BEAL
CONSULTING ENGINEERING & PROJECT MANAGEMENT

REPORT

ENVIRONMENTAL IMPACT
MANAGEMENT SERVICES

VLAKVARKFONTEIN COLLIERY STORM WATER MANAGEMENT PLAN

Submitted to:

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1. INTRODUCTION

EIMS commissioned BEAL Consulting and Project Management (Pty) Ltd (BEAL) to calculate a water and salt balance for the proposed Vlakvarkfontein Colliery and to provide a storm water management plan. This report provides the water and salt balance results for the study, the storm water management plan and supporting drawings, as well as recommendations resulting from the work done.

1.1 Study Objectives

The project objectives are as follows:

- Calculate a desktop water balance for the proposed colliery.
- Size the pollution control dam.
- Locate and size the clean and dirty storm water channels that are proposed to control storm water on and around the site.

1.2 Regulatory framework

Government Notice 704 (GN 704) of the South African National Water Act is the legislation guiding the Storm Water Management Plan.

The Best Practice Guidelines for Water Resource Protection in the South African Mining Industry, Guideline G1 (Storm Water Management) was used to guide the content of this Storm Water Management Plan.

2. RESULTS AND RECOMMENDATIONS

Based on the inputs shown in Appendix C, the work that was done highlighted the following key results:

- The water balance is a deficit water balance on average, with the plant demand exceeding storm water inflows into the pollution control dam.
- The pollution control dam has been designed to contain dirty storm water generated on the site as well as the operational dewatering from the opencast mine. The capacity of the pollution control dam is 14 000 m^3.
- Upfront dewatering volumes have been calculated by Groundwater Square and indicate that approximately 750 000 m^3 of water will need to be dewatered prior to mining. Some of this water can be stored in the transfer sump but the remainder will need to be treated and released. The mine will determine how far in advance upfront dewatering will commence. This timing will determine the size of the water treatment plant required.
- The storm water channels are relatively small, since the proposed colliery is located close to local watersheds and internal catchments are small.

The climate data used in this study is summarised in Table 1.

Table 1: Climate data summary

Month	Average rainfall (mm)	Average evaporation (mm – S-Pan)
January	130	184
February	101	154
March	80	152
April	43	117
May	18	98
June	8	80
July	7	87
August	9	116
September	24	150
October	74	181
November	120	171
December	122	188
Mean annual	**736***	**1 677**

* *Note: The mean annual precipitation does not necessarily equal the sum of the monthly average precipitation.*

3. SITE LOCATION

Vlakvarkfontein Colliery is located approximately 15 km west of Ogies. The site is located on the boundary of quaternary catchments B20E and B20F, in the Olifants River catchment.

4. WATER BALANCE

The water balance presented in this report is a static water balance. It represents average flows between facilities and along hydrological interfaces. Being a static water balance showing average flows, peak flows cannot be accounted for.

The Mpumalanga Highveld has distinct wet and dry seasons. Over 94% of Vlakvarkfontein Colliery's mean annual rainfall falls between September and April inclusively. Over 77% of the area's mean annual evaporation occurs in this period. For this reason, the water balance was divided into a wet season and a dry season water balance. The wet season water balance represents the period 1 September to 30 April. The rest of the year is included in the dry season water balance. An average water balance that represents average flows throughout the year is also presented in Appendix A.

4.1. Water Balance Components

The location of the main water balance components of the proposed Vlakvarkfontein Colliery are shown in Figure 1.

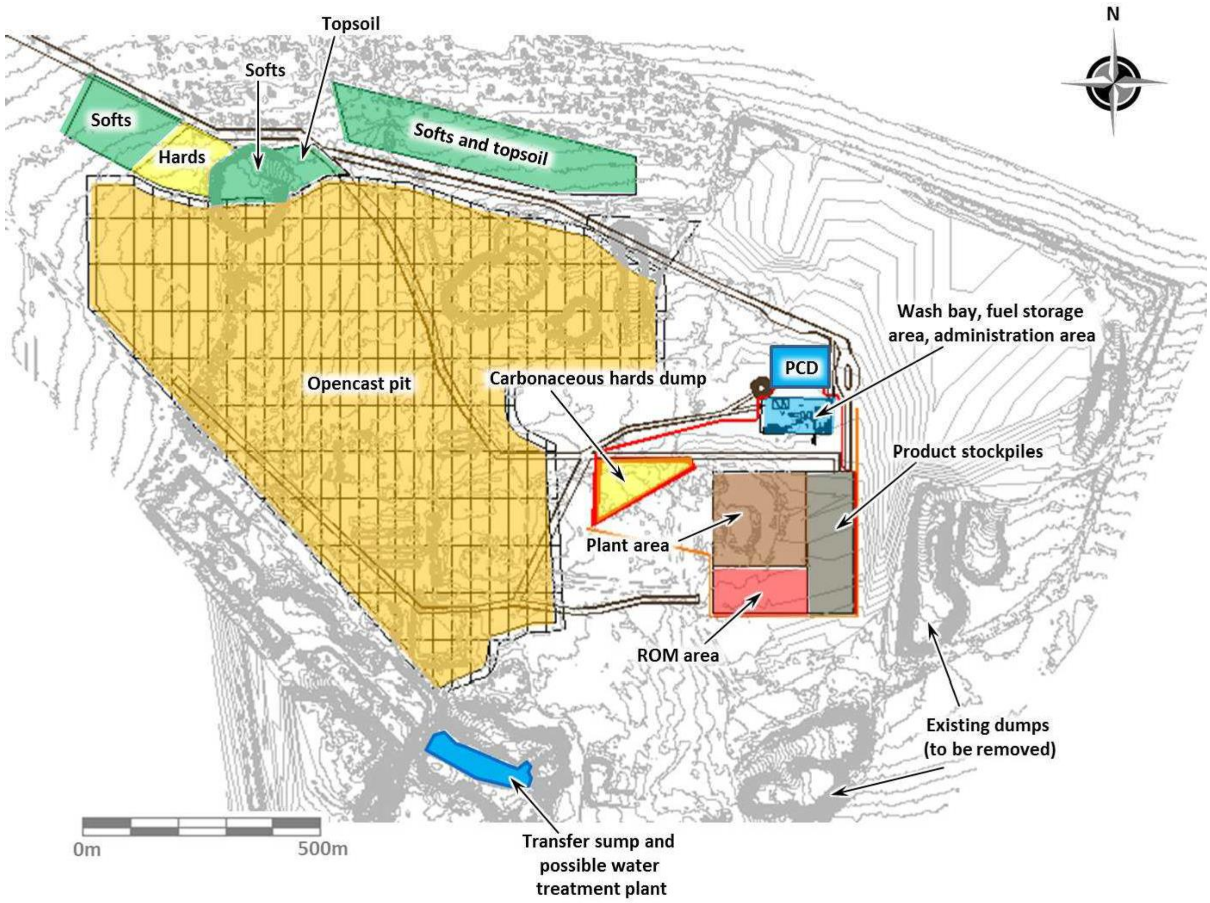


Figure 1: Facilities overview

4.2. Water Balance Description

The average wet and dry season water balances for the proposed Vlakvarkfontein colliery are provided in Appendix A. The inflows are presented on the left of the water balance figures. The facilities and inter-facility flows are shown in the centre of the water balance figures. The outflows are shown on the right of these figures.

The direction of water movement is illustrated with black arrows. The values adjacent to the arrows represent average flows in m^3/day. Clean water flows are shown in blue, while dirty flows are shown in red. The scenario represented is indicated in the top right-hand corner.

One of the fundamental principles of a water balance is that inflows must equal outflows unless the difference is accommodated in storage changes. The pollution control dam is relatively small and will not accommodate storage changes over a season so storage changes are assumed to be zero.

