/L)	MEAN LOG (MG/L)	SD LOG (MG/L)	MEAN LOG (MG/L)	SD LOG (MG/L)
Base flow						
Agricultural	1.30	0.13	-1.05	0.13	0.04	0.13
Industrial	1.20	0.17	-0.85	0.19	0.11	0.12
Unsealed roads	1.20	0.17	-0.85	0.19	0.11	0.12
Sealed roads	1.20	0.17	-0.85	0.19	0.11	0.12
Storm flow						
Agricultural	2.15	0.31	-0.22	0.3	0.48	0.26
Industrial	2.15	0.32	-0.60	0.25	0.30	0.19
Unsealed roads	3.00	0.32	-0.3	0.25	0.34	0.19
Sealed roads	2.43	0.32	-0.3	0.25	0.34	0.19

SD - standard deviation

For the operational scenario, vegetated swales and constructed wetlands were included in the MUSIC model to treat road runoff. The adopted parameters for the swales are given below in Table 5.5. The background concentration (C* and C**) for a swale is defaulted to be relatively high. These values were adjusted in accordance with the approach detailed in Fletcher et al (2004) so that a more realistic reduction of pollutant load would be determined. Details of the adjusted C* and C** parameters for swales are provided in the Hume Coal Project Surface Water Quality Assessment report (Section 5.2.3.1 and Appendix B) (Parsons Brinckerhoff, 2016b).

Table 5.5 Revised swale parameters for mine access roads assessment (replaces Table 5.10 of the EIS Surface Water Quality Assessment Report (PB 2016b))

SWALE PROPERTIES	EIS VALUE (PB 2016b)	REVISED VALUES
Length (m)	Varied to meet NorBE criteria	Varied to meet NorBE criteria (length increased compared to EIS)
Bed slope (%)	3	3
Base width (m)	1	1
Top width (m)	5	5
Swale side slopes	1:3.33	1:3.33
Depth (m)	0.6	0.6
Vegetation height (m)	0.3	0.25
Exfiltration rate (mm/hr)	2	0
C* C** TN	0.89	0.89
C* C** TP	0.096	0.096

5.3.2 MUSIC MODELLING RESULTS

5.3.2.1 COMPARISON OF MEAN ANNUAL POLLUTANT LOADS

Table 5.6 provides a summary of existing and operational scenario mean annual pollutant loads for TSS, TP and TN based on the revised MUSIC modelling. Table 5.6 provides pollutant loads downstream of the proposed swales and downstream of the proposed constructed wetlands to provide an indication of the treatment train effectiveness. The results show that mean annual pollutant loads for TSS, TP and TN are reduced by more than 10%, and therefore meet this NorBE criterion (note that achieving 10% reduction for TN, the most onerous parameter, results in significantly greater than 10% reductions for TSS and TP). This is achieved through provision of swales and constructed wetlands to treat the road runoff. Details of proposed swales and constructed wetlands are provided in Table 5.7.

Constructed wetlands have been modelled downstream of swales and were nominally sized at 50 m^2 each. Constructed wetlands were not required to meet the mean annual pollutant load criteria for NorBE but were required to meet the TN and TP concentration criteria (refer Section 5.3.2.2).

Table 5.6 Mean annual pollutant loads from access road catchments (replaces Table 5.11 of the EIS Surface Water Quality Assessment Report (PB 2016b))

PARAMETER	EXISTING (KG/YR)	OPERATION (KG/YR)	DIFFERENCE TO EXISTING	OPERATION WITH SWALE TREATMENT ONLY (KG/YR)	DIFFERENCE TO EXISTING	OPERATION WITH SWALE AND WETLAND TREATMENT (KG/YR)	DIFFERENCE TO EXISTING
Sealed Road northern catchment (3.47 ha)							
TSS	1800	4140	130%	226	-87%	201	-89%
TP	3.87	7.06	82%	1.46	-62%	1.35	-65%
TN	20.4	32.1	57%	18	-12%	18.1	-11%
Sealed Road middle catchment (0.99 ha)							
TSS	422	630	49%	208	-51%	160	-62%
TP	1.18	1.18	0%	0.564	-52%	0.427	-64%
TN	5.94	6.18	4%	5.31	-11%	4.77	-20%
Sealed Road southern catchment (0.56 ha)							
TSS	351	431	23%	230	-34%	135	-62%
TP	0.845	0.775	-8%	0.497	-41%	0.307	-64%
TN	4.09	3.93	-4%	3.61	-12%	2.92	-29%
Unsealed Road catchment (1.32 ha)							
TSS	287	7050	2356%	86.8	-70%	67.8	-76%
TP	1.24	3.33	169%	0.593	-52%	0.509	-59%
TN	6.73	13.9	107%	5.95	-12%	6.06	-10%

Table 5.7 Proposed swales and constructed wetlands for mine access roads to meet NorBE criteria (replaces Table 5.12 of the EIS Surface Water Quality Assessment Report (PB 2016b))

SUB-CATCHMENT	CATCHMENT AREA (HA)	ROAD CORRIDOR LENGTH (M)	SWALE LENGTH (M)	WETLAND SURFACE AREA (M^2)
Sealed Road catchment				
Sealed Road northern	5.02	2,540	750	50 m^2 (nominal)
Sealed Road middle			15	50 m^2 (nominal)
Sealed Road southern			5	50 m^2 (nominal)
Unsealed Road catchment				
Unsealed Road	1.32	2,000	1,250	50 m^2 (nominal)

5.3.2.2 COMPARISON OF POLLUTANT CONCENTRATIONS BETWEEN THE 50TH AND 98TH PERCENTILES

Cumulative frequency graphs of TN and TP concentrations for the access roads for the existing and operational scenarios are provided in Figure 5.3 to Figure 5.10. The graphs show pollutant concentrations for when runoff occurs. The figures demonstrate that pollutant concentrations for the operational scenario are equal to or better than the existing scenario between the 50th and 98th percentiles, and therefore compliance with this NorBE criterion is achieved.

Constructed wetlands were required to meet the TN and TP concentration criteria as the swales alone did not meet the concentration criteria below around the 60th percentile. This is because the background pollutant concentrations (C*) for swales increased TN and TP concentrations at the low to mid concentration end of the cumulative frequency graphs.

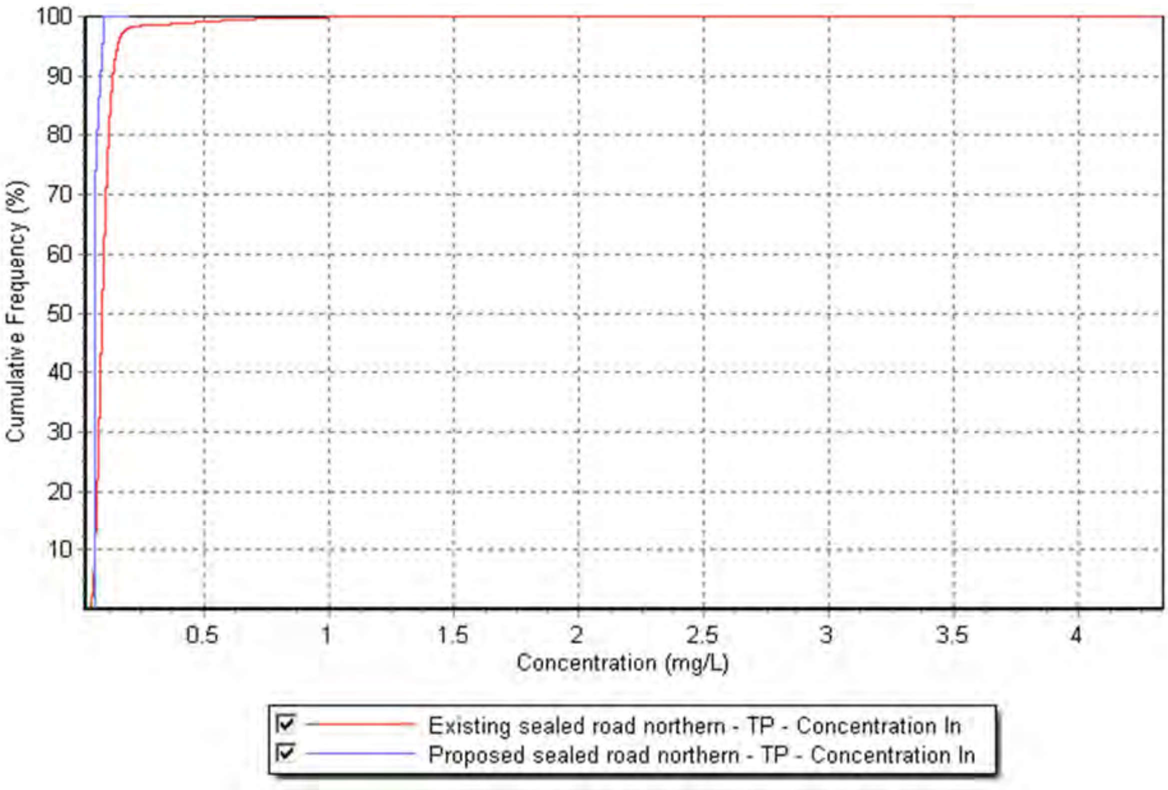


Figure 5.3 Total Phosphorus cumulative frequency graph for sealed road northern catchment (replaces Figure 5.6 of the EIS Surface Water Quality Assessment Report (PB 2016b))

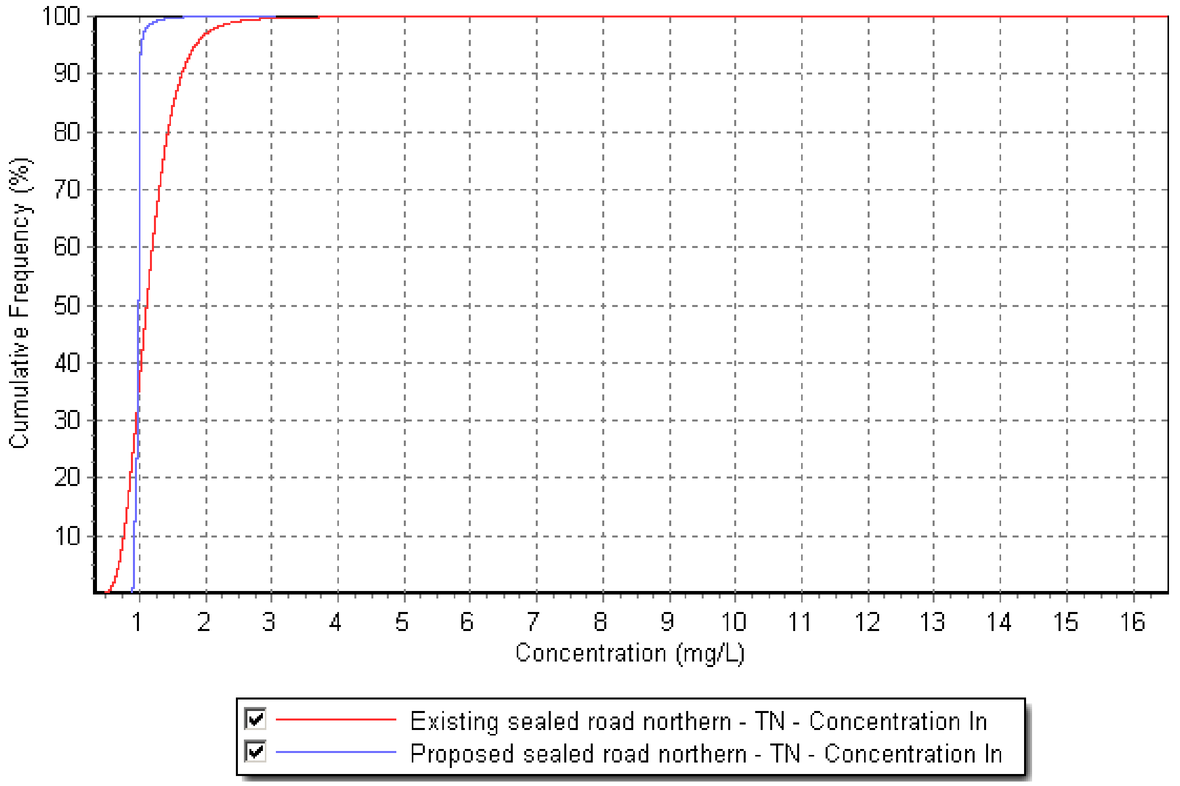


Figure 5.4 Total Nitrogen cumulative frequency graph for sealed road northern catchment (replaces Figure 5.7 of the EIS Surface Water Quality Assessment Report (PB 2016b))

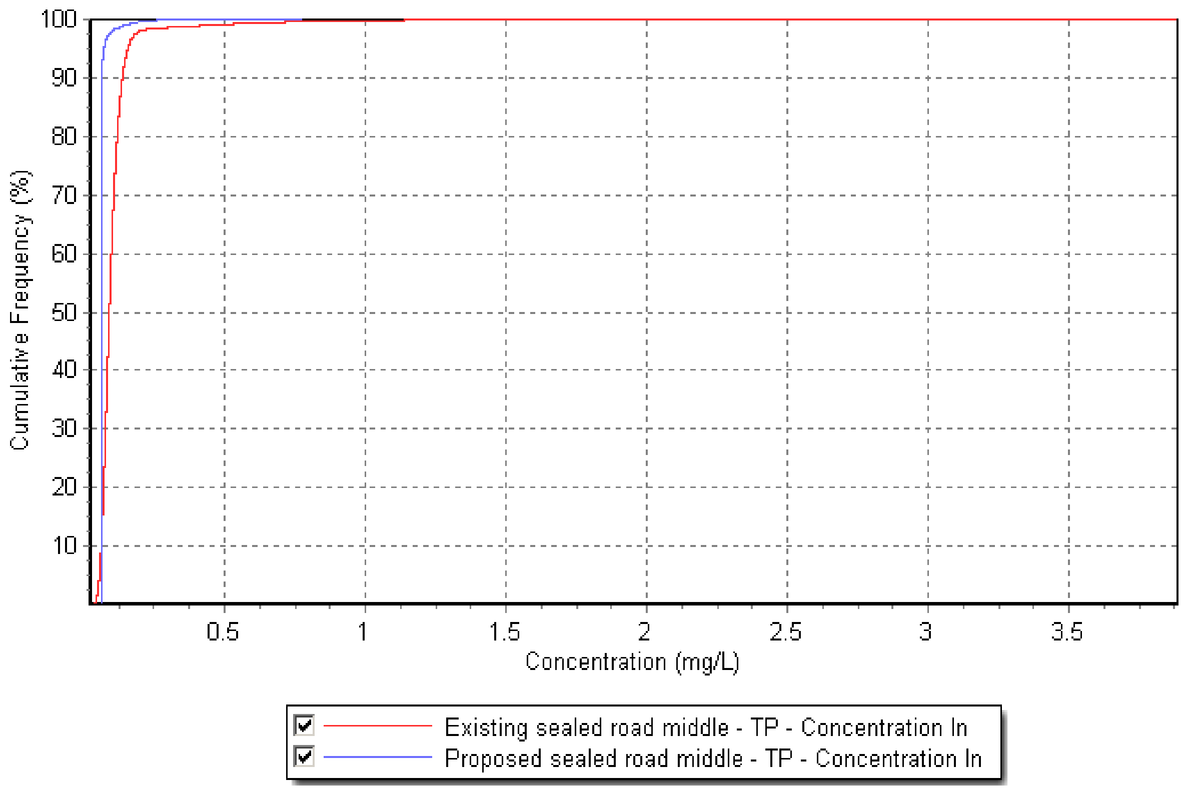


Figure 5.5 Total Phosphorus cumulative frequency graph for sealed road middle catchment (replaces Figure 5.8 of the EIS Surface Water Quality Assessment Report (PB 2016b))

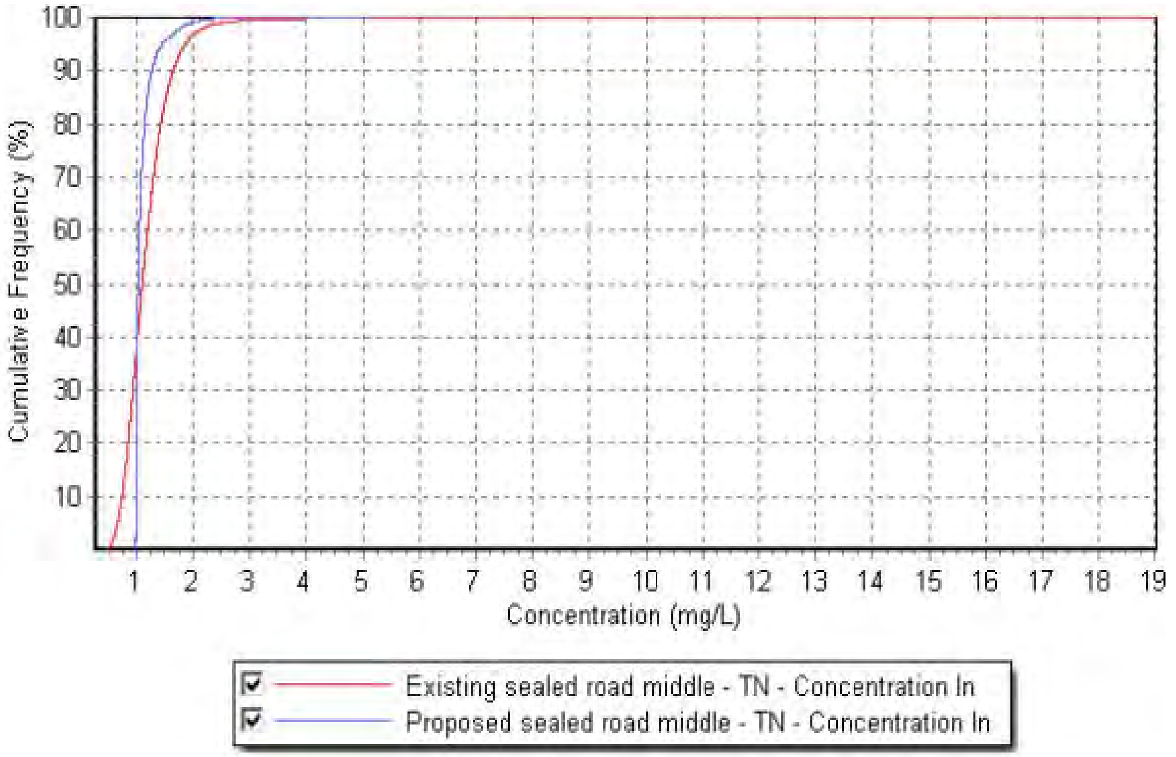


Figure 5.6 Total Nitrogen cumulative frequency graph for sealed road middle catchment (replaces Figure 5.8 of the EIS Surface Water Quality Assessment Report (PB 2016b)))

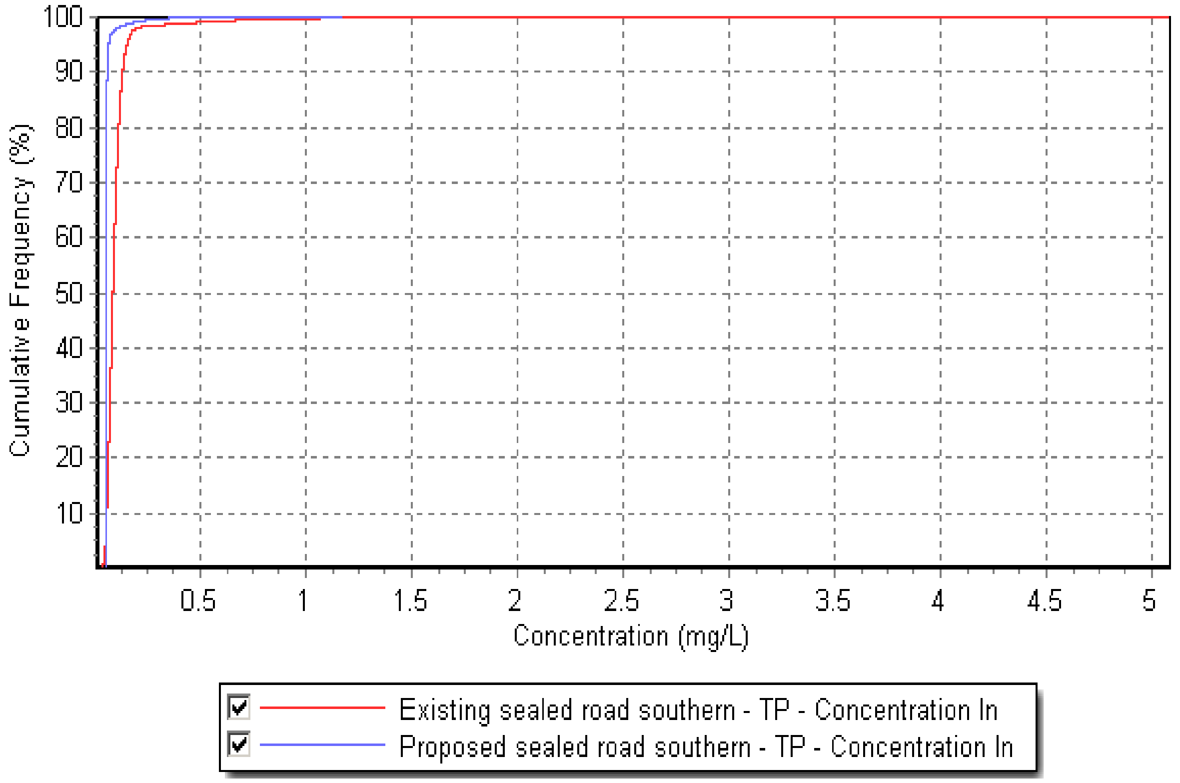


Figure 5.7 Total Phosphorus cumulative frequency graph for sealed road southern catchment (replaces Figure 5.10 of the EIS Surface Water Quality Assessment Report (PB 2016b))

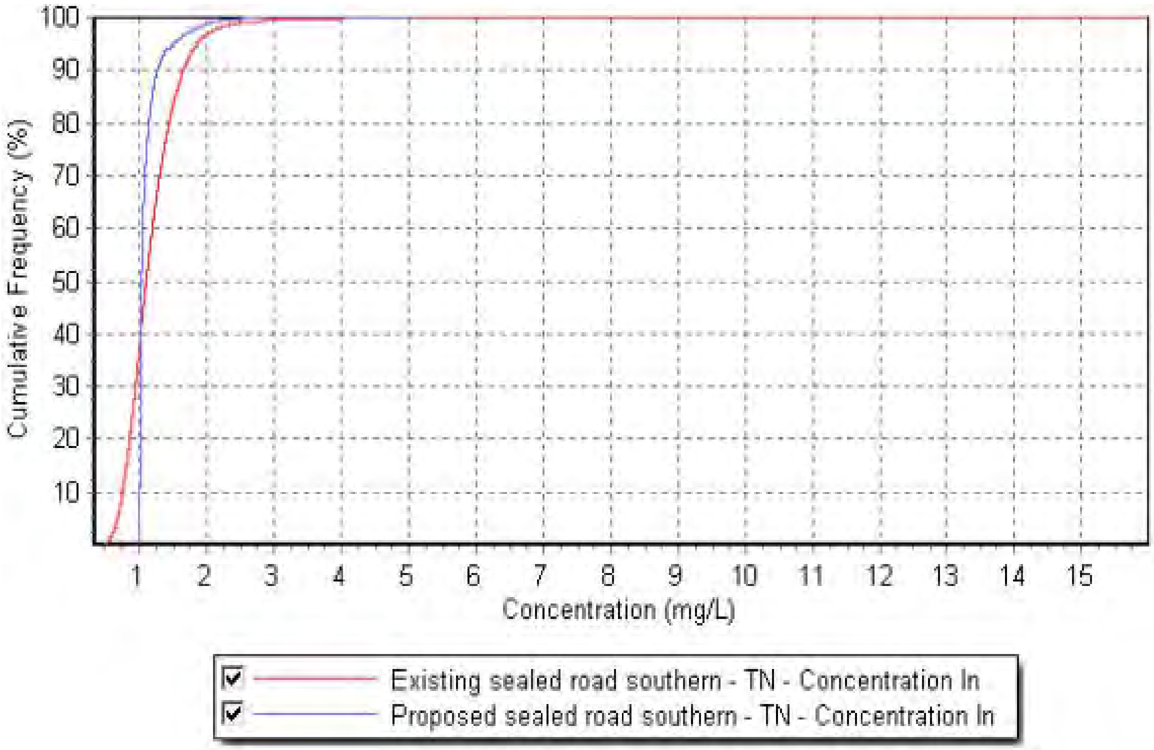


Figure 5.8 Total Nitrogen cumulative frequency graph for sealed road southern catchment (replaces Figure 5.11 of the EIS Surface Water Quality Assessment Report (PB 2016b))

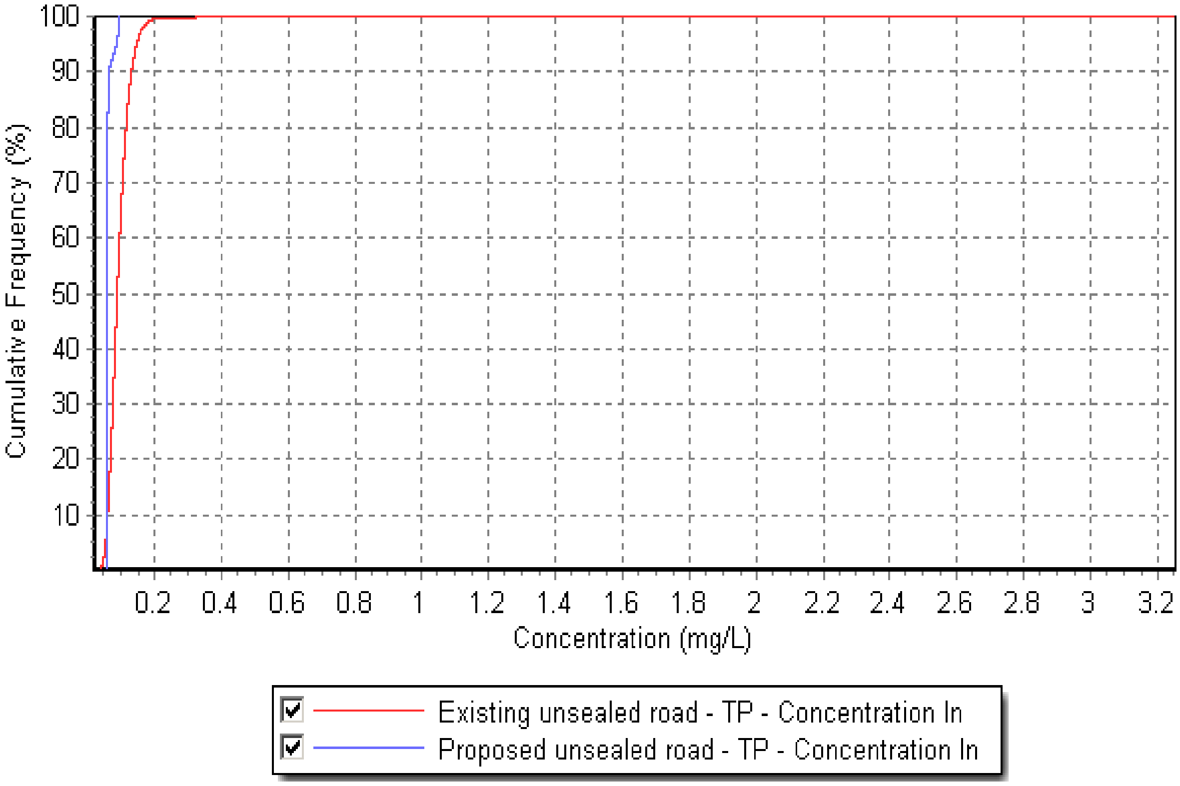


Figure 5.9 Total Phosphorus cumulative frequency graph for unsealed road catchment (replaces Figure 5.12 of the EIS Surface Water Quality Assessment Report (PB 2016b))

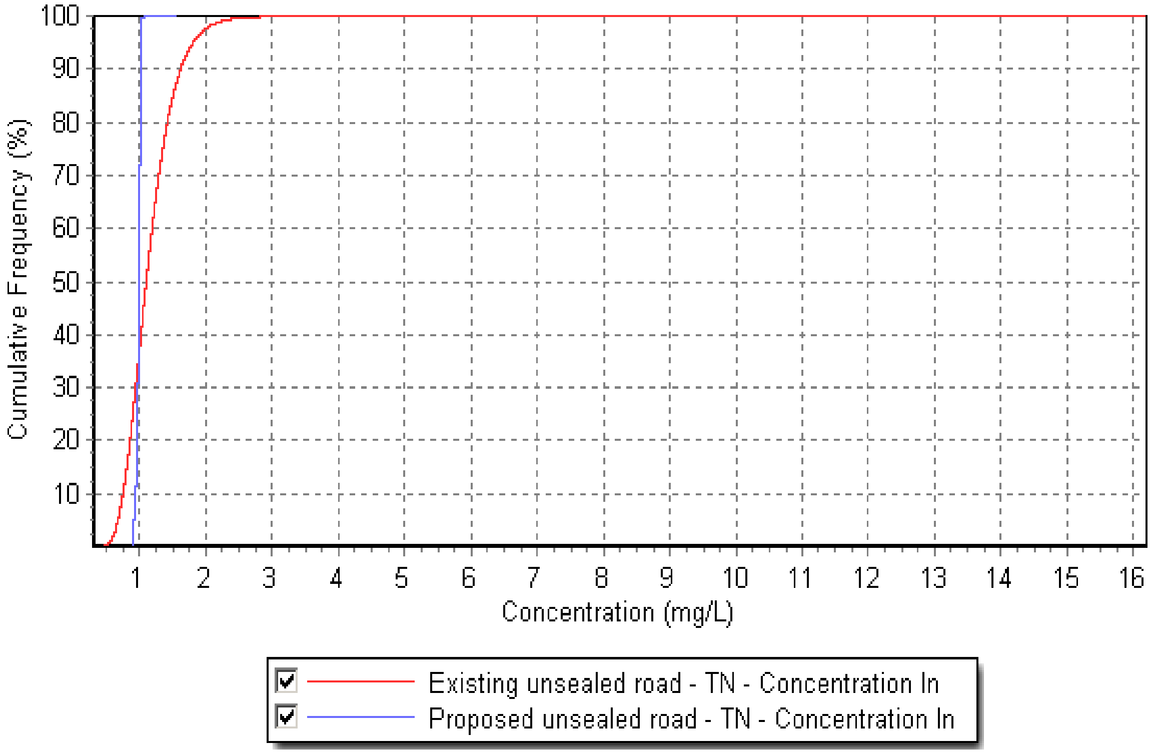


Figure 5.10 Total Nitrogen cumulative frequency graph for unsealed road catchment (replaces Figure 5.13 of the EIS Surface Water Quality Assessment Report (PB 2016b))

5.3.2.3 CONCLUSION

Runoff from the mine access roads will achieve NorBE assuming treatment swales and constructed wetlands are provided along the road corridors to receive and treat the road runoff before discharging into the Medway Rivulet catchment at the low points in each road sub-catchment.

5.4 RAILWAY LINE

MUSIC modelling was undertaken for the Berrima Rail Project EIS to assess the potential impacts of runoff from the railway line on TSS and nutrient loads and concentrations in the receiving environment and to assess compliance with the NorBE criteria. Details of the MUSIC modelling undertaken for the EIS are outlined in the Berrima Rail Project Surface Water Assessment (Sections 5.1.3, 5.3 and 5.4) (Parsons Brinckerhoff, 2017b).

The following revisions have been made to the MUSIC modelling undertaken for the EIS:

- Changes to MUSIC model parameters:
  - swale exfiltration rate set to 0 mm/hr
  - swale side slopes set to 1:3.33
  - swale vegetation height set to 0.25 m
  - industrial land use type adopted for railway cut/fill embankments.

  These changes to modelling parameters were made to address matters raised in submissions from government agencies.

- Changes to proposed water quality treatment measures:

— proposed swale lengths increased

— constructed wetlands proposed downstream of swales.

These changes to treatment measures were made in order to achieve NorBE following the changes to the MUSIC modelling parameters.

5.4.1 MUSIC MODELLING METHODOLOGY

Existing and operational scenarios were modelled using MUSIC by representing the sub-catchments of the railway corridors in their existing conditions as agricultural land and proposed conditions as sealed / unsealed roads and industrial land for railway cut/fill embankments. The operational phase scenarios included simulation of stormwater quality treatment measures to achieve the NorBE criteria. Modelling has been undertaken in accordance with the SCA standard (2012). The operational phase scenario was for the preferred Berrima Rail Project option which includes a railway bridge over Berrima Road as described in the Berrima Rail Project Surface Water Assessment (Section 1.2) (Parsons Brinckerhoff, 2017b).

5.4.1.1 MUSIC MODEL SET UP

Model nodes were established for each section of the rail corridor that is located within an external surface water catchment. The rail corridor spans four sub-catchments of Oldbury Creek and one sub-catchment of Stony Creek. The sub-catchments (denoted as 'segments') are shown in the Berrima Rail Project Surface Water Assessment (Figure 5.1) (Parsons Brinckerhoff, 2017b). Within each catchment the rail corridor runoff is assumed to discharge to the creek line or overland flow path at the lowest point within the sub-catchment, and it is assumed that the treatment measures will be located at these discharge points.

Each model node was set up to represent the following:

— The part of the catchment taken up by the proposed rail and access road corridors (including cut/fill embankments) in its current undeveloped state, i.e. under existing conditions. The land use under existing conditions is assumed to be 'agricultural'.

— The part of the catchment taken up by the proposed rail and access road corridors in its proposed developed state. The land use under these proposed conditions is an operational rail and access road corridor.

— The part of the catchment taken up by the batters of the rail and road embankments in its proposed developed state. The land use under these proposed conditions is assumed 'industrial'. This is different to the EIS where cut/fill embankments were modelled as 'revegetated land'.

Model nodes were separated out into sub-nodes for the proposed rail corridor, sealed access roads and cut/fill embankments. The catchment area of the proposed rail corridor or road was taken as the top width of the rail or road embankment, which includes the rail ballast and road surface and rail/road formation. The embankment areas were taken as the top width of the rail or road embankment to the toe of the embankment. The embankments will be constructed of vegetated clean fill.

5.4.1.2 CLIMATE DATA

The climate data used in the MUSIC model was the zone 3 meteorological template file obtained from the WaterNSW website, as described in the Berrima Rail Project Surface Water Assessment report (Section 5.1.3.2) (Parsons Brinckerhoff, 2017b). This is the same climate data modelled for the EIS.

5.4.1.3 MODELLED SCENARIOS

The existing conditions scenario was set up for each of the sub-catchments using the 'agricultural' MUSIC source node and assumed to be 100% pervious. The operational scenario was set up for each of the sub-catchments for the preferred option. The rail corridor sub-catchments were assumed to have the MUSIC source node of 'unsealed roads', assuming that the sub-catchment is 50% pervious and 50% impervious. The sealed road and hardstand areas were assumed to have the MUSIC source node of ‘sealed roads’, assuming that the sub-catchment is 100% impervious. For the EIS, the ‘revegetated land’ MUSIC source node was adopted for the rail and road cut/fill embankments. For the revised modelling, the ‘industrial’ source node was adopted for cut/fill embankments because it is considered more conservative for cut embankments which may be partially vegetated. The stormwater pollutant parameters used for the source nodes are provided in Table 5.8 and are in accordance with the SCA standard (2012).

Table 5.8 Source node mean pollutant inputs into MUSIC for railway line assessment (replaces Table 5.4 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

LAND USE	TSS		TP		TN	
	MEAN LOG (MG/L)	SD LOG (MG/L)	MEAN LOG (MG/L)	SD LOG (MG/L)	MEAN LOG (MG/L)	SD LOG (MG/L)
Base flow						
Agricultural	1.30	0.13	-1.05	0.13	0.04	0.13
Unsealed roads (rail formation)	1.20	0.17	-0.85	0.19	0.11	0.12
Sealed roads	1.20	0.17	-0.85	0.19	0.11	0.12
Industrial	1.20	0.17	-0.85	0.19	0.11	0.12
Storm flow						
Agricultural	2.15	0.31	-0.22	0.3	0.48	0.26
Unsealed roads (rail formation)	3.00	0.32	-0.3	0.25	0.34	0.19
Sealed roads	2.43	0.32	-0.3	0.25	0.34	0.19
Industrial	2.15	0.32	-0.60	0.25	0.30	0.19

SD standard deviation

For the operational scenario, vegetated swales and constructed wetlands were included in the MUSIC model to treat runoff from the rail corridor. The adopted parameters for the swales are given below in Table 5.9. The background concentration (C* and C**) for a swale is defaulted to be relatively high. These values were adjusted in accordance with the approach detailed in Fletcher et al (2004) so that a more realistic reduction of pollutant load would be determined. Details of the adjusted C* and C** parameters for swales are provided in the Berrima Rail Project Surface Water Assessment (Section 5.1.3.3 and Appendix I) (Parsons Brinckerhoff, 2017b).

Table 5.9 Revised swale parameters for railway line assessment (replaces Table 5.5 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

SWALE PROPERTIES	EIS VALUE (PB 2017b)	REVISED VALUES
Length (m)	Varied to meet NorBE criteria	Varied to meet NorBE criteria (length increased compared to EIS)
Bed slope (%)	2	2
Base width (m)	1	1
Top width (m)	3	5
Swale side slopes	1:1.66	1:3.33
Depth (m)	0.6	0.6

SWALE PROPERTIES	EIS VALUE (PB 2017b)	REVISED VALUES
Vegetation height (m)	0.3	0.25
Exfiltration rate (mm/hr)	2	0
C* C** TN	0.89	0.89
C* C** TP	0.096	0.096

5.4.2 MUSIC MODELLING RESULTS

5.4.2.1 COMPARISON OF MEAN ANNUAL POLLUTANT LOADS

Table 5.10 provides a summary of existing and operational scenario mean annual pollutant loads for TSS, TP and TN for the Oldbury Creek and Stony Creek sub-catchments based on the revised MUSIC modelling. Table 5.10 provides pollutant loads downstream of the proposed swales and downstream of the proposed constructed wetlands to provide an indication of the treatment train effectiveness. The results show that mean annual pollutant loads for TSS, TP and TN are reduced by more than 10%, and therefore meet this NorBE criterion. This is achieved through provision of swales and constructed wetlands to treat the runoff from the rail corridor. Details of proposed swales and constructed wetlands are provided in Table 5.11.

Constructed wetlands have been modelled downstream of swales and were nominally sized at 50 m^2 each. Constructed wetlands were not required to meet the mean annual pollutant load criteria for NorBE but were required to meet the TN and TP concentration criteria (refer Section 5.4.2.2).

Table 5.10 Mean annual pollutant load reduction for railway (preferred option) (replaces Table 5.9 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

PARAMETER	EXISTING (KG/YR)	OPERATION (KG/YR)	DIFFERENCE TO EXISTING	OPERATION WITH SWALE TREATMENT ONLY (KG/YR)	DIFFERENCE TO EXISTING	OPERATION WITH SWALE AND WETLAND TREATMENT (KG/YR)	DIFFERENCE TO EXISTING
Oldbury Creek Sub-Catchment 1							
TSS	332	3200	864%	215	-35%	187	-44%
TP	1.39	1.86	34%	0.556	-60%	0.472	-66%
TN	7.46	9.32	25%	6.73	-10%	6.62	-11%
Oldbury Creek Sub-Catchment 2							
TSS	494	3990	708%	426	-14%	386	-22%
TP	2.12	2.49	17%	0.888	-58%	0.788	-63%
TN	11.7	13.3	14%	10.2	-13%	10.1	-14%
Oldbury Creek Sub-Catchment 3							
TSS	1120	10100	802%	462	-59%	434	-61%
TP	4.66	7.41	59%	1.85	-60%	1.74	-63%
TN	25.8	36	40%	23.2	-10%	23.3	-10%
Oldbury Creek Sub-Catchment 4							

PARAMETER	EXISTING (KG/YR)	OPERATION (KG/YR)	DIFFERENCE TO EXISTING	OPERATION WITH SWALE TREATMENT ONLY (KG/YR)	DIFFERENCE TO EXISTING	OPERATION WITH SWALE AND WETLAND TREATMENT (KG/YR)	DIFFERENCE TO EXISTING
TSS	1330	15300	1050%	676	-49%	646	-51%
TP	5.9	8.98	52%	2.26	-62%	2.14	-64%
TN	31.2	43.8	40%	28.1	-10%	28.2	-10%
Stony Creek Sub-Catchment							
TSS	1090	12800	1074%	504	-54%	474	-57%
TP	4.44	6.95	57%	1.75	-61%	1.64	-63%
TN	24.8	34.1	38%	22	-11%	22	-11%

Table 5.11 Proposed swales and constructed wetlands for railway (preferred option) to meet NorBE criteria (replaces Table 5.10 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

SUB-CATCHMENT	RAIL / ACCESS ROAD CORRIDOR LENGTH (M)	SWALE LENGTH (M)	WETLAND SURFACE AREA (M^2)
Oldbury Creek 1	1,000	100	50 m^2 (nominal)
Oldbury Creek 2	1,050	85	50 m^2 (nominal)
Oldbury Creek 3 rail corridor	1,200	400	50 m^2 (nominal)
Oldbury Creek 3 road corridor	700	190	
Oldbury Creek 4 rail corridor	2,800	510	50 m^2 (nominal)
Oldbury Creek 4 road corridor	400	180	
Stony Creek	2,350	470	50 m^2 (nominal)

The results show that the preferred railway option meets the NorBE criteria for mean annual pollutant loads in the Oldbury Creek and Stony Creek catchments, i.e. more than a 10% reduction in mean annual pollutant load in each sub-catchment.

5.4.2.2 COMPARISON OF POLLUTANT CONCENTRATIONS BETWEEN THE 50TH AND 98TH PERCENTILES

Cumulative frequency graphs of TN and TP concentrations for each modelled sub-catchment for the existing and operation with treatment scenarios are provided in Figure 5.11 to Figure 5.20. The graphs show pollutant concentrations for when runoff occurs. The figures demonstrate that pollutant concentrations for the operational scenario are equal to or better than the existing scenario between the 50th and 98th percentiles, and therefore compliance with this NorBE criterion is achieved.

Constructed wetlands were required to meet the TN and TP concentration criteria as the swales alone did not meet the concentration criteria below around the 60th percentile. This is because the background pollutant concentrations (C*) for swales increased TN and TP concentrations at the low to mid concentration end of the cumulative frequency graphs.

