Annex G.7

Surface Hydrology Specialist Report

PROPOSED GAMSBERG ZINC MINE
NORTHERN CAPE, SOUTH AFRICA

HYDROLOGICAL IMPACT ASSESSMENT

FINAL REPORT

HHO AFRICA
Cape Town

REP-7116-701-8001-REV 2
April 2013

PROPOSED GAMSBERG ZINC MINE

HYDROLOGICAL IMPACT ASSESSMENT

Document Verification

Rev	Date	Prepared by	Checked by	Approved by	Description	Status
0	18/02/2013	F de Villiers	C Avenant	J Gibberd	Draft Report Issued	Approved
1	18/04/2013	F de Villiers	C Avenant	J Gibberd	Final Report Issued	Approved
2	19/04/2013	F de Villiers	C Avenant	J Gibberd	Final Revised Report Issued	Approved

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DECLARATION OF INTEREST

The author of this report, Fred de Villiers, hereby declares that he is an independent consultant appointed by ERM and has no business, financial, personal or other interest in the activity, application or appeal in respect of which he was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of the specialist performing such work. All opinions expressed in this report are his own.

Fred de Villiers PrEng
ECSA Registration Number 20040009
April 2013

EXECUTIVE SUMMARY

The proposed open pit Gamsberg zinc mine near Aggeneys in the Northern Cape is likely to necessitate extensive construction and development. This would have a significant impact on catchment hydrology, as certain characteristics of some of the catchments would undergo permanent change. This report assesses the impact of these changes on surface water resources and presents mitigating measures, which, if applied, would reduce the negative impact of the proposed development.

Flood lines have been calculated based on the available LIDAR survey data for the 1% PE (100 year RI) design storm event and the flood plain delineated accordingly. However, as this survey did not cover the northern sub-catchment in its entirety, it is not possible to verify whether the proposed tailings dam would be situated outside the flood plain as required by DWA.

Apart from the proposed plant area, which would need to be reconfigured or relocated, all other proposed infrastructure is indicated outside the 100 year flood plain, or more than 100m from the centre line of the nearest water course.

It is recommended that, before the tailings dam is finally placed, the topographic survey is extended to include the entire northern sub-catchment. Subsequently, revised flood lines should be determined. Furthermore, it is recommended that the plant area be reconfigured or relocated to outside the 100 year flood line as required by DWA.

The anticipated key impacts of the project on surface water resources are as follows:

- Natural water courses would be removed or and altered
- Reduced peak runoff and discharge volumes
- Reduction in mean annual runoff
- Increased sediment yield
- Increased pollutant load

Whilst the study does not consider any of the above aspects to have a major impact on surface water resources, the prevailing significance of the impacts are moderate. However, through the successful implementation of the proposed mitigation measures, impact significance may be reduced.

GLOSSARY

BPG	Best Practice Guidelines
BMP	Best Management Practices
ESIA	Environmental and Social Impact Assessment
DWA	Department of Water Affairs
EMP	Environmental Management Plan
FRD	Fine Residue Deposits
ICOLD	International Committee on Large Dams
IDF	Intensity- Duration- Frequency
IFC	International Finance Corporation
IWRM	Integrated Water Resource Management
IWWMP	Integrated Water and Waste Management Plan
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MPRDA	Mining and Petroleum Resources Management Act
MRD	Mine Residue Deposits
NWA	National Water Act
PCD	Pollution Control Dams
PE	Probability of Exceedance
PFS	Pre-feasibility Study
RDF	Recommended Design Flood
RI	Recurrence Interval
RMF	Regional Maximum Flood
SANCOLD	South African Committee on Large Dams
SANS	South African National Standard
SCS	Soil Conservation Survey
SDF	Standard Design Flood
SEF	Safety Evaluation Flood
SUH	Synthetic Unit Hydrograph
SWMP	Storm Water Management Plan
SWMS	Storm Water Management System
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
WHO	World Health Organisation
WRC	Water Research Commission
WWTW	Waste Water Treatment Works

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1.0 INTRODUCTION

The purpose of this report is to describe the impact on catchment hydrology likely to be caused by the proposed open pit Gamsberg zinc mine near Aggeneys in the Northern Cape. This will form part of the current ESIA.

A previous EIA was completed and approved in 2000, but has since expired. An interim baseline hydrology and surface water quality report was prepared by SRK Consulting in January 2010. This report formed part of the Pre-feasibility Study (PFS) and described the delineation of water courses and catchment boundaries and the determination of peak rainfall intensities and flood volumes.

HHO Africa were appointed by ERM in November 2012 to provide an hydrological impact assessment, which would form part of the ESIA. The impacts of the anticipated changes to the surface water regime were to be quantified and possible mitigation measures proposed and assessed. This report supersedes the February 2013 draft hydrological impact assessment report.

2.0 APPROACH & METHODOLOGY

HHO Africa adopted the following approach to the project:

Review Previous Studies
Previous reports, which were made available, were reviewed and relevant information utilised.

Site Visit
A site visit was conducted in December 2012 in order to make *in-situ* observations and assessments. Local conditions were determined and a broad understanding gained of the catchment.

Assess Hydrological Impact
The hydrological impact of the proposed open-cast mine was assessed and quantified for all phases of the project, from inception to decommissioning. The following aspects were addressed:

- The proposed project footprint was assessed and its impact on hydrology determined.
- Flood peaks and runoff volumes were calculated for the 50- and 100 year recurrence interval storm events.
- The project impact on Mean Annual Runoff (MAR) was determined.
- Surface water quality issues were identified and qualified.
- Flood lines were determined for the 100 year recurrence interval storm event.

Hydrological Impact Report
Compile a hydrological impact report containing *inter alia*:

- Identification and mapping of sensitive areas, affected receptors and areas of influence
- Direct, indirect, irreversible and cumulative impact of anticipated activities on surface water resources
- Compliance with legal and policy framework, including IFC Performance Standards for Environmental and Social Sustainability (2012)
- Recommendation of mitigating and monitoring measures
- Evaluation and assessment of residual (post mitigation) impacts

Operational Management Plan
Develop guidelines towards an operational management plan for activities in and around surface water features.

3.0 HYDROLOGICAL DETERMINANTS

3.1 Catchment Characteristics

3.1.1 Area

Situated in the Orange River basin, the mine is located at the watershed between two quaternary catchments, being D81G and D82C. The latter is an endoreic catchment, which means that it is an interior drainage basin that does not drain to the sea. The Gamsberg inselberg is situated within quaternary catchment D81G, which drains in a northerly direction towards the Orange River some 35km away. A third quaternary catchment, D82A was identified in the 2010 baseline report, but being remote from any anticipated mine infrastructure, was not considered in this report.

The baseline surface water assessment identified 11 sub-catchments totaling roughly 750 km^2. Of these, only two are of particular interest to this study, being affected by proposed mine infrastructure. These are sub-catchments 4 and 9a. Table 1 compares the baseline catchment nomenclature with that adopted for this report. As the other baseline sub-catchments are unaffected by proposed mining infrastructure, they were not assessed for this impact assessment.

For the baseline assessment, no ineffective areas were identified. Runoff was therefore deemed to be generated by the entire sub-catchment, and calculated accordingly. The full development scenario, however, introduced ineffective areas that had a significant impact on peak flows and volumes. Figure 1 illustrates the baseline sub-catchment layout.

Baseline Hydrology			Impact Assessment	
Sub-Catchment No	**Area (km^2)**	**Quaternary Catchment**	**Sub-Catchment Name**	**Area (km^2)**
1	108.2	D82C		
2	65.9	D82C		
3	52.8	D82C		
4	31.1	D82C	North	38.7
5	0.97	D81G		
6	53.7	D81G		
7	272.7	D81G		
8	21.6	D81G		
9a	13.4	D81G	South	13.1
9b	1.03	D81G		
10	125.7	D82A		
Total	**747.1**			**53.5**

Table 1: Catchment Naming Convention

(4)

Being situated at the watershed between two quaternary catchments, surface water runoff emanating from the mine leasing area affects downstream catchments. In particular, the likely reduction in Mean Annual Runoff (MAR) is an important consideration in determining the mine's impact on local surface water resources.

3.1.2 Topography, Soils & Vegetation

In terms of topography, the two sub-catchments are relatively disparate. The northern catchment, which significantly larger than the southern inselberg catchment, is generally flat with an average slope of 1.5%. By comparison, the average catchment slope of the inselberg catchment is approximately 12%. This catchment discharges through a narrow kloof with steep, high rocky sides.

Both catchments are characterized by loose rocks, coarse sands and gravels and are sparsely planted. The Water Research Commission (WRC) Surface Water Resources of South Africa 1990, developed by DC Midgley, WV Pitman and BJ Middleton, describe the local soils as being moderately deep and sandy. The hydrological soil group could be classified as Group A, implying low runoff potential and high infiltration rates due to the very permeable nature of the soil. The Erodibility Index, which describes expected sediment yield, is 10 designating medium erodibility.

Vegetal cover could be classified as Category D, which in hydrological terms denotes bare surface with negligible vegetation. This implies that very little surface water would be retained by plants, resulting in a higher runoff coefficient.