4.3. Sources of Flow Information

Daily rainfall data was sourced from the CCWR (Computing Centre for Water Research, Natal University) rainfall database (gauge number 0478093 – Ogies). The gauge is located approximately 17 km east of the site. Evaporation data and its monthly distribution were sourced from the Water Resources of South Africa Study data set, zone 4A (Midgley et al., 1990). Runoff factors were informed by average runoff for the quaternary catchments B20E and B20F, documented in the Water Resources of South Africa Study report (Middleton et al., 2009). Peak rainfall was statistically calculated from the rainfall data.

All input data are presented in Appendix C. Groundwater inflow volumes were sourced from Groundwater Square (2017). The water balance assumptions should be revisited once additional reliable data becomes available.

4.4. Water Balance Results

The average, wet and dry season water balances for the proposed Vlakvarkfontein Colliery are provided in Appendix A. A static water balance cannot account for the dynamics of mine development. A snapshot of the colliery's development is used to calculate the water balance. The snapshot comprises the end of the pit life. This will provide the highest water make from the pit and will result in the maximum required return water dam capacity.

5. SALT BALANCE

5.1. Salt Balance Description

The salt balance is a conservative mass balance. It provides average total dissolved solids (TDS) loads that are transported with inflows, outflows and inter-facility flows from the water balance. TDS was used as it is a good representation of sulphates and other pollutants in the water. TDS can be modelled conservatively.

The salt balance is likely to be typical of a coal mining operation, with salts being generated mainly from the on-site coal and carbonaceous material. The salts are diluted and transported into the water circuits. Salts are lost from the system when discharges occur or when water is transported off the site. These include moisture transported off site with the coal product, dust suppression, and discharges to the environment should they occur.

The water balance shows where water is being lost from the system (see Appendix A). The salt balance (Appendix B) shows that this water contains pollution levels common to coal mining activities.

5.2. Sources of Water Quality Information

No water quality information was available since the operations have not commenced. Water quality inputs were based on experience with the existing operations as well as other coal mines on the Mpumalanga coal fields.

Water qualities in the pollution control dam should be measured during operations. This will provide a better basis for calculating the salt balance loads and enable further model calibration. During salt balance updates, the salt balance assumptions should be updated based on measured water quality.

6. PIT DEWATERING

The proposed mining involves extracting coal from old underground workings using opencast mining. The proposed opencast pit is shown in Figure 1. The old underground workings are currently flooded and require dewatering prior to mining. Groundwater modelling has been conducted by Groundwater Square. This work indicates that over 750 000 m^3 needs to be dewatered. Seam 2 (the lower seam) will be mined at the start of the operations so the assumption is that the entire 750 000 m^3 must be dewatered prior to mining.

The transfer sump (shown in Figure 1) has an estimated capacity of approximately 500 000 m^3 between elevation 1 530 mamsl and 1 554 mamsl. The water level at the time of the latest survey (October 2017) was 1 530 mamsl. It is unlikely that the water levels can be increased significantly above 1 554 mamsl. Therefore, there is insufficient capacity in the transfer sump to accommodate the required 750 000 m^3 of upfront dewatering. The processing plant will not yet be operational to consume water and the pollution control dam (shown in Figure 1) will be too small to accommodate a significant portion of this water.

The mine will therefore have to treat and release the water that is dewatered prior to mining.

6.1. Water Treatment Plant Sizing

The water treatment plant capacity will be dependent on the speed that dewatering occurs and how much of the transfer sump storage the mine is willing to utilise. The relationship between treatment plant sizing, time to dewater the old mine workings and the utilised transfer sump storage is shown in Figure 2. Note that the water balance used assumes average rainfall. It is not recommended to aim to utilise more than 400 000 m^3 of the transfer sump storage. The 100 000 m^3 buffer capacity in the transfer sump should be used to buffer against uneven dewatering volumes, high rainfall, as well as to accommodate additional inflows into the mine workings. These additional inflows could be from rainfall recharge and inflows from the surrounding aquifer.

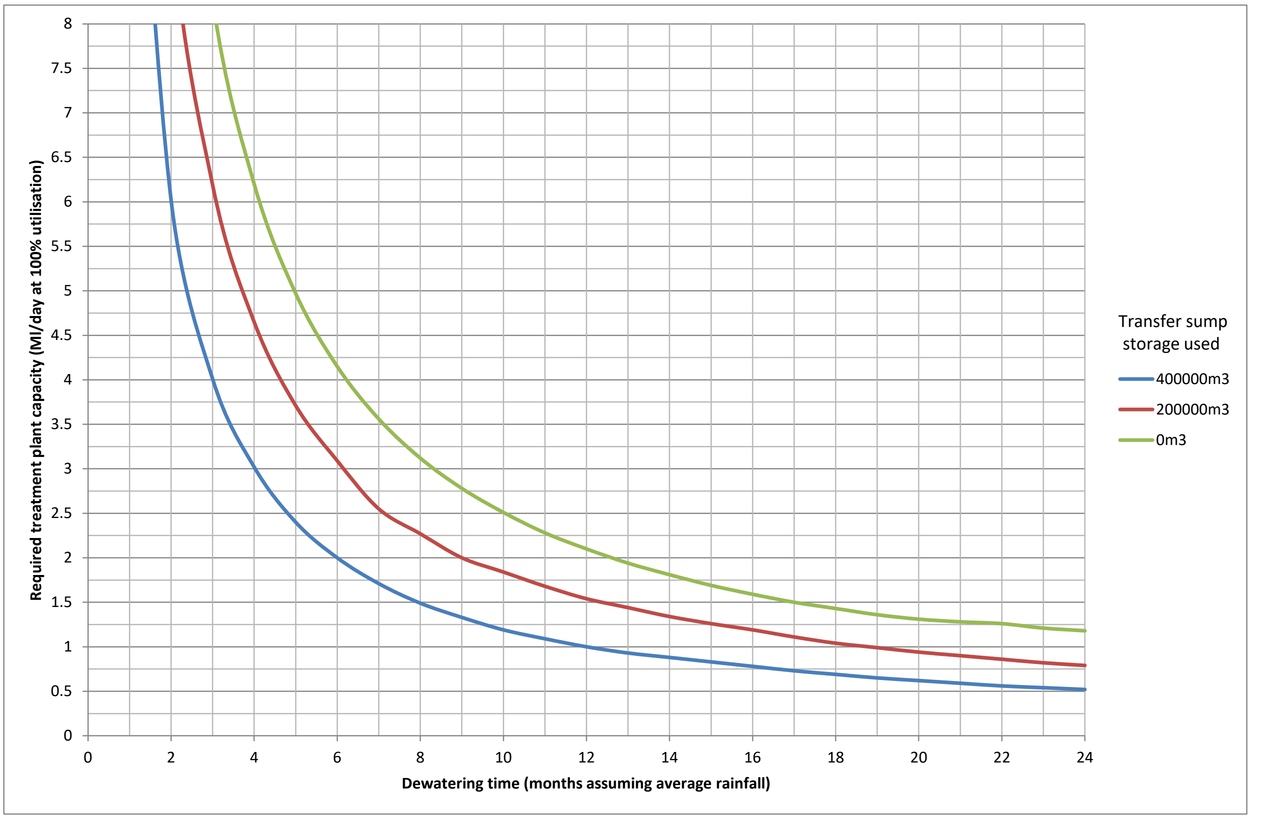


Figure 2: Relationship between treatment plant capacity at 100% utilisation, transfer sump volume used and the time to dewater (assuming average rainfall)

7. POLLUTION CONTROL DAM SIZING

7.1. Introduction

The pollution control dam accommodates storm water from the dirty areas on the colliery during operations. It is assumed that all upfront mine dewatering will have been completed when the pollution control dam comes on line. The location of this infrastructure is shown in Figure 1.

Excess pit water will be pumped into a pollution control dam during operations. Storm water from the colliery's dirty areas will also report to the pollution control dam.

7.2. Methodology

The dam sizing methodology was based on two methods:

1. the required storage resulting from a long term monthly time step water balance, plus the 50-year storm runoff volume. This is to address the requirements set out in Government Notice 704 of the South African National Water Act (GN704).
2. the normal operating volume, plus the 50-year design storm runoff. This is outlined in the GN704 implementation guidelines.