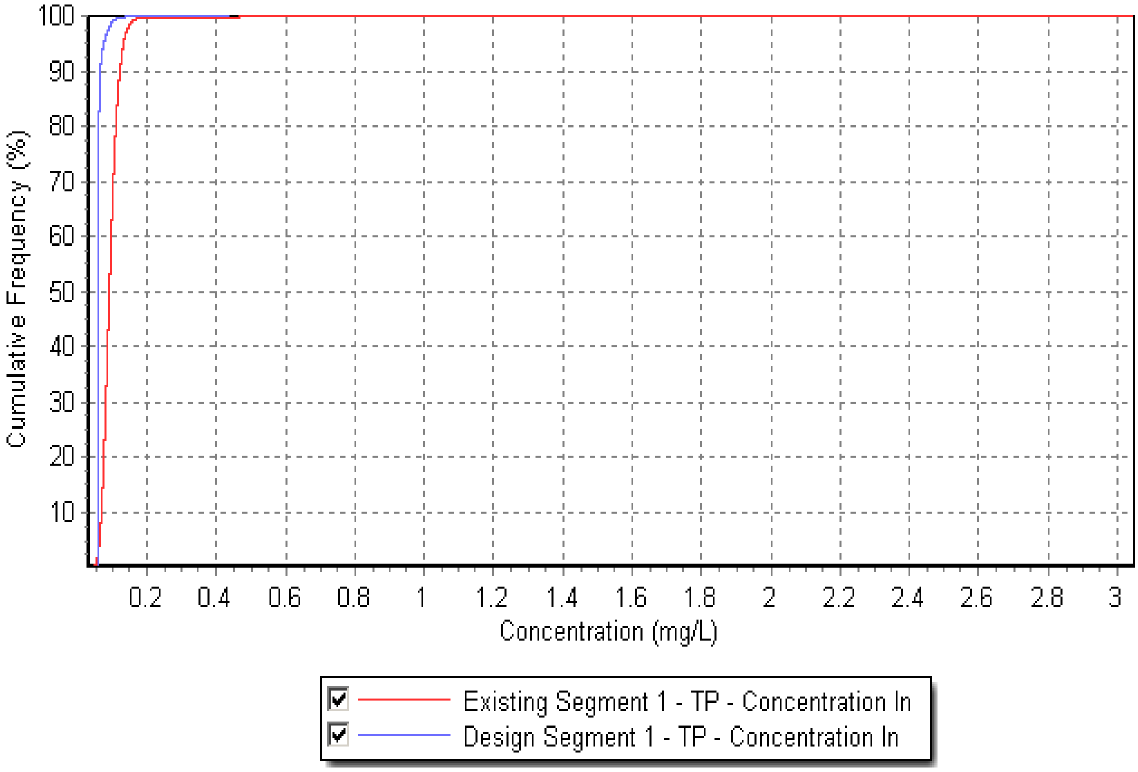


Figure 5.11 Cumulative Frequency Plots of TP for pre development (existing) and post development (operation) with treatment for Segment 1 of Oldbury Creek preferred option (replaces Figure J1 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

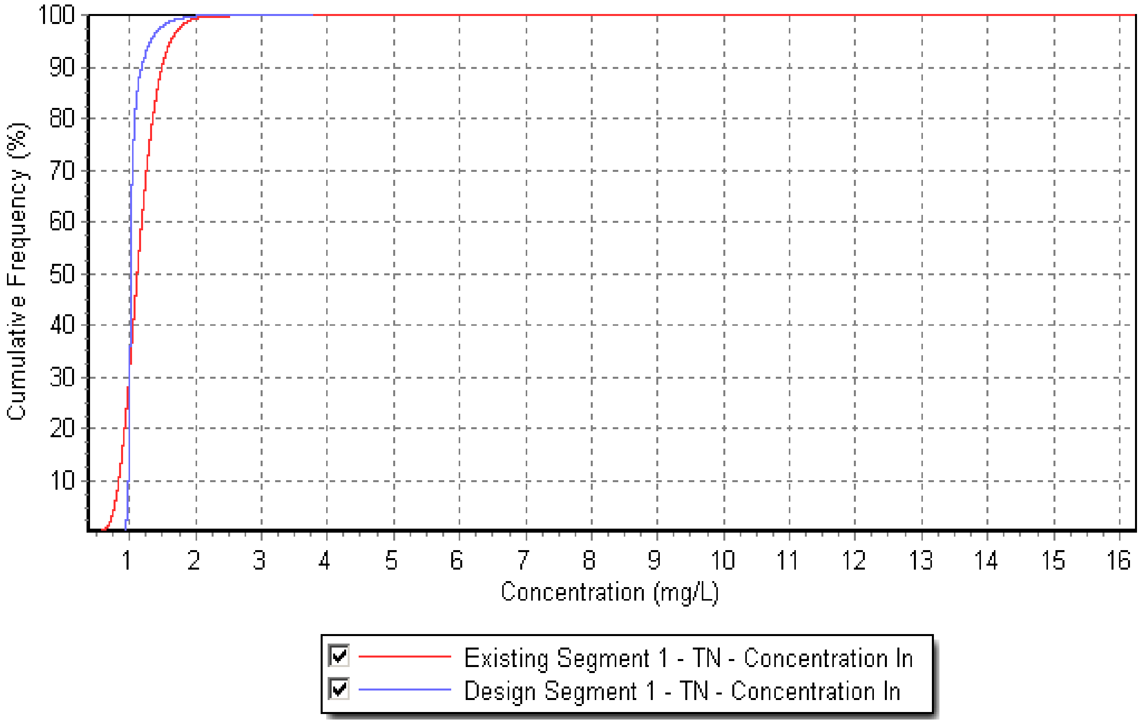


Figure 5.12 Cumulative Frequency Plots of TN for pre development (existing) and post development (operation) with treatment for Segment 1 of Oldbury Creek preferred option (replaces Figure J2 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

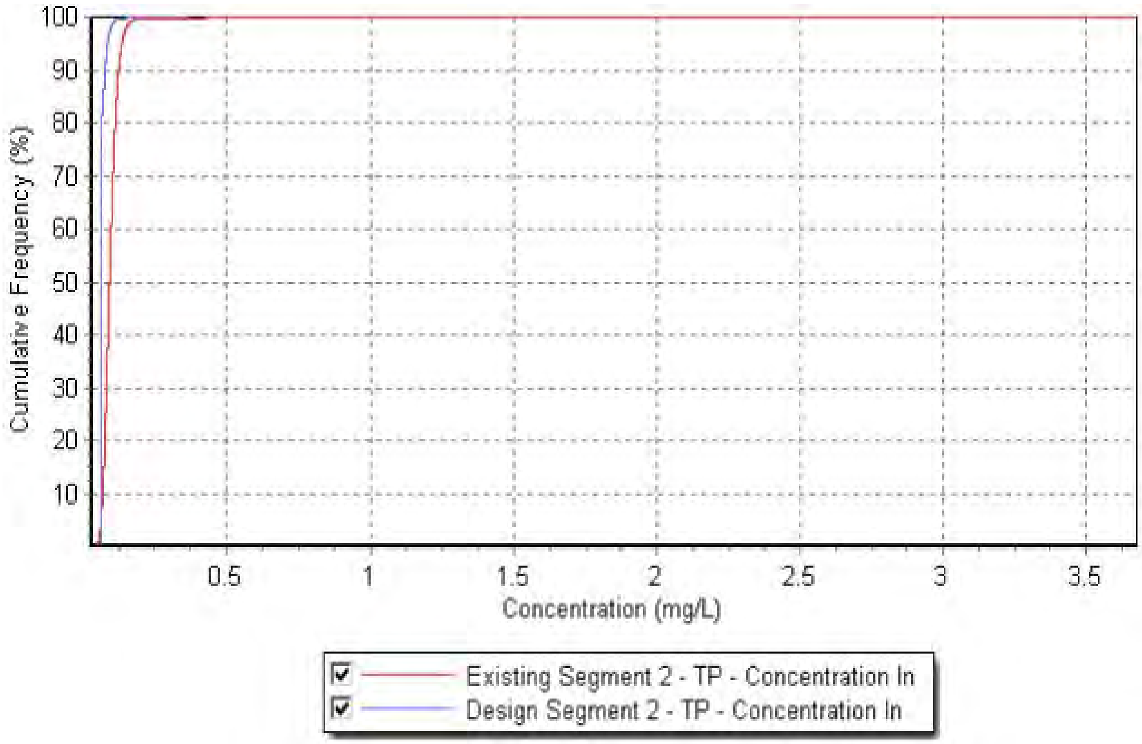


Figure 5.13 Cumulative Frequency Plots of TP for pre development (existing) and post development (operation) with treatment for Segment 2 of Oldbury Creek preferred option (replaces Figure J3 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

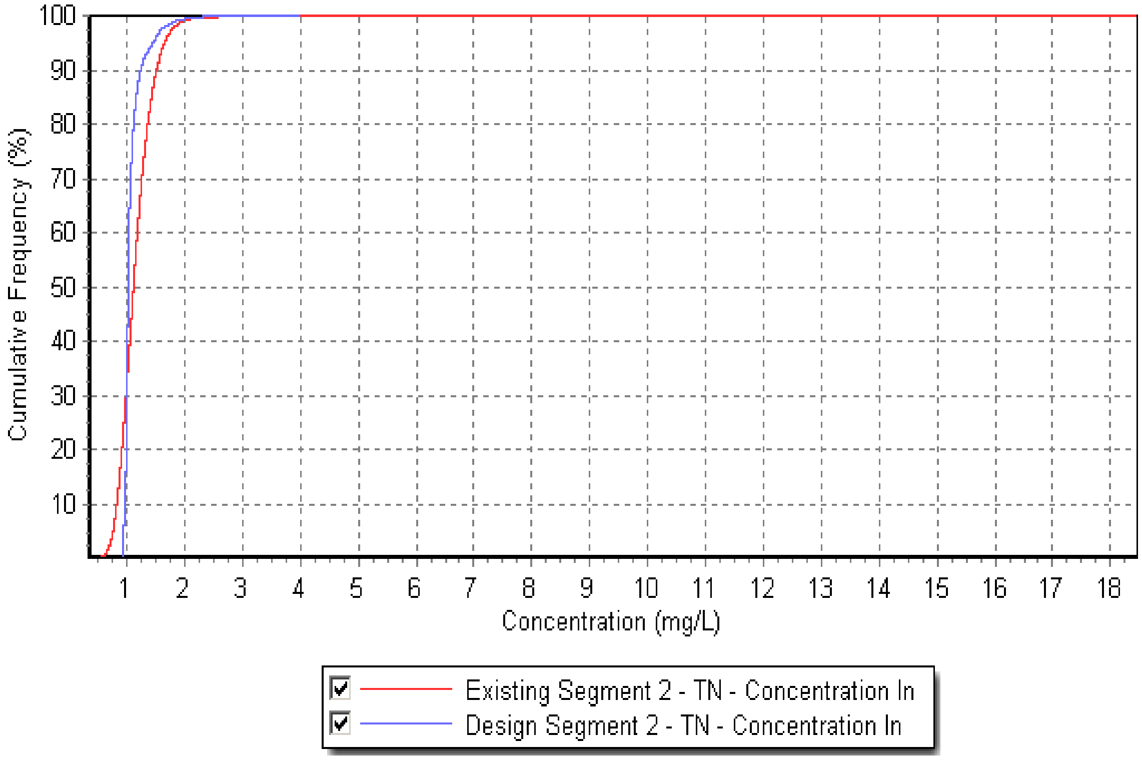


Figure 5.14 Cumulative Frequency Plots of TN for pre development (existing) and post development (operation) with treatment for Segment 2 of Oldbury Creek preferred option (replaces Figure J4 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

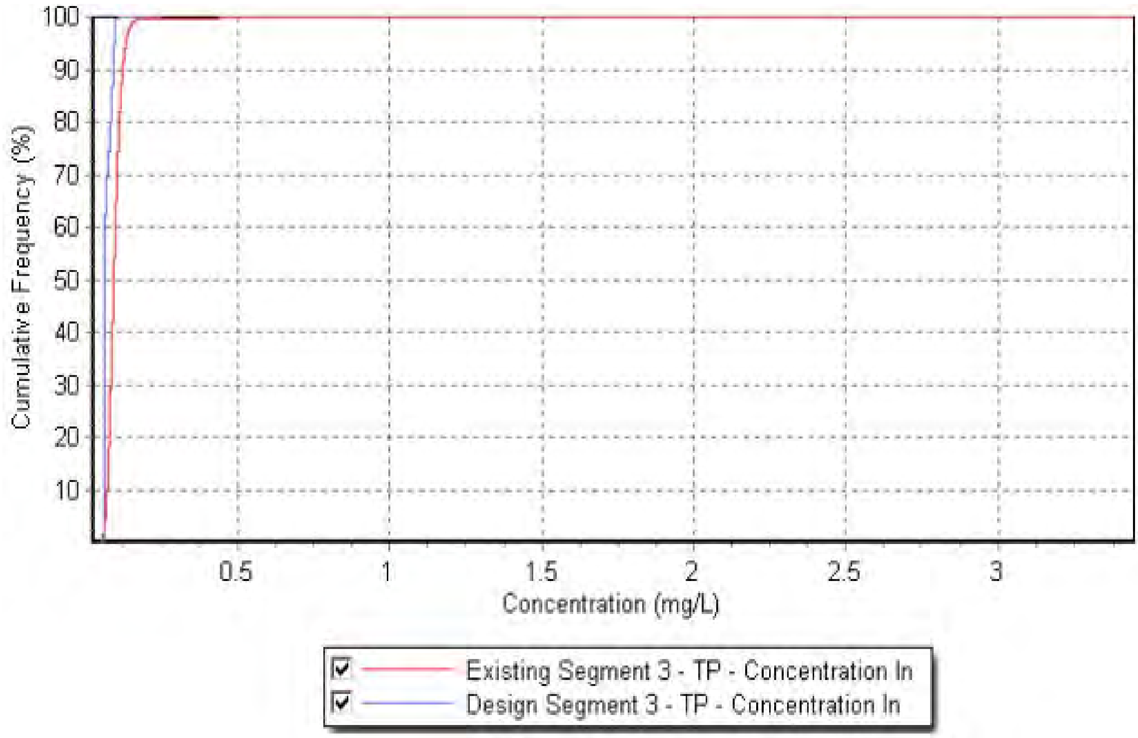


Figure 5.15 Cumulative Frequency Plots of TP for pre development (existing) and post development (operation) with treatment for Segment 3 of Oldbury Creek preferred option (replaces Figure J5 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

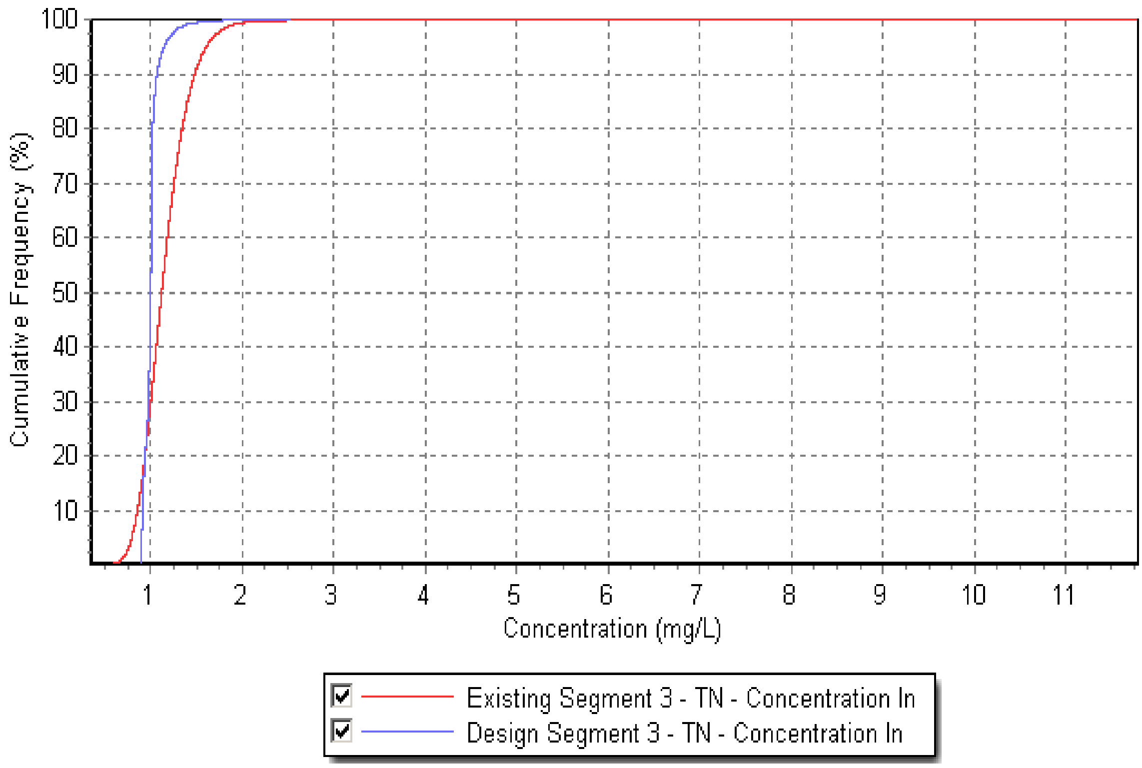


Figure 5.16 Cumulative Frequency Plots of TN for pre development (existing) and post development (operation) with treatment for Segment 3 of Oldbury Creek preferred option (replaces Figure J6 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

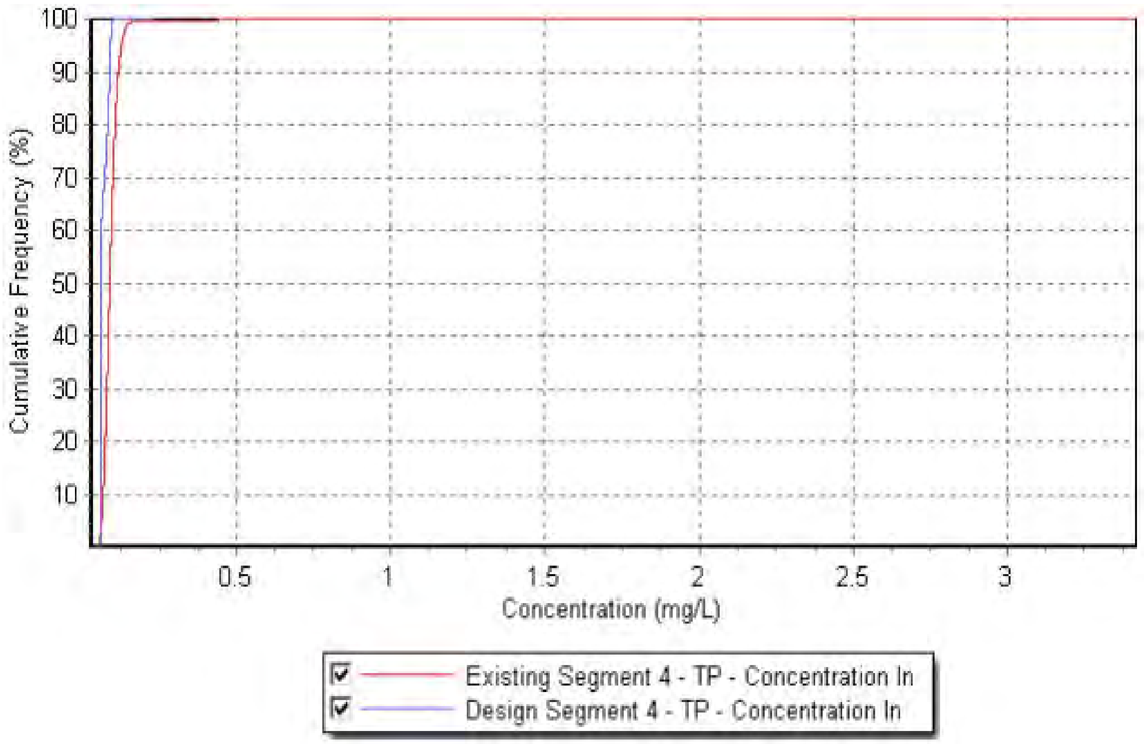


Figure 5.17 Cumulative Frequency Plots of TP for pre development (existing) and post development (operation) with treatment for Segment 4 of Oldbury Creek preferred option (replaces Figure J7 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

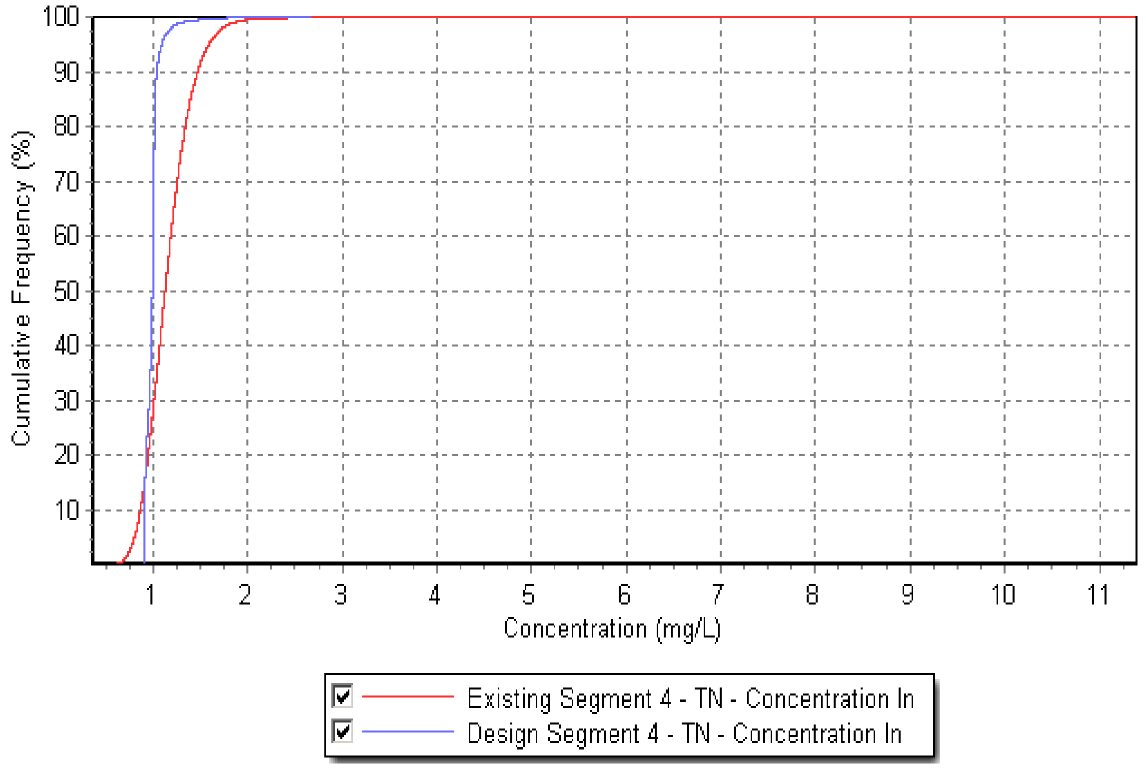


Figure 5.18 Cumulative Frequency Plots of TN for pre development (existing) and post development (operation) with treatment for Segment 4 of Oldbury Creek preferred option (replaces Figure J8 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

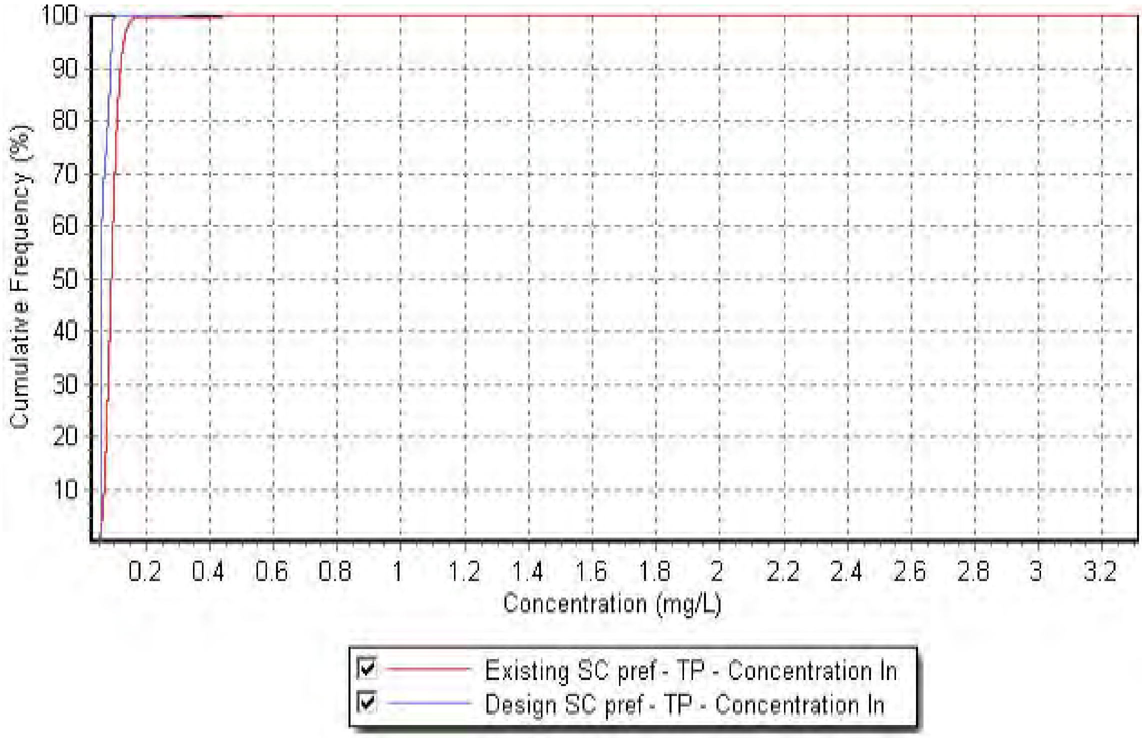


Figure 5.19 Cumulative Frequency Plots of TP for pre development (existing) and post development (operation) with treatment for Stony Creek preferred option (replaces Figure J9 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

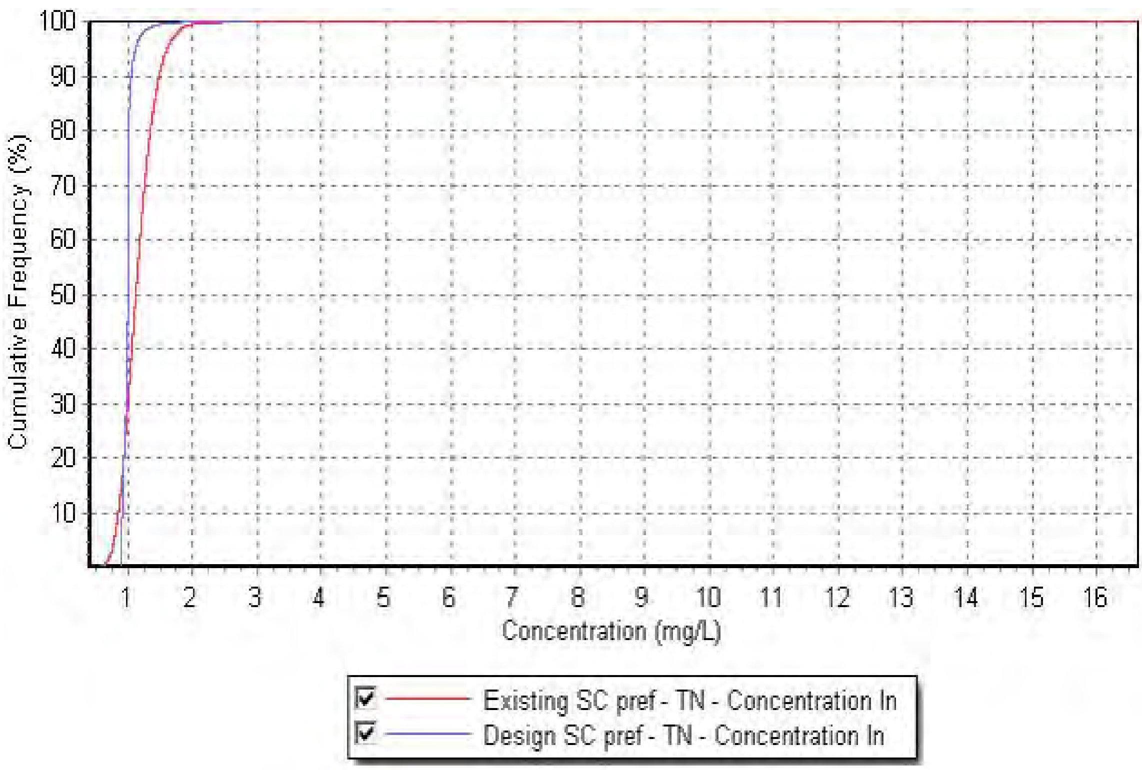


Figure 5.20 Cumulative Frequency Plots of TN for pre development (existing) and post development (operation) with treatment for Stony Creek preferred option (replaces Figure J10 of the Berrima Rail Project Surface Water Assessment (PB 2017b))

5.4.3 CONCLUSION

Runoff from the railway corridor will achieve NorBE assuming treatment swales and constructed wetlands are provided along the rail corridor to receive and treat the railway runoff before discharging into the Oldbury Creek and Stony Creek catchment at the low points in each sub-catchment.

5.5 BASEFLOW REDUCTION

The Hume Coal Project Surface Water Quality Assessment report (Parsons Brinckerhoff, 2016b) (Section 5.2.4) qualitatively assessed the impacts of baseflow reduction on water quality based on a comparison of contaminant concentrations in groundwater and surface water from baseline monitoring results.

An additional mass balance analysis has been undertaken for the RTS to quantitatively assess potential water quality impacts associated with baseflow reduction for the Medway Rivulet Management Zone. Daily mass balance modelling was undertaken for parameters that have higher baseline concentrations in surface water than groundwater, as there is the potential for streamflow concentrations to increase for these parameters due to reduced dilution from baseflow. The baseflow reduction mass balance analysis has been undertaken to address matters raised in the submissions from government agencies.

As a new management measure to offset potential water quality impacts associated with baseflow reduction, riparian protection zones are proposed on the Evandale and Mereworth properties. These properties are both located within the Medway Rivulet Management Zone. The total protection area is 42.5 ha, comprising 19.6 ha on the Evandale property and 22.9 ha on the Mereworth property. Clearing, farming and industrial activities (including roads, infrastructure etc) will be restricted within the proposed protection zones. These restrictions within proposed protection zones will reduce pollutant loads and have a positive impact on water quality.

5.5.1 METHODOLOGY

Baseflow reduction associated with lowering of groundwater phreatic zones during underground mining has been estimated for streams within the project area using the Mean K Groundwater Model (HydroSimulations, 2018). Baseflow reduction is predicted to occur in the following streams:

— Medway Rivulet and its tributaries, including Oldbury Creek, Wells Creek, Wells Creek Tributary and Belanglo Creek

— Upper and Lower Wingecarribee River and its tributaries

— Lower Wollondilly River and its tributaries

— Bundanoon Creek and its tributaries

— Nattai River and its tributaries.

A reduction in baseflow will result in reduced loadings for all parameters. However, concentrations may increase due to reduced dilution from baseflow where groundwater concentrations are lower than surface water concentrations. To identify parameters where the concentration may increase due to reduced baseflow, the water quality of the streams has been compared to groundwater quality. Where groundwater concentrations are higher than surface water concentrations, a reduction in baseflow is likely to improve the quality of surface water. However, where groundwater concentrations are lower than surface water concentrations, a reduction in baseflow may reduce the dilution of contaminants and result in an increase in contaminant concentrations in the surface water.

A comparison of baseline groundwater quality and surface water in the Medway Rivulet Management Zone is provided in Table 5.12. Note that the typographical errors in nutrient concentrations for Medway Rivulet in Table 5.13 of the Hume Coal Project Surface Water Quality Assessment report (Parsons Brinckerhoff, 2016b) have been corrected in Table 5.12. The groundwater quality data is from groundwater monitoring bores in the project area that target the Hawkesbury

Sandstone. Bores targeting the Hawkesbury Sandstone were selected as this is the major water bearing unit in the project area and is understood to be providing baseflow to streams.

The 80th percentile of the baseline surface water data for the Medway Rivulet Management Zone was compared to the baseline groundwater quality data. The adoption of the 80th percentile in the comparison is arbitrary, however, the 80th percentile is adopted in the ANZECC (2000) guidelines for the selection of trigger values where the contaminant poses a threat at higher concentrations. The 80th percentile was adopted for both groundwater and surface water. The results indicate that concentrations are generally higher in groundwater than surface water, with the exception of the following parameters which were generally higher in surface water:

— Nitrate and nitrite

— Calcium, sodium and sulfate

— Aluminium.

Water quality guideline values from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC) (2000) and the Australian Drinking Water Guidelines (ADWG) (2011) are provided in the Hume Coal Project Surface Water Quality Assessment report (Parsons Brinckerhoff, 2016b) (Table 2.2) and the most stringent guidelines are provided in Table 5.12. Additional relevant water quality guideline values for ammonia, cobalt and beryllium raised in the submissions from government agencies are also provided in Table 5.12. Comparison of the baseline monitoring data to the ANZECC (2000) and ADWG (2011) guidelines indicates:

— Nitrate - 80th percentile of groundwater and surface water results are generally within the ANZECC (2000) guideline value for aquatic ecosystems and are well below the ANZECC (2000) guideline value for livestock drinking

— Nitrite - 80th percentile of groundwater and surface water results are well below the ANZECC (2000) guideline values for recreation and livestock drinking

— Calcium - 80th percentile of groundwater and surface water results are well below the ANZECC (2000) guideline value for livestock drinking

— Sodium - 80th percentile of groundwater and surface water results are well below the ANZECC (2000) guideline values for irrigation and recreation and the ADWG (2011) guideline value for aesthetics

— Sulfate - 80th percentile of groundwater and surface water results are well below the ANZECC (2000) guideline values for livestock drinking and recreation and the ADWG (2011) guideline value for aesthetics

— Aluminium - 80th percentile of surface water results exceed the ANZECC (2000) guideline value for aquatic ecosystems and in some cases the ADWG (2011) guideline value for health, but are well below the ANZECC (2000) guideline values for irrigation or livestock.

A daily mass balance model was developed in GoldSim to assess the change to nitrate, nitrite, calcium, sodium, sulfate and aluminium streamflow concentrations resulting from baseflow reduction. The GoldSim model was simulated at a daily time step for the 127-year period 1889 to 2015 using Data Drill sourced historical rainfall and evaporation data.

Existing flow conditions for the Medway Rivulet Management Zone were modelled in GoldSim using the AWBM rainfall-runoff model as outlined in the Hume Coal Project Water Balance Assessment report (Section 2.6 and Appendix A) (Parsons Brinckerhoff, 2016a). The AWBM rainfall-runoff model provides estimates of surface flow and baseflow (and total streamflow) at a daily timestep. For the operational scenario, the baseflow predicted by the AWBM rainfall-runoff model was reduced by 0.982 ML/day when baseflow occurs, which is the peak baseflow reduction for the Medway Rivulet Management Zone predicted by the Mean K Groundwater Model. The peak reduction of 0.982 ML/day was applied over the 127-year simulation period, which is conservative as the predicted baseflow reduction varies over the life of the mine with an average reduction of 0.669 ML/day over the 19-year period of mining (refer Section 2.2 Figure 2.1).

Table 5.12 Comparison of groundwater and surface water quality baseline monitoring results

PARAMETER	UNIT	GUIDELINE		GROUNDWATER (HAWKESBURY SANDSTONE)					MEDWAY RIVULET MANAGEMENT ZONE 80TH %ILE				
				NO. OF SAMPLES	MIN	MEDIAN	80TH %ILE	MAX	MEDWAY RIVULET	OLDBURY CREEK	WELLS CREEK AND WELLS CREEK TRIBUTARY	WHITES CREEK	BELANGLO CREEK AND PLANTING SPADE CREEK
Physical parameters													
Conductivity	µS/cm	30 – 350	ANZECC (2000) Aquatic ecosystem	131	41	241	609	4882	**613**	571	599	**668**	118
Temperature	°C	-		131	10	18	20	33	20	19	18	19	13
Turbidity	NTU	2 – 25	ANZECC (2000) Aquatic ecosystem	2	3.5	8.4	ID	13	9.6	12	22	11	14
pH	pH units	6.5 - 8.0	ANZECC (2000) Aquatic ecosystem	131	4.1	6.1	5.2 (20th%ile) 6.4 (80th%ile)	8.0	6.8 (20th%ile) 7.6 (80th%ile)	7.0 (20th%ile) 7.8 (80th%ile)	6.9 (20th%ile) 7.7 (80th%ile)	6.8 (20th%ile) 7.4 (80th%ile)	5.1 (20th%ile) 6.5 (80th%ile)
TDS	mg/L	600	ADWG (2011) Aesthetic	131	27	159	403	3172	396	366	381	432	79
TSS	mg/L	-		18	<5	<5	15	25	9.0	9.0	17	12	2.8
Nutrients													
Ammonia as N	mg/L	0.5	ADWG (2011) Aesthetic	22	<0.01	0.04	0.13	0.78	0.04	0.12	0.06	0.06	0.02
		0.013	ANZECC (2000) physical and chemical stressor										

PARAMETER	UNIT	GUIDELINE		GROUNDWATER (HAWKESBURY SANDSTONE)					MEDWAY RIVULET MANAGEMENT ZONE 80TH %ILE				
				NO. OF SAMPLES	MIN	MEDIAN	80TH %ILE	MAX	MEDWAY RIVULET	OLDBURY CREEK	WELLS CREEK AND WELLS CREEK TRIBUTARY	WHITES CREEK	BELANGLO CREEK AND PLANTING SPADE CREEK
Nitrate (as N)	mg/L	0.7	ANZECC (2000) Aquatic ecosystem	30	<0.01	0.02	0.08	0.77	0.11	0.66	0.08	**2.6**	0.08
Nitrite (as N)	mg/L	1.0	ANZECC (2000) Recreation	30	<0.01	<0.01	<0.01	<0.1	0.01	0.03	<0.01	0.02	<0.01
Total nitrogen as N	mg/L	0.5	HRC (1998)	ND	ND	ND	ND	ND	1.1	2.1	1.0	3.8	0.40
		0.25	ANZECC (2000) Aquatic ecosystem										
Phosphorus	mg/L	0.03	HRC (1998)	18	<0.01	0.03	0.09	0.19	0.08	**0.12**	0.07	**0.10**	0.02
		0.02	ANZECC (2000) Aquatic ecosystem										
Major ions													
Calcium	mg/L	1,000	ANZECC (2000) Livestock drinking	132	<1	5	29	198	32	40	22	43	1.4
Chloride	mg/L	175	ANZECC (2000) Irrigation	132	5.0	37	123	1300	96	66	114	76	27
Magnesium	mg/L	2,000	ANZECC (2000) Livestock drinking	132	<1	5.0	28	236	23	13	29	13	3.4
Sodium	mg/L	115	ANZECC (2000) Irrigation	132	2.0	21	43	406	54	50	48	66	17
Sulfate as SO_4	mg/L	250	ADWG (2011) Aesthetic	132	<1	5.0	8.0	159	27	73	6	96	2.4

PARAMETER	UNIT	GUIDELINE		GROUNDWATER (HAWKESBURY SANDSTONE)					MEDWAY RIVULET MANAGEMENT ZONE 80TH %ILE				
				NO. OF SAMPLES	MIN	MEDIAN	80TH %ILE	MAX	MEDWAY RIVULET	OLDBURY CREEK	WELLS CREEK AND WELLS CREEK TRIBUTARY	WHITES CREEK	BELANGLO CREEK AND PLANTING SPADE CREEK
Dissolved metals													
Aluminium	mg/L	0.055	ANZECC (2000) Aquatic ecosystem	89	<0.01	<0.01	0.02	0.41*	**0.12**	**0.12**	**0.19**	**0.07**	**0.66**
Antimony	mg/L	0.003	ADWG (2011) Health	89	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	mg/L	0.01	ADWG (2011) Health	89	<0.001	<0.001	0.002	0.04	0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	1.0	ANZECC (2000) Recreation	39	0.003	0.05	0.26	0.83	0.07	0.04	0.06	0.04	0.01
Beryllium^	mg/L	0.06	ADWG (2011) Health	30	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
		0.00013	ANZECC (2000) freshwater interim working level										
Boron	mg/L	0.37	ANZECC (2000) Aquatic ecosystem	89	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	<0.05
Cadmium	mg/L	0.0002	ANZECC (2000) Aquatic ecosystem	89	<0.0001	<0.0001	<0.0001	0.0008	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	ANZECC (2000) Aquatic ecosystem	89	<0.001	<0.001	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/L	0.05	ANZECC (2000) Irrigation	89	<0.001	0.003	0.009	0.27	<0.001	<0.001	<0.001	<0.001	<0.001

PARAMETER	UNIT	GUIDELINE		GROUNDWATER (HAWKESBURY SANDSTONE)					MEDWAY RIVULET MANAGEMENT ZONE 80TH %ILE				
				NO. OF SAMPLES	MIN	MEDIAN	80TH %ILE	MAX	MEDWAY RIVULET	OLDBURY CREEK	WELLS CREEK AND WELLS CREEK TRIBUTARY	WHITES CREEK	BELANGLO CREEK AND PLANTING SPADE CREEK
		0.0014	ANZECC (2000) freshwater interim working level										
Copper	mg/L	0.0014	ANZECC (2000) Aquatic ecosystem	89	<0.001	<0.001	0.006	0.26	0.002	0.001	0.002	0.002	<0.001
Iron	mg/L	0.2	ANZECC (2000) Irrigation	132	<0.05	4.9	11	22	0.51	0.35	0.55	0.14	0.33
Lead	mg/L	0.0034	ANZECC (2000) Aquatic ecosystem	89	<0.001	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.1	ANZECC (2000) Recreation	132	0.001	0.42	0.79	1.7	0.14	0.13	0.22	0.12	0.02
Mercury	mg/L	0.0006	ANZECC (2000) Aquatic ecosystem	18	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	mg/L	0.01	ANZECC (2000) Irrigation	89	<0.001	<0.001	0.001	0.011	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	mg/L	0.011	ANZECC (2000) Aquatic ecosystem	89	<0.001	0.008	0.02	0.63	0.003	0.002	0.002	0.002	<0.001
Selenium	mg/L	0.01	ADWG (2011) Health	89	<0.01	<0.01	<0.01	0.16	<0.01	<0.01	<0.01	<0.01	<0.01
Silver^	mg/L	0.00005	ANZECC (2000) Aquatic ecosystem	ND	ND	ND	ND	ND	<0.01	0.02	<0.001	<0.01	<0.001

PARAMETER	UNIT	GUIDELINE		GROUNDWATER (HAWKESBURY SANDSTONE)					MEDWAY RIVULET MANAGEMENT ZONE 80TH %ILE				
				NO. OF SAMPLES	MIN	MEDIAN	80TH %ILE	MAX	MEDWAY RIVULET	OLDBURY CREEK	WELLS CREEK AND WELLS CREEK TRIBUTARY	WHITES CREEK	BELANGLO CREEK AND PLANTING SPADE CREEK
Zinc	mg/L	0.008	ANZECC (2000) Aquatic ecosystem	89	<0.005	0.02	0.07	0.32	<0.005	0.005	<0.005	0.02	<0.005
Hydrocarbons													
Benzene	µg/L	1	ADWG (2011) Health	20	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	25	ADWG (2011) Aesthetic	20	<2	7.0	18	20	<2	<2	<2	<2	<2
Ethylbenzene	µg/L	3	ADWG (2011) Aesthetic	20	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total xylene	µg/L	20	ADWG (2011) Aesthetic	20	<2	<2	<2	<2	<2	<2	<2	<2	<2
Naphthalene	µg/L	16	ANZECC (2000) Aquatic ecosystem	20	<5	<5	<5	<5	<5	<5	<5	<5	<5

ND No data

ID Insufficient data to calculate

^ Standard and trace laboratory limits of reporting exceed the guideline.

* Concentrations of most dissolved metals are low, as is characteristic for groundwater with circumneutral pH. Most aluminium measurements are below the detection limit (0.01 mg/L), although a maximum of 0.41 mg/L was recorded in one instance. Aluminium concentrations above 0.01 mg/L are not representative of dissolved species and are believed to be outliers (Geosyntec 2016).

Cells shaded grey indicate 80th percentile surface water concentrations exceed 80th percentile groundwater concentrations.

Values in bold indicate lowest guideline value exceeded and 80th percentile surface water concentrations exceed 80th percentile groundwater concentrations

The 80th percentile of the baseline groundwater data for the Hawkesbury Sandstone was adopted in the GoldSim model for baseflow for the existing and operational scenarios. The 80th percentile of the baseline surface water data for the Medway Rivulet was adopted, however, as the baseline surface water data represents total stream flow (i.e. surface flow and baseflow), a mass balance calculation was undertaken to estimate surface water concentrations to be adopted in the GoldSim model. The mass balance calculation was based on the following equations:

$$M_{surface\ flow} = M_{streamflow} - M_{baseflow} \quad (1)$$

$$(C_{surface\ flow} \times Q_{surface\ flow}) = (C_{streamflow} \times Q_{streamflow}) - (C_{baseflow} \times Q_{baseflow}) \quad (2)$$

where:

$M_{baseflow}$ = mass of pollutants in baseflow in kg/day

$M_{surface\ flow}$ = mass of pollutants in surface flow in kg/day

$M_{streamflow}$ = mass of pollutants in streamflow (i.e. combined baseflow and surface flow) in kg/day

$C_{baseflow}$ = pollutant concentration for baseflow in mg/L

$C_{surface\ flow}$ = pollutant concentration for surface flow in mg/L

$C_{streamflow}$ = pollutant concentration for streamflow (i.e. combined baseflow and surface flow) in mg/L

$Q_{baseflow}$ = baseflow rate in ML/day

$Q_{surface\ flow}$ = surface flow rate in ML/day

$Q_{streamflow}$ = streamflow rate (i.e. combined baseflow and surface flow) in ML/day

The mass balance calculation adopted the average baseflow and surface flow estimates for the Wingecarribee River at Greenstead (No. 212009) gauging station over the period 1990 to 2002 from the baseflow analysis undertaken for the EIS Groundwater Assessment Volume 1: Data Analysis report (Coffey, 2016). The average baseflow and surface flow were 25.2 ML/day and 114.0 ML/yr, respectively (average total streamflow 139.2 ML/day).

Concentrations for baseflow and surface flow adopted in the GoldSim model are provided in Table 5.13. These concentrations were adopted for both the existing and operational scenarios.

Table 5.13 Base flow and surface flow concentrations adopted in GoldSim mass balance model for Medway Rivulet Management Zone

PARAMETER	CONCENTRATION (mg/L)		
	80TH %ILE BASEFLOW	80TH %ILE TOTAL STREAMFLOW	SURFACE FLOW (CALCULATED)
Nitrate (as N)	0.08	0.11	0.117
Nitrite (as N)	0.005*	0.01	0.011
Calcium	29	32	32.663
Sodium	43	54	56.432
Sulfate (as SO_4)	8	27	31.200
Aluminium	0.02	12	0.142

Notes: * Baseline concentration less than the laboratory Limit of Reporting. Half laboratory Limit of Reporting adopted.

The following key assumptions have been made in the mass balance modelling for baseflow reduction:

- The analysis considers changes to pollutant concentrations resulting from reduced dilution from baseflow only.
- The mass balance model mixes the water from the baseflow and surface flow and calculates the concentration of total streamflow. This calculation does not include any form of physical or chemical process within the watercourse. No allowance has been made for change in pH within the watercourse resulting from baseflow reduction.
- The analysis has adopted the 80th percentile of the baseline surface water data for the Medway Rivulet and the 80th percentile of the baseline groundwater data for the Hawkesbury Sandstone.
- Where the baseline monitoring result was less than the laboratory limit of reporting, a value of half the limit of reporting was adopted.

5.5.2 MASS BALANCE MODELLING RESULTS

The GoldSim model was used to calculate the Medway Rivulet Management Zone streamflow (i.e. combined baseflow and surface water flow) pollutant loading and concentrations on a daily basis for the 127-year period from 1889 to 2015.

A summary of existing and operational scenario mean annual pollutant loads for nitrate, nitrite, calcium, sodium, sulfate and aluminium is provided in Table 5.14. The results show that mean annual pollutant loads for these parameters are slightly reduced (between approximately 0.5% and 1.7%) for the operational scenario. This is because there is less pollutant loading from the reduced baseflow.

Table 5.14 Simulated mean annual pollutant loads for Medway Rivulet Management Zone due to baseflow reduction

PARAMETER	MEAN ANNUAL LOAD		
	EXISTING	OPERATION	DIFFERENCE TO EXISTING
Nitrate (as N) (kg/yr)	2,270	2,240	-1.3%
Nitrite (as N) (kg/yr)	186	184	-1.1%
Calcium (kg/yr)	711,000	700,000	-1.6%
Sodium (kg/yr)	1,150,000	1,130,000	-1.7%
Sulfate (as SO_4) (kg/yr)	452,000	449,000	-0.7%
Aluminium (kg/yr)	1,870	1,860	-0.5%
Flow (ML/yr)	23,000	22,700	-1.3%

Cumulative frequency graphs of nitrate, nitrite, calcium, sodium, sulfate and aluminium concentrations in streamflow for the Medway Rivulet Management Zone for the existing and operational scenarios are provided in Figure 5.21 to Figure 5.26. The figures show pollutant concentrations for days when flow occurs over the 127-year period simulated in the GoldSim mass balance model. The figures demonstrate that pollutant concentrations for the existing and operational scenarios are very similar. The change in concentration between the existing and operational scenarios is almost undetectable up to the 99th frequency percentile of concentrations for days modelled when flow occurs. There is a slight increase (< 3%) in concentrations between the 99th and 100th frequency percentiles of concentrations for days modelled when flow occurs.

Peak pollutant concentrations predicted over the 127-year period simulated in the GoldSim mass balance model are provided in Table 5.15 for the existing and operational scenario with baseflow reduction. Note that these are the peak of the modelled results, which are based on the assumed pollutant concentrations for base flow and surface flow in Table 5.13. The modelled peaks therefore do not represent the maximum concentrations that may occur in the surface water system, and are provided only as a comparison between the existing and operational scenarios.