3.1.3 Catchment Slope

The slope of a catchment is a very important characteristic in the determination of flood peaks. Steep slopes cause water to run faster and to shorten the critical duration of flood inducing storms, thus leading to the use of higher rainfall intensities in the runoff formulae. On steep slopes the vegetation is generally less dense, soil layers are shallower, and there are fewer depressions, all of which cause water to run off more rapidly. The result is that infiltration is reduced and flood peaks are consequently even higher. The average catchment slope (S_A) for the two catchments under consideration are presented in Table 2 below.

Main watercourse slopes (S_L) were determined using the 10/85 method developed by the US Geological Survey. This method has been found to yield accurate results for relatively small catchments such as these. Table 2 reveals these values.

Sub-Catchment	A_e (km^2)	L (km)	L_C (km)	S_L (m/m)	S_A (m/m)	T_C (h)	T_L (h)
North	38.7	11.0	6.5	0.0075	0.0155	4.6	2.1
South	13.1	6.4	3.1	0.0198	0.1172	1.8	1.1

Table 2: Baseline Catchment Characteristics

3.1.4 Collector Length

The longest watercourse (L) is defined as the route that will be followed by a water particle taking the longest time to reach the catchment outlet from a point on the catchment boundary. This distance consists of both the natural channel and overland flow and, along with the slope of the watercourse, determines the time of concentration for the catchment. The lengths of the two main surface water collectors are given in Table 2 above.

The centre of gravity of each sub-catchment area was calculated. This information was used to determine the centre of gravity catchment length (L_C), which is the distance from the catchment outlet to the point on the longest collector opposite the centre of gravity of the catchment area. This was used to calculate the catchment lag time (T_L) for both sub-catchments as presented in Table 2.

3.2 Climate, Rainfall & Design Storm

The area is classified as a hot desert region with very low rainfall and very high evaporation rates. The mean annual average temperatures is just below 20°C with very hot summers and cool to mild winters. Average calculated monthly evaporation data is shown in Table 3. The Mean Annual Evaporation (MAE) of 2,650mm was determined by the 1990 WRC publication “Surface Water Resources of South Africa.”

Daily rainfall data was extracted from the 2010 Interim Baseline Report, which utilized the software “Design Rainfall in South Africa.” The Pella rainfall station (0247242_W) was chosen as being representative of the catchment and design rainfall determined accordingly. Table 3 illustrates the monthly distribution of the Mean Annual Precipitation (MAP) 77mm and adopted storm rainfall depths are presented in Table 4. Rainfall depths for durations shorter than 24 hours are indicated in Table 5 below.

Month	Average Rainfall (mm)	Average Evaporation (mm)
October	3.5	253
November	4.1	304
December	5.9	351
January	6.0	355
February	15.1	290
March	15.8	259
April	9.5	184
May	5.6	129
June	3.8	98
July	2.9	101
August	1.9	137
September	3.1	189
Total	**77.0**	**2,650**

Table 3: Monthly Precipitation and Evaporation Data

Duration (days)	Return Period (years)						
	2	5	10	20	50	100	200
1	20.5	34.8	46.3	59.1	78.9	96.5	116.7
2	23.2	39.8	53.4	68.8	92.9	114.6	139.9
3	24.2	41.9	56.7	74.0	101.4	126.6	156.6
4	24.6	42.4	57.3	74.5	102.0	127.2	157.0
5	24.9	42.9	57.9	75.0	102.2	126.9	156.1
6	25.6	44.0	59.2	76.4	103.6	128.1	156.9
7	26.3	45.0	60.3	77.6	104.6	128.9	157.2

Table 4: Design Rainfall (mm)
(Source: 2010 Interim Baseline Report)

Duration	Return Period (years)						
	2	5	10	20	50	100	200
5 minutes	4.8	8.1	10.8	13.8	18.4	22.5	27.3
10 minutes	6.9	11.7	15.6	20.0	26.6	32.6	39.4
15 minutes	8.6	14.6	19.4	24.8	33.1	40.4	48.9
30 minutes	10.4	17.6	23.4	30.0	40.0	48.9	59.2
45 minutes	11.6	19.7	26.2	33.5	44.7	54.6	66.1
1 hour	12.6	21.3	28.4	36.2	48.4	59.1	71.5
1.5 hour	14.1	23.8	31.7	40.5	54.1	66.1	80.0
2 hour	15.2	25.8	34.3	43.8	58.5	71.5	86.5
4 hour	17.2	29.1	38.7	49.4	66.0	80.7	97.6
6 hour	18.4	31.2	41.5	53.0	70.8	86.6	104.7
8 hour	19.4	32.8	43.6	55.8	74.4	91.0	110.1
10 hour	20.1	34.1	45.4	58.0	77.4	94.6	114.5
12 hour	20.8	35.2	46.8	59.8	79.9	97.7	118.2
16 hour	21.8	37.0	49.2	62.9	84.0	102.7	124.2
20 hour	22.7	38.5	51.2	65.4	87.3	106.7	129.1
24 hour	23.4	39.7	52.8	67.5	90.1	110.2	133.3

Table 5: Rainfall Depths for Durations Shorter than 24 hours (mm)
(Source: 2010 Interim Baseline Report)

The commonly used “return period,” or Recurrence Interval (RI), requires further explanation. In hydrological terms, the more accurate term is Probability of Exceedance (PE). The PE denotes the statistical probability of a certain flood magnitude being exceeded. By contrast, the RI suggests a flood that recurs with certain regularity. Table 14 below shows the correlation between these terms. As can be seen, the 1 year RI flood has a PE of 100%, which means that there is a 100% probability in any given year that a flood with that magnitude will occur. Similarly, there is only a 1% probability that the 100 year RI flood will be exceeded in any given year. This distinction is important when assessing the impact of storm flows. By way of extreme example, a 100% PE storm event would be less threatening than a 1% PE storm event. These storm events are vastly different and have vastly disparate outcomes. In the case of the 100% PE storm, the flood peak and volume is beneficial to the ecosystem, while typically the 1% PE storm is potentially threatening to downstream infrastructure and communities. Clearly, in terms of impact, a reduction in small PE storms would be seen as a positive impact, whilst a reduction in large PE storms would have negative consequences. It should, however, be stated that downstream of the proposed development there are no communities or significant infrastructure.

3.3 Time of Concentration

The time that a water particle requires to travel from the furthest point in the catchment to the outlet is known as the time of concentration. In the case of extreme events it is assumed that the storm duration is similar to the time of concentration. The time of concentration can consist of natural stream flow and overland flow components.

Table 2 illustrates the baseline catchment characteristics that affect the time of concentration. It is anticipated that the proposed mining infrastructure will affect the nature of the sub-catchments and alter the rainfall- runoff response. Anticipated changes are presented in Table 6 below. It should be noted that the effective catchment areas are significantly reduced due to the assumed capture, retention and reuse of rainfall within the designated “dirty” areas. These include the open pit, the waste rock stockpiles, the processing plant, tailings dam, pollution control- and return water dams. A further change in the southern sub-catchment involves the curtailing of the baseline watercourse due to the location of the proposed open pit, which would traverse its upper reaches. Figure 2 illustrates the pre-mitigation sub-catchment layout.

Sub-Catchment	A_e (km^2)	L (km)	L_C (km)	S_L (m/m)	S_A (m/m)	T_C (h)	T_L (h)
North	35.4	11.0	6.5	0.0075	0.0155	4.6	2.1
South	9.0	5.3	2.8	0.0236	0.1172	1.7	1.0

Table 6: Probable Post-Development Catchment Characteristics

3.4 Peak Runoff Flow & Volume

Calculated storm peak flows were determined using the Rational, SDF and SUH deterministic methods and results compared to the empirical RMF method. Peak runoff volumes were calculated assuming a simple triangular hydrograph. Table 7 illustrates the calculated baseline peak runoff flows and volumes for the two sub-catchments for the 50 and 100 year recurrence interval storm events.

Sub-Catchment	Q_{50} (m^3/s)	Q_{100} (m^3/s)	V_{50} (X10^{6}m^3)	V_{100} (X10^{6}m^3)
North	50.5	61.7	1.25	1.53
South	33.1	48.8	0.32	0.47

Table 7: Baseline Peak Runoff Flows and Volumes

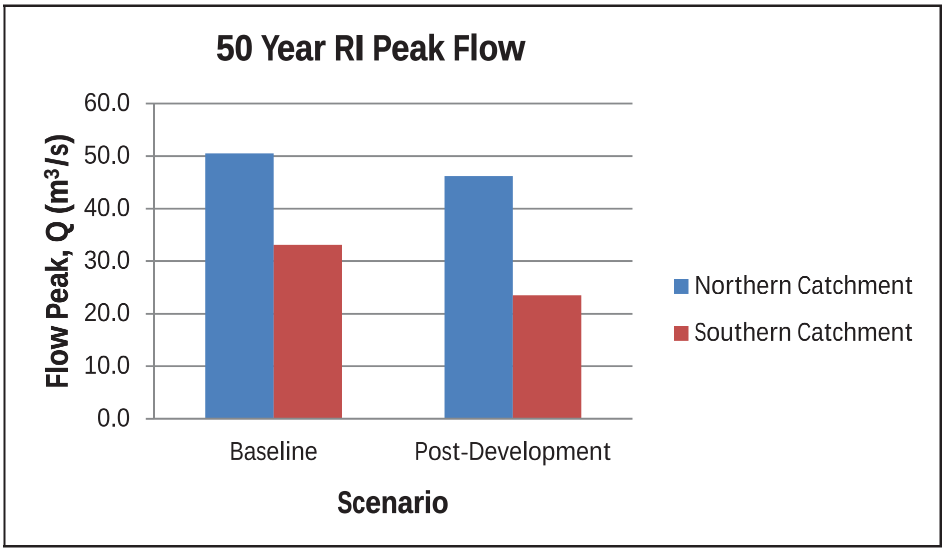
Table 8 demonstrates the likely effect of the proposed development on peak flows and runoff volumes for the proposed post-mitigation (Figure 3) layout. The slightly lower post-mitigation flows are largely attributable to the reduction in effective catchment area due to the construction of the tailings dam, the return water dam, pollution control dams, processing plant, the open pit itself and the waste rock stockpiles. In terms of the

DWA Best Practice Guidelines (BPG), it was assumed that runoff from the designated "dirty" areas would be captured and reused, or attenuated, treated and released.