In the GN704 simulations, the 50-year storm was added to the long term monthly time series because individual storms during the month are not modelled and are averaged out during the month.

7.2.1 50-year and 100-year Storm Events

The peak rainfall data used is presented in Table 2.

Table 2: Peak 24-hr rainfall depth for the propsed Vlakvarkfonetin Colliery

Recurrence interval	24-hr rainfall depth (mm)
50-yr	126
100-yr	145

Peak storm water discharge was calculated using the SCS runoff equations (Schmidt and Schulze, 1987). The catchment areas and curve numbers used in the calculations are presented in Table 3.

Table 3: Inputs used for the SCS storm water calculations

Pollution Control Dam	Area (% of total)	Curve Number (CN)
Roads and compacted areas	5%	88
Dumps and stockpiles	43%	65
Undeveloped catchments	52%	65
Total/composite	100% (18.5 ha)	66.15

7.2.2 Monthly Continuous Modelling

Monthly rainfall data from the CCWR's database (gauge number 0478093) as well as the purchased data was used in the long-term water balance modelling. The modelling incorporated the inputs and outputs shown in Table 4.

Table 4: Inputs and outputs modelled

Inputs	Outputs
Direct rainfall on the dam	Evaporation losses
Storm water generated by the upstream catchment	Recycling to satisfy dust suppression
Operational dewatering flows into the dam	Plant make-up

Storm water generated from the catchment was calculated on a non-linear relationship between monthly rainfall and runoff. This is presented in Appendix B. No antecedent moisture conditions were accounted for. Water reuse from the pollution control dam is based on the water balance presented in Appendix A.

7.3. Results

All water that accumulates in the pollution control dam must be consumed by dust suppression and plant make-up. The sizing of the pollution control dam is presented in Table 5. The size of the pollution control dam is based on the assumption that all upfront dewatering is completed prior to mining. The pollution control dam should be operated as empty as possible and not used to store water for future consumption. All captured storm water should be consumed as fast as possible.

The required pollution control dam capacities were based on withdrawals shown in the water balance diagrams presented in Appendix A.

Table 5: Pollution control dam sizing results

Parameter (Pollution Control Dam)	Value
50-yr storm volume	9 769 m^3
Normal operating storage	4 203 m^3
Normal operating storage + 50-yr storm volume	13 973 m^3
Volume below spillway level	13 973 m^3
Full supply area	5 865 m^2

7.4. Spillway Sizing

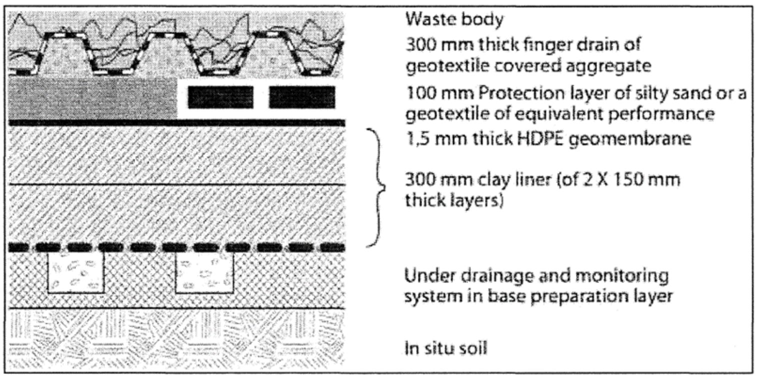
The spillway on the pollution control dam will need to cater for storm water generated from the dirty upstream catchments, plus direct rainfall on the dam. This is shown in Table 6.

Table 6: Spillway sizing

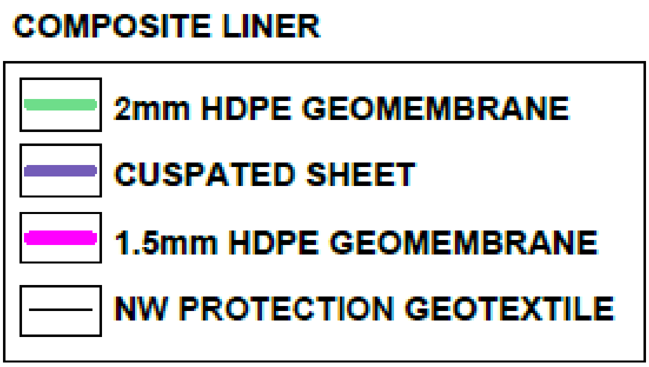
Dam	50-yr flood peak	100-yr flood peak	Spillway width	50-yr flow depth	100-yr flow depth
Pollution control dam	2.4 m^3/s	3.4 m^3/s	6 m	0.40 m	0.50 m

8. POLLUTION CONTROL DAM LINER SPECIFICATIONS AND SERVICE LIFE CONSIDERATIONS

This waste type require a class C barrier system as described in the Norms and Standards and comprise of the following components:



For the Vlakvarkfontein PCD the following barrier system are proposed.



This deviation is due to the following:

- The minimum requirement specification requires the installation of a 300mm clay layer. This layer has very specific properties and will also require clay from a specific source which is not available in the Mpumalanga area;
- The primary liner system will be an exposed 2mm HDPE liner. The deviation from a 1.5mm HDPE to a 2mm HDPE is due to possibility of deferential settlement that may occur on the backfilled void area;
- A Cuspated sheet will collect any leakage from the primary liner to a collection manhole where frequent monitoring will be done to ensure that the leakage action rate is not exceeded;
- An underdrain system will be installed should the detailed investigation indicate a shallow groundwater aquifer.

9. STORM WATER CHANNEL SIZING

Clean and dirty storm water channels have been identified (shown in Figure 3). These were sized during this study.

9.1. Catchment Delineation

The catchments were delineated using 1 m contour data supplied by the mine. These sub-catchments are shown in Figure 4.

9.2. Peak Rainfall

The peak rainfall data, presented in Table 2 was used to calculate the flood peaks.