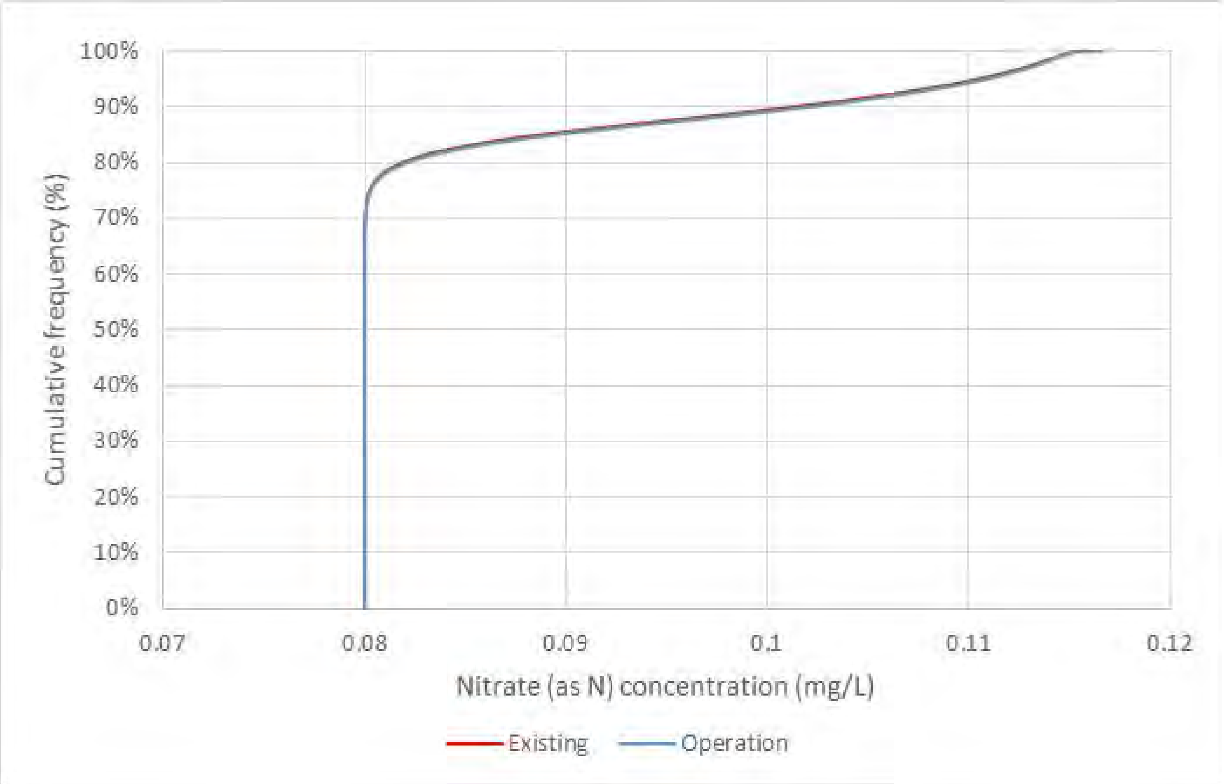


Figure 5.21 Nitrate (as N) concentration cumulative frequency graph for baseflow reduction assessment

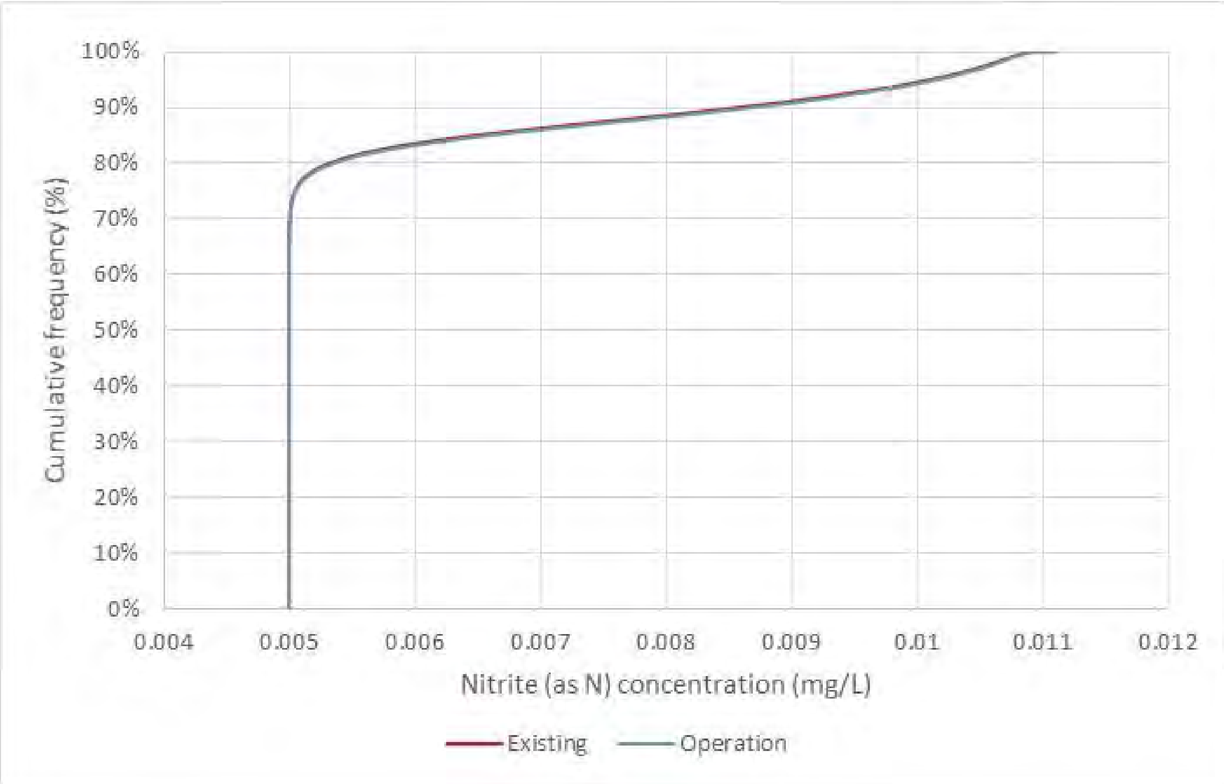


Figure 5.22 Nitrite (as N) concentration cumulative frequency graph for baseflow reduction assessment

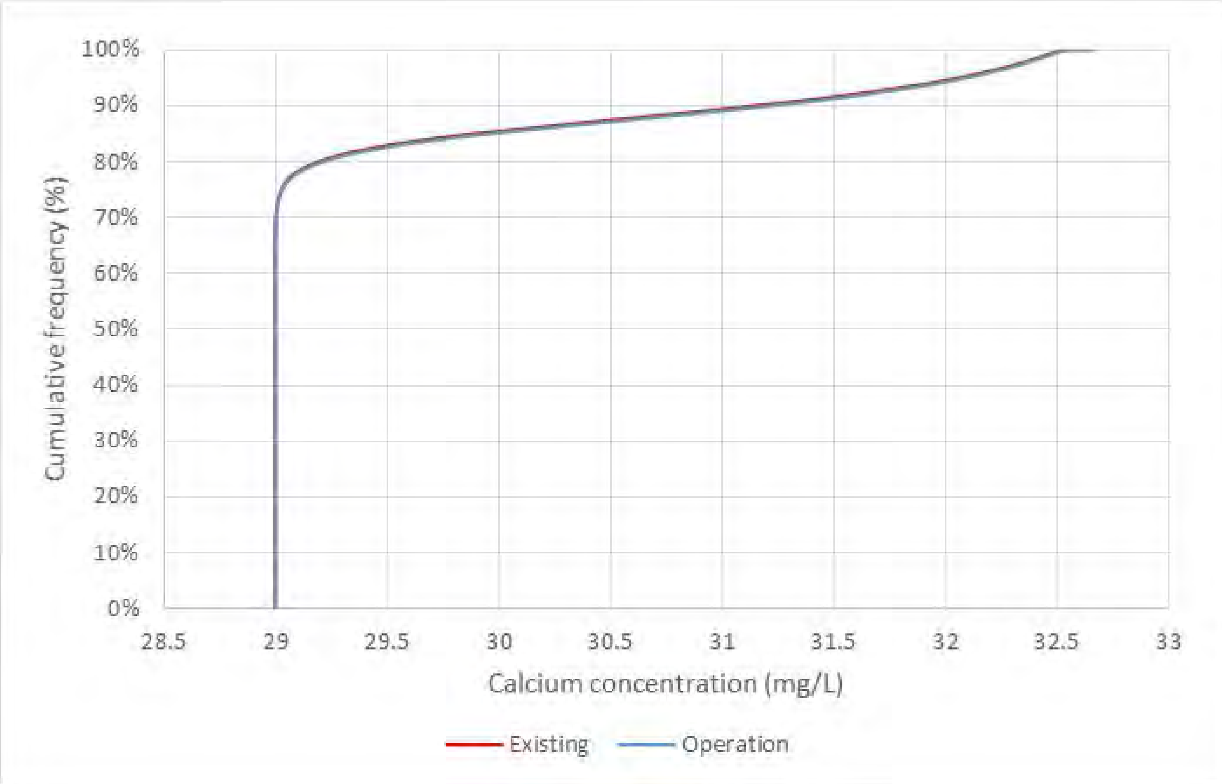


Figure 5.23 Calcium concentration cumulative frequency graph for baseflow reduction assessment

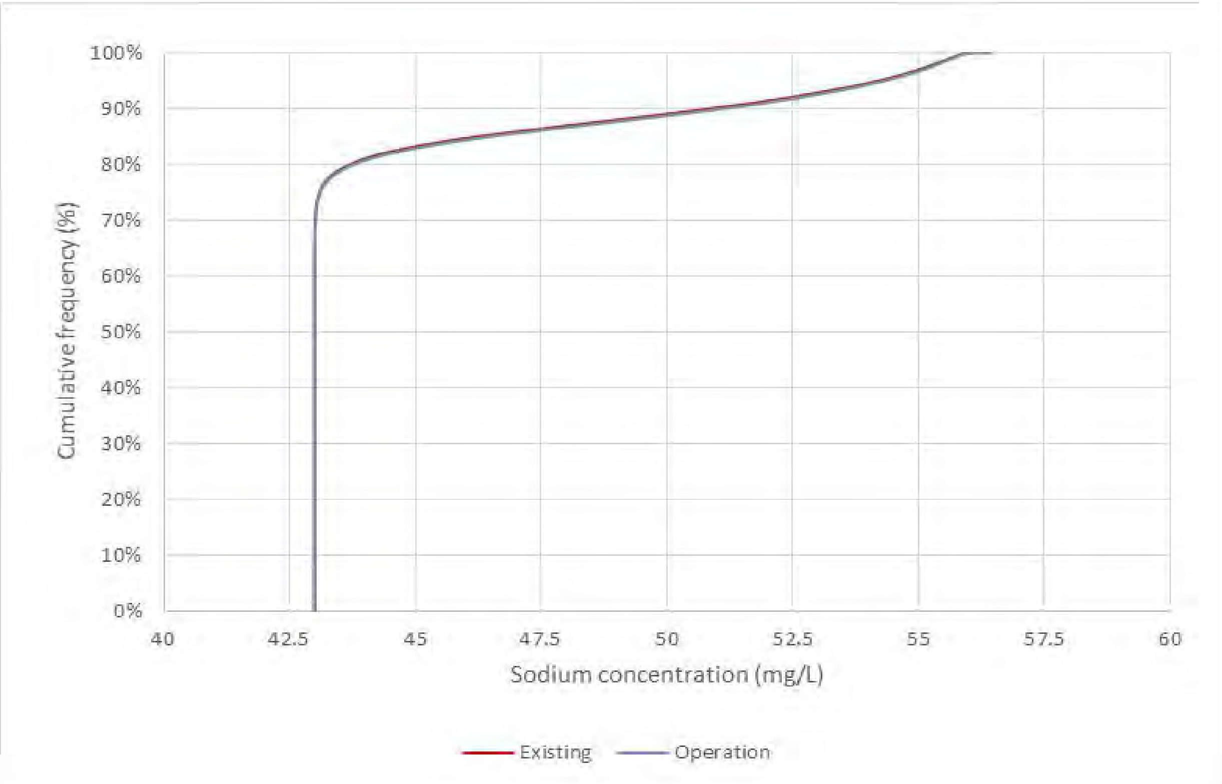


Figure 5.24 Sodium concentration cumulative frequency graph for baseflow reduction assessment

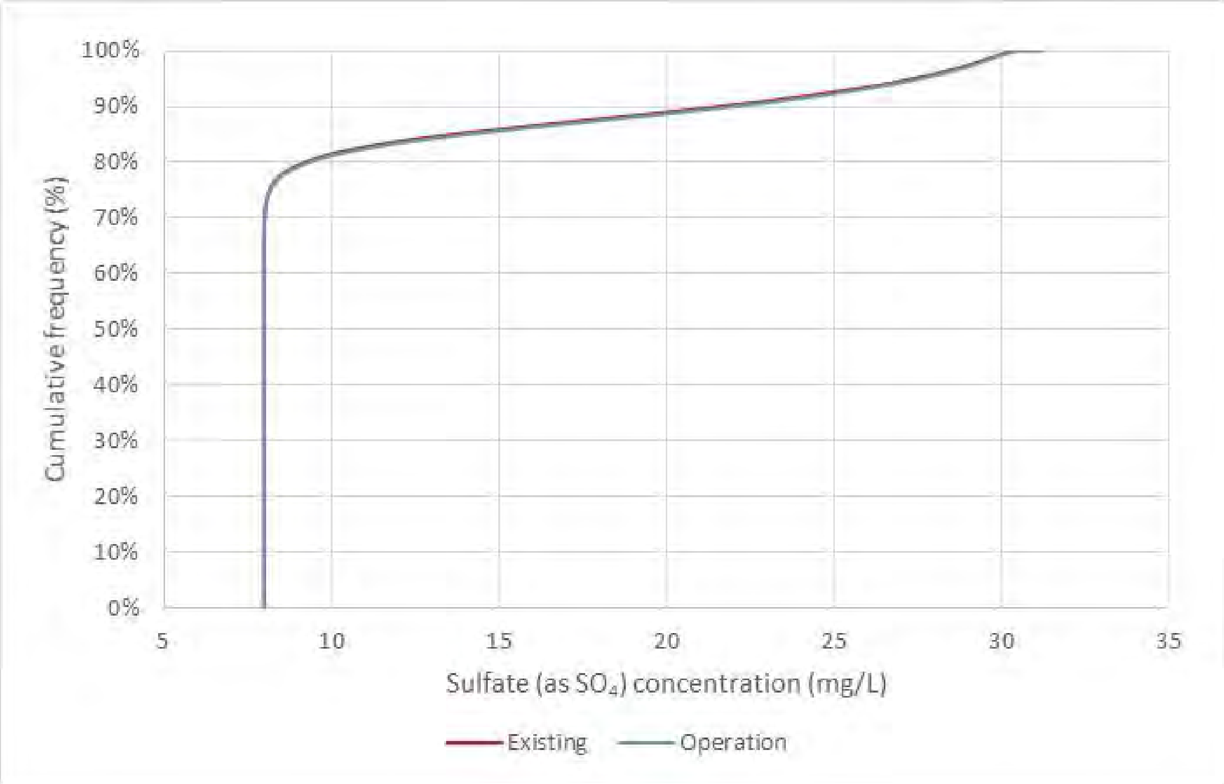


Figure 5.25 Sulfate (as SO_4) concentration cumulative frequency graph for baseflow reduction assessment

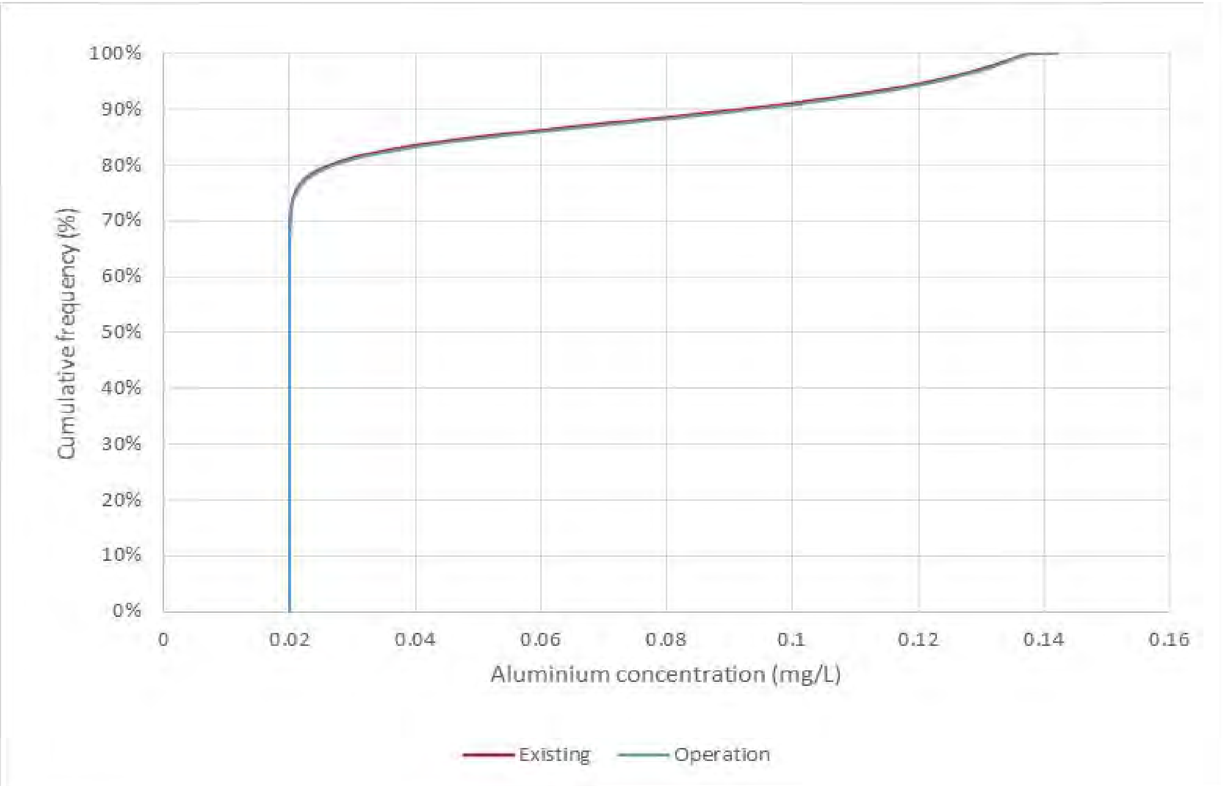


Figure 5.26 Aluminium concentration cumulative frequency graph for baseflow reduction assessment

Table 5.15 Simulated peak pollutant concentrations in stream flow for Medway Rivulet Management Zone for existing and operational scenario due to baseflow reduction

PARAMETER	PEAK POLLUTANT CONCENTRATION (mg/L)		DIFFERENCE TO EXISTING
	EXISTING	OPERATION	
Nitrate (as N)	0.115	0.117	1.7%
Nitrite (as N)	0.0109	0.0111	1.8%
Calcium	32.542	32.663	0.4%
Sodium	55.989	56.432	0.8%
Sulfate (as SO_4)	30.435	31.200	2.5%
Aluminium	0.138	0.142	2.9%

Comparison of the predicted pollutant concentrations in Table 5.15 to the ANZECC (2000) and ADWG (2011) guidelines indicates:

— Nitrate, nitrite, calcium, sodium and sulfate are all well below the ANZECC (2000) and ADWG (2011) guideline values for both the existing and operation scenarios.

— Aluminium exceeds the ANZECC (2000) guideline value for aquatic ecosystems for both the existing and operation scenarios, but is below the ADWG (2011) guideline value for health and well below the ANZECC (2000) guideline values for irrigation or livestock for both the existing and operation scenarios.

5.5.3 CONCLUSION

A comparison of baseline contaminant concentrations in groundwater and surface water for the Medway Rivulet Management Zone indicates that contaminant concentrations are generally higher in groundwater than in surface water with the exception of nitrate, nitrite, calcium, sodium, sulfate and aluminium which are higher in surface water. GoldSim mass balance modelling for the Medway Rivulet Management Zone has demonstrated that the cumulative frequency graphs of nitrate, nitrite, calcium, sodium, sulfate and aluminium concentrations in streamflow are very similar for the existing and operational scenarios. The change in concentration between the existing and operational scenarios is almost undetectable up to the 99^{th} frequency percentile. There is a slight increase (< 3%) in concentrations between the 99^{th} and 100^{th} frequency percentiles. Comparison to guideline values for aquatic ecosystems, drinking water, irrigation and livestock suggest that changes in surface water concentrations as a result of baseflow reduction will not affect the beneficial use of surface water in the project area.

As a new management measure to offset potential water quality impacts associated with baseflow reduction, riparian protection zones are proposed on the Evandale and Mereworth properties (total protection area is 42.5 ha). Clearing, farming and industrial activities (including roads, infrastructure etc) will be restricted within the proposed protection zones. These restrictions within proposed protection zones will reduce pollutant loads and have a positive impact on water quality.

5.6 DUST DEPOSITION

An additional analysis has been undertaken for the RTS to assess potential water quality impacts associated with coal dust deposition in the Oldbury Creek and Wells Creek catchments. The coal dust deposition analysis has been undertaken to address matters raised in the submissions from government agencies.

The coal dust deposition analysis has applied the results of water extract testing of coal samples to predicted catchment average dust deposition rates and runoff volumes to estimate the concentration of contaminants in surface water runoff resulting from dust deposition. The predicted contaminant concentrations have then been compared to baseline surface water quality monitoring results and guideline values.

5.6.1 METHODOLOGY

Predicted annual average incremental dust deposition rates for the operational scenario are provided in the Hume Coal Project Air Quality Impacts and Greenhouse Gas Assessment (Ramboll Environ, 2017). Post-EIS analysis of the air quality modelling results has been undertaken by Ramboll Environ to estimate catchment average incremental dust deposition rates for the Oldbury Creek and Wells Creek catchments for the operational scenario. The estimated catchment averaged incremental dust deposition rates for the Oldbury Creek and Wells Creek catchments are 2.067 g/m^2/year and 0.569 g/m^2/year, respectively.

Water extract results for coal and coal reject samples are provided in the Hume Coal Project Geochemical Assessment of Coal and Mining Waste Materials (RGS, 2016) (Table C5). The results from multi-element testing of water extracts from product coal, which is assumed to have a similar composition to coal dust, are summarised in Table 5.16.

The mass of leachable metals in deposited coal dust was estimated by multiplying the catchment average dust deposition rates by the water extract result for product coal. Where the water extract result is less than the laboratory limit of reporting, the laboratory limit of reporting was adopted for a conservative approach. The mass of leachable metals in deposited coal dust for the Oldbury Creek and Wells Creek catchments are provided in Table 5.16.

Table 5.16 Water extract results (RGS, 2016) and estimated mass of leachable metals in deposited coal dust

PARAMETER	WATER EXTRACT RESULT FOR PRODUCT COAL (RGS, 2016) (mg/kg)	ESTIMATED MASS OF LEACHABLE METALS IN DEPOSITED COAL DUST (mg/m^2)	
		OLDBURY CREEK CATCHMENT	WELLS CREEK CATCHMENT
Major Elements			
Aluminium	<1	0.00207*	0.00057*
Calcium	40	0.08267	0.02276
Iron	10	0.02067	0.00569
Magnesium	30	0.06200	0.01707
Potassium	10	0.02067	0.00569
Sodium	10	0.02067	0.00569
Minor Elements			
Antimony	<0.1	0.00021*	0.00006*
Arsenic	0.2	0.00041	0.00011
Boron	<1	0.00207*	0.00057*
Cadmium	<0.1	0.00021*	0.00006*
Chromium	<0.1	0.00021*	0.00006*
Cobalt	1.6	0.00331	0.00091
Copper	0.2	0.00041	0.00011
Fluoride	<1	0.00207*	0.00057*
Lead	0.2	0.00041	0.00011

PARAMETER	WATER EXTRACT RESULT FOR PRODUCT COAL (RGS, 2016) (mg/kg)	ESTIMATED MASS OF LEACHABLE METALS IN DEPOSITED COAL DUST (mg/m^2)	
		OLDBURY CREEK CATCHMENT	WELLS CREEK CATCHMENT
Manganese	4.2	0.00868	0.00239
Molybdenum	<0.1	0.00021*	0.00006*
Nickel	4.4	0.00909	0.00250
Phosphorus	<0.1	0.00021*	0.00006*
Selenium	<0.1	0.00021*	0.00006*
Thorium	<0.01	0.00002*	0.00001*
Uranium	<0.01	0.00002*	0.00001*
Zinc	3.3	0.00682	0.00188

Notes: < indicates less than the laboratory Limit of Reporting. * Water extract result in RGS (2016) less than the laboratory Limit of Reporting. Water extract result laboratory Limit of Reporting adopted.

The contaminant concentration in surface water runoff for the Oldbury Creek and Wells Creek catchments resulting from coal dust deposition was estimated using the leachable metal masses in Table 5.16. It was assumed that all leachable metals in deposited coal dust are leached and that there is no influence on contaminant concentrations from other physical or chemical processes within the watercourse. Average annual surface water runoff volumes were estimated based on an average annual rainfall of 824 mm/yr and a long term runoff coefficient of 0.18. The average annual rainfall of 824 mm/yr was reported in the Hume Coal Project Water Balance Assessment (Parsons Brinckerhoff, 2016a) (refer to Table 2.3). The runoff coefficient of 0.18 is based on the runoff coefficient for the Wingecarribee River at Greenstead (No. 212009) gauging station over the period 1990 to 2015 reported in the Hume Coal Project Water Balance Assessment (Parsons Brinckerhoff, 2016a) (refer to Table A3).

5.6.2 RESULTS

The estimated contaminant concentrations in the Oldbury Creek and Wells Creek catchments resulting from dust deposition are provided in Table 5.17. The mean baseline surface water concentrations for Medway Rivulet and guideline values are also provided in Table 5.17. The estimated concentration of contaminants in Oldbury Creek and Wells Creek resulting from dust deposition are significantly lower than the mean baseline concentrations and the guideline values.

Table 5.17 Estimated concentration of contaminants in surface water runoff resulting from dust deposition

CONTAMINANT	GUIDELINE VALUE (mg/L)		MEAN BASELINE CONCENTRATION (MEDWAY RIVULET) (mg/L)	ESTIMATED CONCENTRATION RESULTING FROM DUST DEPOSITION (mg/L)	
				OLDBURY CREEK CATCHMENT	WELLS CREEK CATCHMENT
Major ions					
Calcium	1,000	ANZECC (2000) Livestock drinking	27	0.0006	0.0002
Chloride	175	ANZECC (2000) Irrigation	56	0.003	0.0009
Magnesium	2,000	ANZECC (2000) Livestock drinking	10	0.0004	0.0001
Sodium	115	ANZECC (2000) Irrigation	38	0.0001	0.00004
Sulfate as SO_4	250	ADWG (2011) Aesthetic	45	0.001	0.0003
Dissolved metals					
Aluminium	0.055	ANZECC (2000) Aquatic ecosystem	0.08	0.00001*	0.000004*
Antimony	0.003	ADWG (2011) Health	<0.001	0.000001*	0.0000004*
Arsenic	0.01	ADWG (2011) Health	<0.001	0.000003	0.000001
Barium	1	ANZECC (2000) Recreation	0.04	Not reported**	Not reported**
Beryllium	0.06	ADWG (2011) Health	<0.001	Not reported**	Not reported**
	0.00013	ANZECC (2000) freshwater interim working level			
Boron	0.37	ANZECC (2000) Aquatic ecosystem	<0.05	0.00001*	0.000004*
Cadmium	0.0002	ANZECC (2000) Aquatic ecosystem	<0.0001	0.000001*	0.0000004*
Chromium	0.001	ANZECC (2000) Aquatic ecosystem	<0.001	0.000001*	0.0000004*
Cobalt	0.05	ANZECC (2000) Irrigation	<0.001	0.00002	0.000006
	0.0014	ANZECC (2000) freshwater interim working level			

CONTAMINANT	GUIDELINE VALUE (mg/L)		MEAN BASELINE CONCENTRATION (MEDWAY RIVULET) (mg/L)	ESTIMATED CONCENTRATION RESULTING FROM DUST DEPOSITION (mg/L)	
				OLDBURY CREEK CATCHMENT	WELLS CREEK CATCHMENT
Copper	0.0014	ANZECC (2000) Aquatic ecosystem	0.001	0.000003	0.000001
Iron	0.2	ANZECC (2000) Irrigation	0.25	0.0001	0.00004
Lead	0.0034	ANZECC (2000) Aquatic ecosystem	<0.001	0.000003	0.000001
Manganese	0.1	ANZECC (2000) Recreation	0.17	0.00006	0.00002
Mercury	0.0006	ANZECC (2000) Aquatic ecosystem	<0.0001	Not reported**	Not reported**
Molybdenum	0.01	ANZECC (2000) Irrigation	<0.001	0.000001*	0.0000004*
Nickel	0.011	ANZECC (2000) Aquatic ecosystem	<0.001	0.00006	0.00002
Selenium	0.01	ADWG (2011) Health	<0.01	0.000001*	0.0000004*
Silver	0.00005	ANZECC (2000) Aquatic ecosystem	0.01	Not reported**	Not reported**
Zinc	0.008	ANZECC (2000) Aquatic ecosystem	0.01	0.00005	0.00001

Notes: * Water extract result in RGS (2016) less than the laboratory Limit of Reporting. Water extract result laboratory Limit of Reporting adopted. **No water extract result reported in RGS (2016).

5.6.3 CONCLUSION

The estimated surface water runoff contaminant concentrations in the Oldbury Creek and Wells Creek catchments resulting from dust deposition are significantly lower than the mean baseline concentrations and the guideline values. The surface water quality impact associated with dust deposition in the Oldbury Creek and Wells Creek catchments is therefore considered to be insignificant and will not affect the beneficial use of surface water in the project area.

6 KEY CONCLUSIONS

The surface water modelling undertaken for the Hume Coal Project EIS and the related Berrima Rail Project EIS has been revised to address matters raised in the submissions from government agencies and stakeholders. The surface water modelling has also been revised to reflect post-EIS numerical groundwater modelling, including uncertainty analysis and climate sensitivity analysis, undertaken by HydroSimulations (2018).

The water balance modelling was revised to include revised groundwater inflow estimates. The water balance model base case adopts groundwater inflow estimates from the Mean K Groundwater Model. The base case modelling predicts no overflows for any of the MWDs or SBs based on the 107 water balance realisations (or climate sequences) simulated. The predicted peak stored volume in the PWD is 625 ML, which is far less than the maximum capacity of the dam (730 ML). The predicted maximum annual releases to Oldbury Creek of 30.6 ML/yr and 41.1 ML/yr from SB04 and SB04 (following the first flush), respectively, which is the same as the EIS. A water balance model climate sensitivity analysis has been undertaken adopting groundwater inflow estimates from the Modified EIS Groundwater Model static average climate, wet climate scenario and dry climate scenario. The sensitivity analysis demonstrated that there is no change to the predicted risk of overflows from MWDs or SBs and that there is no change to the predicted releases from SB03 and SB04 between the climate sensitivity analysis wet and dry climate scenarios compared to the climate sensitivity analysis static average climate.

The flow assessment was revised to include the revised baseflow reduction estimates. The flow assessment base case adopts baseflow reduction estimates from the Mean K Groundwater Model. The results indicate that the project will result in a 0.9% and 1.6% reduction in yield for the Medway Rivulet Management Zone under wet and dry conditions, respectively. This compares to a 0.8% and 1.4% reduction in yield under wet and dry conditions, respectively, predicted in the EIS. A flow assessment climate sensitivity analysis has been undertaken adopting baseflow reduction estimates from the Modified EIS Groundwater Model static average climate, wet climate scenario and dry climate scenario. The sensitivity analysis demonstrated that yield impacts for the climate sensitivity analysis wet and dry climate scenarios are generally similar to the climate sensitivity analysis static average climate.

The MUSIC water quality modelling of releases from SB03 and SB04 to Oldbury Creek (following the first flush) has been revised in line with WaterNSW recommended modelling practices. The existing flows were modelled as a mix of base flow and surface flow; and the model timestep was changed from daily to 6 min. The revised modelling results show that mean annual pollutant loads for TSS, TP and TN are reduced by significantly more than 10%, and that TP and TN concentrations for the operational scenario are equal to or lower than the existing scenario between the 50^{th} and 98^{th} percentiles. Releases from SB03 and SB04 meet the NorBE criteria for TSS, TP and TN.

The MUSIC water quality modelling for the mine access roads and railway line have been revised in line with WaterNSW recommended modelling practices. The swale exfiltration rate was set to 0 mm/hr; the swale vegetation height was set to 0.25 m; the swale side slopes were set to a maximum of 1:3.33; and the industrial landuse type was adopted for road cut/fill embankment. To achieve NorBE following these changes, the proposed swale lengths have been increased and constructed wetlands are now proposed downstream of swales. The revised modelling results show that mean annual pollutant loads for TSS, TP and TN are reduced by more than 10%, and that TP and TN concentrations for the operational scenario are equal to or lower than the existing scenario between the 50^{th} and 98^{th} percentiles. Runoff from the mine access road and railway line meet the NorBE criteria for TSS, TP and TN.

An additional mass balance analysis has been undertaken to assess potential water quality impacts associated with reduced dilution from baseflow for the Medway Rivulet Management Zone. Daily mass balance modelling was undertaken for nitrate, nitrite, calcium, sodium, sulfate and aluminium as baseline monitoring indicates that these parameters have higher concentrations in surface water than groundwater, and there is the potential for streamflow concentrations to increase for these parameters due to reduced dilution from baseflow. The results of daily mass balance modelling show that the cumulative frequency graphs of streamflow concentrations for these parameters are very similar for the existing and operational scenarios. The change in concentration between the existing and operational scenarios is almost undetectable up to the 99^{th} frequency percentile. There is a slight increase (< 3%) in concentrations between the

99^{th} and 100^{th} frequency percentiles. Comparison to guideline values for aquatic ecosystems, drinking water, irrigation and livestock suggest that changes in surface water concentrations as a result of baseflow reduction will not affect the beneficial use of surface water in the project area. As a new management measure to offset potential water quality impacts associated with baseflow reduction, riparian protection zones are proposed on the Evandale and Mereworth properties (total protection area 42.5 ha).

An additional analysis has been undertaken to assess potential water quality impacts associated with coal dust deposition in the Oldbury Creek and Wells Creek catchments. The dust deposition analysis has applied the results of water extract testing of coal samples to predicted catchment average dust deposition rates and runoff volumes to estimate the concentration of contaminants in surface water runoff resulting from dust deposition. The estimated contaminant concentrations are significantly lower than the mean baseline concentrations and the guideline values. The surface water quality impact associated with dust deposition is therefore considered to be insignificant and will not affect the beneficial use of surface water in the project area.

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APPENDIX A

HUME COAL PROJECT EIS WATER BALANCE ASSESSMENT

Hume Coal

Water Balance Assessment for Hume Coal Project

PARSONS BRINCKERHOFF

Document information
Client: Hume Coal Title: Water Balance Assessment for Hume Coal Project Document No: 2200539A-SW-REP-001 Rev10 Date: 22 December 2016

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8	25/11/2016	Final draft for submission
9	19/12/2016	Final report
10	22/12/2016	Updated final report

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Glossary

AEP	Annual exceedance probability
AWBM	Australian Water Balance Model
ARI	Average recurrence interval
BOM	Bureau of Meteorology
CPP	Coal preparation plant
DPI Water	Department of Primary Industries – Water
DP&E	NSW Department of Planning and Environment
EIS	Environmental impact statement
GL	Gigalitres
MWD	Mine water dam
ML	Megalitres
Mt	Million tonnes
Mtpa	Million tonnes per annum
PEA	Preliminary Environmental Assessment
PWD	Primary water dam
ROM	Run of mine
SB	Stormwater basin
SEARs	Secretary's Environmental Assessment Requirements
TLO	Train load out
WTP	Water treatment plant

Executive summary

This report documents the mine water balance modelling assessment and water management strategy for the Hume Coal Project. The assessment is based on the infrastructure layout developed by Arkhill Engineers, mine water demand estimates provided by Hume Coal and the groundwater modelling analysis undertaken by Coffey.

The water balance model incorporates a rainfall runoff model developed using the Australian Water Balance Model (AWBM). The AWBM model has been calibrated to streamflow gauge records maintained by WaterNSW and Hume Coal. The AWBM model achieved a good calibration to medium and high flows but not to low flows. The model under-predicts low flows due to sewage treatment plant discharges and groundwater contributions to baseflow, which are not modelled by AWBM. However, the calibration result means that the model is conservative with respect to low flows as it predicts lower harvestable volumes available from site runoff for reuse in mining operations during dry periods. The good calibration to high flows means that the model is capable of reliable predictions of potential uncontrolled spills from storages during wet periods.

The water management strategy for the project can be summarised as follows:

- Runoff from undisturbed catchments within the project area will be diverted around or away from the infrastructure into natural watercourses via clean water diversion drains.
- Runoff from the disturbed areas, from within the mine infrastructure footprint, will be directed to a series of stormwater basins, mine water dams and the primary water dam for storage and reuse.
- Runoff not in direct contact with coal may be released to local creeks after the first flush provided water quality is acceptable. Runoff from the rainfall not meeting the adopted first flush criteria will be transferred to the primary water dam for storage and reuse.
- Most of the groundwater collected in the underground mine sump will be utilised in meeting the project water demand. The sump will also collect return water from the underground mining operations, decant from co-disposed reject and runoff from one of the mine water dams on the surface. The mixed water from these sources will be pumped to the primary water dam for reuse.
- Any surplus of water in the system will be first reinjected from the sump into the void space behind the bulkheads. If the void space is full and cannot take the excess water, and the primary water dam volume is also above an adopted flood storage limit, then the excess water will be treated in a water treatment plant for release into Oldbury Creek if required. The water treatment plant is included in the project infrastructure as a provisional item as the water balance modelling indicates that the primary water dam has adequate capacity to ensure that there is no requirement to treat and release excess water in all climate sequences modelled.
- If the water volume in the primary water dam is very low and unable to meet the mine water demands, then additional water will be sourced from the reinjected and natural groundwater that will be stored in the void spaces.

The mine water balance model was developed in the GoldSim software program. The varying mine water demands and groundwater inflows over the 19-year operational mining period were input to the model. The climate data input to the model was a continuous record of rainfall and potential evaporation data from 1889 to 2015 obtained from Scientific Information for Land Owners, which is a database of historical daily climate records for Australia. This allowed the model to simulate 107 climate sequences for the 19-year mining period.

The water balance model simulations undertaken for the 107 climate sequences indicate that:

- The project will be able to supply all demands by using the net harvestable rainfall-runoff from all stormwater basins, mine water dams and groundwater collected from the underground mine.
- The primary water dam, stormwater basins and mine water dams can be operated without any spills occurring.
- There is no requirement to treat and release excess water from the primary water dam in all modelled climate sequences.
- In the majority of climate sequences most of the groundwater reporting to the underground sump will be used in the mining operation. Additional water from the void spaces behind the bulkheads will be required to supplement supply to meet all demands, except potable and construction water requirements.
- Two stormwater basins will release water to Oldbury Creek following the first flush. The combined wet year annual releases are expected to be in the range 67 ML to 72 ML. Dry year releases are expected to be less than 1 ML per year.

1. Introduction

WSP | Parsons Brinckerhoff has been commissioned by Hume Coal Pty Limited (Hume Coal) to undertake a water balance assessment for the Hume Coal Project since September 2015. A number of iterations have occurred to the water balance assessment as part of the progressive improvement to mine infrastructure layout and water management strategies. This report relates to the latest revision of the mine infrastructure layout that was designed by Arkhill Engineers (drawing reference number 3713G0910, 19 May 2016).

A water balance model was developed for the water management system for the Hume Coal Project using the GoldSim software package (www.goldsim.com) to:

- assess the performance of the Hume Coal Project's water management system and strategies;
- estimate water surpluses and deficits during the operational phase of mining; and
- inform the design of the proposed water management infrastructure including stormwater basins (SBs), mine water dams (MWDs), the primary water dam (PWD), pumps / pipelines and water treatment systems.

1.1 Project description

The project involves developing and operating an underground coal mine and associated infrastructure over a total estimated project life of 23 years. The indicative surface infrastructure footprint is provided in Figure 1.1 and an overview of the water management infrastructure is provided in Figure 1.2. A full description of the project, as assessed in this report, is provided in Chapter 2 of the main EIS (EMM 2016).

In summary it involves:

- Ongoing resource definition activities, along with geotechnical and engineering testing, and other low impact fieldwork to facilitate detailed design.
- Establishment of a temporary construction accommodation village.
- Development and operation of an underground coal mine, comprising of approximately two years of construction and 19 years of mining, followed by a closure and rehabilitation phase of up to two years, leading to a total project life of 23 years. Some coal extraction will commence during the second year of construction during installation of the drifts, and hence there will be some overlap between the construction and operational phases.
- Extraction of approximately 50 million tonnes (Mt) of run-of-mine (ROM) coal from the Wongawilli Seam, at a rate of up to 3.5 million tonnes per annum (Mtpa). Low impact mining methods will be used, which will have negligible subsidence impacts.
- Following processing of ROM coal in the coal preparation plant (CPP), production of up to 3 Mtpa of metallurgical and thermal coal for sale to international and domestic markets.
- Construction and operation of associated mine infrastructure, mostly on cleared land, including:
  - one personnel and materials drift access and one conveyor drift access from the surface to the coal seam;
  - ventilation shafts, comprising one upcast ventilation shaft and fans, and up to two downcast shafts installed over the life of the mine, depending on ventilation requirements as the mine progresses;
  - a surface infrastructure area, including administration, bathhouse, washdown and workshop facilities, fuel and lubrication storage, warehouses, laydown areas, and other facilities. The surface

infrastructure area will also comprise the CPP and ROM coal, product coal and emergency reject stockpiles;

  - surface and groundwater management and treatment facilities, including storages, pipelines, pumps and associated infrastructure;
  - overland conveyors;
  - rail load-out facilities;
  - explosives magazine;
  - ancillary facilities, including fences, access roads, car parking areas, helipad and communications infrastructure; and
  - environmental management and monitoring equipment.
- Establishment of site access from Mereworth Road, and minor internal road modifications and relocation of some existing utilities.
- Coal reject emplacement underground, in the mined-out voids.
- Peak workforces of approximately 414 full-time equivalent employees during construction and approximately 300 full-time equivalent employees during operations.
- Decommissioning of mine infrastructure and rehabilitating the area once mining is complete, so that it can support land uses similar to current land uses.

The project area, shown in Figure 1.1, is approximately 5,051 hectares (ha). Surface disturbance will mainly be restricted to the surface infrastructure areas shown indicatively on Figure 1.1, though will include some other areas above the underground mine, such as drill pads and access tracks. The project area generally comprises direct surface disturbance areas of up to approximately 117 ha, and an underground mining area of approximately 3,472 ha, where negligible subsidence impacts are anticipated.

A construction buffer zone will be provided around the direct disturbance areas. The buffer zone will provide an area for construction vehicle and equipment movements, minor stockpiling and equipment laydown, as well as allowing for minor realignments of surface infrastructure. Ground disturbance will generally be minor and associated with temporary vehicle tracks and sediment controls as well as minor works such as backfilled trenches associated with realignment of existing services. Notwithstanding, environmental features identified in the relevant technical assessments will be marked as avoidance zones so that activities in this area do not have an environmental impact.

Product coal will be transported by rail, primarily to Port Kembla terminal for the international market, and possibly to the domestic market depending on market demand. Rail works and use are the subject of a separate EIS and State significant development application for the Berrima Rail Project.

1.2 Environmental assessment requirements

The Secretary's Environmental Assessment Requirements (SEARs) relating to mine water balance and water management, and the section of this report where the requirement is addressed, are provided in Table 1.1.

Table 1.1 SEARs relating to mine water balance and water management

REQUIREMENT	SECTION WHERE ADDRESSED
A water management strategy, having regard to the EPA's, DPI's and WaterNSW's requirements and recommendations	Sections 3 and 4.2

To inform preparation of the SEARs, the NSW Department of Planning and Environment (DP&E) invited other government agencies to recommend matters to be addressed in the Environmental Impact Statement (EIS). These matters were then taken into account by the Secretary for DP&E when preparing the SEARs. Copies of the government agencies' advice to DP&E was attached to the SEARs. Agency requirements relating to mine water balance and water management are provided in Table 1.2.

Table 1.2 Agency requirements relating to mine water balance and water management

REQUIREMENT	SECTION WHERE ADDRESSED
DPI RESOURCES & ENERGY	
The EIS should state the interaction between the proposed mining activities and the existing environment and include a comprehensive description of the following activities and their impacts: Surface and groundwater usage and management	Sections 3, 4.5 and 5
DPI FISHERIES NSW	
It is recommended that the EIS be required to include:	
A detailed and consolidated site water balance	Sections 4 and 5
Full technical details and data of all surface …modelling	Sections 2 to 5
Proposed management and disposal of produced or incidental water	Sections 3 and 5
Description of all works and surface infrastructure that will intercept, store, convey, or otherwise interact with surface water resources	Sections 3, 4.3 and 5
OFFICE OF ENVIRONMENT & HERITAGE	
The EIS must assess the impact of the development on hydrology, including: Water balance including quantity, quality and source	Sections 4 and 5 Note: An assessment of the impacts on water quality are addressed in the Surface Water Quality Assessment Report (Parsons Brinckerhoff 2016a). Given that the water management strategy does not involve release (other than after first flush or treatment) the site is contained, and hence simulation of water quality is not required.
WATER NSW	
WaterNSW recommends the following be included in the SEARs: The management of dirty water from the washing and preparation of coal for transport Details of the measures to manage site water associated with processing coal and coal reject, general site runoff and any human activities likely to affect water quality at the site	Sections 3.3, 4.2 and 5

The Hume Coal Project was declared as a controlled action on 1 December 2015 by the then Commonwealth Department of the Environment (now Department of the Environment and Energy). The project will be assessed under the Bilateral Agreement between the NSW Government and the Commonwealth Government. Accordingly, the Commonwealth Department of the Environment and Energy has issued supplementary SEARs to address matters of national environmental significance relevant to the project. These matters are provided in Table 1.3, and have been taken into account in preparing this report, as indicated in the table.

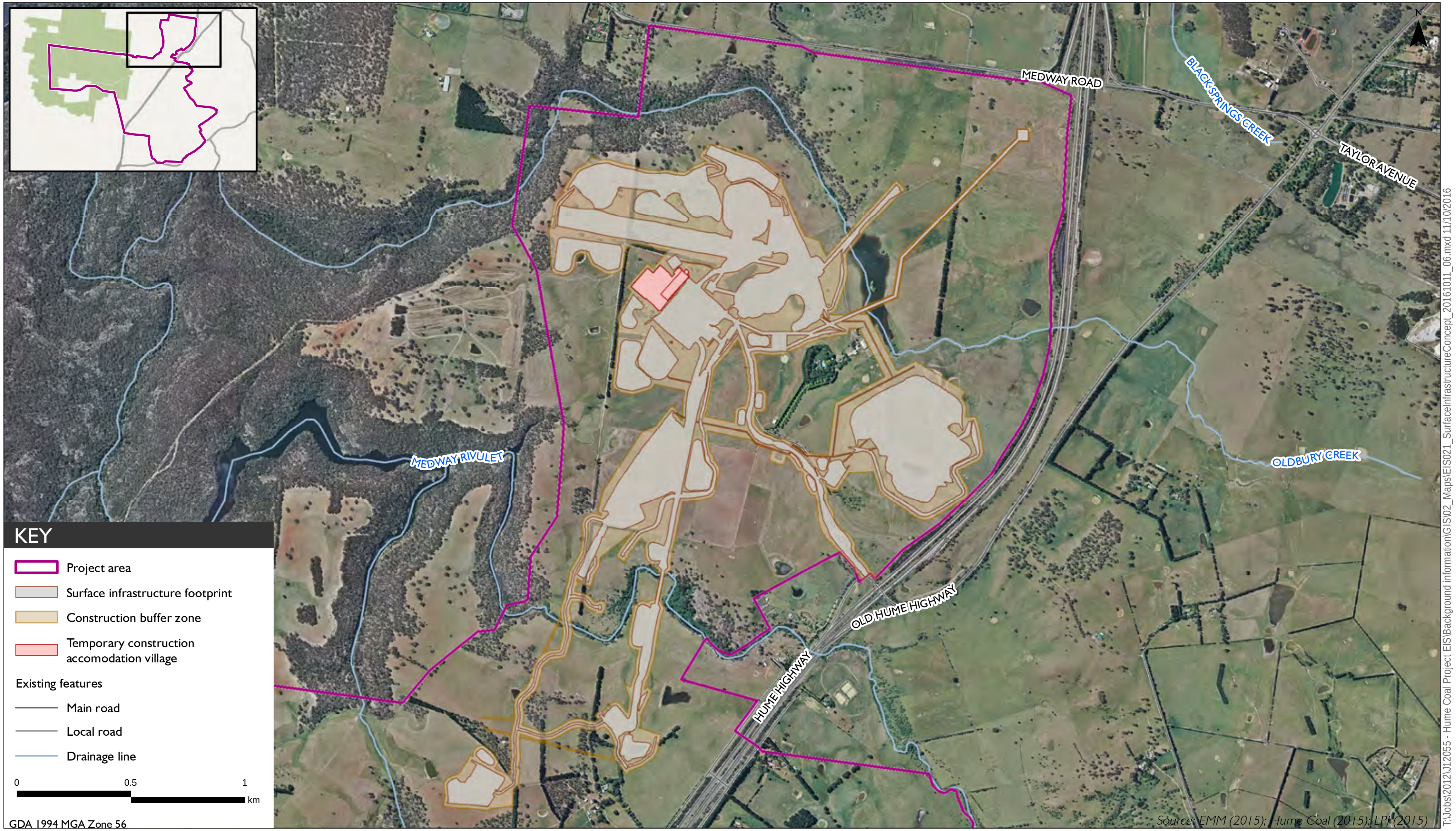
Table 1.3 Supplementary SEARs relating to mine water balance and water management

REQUIREMENT	SECTION WHERE ADDRESSED
The EIS must provide adequate information to allow the project to be reviewed by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, as outlined in the *Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals* (2015)	Sections 4 and 5

1.3 Scope of work

The scope of work for the water balance is as follows:

- Develop a water balance model for the Hume Coal Project using GoldSim software.
- Assess the performance of the water management system, including estimation of likely water surpluses and deficits.
- Use the model to inform the design of the proposed SBs and MWDs and to identify the required management strategy for water transfer between the proposed basins and dams (Figure 1.2).



EMM HUMECOAL PROJECT

Indicative surface infrastructure footprint

Hume Coal Project
Environmental Impact Statement

Figure 1.1

Water management infrastructure

Hume Coal Project
Environmental Impact Statement

Figure 1.2

1.4 Available data

The following information has been used for the water balance:

- Hume Coal Project Preliminary Environmental Assessment (EMM 2015).
- Surface infrastructure general arrangement drawing (drawing 3713G0910-2.DWG, Arkhill Engineers, May 2016, provided in Appendix B) prepared for the Hume Coal Project.
- Water management flow diagram for the proposed arrangement drawing for the Hume Coal Project shown in Figure 3.1 (ref: 3713H5010-1.DWG, Arkhill Engineers, November 2016).
- Stage-storage-area data for SB01, SB02, and the PWD by WSP | Parsons Brinckerhoff from the topographic data for pre-development and post-development surfaces for the basin / dam catchments (Appendix C).
- Stage-storage-area data for SB03, SB04, MWD05, MWD06, MWD07 and MWD08 by Arkhill Engineers as a part of the surface infrastructure arrangement design (Appendix C)
- Demand estimates for the CPP and underground operations provided by Palaris in May 2016 (Appendix D).
- Demand estimates for the Administration and Workshop Area and coal handling provided by WSP | Parsons Brinckerhoff in August 2015 (Appendix D).
- Estimates of loss of underground water to ventilation air provided by Hume Coal in September 2015.
- Groundwater inflow estimates to the mine sump and to the mined out void spaces modelled by Coffey and provided by Hume Coal in an email dated 28 May 2016
- Estimates of mined out void spaces prepared by Palaris and provided by Hume Coal in an email dated May 2016.
- Daily rainfall and evaporation data for the mine site area sourced from the Queensland Government Department of Environment and Resource Management (DERM) Data Drill service
- Daily stream gauge records for the Wingecarribee River sourced from WaterNSW.
- Daily stream gauge records for Black Bobs Creek, Medway Rivulet and Long Swamp Creek sourced from Hume Coal.

2. Hydrological data and modelling

2.1 Introduction

This section provides a summary of the climate and catchment characteristics of the project area, the hydrological datasets used in the study, the rainfall-runoff modelling approach and calibration process and the key modelling parameters adopted.