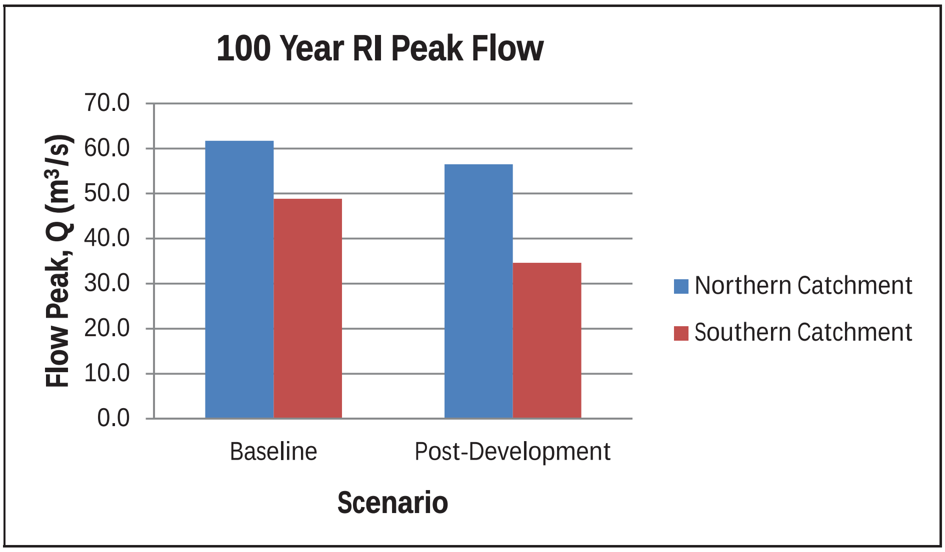
Peak flow results for both the baseline and post-development scenarios are graphically depicted for the 50 year and 100 year Recurrence Interval (RI) storm events in Graphs 1 and 2 respectively.

Sub-Catchment	Q_{50} (m^3/s)	Q_{100} (m^3/s)	V_{50} ($X10^6 m^3$)	V_{100} ($X10^6 m^3$)
North	46.2	56.5	1.15	1.40
South	23.5	34.6	0.22	0.32

Table 8: Calculated Post-Development Peak Runoff Flows and Volumes



Graph 1: Comparison between Baseline and Post-Development 50 year RI Peak Flows



Graph 2: Comparison between Baseline and Post-Development 100 year RI Peak Flows

3.5 Mean Annual Runoff

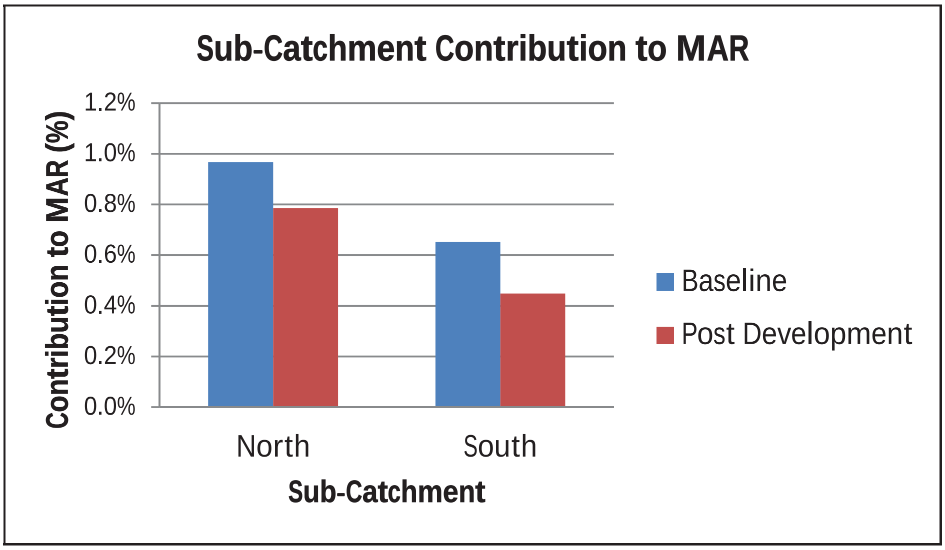
Given the desert climate, characterized by low Mean Annual Precipitation (MAP), high evaporation and high infiltration rates, the watercourses are ephemeral in nature and completely dry for much of the year. Consequently, the quaternary catchments within which the study area is situated are known to have very low Mean Annual Runoff (MAR) values. These have been published in the 1990 WRC publication "Surface Water Resources of South Africa" and MAR values for the two sub-catchments under consideration were calculated by the weighted area method. Table 9 illustrates the baseline MAR in the context of the quaternary catchments, whilst Table 10 presents the anticipated reduction in MAR as a consequence of the development. However, it should be noted that there are no known downstream users of surface water given the unreliable nature of this resource.

Sub-Catchment	Quaternary Catchment	Quaternary Catchment Area (km^2)	Quaternary Catchment MAR ($X10^3$ m^3)	Baseline Sub-Catchment MAR ($X10^3$ m^3)	Sub-Catchment Contribution to MAR (%)
North	D82C	3,996	800	7.74	1.0%
South	D81G	2,007	900	5.87	0.7%

Table 9: Baseline MAR

Sub-Catchment	Post-Development Sub-Catchment MAR ($X10^3$ m^3)	Reduction in Sub-Catchment MAR (%)	Sub-Catchment Contribution to MAR (%)
North	7.09	8%	0.8%
South	4.05	31%	0.4%

Table 10: Anticipated Post-Development Reduction in MAR



Graph 3: Comparison between Baseline and Post-Development Contribution to MAR

3.6 Regional Maximum Flood

One of the likely effects of global climate change is an increase in large storm events. Whilst almost impossible to predict the magnitude of extreme rainfall events, the Directorate of Water Affairs published a study in 1980 entitled "Maximum Flood Peak Discharges in South Africa: An Empirical Approach." This study by Z Kovacs analysed the approximately 300 highest flood peaks recorded in South Africa between 1894 and 1979. This information was processed using the Francou-Rodier relationship to determine local Regional Maximum Flood (RMF) curves. The RMF for the northern sub-catchment was calculated to be roughly 133 m^3/s, while the southern catchment RMF would be approximately 99 m^3/s. The impact of the RMF was not considered in this report as it is dealt with in the climate change impact study.

3.7 Site Specific Water Resources

A significant fresh water spring is situated on the east side of the inselberg. However, this spring is located outside the study area and consequently has no bearing on this surface water hydrology impact assessment. No evidence of other springs or fountains could be found during the site visit.

3.8 Surface Water Quality

A water quality baseline assessment was undertaken by SRK Consulting in 2010. Their findings are replicated below. Recommendations for monitoring during the construction and operational phases of the development are made in Section 7 of this report.

The baseline water quality study found that water emanating as springs from the Gamsberg Inselberg is fit for domestic use and livestock watering, according to the South African National Standard (SANS) for drinking water quality (SANS 241:2006) and the Department of Water Affairs Guidelines for Livestock Watering (DWAF, 1996).

The study recommended that springs emerging from the Inselberg should be adequately protected and canalized to prevent contamination.

3.9 Flood Line Determination

3.9.1 Assumptions

Hydrology

Hydrological calculations were undertaken for both the northern and southern sub-catchments as described. The 1% probability of exceedance, or 100 year Recurrence Interval (RI) flood peaks and volumes were calculated using a number of different deterministic methods, being the SDF, Rational Method, SUH, SDF and RMF. Flood peaks were calculated for a number of return periods for both the baseline (ie pre-development) and post-development scenarios.

The baseline 100 year RI flood peak is of particular significance in that this flood is determines the flood plain, which in terms of the Water Act may not be impinged upon by any mining development. Flood lines were accordingly determined for this flood. The values of Q_{100} used for the flood line assessment were 61.7 m^3/s and 48.8 m^3/s respectively for the northern and southern sub-catchments.

An assumption employed in modeling this flood was that the flood peak accumulates along the length of the watercourse(s), such that the full flood value is reached at the downstream discharge point, whilst the flood value at the upstream extremity is zero. A linear progression was assumed.

Topographic Survey

A topographic LIDAR survey with a contour interval of 1m was provided by the client. Although the surveyed data did not extend across the entire northern sub-catchment, it did sufficiently cover the southern area where most of the mining activities will be centred. Consequently, flood lines could not be accurately determined for the upstream reaches of the northern sub-catchment watercourses.