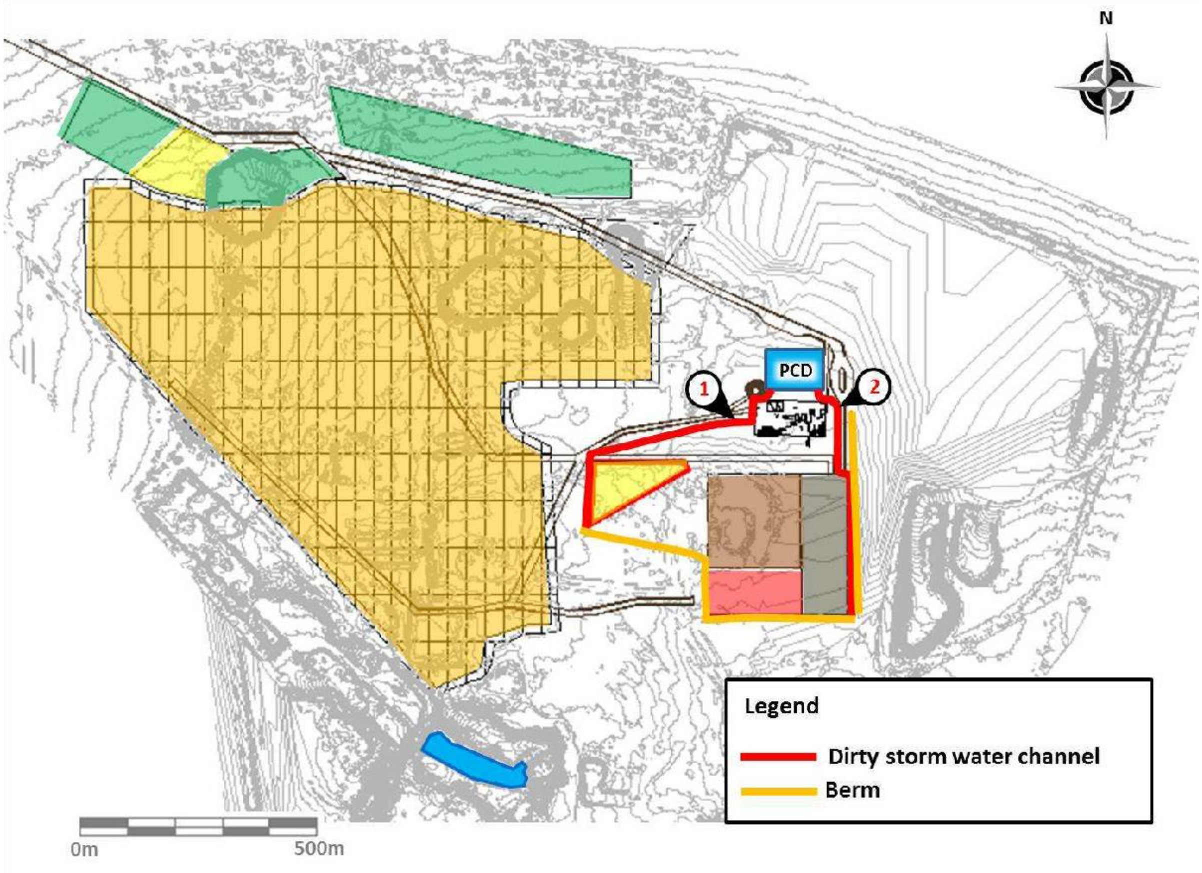


Figure 3: Storm water channel locations

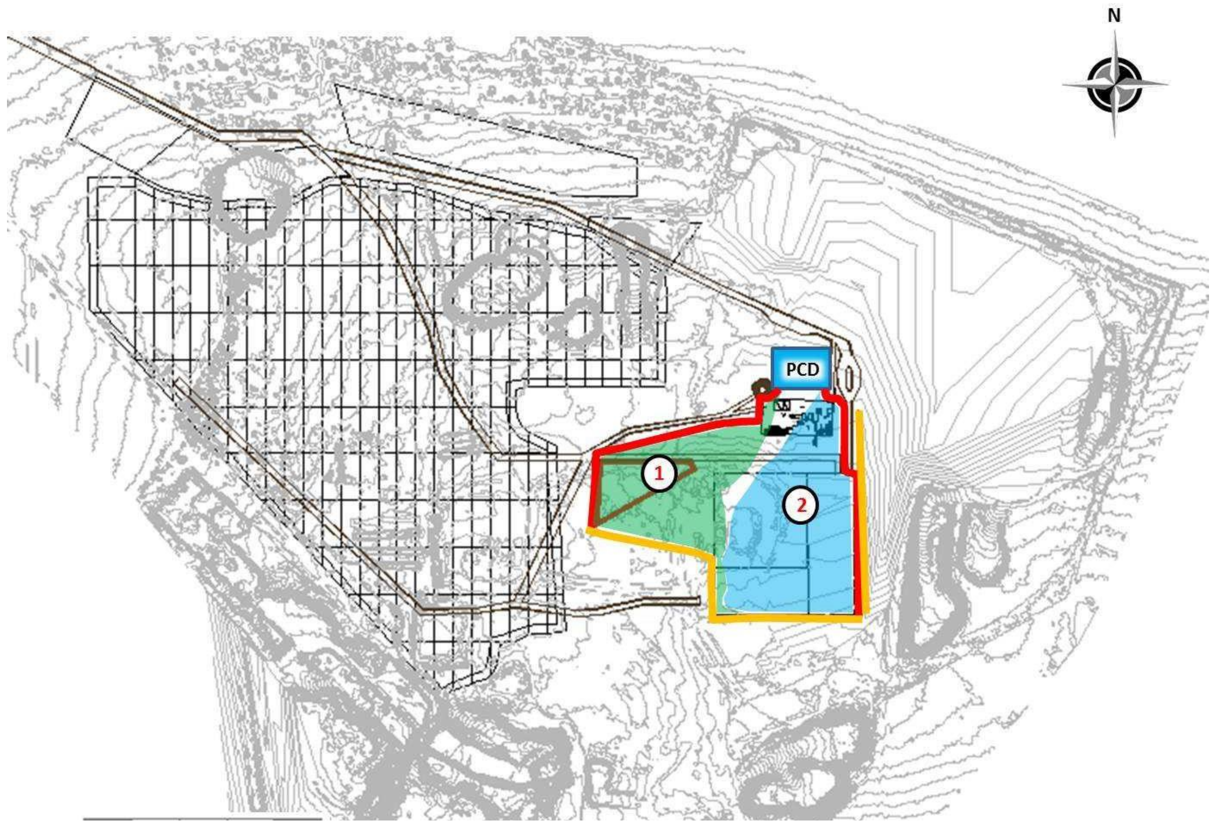


Figure 4: Sub-catchments

9.3. Flood Peak Calculation

The positions of the storm water channels are shown in Figure 3. The sub-catchments reporting to these channels were delineated (Figure 4). The sub-catchments are small and the rational method is therefore a suitable method of determining the flood peaks. The old Department of Water Affairs' calculation sheet was used to determine the runoff coefficients. The time-to-concentration of the sub-catchments was calculated using the SCS method which is suitable for relatively undeveloped catchments. Adamson's TR102 (Adamson, 1981) was used to convert the 24-hour peak rainfall data to rainfall intensities appropriate to the time-to-concentration of the catchments. The 1085 method was used to calculate catchment slopes. The results of these calculations for all sub-catchments are summarised in Table 7.

9.4. Channel Specifications

The dirty channels are specified as concrete lined channels.

Berms should be compacted and vegetated. A geotechnical investigation of the soils should be undertaken to confirm the compaction specifications. The channel should be kept free of long grass, shrubs and woody vegetation.

9.5. Channel Sizing

The channels were sized to accommodate the flood peaks presented in Table 7. The Mannings open channel flow equation was used to calculate flow depth in the channel. A Mannings n of 0.015 was used for concrete lined channels. The channels are sized assuming trapezoidal channels with side slopes of 1:1.5 (V:H).

It is good practice to allow approximately 0.3 m of freeboard in the channel. This is to allow for wave action and flow surges in the channel. A summary of the channel sizes is presented in Table 7.

Table 7: Summary of channel sizes (proposed Vlakvarkfontein Colliery)

Channel	50-yr flood peak (m^3/s)	Lining	Bottom width (m)	Longitudinal slopes (V:H)*	Max flow depth (m)	Channel depth (m)	Max flow velocity (m/s)*	Flow type at max velocity
Channel 1	1.1	Concrete	1.0	1:200	0.36	0.7	1.8	Supercritical
Channel 2	1.4	Concrete	1.0	1:78	0.33	0.6	2.8	Supercritical

General note: All channels are trapezoidal with side slopes of 1:1.5 (V:H)
** Note: Flow velocities are based on the maximum longitudinal gradient. These gradients will need to be confirmed during subsequent design phases.*

10. CULVERT SIZING

Four culverts will be required. The locations of the culverts are shown in Figure 5. The culvert sizing is summarised in Table 8.