2.2 Catchment overview

The project area is traversed by Medway Rivulet and its tributaries, including Oldbury Creek, Wells Creek and Belanglo Creek. Long Acre Creek and Red Arm Creek originate from the north-west corner of the project area and are tributaries of Black Bobs Creek (Figure 2.1). Medway Rivulet and Black Bobs Creek ultimately discharge to the Wingecarribee River, located around 2 km north of the project area. The Wingecarribee River's catchment forms part of the broader Warragamba Dam and Hawkesbury-Nepean catchments. Medway Dam is located west of the SBs and MWDs and receives inflows from Wells Creek and Medway Rivulet (Figure 2.1).

Most of the surface infrastructure is within the Oldbury Creek and Medway Rivulet sub-catchments. Oldbury Creek, just north of the proposed CPP precinct, flows west through a deeply incised sandstone gully and joins Medway Rivulet downstream of Medway Dam.

Medway Rivulet flows north-west along the project area's eastern boundary before crossing it between the proposed MWD05 and MWD06. Medway Rivulet has a sandy, grassy channel with steep, rocky banks at this location. The catchment areas of Medway Rivulet at its confluence with Wells Creek and the Wingecarribee River are approximately 65.3 km^2 and 124 km^2 respectively.

2.3 Climate

Figure 2.2 shows the Bureau of Meteorology (BOM) rain gauges located around the Medway Rivulet catchments for gauges that are either actively recording or have long term datasets. Long term continuous rainfall data are available at the following gauges:

- 68186 – Berrima West (Medway, Wombat Creek) with 45.2 years of data
- 68093 – Sutton Forest (Eling Forest) with 50.8 years of data
- 68045 – Moss Vale (Hoskins Street) with 144 years of data
- 68008 – Bundanoon (Ballymena) with 108 years of data

Table 2.1 summarises details of the gauging stations presented in Figure 2.2. Table 2.2 provides comparisons of mean annual rainfalls for a selection of the gauging stations, which suggest that the rainfall decreases from south to north within the Medway Rivulet catchment.

The SBs and MWDs proposed for the Hume Coal Project are located within the lowest rainfall zone of the Medway Rivulet catchment and are within an aerial distance of 4.5 km to the nearest BOM gauging site 68186 Berrima West (Medway, Wombat Creek). The rainfall data at this gauge is available from May 1970 and has data gaps in 3% of the full record duration. The mean annual rainfall for a gap free period from 1970 to1975 is calculated to be 656 mm (Table 2.2). The next nearest BOM gauging site with a longer rainfall record is 68045 Moss Vale (Hoskins Street) with a mean annual rainfall of 1,032 mm for the same period from 1970 to 1975. The BOM gauging site 68093 Sutton Forest (Eling Forest) recorded a mean annual rainfall of 907 mm for the same period from 1970 to 1975. This site is located within the Wells Creek catchment. The BOM rainfall gauging site 68008 – Bundanoon (Ballymena) recorded the highest mean annual rainfall of 1,275 mm for the period from 1970-1975 and is located south of the Medway Rivulet catchment boundary.

Pan evaporation data is not available from any of the BOM gauging sites listed in Table 2.1. The nearest pan evaporation measurement occurs at the BOM gauging site 070263 at Goulburn TAFE campus.

Rather than undertaking a separate data extension and gap filling exercise, a continuous record of rainfall and potential evaporation data was obtained from SILO (Scientific Information for Land Owners), which is a database of historical climate records for Australia. SILO provides historical daily weather records for Australia from 1889 to present for the following products:

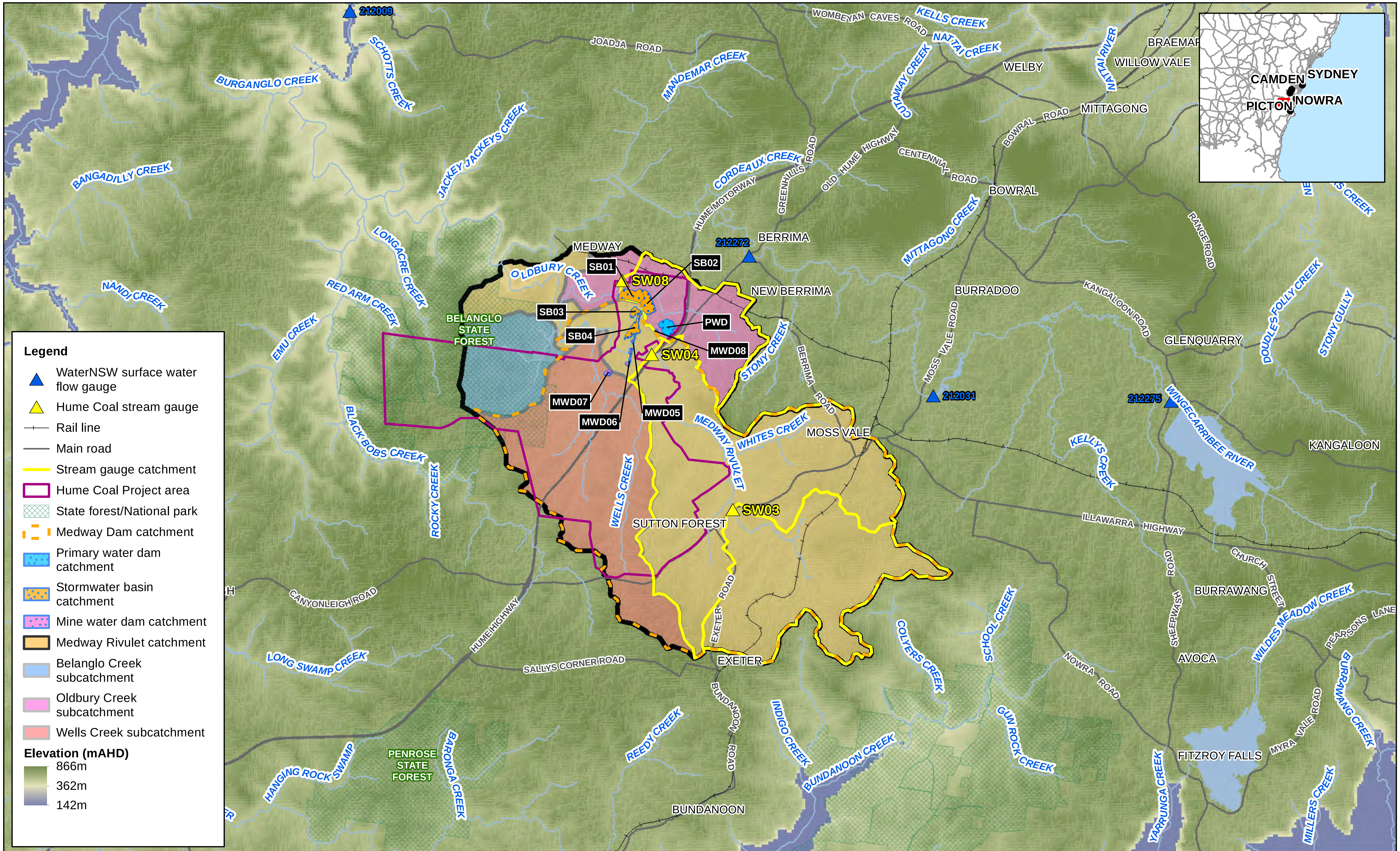
- Gridded datasets: interpolated surfaces which have been derived either by splining or kriging the observational data. The grids are stored on a regular 0.05° x 0.05° grid, which is approximately 5 km x 5 km.
- Patched Point Data: a daily time series of data at a point location consisting of station records which have been supplemented by interpolated estimates when observed data are missing. Patched datasets are available at approximately 4800 BOM recording stations around Australia.
- Data Drill: a daily time series of data at a point location consisting entirely of interpolated estimates. The data are taken from the gridded datasets and are available at any grid point over the land area of Australia (including some islands).

SILO datasets are constructed from observational records provided by the BOM. SILO processes the raw data, which may contain missing values, to derive datasets which are both spatially and temporally complete. SILO datasets are hosted on the Long Paddock website (https://www.longpaddock.qld.gov.au/silo/about.html) which is operated by the Queensland Government Department of Science, Information Technology, Innovation and the Arts (DSITI).

A continuous gap-free time series of rainfall, potential evaporation and lake surface evaporation for 127 years from 1889 to 2015 were obtained for the grid specified by latitude -34.50º and longitude 150.30º. The Data Drill location is 0.5 km north of SB01 and SB02 and was adopted as the key data location for the project surface infrastructure area.

A plot of the Data Drill annual rainfall is provided in Figure 2.3. This plot also contains a 10-year moving average time series, which identifies the period from 1949 to1969 as the wettest 20 year period. Similarly the period from 1999 to date appears to be one of the sustained dry periods. A plot of monthly distribution of average daily evaporation from the Data Drill for the site is provided in Figure 2.4. Lake evaporation data was used in the water balance assessment to estimate evaporation from storages and evapotranspiration data was used for other areas. In the project area, lake evaporation and evapotranspiration is lowest in winter months and highest in summer months.

Annual rainfalls from the Data Drill site near Oldbury is compared with other BOM rainfall gauge data in Table 2.2. The table shows mean annual rainfall for the relatively wet climate period from 1945 to 1964 and the relatively dry climate period from 1970 to 1975, as well as the data for 2015 when gauging data for SW08 was collected. The last column of this table presents a ratio for 2015 annual rainfall data between the BOM gauges and the Data Drill. Summary statistics for rainfall and evaporation are provided in Table 2.3 for the period from 1889 to 2014.



Map: 2200540A_GIS_004_A3	Author: RP
Date: 8/11/2016	Approved by: LR

Data source: , Hume Coal, Google Earth

0 2,000 4,000 m

1:115,000

Coordinate system: GDA 1994 MGA Zone 56

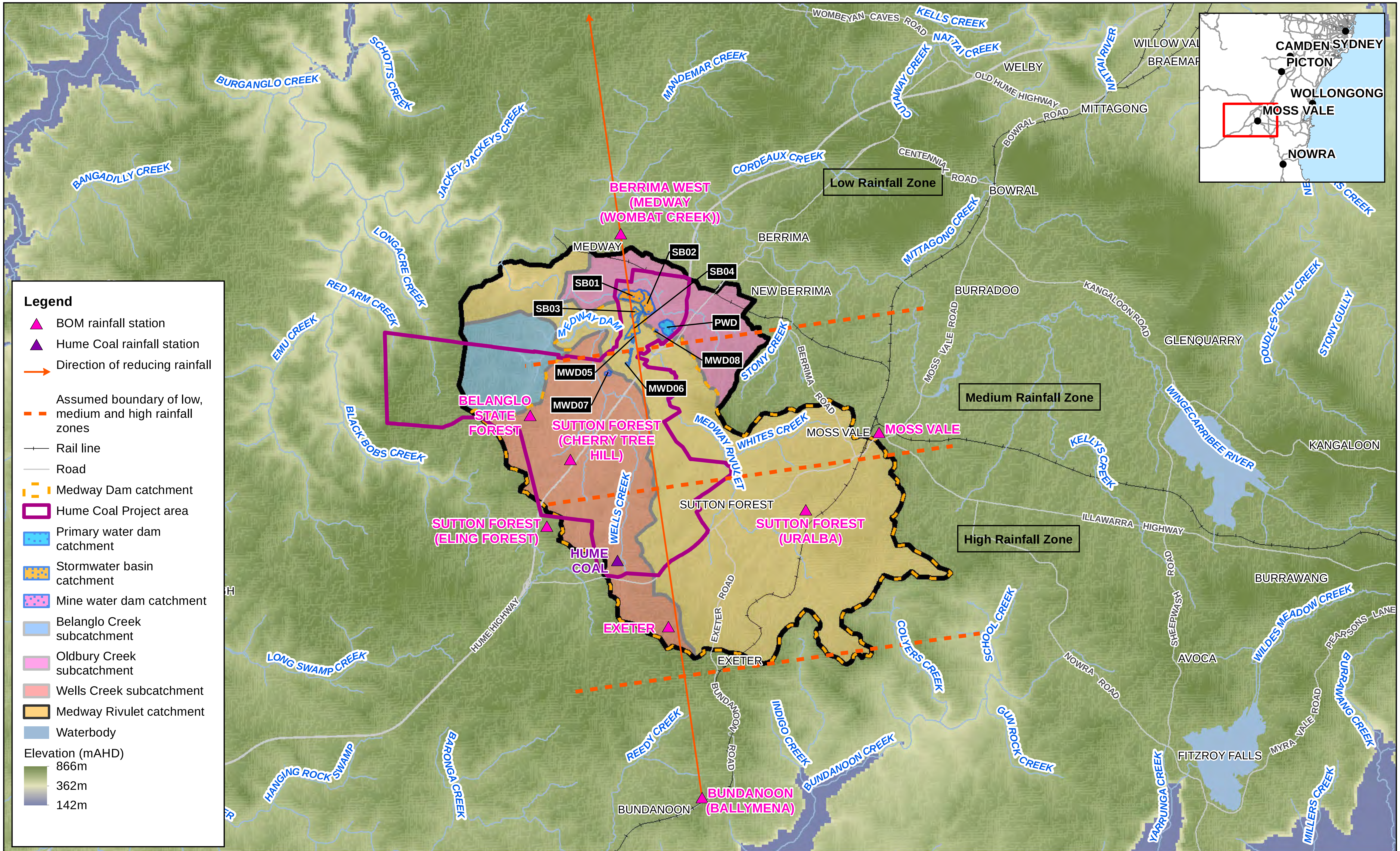
Scale ratio correct when printed at A3

Hume Coal Project Water Balance Assessment

Figure 2.1

Hume Coal stream gauges and surface water catchments

WSP | PARSONS BRINCKERHOFF



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Date: 8/11/2016	Approved by: AJ		
Data source: , Hume Coal, Google Earth			

Hume Coal Project
Water Balance Assessment
Figure 2.2
BOM rainfall gauges and conceptualised linear gradient of rainfall from south to north

Table 2.1 BOM rain gauges located around Medway Rivulet catchment

Site	Name	Longitude (degree)	Latitude (degree)	Start Month	Start Year	End Month	End Year	Years	% complete
68008	BUNDANOON (BALLYMENA)	150.3103	-34.6506	Jan	1902	Aug	2015	108	91
68195	MOSS VALE (TOROKINA)	150.4026	-34.6368	Oct	1971	Mar	2009	37.5	99
68025	EXETER	150.3	-34.6	Jan	1908	Dec	1975	67.4	99
68093	SUTTON FOREST (ELING FOREST)	150.2576	-34.5695	Jan	1945	Jun	2000	50.8	91
68058	SUTTON FOREST (URALBA)	150.35	-34.5667	Feb	1901	Jun	1966	62.3	95
68075	SUTTON FOREST (CHERRY TREE HILL)	150.2667	-34.55	Feb	1956	Sep	1980	24.7	100
68045	MOSS VALE (HOSKINS STREET)	150.3768	-34.5444	Oct	1870	Jan	2016	144.3	97
68006	BELANGLO STATE FOREST	150.2528	-34.5367	Jan	1940	Sep	1990	49.9	98
68186	BERRIMA WEST (MEDWAY (WOMBAT CREEK))	150.2867	-34.4839	May	1970	Jan	2016	45.2	97

Table 2.2 Annual average rainfalls recorded at BOM rain gauges for relatively wet (1945 to 1964) and dry (1970 to 1975) periods and 2015

Site	Name	Mean Annual Rain (mm) for relatively wet period of 1945-1964	Mean Annual Rain (mm) for relatively dry period of 1970-1975	Annual Rain (mm) 2015	Ratio with Data Drill Rainfall 2015
68008	BUNDANOON (BALLYMENA)	1423	1275	1392	1.62
68025	EXETER	1331	1185	No data	No data
68045	MOSS VALE (HOSKINS STREET)	1092	1032	1062	1.23
68058	SUTTON FOREST (URALBA)	1049	No data	No data	No data
68093	SUTTON FOREST (ELING FOREST)	909	907	No data	No data
68186	BERRIMA WEST (MEDWAY (WOMBAT CREEK))	No data	656	821	0.95
DATA DRILL	OLDBURY	949	848	861	1.0

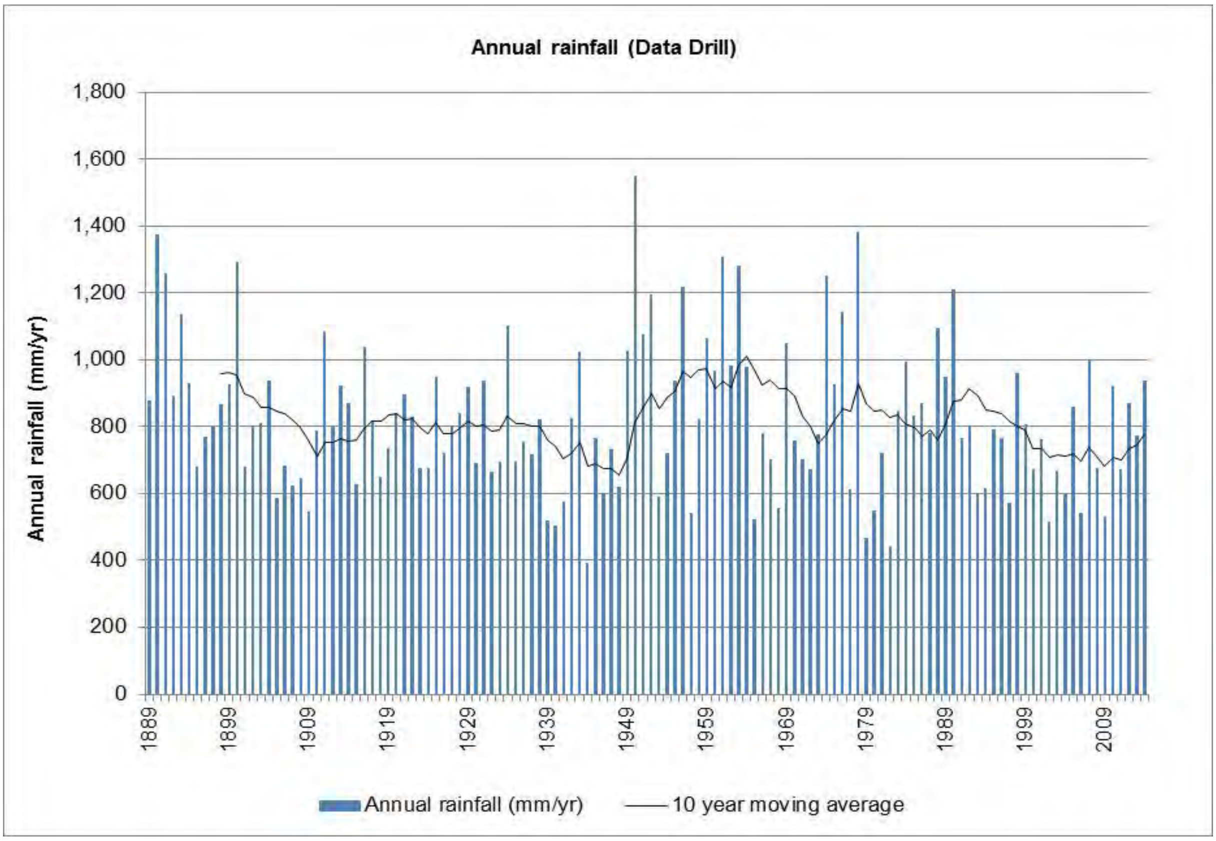

Figure 2.3 Annual rainfall for Hume Coal Project site — Data Drill (1889 to 2014)

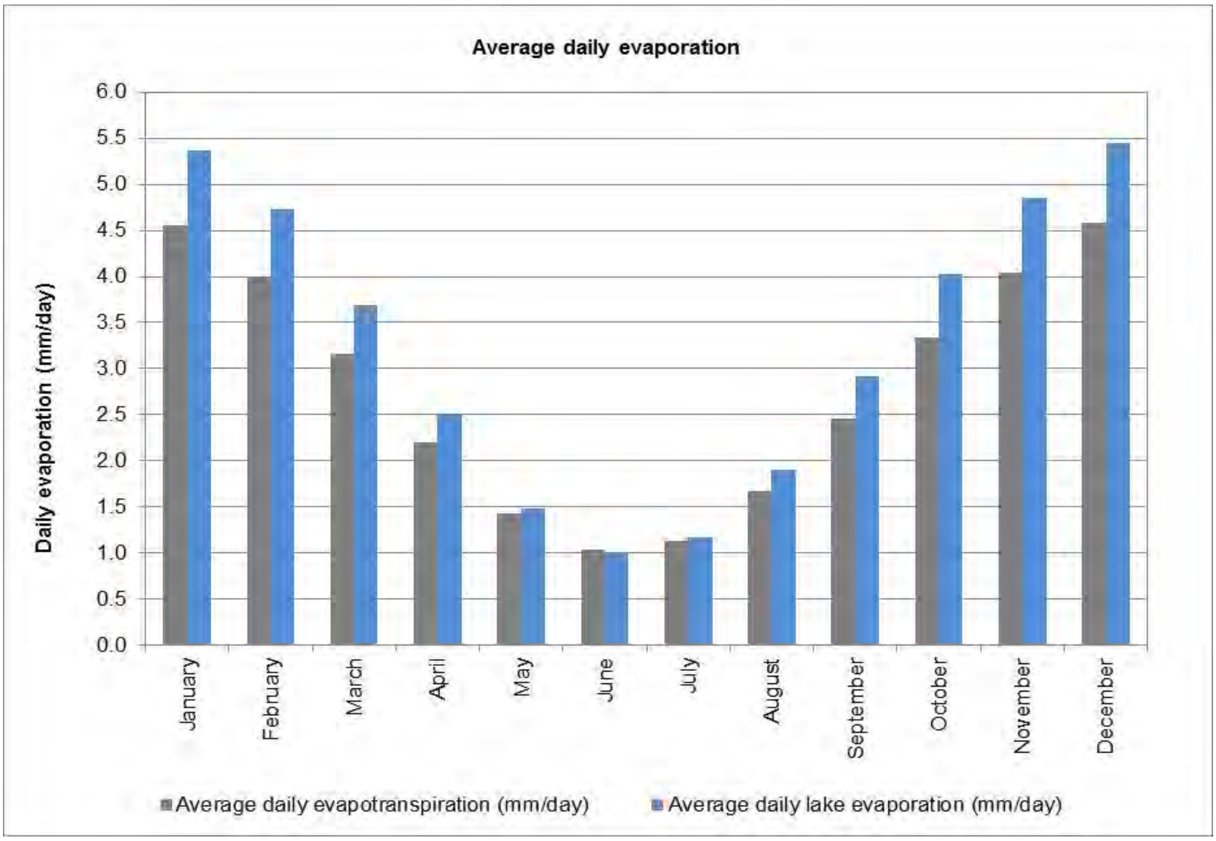

Figure 2.4 Average daily evaporation for Hume Coal Project site — Data Drill (1889 to 2014)

Table 2.3 Summary climate statistics for Hume Coal Project site — Data Drill (1889 to 2014)

Statistic	Annual rainfall (mm)	Annual potential evapotranspiration[1] (mm)	Annual lake evaporation[2] (mm)
Minimum	393	878	1,034
5th percentile (dry)	525	930	1,095
10th percentile	564	946	1,114
50th percentile (median)	800	1,016	1,190
90th percentile	1,120	1,109	1,264
95th percentile (wet)	1,256	1,122	1,275
99th percentile	1,380	1,150	1,288
Maximum	1,550	1,180	1,306
Average	824	1,021	1,187
Standard deviation	220	60	57

(1) Potential evapotranspiration calculated using the Penman-Monteith formula (Food and Agriculture Organization of the United Nations, 1998)

(2) Lake evaporation calculated using the Morton formula for shallow lakes (Morton, 1983)

2.4 Design rainfall data

2.4.1 Terminology

Australian Rainfall & Runoff (AR&R) (Institution of Engineers Australia, 1987) has indicated that the annual exceedance probability (AEP) terminology is preferred to the average recurrence interval (ARI) terminology. The ARI and the AEP are both a measure of the probability of occurrence of a rainfall event. The ARI terminology has been used throughout this report.

ARI is defined as the average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that the periods between exceedances are generally random. AEP is defined as the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.

With ARI expressed in years, the relationship is:

$$AEP = 1 - \exp\left(\frac{-1}{ARI}\right)$$

A summary of the conversion between ARI and AEP is shown in Table 2.4.

Table 2.4 Conversion from ARI to AEP

ARI (years)	AEP
1	0.632
2	0.393
5	0.181

ARI (years)	AEP
10	0.095
20	0.049
50	0.020
100	0.010

ARIs greater than 10 years are very closely approximated by the reciprocal of the AEP.

2.4.2 Rainfall intensity-frequency-duration data

Design intensity-frequency-duration (IFD) rainfall data was used to undertake initial sizing of the proposed SBs and MWDs (refer to Section 3.3.1). IFD data for a representative location of the SBs and MWDs for recurrence intervals up to the 100 year ARI were obtained from the BOM website using the AR&R (Institution of Engineers Australia, 1987) method and are provided in Table 2.5. The IFD data was obtained for Easting 250000 and Northing 6176000 in Zone 56. IFD rainfall data for the 500 year ARI were estimated using the Generalised Southeast Australia Method (GSAM) (Bureau of Meteorology, 2006) and are also provided in Table 2.4. Refer to the Hume Coal Project Flooding Assessment Report (Parsons Brinckerhoff 2016) for full details of the GSAM calculations.

Table 2.5 IFD data for Hume Coal Project site

Duration	Rainfall intensity (mm/hr)							
	1 year ARI	2 year ARI	5 year ARI	10 year ARI	20 year ARI	50 year ARI	100 year ARI	500 year ARI
5 mins	71.5	92.9	122	139	162	193	216	264.19
6 mins	66.9	86.9	114	130	152	180	202	246.95
10 mins	54.7	71.1	93.1	106	124	147	165	201.58
20 mins	39.8	51.6	67.5	77	89.6	106	119	145.28
30 mins	32.3	41.8	54.7	62.3	72.4	85.8	96.1	117.36
1 hr	21.9	28.4	37	42.1	48.9	57.9	64.8	79.10
2 hrs	14.5	18.8	24.5	27.8	32.3	38.2	42.7	52.13
3 hrs	11.4	14.8	19.1	21.8	25.2	29.7	33.3	40.56
6 hrs	7.51	9.71	12.6	14.2	16.5	19.4	21.7	26.43
12 hrs	4.91	6.34	8.19	9.28	10.7	12.6	14.1	17.15
24 hrs	3.14	4.06	5.25	5.96	6.89	8.13	9.08	11.06
48 hrs	1.93	2.5	3.25	3.7	4.29	5.08	5.68	6.93
72 hrs	1.41	1.83	2.39	2.73	3.17	3.75	4.2	5.57

2.5 Streamflow

Stream gauging stations in the vicinity of the project area are operated by WaterNSW and Hume Coal and available stream gauging data is summarised in Table 2.6. Note that numerous stream gauging stations are operated by DPI Water within the wider Hawkesbury River Basin, but these stations are not in close proximity to the project area and have therefore not been considered.

Table 2.6 Stream gauging data in vicinity of Hume Coal Project site

Station ID	Operator	Location	Approx. catchment area (km^2)	Period of record
212009	WaterNSW	Wingecarribee River at Greenstead	587	26/10/1989 to 3/12/2015
212272	WaterNSW	Wingecarribee River at Berrima	201	22/08/1975 to 1/01/2016
212031	WaterNSW	Wingecarribee River at Bong Bong (downstream of Bong Boing Reservoir)	134	07/06/1989 to 1/01/2016
SW01	Hume Coal	Black Bobs Creek near Hume Hwy	21	21/1/2012 to 8/10/2015
SW02	Hume Coal	Black Bobs Creek near Belanglo Forest	12	06/09/2012 to 3/07/2015
SW03	Hume Coal	Medway Rivulet near Illawarra Hwy	0.02	22/01/2012 to 8/10/2015
SW04	Hume Coal	Medway Rivulet near Hume Hwy	37	21/1/2012 to 8/10/2015
SW05	Hume Coal	Long Swamp Creek near Hume Hwy	3	22/06/2015 to 8/10/2015
SW08	Hume Coal	Oldbury Creek adjacent to proposed mine surface infrastructure area	10.52	14/05/2015 to 8/10/2015

Stream gauge records were obtained from WaterNSW for the Wingecarribee River at Wingecarribee River at Bong Bong (No. 212031), Berrima (No. 212272) and Greenstead (No. 212009) gauging stations. Stream flows from SW04 and SW08 were also obtained from Hume Coal.

All proposed SBs and MWDs are within 2.5 km from the SW08 streamflow gauge, and therefore rainfall-runoff characteristics of the undisturbed portions of the SB and MWD catchments would be similar to the SW08 gauged flows.

2.6 Surface water catchment modelling

2.6.1 Rainfall runoff model and calibration

There are four proposed SBs and four proposed MWDs (Figure 1.2) for the project to manage rainfall-runoff from catchments affected by mining operation. The locations of the basins and dams were chosen to minimise the capture of runoff from the broader catchment areas that are not affected by mining, material handling or processing operations. Diversion drains will be provided around the basins and dams to divert external runoff from undisturbed areas. Refer to Appendix B for layouts of the proposed surface infrastructure.

Estimates of expected runoff volumes from the engineered and undisturbed surfaces draining to all of the SBs and MWDs are required for the water balance for the project.

Because the gauged local streamflow at SW08 is of short duration (5 months), a rainfall-runoff model is required to simulate expected runoff from historical rainfall from 1889 to date.

The volume of surface water runoff from SB and MWD catchments has been estimated using the Australian Water Balance Model (AWBM) rainfall-runoff model (Boughton, 1993) that has been incorporated into the GoldSim water balance model (refer to Appendix A for further details). The AWBM model is suitable for unregulated runoff estimation and does not account for in-stream water storages directly. The AWBM model was first calibrated to gauged streamflow to obtain representative parameters for the broader catchment areas (refer to Appendix A for more details of the calibration process). The parameters were suitably adjusted to reflect engineered surfaces that are likely to drain towards the SBs and MWDs.

AWBM parameters for undisturbed areas were selected by a simple calibration process that involved matching the gauged daily flow time series with the simulated daily flow time series. Note that the pre-mining catchment is largely rural, however, is referred to as 'undisturbed' for the purposes of this study.

The performance of the calibration was judged by comparing peak flows and low flows in time series and flow duration curve plots. The model's ability to simulate measured flow volume was judged by computing and comparing average volumetric runoff coefficients for the simulated duration.

High runoff volumes are important for water supply reliability as well as in assessments for potential discharges from SBs and MWDs to the local creeks. The low flows are important for accounting for likely deficits for mine water supply during relatively low rainfall years during mining.

Comparison between the gauged and simulated flow daily time series for SW08 (Figure 2.5) suggests the adopted AWBM parameter set (Table 2.7) is able to provide adequate simulation of runoff depths for medium to high flows.

Comparison of flow duration curves for SW08 for the gauged and the AWBM simulated flow dataset (Figure 2.6) suggests that the top 20 percentile flow depths are captured very well. The simulated curve diverges from the gauged dataset for flows less than 0.8 mm/day. Note that baseflow is a dominant feature in the SW08 dataset.

Comparison of runoff coefficients presented in Table 2.8 suggests that the calibrated AWBM model was able to capture 75% of gauged runoff depth (i.e. 101 mm out of 133 mm). The under prediction for flows less than 0.8 mm/day accounts for the remaining 25% of the unmatched runoff depth.

The poor calibration to low flows is likely to be due to the groundwater contribution to baseflow (which is not modelled in AWBM) and to some extent due to the discharge from the Berrima sewage treatment plant into Oldbury Creek that occurs upstream of SW08. The Berrima sewage treatment plant discharges equate to 0.02 to 0.1 mm per day of runoff depending on rainfall conditions, based on the plant effluent discharge data for 2014 to 2015 provided by Wingecarribee Shire Council.

Given that the average daily evaporation from water surfaces is greater than 1 mm/day, the impact of the under prediction of low flows is not expected to be significant for assessing water supply needs in meeting the project demands during dry conditions. The good calibration to medium and high flows means that the model will be capable of reliable predictions of water surpluses, and potential overflows from storages, during wet conditions.

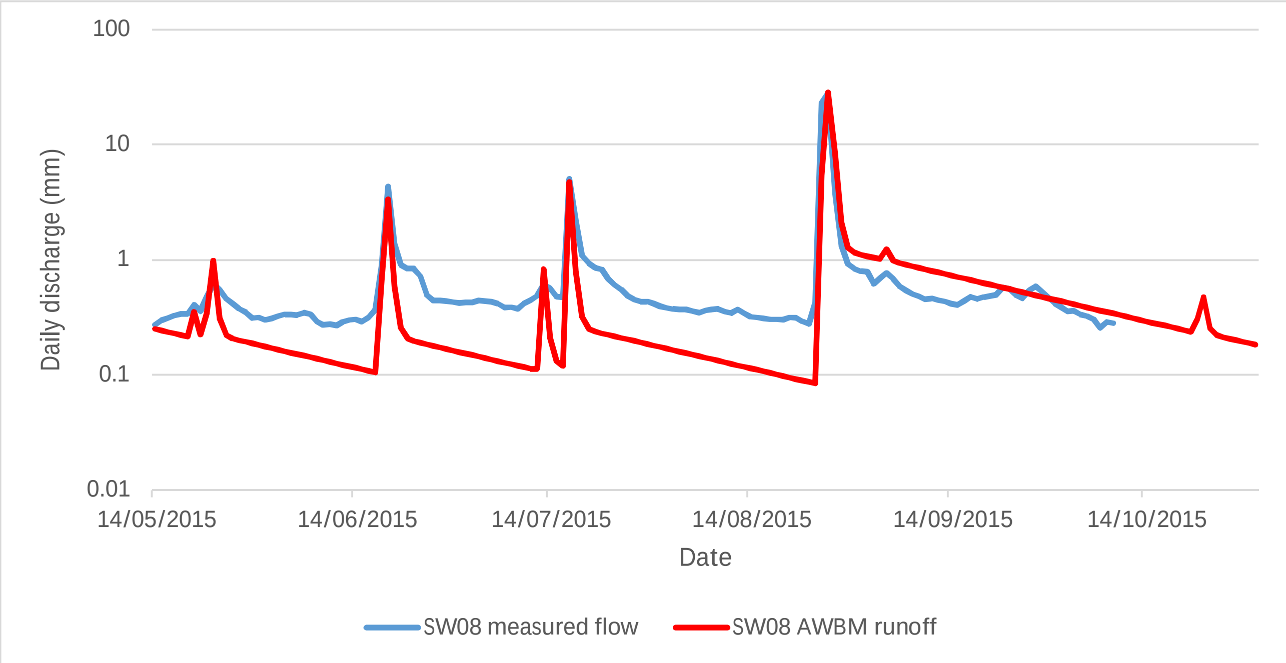

Figure 2.5 **Comparison of daily measured and AWBM simulated runoffs from the SW08 catchment**

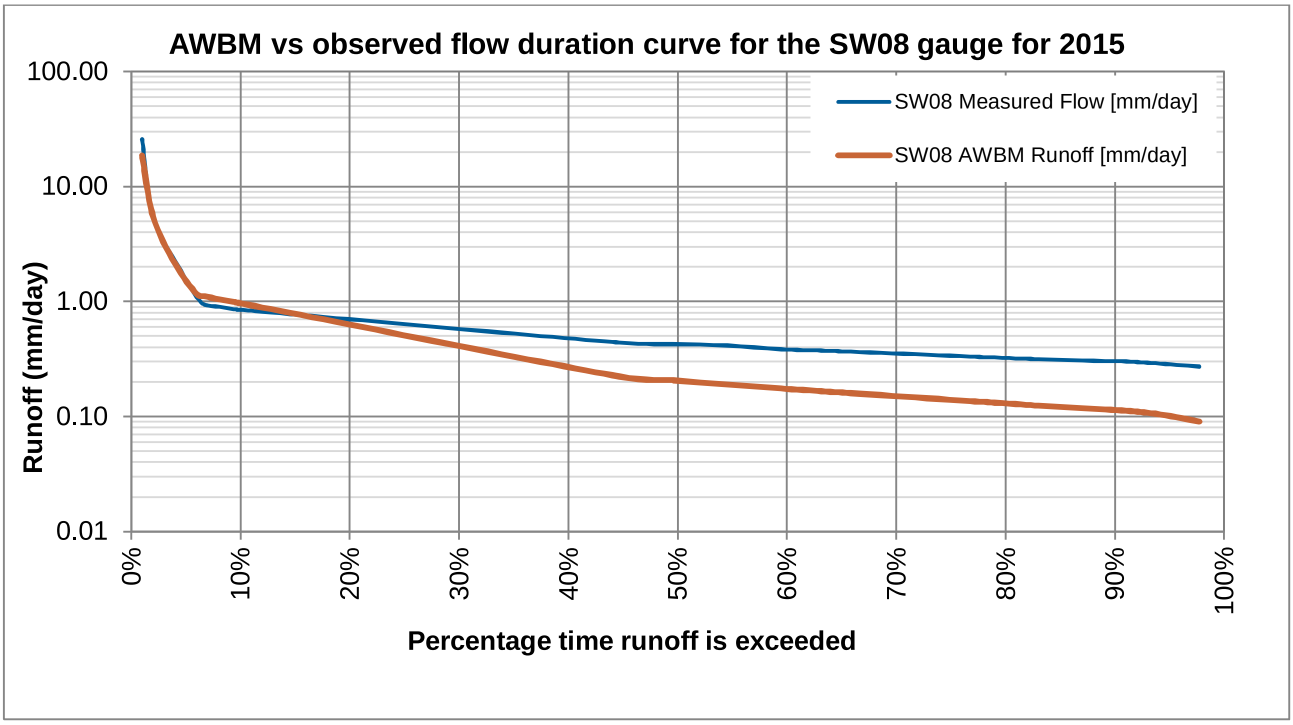

Figure 2.6 **Comparison of AWBM simulated and observed flow duration curves for available data from 2015 for the Hume Coal gauge SW08**

Table 2.7 Adopted AWBM parameters for Oldbury Creek

Calibration case	Ks	BFI	K	A1	A2	A3	C1 (mm)	C2 (mm)	C3 (mm)	Data Drill Rain Multiplier
SW08 AWBM - high + low flow calibration	0.12	0.50	0.97	0.25	0.31	0.44	5.00	150.00	250.00	0.96

Table 2.8 Summary of total runoff volumes and average daily runoff coefficients for measured and simulated flows

Site data cases	Runoff (mm) May 2015 - Sep 2015	Runoff (%) May 2015 - Sep 2015
SW08 gauged flows	133	39%
SW08 AWBM - high + low flow calibration	101	29%
Note: The Data Drill rainfall was 344mm for this period		

2.6.2 Surface infrastructure area catchments

The catchments of the proposed SBs and MWDs will be modified from their current state. The land uses within the modified catchments will be as follows (refer to surface infrastructure general arrangement plans in Appendix B):

- The catchment of SB01 will consist of product stockpile and temporary reject stockpiles.
- The catchment of SB02 will consist of the ROM pad, a tertiary sizing plant and temporary reject stockpiles and CPP.
- The catchment of SB03 will consist of the Administration and Workshop Area infrastructure.
- The PWD catchment will be mainly taken up with open water surface at full capacity.
- The catchment of SB04 will consist of the man and materials drift portal and top soil bund, mine access road and overland conveyor embankment.
- The catchments of MWD05, MWD06, MWD07 and MWD08 will mainly contain constructed pads, roads and conveyor embankments.

The surface water runoff in each of the basin and dam catchments will increase substantially as the majority of the surfaces will be engineered to support the proposed mining, processing and product handing facilities.

In order to characterise runoff for each basin and dam with different combinations of engineered and non-engineered landform types, the basin and dam sub-catchment areas were assigned the set of parameters summarised in Table 2.9. The parameters for the landform types were adapted from the Australian Coal Industry's Research Program research publication Water Quality and Discharge Prediction for Final Void and Spoil Catchments (PPK Environment and Infrastructure, 2001).

The calibrated AWBM parameters for the SW08 catchment were adopted to represent runoff from the sub-catchments that may contain remnants of natural landforms.

The following rationale was applied in adjusting the parameters for other engineered landforms within the dam catchments:

- The baseflow index was set to zero to reflect minimal to no seepage from the ground surface.
- The capacities of AWBM surface water stores C1, C2 and C3 and A1, A2 and A3 were adjusted to achieve an annual runoff proportion as high as 80% from sealed surfaces.
- The capacities of AWBM surface water stores C1, C2 and C3 and A1, A2 and A3 were adjusted to achieve an annual runoff proportion as high as 60% from unsealed hardstand surfaces.
- Parameters for stockpiles such as ROM, reject material and product coals were set based on ACARP research paper recommendations (PPK Environment and Infrastructure, 2001).

2.6.3 Adopted modelling parameters

Adopted AWBM parameters for modelling are summarised in Table 2.9 for the modelled land uses. Average annual runoff coefficients estimated from the AWBM using the parameters in Table 2.9 are summarised in Table 2.10.

Using the Data Drill rainfall data for the driest climate period from 1991 to 2009, the calculated runoff coefficient for SW08 is 35%, which is comparable to the runoff coefficient of 36% for the WaterNSW 212272 gauge located 5.4 km up-gradient along the Wingecarribee River (refer to Appendix A for more details of the AWBM model calibration). This suggests that the effect of under-prediction of low runoff depth using the adopted AWBM parameter set is likely to be insignificant. A similar comparison of runoff coefficients for the wettest climate period from 1949 to 1967 is not possible as the gauge record starts in 1975.

With respect to the SW08 catchment characteristics, the engineered landforms were simulated to produce the following runoff coefficients for the driest rainfall sequence from 1991 to 2009:

- 36% for the undisturbed surface
- 39% for the impervious surface (sealed hardstand area)
- 14% for the unsealed hardstand area
- 11% for the active spoil area

Under the wettest rainfall sequence from 1949 to 1967 the simulated runoff coefficients were:

- 47% for the undisturbed surface
- 79% for the impervious surface (sealed hardstand area)
- 59% for the unsealed hardstand area
- 54% for the active spoil area

Note that the water balance modelling does not use the runoff coefficients in estimating runoff to the dam catchments. The daily simulated runoff depths calculated by AWBM is directly used in the reservoir water balance for each SB / MWD.

Table 2.9 Adopted AWBM parameters for mine site catchments

Landform	C1 (mm)	C2 (mm)	C3 (mm)	A1	A2	A3	BFI	K	Ks	Data Drill Rain Multiplier
Undisturbed areas	5	150	250	0.25	0.31	0.44	0.5	0.97	0.12	1
Impervious	1	15	25	0.9	0.1	0	0	0.97	0.12	1
Hard stand areas	1	15	25	0	0.3	0.7	0	0.97	0.05	1
Active spoils	5	42.5	70	0.2	0.3	0.5	0	0.97	0.05	1

Table 2.10 Simulated average long term (1889 to 2015) runoff coefficients from adopted AWBM parameters for mine site catchments

Climate period	Impervious	Undisturbed (SW08 characteristics)	Active spoil	Hardstand
1949 to 1967 (wet sequence)	79%	47%	54%	59%
1991 to 2009 (dry sequence)	74%	35%	46%	49%

3. Water management system overview

3.1 Philosophy

The water management system for the project is based on the infrastructure layout plan by Arkhill Engineers (drawing reference 3713G0910). A sample of the infrastructure drawings is provided in Appendix B, which show the catchment area for each basin and dam. Figure 1.2 also provides an overview of the infrastructure layout, SBs and MWDs.

Arkhill Engineers also provided the water management flow chart shown in Figure 3.1, which was used as the basis for this water balance modelling assessment.

The water management philosophy adopted for the project can be summarised as follows:

- Runoff from undisturbed catchments within the project area flowing towards mine infrastructure will be diverted around or away from the infrastructure into natural watercourses via clean water diversion drains.
- Runoff from the disturbed areas, from within the mine infrastructure footprint, will be directed to the SBs, MWDs and the PWD for storage and reuse.
  - Runoff not in direct contact with coal may be released to local creeks after the first flush provided water quality is acceptable. The first flush criteria for the project are discussed in Section 3.2.
  - Runoff from the rainfall not meeting the adopted first flush criteria will be transferred to the PWD for storage.

The project proposes to manage runoff (refer to Figure 3.1) using the SBs, MWDs and PWD as follows:

- The main function of the PWD is to receive and contain all runoff from coal contact areas such as the CPP, ROM and product stockpiles. This dam will be maintained at low volumes to provide ample storage to store runoff from the SB and MWD catchments. This dam will supply water for all project water demands, except for the potable water requirement that will be sourced externally from registered groundwater bores and water tankers.
- The main function of SB01 is to collect runoff from the product stockpile and the temporary reject areas. Water collected in this basin will be immediately transferred to the PWD for storage and reuse.
- The main function of SB02 is to collect runoff from the ROM stockpile and return water from the CPP. Water collected in this basin will be immediately transferred to the PWD for storage and reuse.
- The main function of SB03 is to collect runoff from the Administration and Workshop Area. There is considered to be a low risk of coal contact with runoff in SB03 – refer to the Surface Water Quality Assessment Report (Parsons Brinckerhoff 2016a) for further details. Water collected in this basin will be transferred to the PWD if the corresponding rainfall does not meet the first flush criteria. Once the rainfall meets the first flush criteria, water from this basin will be released to Oldbury Creek, provided water quality targets are met (refer to Parsons Brinckerhoff 2016a for further details of the release criteria).
- The main function of SB04 is to collect runoff from the mine road and conveyor corridor area north of Medway Rivulet. There is considered to be a low risk of coal contact with runoff in SB03 – refer to the Surface Water Quality Assessment Report (Parsons Brinckerhoff 2016a) for further details. Water

collected in this basin will be transferred to the PWD if the corresponding rainfall does not meet the first flush criteria. Once the rainfall meets the first flush criteria, water from this basin will be released to Oldbury Creek, provided water quality targets are met (refer to Parsons Brinckerhoff 2016a for further details of the release criteria).

- The main function of MWD05 is to collect runoff from the overland conveyor number 1 corridor and transfer it to the PWD for storage and reuse.
- The main function of MWD06 is to collect runoff from the area in between the conveyor portal and the overland conveyor number 1 corridor and transfer it to the PWD for storage and reuse.
- The main function of MWD07 is to collect runoff from the ventilation shaft pad area and transfer it to the underground mine sump for reinjection into the void spaces in the mined out panels or transfer to the PWD for reuse. Note that the mined out panels will be sealed with bulkheads.
- The main function of MWD08 is to store and treat any excess water before it can be released to Oldbury Creek. This dam, along with the water treatment plant (WTP), is included as provisional infrastructure in the unlikely event that excess water stored in the PWD may need to be treated and released to Oldbury Creek. The water balance modelling indicates that this is not required for all climate sequences tested. Note that this dam is not included in the water balance model as it is part of the provisional WTP and independent of the mine water balance which covers transfer of water between the SBs, other MWDs, the underground mine and the PWD. MWD08 would only be used when excess water needs to be transferred from the PWD to the WTP for treatment and release. The capacity of MWD08 and the WTP would be determined during the detailed design stage of the project, if required.
- The underground mine sump (sump) is the last collection point of all runoff that may occur within the underground mine. The sump will receive water transferred from MWD07, the local groundwater system and excess water from underground mining equipment operation.
- The void spaces behind the bulkheads will be utilised to store the coal rejects in the form of co-disposed reject as well as excess water from the sump. Water stored within the void spaces will be pumped to the PWD to meet water demands, if required. The reinjection of excess water from the sump to the void spaces will only occur if the void spaces are not already filled up with the naturally inflowing groundwater.

Sediment dams will be provided during the construction phase of the project. These dams will release water to Medway Rivulet or Oldbury Creek once the sediments are settled. Once mining starts, the sediment dams will not be the part of the water management system. These dams have therefore not been included in the water balance modelling, which has focussed on the operational mining phase.

The water management system will aim to reuse as much mine water as possible on site, with mine water being used as a priority to meet all water demands except potable water.

Water balance modelling has been undertaken to inform the infrastructure design on the adequacy of basin and dam sizes, and the likely conditions for project water surpluses and deficits to inform on-going iterative design and/or strategic improvements. The assessed surplus water management strategies were:

- Releases from SB03 and SB04 to Oldbury Creek when the first flush rainfall has occurred.
- Reinjection from the sump to the void spaces.
- Provisional strategy to treat and release excess water when the void spaces and the PWD are unable to store water (demonstrated by the modelling to be not required for all climate sequences tested).

The assessed deficit management strategies were:

- Supply from the reinjected volume of water from the void spaces.
- Abstract natural groundwater from the void spaces to meet the demand.