It should be noted that 1m contour interval is deemed coarse in the case of the northern sub-catchment, which is flat. Furthermore, the ephemeral watercourses traversing the northern sub-catchment are poorly defined. These factors imply a wide flood plain likely to meander.

Catchment characteristics, such as collector gradient and catchment slope were determined from the LIDAR survey for the southern (inselberg) sub-catchment. In the case of the northern sub-catchment, these values were determined from 1:50,000 topographic maps obtained from the Surveyor General's office. Whilst wholly adequate for hydrology, the contour interval of 20m is not sufficient for the determination of flood lines.

3.9.2 Methodology

The LIDAR survey described above was converted into a Digital Terrain Model (DTM) using Civil Designer 6.5 software. River transects were extracted from the DTM and imported into HEC-RAS 4.1.0. A number of river reaches were specified for the northern sub-catchment, given its tributaries.

Manning's n-value was assumed to be 0.035 for the main channel and overbanks. Steady state flow was assumed and upstream and downstream boundary conditions stipulated as normal flow depth. Not surprisingly, the flow in the northern watercourses was found to be sub-critical. The main inselberg water course through the kloof was naturally faster flowing and flow was predominantly super-critical. The model calculated several hydraulic jumps, which would be expected given the steepness and irregularity of the kloof. Figure 4 illustrates the water profile for the main southern sub-catchment watercourse, whist Figure 5 shows the water profile for the major watercourse draining the northern sub-catchment.

3.9.3 Conclusions & Recommendations

Given the inherent limitations of the LIDAR survey, the flood lines are deemed to reasonably accurate. It is unfortunate that the existing survey does not cover the area of the critical tailings facility. Before the final placement of the tailings dam, it would be prudent to extend the survey to include this area and to determine revised flood lines.

All Mine Residue Deposits (MRD), Pollution Control Dams (PCD) and mining infrastructure and should be placed outside the designated 100 year RI flood plain, and more than 100m away from any watercourse as stipulated by the Department of Water Affairs.

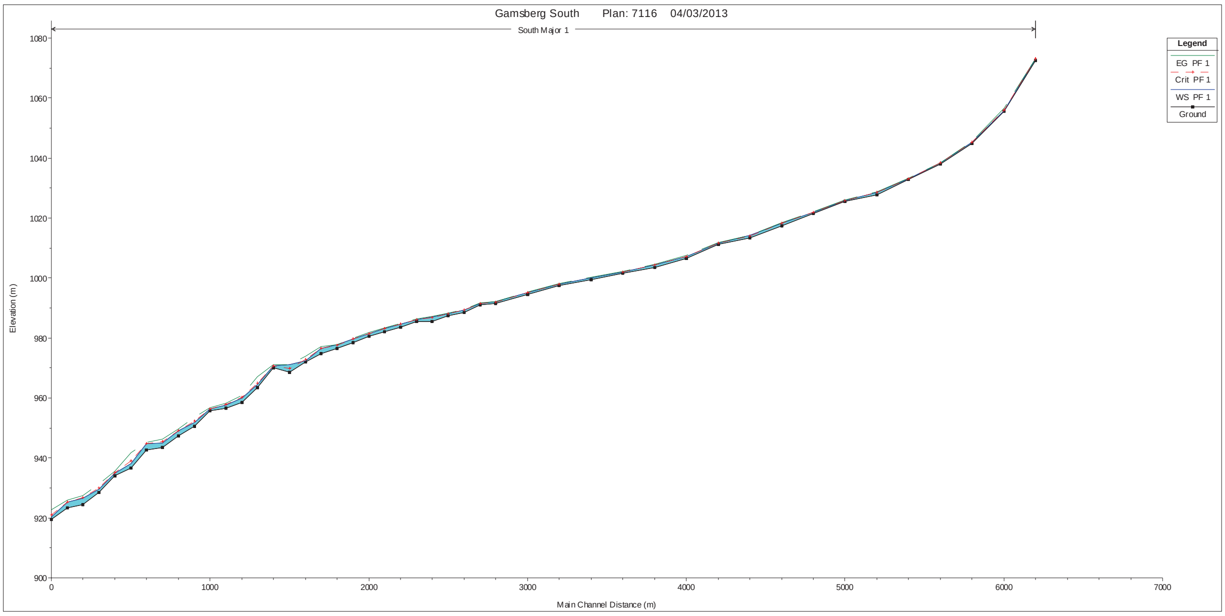


Figure 4: Water profile for Southern Sub-Catchment

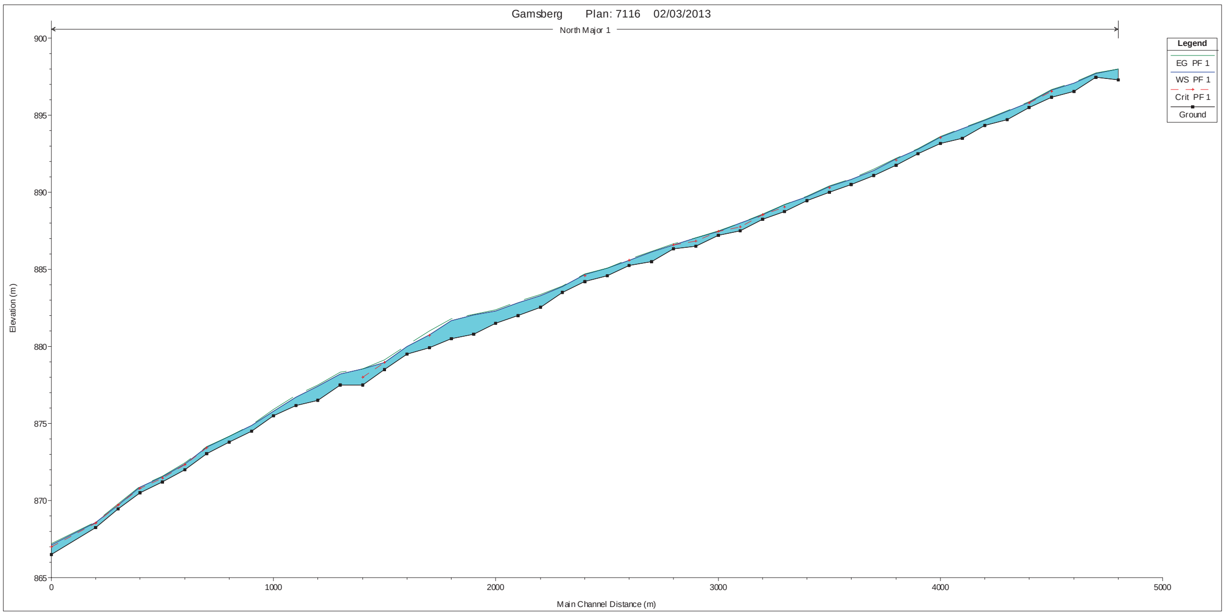


Figure 5: Water profile for Major Watercourse: Northern Sub-Catchment

4.0 APPLICABLE POLICIES, LEGISLATION, STANDARDS & GUIDELINES

Water management at mines is controlled by the National Water Act (NWA), 1998 (Act 36 of 1998), which is the primary statute providing the legal basis for water management in South Africa and has to ensure ecological integrity, economic growth and social equity when managing and using water. Use of water for mining and related activities is also regulated through regulations that were updated after the promulgation of the NWA (Government Notice No. GN704 dated 4 June 1999).

4.1 National Water Act, 1998 (Act 36 of 1998)

The following chapters of the NWA are of particular importance:

- Chapter 3, Part 4 states that anyone who owns, occupies, controls or uses land is deemed responsible for taking measures to prevent pollution of water resources.
- Chapter 4 deals with water use regulation.
- Chapter 12 deals with water management in terms of dam safety.
- Section 19 deals with water management at mines in terms of pollution prevention and control.
- Section 21 states the water uses requiring authorization. The following particular uses are typically relevant for mining projects:

  - 21 (a): Abstraction (water supply)
  - 21 (b): Storage (raw and potable water reservoirs)
  - 21 (c): Impeding or diverting the flow of water in a watercourse
  - 21 (f): Discharging waste or water containing waste into a water resource through a pipe, canal, sewer or other conduit
  - 21 (g): Disposing of waste in a manner which may detrimentally impact on a water resource
  - 21 (i): Altering the bed, banks, course or characteristics of a watercourse.

- Section 26 (1) provides for the development of regulations requiring monitoring, measurement and recording as well as the effects to be achieved through management practices prior to discharge or disposal.

The NWA introduced the concept of Integrated Water Resource Management (IWRM), comprising all aspects of the water resource, including water quality, water quantity and the aquatic ecosystem quality. The IWRM approach provides for both resource directed and source directed measures. Resource directed measures aim to protect and manage the receiving environment, whilst source directed measures aim to control the impacts at source.

This report focuses on the following source directed measures:

- Identification of pollution sources and suggestions to implement pollution prevention measures
- Water reuse
- Water treatment

4.2 Government Notice No 704, National Water Act, 1998 (Act 36 of 1998)

The following regulations pertaining to mining and related activities are noteworthy:

- Regulation 2: Information and notification
- Regulation 4: Restrictions on locality
- Regulation 5: Restrictions on use of material
- Regulation 6: Capacity requirements of clean and dirty water systems
- Regulation 7: Protection of water resources
- Regulation 8: Security and additional matters
- Regulation 9: Temporary or permanent cessation of a mine

4.3 Dam Safety Regulations (Government Notice R.1560 of 25 July 1986)

These regulations require that every dam with a safety risk shall be classified in accordance with regulation 2.4 on the basis of its size and hazard potential. An authorization is required from the dam safety office before construction of a dam commences.