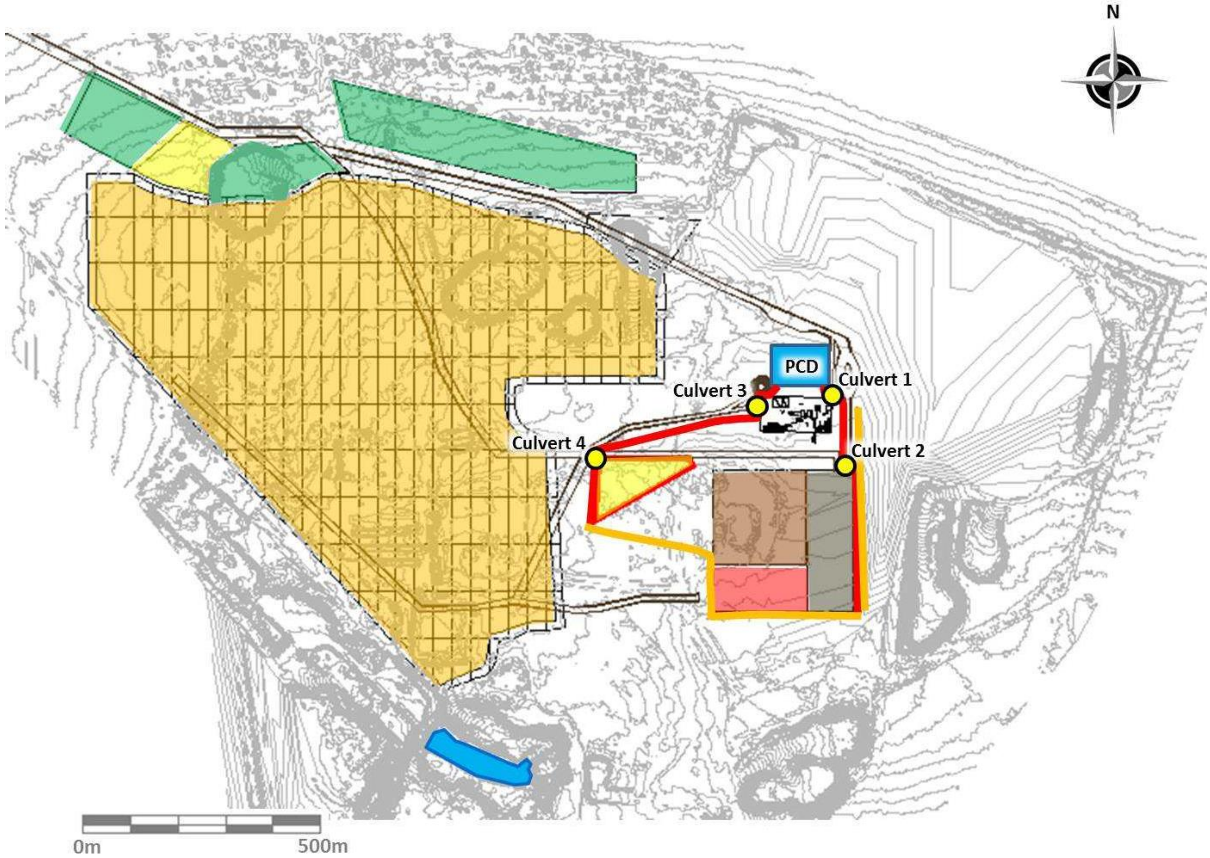


Figure 5: Culverts

Table 8: Culvert Sizing

Culvert	Flow (m^3/s)	Storm equivalent	Size	No of barrels
1	1.4	50-yr	900 NB	2
2	1.3	50-yr	900 NB	2
3	1.0	50-yr	900 NB	2
4	0.1	50-yr	450 NB	1

11. SILT TRAP CONSIDERATIONS

As part of the storm water management plan, BEAL investigated the silt loading potential of the dirty water area. Due to the small dirty water catchment area and a short life of mine the benefit of the silt trap should be considered.

As part of the detailed engineering design the silt loading will be further investigated.

12. CONCLUSION

The key results and recommendations are presented in Section 2. The water balance was calculated and is presented in Appendix A.

The water balance is a deficit water balance on average, with the plant demand exceeding storm water inflows into the pollution control dam.

The pollution control dam has been designed to contain dirty storm water generated on the site as well as the operational dewatering from the opencast mine. The capacity of the pollution control dam is 14 000 m3.

Upfront dewatering volumes have been calculated by Groundwater Square and indicate that approximately 750 000 m3 of water will need to be dewatered prior to mining. Some of this water can be stored in the transfer sump but the remainder will need to be treated and released. The mine will determine how far in advance upfront dewatering will commence. This timing will determine the size of the water treatment plant required.

The water balance conducted in this study is a high-level desktop water balance, providing high-level water balance outputs. A number of flows are estimates requiring confirmation. The flows produced are therefore unsuitable for detailed design purposes. A detailed water balance with supporting work to confirm flow estimates should be done to provide more confidence for detailed design purposes.

13. REFERENCES

Adamson, P.T., *Southern African Storm Rainfall,* Department of Environment Affairs, Technical Report TR102, Pretoria, 1981.

Middleton, B.J. and Bailey, A.K., *Water Resources of South Africa*, 2005 study (WR2005), 2009. WRC Report No TT 382/08.

Midgley, D.C., Pitman, W.V., Middleton, B.J. *Surface Water Resources of South Africa,* 1990. WRC Report No 298/2.1/94, Volume 2.

Schmidt E.J and Schulze R.E (1987), *User Manual for SCS-Based Design Runoff Estimation in Southern Africa*, Water Research Commission Project No.155, Report No.TT 33/87

Groundwater Square, Vlakvarkfontein Colliery Pillar Mining Project: Groundwater Feasibility Assessment, June 2017, Report No: 069d(feas).

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APPENDIX A

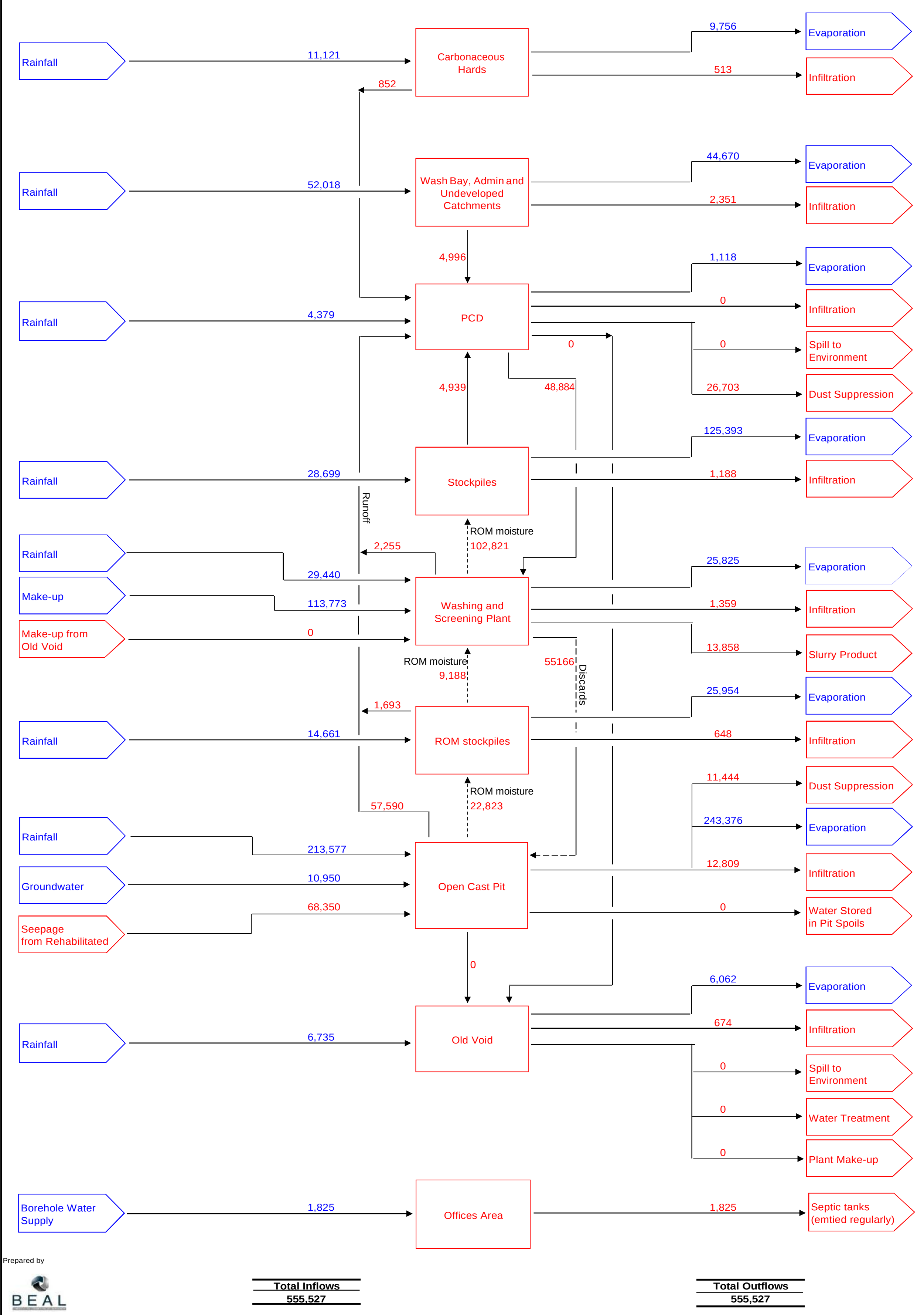
WATER BALANCE AND SUMMARY WATER BALANCE DIAGRAMS

Appendix A Rev 3

Daily Average: m³/year - Steady state

Annual
Rev 3

Vlakvarkfontein Colliery
Water balance



Total Inflows
555,527

Total Outflows
555,527

Legend
000 Dirty Flow (m³/day)
000 Clean Flow (m³/day)