- Procure additional water from registered bores if the above groundwater sources are insufficient to meet the demand, while utilising the net harvestable rainfall-runoff from the basin and dam catchments. Note that the water balance modelling indicates that the groundwater from the underground mine will be sufficient to meet demand and additional water from registered bores may not be required, other than for potable water supply.

3.2 First flush criteria

The following first flush criteria were developed for the project based on the NSW EPA guideline provided at the http://www.epa.nsw.gov.au/mao/stormwater.htm (see Table 3.1):

- The first flush is assumed to have occurred once the daily rainfall exceeds 20 mm. On such days, runoff could be released from SB03 and SB04 to Oldbury Creek. This criterion assumes that the water quality is acceptable for release.
- From the day of occurrence of the first flush, subsequent daily rainfall amounts less than 20 mm for the next four days are assumed to produce clean runoff and releases are allowed to continue to Oldbury Creek.
- If daily rainfall depth remains less than 10 mm after the fifth day, no runoff is released to Oldbury Creek until the next first flush event.

Table 3.1 The EPA design criteria for first flush containment systems (http://www.epa.nsw.gov.au/mao/stormwater.htm)

Pollutants	Catchment surface	Examples of industries	Rainfall depth to be contained
Substances easily mobilised, such as soluble materials, fine dusts and silts	Impervious: concrete, cement, bitumen	Concrete batching plants	10 mm
Substances that are more difficult to mobilise, such as oil, grease and other non-volatile hydrocarbons	Impervious: concrete, cement, bitumen	Petrochemical plants, motor vehicle courtyards, chemical manufacturers, hot mix bitumen emulsion plants, roadways	15 mm
All types of pollutant	Pervious surfaces (including natural ground surface) that are not as easily cleansed of deposited pollutants	Market gardens, nurseries	20 mm

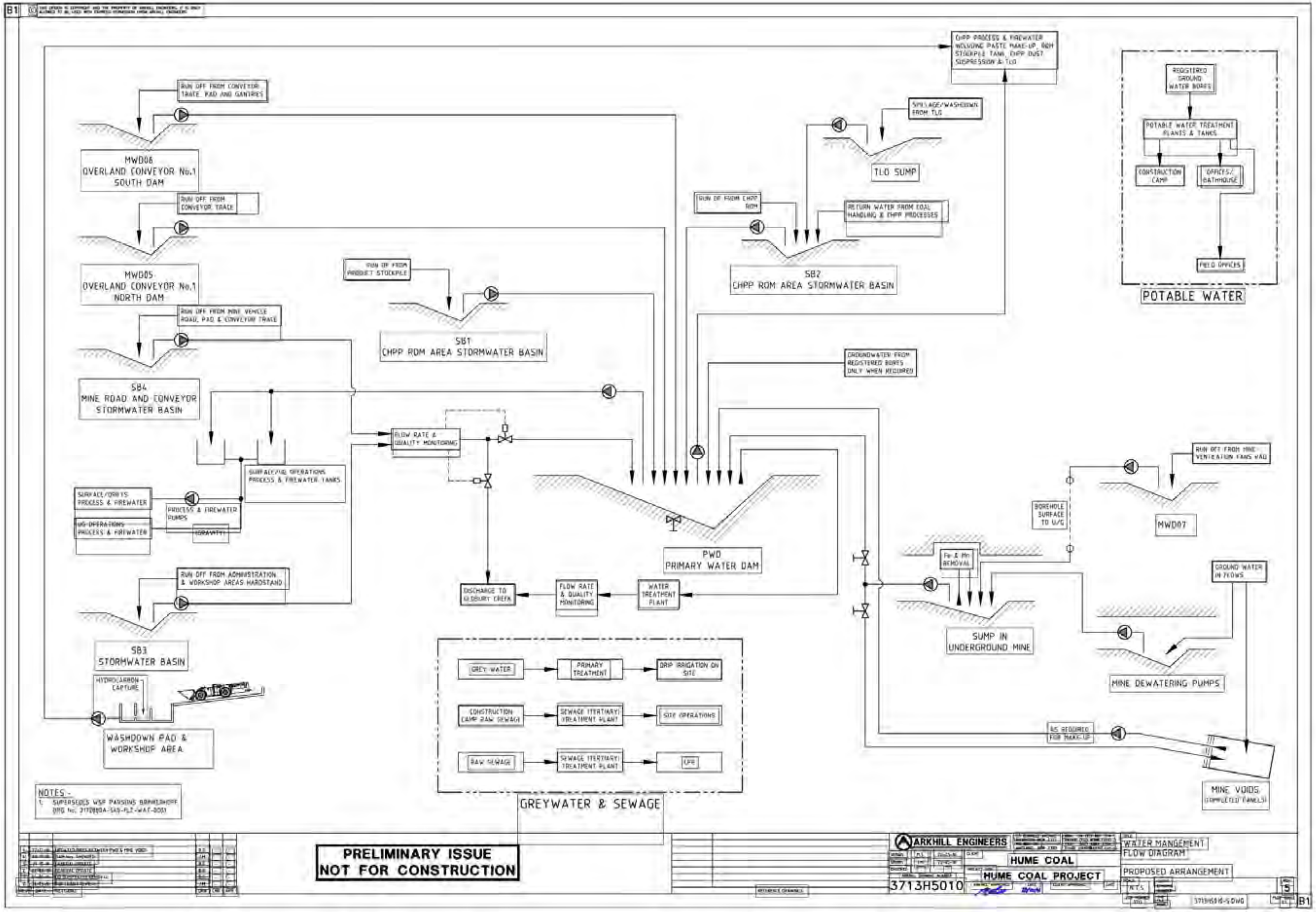

Figure 3.1 **Water management system flow chart (Arkhill Engineers 2016)**

3.3 Basin and dam design criteria

This section outlines the design criteria for the basins and dams. Design data for the basins and dams are presented in Section 4.

3.3.1 Stormwater basins and mine water dams

SBs and MWDs were initially sized to capture the 500 year ARI 72 hour storm event for the local catchment assuming a runoff coefficient of 1.0 (rainfall depth 401 mm), with an additional 10% allowance for sediment storage. The final capacities of these dams were based on physical constraints and a requirement to achieve no dam overflows when operated as part of the overall site water management system under historical climate conditions.

3.3.2 Primary water dam

The capacity of the PWD has been sized based on the requirement to hold all water on site without the need to dispose of excess or surplus water. The adopted dam capacity of 730 ML is significantly larger than the volume required to meet the 500 year ARI event criterion given above for the SBs and MWDs and was assessed by the water balance modelling under historical climate conditions to be able to prevent discharges for all 107 climatic sequences tested.

4. Water balance modelling methodology

4.1 Modelling approach

A water balance model of the project water management system was developed using the GoldSim software, a widely used platform for mine site water balance studies.

The GoldSim model was used to calculate the volume of water in storages at the end of each day by taking into account daily rainfall-runoff inflow, groundwater inflow, reinjection to the mine void, evaporation from storages, water usage, pumping between storages in the form of a pumping policy and storage overflow.

In the GoldSim model each reservoir has been represented by a computational node or 'box' as shown in Figure 4.1. The model construction has been based on the flow chart presented in Figure 3.1.

The GoldSim model was simulated at a daily time step for a 19-year duration (assumed to be from 2021 to 2039). The model was simulated for 107 realisations (or sequences) of rainfall and evaporation data developed by 'stepping through' the Data Drill sourced historical data from 1 January 1889 to 1 January 2015. The first realisation started on 1 January 1889, the second realisation on 1 January 1890 and so on. The model inputs (demands and groundwater inflows) were varied in the model over the 19-year simulation period. Probability distributions were then developed using the daily and annual results from all of the 107 realisations.

4.2 Modelling assumptions

The following assumptions were made in the water balance analysis for the adopted water management strategy:

- Water that cannot be stored within the PWD or the void spaces will be treated and discharged to Oldbury Creek (note that this is a provisional assumption that has been demonstrated by the modelling to be not required – see Section 5.6 for further discussion).
    - Most of the groundwater collected in the sump will be utilised in meeting the project water demand. The sump will also collect return water from the underground mining equipment, decant from co-disposed reject and runoff from MWD07. The mixed water from these two sources will be pumped to the PWD for reuse.
    - The sump will target to pump all water to the PWD for project use. When the PWD is at the upper level set for operations of 124 ML, the water in the sump will be reinjected into the void space behind the bulkheads. If the void space is full and cannot take the excess water then the sump will continue pumping to the PWD.
    - Similarly, if the water volume in the PWD is very low and unable to meet water demands then additional water will be sourced from the reinjected and natural groundwater that will be stored in the void spaces.
- A pumping strategy has been included in the water balance model.
- It is assumed that the 'sediment zone' of SBs and MWDs is 50% full of sediment throughout the simulation. It is assumed that SBs and MWDs cannot be pumped out below the 'sediment zone' and that the only outflows from the remaining 'sediment zone' is evaporation.

- The initial volume at the start of the 19-year period simulation was assumed to be 100 ML for the PWD and 6 ML for the underground sump so that mining operation could be supplied with water until rainfall-runoff or groundwater could be harvested. Other basins and dams were assumed empty at the start of the simulations.
- The man & materials portal and conveyor portal (refer to Appendix B) would be covered and runoff would not be captured by these portals.
- Volume and timing of the available void space behind the bulkheads was estimated from the ROM production schedule and provided by Hume Coal.
- Annual groundwater inflows to the sump and the void spaces were assessed by the groundwater model. The co-disposed reject volumes were subtracted from the volume of the void space. The resulting volume is the void space available for both the groundwater make to void and reinjection of water from the sump.
- Annual groundwater inflow to the sump and void was distributed uniformly to obtain average daily inflow rates for the water balance model.
- Annual demand estimates have been distributed uniformly to obtain average daily demands for the water balance model.
- It has been assumed that pumping of water from the void space to the PWD occurs at a rate that is adequate to meet peak daily demands when the site is in a water deficit.
- Inflows to MWD08 are not considered in the water balance as the dam is part of the WTP and independent of the mine water balance which covers transfer of water between the SBs, other MWDs, the underground mine and the PWD.
- The water balance modelling is focussed on the operational phase and does not consider sediment dams that will be required at the construction phase.
- While the model assesses the performance of the system under historical extremes that may reasonably be expected to reoccur in the future, it does not quantify the potential impact of future climate change on the site water balance.

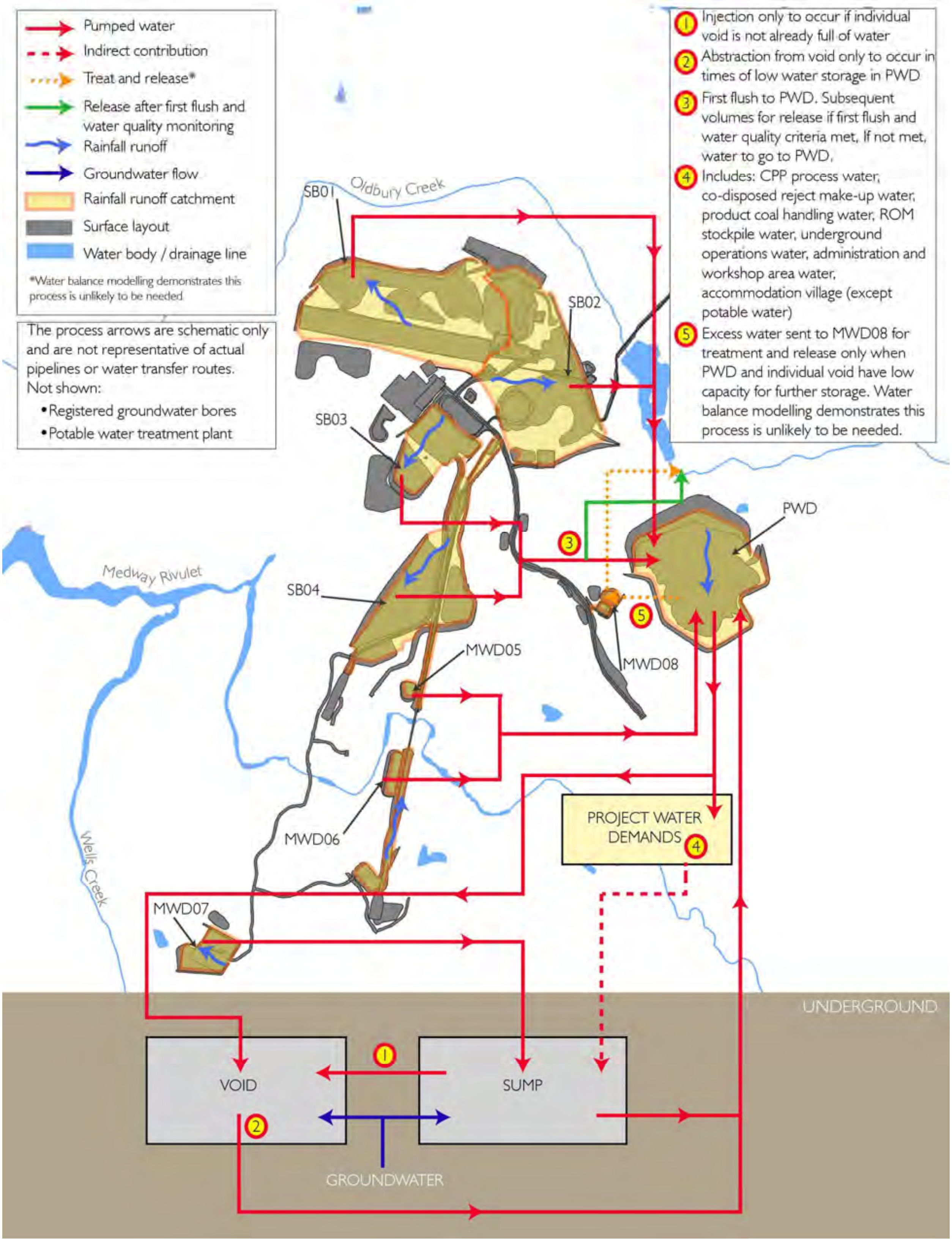

Figure 4.1 Flow chart representation in GOLDSIM (EMM 2016)

4.3 Model data

4.3.1 Catchments

Table 4.1 lists catchment area data for the basin and dam catchments based on the surface water infrastructure general arrangement plan shown in Appendix B (with an overview provided in Figure 1.2). Basin and dam catchments were further sub-divided into 4 categories:

1. Impervious – such as sealed roads, building roofs, car parks, conveyors, etc.
2. Undisturbed – natural ground surface.
3. Active spoil area – such as stockpiles.
4. Hardstand area – such as compacted pads.

It is assumed that catchment areas will be constant over the life of the mine. The sub-area characterisation was used in the AWBM modelling to simulate the total runoff from a basin / dam catchment.

Table 4.1 Basin / dam catchment and land use areas

Land use	PWD (ha)	SB 01 (ha)	SB 02 (ha)	SB 03 (ha)	SB 04 (ha)	MWD 05 (ha)	MWD 06 (ha)	MWD 07 (ha)
Impervious	0.00	3.94	1.54	0.71	0.00	0.00	0.00	0.00
Undisturbed	18.28	15.41	14.71	2.56	8.29	0.26	0.64	0.73
Active spoil area	0.00	7.00	5.13	0.00	1.89	0.00	0.00	0.00
Hard stand or unsealed road	0.00	0.00	1.26	2.64	4.55	0.38	2.05	1.87
Total area	18.28	26.36	22.64	5.91	14.73	0.64	2.69	2.60

4.3.2 Basin and dam capacities

Table 4.2 summarises adopted basin and dam capacities for the project water balance assessment. Capacities are generally set by the maximum capacity available based on the physical constraints of the site, and checked against the volume of the 500 year ARI 72 hour rainfall event with a 10% allowance for sediment storage (refer to Section 3.3.1). The dam capacity for the PWD is set at 730 ML and is the maximum possible volume within the site constraints, and which far exceeds the volume of the 500 year ARI 72 hour rainfall event.

The stage-storage-area relationships for the proposed basins and dams are based on the three-dimensional basin and dam designs developed for the engineering concept design. Stage-storage-area relationships are provided in Appendix C.

The water balance modelling confirmed that no spilling of the basins or dams occurs with the adopted capacities for any of the wettest periods in the climate sequence – refer to Section 5.4.

Table 4.2 Proposed basin and dam capacities summary

Dam ID	Description	Catchment area (ha)	Adopted storage volumes to spillways of the dams (ML)
SB01	Proposed stormwater basin capturing runoff from product stockpile area	26.36	106.4
SB02	Proposed stormwater basin capturing runoff from CPP and ROM areas	22.64	91.1
SB03	Proposed stormwater basin capturing runoff from Administration and Workshop Area	5.91	19.4
SB04	Proposed stormwater basin capturing runoff from mine road and conveyor embankment	14.73	140.2
MWD05	Proposed mine water dam capturing runoff from north of Medway Rivulet - overland conveyor no. 1	0.64	5.9
MWD06	Proposed mine water dam capturing runoff from south of Medway Rivulet - conveyor portal	2.69	14.8
MWD07	Proposed mine water dam capturing runoff from ventilation shaft pad dam	2.60	5.7
MWD08	Proposed mine water dam capturing runoff from water treatment area	0.27	4.1
PWD	Proposed primary water dam storing mine water pumped from stormwater basins, mine water dams and underground mine sump dewatering	18.28	730.0

4.4 Water inputs

Water inputs for the project comprise:

- surface water runoff captured within each dam
- direct rainfall falling on water storages
- groundwater inflows to the mine sump
- groundwater inflows to the void spaces behind the bulkheads
- imported potable water from registered bores
- imported water from registered bores to augment supplies for the demands (if required)

4.4.1 Surface water runoff

The AWBM rainfall-runoff model (using the Data Drill daily rainfall and evapotranspiration data) was incorporated into the GoldSim model to generate a daily time series of runoff from mine site catchments. The AWBM rainfall-runoff model and parameters are described in Section 2.5.

4.4.2 Direct rainfall

Direct rainfall falling on basins and dams has been determined based on assumed basin and dam stage-storage-area relationships. Stage-storage-area relationships are discussed in Section 4.3.2.

4.4.3 Groundwater inflows to mine sump

Modelled groundwater inflow estimates developed by Coffey were supplied by Hume Coal. Table 4.3.provides a comparison of groundwater flows to the sump and the void spaces behind the bulkheads.

The annual groundwater inflow to the sump peaks in Year 17 at 985 ML and the annual groundwater inflow to the void space peaks in Year 15 at 1,834 ML.

Table 4.3 Groundwater inflow estimates

Year	Mining year	Groundwater inflow to mine sump (ML/yr)	Groundwater inflow to mine void (ML/yr)	Total Groundwater inflow (ML/yr)
1	2021	127.0	-	127.0
2	2022	181.1	320.4	501.5
3	2023	281.7	658.0	939.7
4	2024	325.9	904.0	1229.9
5	2025	330.6	953.0	1283.6
6	2026	331.6	883.2	1214.8
7	2027	594.7	808.9	1403.6
8	2028	373.0	1344.3	1717.3
9	2029	433.5	1486.3	1919.8
10	2030	388.9	1705.7	2094.7
11	2031	428.3	1700.0	2128.4
12	2032	457.4	1694.9	2152.3
13	2033	491.7	1639.0	2130.7
14	2034	409.4	1804.3	2213.8
15	2035	425.4	1834.5	2259.9
16	2036	488.5	1735.1	2223.7
17	2037	985.1	956.9	1942.0
18	2038	792.0	843.0	1635.0
19	2039	512.7	711.6	1224.4

4.4.4 Imported water

The water balance model assumes that additional water, if required, will be available from registered groundwater bores.

At the start of mining an initial reserve of water will be required to start mining. Subsequently, as the rainfall-runoff occurs or groundwater flows into the sump and the void spaces become available, reliance on externally sourced water would reduce. The model assumes that 100 ML will be available in the PWD at the start of mining.

4.5 Water outputs

4.5.1 Demands

Water for all demands except the potable water requirements will be supplied from water stored within the PWD. Demands for the project during operation include:

- CPP process water
- co-disposed reject makeup water
- product coal handling water
- ROM stockpile water
- underground operations water
- Administration and Workshop Area water
- accommodation village (potable water is assumed to be supplied from registered bores and has not been modelled)

Information used to estimate demands for the project is provided in Appendix D.

4.5.1.1 Coal production rates

Coal production rates have been provided by Palaris in May 2016 and are summarised in Table 4.4. The peak ROM coal production rate is 3.3 Mtpa occurring in Year 9. The second and third peak ROM production occurs in Year 14 and in Year 13 respectively. Table 4.4 also summarises the schedules for the primary and secondary products and the coal reject in the form of co-disposed reject.

Table 4.4 Schedules for ROM, primary and secondary products

Year	ROM tonnes at 8% moisture by total mass (Mtpa)	Primary product (Mtpa)	Secondary product (Mtpa)	Product total moisture (% by total mass)	Coal reject as co-disposed reject at 40% moisture by total mass (GL per year)
1	0.381	0.083	0.232	9.746	0.095
2	1.693	0.378	1.008	9.805	0.434
3	2.819	0.670	1.689	10.001	0.671
4	2.537	0.949	1.212	10.626	0.574
5	2.824	1.725	0.578	11.359	0.771
6	3.084	2.068	0.376	11.418	0.927
7	3.147	1.655	0.812	10.106	0.958
8	3.161	0.985	1.414	10.032	1.023
9	3.314	0.952	1.630	10.230	0.998
10	2.871	1.190	1.229	10.312	0.682
11	2.726	1.110	1.100	10.391	0.741
12	2.950	1.308	1.146	10.743	0.738
13	3.282	1.482	1.128	10.916	0.951
14	3.289	1.527	0.832	11.190	1.230

Year	ROM tonnes at 8% moisture by total mass (Mtpa)	Primary product (Mtpa)	Secondary product (Mtpa)	Product total moisture (% by total mass)	Coal reject as co-disposed reject at 40% moisture by total mass (GL per year)
15	3.041	1.542	0.361	11.294	1.443
16	2.593	1.318	0.694	10.748	0.809
17	3.081	1.462	1.109	10.119	0.766
18	2.546	0.759	1.327	10.014	0.662
19	1.141	0.415	0.531	10.383	0.286

Source: Palaris (May 2016)

4.5.1.2 CPP and ROM stockpile demands

CPP process water demands were provided by Palaris in May 2016 and are summarised in Table 4.5. This demand will be sourced from the PWD. In the current proposal the CPP will receive water from a single source. CPP return water is assumed to flow into SB02.

CPP process water demands are based on an assumed 450 tonne per hour plant operating 7,000 hours per year. A flow chart of the CPP system is provided in Appendix D. The CPP water balance was undertaken by QCC Resources in September 2013.

The water balance flow chart suggests that a total of 63 m^3/hr of water is required if the plant is 100% utilised to produce at full capacity. The back calculated weighted average moisture contents for the coal products and the reject from the QCC water balance were estimated to be 9.4% and 10.5% by total mass respectively. The estimates for the moisture contents provided by Palaris in May 2016 were 10.5% and 15.0% by total mass respectively.

The CPP water demands were adjusted to reflect the final average moisture contents of 10.5% by total mass for the coal products and 15.0% by total mass for the reject.

Table 4.5 Assumed CPP process water demands

Year	CPP plant utilisation (%)	CPP water requirement for the product at 9.42% and the reject at 10.5% moisture by total mass (ML/yr)	Adjusted CPP water requirement for the product at 10.5% and the reject @15% moisture by total mass (ML/yr)	CPP return to mine water dams ^ (ML/yr)	Net CPP process water demand (ML/yr)
1	9%	39.6	40.2	17.7	22.4
2	40%	175.7	178.9	78.6	100.4
3	66%	292.6	303.7	130.8	172.8
4	60%	263.4	288.6	117.8	170.9
5	67%	293.1	337.6	131.1	206.5
6	73%	320.1	368.2	143.1	225.0
7	74%	326.7	339.4	146.1	193.3
8	74%	328.1	337.8	146.7	191.1
9	78%	344.0	360.7	153.8	206.9
10	68%	298.0	317.7	133.2	184.4
11	64%	283.0	302.0	126.5	175.5
12	70%	306.3	337.5	136.9	200.6
13	77%	340.7	377.8	152.3	225.4

Year	CPP plant utilisation (%)	CPP water requirement for the product at 9.42% and the reject at 10.5% moisture by total mass (ML/yr)	Adjusted CPP water requirement for the product at 10.5% and the reject @15% moisture by total mass (ML/yr)	CPP return to mine water dams ^ (ML/yr)	Net CPP process water demand (ML/yr)
14	77%	341.5	379.4	152.7	226.7
15	72%	315.7	345.4	141.2	204.2
16	61%	269.2	293.5	120.3	173.1
17	73%	319.8	335.0	143.0	192.1
18	60%	264.3	273.9	118.2	155.7
19	27%	118.5	126.8	53.0	73.8

Source: Palaris (May 2016)
^ Assume that all water noted as 'water largely lost from process' in the CPP water balance flow diagram - 600 tonne per hour (Source: QCC Resources, November 2013) is returned to SB02. This is a WSP | Parsons Brinckerhoff assumption for the purposes of water balance modelling.

Co-disposed reject makeup water demands were provided by Palaris in May 2016 and are summarised in Table 4.6. Demands are based on raising the water content in the reject from 15% by total mass to 40% by total mass. Co-disposed reject makeup water demands will be sourced from the PWD. Once the co-disposed reject are emplaced in the void spaces, decant from the co-disposed reject is estimated to occur at 33% of total moisture (refer to Table 4.6).

Table 4.6 Assumed co-disposed reject makeup water demands

Year	Water contained in the co-disposed reject at 40% moisture by total mass (ML/yr)	Decant water (33% of total moisture) from the co-disposed reject emplaced in the underground void (ML/yr)	Water added to the reject at 15% moisture by total mass to make the co-disposed reject at 40% moisture by total mass (ML/yr)	Net co-disposed reject makeup water requirement (ML/yr)
1	0	0	0	0
2	204.4	67.5	150.3	82.8
3	313.7	103.5	230.6	127.1
4	268.1	88.5	197.1	108.7
5	370.9	122.4	272.7	150.3
6	448.4	148.0	329.7	181.7
7	451.6	149.0	332.1	183.0
8	499.9	165.0	367.6	202.6
9	487.5	160.9	358.5	197.6
10	314.3	103.7	231.1	127.4
11	352.1	116.2	258.9	142.7
12	348.9	115.1	256.5	141.4
13	462.8	152.7	340.3	187.6
14	621.2	205.0	456.8	251.8
15	740.1	244.2	544.2	300.0
16	393.1	129.7	289.0	159.3
17	348.8	115.1	256.5	141.4
18	310.4	102.4	228.3	125.8
19	134.7	44.5	99.0	54.6

Source: Palaris (May 2016)

Product coal handling demands were provided by WSP | Parsons Brinckerhoff in August 2015 and are summarised in Table 4.7. Product coal handling demands will be sourced from the PWD. It has been assumed that 20% of the coal handling and preparation water will be returned to SB02.

Table 4.7 Assumed product coal handling demands

Year	Total product coal handling demand (ML/yr)	Water returned to SB02 (ML/yr)	Net product coal handling demand (ML/yr)
1	134	24	110
2	134	24	110
3	135	24	111
4	136	24	112
5	137	24	113
6	136	24	112
7	136	24	112
8	137	24	113
9	137	24	113
10	137	24	113
11	137	24	113
12	137	24	113
13	137	24	113
14	137	24	113
15	136	24	112
16	136	24	112
17	137	24	113
18	136	24	112
19	135	24	111

Source: WSP | Parsons Brinckerhoff (August 2015)
^ Assume that 20% of the wash-down water component of the product coal handling demand is returned to SBs / MWDs. This is a WSP | Parsons Brinckerhoff assumption for the purposes of water balance modelling.

ROM stockpile water demands, including demands for the overland conveyor and stockpile sprays, were provided by Palaris in May 2016 and are summarised in Table 4.8. ROM stockpile water demands will be sourced from the PWD.

Table 4.8 Assumed ROM stockpile demands

Year	ROM overland conveyor demand (ML/yr)	ROM stockpile sprays demand (ML/yr)	Total ROM demand (ML/yr)
1	0.1	28	28.1
2	0.5	28	28.5
3	0.7	28	28.7
4	1.5	28	29.5
5	1.8	28	29.8
6	1.5	28	29.5
7	1.6	28	29.6

Year	ROM overland conveyor demand (ML/yr)	ROM stockpile sprays demand (ML/yr)	Total ROM demand (ML/yr)
8	1.7	28	29.7
9	1.7	28	29.7
10	1.8	28	29.8
11	2.0	28	30.0
12	1.9	28	29.9
13	1.9	28	29.9
14	1.7	28	29.7
15	1.6	28	29.6
16	1.6	28	29.6
17	1.8	28	29.8
18	1.5	28	29.5
19	0.8	28	28.8

Source: Palaris (May 2016)

4.5.1.3 Underground operations demand

Demands for operation of underground mine equipment were provided by Palaris in May 2016 and are summarised in Table 4.9. Underground operations input water will be sourced from the PWD prior to use for underground operations. It has been assumed that 10% of water that will be supplied to the coal cutting equipment will be lost as retention to the in-situ material and that approximately 49 ML/yr will be lost as evaporation through ventilation air. It has also been assumed that a portion of the water supplied for the underground operations will be used in increasing the in-situ ROM water content from 4.12% average moisture content by total mass to 8% moisture content by total mass.

Table 4.9 Assumed underground operations demands

Year	Total water supply for underground mining (ML/yr)	Moisture increase in ROM from 4.12% to 8% by total mass (ML/yr)	Evaporative loss of water from the underground ventilation system (ML/yr)	Moisture retention by in-situ material, 10% of cutting equipment requirement (ML/yr)	Net water use underground (ML/yr)	Expected return from the underground mine (ML/yr)
1	68.1	15.5	30.0	5.0	50.5	17.6
2	222.3	68.5	49.0	12.8	130.2	92.1
3	402.4	113.4	49.0	18.3	180.7	221.7
4	373.5	101.2	49.0	17.3	167.6	206.0
5	501.5	112.6	49.0	18.9	180.4	321.1
6	629.5	124.9	49.0	20.8	194.7	434.8
7	724.2	127.2	49.0	20.9	197.1	527.1
8	763.7	128.0	49.0	20.1	197.1	566.6
9	726.6	133.4	49.0	21.1	203.5	523.1

Year	Total water supply for underground mining (ML/yr)	Moisture increase in ROM from 4.12% to 8% by total mass (ML/yr)	Evaporative loss of water from the underground ventilation system (ML/yr)	Moisture retention by in-situ material, 10% of cutting equipment requirement (ML/yr)	Net water use underground (ML/yr)	Expected return from the underground mine (ML/yr)
10	584.8	114.3	49.0	19.2	182.6	402.3
11	477.5	109.9	49.0	18.5	177.4	300.1
12	572.7	118.1	49.0	19.7	186.8	385.9
13	546.2	132.5	49.0	21.1	202.6	343.6
14	527.7	134.8	49.0	20.6	204.4	323.3
15	563.6	130.6	49.0	18.9	198.6	365.0
16	447.0	104.8	49.0	18.5	172.3	274.7
17	504.3	123.7	49.0	17.1	189.8	314.5
18	357.0	104.9	49.0	11.4	165.2	191.8
19	126.8	46.0	49.0	5.4	100.4	26.3

Source: Palaris (May 2016)
^ Assume that a nominal 10% of mine equipment input water is lost to mine void. This is a WSP | Parsons Brinckerhoff assumption for the purposes of water balance modelling.
^^ Assume that 49 ML/yr of mine equipment input water is lost to ventilation air (Hume Coal, September 2015). In Year 1 loss is limited by underground operations input water.

4.5.1.4 Administration and Workshop Area demands

Demands for the Administration and Workshop Area were provided by WSP | Parsons Brinckerhoff in August 2015 and are summarised in Table 4.10. The fire water demand will be supplied directly from the PWD. However, the potable water will be sourced from registered groundwater bores.

Table 4.10 Assumed Administration and Workshop Area demands

Year	Fire demand (ML/yr)	Potable water demand (ML/yr)	Total Administration and Workshop Area demand (ML/yr)
1	4.0	1.0	5.0
2	13.0	3.0	16.0
3	16.0	4.0	20.0
4	29.0	7.0	36.0
5	33.0	8.0	41.0
6	31.0	8.0	39.0
7	34.0	9.0	43.0
8	34.0	9.0	43.0
9	35.0	9.0	44.0
10	37.0	9.0	46.0
11	37.0	9.0	46.0
12	35.0	9.0	44.0

Year	Fire demand (ML/yr)	Potable water demand (ML/yr)	Total Administration and Workshop Area demand (ML/yr)
13	37.0	9.0	46.0
14	36.0	9.0	45.0
15	34.0	8.0	42.0
16	33.0	8.0	41.0
17	35.0	9.0	44.0
18	30.0	8.0	38.0
19	16.0	4.0	20.0

Source: WSP | Parsons Brinckerhoff (August 2015)

4.5.1.5 Demand summary

A summary of net demands (water supplied minus water returned) is provided in Table 4.11, which has been graphically displayed in Figure 4.2.

The total annual net demand is estimated to peak in Year 15 at 886 ML/yr (equivalent to 2.43 ML/day).

Table 4.12 provides a comparison of annual groundwater inflow to the sump and the total annual net project water demand. The same dataset is also presented in Figure 4.3. It can be seen from Table 4.12 that the total net project demand over the 19-year mining period is expected to be 12,838 ML. The 19-year total groundwater volume for the sump is estimated to be 65% of the total project demand.

This suggests that an additional supply of at least 35% is required from either the site based rainfall-runoff or the groundwater that will be collected in the void spaces, or both. The requirement is likely to be more than 35% given that water will be lost to evaporation.

Water balance modelling consisting of interaction between rainfall-runoff, climatic evaporation from the water surface, groundwater inflows and water demand supplies was required to quantify likely project water deficits and surpluses. Results from water balance modelling are presented in Section 5.

Table 4.11 Demand summary

Year	Net product coal handling demand (ML/yr)	Net CPP demand (ML/yr	Net ROM demand (ML/yr)	Net co-disposed reject makeup water demand (ML/yr)	Net underground operations demand (ML/yr)	Net Administration and Workshop Area demand (ML/yr)	Total Net Demand (ML/yr)
1	110.0	22.4	28.0	0.0	50.5	5.1	216.1
2	110.0	100.4	28.4	82.8	130.2	15.7	467.5
3	111.0	172.8	28.7	127.1	180.7	19.7	640.0
4	112.0	170.9	29.5	108.7	167.6	36.5	625.0
5	113.0	206.5	29.7	150.3	180.4	41.6	721.6
6	112.0	225.0	29.4	181.7	194.7	38.7	781.6
7	112.0	193.3	29.6	183.0	197.1	43.1	758.2
8	113.0	191.1	29.6	202.6	197.1	42.7	776.1
9	113.0	206.9	29.7	197.6	203.5	44.2	794.9
10	113.0	184.4	29.7	127.4	182.6	46.0	683.1
11	113.0	175.5	29.9	142.7	177.4	46.0	684.5
12	113.0	200.6	29.8	141.4	186.8	44.2	715.8

Year	Net product coal handling demand (ML/yr)	Net CPP demand (ML/yr	Net ROM demand (ML/yr)	Net co-disposed reject makeup water demand (ML/yr)	Net underground operations demand (ML/yr)	Net Administration and Workshop Area demand (ML/yr)	Total Net Demand (ML/yr)
13	113.0	225.4	29.8	187.6	202.6	46.0	804.4
14	113.0	226.7	29.7	251.8	204.4	45.6	871.2
15	112.0	204.2	29.5	300.0	198.6	42.0	886.2
16	112.0	173.1	29.6	159.3	172.3	40.5	686.9
17	113.0	192.1	29.7	141.4	189.8	43.4	709.4
18	112.0	155.7	29.5	125.8	165.2	38.0	626.2
19	111.0	73.8	28.7	54.6	100.4	19.3	387.9
Total	**2,131.0**	**3,300.8**	**558.6**	**2,865.9**	**3,282.1**	**698.2**	**12,836.6**

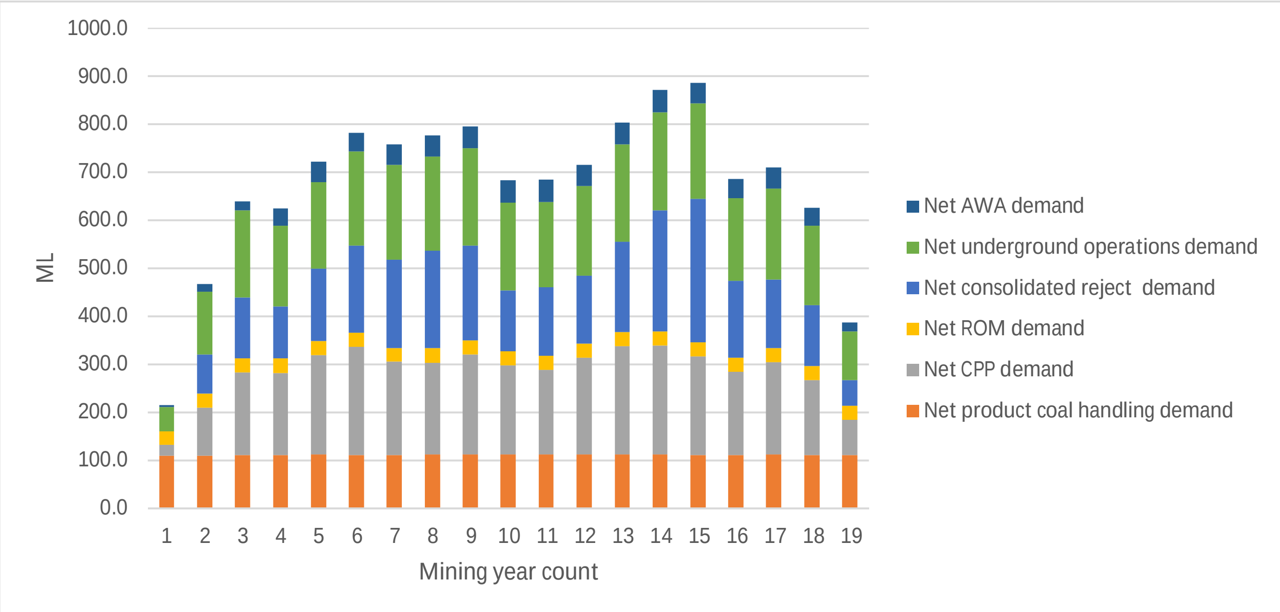

Figure 4.2 **Net annual project demand components**

Table 4.12 **Comparison of net annual demands to annual groundwater inflows to the sump**

Year	Groundwater inflow to mine sump (ML/yr)	Total Net Demand (ML/yr)	Comparison of groundwater inflow to sump and total net demand (%)
1	127.0	216.1	59%
2	181.1	467.5	39%
3	281.7	640.0	44%
4	325.9	625.0	52%
5	330.6	721.6	46%
6	331.6	781.6	42%
7	594.7	758.2	78%
8	373.0	776.1	48%
9	433.5	794.9	55%

Year	Groundwater inflow to mine sump (ML/yr)	Total Net Demand (ML/yr)	Comparison of groundwater inflow to sump and total net demand (%)
10	388.9	683.1	57%
11	428.3	684.5	63%
12	457.4	715.8	64%
13	491.7	804.4	61%
14	409.4	871.2	47%
15	425.4	886.2	48%
16	488.5	686.9	71%
17	985.1	709.4	139%
18	792.0	626.2	126%
19	512.7	387.9	132%
Total	**8,358.7**	**12,836.6**	**65%**

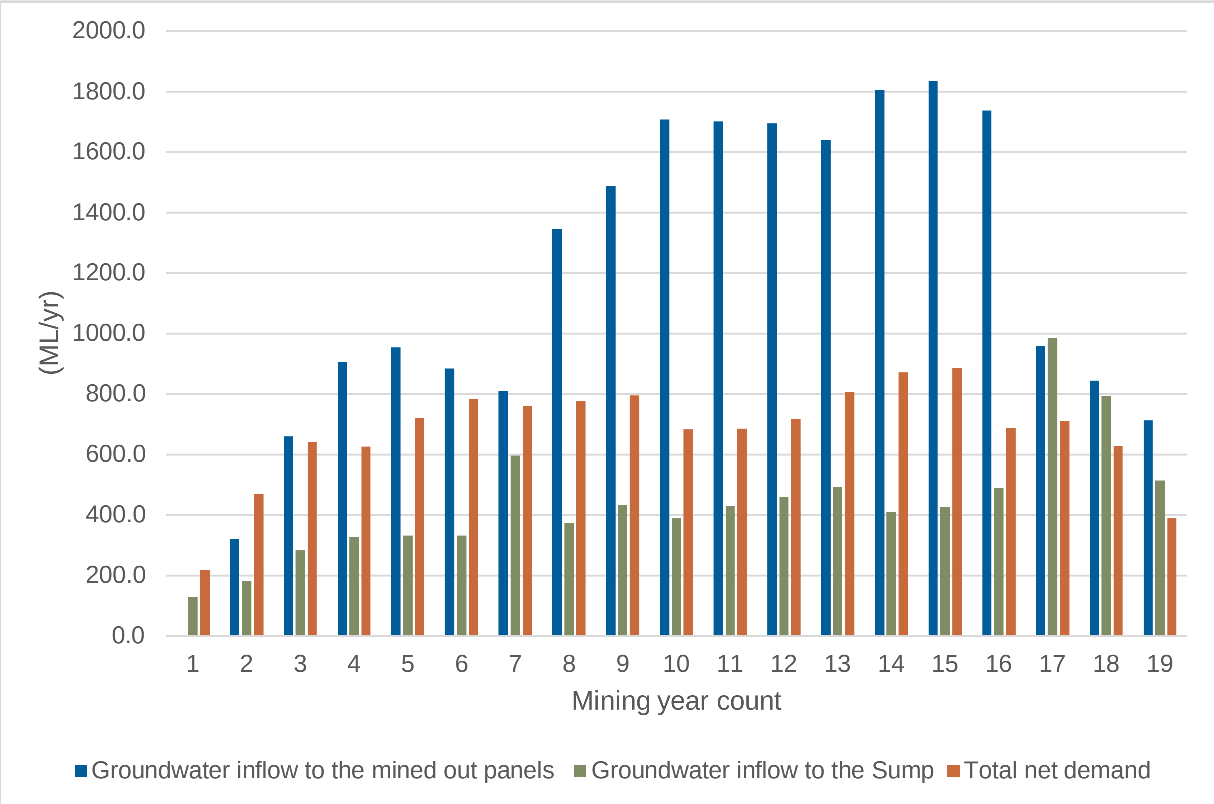

Figure 4.3 Comparison of net annual demands to groundwater inflows to the sump and void spaces

4.5.2 Evaporation

Evaporation estimates for open water bodies were based on daily Morton's Lake evaporation data sourced from Data Drill. The Data Drill calculates Morton's Lake evaporation using Morton's formula for shallow lakes (Morton, 1983). Evaporative surface area for dams has been determined based on the assumed basin and dam stage-storage-area relationships (refer Section 4.3.2).

4.5.3 Reinjection of surplus water to mine void

Mine void space availability for water (including natural groundwater inflow and reinjected water from the sump) has been calculated by accumulating total void space available behind the bulkheads after deducting the volume of co-disposed reject that will be placed behind the bulkheads. The co-disposed reject volume is expected to be 36% of the total ROM volume produced from the mine.

Figure 4.4 shows the total volume within the mined out panels created each year, with the volume remaining after placement of the co-disposed reject. The net volume available for water storage (i.e. combination of natural groundwater inflow and reinjected water) is 64% of the total incremental mined out volume.

The calculated annual volumes from this dataset are presented in Table 4.13, which provides the annual mined out void volume, the net void space available after placement of the co-disposed reject, and the net void space available for reinjection of surplus water after the natural groundwater inflow. The groundwater inflow to void estimates were taken from the groundwater model. Within these estimates is included void water abstraction to meet process demands and therefore where there is a negative shown in the table, it indicates that water has been abstracted from the void to meet process demands.

For water balance modelling, the net void space availability for surplus water reinjection was calculated at a daily time step by subtracting the natural groundwater inflows to the void from the available void space. If the predicted daily inflow of groundwater to the void exceeded the available void space then the inflow was reduced to match the available void space. Assumed peak rates of water transfer are summarised in Table 4.14.

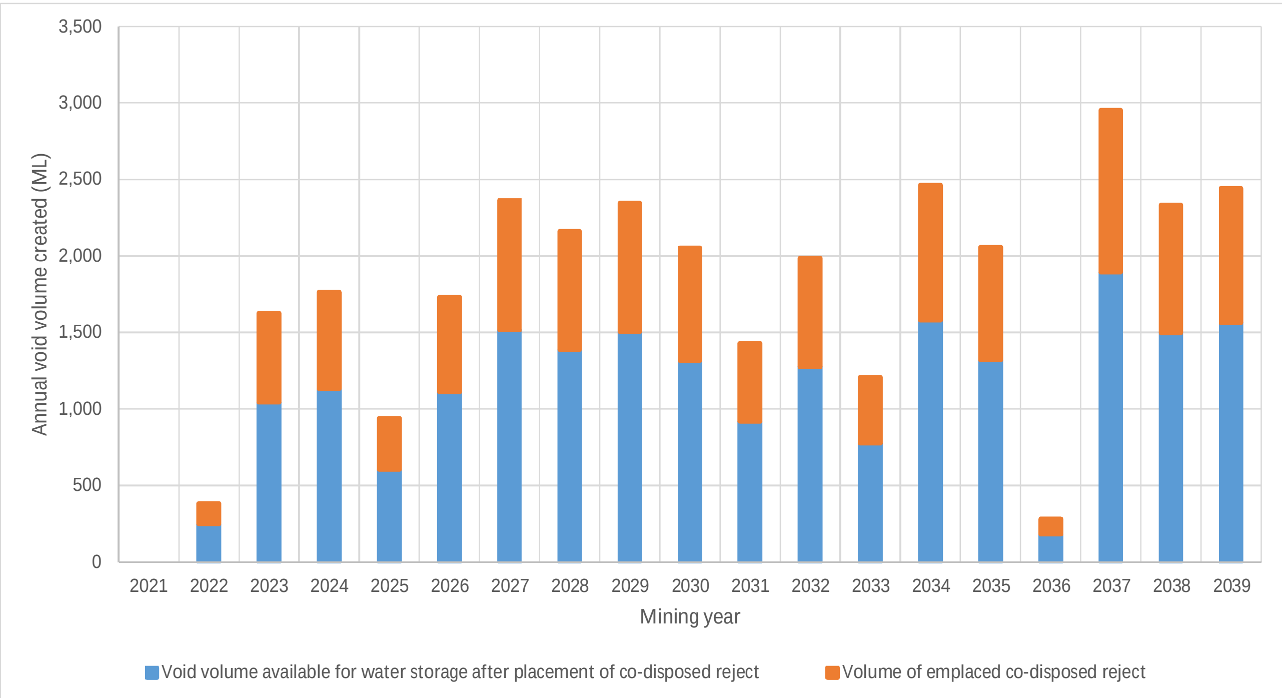

Figure 4.4 Annual schedule of void volume created and void volume available for water storage after placement of co-disposed reject

Table 4.13 Mine void capacity available for reinjection

Mining year	Total void volume (ML)	Net void space available after placement of co-disposed reject (ML)	Groundwater inflow to mined out panels (ML/year)	Net void space available for reinjection (ML)
2021	0.0	0.0	0.0	0.0
2022	384.5	246.2	320.4	-74.2
2023	1628.7	1043.1	658.0	385.1
2024	1764.9	1130.3	904.0	226.3
2025	940.6	602.4	953.0	-350.6
2026	1734.1	1110.5	883.2	227.3
2027	2367.1	1516.0	808.9	707.1
2028	2165.5	1386.8	1344.3	42.5
2029	2348.7	1504.1	1486.3	17.9
2030	2054.4	1315.7	1705.7	-390.1
2031	1430.9	916.4	1700.0	-783.6
2032	1990.4	1274.7	1694.9	-420.2
2033	1209.2	774.4	1639.0	-864.6
2034	2463.9	1577.9	1804.3	-226.4
2035	2058.5	1318.3	1834.5	-516.2
2036	282.2	180.7	1735.1	-1554.4
2037	2954.9	1892.3	956.9	935.5
2038	2336.5	1496.3	843.0	653.3
2039	2443.3	1564.7	711.6	853.1

4.6 Pumping rates

The following peak pumping rates were adopted in the water balance model. It is assumed that pumps operate at an average rate for 24 hours per day. This is how water is assumed to be transferred between storages in the model. It does not represent the detailed pumping rules that would be used during operations, which would be determined at the detailed design stage.