According to the regulations, the proposed tailings dam would be classified as a Category III dam with a high hazard potential rating. The owner of a dam with a safety risk is required to operate and maintain the dam in a safe and responsible manner.

4.4 Mining and Petroleum Resources Management Act, 2002 (Act 28 of 2002)

This act regulates prospecting and mining activities in the Republic of South Africa. Mining rights are granted in terms of section 23(1) and mining permits issued in terms of section 27(6). Mine closure plans are to be submitted in accordance with the provisions of the act.

4.5 Department of Water Affairs Best Practice Guidelines

The DWAF has developed a series of Best Practice Guidelines (BPGs) for mines in line with International Principles and Approaches towards sustainability. The series of BPGs have been grouped as outlined below:

Best practice guidelines dealing with aspects if DWAF's water management hierarchy are prefaced with the letter H. The topics that ate covered in these guidelines include:

- H1. Integrated Mine Water Management
- H2. Pollution Prevention and Minimization of Impacts
- H3. Water Reuse and Reclamation
- H4. Water Treatment

Best practise guidelines dealing with general water management strategies, techniques and tools, which could be applied cross-sectrol and always prefaced by the letter G. The topics that are covered in these guidelines include:

- G1. Storm Water Management
- G2. Water and Salt Balances
- G3. Water Monitoring Systems
- G4. Impact Prediction
- G5. Water Management Aspects for Mine Closures

Best practise guidelines dealing with specific mining activities or aspects and always prefaced by the letter A. These guidelines address the prevention and management of impacts from:

- A1. Small-Scale Mining
- A2. Water Management for Mine Residue Deposits
- A3. Water Management in Hydrometallurgical Plants
- A4. Pollution Control Dams
- A5. Water Management for Opencast Mines
- A6. Water Management for Underground Mines

The development of the guidelines is an inclusive consultative process that incorporates the input from a wide range if experts, including specialists within and outside the mining industry and government. The process of identifying which BPGs to prepare, who should participate in the preparation and consultative processes, and the approval of the BPGs was managed by a Project Steering Committee (PSC) with representation by key role-players.

The BPGs will perform the following functions within the hierarchy of decision making:

- Utilization by the mining sector as input for compiling water use authorization applications (and other legally required documents such as EMPs, EIAs, closure plans, etc.) and for drafting authorization conditions.
- Serve as a uniform basis for negotiations through the licensing process prescribed by the NWA.
- Used specifically by DWAF personnel as a basis for negotiation with the mining industry, and likewise by the mining industry as a guideline as to what the DWAF considers as best practice in resource protection and waste management.
- Inform Interest and Affected Parties on good practice at mines.

Figure 6 represents a schematic diagram of the mining sector resource protection and waste management strategy.

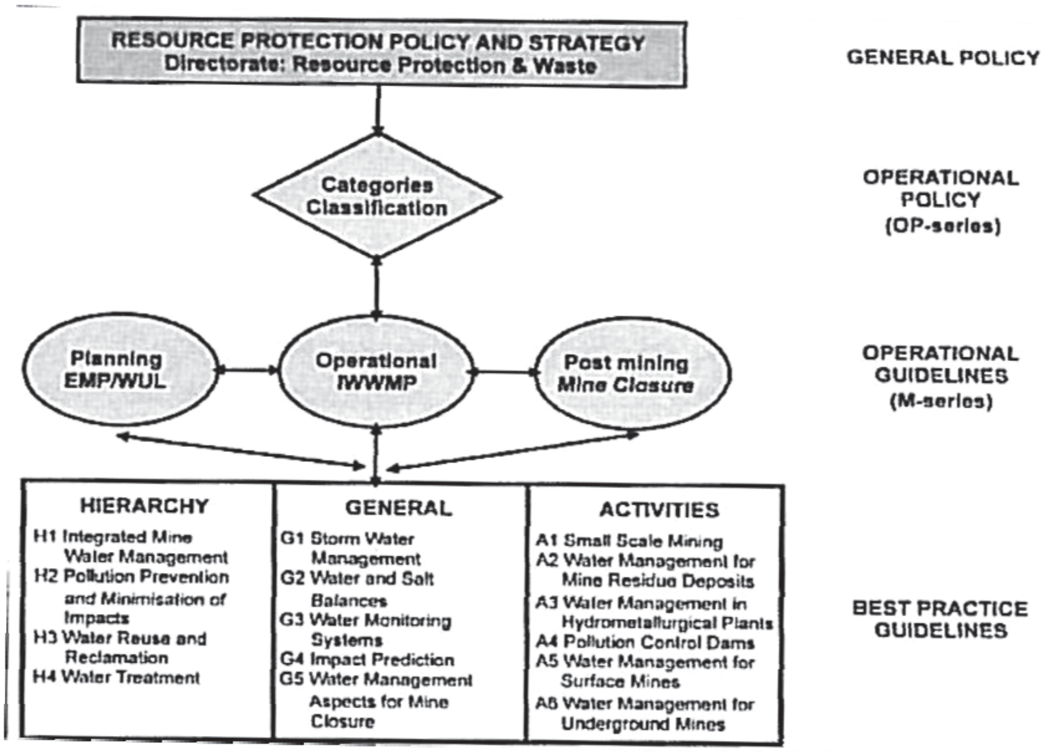


Figure 6: Mining Sector Resource Protection and Waste Management Strategy

5.0 KEY ISSUES & SCENARIOS

From a hydrological perspective, the following key issues have been identified. These issues are discussed below, while their impact and possible mitigating measures are discussed in the following chapter.

5.1 Changes in Catchment Characteristics

The catchment characteristics of both sub-catchments would be altered by the proposed development. Table 11 provides a list of proposed mining infrastructure affecting surface water hydrology. Infrastructure has been classified as “dirty” or “clean” in terms of the DWA Best Practice Guidelines (BPG). Every effort must be made to keep “clean” areas clean and to collect and contain runoff from “dirty” areas.

Surface water runoff from clean areas should be discharged directly to natural watercourses and not contained or contaminated. Clean storm water should only be contained if the volume of the runoff poses a risk, if the water cannot be discharged to watercourses by gravitation, for attenuation purposes, or when the clean area is small and located within a large dirty area. Given the proposed layout and natural topography, there is no need for attenuation of clean storm water for this project.

Surface water runoff from dirty areas should be collected and contained in order to ensure that the following objectives are met:

- Minimisation of contaminated areas and reuse of dirty water (wherever possible)
- Prevention of overflows and minimisation of seepage losses from storage facilities (such as polluted dams)
- Prevention of further deterioration of water quality
- Separation of dirty water in terms of degree of contamination (very dirty water should be kept separate from moderately dirty water)

Description	Area (ha)			Ineffective Area (ha)	Dirty or Clean
	North	South	Total		
Tailings Dam	280		280	280	DIRTY
Processing Plant	45		45		DIRTY
Open Pit	50	280	330	330	DIRTY
Contractors' Camp	32				CLEAN
Haul Roads	±35	±20	55		MOD
Workshop	2		2		DIRTY
Explosives Magazine	2		2		CLEAN
Waste Rock Dump	490		490		DIRTY

Table 11: Proposed Mining Infrastructure

Certain infrastructure, such as the open pit, processing plant, workshops, tailings and return water dam would cause an increase in hydrologically ineffective areas. Being dirty, surface water emanating from these areas would be captured and treated as close to source as possible. Consequently, the calculated flood peak values and MAR would decrease as shown in Tables 8 and 10 respectively.

5.2 Removal or Alteration of Natural Water Courses

Figure 1 illustrates the baseline sub-catchment layout, showing the sub-catchment boundaries, natural contours, watercourses and ecologically sensitive areas. Figure 2 demonstrates the proposed pre-mitigation layout, which shows the anticipated impact on certain natural water courses. The impact of this change on surface water hydrology follows in Section 6.1 of this report.

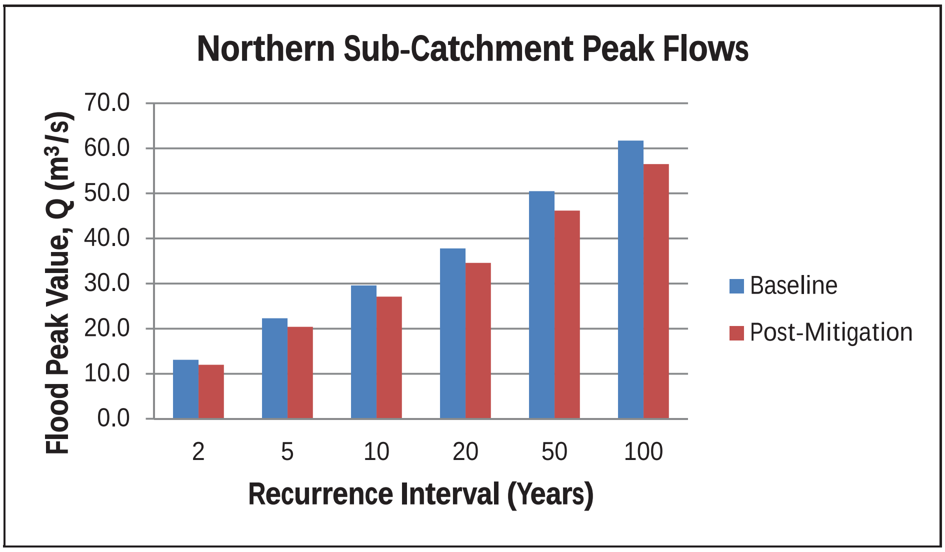
The proposed open pit would require the curtailment of the longest watercourse in the southern catchment. Ordinarily this would indicate a decrease in the time of concentration. However, the circular shape of this catchment, its mountainous character and the number of ephemeral watercourses have resulted in only a marginal change in time of concentration and other catchment characteristics. A comparison between Table 2 (baseline) and Table 6 (post-development) reveals remarkably similar characteristics.