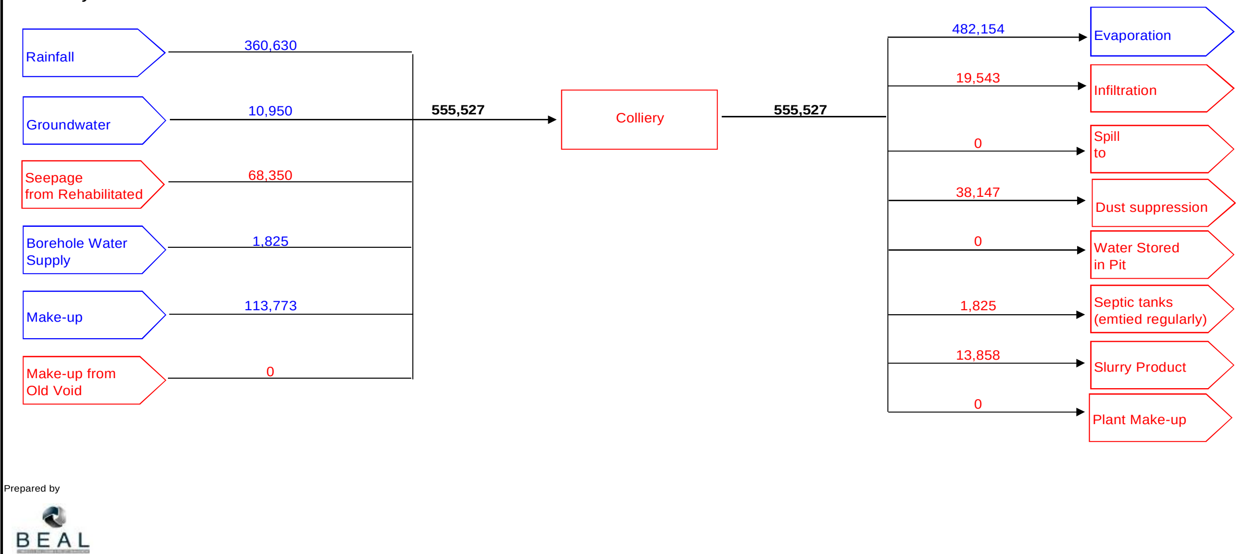
Note: These flows are rounded to zero decimal places for clarity. Consequently some flows may appear out of balance.

Appendix A Rev 3

Daily Average: m³/year

Annual
Rev 3

Vlakvarkfontein Colliery
Summary water balance



Legend
000 Dirty Flow (m³/day)
000 Clean Flow (m³/day)

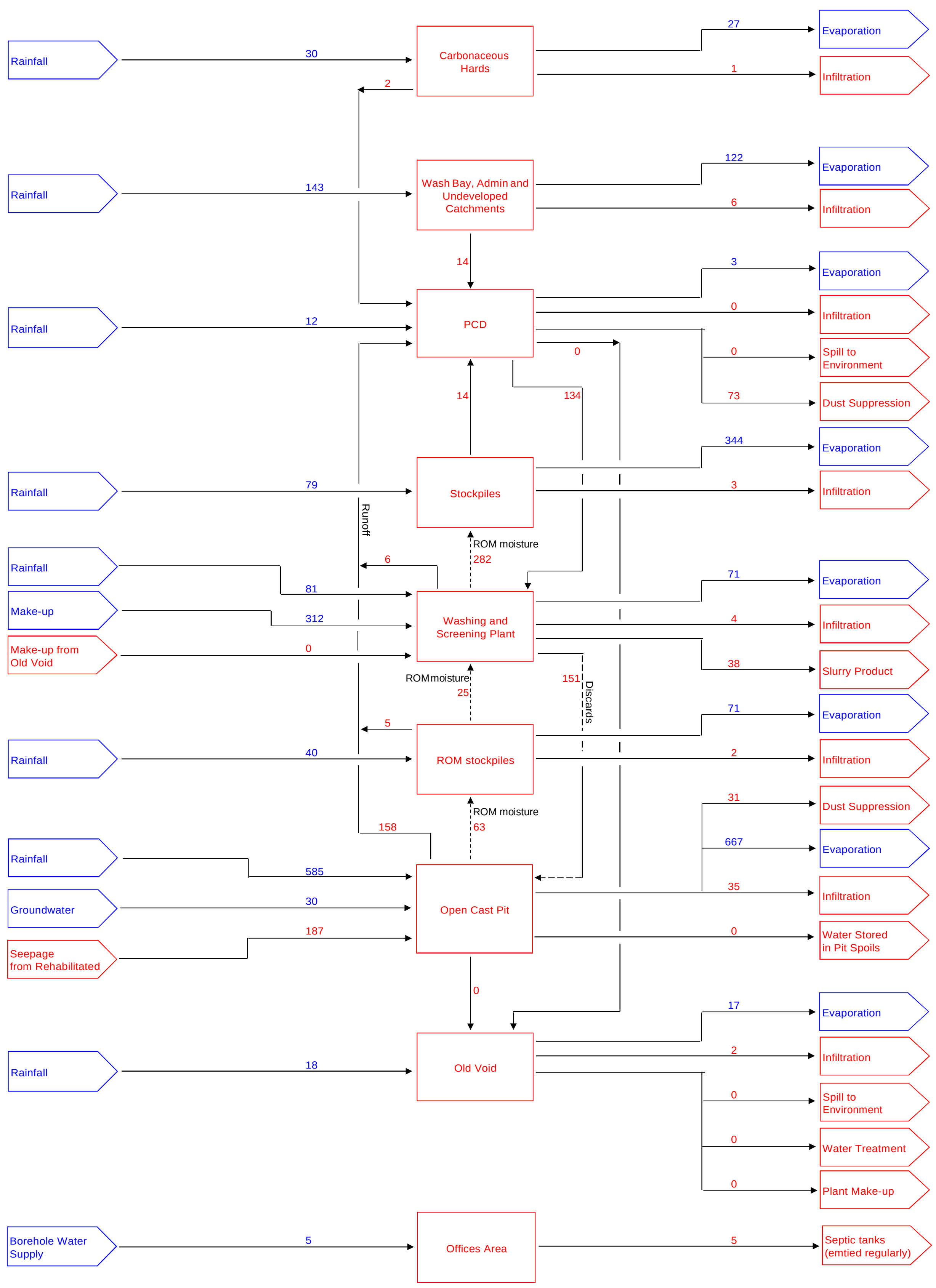
Note: These flows are rounded to zero decimal places for clarity. Consequently some flows may appear out of balance.