Table 4.14 Assumed daily pumping rates applied in simulations for water balance assessments

Pump from	Pump to	Modelled peak pumping rate (ML/day)
PWD	Underground operation	2.1
PWD	Fire water for Administration and Workshop Area	0.1
SB01	PWD	1
SB02	PWD	3
SB03	PWD	0.5
SB04	PWD	0.5
MWD05	PWD	0.5

Pump from	Pump to	Modelled peak pumping rate (ML/day)
MWD06	PWD	0.5
MWD07	Sump	1.5
Sump	PWD	5.4
Sump	Void space	5.4
Void space	PWD	4.9

4.7 Operating rules

The following operating rules have been assumed for the water balance assessment:

- MWDs and SBs:
  - All SBs and MWDs except MWD07 and MWD08 pump directly to the PWD at the peak daily pumping rates presented in Table 4.14.
  - All SBs and MWDs can only pump water to the PWD when the sediment store is fully saturated and water is above the sediment store volume. The sediment store is assumed to contain water volume equal to half the volume of the sediment store.
  - Water transfer from SB01 to the PWD and from SB02 to the PWD are not restricted by any volumetric constraint in the PWD.
  - No overflows from SB01 and SB02 are allowed to occur in the model, however, spillways have been provided to direct overflows from these dams to nearby watercourses (overflows may occur under very high rainfall conditions, such as those that significantly exceed the 500 year ARI event).
  - Water transfer from other SBs and MWDs into the PWD are stopped when the PWD water volume is greater than 730 ML.
  - Releases to Oldbury Creek from SB03 and SB04 are assumed to occur when the first flush criteria are satisfied. If first flush criteria are not met, the water will be pumped to the PWD.
- PWD:
  - The PWD is the main dam that will supply water to meet all demands except the potable water requirement, which will be sourced from registered bores.
  - The PWD operating levels are between 83 and 124ML. The PWD is designed, however, to store all water on site and has a storage limit of 730ML.
  - The water balance operating rule has been optimised to avoid overflows from the PWD. If there is a risk of overflow from the PWD, water will be treated in the WTP and then released to Oldbury Creek.
- Sump:
  - The underground sump is the ultimate point of water collection from all underground water sources and includes transfer from MWD07, groundwater, decant from the co-disposed reject emplacement and unused water from the underground mining operation.
  - When the PWD level is less than 124ML, water accumulated daily at the sump is pumped to the PWD.

  - When the PWD level is more than 124ML, the water accumulated at the sump is reinjected into the void space behind the bulk heads. If there is no void space available, then the water accumulated at the sump will continue to be pumped to the PWD.
  - The underground mine sump is assumed to be 6 ML and will maintain this volume in the sump most of the time unless water deficit occurs.
- Void:
  - Water transfer from the void spaces behind the bulkheads to the PWD occurs when the PWD level is less than 83ML and occurs at a daily rate that ensures the level of the PWD remains at 83ML at the end of each daily time step.

5. Water balance modelling results

This chapter presents key results obtained from the modelled daily water balance for the Hume Coal Project water management system.

This chapter is organised as follows:

- An average project balance summary from 107 climate sequences is presented in Table 5.1 for the surface storages (SB01 through to MWD06 and the PWD, excluding MWD07 which transfers water to the underground sump and MWD08 which is part of the WTP and independent of the mine water balance).
- The underground system balance is summarised in Table 5.2.
- Section 5.1 presents annual variation in the simulated net rainfall-runoff for the project.
- Section 5.2 compares annual variation in the project demand with available supply from rainfall-runoff and groundwater.
- Section 5.3 presents annual distribution of average demand and supply for the project from harvestable rainfall-runoff and natural groundwater that would be collected in the void spaces and the underground mine sump.
- Section 5.4 demonstrates that the project SBs and MWDs have capacities to avoid uncontrolled spills.
- Section 5.5 summarises modelled reinjection volumes from the underground sump to the void spaces as a means of managing surpluses and minimise potential evaporative loss of water from the PWD.
- Section 5.6 discusses the likelihood of the need to treat and release excess water from the PWD.

The Hume Coal Project water management system was tested against 107 sets of 19-year climate sequences. The pumping rates for water transfers from all SBs and MWDs to the PWD and from underground operation to the PWD were optimised to provide adequate buffers in the PWD so that uncontrolled spills would not occur. In doing so, it was assumed that rainfall-runoff arriving at SB03 and SB04 after the first flush would be released to Oldbury Creek subject to water quality being acceptable. An average of simulated results from 107 sets of 19-year climate sequences was calculated and is summarised in Table 5.1. The project water supply will be provided from rainfall-runoff and groundwater from the underground mine. On average 69% of the project demand is likely to be supplied from the groundwater arriving at the sump and the void spaces. The breakdown of the total inflow to the underground mine sump and void spaces is provided in Table 5.2.

Table 5.1 Average project water balance summary for surface storages PWD and SB01 to MWD06

Surface storages		ML	ML/year	%
Inflows	Rainfall	2,085	110	7.7%
	Runoff	3,593	189	13.3%
	CPP wash and dust suppression return	2,799	147	10.4%
	Supplied from the underground mine sump	15,062	793	55.9%
	Supplied from void space groundwater	3,410	179	12.7%
	Total	26,949	1,418	100.0%
Outflows	Dam evaporation	2,892	152	10.7%
	Releases from SB03 and SB04 to Oldbury Creek after first flush	361	19	1.3%
	Treat before release to Oldbury Creek	0	0.0	0.00%
	Underground mine equipment water supply	9,119	480	33.9%
	Product coal handling water supply	2,587	136	9.6%
	CPP process water supply	5,644	297	21.0%
	ROM stockpile water supply	559	29	2.1%
	Co-disposed reject water supply	5,199	274	19.3%
	Administration and Workshop Area fire water supply	560	29	2.1%
	Total	26,922	1,417	100.0%
Storage	Initial dam storage	124		
	Final dam storage	151		
Note: MWD07 is excluded from the surface storages as it transfers water to the underground system (see Table 5.2) MWD08 is excluded from the water balance - refer to Section 4.2				

Table 5.2 Average project water balance summary for underground mine

Underground sump water balance		ML	ML/year	%
Inflows	Co-disposed reject decant	2,333	123	14.0%
	Groundwater in to the sump	8,358	440	50.2%
	Rainfall-runoff transfer from MWD07 to the sump	118	6	0.7%
	Return water from underground processes less losses in underground mine	5,837	307	35.1%
	Total	16,646	876	100.0%
Outflows	Supplied from the sump to the PWD	15,062	793	90.5%
	Reinjection from the sump to the void	1,584	83	9.5%
	Total	16,646	876	100.0%
Void space water balance		**ML**	**ML/year**	**%**
Inflows	Groundwater in to the void	21,984	1,157	93.3%
	Reinjection from the sump	1,584	83	6.7%
Outflows	Supplied from the void to the PWD	3,410	179	14.5%
Balance	Inflows minus outflows	20,158	1,061	85.5%

5.1 Water management system rainfall-runoff

The variability of available water supply from harvestable rainfall – runoff within the SB and MWD catchments are presented in Table 5.3. The runoff volumes were estimated by the AWBM (refer to Section 4). The data presented in Table 5.3 suggest that the harvestable annual net rainfall-runoff (allowing for evaporation loss) from SBs and MWDs during the 19-year mining period can range from zero or negative values during dry years to a maximum of 707 ML during wet years. The total simulated harvestable volume over the 19-year mining operation was found to range from 1,409 ML to 4,821 ML. If annual rainfalls in each year during mining were to be of the order of the simulated 75th percentile, the total harvestable volume could be 4,225 ML.

Table 5.3 Annual rainfall-runoff (net of evaporation) based on 107 water balance realisations

Year	Net annual rainfall-runoff (ML/yr)									
	Mean	Least result (driest)	5th percentile (very dry)	10th percentile	25th percentile	50th percentile (median)	75th percentile	90th percentile	95th percentile (very wet)	Greatest result (wettest)
2021	167	-5	4	28	50	124	246	409	504	688
2022	165	-44	-2	23	48	121	260	413	507	691
2023	163	-29	-7	23	47	120	246	402	513	702
2024	162	-26	-4	25	47	120	249	390	499	704
2025	161	-25	-3	22	47	120	250	389	501	706
2026	159	-25	-3	22	47	117	219	378	501	707
2027	157	-25	-4	22	47	112	219	376	501	707
2028	157	-25	-8	16	47	114	218	378	500	706
2029	156	-24	-8	15	46	115	219	379	501	705
2030	154	-24	-14	10	46	111	219	378	501	704
2031	153	-24	-14	10	46	111	219	378	500	704
2032	150	-25	-14	4	45	109	209	378	500	705
2033	147	-24	-14	4	45	110	210	360	485	702
2034	147	-24	-14	4	44	110	210	361	486	703
2035	146	-24	-17	-2	42	107	210	361	485	703
2036	144	-24	-17	-3	42	107	208	356	478	702
2037	136	-33	-24	-11	33	95	205	355	478	687
2038	141	-31	-24	-9	38	103	205	358	485	698
2039	140	-31	-24	-9	38	107	204	356	481	690
Total	**2,904**	**-493**	**-212**	**194**	**847**	**2,135**	**4,225**	**7,155**	**9,407**	**13,317**

Note: * Negative values indicate water evaporated from PWD water surface that would be maintained between 83ML and 124MLwith water supplied from mined out panels or CPP washing return in SB02.

5.2 Project demand and groundwater supply

Annual water volume that will be supplied from the PWD each year is presented in the column 2 of Table 5.4. The net annual volume consumed during the mining operation is listed in column 3 of Table 5.4, which ranges from 215 ML in the first year to a maximum of 878 ML in the 15th year of mining. The net water consumption cannot be fully supplied by using the net harvestable annual rainfall-runoff from the SBs and MWDs only. Groundwater that would be collected at the underground mine sump and in the void spaces behind the bulkheads will be required in supplying the rest of the annual water demands. The data presented in Table 5.4 suggests that all of the groundwater that would arrive at the underground sump is likely to be utilised. Moreover, additional water would be pumped from the void spaces to meet the demands fully.

Net annual rainfall-runoff volumes for the wettest rainfall sequence (1949 to 1969) and the driest rainfall sequence (1991 to 2009) are presented in column 6 and column 7 of Table 5.4 respectively.

Comparisons of the sums of net annual harvestable rainfall-runoff volumes over the 19-year mining period with the required potential supply (column 5 of Table 5.4) provide an indication of the likely range of utilisation of natural groundwater from the void spaces for meeting the project demands, in addition to the groundwater that would be collected in the underground mine sump.

The likely range of utilisation of the natural groundwater from void spaces is expected to be from 105 ML in the wettest climate sequence (obtained by subtracting the total of column 6 from the total of column 5) up to 3,517 ML in the driest climate sequence (obtained by subtracting the total of column 7 from the total of column 5). It should be noted that this is the 'groundwater to void' abstraction required, which differs from the total amount of water abstracted from the void to the PWD as the water balance model indicates there will be water reinjected from the sump to the void in all climate sequences.

The exact volume of water utilisation from the underground mine will depend on the complex interaction between basin and dam storage, climate, rainfall-runoff, water transfer volumes and mode of operation. For example, the rainfall-runoff volume from MWD07 is transferred directly to the sump, which may get reinjected to the void spaces rather than being transferred to the PWD for water supply. The results from daily simulation for the mean annual rainfall-runoff condition are presented in Section 5.3.

Table 5.4 Summary of the annual project water demand and supply

Mining year (column 1)	Total demand (ML) (column 2)	Net demand (ML) (column 3)	Annual groundwater to the sump (ML) (column 4)	Potential supply from the mined out panel groundwater without surface water (ML) (column 5)	Net annual rainfall - runoff for wet climate sequence (1949 to 1969) (ML) (column 6)	Net annual rainfall - runoff for dry climate sequence (1991 to 2009) (ML) (column 7)
2021	275	215	127	88	266	118
2022	727	465	181	284	691	89
2023	1,116	636	282	355	360	30
2024	1,054	618	327	291	423	26
2025	1,312	713	330	383	49	121
2026	1,524	774	331	443	78	76
2027	1,596	749	594	155	186	42
2028	1,670	768	374	394	542	299
2029	1,648	786	433	353	-3	85
2030	1,337	674	389	285	125	77

Mining year (column 1)	Total demand (ML) (column 2)	Net demand (ML) (column 3)	Annual groundwater to the sump (ML) (column 4)	Potential supply from the mined out panel groundwater without surface water (ML) (column 5)	Net annual rainfall - runoff for wet climate sequence (1949 to 1969) (ML) (column 6)	Net annual rainfall - runoff for dry climate sequence (1991 to 2009) (ML) (column 7)
2031	1,242	675	428	247	272	84
2032	1,369	707	458	249	122	-23
2033	1,468	795	491	304	439	46
2034	1,567	862	409	453	266	-19
2035	1,652	878	425	453	485	141
2036	1,228	679	490	189	285	-4
2037	1,297	701	984	0	14	238
2038	1,055	619	791	0	108	13
2039	532	384	512	0	112	-30
Total	**23,668**	**12,698**	**8,358**	**4,926**	**4,821**	**1,409**

Note: * Negative values indicate water evaporated from PWD water surface that would be maintained between 83ML and 124MLwith water supplied from mined out panels or CPP washing return in SB02.

5.3 Summary of mean annual water balance

The water balance model was run at a daily time step for 107 sets of climatic sequences for the 19-year mining period to estimate surpluses and deficits in meeting total annual project demands. The mean values calculated from 107 likely sets of climatic sequences for annual project inflows and outflows are presented in Table 5.5.

Project water demands over the period of the 19-year mine life are expected to be fully met by the use of the net harvestable rainfall-runoff from the SBs and MWDs, the groundwater collected by the underground mine sump and the groundwater within the mined out void spaces behind the bulkheads.

The PWD will receive all transferred rainfall-runoff and any water returns from mining operation. On average 22% of the total demand over the 19-year mining period could be supplied from the simulated net rainfall-runoff (column 2 of Table 5.5) that is transferrable from the dam catchments to the PWD, including the CPP return from SB02. The remainder of water supply to the PWD will come from the underground sump (64%) and the void spaces (14%) (Table 5.5). Note that the void spaces will receive natural groundwater as well as any reinjected water from the underground sump, and therefore the water pumped from the void to the PWD will be a mixture of these water sources. On average, 90% of the water collected in the sump will be returned to the PWD.

The simulated net rainfall-runoff sequence volume was the lowest for the climate sequence 103 from 1991 to 2009 (refer to column 7 of Table 5.4 for annual volumes). For this sequence the simulated daily volume and supply deficit report for the PWD confirms that the project demands can be fully met by the net rainfall-runoff and groundwater from the underground mine and there is no deficit. For this climate sequence, the majority of simulated water supply for the project demand came from the groundwater from the underground mine (refer to Figure 5.1 for daily distribution of supply). Over the 19-year simulation for this sequence a total volume of 3,998 ML was supplied from the void.

Figure 5.2 shows the total (i.e. 19 year sum of) net rainfall-runoff, water transferred from the void to the PWD and water reinjected to the void for all climate realisations. The peak volume stored in the PWD is also shown on the figure. The figure shows the correlation between net rainfall-runoff and reinjection to the void. The transfer of water from the void to the PWD is inversely correlated to net rainfall-runoff volumes in the dry climate sequences when the PWD needs to be maintained at volumes > 83ML more regularly within the 19 year mining period for operations and to meet project demands including evaporation (e.g. refer to climate sequences 13 to 45 in Figure 5.2).

Results presented in Table 5.5 are subject to modelled reinjection rules applied at the underground sump. The mean of annual results for the groundwater balance is presented in Table 5.6. The underground sump is expected to receive water from:

- local groundwater (column 2 of Table 5.6)
- MWD07 (column 3 of Table 5.6)
- decant from the co-disposed reject emplaced behind the bulkheads
- the remainder of the water supplied for the underground mining equipment and operation from the PWD.

From the total daily inflow to the sump, a daily water volume equal to the volume of water lost that day from all operations will be pumped back to the PWD, thus maintaining a volume between 83ML and 124ML in the PWD. The reinjection behind the bulkheads from the sump only occurs when the volume in the PWD exceeds 124ML.

Natural groundwater and reinjection from the sump that will be stored in the void spaces over the 19-year mining operation will be pumped to the PWD to meet other project demands as required. During the 19-year mine life it is expected that 1,826 ML may be pumped out in excess of total volume reinjected to the void spaces (refer to the last column of Table 5.6).

Simulations undertaken for the 107 sets of 19-year climate sequences suggest that the water volume in the PWD and all SBs and MWDs will not exceed its capacity during the mining operation. Refer to Section 5.4 for discussion of results for all basins and dams.

The minimum, median and maximum of simulated annual releases to creeks from SB03 and SB04 are presented in Table 5.7. The modelled annual volumes released from SB03 and SB04 are roughly between 4% and 6% of the overall net harvestable rainfall-runoff from all basins and dams within the project area for the median and the wettest years.

Table 5.5 Simulated mean annual PWD water balance based on 107 water balance realisations

Mining year	Net water transfer from SBs and MWDs* to PWD (ML)	Water transfer from underground sump to PWD (ML)	Groundwater from the void spaces supplied to PWD (ML)	Rainfall and runoff in excess of evaporation at PWD (ML)	Total annual project demand (ML)	Water stored in PWD at the start of a year (ML)	Annual overflow from PWD (ML)
2021	164.3	150.5	0.0	1.8	274.7	124.0	0.0
2022	236.4	297.6	146.2	4.2	726.7	165.9	0.0
2023	285.2	556.7	235.8	6.1	1116.4	123.6	0.0
2024	270.9	577.7	197.6	6.4	1053.9	90.9	0.0
2025	283.6	741.3	279.5	6.6	1311.7	89.6	0.0
2026	293.5	887.9	335.9	6.2	1523.8	88.8	0.0
2027	295.9	1,205.0	94.6	5.3	1595.6	88.6	0.0
2028	296.4	1,074.2	289.0	5.6	1670.0	93.9	0.0

Mining year	Net water transfer from SBs and MWDs* to PWD (ML)	Water transfer from underground sump to PWD (ML)	Groundwater from the void spaces supplied to PWD (ML)	Rainfall and runoff in excess of evaporation at PWD (ML)	Total annual project demand (ML)	Water stored in PWD at the start of a year (ML)	Annual overflow from PWD (ML)
2029	302.8	1,082.2	257.4	5.6	1647.9	89.1	0.0
2030	281.0	852.4	199.3	5.1	1337.2	89.3	0.0
2031	273.7	797.7	167.0	4.8	1242.2	89.9	0.0
2032	282.0	914.3	168.3	4.1	1369.0	90.8	0.0
2033	295.0	951.7	216.7	3.7	1468.0	90.5	0.0
2034	295.1	916.2	350.5	3.9	1567.0	89.6	0.0
2035	282.9	1012.3	353.6	3.7	1652.2	88.3	0.0
2036	262.3	873.9	118.1	1.5	1227.6	88.6	0.0
2037	283.0	1029.3	0.3	-4.1	1297.2	116.8	0.0
2038	259.6	791.9	0.0	-1.2	1055.0	128.2	0.0
2039	195.0	349.0	0.0	-2.2	532.0	123.5	0.0
Total	**5,138.6**	**15,061.9**	**3,409.8**	**67.1**	**23,668.1**	**133.2**	**0.0**

*Note:
MWD07 is excluded from the surface storages as it transfers water to the underground system
MWD08 is excluded from the water balance as it is a small storage associated with the WTP (refer Section 4.2)

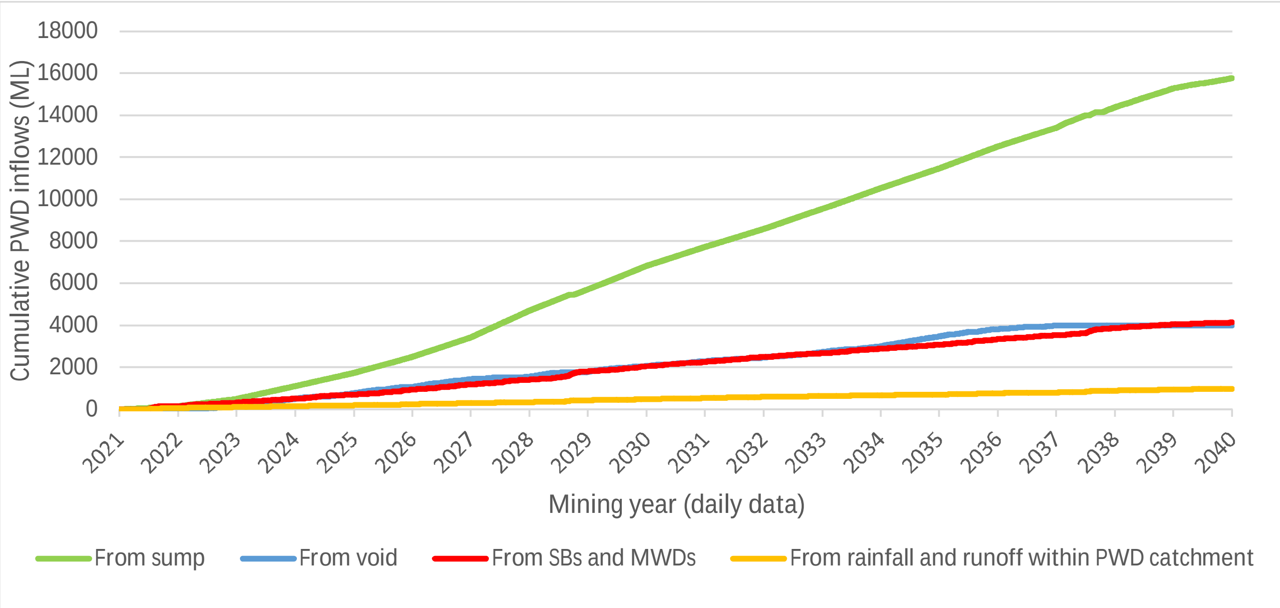

Figure 5.1 **Simulated daily inflows to the PWD from sump, void, SBs and MWDs and the PWD local catchment for climate realisation 103 (1991 to 2009)**

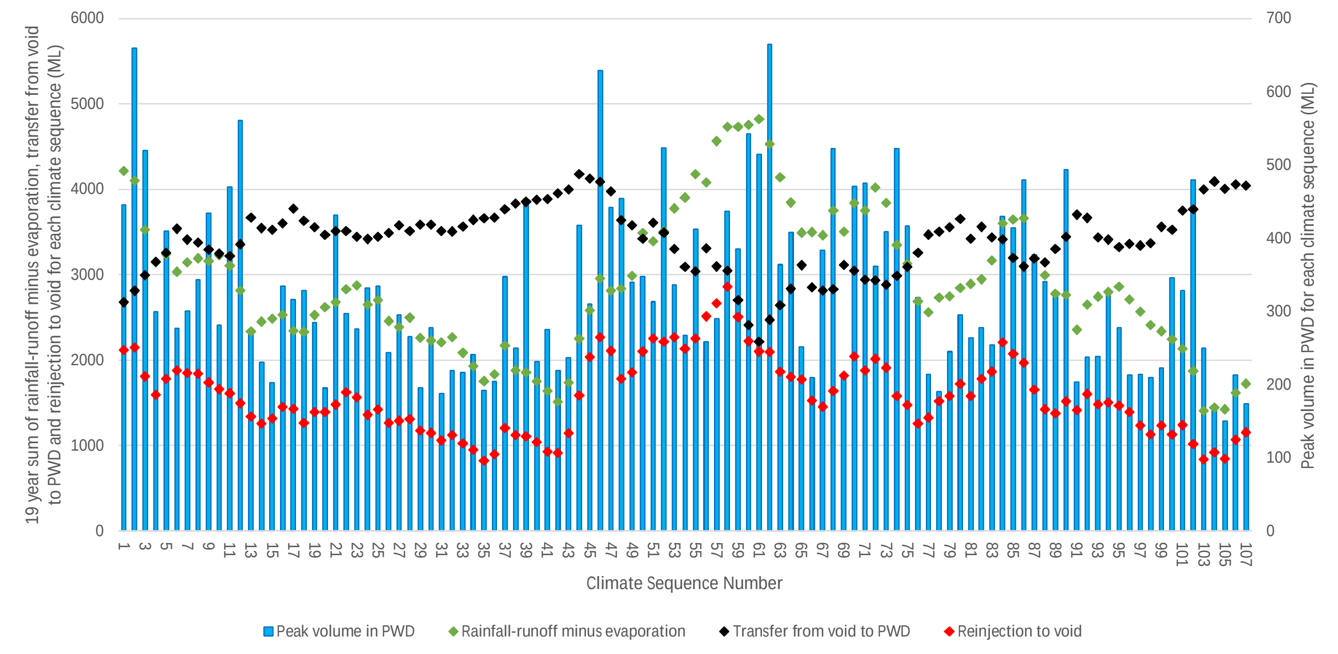

Figure 5.2 **Simulated 19 year sum of rainfall runoff, transfer from void to PWD and reinjection to void, with peak volume in PWD for all climate realisations**

Table 5.6 **Simulated mean annual underground mine balance based on 107 water balance realisations**

Mining year	Annual groundwater volume to sump (ML)	Annual transfer from MWD07 to sump (ML)	Annual reinjection to the void spaces (ML)	Annual natural groundwater to the void spaces (ML)	Supply from the void spaces behind the bulkheads (ML)	*Net supply from the natural groundwater in void spaces (ML)
2021	126.9	6.0	0.0	0.0	0.0	0.0
2022	180.9	6.6	49.5	320.2	146.2	96.7
2023	281.5	6.5	56.5	657.5	235.8	179.2
2024	326.6	6.4	49.8	905.8	197.6	147.9
2025	330.4	6.4	39.0	952.4	279.5	240.4
2026	331.4	6.4	32.5	882.6	335.9	303.4
2027	594.3	6.3	71.8	808.3	94.6	22.8
2028	373.8	6.3	37.5	1347.1	289.0	251.6
2029	433.2	6.3	41.2	1485.3	257.4	216.2
2030	388.7	6.2	48.4	1704.6	199.3	150.9
2031	428.1	6.2	52.8	1698.9	167.0	114.1
2032	458.3	6.1	51.2	1698.4	168.3	117.1
2033	491.4	6.0	42.0	1637.8	216.7	174.7
2034	409.2	6.0	27.2	1803.1	350.5	323.3

Mining year	Annual groundwater volume to sump (ML)	Annual transfer from MWD07 to sump (ML)	Annual reinjection to the void spaces (ML)	Annual natural groundwater to the void spaces (ML)	Supply from the void spaces behind the bulkheads (ML)	*Net supply from the natural groundwater in void spaces (ML)
2035	425.1	6.0	28.0	1833.3	353.6	325.6
2036	489.5	6.0	26.0	1738.7	118.1	92.0
2037	984.5	5.9	390.6	956.2	0.3	-390.3
2038	791.5	6.0	299.7	842.4	0.0	-299.7
2039	512.4	6.0	240.2	711.2	0.0	-240.2
Total	**8,357.5**	**117.6**	**1,584.1**	**21,983.9**	**3,409.8**	**1,825.7**

*Note: Negative values indicate a surplus of reinjected water that is not needed to meet demand (column 4 minus column 7).

Table 5.7 Simulated annual volumes of releases from SB03 and SB04 to Oldbury Creek subject to meeting the first flush criteria based on 107 water balance realisations

Mining Year	Minimum SB03 releases (driest) (ML)	50th percentile SB03 releases (median) (ML)	Maximum SB03 releases (wettest) (ML)	Minimum SB04 releases (driest) (ML)	50th percentile SB04 releases (median) (ML)	Maximum SB04 releases (wettest) (ML)
2021	0.2	7.6	29.4	0.0	7.9	38.0
2022	0.9	8.1	30.6	0.0	8.5	41.1
2023	0.9	8.1	30.6	0.0	8.5	41.1
2024	0.9	8.1	30.6	0.0	8.5	41.1
2025	0.9	8.0	30.6	0.0	8.5	41.1
2026	0.9	8.0	30.6	0.0	8.1	41.1
2027	0.9	8.0	30.6	0.0	7.9	41.1
2028	0.9	8.0	30.6	0.0	7.9	41.1
2029	0.9	8.0	30.6	0.0	7.9	41.1
2030	0.9	7.9	30.6	0.0	7.6	41.1
2031	0.9	7.9	30.6	0.0	7.6	41.1
2032	0.9	7.9	30.6	0.0	7.5	41.1
2033	0.8	7.9	30.6	0.0	7.5	41.1
2034	0.8	7.9	30.6	0.0	7.5	41.1
2035	0.8	7.9	30.6	0.0	7.4	41.1
2036	0.8	7.9	30.6	0.0	7.4	41.1
2037	0.8	7.8	30.6	0.0	7.3	41.1
2038	0.8	7.9	30.6	0.0	7.4	41.1

Mining Year	Minimum SB03 releases (driest) (ML)	50th percentile SB03 releases (median) (ML)	Maximum SB03 releases (wettest) (ML)	Minimum SB04 releases (driest) (ML)	50th percentile SB04 releases (median) (ML)	Maximum SB04 releases (wettest) (ML)
2039	0.8	7.9	30.6	0.0	7.4	41.1
Total	**15.4**	**150.9**	**579.7**	**0.0**	**148.7**	**777.4**

5.4 Uncontrolled spill risk

Water storage capacity and pumping rates for the project basins and dams were tested in the water balance modelling to ascertain that no uncontrolled overflows occur from any of the storages, for the assumed AWBM estimated rainfall-runoff volumes. The capacities and peak simulated stored volume in each basin and dam from the 107 water balance model realisations are provided in Table 5.8, demonstrating that none of the basins or dams spill in the 107 realisations.

Figure 5.3 shows the simulated stored volume in the PWD over the 19 year mining period for the 107 water balance model realisations, demonstrating that the capacity of 730 ML is approached, but still with more than 65 ML of buffer, in the initial years of mining when demand is low and there is less void space available to receive excess water, and in the latter years when there is a reduction in capacity in the void spaces to receive excess water. The graph shows the probability envelope of all simulated results for stored volume within the PWD.

Table 5.8 Capacities and simulated peak water volumes in stormwater basins, mine water dams, the PWD and the underground mine sump

Dam	Capacity (ML)	Peak Simulated Volume (ML)
SB01	106.40	82.9
SB02	91.10	51.8
SB03	19.44	17.5
SB04	140.24	57.8
MWD05	5.95	2.1
MWD06	14.80	8.0
MWD07	5.73	5.0
PWD	730.00	664.8
SUMP	6.00	6.0

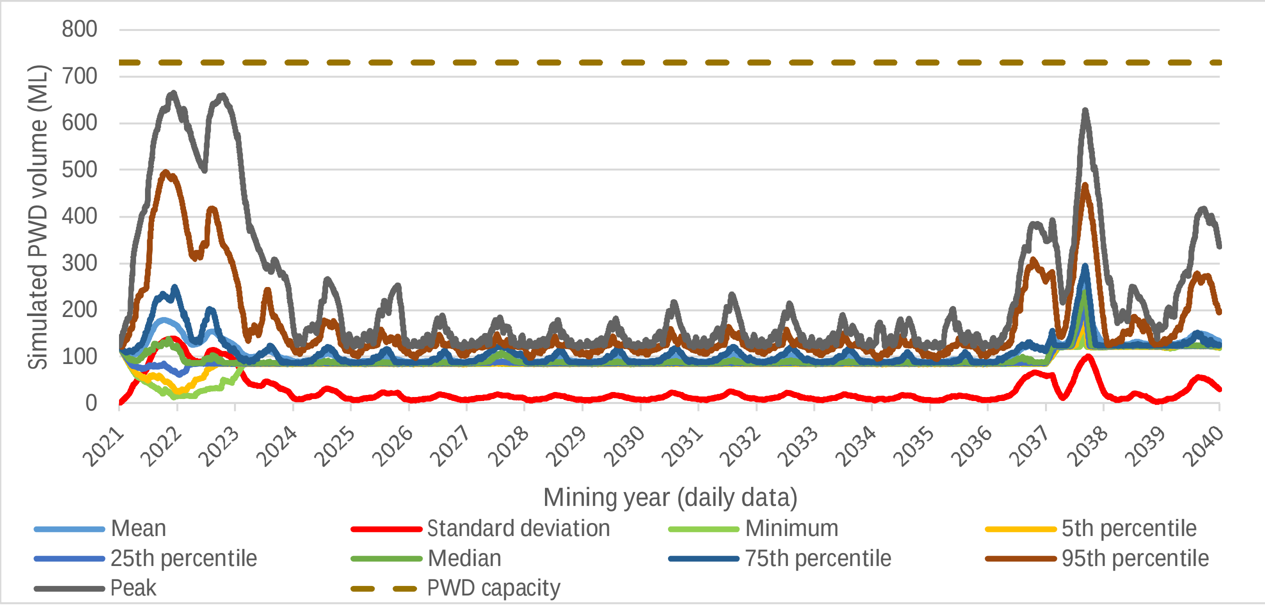

Figure 5.3 **Daily statistics of simulated stored volume in the PWD over life of project based on 107 sets of climate sequences**

5.5 Reinjection to mine void

The mine void space available to accommodate surplus water reinjected behind the bulkheads will depend on the volume of co-disposed reject placed in the void and the natural groundwater ingress into the void. The data presented in Table 4.13 provides the physically available storage space created each year, however, the actual availability may increase during the mining operation due to pumping from the void for supply of project water demands when the PWD storage reduces to less than 83ML.

Figure 5.4 shows the annually available net void space with co-disposed reject, cumulative groundwater inflows to the void and sump, and cumulative volumes of water reinjected from the sump to behind the bulkheads for the wet climate sequence 62. Total groundwater inflow to the panels at the end of 19-year simulation was limited by the available net void space. The void space limitation is evident from 2033 to 2038 in Figure 5.4. Note that the groundwater inflow to the void exceeds the available void space around the period 2036 to 2038, which is due to abstraction of water out of the void in this period.

Calculated annual statistics from 107-realisations are summarised in Table 5.9. The results presented for the above 75th percentile value suggests that there is at least a 25% chance that the total volume of water that would be reinjected throughout the 19-year mining period would be greater than 2,000 ML.

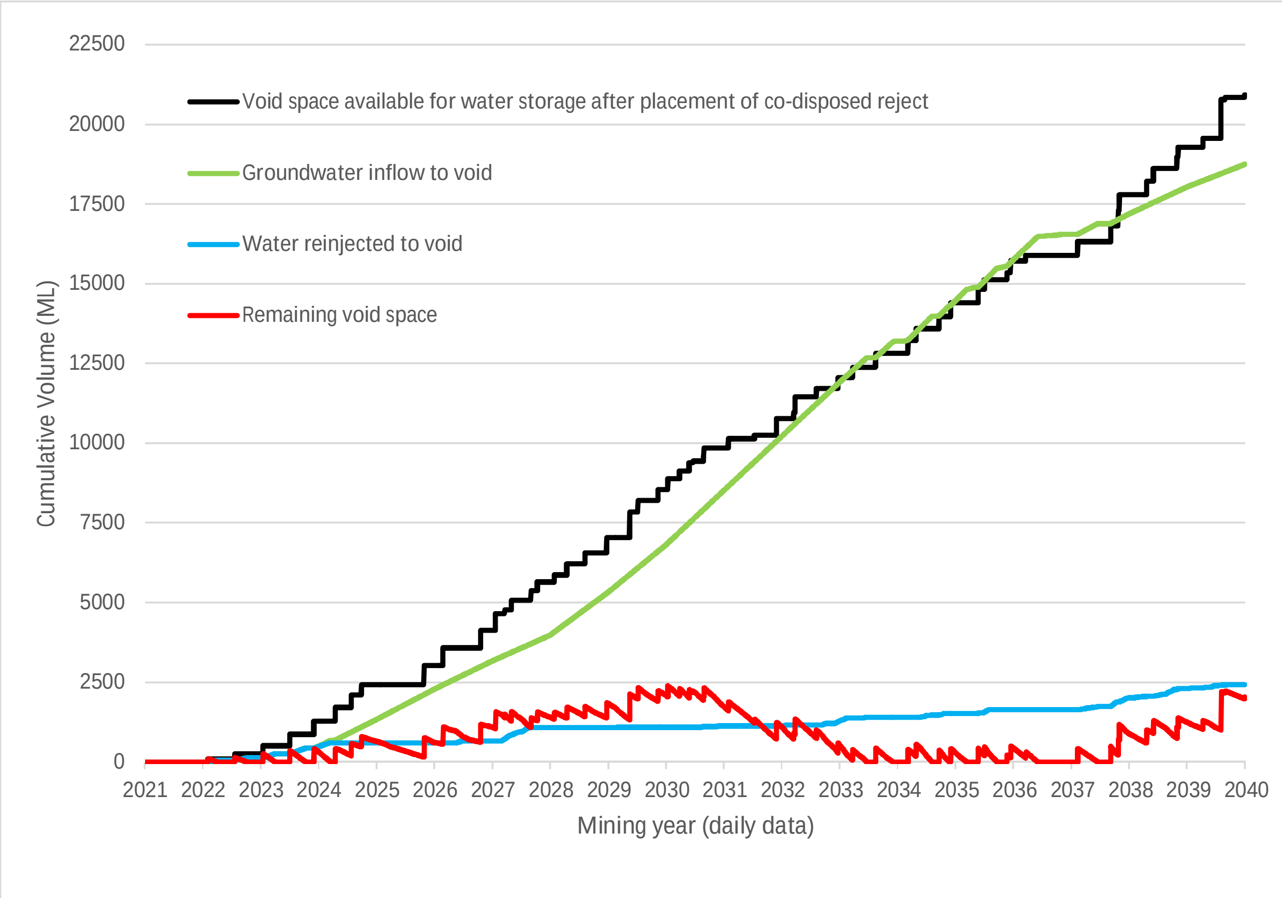

Figure 5.4 **Simulated annual volumes of available void space, groundwater inflows to void and sump, water reinjected to void and remaining void space for climate sequence 62 (wet conditions)**

Table 5.9 Annual reinjection to mine void based on 107 water balance realisations

Year	Average annual reinjection (ML)							
	Average	Minimum	25th percentile	50th percentile (median)	75th percentile	90th percentile	95th percentile	Maximum
2021	0	0	0	0	0	0	0	0
2022	49	0	0	30	100	128	129	132
2023	57	0	0	13	78	201	279	351
2024	50	0	0	5	69	171	238	372
2025	39	0	0	0	52	147	208	312
2026	33	0	0	0	36	123	187	284
2027	72	0	0	17	101	223	312	487
2028	37	0	0	0	50	143	205	305
2029	41	0	0	0	57	158	221	325
2030	48	0	0	0	67	176	248	380
2031	53	0	0	2	73	183	262	409
2032	51	0	0	0	70	180	261	409
2033	42	0	0	0	61	151	223	366
2034	27	0	0	0	29	106	148	275
2035	28	0	0	0	30	112	150	276
2036	26	0	0	0	17	89	121	438
2037	391	218	286	352	472	622	656	704
2038	300	143	206	260	353	508	617	810
2039	240	97	158	208	303	421	486	546
Total	**1,584**	**457**	**650**	**889**	**2,019**	**3,841**	**4,949**	**7,182**

5.6 Consideration of excess water disposal requirements

Excess water is likely to be generated when the void space becomes full towards the last 4 years of the proposed 19-year operational mining period. Under this circumstance the groundwater that would be collected in the sump and from other sources cannot be reinjected and will require pumping straight into the PWD provided the dam volume is not greater than 730 ML.

Simulations undertaken for 107 climate sequences showed that the excess water can be managed by either reinjection or by pumping into the PWD, and there is no requirement for disposing of excess water by treatment and release to Oldbury Creek.

Table 5.10 presents simulated peak annual volumes in the PWD for the 10 wettest climate sequences out of 107, when the volume exceeds 500ML. The peak volume in PWD exceeds 500 ML in year 2037 (or the fourth last year of mining) in 4 out of 107 climate sequences. In all cases, the peak volume in the dam remained less than 670ML. This demonstrates that no disposal of excess water (via treatment in the WTP and release to Oldbury Creek) would be required for the simulated combination of climates and operating rules.

Figure 5.5 shows the daily distribution of the volumes of water in the PWD if the wet climate sequence from 1950 (sequence number 62) repeats during mining. Refer to Figure 5.6 which shows the dam volume in the PWD for the wet climate sequence from 1930 (sequence number 46).

Table 5.10 Simulated annual peak volume (ML) in PWD

Mining year	Climate sequence									
	2	3	12	46	52	60	61	62	68	74
2021	584.83	519.76	560.87	208.21	124.00	124.00	287.97	664.77	522.60	213.26
2022	659.61	491.33	537.53	184.43	82.91	183.53	514.92	640.57	473.76	217.37
2023	588.07	249.39	149.34	98.15	124.32	273.52	469.18	526.06	124.46	206.91
2024	159.53	136.66	113.09	97.65	218.91	162.33	191.07	168.57	126.94	113.05
2025	130.90	122.52	165.21	129.11	97.40	253.59	110.48	104.74	105.13	113.52
2026	120.34	126.06	95.11	89.13	117.43	104.18	99.42	130.01	131.57	124.52
2027	132.89	131.65	126.88	100.19	116.80	119.32	129.43	139.16	134.35	112.23
2028	125.12	127.89	108.00	102.86	99.44	129.22	134.73	103.06	130.22	126.96
2029	127.81	155.27	126.54	124.25	105.80	135.21	101.11	124.32	151.18	111.04
2030	167.47	217.36	96.57	198.38	151.72	102.03	125.38	126.89	112.22	101.71
2031	233.96	113.83	129.32	100.60	183.36	125.79	125.49	114.27	121.43	111.46
2032	113.54	126.59	132.86	124.93	151.15	127.30	113.91	142.54	130.22	98.60
2033	125.61	114.60	129.50	104.85	166.74	107.96	136.50	134.91	106.94	159.59
2034	114.10	154.78	146.79	96.80	103.80	131.96	173.08	132.18	126.58	135.35
2035	146.98	95.45	117.84	98.48	102.77	132.05	148.92	149.20	109.41	126.20
2036	98.39	125.07	125.25	157.25	199.85	336.48	312.12	117.94	105.31	124.45
2037	225.52	236.19	217.02	628.61	523.63	542.31	260.80	227.07	207.25	522.75
2038	131.16	150.79	128.14	330.64	146.53	181.21	139.00	139.41	128.17	175.75
2039	168.89	132.92	139.46	271.98	155.72	147.91	164.08	138.22	305.33	129.54
2040	120.34	122.87	119.75	184.33	124.30	126.62	122.62	122.25	208.15	121.65

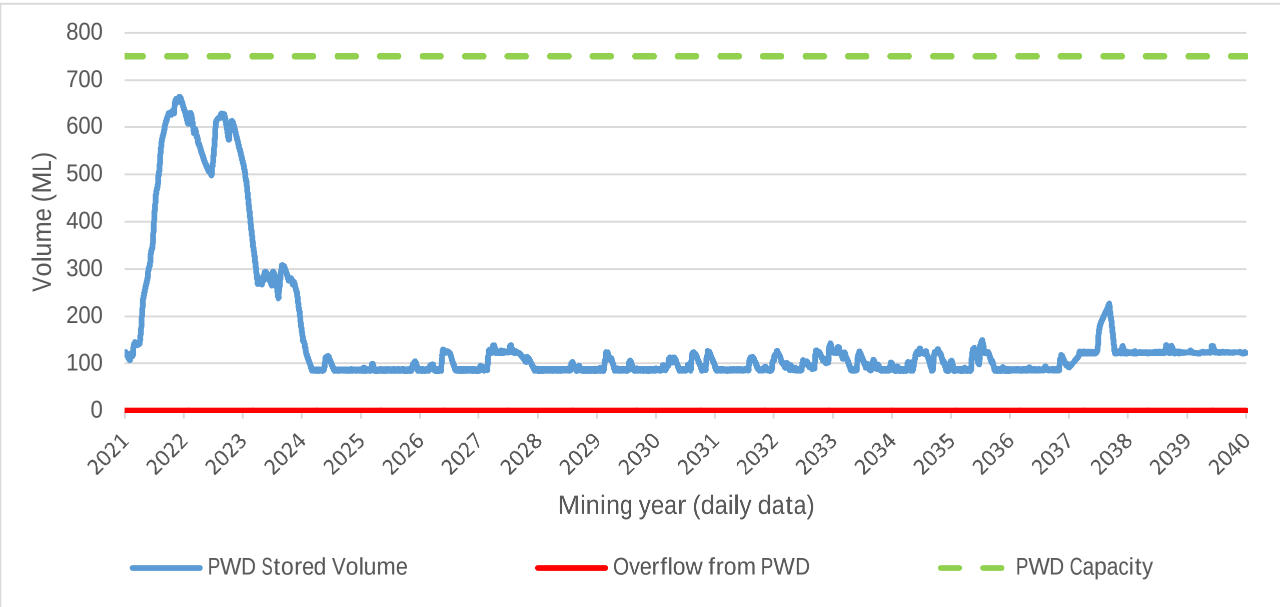

Figure 5.5 Simulated daily volumes in the PWD for wet climate sequence 62 (1950 to 1968)

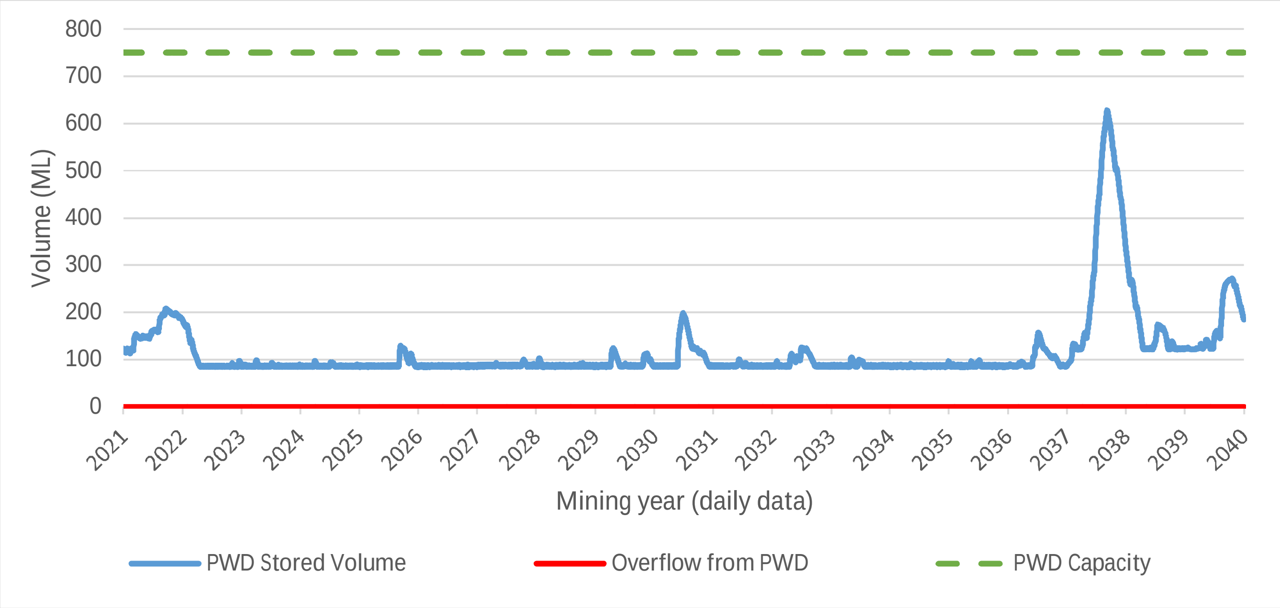

Figure 5.6 Simulated daily volumes in the PWD for wet climate sequence 46 (1934 to 1952)

6. Conclusions

The GoldSim based water balance model for the Hume Coal Project was developed to represent the surface infrastructure general arrangement from Arkhill Engineers (see Appendix B). The features of the system and model are:

- Four proposed SBs and three proposed MWDs in addition to the PWD.
- Rainfall-runoff characteristics were developed for engineered and non-engineered landforms within the proposed dam catchment.
- Water transfer rules were defined in the water balance model to reflect the water management strategy proposed by the Hume Coal Project. The key elements of the strategy are
  - The PWD functions as the primary dam and water will be transferred directly to the PWD.
  - The PWD will supply water to meet all project demands excluding potable and construction water demands.
  - Water sources for the PWD include transferrable rainfall-runoff harvested from all dam catchments and groundwater from the underground mine.
  - The PWD volume will be kept between 83ML and 124ML in order to provide operating storage for project water supply, allocating the remainder of storage to contain runoffs from all other dams.
  - The mined out void spaces will be utilised to store all water that will be collected in the underground sump, if the PWD volume is greater than 124ML or until these void spaces become full. These panels will be sealed by bulkheads after coal extraction.
  - Water collected in SB03 (Administration and Workshop Area basin) and SB04 (mine road and conveyor area basin) will be released to Oldbury Creek if the rainfall meets the adopted first flush criteria. The modelling has assumed that the runoff quality is acceptable for release to Oldbury Creek after the first flush. If the quality inhibits water release to Oldbury Creek then the WTP will be used to treat the water before release.
  - In the extremely event that neither the PWD nor the void spaces behind the bulkheads are able to contain water, excess water will be sent to MWD08 (water treatment dam) for treatment and subsequent release to Oldbury Creek, if required.