Ephemeral watercourses in the northern catchment would not require removal or alteration.

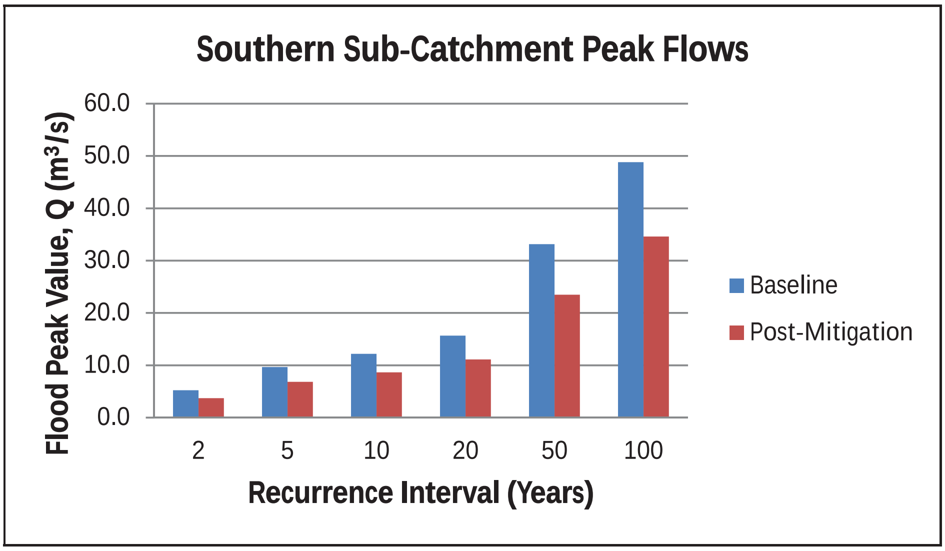
5.3 Changes in Peak Runoff & Discharge Volumes

The calculation of baseline and anticipated post-mitigation peak runoff flows and volumes are presented in Section 3.4 of this report. This section assesses the key issues associated with these changes, whilst the impact on surface water hydrology follows in Section 6.2 of this report.

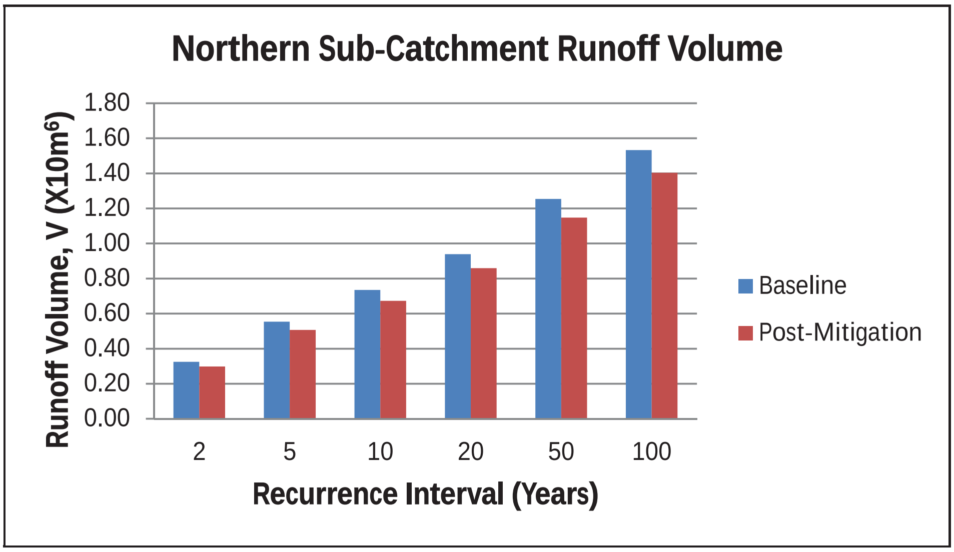
Graphs 4, 5, 6 and 7 below graphically illustrate the net effect of changes in the sub-catchments on peak storm flows and runoff volumes. It is clear that the northern sub-catchment is not as severely impacted than the southern sub-catchment, and a comparison between the baseline and post-mitigation values reveal an average net decrease of roughly 8.5% in both peak flow and volume. The expected decrease in peak flow and volume is approximately 18% for the southern sub-catchment.



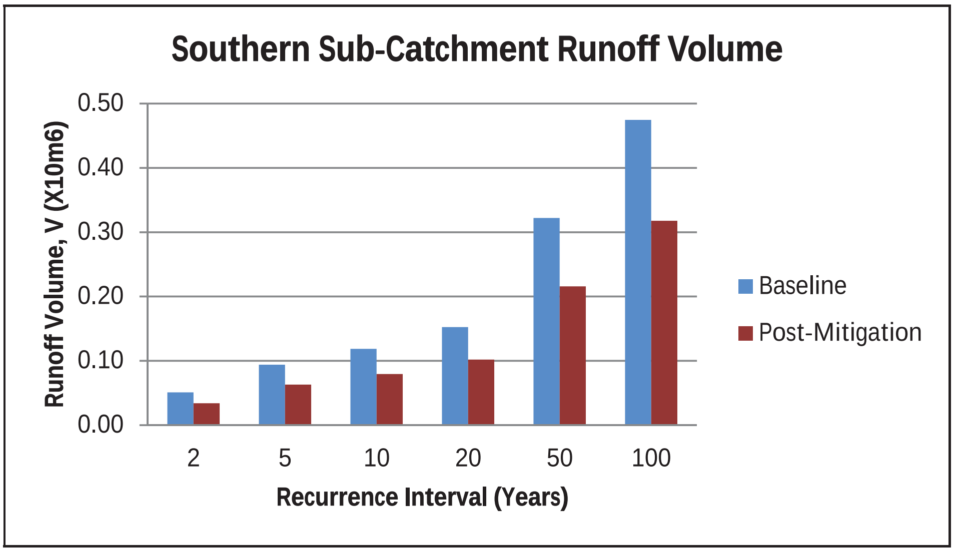
Graph 4: Calculated Peak Flows for the Northern Sub-Catchment



Graph 5: Calculated Peak Flows for the Southern Sub-Catchment



Graph 6: Calculated Runoff Volumes for the Northern Sub-Catchment



Graph 7: Calculated Runoff Volumes for the Southern Sub-Catchment

5.4 Changes in Mean Annual Runoff

It is clear from the MAR values in Tables 9 and 10 that the proposed mining development would significantly affect the southern (Inselberg) sub-catchment. In particular, the ecologically sensitive kloof would be impacted by the anticipated reduction in MAR as illustrated in Graph 3. The impact of this change on surface water hydrology follows in Section 6.3 of this report.

Post-development MAR would be 4,050 m^3 per annum if surface runoff from the north-western ridge is allowed to enter the pit. This quantity of surface water would exit via the kloof. This implies that an estimated 1,820 m^3 of surface water would enter the pit annually. The reduction in MAR for the quaternary catchment would be in the order of

0.2%, which would be negligible. However, the reduction in MAR for the Inselberg sub-catchment itself would be about 31%.

Should surface runoff from the north-western ridge be diverted away from the pit towards the kloof, the post-development MAR leaving the Inselberg catchment via the kloof would be approximately 4,520 m^3 per annum. This would represent a 23% reduction in sub-catchment MAR, but only a 0.2% reduction in quaternary catchment MAR. Surface water entering the pit annually would amount to roughly 1,350 m^3.

Technically it would be very difficult to divert surface water runoff from the north-western ridge towards the kloof without causing extensive ecological damage to that part of the sub-catchment. This risk of damage would negate any benefits this intervention may hope to achieve. Accordingly, it would be preferable for this small area to be allowed to enter the pit. The above findings verify that there certainly would be no noticeable impact on the larger quaternary catchment. Similarly, the local impact on the kloof would be only marginally worse (31% reduction in MAR as opposed to 23%).

5.5 Increased Sediment Yield

Notwithstanding the arid, sparsely planted terrain, the proposed mine infrastructure would require removal of vegetation and the stripping of topsoil. This would increase the erosion potential of the sub-catchments and subsequently result in increased sediment deposition in water courses. Furthermore, the construction of haul roads, and general mining activities such as blasting, loading and hauling would increase the quantity of airborne dust. This dust would settle on the ground surface where it would present an additional source of sediment during rain events. The impact of this change on surface water hydrology follows in Section 6.4 of this report.