Appendix A Rev 3

Daily Average: m³/day - Steady state

Full Year
Rev 3

Vlakvarkfontein Colliery
Water balance



Prepared by

BEAL

Total Inflows
1,522

Total Outflows
1,522

Legend
000 Dirty Flow (m³/day)
000 Clean Flow (m³/day)

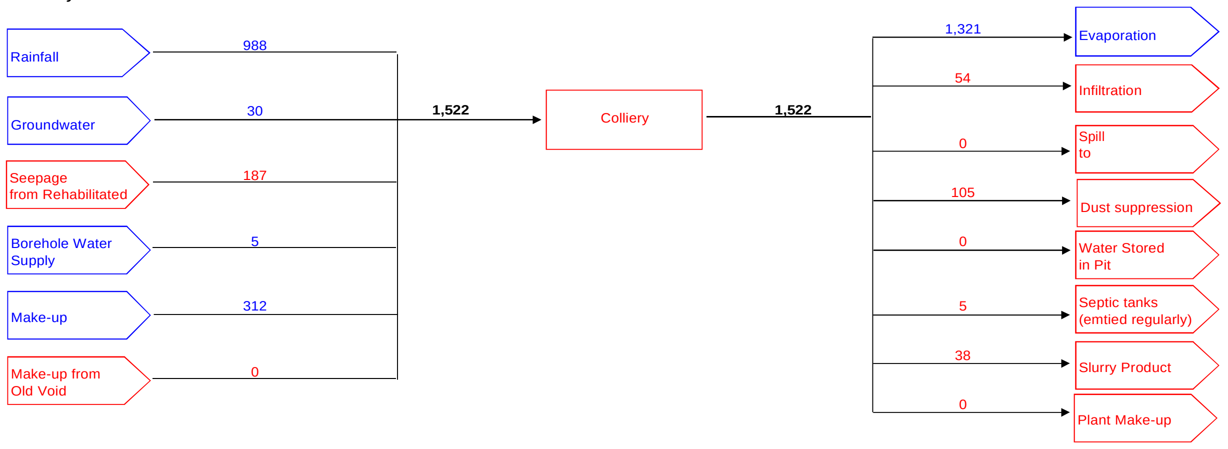
Note: These flows are rounded to zero decimal places for clarity. Consequently some flows may appear out of balance.

Appendix A Rev 3

Daily Average: m³/day

Full Year
Rev 3

Vlakvarkfontein Colliery
Summary water balance



Prepared by

BEAL

Legend
000 Dirty Flow (m³/day)
000 Clean Flow (m³/day)

Note: These flows are rounded to zero decimal places for clarity. Consequently some flows may appear out of balance.

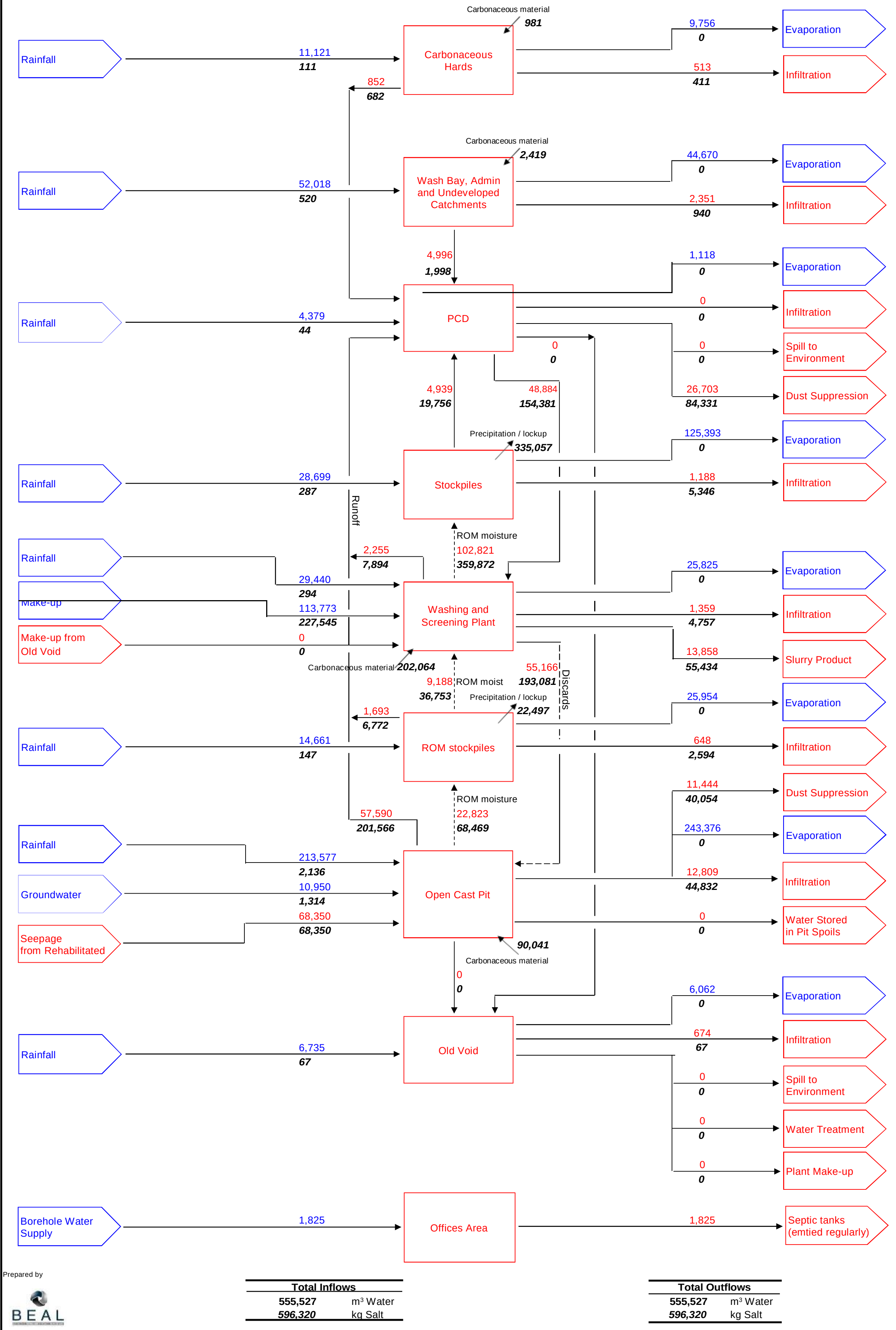
APPENDIX B
SALT BALANCE AND SUMMARY BALANCE DIAGRAMS

Appendix B Rev 3

Average: m³ /yr, kg/yr - Steady state

Annual
Rev 3

Vlakvarkfontein Colliery
Water balance



Legend

000 Dirty Flow (m³/day)
000 Clean Flow (m³/day)
000 TDS salt load (kg/day)

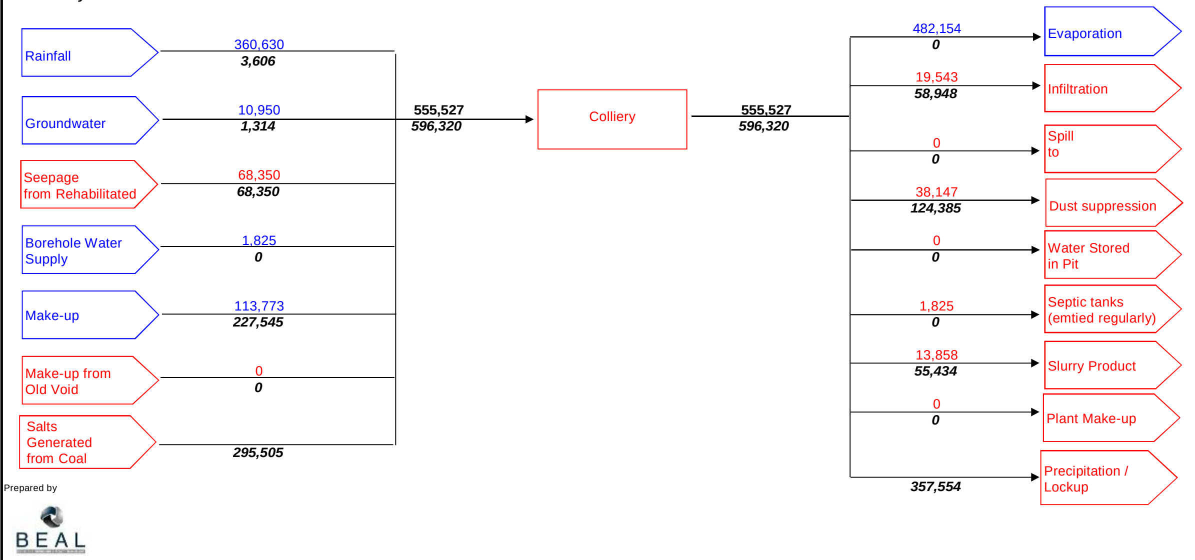
Note: These flows are rounded to zero decimal places for clarity. Consequently some flows may appear out of balance.