The project water demands and groundwater inflows to the underground mine were provided by Hume Coal and other consultants for the project. Climate data were obtained from the Data Drill service, which enabled development of 107 climate sequences for the 19-year mining period.

The water balance simulations undertaken for the 107 climate sequences indicate that

- The project will be able to supply all demands by reusing the net harvestable rainfall-runoff from all SBs and MWDs and groundwater collected from the underground mine.
- The PWD and all SBs and MWDs can be operated without any overflows occurring from their spillways.
- The PWD will be able to contain all rainfall-runoff and water transferred from the sump or the mined out panels. The water balance model did not predict any situation where disposal of excess water via treatment in the WTP and release to Oldbury Creek would be required in the 107 climate realisations tested.
- In the majority of climate sequences most of the groundwater reporting to the underground sump will be used in the mining operation. Additional water from the void spaces behind the bulkheads will be

required to supplement supply to meet all demands, except potable and construction water requirements.

- Wet year annual releases are expected to be in the ranges from 29 ML to 31 ML from SB03 and 38 ML to 41 ML from SB04. Dry year releases are expected to be less than 1 ML per year.

7. Limitations

The performance of the water management system is highly dependent on the strategy to deal with surplus water and adopted sizes for SBs and MWDs.

The estimated surpluses / deficits presented in this report are subject to the validity of the adopted rainfall-runoff parameters and sets of climate sequences analysed in this report. It was assumed that the adopted historical dataset is representative of what can be expected to occur in the future. No allowance has been made for possible future changes in rainfall and evaporation that may result from climate change.

The estimated surpluses / deficits presented in this report are also subject to modelled assessments of groundwater inflows to the underground mine sump and the void spaces behind the bulkheads. The groundwater inflow and demands were considered static and assumed to be constant annually. The impact of intra-annual variation in these inputs on the water balance was not assessed.

Further analyses and data collection would be required to assess sensitivity of the project surpluses and deficits in more detail to intra-annual variation in rainfall, runoff and groundwater.

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Appendix A

Hydrological analyses

A1. Streamflow analysis

The streamflows were analysed for flow duration curves and volumetric runoff coefficients to compare similarity and representativeness of Hume Coal gauged data with the WaterNSW records.

The runoff coefficient is the fraction of rainfall that appears as stormwater run-off from a surface. Depending on the soil type and rainfall intensity the runoff coefficient from pervious areas could be as low as no runoff at all (for the case of low rainfall intensity on sandy soil) or up to 80% (for the case of high rainfall on clay soil).

Table A1 summarises annual average runoff coefficients for three sub-sets of data from 1990 to 2015: Jan 1990 to Sep 2015, May 2015 to Sep 2015 (data availability period for SW08) and Aug 2014 to Sep 2015 (data availability period for SW04). Note that the runoff coefficients in Table A1 are presented as percentage. The rainfall data from Data Drill for the Oldbury location was used in the runoff coefficient calculations.

The table clearly shows variability in volumetric runoff coefficients for the gauging sites for the Wingecarribee River. The runoff coefficients for the gauging sites, 212031 and 212272, upstream of the SBs and MWDs are 45% and 36% based on the data period from 1990 to 2015. The runoff coefficient is as low as 18% for the Wingecarribee River at 212009 which is roughly 30 km downstream from the 212272 stream gauge.

The runoff coefficients for the WaterNSW gauges for the data period from May 2015 to September 2015 were more than 53% but less than 60%. For the same period the runoff coefficient from SW04 gauge was found to be 88%. Similarly the runoff coefficient for the SW08 gauge was 39%. Similarly the runoff coefficients for the period from August 2015 to September 2015 were calculated to be 51% for SW04 and 42% for the up-gradient WaterNSW gauges. The runoff coefficient analyses demonstrates that the SW04 recorded much higher runoff compared to both up-gradient WaterNSW stream gauges. The runoff coefficient from the Hume Coal SW08 gauge was the lowest.

A flow duration curve represents how often any given flow discharge is likely to be equalled or exceeded. The x axis corresponds to probabilities of exceedance, while the y axis corresponds to stream flow discharges.

Daily flow duration curves for the gauging stations in the Wingecarribee River for the data period from 1989 to 2015 are provided in Figure A1. Flows are represented as runoff depths (volume per unit area) to allow comparison between the three gauging stations. Only 1% of the daily runoff depths are greater than 7 mm/day at all gauging sites. For 99% of the data points the Bong Bong (No. 212031) and Berrima (No. 212272) gauging sites were greater than the Greenstead (No. 212009) gauging site, the former being the greatest. This is potentially due to the relative proportion of in-stream weir volume capacity per unit catchment area and illustrates the effects of river streamflow regulation by weir structures.

Table A1 **Average volumetric runoff coefficients for gauged streamflows**

Gauging site	Runoff (mm) Jan 1990 - Sep 2015	Runoff (mm) May 2015 - Sep 2015	Runoff (mm) Aug 2014 - Sep 2015	Runoff (%) Jan 1990 - Sep 2015	Runoff (%) May 2015 - Sep 2015	Runoff (%) Aug 2014 - Sep 2015
212009	3,478	182	391	18%	53%	29%
212272	7,158	203	569	36%	59%	42%
212031	8,764	191	569	45%	55%	42%
SW04	Gap	302	695	Gap	88%	51%
SW08	Gap	133	Gap	Gap	39%	Gap
Data Drill Rainfall	19,654	344	1370	100%	100%	100%

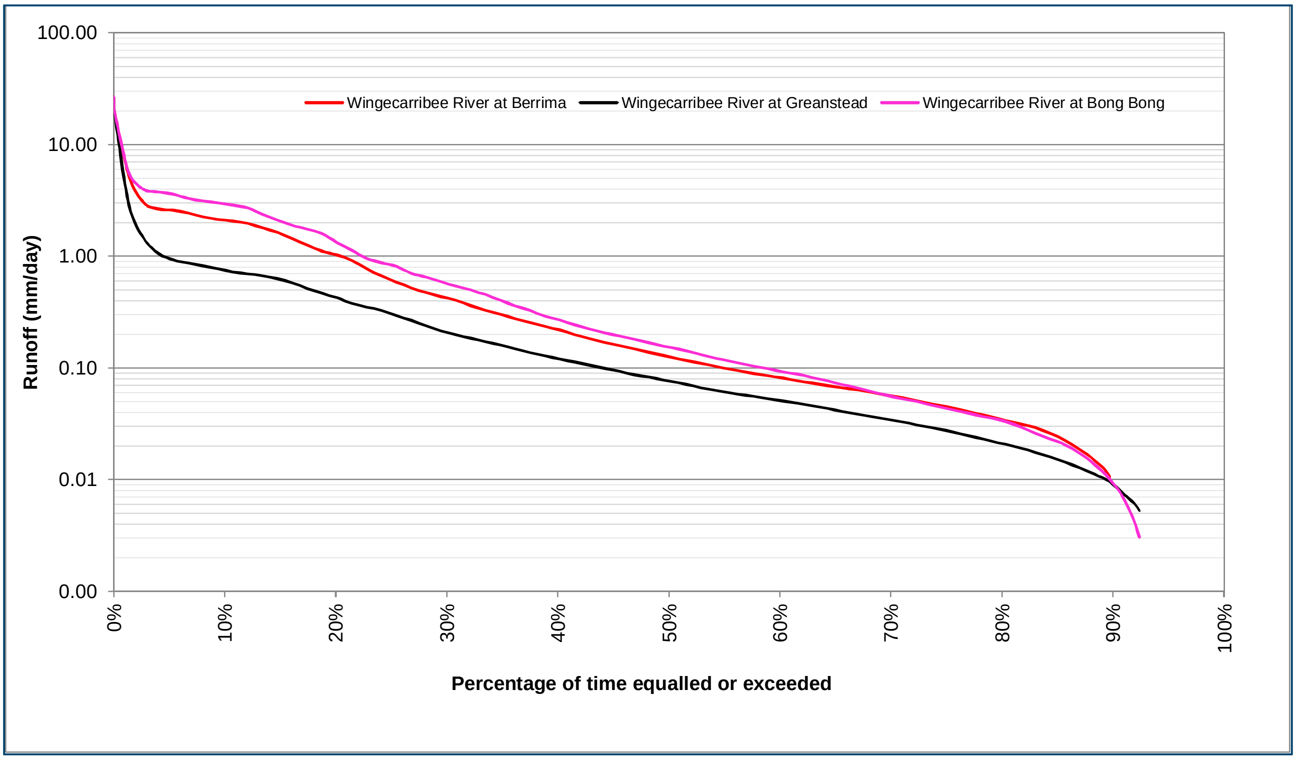


Figure A1 **Flow duration curves for WaterNSW gauging stations on the Wingecarribee River (1989 to 2015)**

A2. Rainfall-runoff

A2.1 AWBM

The AWBM is a partial area saturation overland flow model. The use of partial areas divides the catchment into regions (contributing areas) that produce runoff during a rainfall-runoff event and those that do not. These contributing areas vary within a catchment according to antecedent catchment conditions and allow for the spatial variability of surface storage in a catchment. The use of the partial area saturation overland flow approach is simple and provides a good representation of the physical processes occurring in most Australian catchments (Boughton, 1993). This is because daily infiltration capacity is rarely exceeded, and the major source of runoff is from saturated areas. Figure A2 shows a flowchart of the AWBM algorithm.

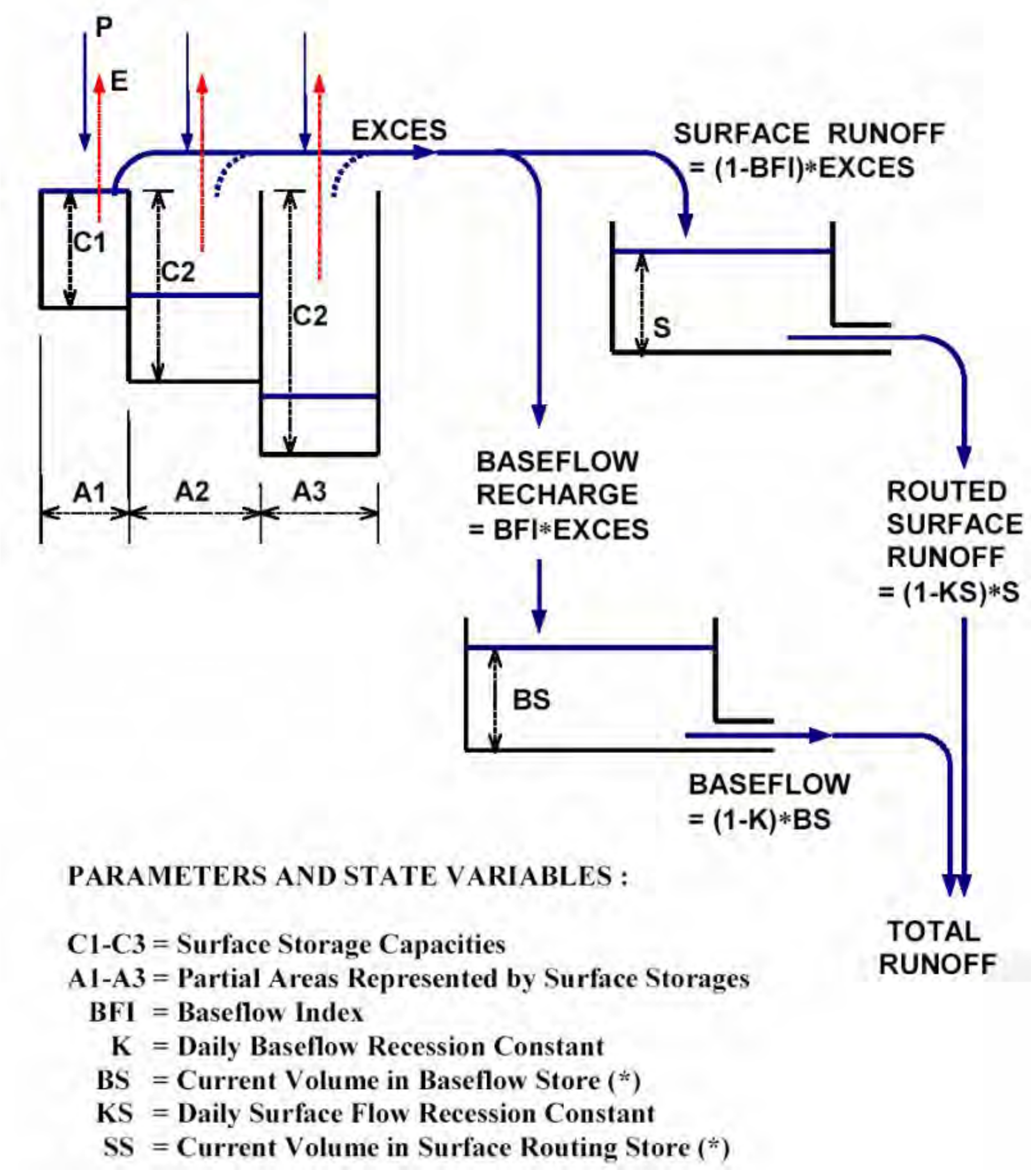


Figure A2 **Structure of the AWBM rainfall-runoff model (CRC for Catchment Hydrology Australia, 2004)**

To implement the AWBM in a given catchment, a set of nine parameters must be defined as summarised in Table A2. These parameters define the generalised model for a particular catchment. The parameters are usually derived for a gauged catchment by a process of calibration where the recorded stream flows are compared with calculated stream flows.

Table A2 Description of AWBM parameters

Parameter	Description
A1, A2, A3	Partial areas represented by surface storages
C1, C2, C3	Surface storage capacities
Ks	Daily surface flow recession constant
BFI	Baseflow index
K	Daily baseflow recession constant

A2.2 AWBM calibration for undisturbed catchment

AWBM parameters for undisturbed areas were selected by a simple calibration process that involved matching the simulated daily flow duration curve and average runoff coefficient to stream flow records for the Wingecarribee River gauging stations and the nearest Hume Coal gauging stations, SW04 and SW08. Note that the pre-mining catchment is largely rural, however, is referred to as 'undisturbed' for the purposes of this study.

The Wingecarribee River at Greenstead (No. 212009) station receives runoff from a total catchment area of 587 km^2, however; 200 km^2 of this area is regulated by two in-stream reservoirs located just upstream of the other two gauging stations (No. 212031 and No. 212272). An area of 39.4 km^2 is captured by the Wingecarribee Reservoir. Overflows and releases from this reservoir and runoffs from local catchment of 93.8 km^2 are captured by the Bong-Bong Reservoir upstream of the 212031 gauging station. The intermediate area between the Bong-Bong Reservoir and the Berrima gauging station (No 212272) is captured by the Berrima Weir which is located upstream of the gauging station (No 212272).

A comparison of simulated and observed flow duration curves for Wingecarribee River at Greenstead (No. 212009) is provided in Figure A3 for the period from 1989 to 2015.

Two sets of calibration results are compared with the measured data in the form of flow duration curves.

The curve related to "low-flow calibration" for AWBM runoffs compares reasonably well to that observed low flows (<10mm/day), however fails to match high flows (<1% of the flow duration curve). The curve related to "high+low-flow calibration" for AWBM runoffs matches the high flows much better; however, the simulated discharge values less than 1mm/day are consistently under predicted.

High runoff volumes are important for water supply reliability as well as accounting for potential discharges from SBs and MWDs to the local creeks. The low flows are important for accounting for likely deficits for mine water supply during relative low rainfall years during mining.

Although a short duration of records are available from the Hume Coal gauges SW04 and SW08, the runoff characteristics for SW08 are more representative of local runoffs expected from the mine site than SW04.

Figure A4 shows a comparison between the flow duration curves for SW08 for the gauged and the AWBM simulated flow dataset. The simulated flow data points compares very well for flows exceeding 15% of the time. The simulated curve diverges from the gauged dataset for flows less than 1 mm/day. Note that baseflow is a dominant feature in the SW08 dataset.

The AWBM relationship for SW08 will require further refinement as more data points become available from future gauging. The AWBM generated runoff time series will be used in quantifying changes to the hydrological regime for Oldbury Creek and Medway Rivulet from mine related surface flow reduction or increased discharges to the creeks.

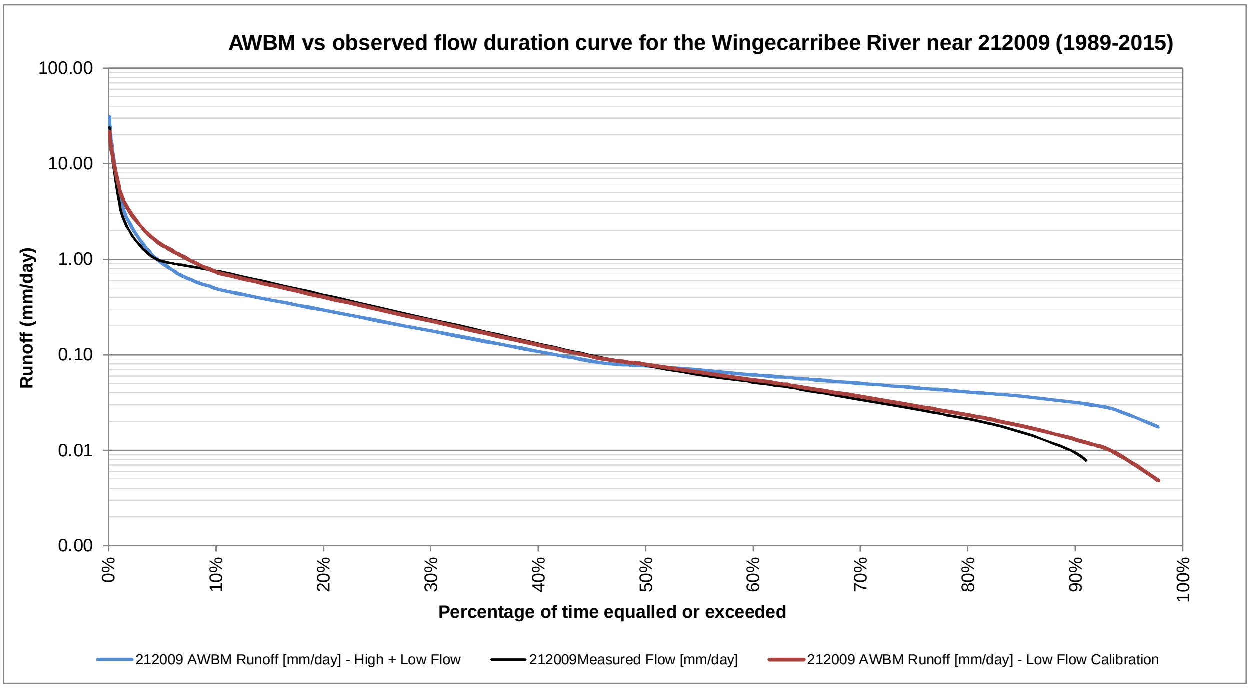


Figure A3 **Comparison of AWBM simulated and observed flow duration curves (1889 to 2015) for the data from Wingecarribee River at Greenstead**

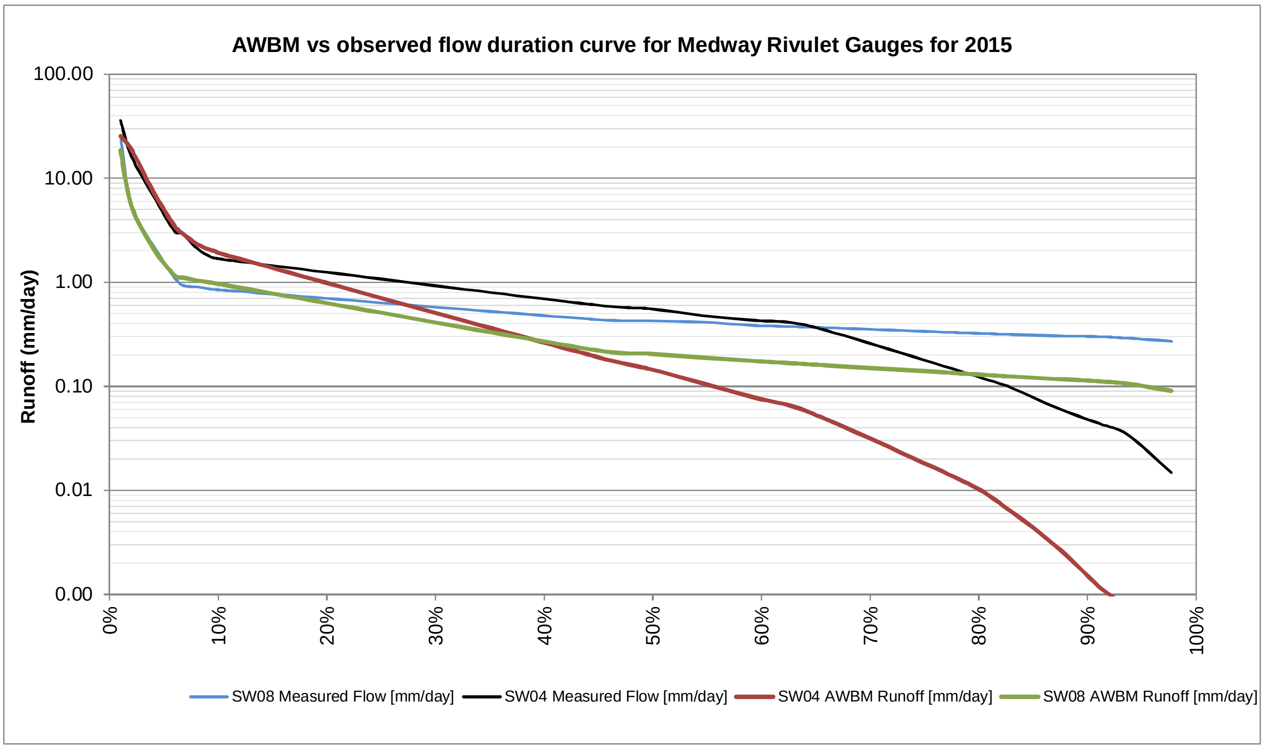


Figure A4 **Comparison of AWBM simulated and observed flow duration curves for available data from 2014 to 2015 for Hume Coal gauges, SW04 and SW08**

Table A3 presents a summary of runoff volumes and runoff coefficients for gauged and AWBM simulated runoffs for three data periods: January1990- September 2015, August 2014 – September 2015 and May 2015 to September 2015. The data periods reflect availability of datasets from the gauging stations for the Wingecarribee River, SW04 and SW08 respectively.

The AWBM model calibration was undertaken based on the longest available dataset, however the data summary for shorter periods were sampled from the same simulated result. For example, the AWBM simulated runoffs from 1989 to 2015 were resampled to extract total runoff volume and average daily runoff coefficients for January1990- September 2015, August 2014 – September 2015 and May 2015 to September 2015.

The following can be observed from the data presented in Table A3:

- The long term AWBM runoff volumes and coefficients for 212009 compare well with the gauged runoff volume and average coefficients for the period of 1990-2015. The runoff coefficient obtained using the "Low-Flow Calibration" matches the best.
- The resampled simulated values for shorter data periods are substantially less than the measured dataset for 212009 gauging station.
- The simulated data summaries for 212272 and 212031 gauging stations compare well with the numbers for the respective gauged values for shorter data periods but are grossly under predicted for the long term values.
- The simulated data summaries for SW04 and SW08 compare well with the data summary obtained from the gauged dataset for the May 2015 to September 2015 data period.

These observations suggest that streamflow regulation plays an important role in maintaining summer flows in the Wingecarribee River. AWBM will be able estimate flow volumes from larger rainfall events with a reasonable accuracy, however the model will be under predicting the summer flows in the river as the model does not simulate storages and operating rules for the weir and the in-stream reservoirs. Nevertheless, the AWBM calibrations were considered reasonable regardless of the streamflow regulation complications.

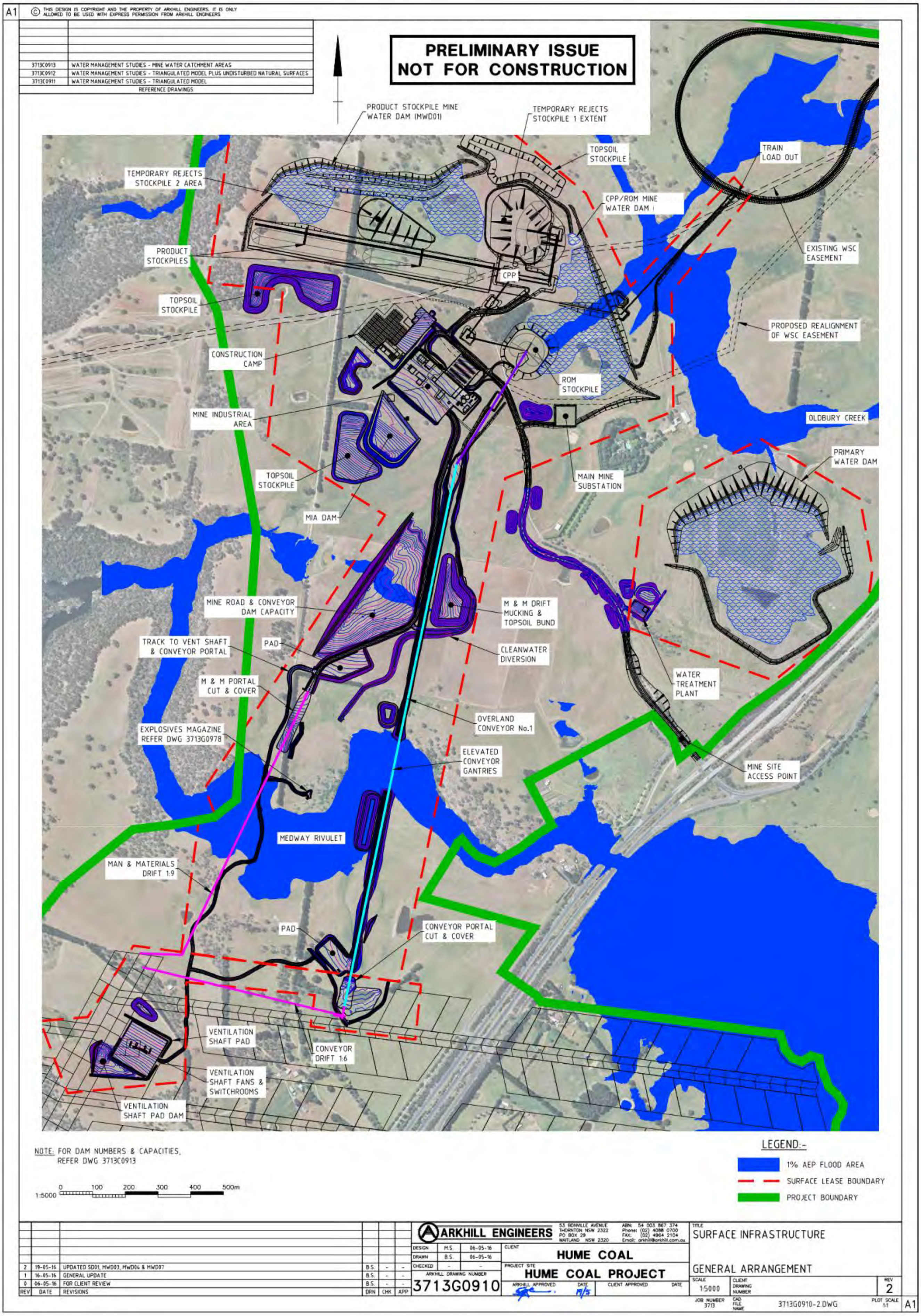
The AWBM model will be able to simulate local scale flows from the SW04 and SW08 catchments for the majority of large rainfall events for undisturbed catchments. The model parameters will require further refinement as more data becomes available. Given the proximity of mine dam catchments to SW08 catchment and in the low rainfall zone, the AWBM rainfall-runoff model calibrated for SW08 was adopted for the project site rainfall-runoff from the undisturbed area.

Table A3 Summary of total runoff volumes and average daily runoff coefficients for measured and simulated flows

Site data cases	Runoff (mm) Jan 1990 - Sep 2015	Runoff (mm) May 2015 - Sep 2015	Runoff (mm) Aug 2014 - Sep 2015	Runoff (%) Jan 1990 - Sep 2015	Runoff (%) May 2015 - Sep 2015	Runoff (%) Aug 2014 - Sep 2015
212009 gauged flow	3,478	182	391	18%	53%	29%
212009 AWBM - high + low flow calibration	3,393	156	372	17%	45%	27%
212009 AWBM - low flow calibration	3,657	177	434	19%	51%	32%
212272 gauged flow	7,158	203	569	36%	59%	42%
212272 AWBM - high flow calibration	4,644	198	527	24%	57%	39%
212272 AWBM - high + low flow calibration	4,627	189	505	24%	55%	37%
212031 gauged flow	8,764	191	569	45%	55%	42%
212031 AWBM - high flow calibration	3,767	178	444	19%	52%	32%
212031 AWBM - high + low flow calibration	3,739	159	407	19%	46%	30%
SW04 gauged flows	Gap	302	695	Gap	88%	51%
SW04 AWBM - high + low flow calibration	Gap	241	571	Gap	70%	42%
SW08 gauged flows	Gap	133	Gap	Gap	39%	Gap
SW08 AWBM - high + low flow calibration	Gap	101	Gap	Gap	29%	Gap
Data Drill Rainfall	19,654	344	1,370			

Appendix B

Infrastructure layout plans


A1
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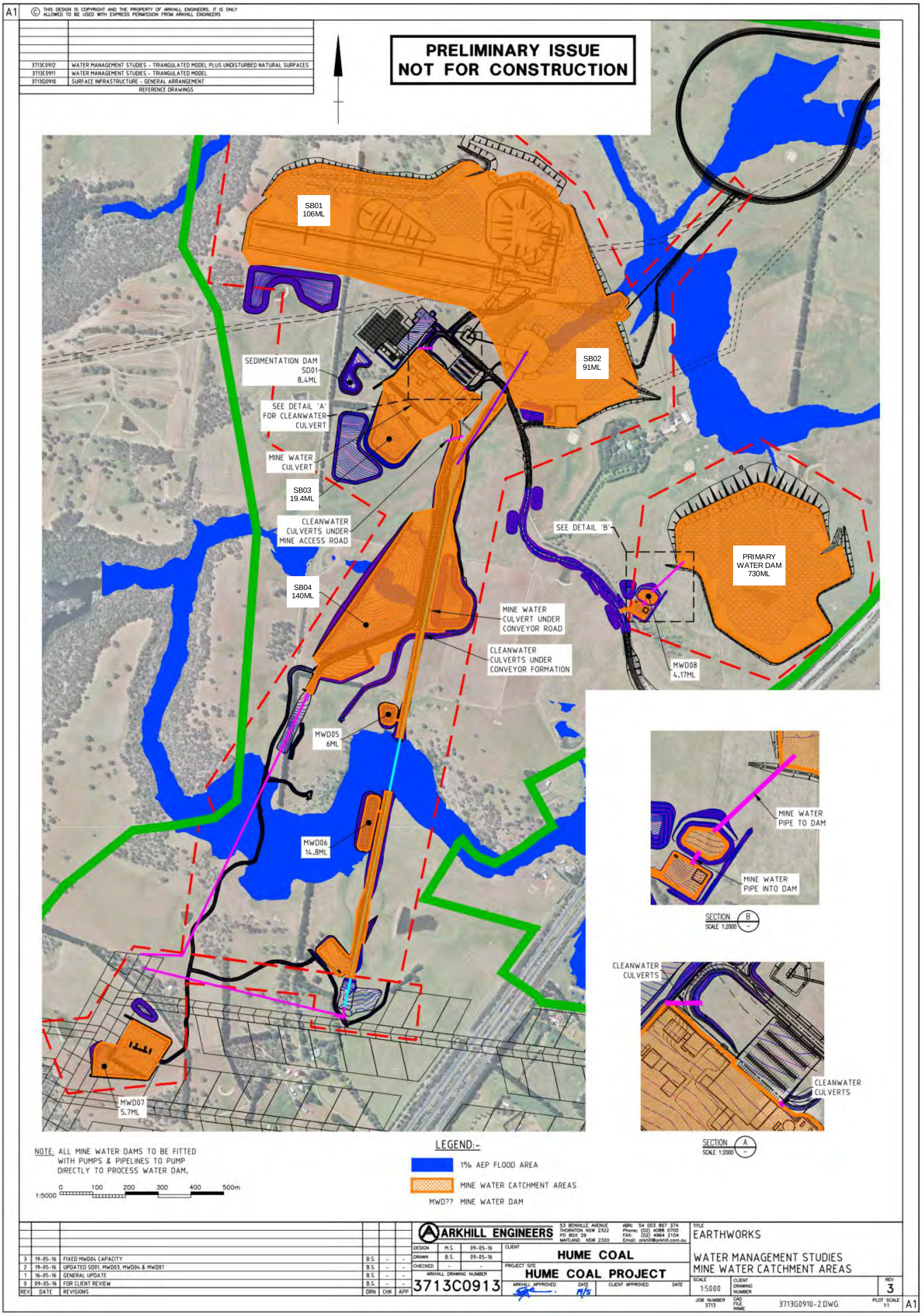
3713C0913 WATER MANAGEMENT STUDIES - MINE WATER CATCHMENT AREAS
3713C0912 WATER MANAGEMENT STUDIES - TRIANGULATED MODEL PLUS UNDISTURBED NATURAL SURFACES
3713C0911 WATER MANAGEMENT STUDIES - TRIANGULATED MODEL
REFERENCE DRAWINGS
PRELIMINARY ISSUE
NOT FOR CONSTRUCTION
PRODUCT STOCKPILE MINE WATER DAM (MWD01)
TEMPORARY REJECTS STOCKPILE 1 EXTENT
TOPSOIL STOCKPILE
TRAIN LOAD OUT
TEMPORARY REJECTS STOCKPILE 2 AREA
CPP/ROM MINE WATER DAM
EXISTING WSC EASEMENT
PRODUCT STOCKPILES
CPP
TOPSOIL STOCKPILE
PROPOSED REALIGNMENT OF WSC EASEMENT
CONSTRUCTION CAMP
ROM STOCKPILE
MINE INDUSTRIAL AREA
OLDBURY CREEK
PRIMARY WATER DAM
TOPSOIL STOCKPILE
MAIN MINE SUBSTATION
MIA DAM
MINE ROAD & CONVEYOR DAM CAPACITY
M & M DRIFT MUCKING & TOPSOIL BUND
TRACK TO VENT SHAFT & CONVEYOR PORTAL
PAD
CLEANWATER DIVERSION
M & M PORTAL CUT & COVER
WATER TREATMENT PLANT
OVERLAND CONVEYOR No.1
EXPLOSIVES MAGAZINE REFER DWG 3713G0978
ELEVATED CONVEYOR GANTRIES
MINE SITE ACCESS POINT
MEDWAY RIVULET
MAN & MATERIALS DRIFT 1:9
PAD
CONVEYOR PORTAL CUT & COVER
VENTILATION SHAFT PAD
CONVEYOR DRIFT 1:6
VENTILATION SHAFT FANS & SWITCHROOMS
VENTILATION SHAFT PAD DAM
NOTE: FOR DAM NUMBERS & CAPACITIES, REFER DWG 3713C0913
1:5000 0 100 200 300 400 500m
LEGEND:-
1% AEP FLOOD AREA
SURFACE LEASE BOUNDARY
PROJECT BOUNDARY
2 19-05-16 UPDATED SD01, MWD03, MWD04 & MWD07 B.S. - -
1 16-05-16 GENERAL UPDATE B.S. - -
0 06-05-16 FOR CLIENT REVIEW B.S. - -
REV DATE REVISIONS DRN CHK APP
ARKHILL ENGINEERS
53 BONVILLE AVENUE THORNTON NSW 2322 PO BOX 29 MAITLAND NSW 2320
ABN: 54 003 867 374 Phone: (02) 4088 0700 FAX: (02) 4964 2104 Email: arkhill@arkhill.com.au
DESIGN M.S. 06-05-16
DRAWN B.S. 06-05-16
CHECKED - -
ARKHILL DRAWING NUMBER
3713G0910
CLIENT HUME COAL
PROJECT SITE HUME COAL PROJECT
ARKHILL APPROVED DATE 19/5 CLIENT APPROVED DATE
TITLE SURFACE INFRASTRUCTURE
GENERAL ARRANGEMENT
SCALE 1:5000
CLIENT DRAWING NUMBER
REV 2
JOB NUMBER 3713
CAD FILE NAME 3713G0910-2.DWG
PLOT SCALE 1:1
A1



A1
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3713C0912 WATER MANAGEMENT STUDIES - TRIANGULATED MODEL PLUS UNDISTURBED NATURAL SURFACES
3713C0911 WATER MANAGEMENT STUDIES - TRIANGULATED MODEL
3713G0910 SURFACE INFRASTRUCTURE - GENERAL ARRANGEMENT
REFERENCE DRAWINGS
PRELIMINARY ISSUE
NOT FOR CONSTRUCTION
SB01
106ML
SB02
91ML
SEDIMENTATION DAM
SD01
8.4ML
SEE DETAIL 'A' FOR CLEANWATER CULVERT
MINE WATER CULVERT
SB03
19.4ML
CLEANWATER CULVERTS UNDER MINE ACCESS ROAD
SEE DETAIL 'B'
PRIMARY WATER DAM
730ML
SB04
140ML
MINE WATER CULVERT UNDER CONVEYOR ROAD
CLEANWATER CULVERTS UNDER CONVEYOR FORMATION
MWD08
4.17ML
MWD05
6ML
MWD06
14.8ML
MWD07
5.7ML
MINE WATER PIPE TO DAM
MINE WATER PIPE INTO DAM
SECTION B
SCALE 1:2000
CLEANWATER CULVERTS
CLEANWATER CULVERTS
SECTION A
SCALE 1:2000
NOTE: ALL MINE WATER DAMS TO BE FITTED WITH PUMPS & PIPELINES TO PUMP DIRECTLY TO PROCESS WATER DAM.
1:5000 0 100 200 300 400 500m
LEGEND:-
1% AEP FLOOD AREA
MINE WATER CATCHMENT AREAS
MWD?? MINE WATER DAM
3 19-05-16 FIXED MWD04 CAPACITY B.S. - -
2 19-05-16 UPDATED SD01, MWD03, MWD04 & MWD07 B.S. - -
1 16-05-16 GENERAL UPDATE B.S. - -
0 09-05-16 FOR CLIENT REVIEW B.S. - -
REV DATE REVISIONS DRN CHK APP
ARKHILL ENGINEERS
53 BONVILLE AVENUE THORNTON NSW 2322 PO BOX 29 MAITLAND NSW 2320
ABN: 54 003 867 374 Phone: (02) 4088 0700 FAX: (02) 4964 2104 Email: arkhill@arkhill.com.au
DESIGN M.S. 09-05-16
DRAWN B.S. 09-05-16
CHECKED - -
CLIENT HUME COAL
PROJECT SITE HUME COAL PROJECT
ARKHILL DRAWING NUMBER 3713C0913
ARKHILL APPROVED DATE 19/5
CLIENT APPROVED DATE
TITLE EARTHWORKS
WATER MANAGEMENT STUDIES
MINE WATER CATCHMENT AREAS
SCALE 1:5000
CLIENT DRAWING NUMBER
REV 3
JOB NUMBER 3713
CAD FILE NAME 3713G0910-2.DWG
PLOT SCALE 1:1
A1