5.6 Increase in Pollutant Load

The proposed construction of a Waste Water Treatment Works (WWTW) would inevitably increase the risk of surface water resources being contaminated by untreated sewage. This contamination could be caused by insufficient maintenance of the WWTW, or as a consequence of blocked sewer mains or manholes. Furthermore, raw sewerage spillages could occur in the event of power outages affecting foul sewer pump stations or the WWTW.

By their very nature, metallurgical processes are dirty and a potential major source of pollutants. Whilst the proposed mining infrastructure has been classified as either “clean” or “dirty,” it is imperative that surface water runoff from the dirty areas we captured and adequately treated. Wherever possible, treated water should be reused in the mining process.

Hydrocarbons, such as oils and petroleum fuels, represent a potential threat to surface water quality. As such, the potential impact of accidental spillages should be assessed and mitigated. The impact of the expected increase in pollutant load on surface water resources follows in Section 6.5 of this report.

6.0 IMPACT ASSESSMENT

This section provides a description of the potential impacts the proposed Project may have on surface water hydrology. The key receptors or resources considered are the sub-catchments and watercourses affected by the proposed development.

6.1 Impact of the Removal and Alteration of Natural Water Courses on Catchment Response

The key issues related to this impact were described in Section 5.2. The findings of the impact assessment are presented below and tabulated in Table 12.

Impact Assessment

As the proposed open pit covers a significant portion of the southern catchment it is inevitable that certain existing water courses that collect and convey surface water runoff from the western section of this catchment would be removed or altered. Certain of the minor water courses would be permanently removed by the proposed mining operation, while the longest collector, which governs catchment response, would be curtailed. However, it has been demonstrated that the post-mitigation hydrological response of the southern catchment is similar to that of the baseline scenario. The anticipated decrease in time of concentration is negligible.

The significance is therefore considered to be MODERATE during the construction and operational phases of the project. The degree of confidence in this assessment is HIGH.

Mitigation Measures

- Where mining infrastructure, such as haul roads, are required across natural watercourses, new storm water infrastructure, such as pipes and culverts could replace the hydraulic function currently offered by the natural water courses. This infrastructure should be designed for both hydraulic performance and environmental functionality. A thorough assessment of the suitability of the new stormwater infrastructure must be made at preliminary design stage.
- The water quality of rivers and the proposed canals should be monitored on a monthly basis as described in the operational management plan.

Residual Impact

With the implementation of the above mitigation, impact intensity and magnitude will be reduced in the southern catchment during the construction phase. The impact significance would accordingly reduce to MINOR. The degree of confidence in this assessment is HIGH.

	Without Mitigation	Residual Impact (with Mitigation)
Construction Phase		
Duration	Permanent	Permanent
Extent	On-site	On-site
Intensity	Medium	Medium
Magnitude	Medium	Low
Likelihood	Definite	Definite
Significance	**Moderate**	**Minor**
Operational Phase		
Duration	Permanent	Permanent
Extent	On-site	On-site
Intensity	Medium	Medium
Magnitude	Medium	Low
Likelihood	Definite	Definite
Significance	**Moderate**	**Minor**
Decommissioning Phase		
Duration	Permanent	Permanent
Extent	On-site	On-site
Intensity	Medium	Medium
Magnitude	Medium	Low
Likelihood	Definite	Definite
Significance	**Moderate**	**Minor**

Table 12: Impact of the Removal and Alteration of Natural Water Courses on Catchment Response

6.2 Impact of Reduced Peak Runoff and Discharge Volumes on Water Courses

The key issues related to this impact were described in Section 5.3. The findings of the impact assessment are presented below and tabulated in Table 13.

Impact Assessment

The proposed mining development at Gamsberg would require the excavation of a large open pit and the construction of a tailings dam, pollution control dams, process plant and ancillary infrastructure. Being classified as “dirty,” rain falling on this infrastructure would be captured and contained. Consequently, the quantum of surface water runoff would reduce. Post-development storm peak flows and volumes have been calculated and compared to baseline values, as can be seen in Graphs 4 to 7 (inclusive).

Recurrence Interval, RI (Years)	Probability of Exceedance, PE (%)
100	1%
50	2%
20	5%
10	10%
5	20%
2	50%
1	100%

Table 13: Comparison between Recurrence Interval (RI) & Probability of Exceedance (PE)

A brief description of the relevance and applicability of the range of design rainfall events in Table 13 was is provided in Section 3.2 of this report. As mentioned, the small PE events typically cause flood damage, whilst the large PE storms do not. For the purpose of this impact assessment, these contradictory outcomes will be considered separately. This section shall consider the reduction in small PE floods, whilst the subsequent section will consider the impact of the reduction in Mean Annual Runoff.

In summary, the calculated reduction in small PE (*ie* large RI) floods is viewed as a POSITIVE impact as the risk of damage to downstream communities, property, operations or infrastructure would be reduced. However, the concomitant reduction in MAR, is considered a NEGATIVE impact and is presented in Section 6.3 below.

The positive significance is therefore considered to be MODERATE during the construction phase of the project. The degree of confidence in this assessment is MEDIUM.

Mitigation Measures
As the impact is deemed POSITIVE, no mitigating measures are proposed.

Residual Impact
It is unlikely that the ineffective areas giving rise to the reduction in flood peaks would be removed in the closure phase. Consequently, the residual impact is MODERATE. The degree of confidence in this assessment is MEDIUM.

	Without Mitigation	Residual Impact (with Mitigation)
Construction Phase		
Duration	Permanent	N/A
Extent	Local	N/A
Intensity	Medium	N/A
Magnitude	Medium	N/A
Likelihood	Likely	N/A
Significance	**Moderate, Positive**	N/A
Operational Phase		
Duration	Permanent	N/A
Extent	Local	N/A
Intensity	Medium	N/A
Magnitude	Medium	N/A
Likelihood	Likely	N/A
Significance	**Moderate, Positive**	N/A
Decommissioning Phase		
Duration	Permanent	N/A
Extent	Local	N/A
Intensity	Medium	N/A
Magnitude	Medium	N/A
Likelihood	Likely	N/A
Significance	**Moderate, Positive**	N/A

Table 14: Impact of Reduced Peak Runoff and Discharge Volumes on Water Courses

6.3 Impact of Reduction in Mean Annual Runoff on Downstream Surface Water Resources

The key issues related to this impact were described in Section 5.4. The findings of the impact assessment are presented below and tabulated in Table 15.

Impact Assessment

Whereas the reduction in small PE (*i.e.* large RI) storm peak flows is seen as a positive impact, the reduction in MAR is considered a negative impact. The reason for this apparent contradiction is that smaller storm events have a natural, restorative function in the local ecosystem. Conversely, large storm events, while part of the natural cycle, can be destructive. The impact of large storms is presented in the preceding section.

The calculated reduction in MAR can be viewed in terms of the greater quaternary catchment, or assessed at the local sub-catchment level. As has been demonstrated in Graph 3 and Table 10, the resultant reduction in quaternary catchment MAR is 0.2%. This is seen as negligible. However, at the sub-catchment level future MAR will reduce by 8% in the case of the northern sub-catchment, and 31% for the southern sub-catchment. This report will consider the reduction in MAR at the sub-catchment level.

The 31% calculated reduction of MAR in the southern sub-catchment is likely to cause irreversible change to the Inselberg kloof. By implication, aquatic biota will receive less than three quarters of their current allotment of surface water flow. Whilst this reduction could be seen as acceptable in the short term, the long term effect may be significant. The anticipated reduction in MAR from the northern catchment is relatively insignificant.

The combined significance of this impact is therefore considered to be MODERATE during the construction, operation and decommissioning phases of the project. The degree of confidence in this assessment is HIGH.

Mitigation Measures
As it is extremely unlikely that the open pit could be relocated or reduced in extent, other possible solutions must be found. One such suggestion could be to supply piped fresh water of similar quantity and quality to the kloof watercourse. This water would replace the lost MAR and provide artificial replenishment.

Residual Impact
Should the above mitigation measure be accepted, the ecological risk attributable to decreased MAR could be greatly reduced through judicious design and implementation. Accordingly, the impact significance on local downstream water resources could be classified as MINOR during the all phases of the project. The degree of confidence in this assessment is HIGH.

	Without Mitigation	**Residual Impact (with Mitigation)**
Construction Phase		
Duration	Permanent	Temporary
Extent	Local	On-site
Intensity	Low	Low
Magnitude	Medium	Low
Likelihood	Likely	Likely
Significance	**Moderate**	**Minor**
Operational Phase		
Duration	Permanent	Temporary
Extent	Local	On-site
Intensity	Low	Low
Magnitude	Medium	Low
Likelihood	Likely	Likely
Significance	**Moderate**	**Minor**
Decommissioning Phase		
Duration	Permanent	Temporary
Extent	Local	On-site
Intensity	Low	Low
Magnitude	Medium	Low
Likelihood	Likely	Likely
Significance	**Moderate**	**Minor**

Table 15: Impact of Reduction in Mean Annual Runoff on Downstream Surface Water Resources

6.4 Impact of Increased Sediment Yield on Surface Water Quality

Given the erosion potential of the local soils, it is likely that the construction and operational phases of the proposed development would cause an increase in erosion. Thus an increase in sediment deposition could be expected along slow moving water courses. In order to limit the environmental impact on faunal and floral communities, it is essential that sediment yield be reduced as far as is possible. Sediment load is measured in terms of Total Suspended Solids (TSS), but through the effective design and deliberate implementation of BMP "treatment trains" its impact can be mitigated. The key issues related to this impact were described in Section 5.5. The findings of the impact assessment are presented below and tabulated in Table 16.