Appendix A Rev 3

Average: m³ /yr, kg/yr - Steady state

Annual
Rev 3

Vlakvarkfontein Colliery
Summary water balance



Legend

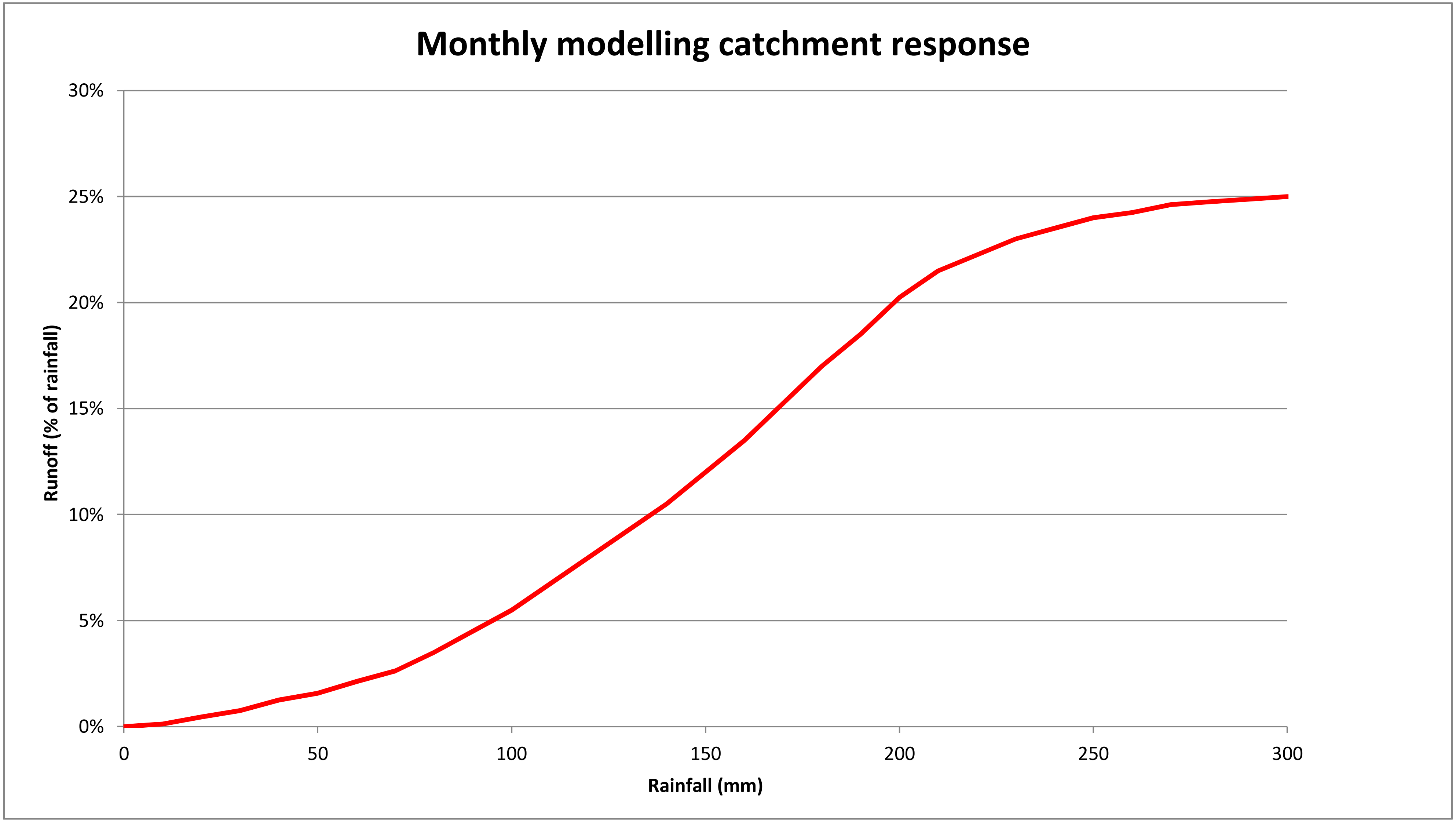
000 Dirty Flow (m³/day)
000 Clean Flow (m³/day)
000 TDS salt load (kg/day)

Note: These flows are rounded to zero decimal places for clarity. Consequently some flows may appear out of balance.

APPENDIX C
INPUT INFORMATION

Appendix C Rev 3

Global info		
Mean Annual Precipitation	736	mm
Wet Season Rainfall	694	mm
Mean annual Evaporation	1677	mm
Wet Season Evaporation	1296	mm
Start of wet seaon	01-Sep	
Start of dry season	01-May	
Wet Season Loss ratio to Evaporation	95%	of losses
Dry Season Loss ratio to Evaporation	95%	of losses
PCD		
Dam Area	5,950	m2
Old Void "A"		
Dam Area	9,151	m2
Carbonaceous hards		
Catchment Area	15,110	m2
Runoff factor wet season	8%	
Runoff factor dry season	2%	
Wash bay, admin and undeveloped catchments		
Catchment Area	70,676	m2
Runoff factor wet season	10%	
Runoff factor dry season	3%	
Stockpiles		
Catchment Area	38,993	m2
Runoff factor wet season	18%	
Runoff factor dry season	4%	
Plant area		
Catchment Area	40,000	m2
Runoff factor wet season	8%	
Runoff factor dry season	2%	
ROM Stockpiles		
Catchment Area	19,920	m2
Runoff factor wet season	12%	
Runoff factor dry season	4%	
ROM from mining		
OC ROM (Outgoing) moisture content	2%	by mass
OC ROM (Outgoing) tonnage	1,385,846	tpa
Dust suppression		
Haul road length	3,284	m
Haul road width	12	m
Rate of application	1	l/m2
Application frequency	4	/day
Washing and screening plant		
ROM (Incoming) moisture content	1%	by mass
ROM (Incoming) tonnage	1,385,846	tpa
Yield	62%	
Slurry percentage	5%	
Product (Outgoing) moisture content	12%	by mass
Discard moisture content	12%	by mass
Slurry moisture content	20%	by mass
Opencast Pit		
Open Pit Area	93,017	m2
Unlevelled Spoils Area	74,830	m2
Levelled Spoils Area	122,338	m2
Rehabbed Spoils Area	417,049	m2
Open Pit Wet season RO factor	12%	
Open Pit Dry Season RO factor	1%	
Unlevelled Spoils Wet season RO factor	1%	
Unlevelled Spoils Dry Season RO factor	0%	
Levelled Spoils Wet season RO factor	5%	
Levelled Spoils Dry Season RO factor	0%	
Unlevelled Spoils Wet season Recharge	60%	
Unlevelled Spoils Dry Season Recharge	5%	
Levelled Spoils Wet season Recharge	19%	
Levelled Spoils Dry Season Recharge	5%	
Rehabbed Spoils Wet season Recharge	7%	
Rehabbed Spoils Dry Season Recharge	2%	
GW Inflow		
Wet Season GW inflows into pit	30	m3/day
Dry Season GW inflows into pit	30	m3/day


Monthly modelling catchment response
30%
25%
20%
15%
10%
5%
0%
Runoff (% of rainfall)
0
50
100
150
200
250
300
Rainfall (mm)

APPENDIX D
CONCEPTUAL DRAWINGS