Appendix C

Basin and dam stage-storage-area relationships

C1. Basin and dam stage-storage-area relationships

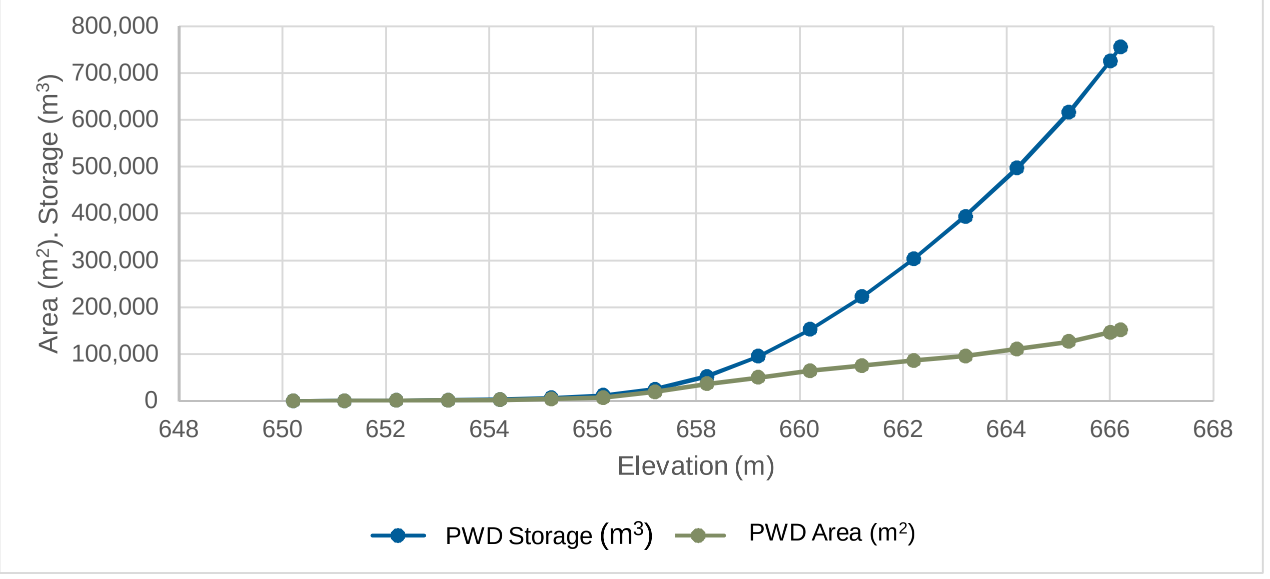

Figure C1.1 Stage-Storage-area-volume relationship for PWD

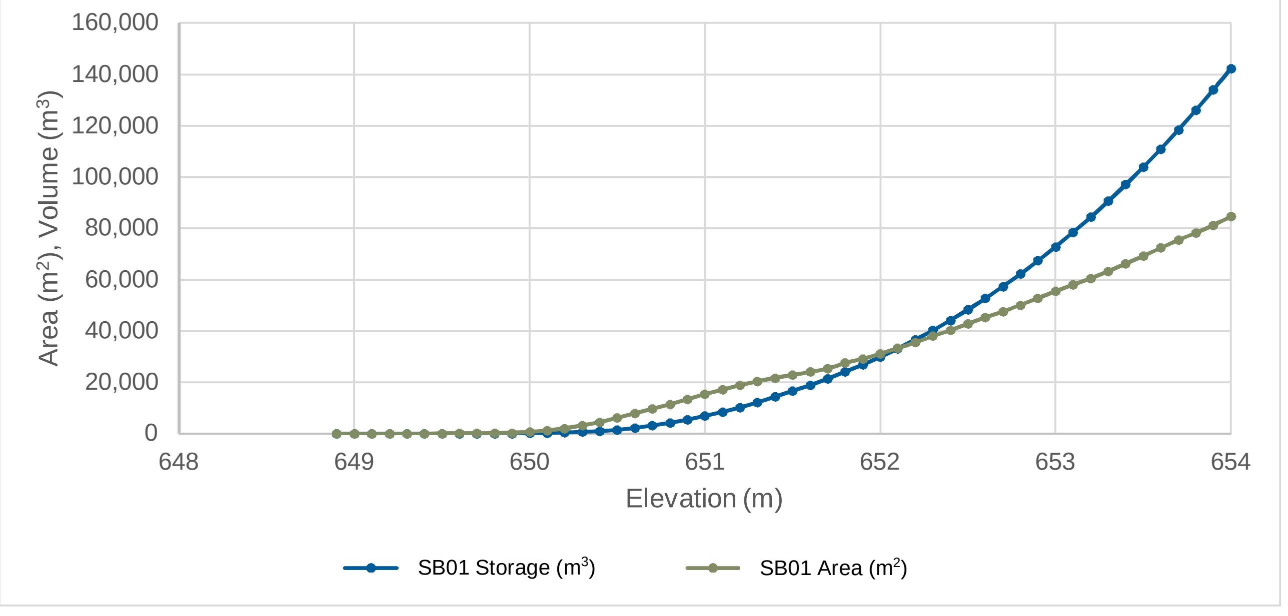

Figure C1.2 Stage-storage-area-volume relationship for SB01

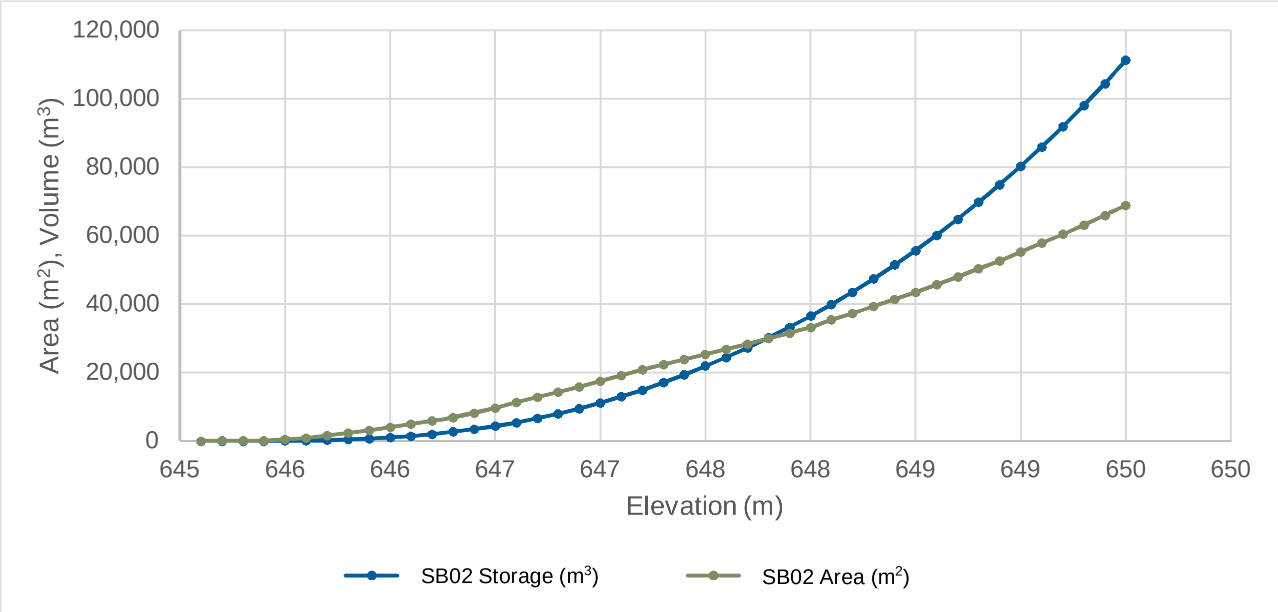

Figure C1.3 Stage-storage-area-volume relationship for SB02

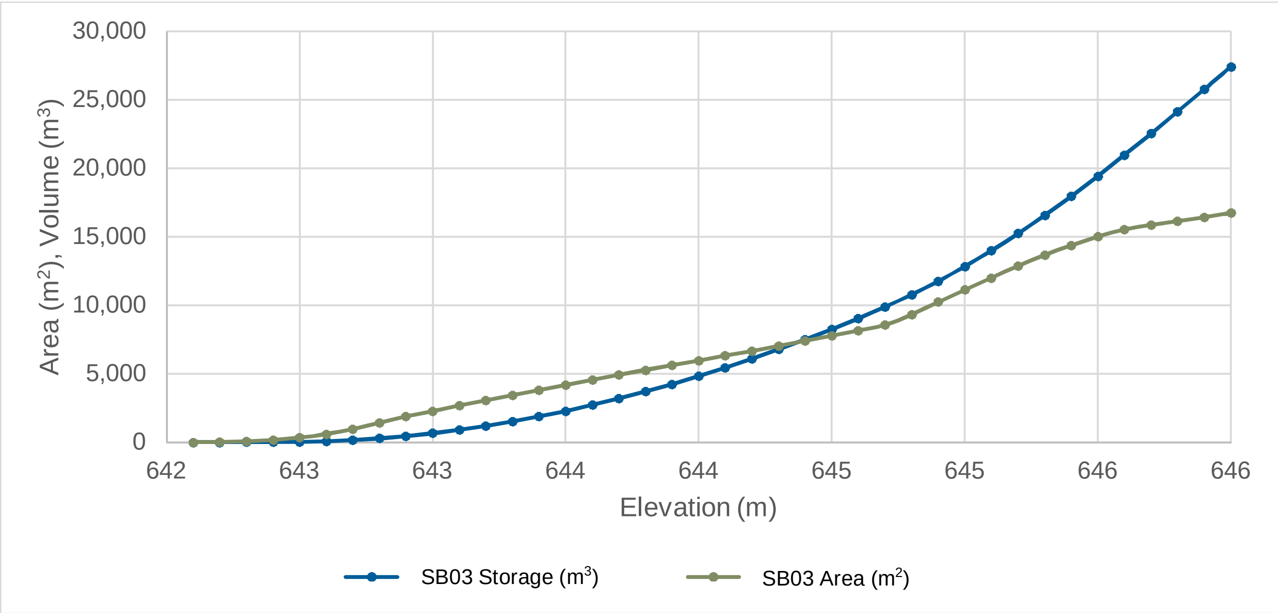

Figure C1.4 Stage-storage-area-volume relationship for SB03

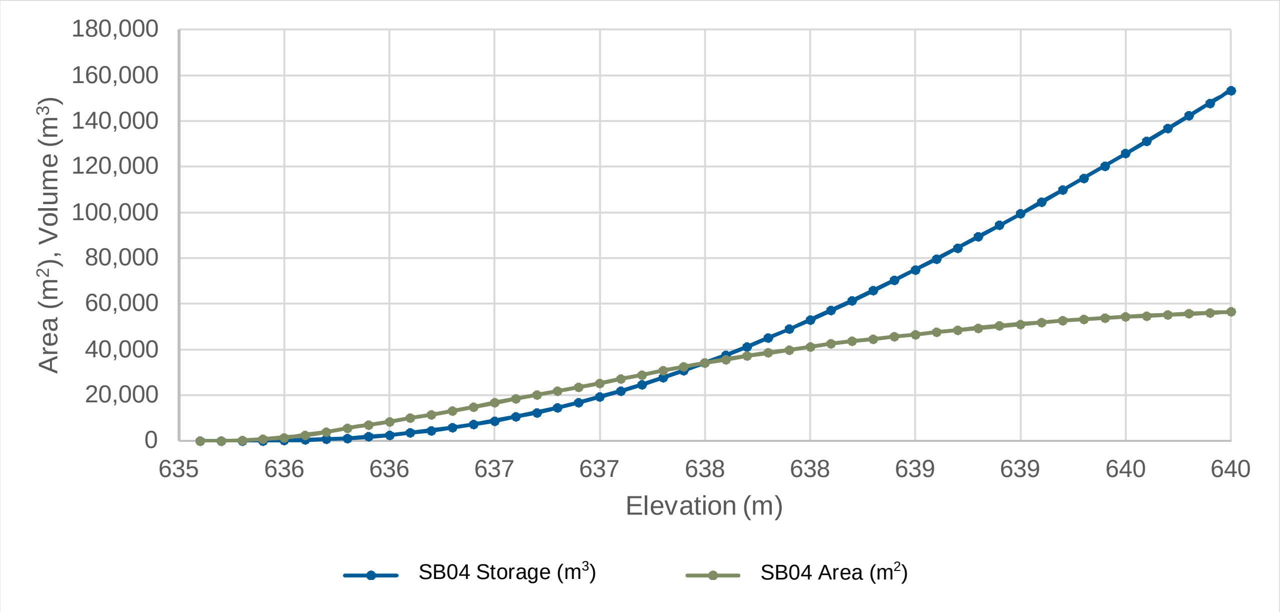

Figure C1.5 **Stage-storage-area-volume relationship for SB04**

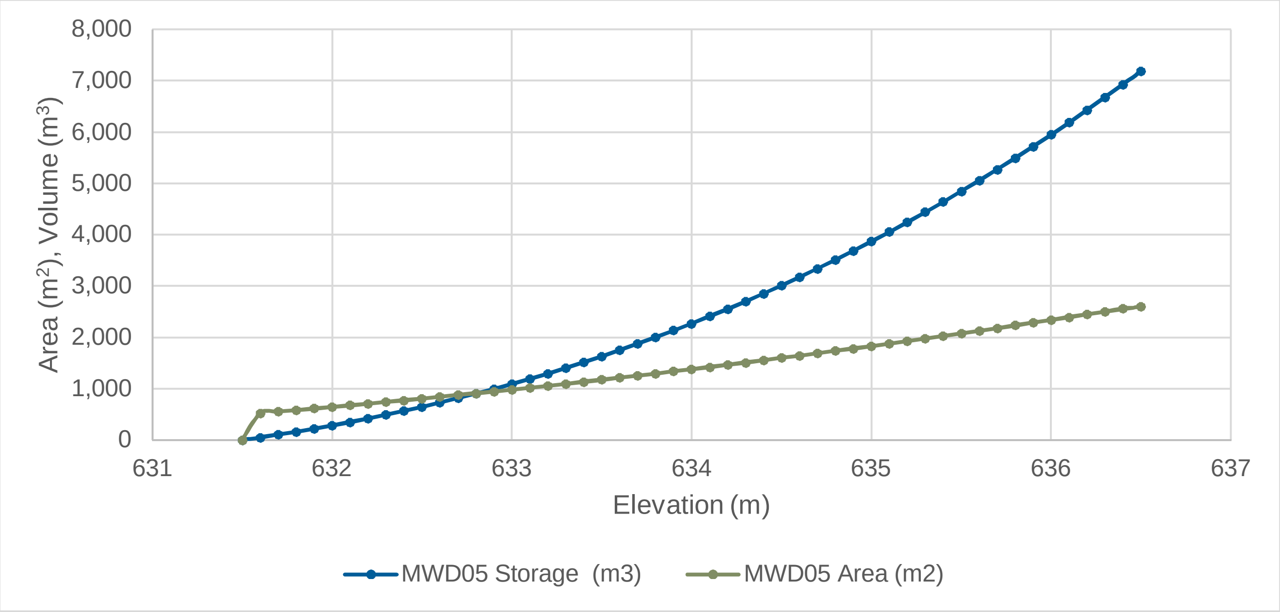

Figure C1.6 **Stage-storage-area-volume relationship for MWD05**

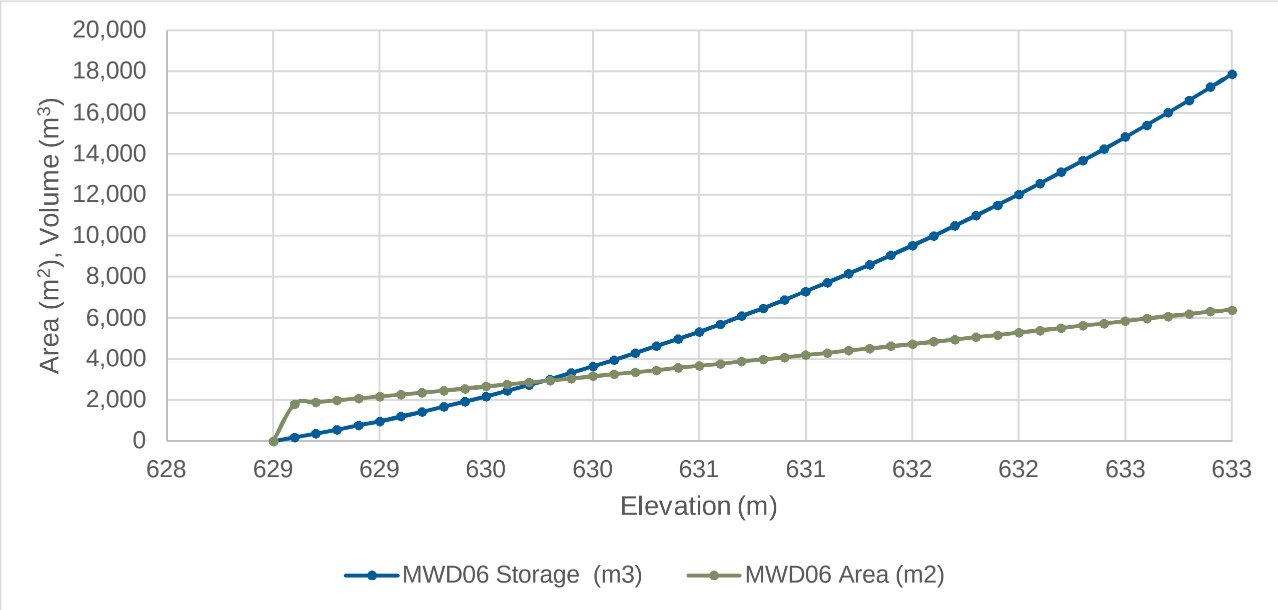

Figure C1.7 Stage-storage-area-volume relationship for MWD06

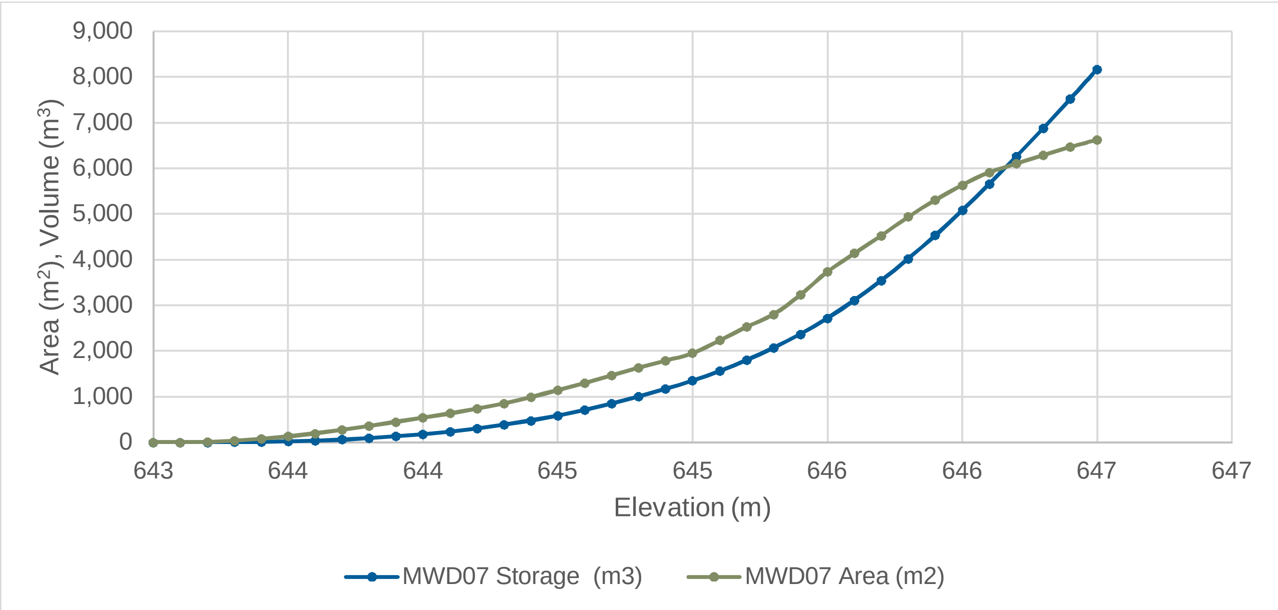

Figure C1.8 Stage-storage-area-volume relationship for MWD07

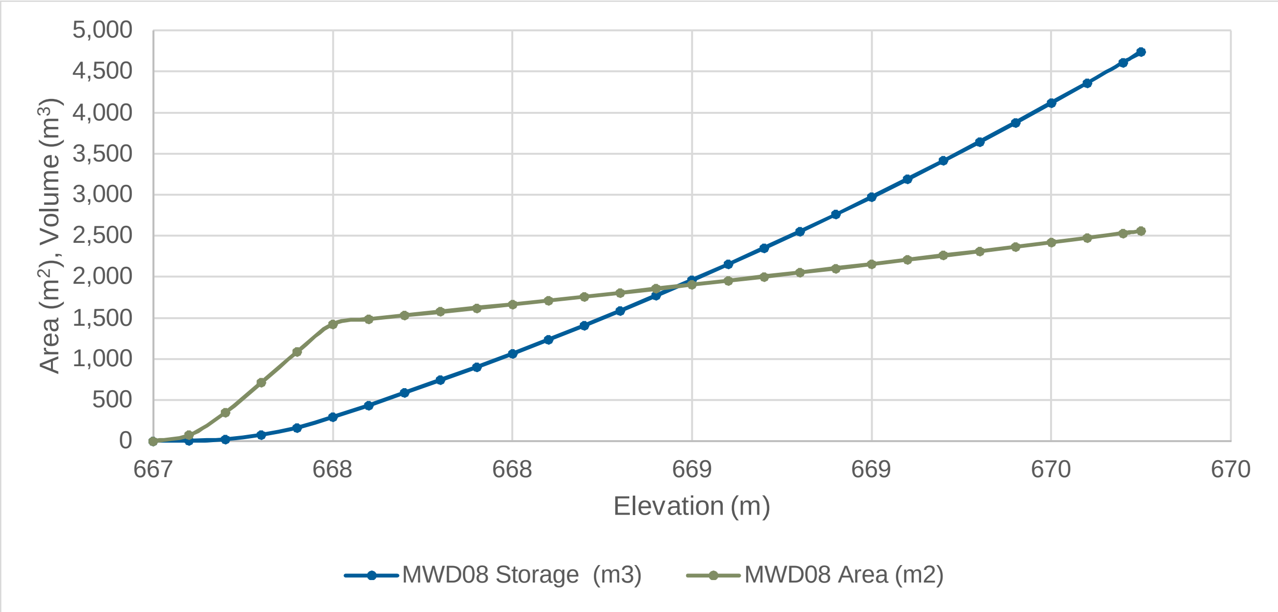

Figure C1.9 **Stage-storage-area-volume relationship for MWD08**

Appendix D

Demand information

D1. CHPP water balance

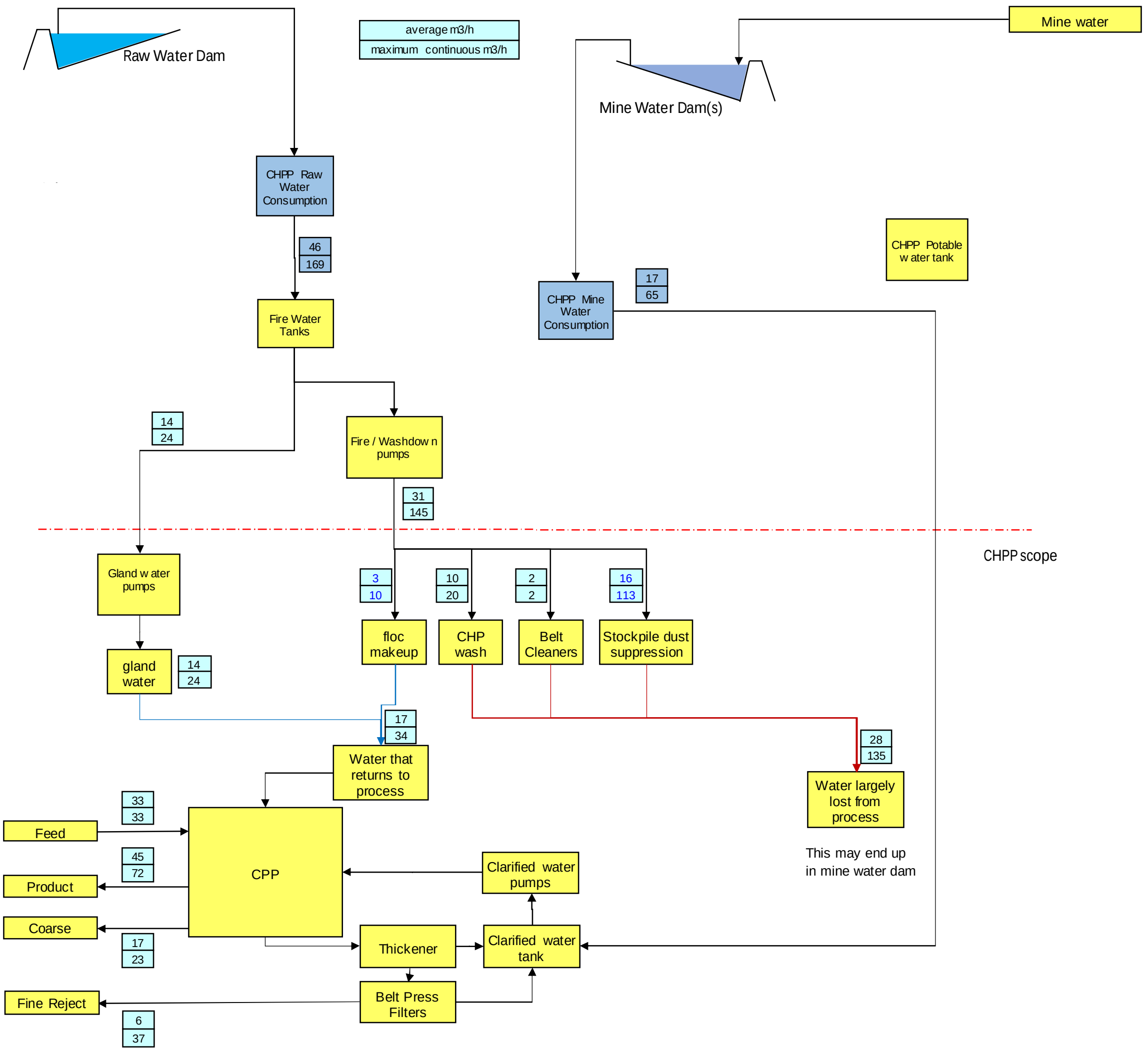

Figure D1.1 **CHPP water balance flow diagram for 600 tonne per hour plant feed (source: HUM1652-373 Water Balance Spreadsheet mdb090516.xlsx, Hume Coal, 21 June 2016)**

Table D1.1 CHPP water balance calculation for 600 tonne per hour plant feed (source: HUM1652-373 Water Balance Spreadsheet mdb090516.xlsx, Hume Coal, 21 June 2016)

QCC RESOURCES

HUME COAL PROJECT
600 t/h *CHPP* WATER BALANCE
QCC Doc. No.: HUM01-JA315-NCAL-G-016
Revision: A
Date: 22/11/2013

Stream	average solids tonnage (a.r.) t/h	maximum solids tonnage t/h	% solids	max pulp flow m3/h	average water flow m3/h	Maximum continuous water Flow m3/h	water source	assumptions
annual operating hours								7000
plant feed	600				33	33		5,5%free moisture
product					45	72		
coarse reject					17	23		
Belt Press fine reject	15	16			6	37		Max assumes tailings to emergency pond
Required CPP clarified water makeup					35	99	mine	
gland water					14	24	clean	2x DMC + 2x Filtrate: 60l/min nom, 100l/min max
floc makeup					3	10	clean	500 g/t dosage, 0.3% solution (thick +bp)
CHP washdown					10	20	clean	1 hoses nom, 2 hoses max
Belt Cleaners					2	2	clean	
Dust Suppression					16	113	clean	1 cannon, 2 dayshifts / week average
Fire washdown water pumps					31	145	clean	
CPP washdown					0	0		2 hoses nom, 4 hoses max off clarified water
floc secondary dilution					0	0		10:1 dilution off clarified water supply
subtotal water lost to process					28	135		
subtotal water return to process					17	34		
additional makeup water required to clarified water					17	65		
CHPP Clean Water Consumption					46	169		
CHPP Mine Water Consumption					17	65		
Total water consumption					63			
Water consumption per ROM tonne					0.105			

This water balance assumes that:

1. CPP washdown hoses are operated from the low and/or high pressure clarified water system
2. Secondary Flocculant dilution is from Clarified water(rather than raw water which would be more secure)

D2. Mining and water demand data

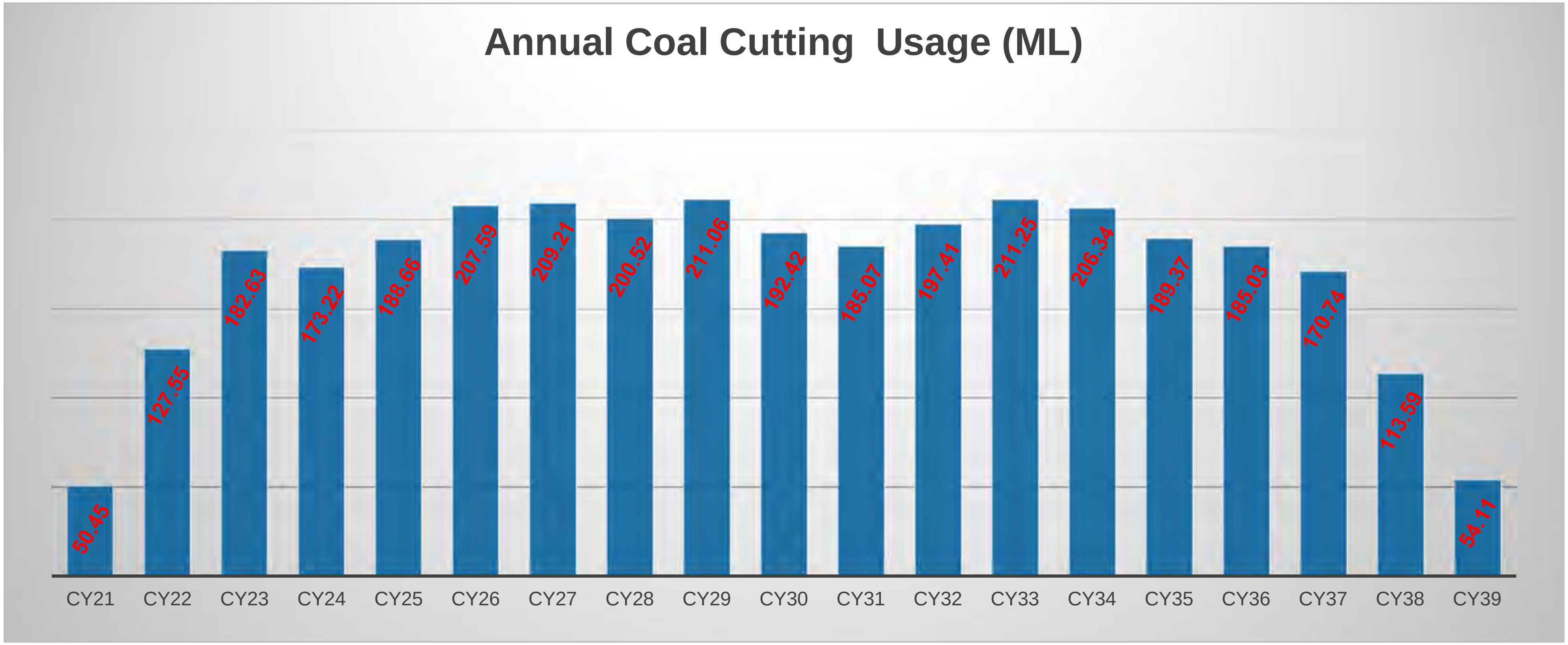

Figure D2.1 Total underground mine equipment water input for coal cutting (source: HUM1652-373 Water Balance Spreadsheet mdb090516.xlsx, Hume Coal, August 2015)

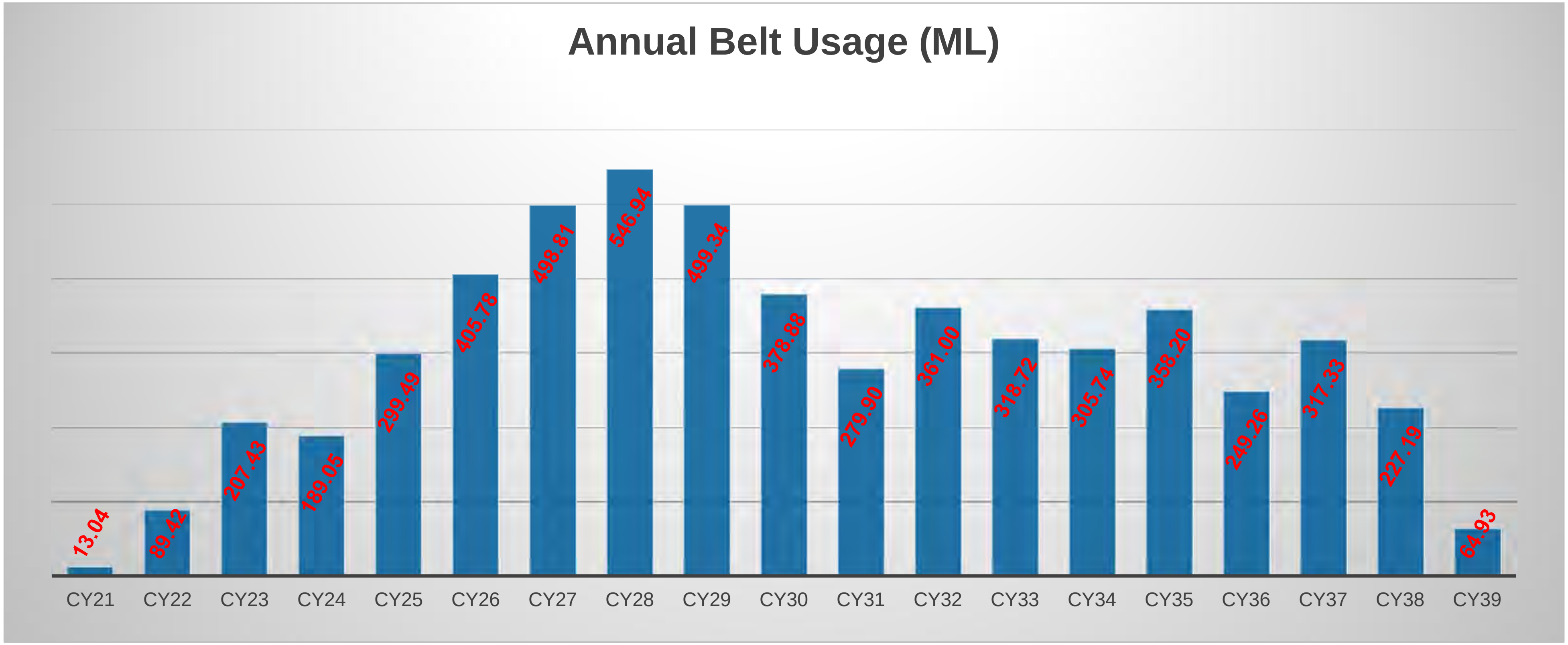

Figure D2.2 **Total underground mine equipment water input for belt usage (source: HUM1652-373 Water Balance Spreadsheet mdb090516.xlsx, Hume Coal, August 2015)**

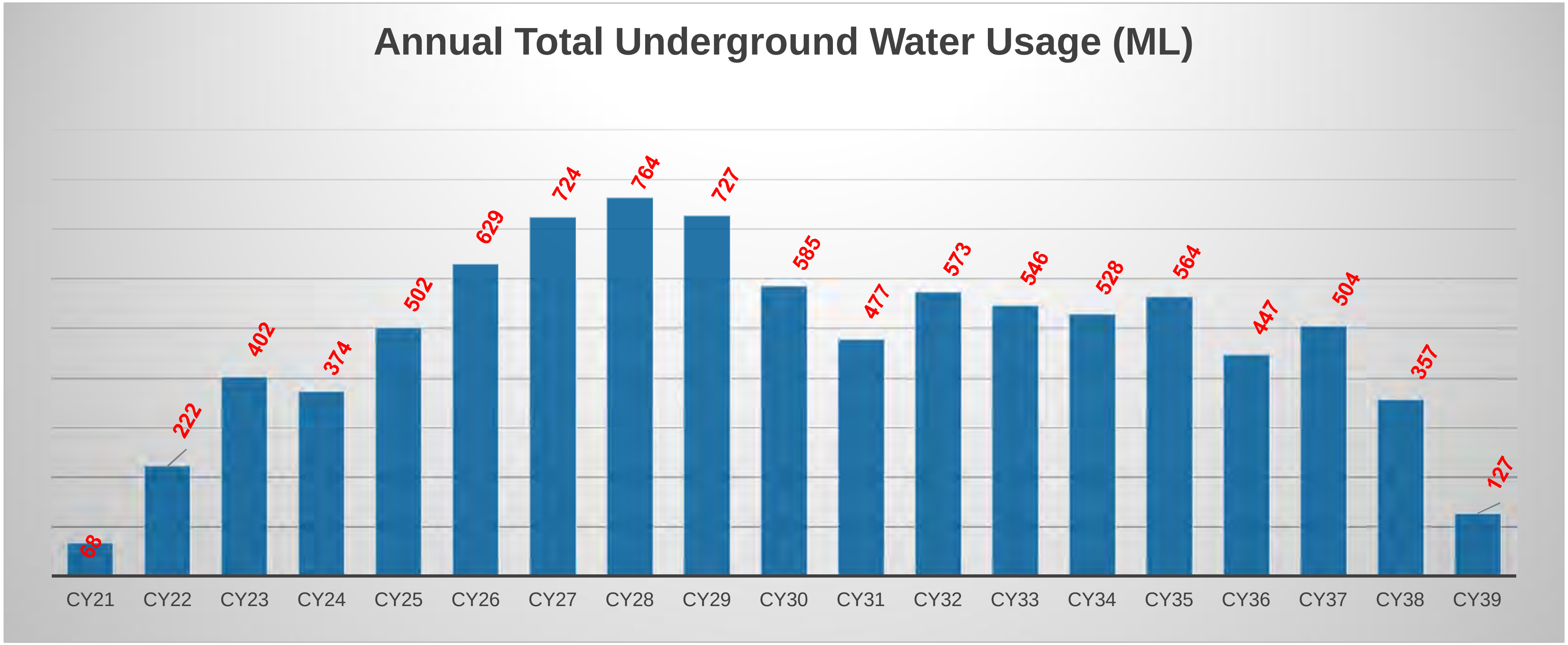

Figure D2.3 Total underground mining water requirement (source: HUM1652-373 Water Balance Spreadsheet mdb090516.xlsx, Hume Coal, August 2015)

Document Number	2172880A-520-CAL-MIA-0001	By	Dean Baker	31/08/2015
Document title	Hume coal option study - mine industrial area and construction water consumption estimate	Reviewed	Darren Morgan	31/08/2015
Revision	B	Approved	Martin Densham	31/08/2015

Design data																							
0. Mine industrial area water demands																							
Item	Type	Units	Year -1	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
0.01 Fire (raw) water	Average	(kL/day)	0	0	12	35	44	80	91	85	94	94	97	101	101	97	101	100	92	89	95	83	43
	Peak inst	(L/min)	0	0	1003	1013	1018	1034	1039	1036	1041	1041	1042	1044	1044	1042	1044	1043	1040	1039	1041	1036	1017
0.02 Potable water	Average	(kL/day)	0	0	2	8	10	20	23	21	24	23	24	25	25	24	25	25	23	22	24	21	10
	Peak inst	(L/min)	0	0	3	13	18	34	39	36	41	41	42	44	44	42	44	43	40	39	41	36	17
1. Construction water demands																							
Item	Type	Units	Year -1	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
1.01 Fire (raw) water	Average	(kL/day)	2497	2497	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Peak inst	(L/min)	2709	2709	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.02 Potable water	Average	(kL/day)	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Peak inst	(L/min)	17	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Village water demands																							
Item	Type	Units	Year -1	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
2.01 Fire (raw) water	Average	(kL/day)	36	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Peak inst	(L/min)	347	347	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.02 Potable water	Average	(kL/day)	27	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Peak inst	(L/min)	47	47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.Total MIA and construction water demands																							
Item	Type	Units	Year -1	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
3.01 Fire (raw) water	Average	(ML/year)	925	925	4	13	16	29	33	31	34	34	35	37	37	35	37	36	34	33	35	30	16
3.02 Potable water	Average	(kL/day)	14	14	1	3	4	7	8	8	9	9	9	9	9	9	9	9	8	8	9	8	4

Figure D2.4 Fire water and potable water requirement (source: 2172880A-100-MEM-PMN-0005_A_FINAL.pdf, WSP|Parsons Brinckerhoff, August 2015)

Document number	2172880A-340-CAL-MHG-0015	By	RL		21/08/2015
Document title	Hume Coal Options Study - Product handling water consumption estimate	Reviewed	BA		21/08/2015
Revision	A3	Approved	MD		

Item	Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Reference / remarks
Design Data																					
0. Production and throughput data																					
0.01 Product tonnes	t	127,430	688,961	1,030,528	2,152,417	2,512,246	2,108,967	2,314,694	2,359,456	2,493,287	2,574,334	2,817,683	2,687,989	2,692,990	2,498,811	2,214,547	2,313,737	2,518,973	2,207,960	1,122,058	HUM1652 - 280 Annual production supplied to PB 20/08/2015
0.02 Product handling throughput	t/h	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	Basis of design
0.03 Wagon payload	t	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	77.67	Basis of design
1. Stockpile dust suppression																					
Item	Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Reference / remarks
1.01 Application wind velocity 1 (days exceeding)	m/s	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	Approximately equal to major dust lift-off wind speed, ACARP report C19007, p. 24
1.02 Number of days exceeding wind velocity 1	days/y	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	Estimated based on wind roses
1.03 Spray duration for wind velocity 1	h/day	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	Assumed
1.04 Annual spray duration for wind velocity 1	h/y	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	[1.02 x 1.03]
1.05 Dust suppression rate for wind velocity 1	mm/h/m²	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	Assumed, based on WSP | PB past experience
1.06 Application wind velocity 2 (days exceeding)	m/s	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	Approximately equal to saltation wind speed, ACARP report C19007, p. 24
1.07 Number of days exceeding wind velocity 2	days/y	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	Estimated based on wind roses
1.08 Spray duration for wind velocity 2	h/day	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	Assumed
1.09 Annual spray duration for wind velocity 2	h/y	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	[1.07 x 1.08]
1.10 Dust suppression rate for wind velocity 2	mm/h/m²	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Assumed, based on WSP | PB past experience
1.11 PC stockpile capacity	t	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	Basis of design
1.12 PC stockpile area length	m	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750m x 50m stockpile area
1.13 PC stockpile area width	m	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	750m x 50m stockpile area
1.14 PC stockpile area	m²	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	37,500	[1.12 x 1.13]
1.15 PC stockpile annual dust suppression	kl/y	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	[[1.05 ÷ 1,000mm/m] x 1.14 x 1.04 + [1.10 ÷ 1,000mm/m] x 1.14 x 1.09]
1.16 Total stockpile dust suppression	kl/y	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	103,500	[1.15]
2. Conveyor / transfer dust suppression																					
Item	Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Reference / remarks
2.01 Reclaim conveyor transfer station dust suppression	l/min	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	Assumed, Martin Engineering 48" belt, 20psi
2.02 Reclaim conveyor transfer station hours per year	h/y	35	191	286	598	698	586	643	655	693	715	783	747	748	694	615	643	700	613	312	[0.01 ÷ 0.02]
2.03 Reclaim conveyor transfer station dust suppression	kl/y	89	482	721	1,507	1,759	1,476	1,620	1,652	1,745	1,802	1,972	1,882	1,885	1,749	1,550	1,620	1,763	1,546	785	[2.01 x 60min/h x 2.02 ÷ 1,000l/kl]
2.04 TLO dust suppression per wagon	l/wagon	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	Aston Maules Creek
2.05 Wagons per year	wagons/y	1,641	8,870	13,268	27,712	32,345	27,153	29,802	30,378	32,101	33,145	36,278	34,608	34,672	32,172	28,512	29,789	32,432	28,427	14,446	[0.01 ÷ 0.03]
2.06 TLO dust suppression	kl/y	57	310	464	970	1,132	950	1,043	1,063	1,124	1,160	1,270	1,211	1,214	1,126	998	1,043	1,135	995	506	[2.04 x 2.05 ÷ 1,000l/kl]
2.07 Total conveyor / transfer dust suppression	kl/y	147	793	1,186	2,477	2,891	2,427	2,663	2,715	2,869	2,962	3,242	3,093	3,099	2,875	2,548	2,662	2,898	2,541	1,291	[2.03 + 2.06]
3. Washdown																					
Item	Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Reference / remarks
3.01 Allowance for CHP area washdown	kl/y	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	Assumed
3.02 Allowance for TLO area washdown	kl/y	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	Assumed
3.03 Total allowance for washdown	kl/y	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	[3.01 + 3.02]
4. Belt cleaners																					
Item	Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Reference / remarks
4.01 Belt cleaner spray poles	ea	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	Secondary scrapers
4.02 Belt cleaner water consumption	l/min	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	Flexco
4.03 Minutes per year	min/y	2,124	11,483	17,175	35,874	41,871	35,149	38,578	39,324	41,555	42,906	46,961	44,800	44,883	41,647	36,909	38,562	41,983	36,799	18,701	[60min/h x 0.03 ÷ 0.04]
4.04 Total belt cleaners water consumption	kl/y	17	92	137	287	335	281	309	315	332	343	376	358	359	333	295	308	336	294	150	[4.01 x 4.02 x 4.03 ÷ 1,000l/kl]
5. Total product coal handling system water consumption																					
Item	Units	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Reference / remarks
5.01 Total product coal handling system water consumption per year	Ml/y	**134**	**134**	**135**	**136**	**137**	**136**	**136**	**137**	**137**	**137**	**137**	**137**	**137**	**137**	**136**	**136**	**137**	**136**	**135**	[[1.16 + 2.07 + 3.03 + 4.04] ÷ 1,000kl/Ml]

Figure D2.5 Product handling water requirement (source: 2172880A-100-MEM-PMN-0005_A_FINAL.pdf, WSP|Parsons Brinckerhoff, August 2015)

Name		Calendar Year		CY21	CY22	CY23	CY24	CY25	CY26	CY27	CY28	CY29	CY30	CY31	CY32	CY33	CY34	CY35	CY36	CY37	CY38	CY39
		Total/Average		1/01/2021	1/01/2022	1/01/2023	1/01/2024	1/01/2025	1/01/2026	1/01/2027	1/01/2028	1/01/2029	1/01/2030	1/01/2031	1/01/2032	1/01/2033	1/01/2034	1/01/2035	1/01/2036	1/01/2037	1/01/2038	1/01/2039
Void Volume																						
Total Void Volume (m3)	Exported from Deswik	32,665,796		247,980	1,102,692	1,839,725	1,665,325	1,841,464	1,994,056	2,045,160	2,040,342	2,154,903	1,888,687	1,772,364	1,915,615	2,132,458	2,102,426	1,853,594	1,671,060	2,013,607	1,640,445	743,896
Insitu Tonnages																						
Volume (m3)	Volume of roadways etc. (subject to rounding)	32,634,768		247,860	1,102,179	1,839,159	1,664,752	1,838,791	1,990,485	2,043,916	2,039,305	2,154,235	1,888,228	1,770,607	1,913,286	2,131,447	2,100,256	1,846,884	1,667,515	2,013,034	1,639,163	743,665
Tonnages (In situ) (t)	Estimated tonnages in the ground in its untouched state - Exported from Deswik	48,475,515		366,366	1,625,781	2,706,993	2,435,477	2,709,759	2,962,171	3,023,064	3,034,652	3,182,264	2,756,603	2,617,873	2,831,544	3,152,278	3,158,437	2,920,464	2,488,645	2,958,692	2,448,170	1,096,283
Average Relative Density (In situ	Relative density of material at an in situ moisture basis - Exported from Deswik	1.48		1.48	1.48	1.47	1.46	1.47	1.49	1.48	1.49	1.48	1.46	1.48	1.48	1.48	1.50	1.58	1.49	1.47	1.49	1.47
Average Moisture (In situ) (%)	All internal moisture - Exported from Deswik	4.23		4.3	4.2	4.2	4.2	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.3	4.2	4.2
ROM Tonnages																						
Total ROM Production (t)	Estimated in excel using average values (subject to rounding)	50,462,627		381,128	1,692,120	2,818,765	2,536,668	2,820,087	3,082,265	3,146,965	3,159,159	3,313,774	2,870,026	2,725,480	2,948,463	3,281,425	3,289,042	3,039,787	2,591,141	3,077,079	2,548,252	1,141,002
Total ROM Production (t)	Export from the Deswik model	50,481,367		381,433	1,692,557	2,819,098	2,536,996	2,823,875	3,084,090	3,146,861	3,161,103	3,314,168	2,870,590	2,726,088	2,950,325	3,282,361	3,289,321	3,041,431	2,592,817	3,080,589	2,546,337	1,141,323
Total ROM Moisture (t)	Tonnes of moisture	4,038,509		30,515	135,405	225,528	202,960	225,910	246,727	251,749	252,888	265,133	229,647	218,087	236,026	262,589	263,146	243,314	207,425	246,447	203,707	91,306
Total ROM Moisture (ML)	ML	4,039		31	135	226	203	226	247	252	253	265	230	218	236	263	263	243	207	246	204	91
Product Tonnages																						
Primary Product Tonnage (t)	Export from the Deswik model	21,576,787		82,970	378,179	669,822	949,225	1,725,099	2,067,533	1,654,640	985,199	951,845	1,189,742	1,109,562	1,308,320	1,482,152	1,526,670	1,541,866	1,318,261	1,462,188	758,647	414,868
Primary Product Moisture (t)	Tonnes of moisture	2,589,214		9,956	45,382	80,379	113,907	207,012	248,104	198,557	118,224	114,221	142,769	133,147	156,998	177,858	183,200	185,024	158,191	175,463	91,038	49,784
Primary Product Moisture (ML)	ML	2,589		10	45	80	114	207	248	199	118	114	143	133	157	178	183	185	158	175	91	50
Secondary Product Tonnage (t)	Export from the Deswik model	18,410,257		232,473	1,008,331	1,689,181	1,212,323	578,093	376,220	812,353	1,413,812	1,630,016	1,229,213	1,099,886	1,146,344	1,128,369	831,525	360,990	693,744	1,108,848	1,327,199	531,335
Secondary Product Moisture (t)	Tonnes of moisture	1,656,923		20,923	90,750	152,026	109,109	52,028	33,860	73,112	127,243	146,701	110,629	98,990	103,171	101,553	74,837	32,489	62,437	99,796	119,448	47,820
Secondary Product Moisture (ML)	ML	1,657		21	91	152	109	52	34	73	127	147	111	99	103	102	75	32	62	100	119	48
Total Product Tonnage (t)	Export from the Deswik model	39,987,044		315,443	1,386,510	2,359,003	2,161,548	2,303,192	2,443,753	2,466,993	2,399,011	2,581,861	2,418,955	2,209,449	2,454,664	2,610,521	2,358,195	1,902,856	2,012,006	2,571,036	2,085,846	946,203
Total Product Moisture (t)	Tonnes of moisture	4,246,138		30,879	136,131	232,405	223,016	259,040	281,964	271,669	245,467	260,923	253,398	232,137	260,169	279,411	258,038	217,513	220,628	275,259	210,486	97,604
Total Product Moisture (ML)	ML	4,246		31	136	232	223	259	282	272	245	261	253	232	260	279	258	218	221	275	210	98
Average Total Product Moisture (	%	10.6%		9.8%	9.8%	9.9%	10.3%	11.2%	11.5%	11.0%	10.2%	10.1%	10.5%	10.5%	10.6%	10.7%	10.9%	11.4%	11.0%	10.7%	10.1%	10.3%

Moisture	Content	Comment
ROM (%)	8.0%	Based on input moisture of 8% for ROM product
Primary Prod (%)	12.0%	Based on input moisture of 12% for primary product
Secondary Prod (%)	9.0%	Based on input moisture of 9% for the secondary product

Convert cubic metres to M	1,000

Figure D2.6 Annual production schedules (source: HUM1652_383 Web Panel Layout Moisture ROM and Prod + reject tonne calcs.xlsx, Palaris, 12 July 2016)

Reject Estimation undertaken in Deswik																						
Rejects																						
Reject t (ad) (t)	Exported from Deswik model	12,858,583		82,474	378,264	584,547	499,971	671,690	807,913	834,712	890,751	869,155	593,973	645,942	642,636	828,472	1,071,641	1,257,860	705,135	667,114	576,991	249,342
Reject slurry tonnes @ 15% Moisture (t)	Exported from Deswik model	14,896,717		95,519	438,138	677,316	579,428	778,433	935,719	966,782	1,032,274	1,007,058	688,148	748,245	744,679	959,632	1,241,558	1,456,875	817,073	772,890	668,096	288,855
Reject slurry tonnes @ 30% Moisture (t)	Exported from Deswik model	18,088,870		115,987	532,025	822,456	703,591	945,240	1,136,230	1,173,950	1,253,476	1,222,856	835,608	908,583	904,253	1,165,267	1,507,606	1,769,062	992,159	938,509	811,260	350,752
Reject slurry tonnes @ 40% Moisture (t)	Exported from Deswik model	21,103,682		135,319	620,696	959,532	820,856	1,102,780	1,325,602	1,369,608	1,462,388	1,426,665	974,876	1,060,014	1,054,962	1,359,479	1,758,873	2,063,906	1,157,519	1,094,927	946,470	409,211
Reject Estimation undertaken in Excel																						
Air dried tonnages																						
Volume (m3)	Subject to rounding	32,637,097		247,962	1,102,444	1,839,449	1,665,031	1,838,938	1,990,653	2,044,178	2,039,524	2,154,447	1,888,460	1,770,755	1,913,416	2,131,617	2,100,330	1,846,405	1,667,479	2,013,202	1,639,145	743,660
Total air dried cut tonnage (ad) (t)	Exported from Deswik model	49,152,541		371,530	1,648,248	2,743,738	2,467,872	2,746,592	3,004,046	3,064,884	3,077,125	3,225,786	2,792,988	2,653,934	2,870,354	3,195,717	3,204,157	2,969,285	2,523,715	2,998,523	2,482,939	1,111,109
Average relative density (ad) (g/cc)	Exported from Deswik model	1.51		1.50	1.50	1.49	1.48	1.49	1.51	1.50	1.51	1.50	1.48	1.50	1.50	1.50	1.53	1.61	1.51	1.49	1.51	1.49
Average air dried moisture content of coal (ad) (%)	Internal moisture, less an air-dry rim - Exported from Deswik model	1.53		1.6	1.5	1.5	1.5	1.5	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.5
Reject tonnes (ad) - estimated in excel (t)	Subject to rounding error	12,858,370		82,473	378,259	584,544	499,974	671,641	807,980	834,786	890,793	869,163	593,966	645,894	642,579	828,370	1,071,604	1,257,663	705,082	667,147	577,112	249,338
Reject slurry tonnes @ 15% Moisture - estimated in excel (t)	Subject to rounding error	14,896,781		95,519	438,139	677,317	579,428	778,437	935,728	966,788	1,032,276	1,007,061	688,149	748,248	744,682	959,636	1,241,559	1,456,886	817,077	772,894	668,102	288,856
Reject slurry tonnes @ 30% Moisture - estimated in excel (t)	Subject to rounding error	18,088,948		115,988	532,026	822,456	703,591	945,245	1,136,241	1,173,956	1,253,478	1,222,859	835,610	908,586	904,257	1,165,272	1,507,608	1,769,076	992,165	938,515	811,266	350,753
Reject slurry tonnes @ 40% Moisture - estimated in excel (t)	Subject to rounding error	21,103,773		135,319	620,697	959,532	820,856	1,102,786	1,325,614	1,369,616	1,462,391	1,426,669	974,878	1,060,017	1,054,967	1,359,484	1,758,876	2,063,922	1,157,526	1,094,934	946,477	409,212
Total cut tonnage without any moisture from Row 38 and Row 39	4.2%	48,403,171		365,755	1,622,797	2,702,317	2,431,046	2,705,824	2,957,158	3,017,094	3,030,978	3,176,940	2,750,483	2,613,322	2,827,475	3,146,800	3,155,483	2,923,696	2,485,893	2,952,738	2,443,247	1,094,126
Total ROM without any moisture from Row 4 and Row 5		46,442,858		350,919	1,557,153	2,593,571	2,334,037	2,597,965	2,837,363	2,895,112	2,908,215	3,049,034	2,640,943	2,508,001	2,714,299	3,019,772	3,026,176	2,798,116	2,385,392	2,834,142	2,342,630	1,050,018

Figure D2.7 Annual reject and co-disposed reject schedules (source: HUM1652_383 Web Panel Layout Moisture ROM and Prod + reject tonne calcs.xlsx, Palaris, 12 July 2016)