The potential impact, which would be direct and negative, is considered to be of MODERATE significance during the construction and operation phases of the project, and MINOR significance during the decommissioning phase. The degree of confidence in this assessment is HIGH.

Mitigation Measures

- Pollution control dams should be constructed to contain surface water runoff from all dirty areas, such as waste rock stockpiles. Dirty runoff should be directed towards these dams though a well designed system of berms and channels. The dams should be designed to accommodate and retain transported sediment. It is therefore important that dams are designed to have adequate dead storage volume.
- The runoff from bare areas, such as haul roads, would need to be collected and conveyed by adequate side drains. This water, which would be high in TSS content, should be attenuated and retained sufficiently to allow sediment to settle prior to the discharge of the sufficiently clean supernatant.
- Dust mitigation should be implemented in accordance with the air quality impact assessment forming part of this ESIA.
- The quality of runoff in watercourses should be monitored on a monthly basis as described in Section 7.2 and corrective actions taken as appropriate. Baseline water quality is described in Section 3.8 of this report.
- During the decommissioning phase, all unnecessary bare surfaces and developed zones should be removed and, as far as is possible, restored to their natural state.

Residual Impact

Should the above mitigation measure be accepted, the anticipated decrease in water quality attributable to increased sediment load could be greatly reduced. Accordingly, the impact significance on local downstream water resources could be classified as MINOR during the construction and operation phases of the project, and NEGLIGIBLE significance during the decommissioning phase.. The degree of confidence in this assessment is HIGH.

	Without Mitigation	Residual Impact (with Mitigation)
Construction Phase		
Duration	Short term	Short term
Extent	Local	Local
Intensity	Medium	Low
Magnitude	Medium	Low
Likelihood	Likely	Likely
Significance	**Moderate**	**Minor**
Operational Phase		
Duration	Long Term	Long Term
Extent	Local	Local
Intensity	Low	Negligible
Magnitude	Medium	Low
Likelihood	Likely	Likely
Significance	**Moderate**	**Minor**
Decommissioning Phase		
Duration	Short term	Short term
Extent	Local	Local
Intensity	Negligible	Negligible
Magnitude	Low	Negligible
Likelihood	Likely	Likely
Significance	**Minor**	**Negligible**

Table 16: Impact of Increased Sediment Yield on Surface Water Quality

6.5 Impact of Increased Pollutant Load on Surface Water Quality

The key issues related to this impact were described in Section 5.6. The findings of the impact assessment are presented below and tabulated in Table 17.

Mitigation Measures

- A thorough, regular inspection and maintenance regime should be implemented by the operator of the proposed Waste Water Treatment Works (WWTW).
- Pump stations should be inspected, serviced and cleaned on a monthly basis, and manholes and underground pipes inspected and cleaned every six months.
- The WWTW and all sewer pump stations should be equipped with emergency generators, or adequate emergency storage. Typically, four hours' storage should suffice.
- An emergency response unit should be established to undertake urgent maintenance and repair work after hours.
- It is imperative that surface water runoff from the dirty areas (*eg* process plant, waste rock stockpiles, tailings dam) be captured and wherever possible, reused in the mining process. Pollution control dams should be deployed as indicated on Figure 3. Dirty runoff should be directed towards these dams though a well designed system of berms and channels.
- Dirty water not used in the mining process should be adequately treated prior to release. Treatment should be undertaken to as described in Section 7.2.

- All areas where hydrocarbons, such as oils and petroleum fuels are handled (*i.e.* workshops should be bunded and strictly controlled to minimise the risk of accidental spillages.
- The quality of runoff in watercourses should be monitored on a monthly basis as described in Section 7.2 and corrective actions taken as appropriate. Baseline water quality is described in Section 3.8 of this report.

Residual Impact

Should the above mitigation measure be accepted, the anticipated decrease in water quality attributable to increased pollutant load could be greatly reduced. Accordingly, the impact significance on local downstream water resources could be classified as MINOR during the construction and operation phases of the project, and NEGLIGIBLE significance during the decommissioning phase.. The degree of confidence in this assessment is HIGH

	Without Mitigation	**Residual Impact (with Mitigation)**
Construction Phase		
Duration	Short term	Short term
Extent	Local	Local
Intensity	Medium	Low
Magnitude	Medium	Low
Likelihood	Likely	Likely
Significance	**Moderate**	**Minor**
Operational Phase		
Duration	Long Term	Long Term
Extent	Local	Local
Intensity	Low	Negligible
Magnitude	Medium	Low
Likelihood	Likely	Likely
Significance	**Moderate**	**Minor**
Decommissioning Phase		
Duration	Short term	Short term
Extent	Local	Local
Intensity	Negligible	Negligible
Magnitude	Low	Negligible
Likelihood	Likely	Likely
Significance	**Minor**	**Negligible**

Table 17: Impact of Increased Pollutant Load on Surface Water Quality

7.0 OPERATIONAL MANAGEMENT PLAN

The legal requirements governing surface water are presented in Section 4 of this report. In order to assist Applicants achieve compliance, the DWA have compiled Best Practice Guidelines (BPG). The following sections reflect a few specific excerpts from the BPG, but are by no means a comprehensive summary. The Applicant is referred to the full do

Storm water management and drainage planning are critical components of integrated water and waste management (IWWM) at mining sites. While storm water management is an integral part of the IWWM and is documented as part of the Integrated Water and Waste Management Plan (IWWMP), for the purpose of this document, the component of the IWWMP that refers to storm water management is referred to separately as the storm water management plan (SWMP). A SWMP must address the impact of:

- Mining operations on the water flow and water quality processes of the hydrological cycle, and the associated upstream and downstream environmental impacts.
- The hydrological cycle on mining operations, including effects such as loss of production, costs, and impacts of both floods and droughts on the mining operations.

The objectives of a SWMP are site-specific but some general objectives include:

- Protection of life (prevent loss of life) and property (reduce damage to infrastructure) from flood hazards;
- Planning for drought periods in a mining operation;
- Prevention of land and watercourse erosion (especially during storm events);
- Protection of water resources from pollution;
- Ensuring continuous operation and production through different hydrological cycles;
- Maintaining the downstream water quantity and quality requirements;
- Minimizing the impact of mining operations on downstream users;
- Preservation of the natural environment (water courses and their ecosystems).

The SWMP must cover the life cycle of the mine from exploration, through construction, operation, decommissioning, and up to post-closure.

Potential adverse effects of inadequate storm water management include:

- Downstream contamination of natural watercourses due to runoff or spillage of contaminated storm water.
- Flooding, with the resultant damage to property, land and potentially loss of life
- Loss of catchment yield and addition of large volumes of water to the mine water balance when optimal runoff of clean storm water is not achieved.
- Erosion of beds and banks of waterways.
- Increased recharge through spoils or fracture zones, unnecessarily increasing the water volume that comes into contact with contaminants.

7.1 Design Phase

- A comprehensive Storm Water Management System (SWMS) should be created at the design stage of the project.
- An Operation Manual is required for each Pollution Control Dams (PCD). The purpose of the manual is to provide guidelines to the owner for the safe operation and maintenance of the dam during its lifespan. Emergency and monitoring procedures are suggested in the BPG.
- All Mine Residue Deposits (MRD), such as tailings (Fine Residue Deposits, FRD) and waste rock dumps, and PCD should be situated outside the 100 year flood lines and more than 100m away from any watercourse.
- Open cast mines should be situated outside the 50 year flood line, and a horizontal distance of 100m from the centre line of the watercourse.
- All surface water runoff emanating outside MRD should be diverted away from MRD. Diversion channels should be designed for the maximum precipitation expected in 24 hours with a RI of 100 years. Freeboard of at least 0.5m should be provided.
- Rain falling within MRD areas should be retained in those areas. Retention facilities should be designed for the maximum precipitation expected in 24 hours with a RI of 50 years. Freeboard of at least 0.8m is required above this maximum predicted water level.
- A well designed system of sub-surface drains is required for tailings dams. These ensure that the stability of the structure is not compromised and that groundwater is not contaminated. Proper engineering drawings showing details, calculated flow values and water levels are required.
- Tailings and other PCD should be designed in accordance with the Dam Safety Regulations.
- A comprehensive water balance model should be created. Surface water should be used in the mining process as far as is possible.
- PCD should be designed such that retained storm water is removed as soon as practicable in order to swiftly restore design storage volumes.
- Evaporation dams should be avoided as far as possible as water cannot be reused.
- PCD and diversion berms should be designed to overtop not more than once in 50 years (*i.e.* for storms with a PE of 2%).
- PCD should be designed in accordance with ICOLD and SANCOLD guidelines. Spillways should be designed to pass the RDF with the required freeboard. PCD should withstand the SEF without failing.
- All open channels should be designed such that supercritical velocities are avoided, i.e. flow velocities should remain sub-critical.

7.2 Operational Phase

- Inspection procedures must be clearly stipulated in the Storm Water Management Plan (SWMP) and records must be kept accordingly.
- FRD penstocks and outlets should be inspected on a monthly basis and cleared of blockages or residue deposits.

- Seepage through sub-surface drains at MRD should be monitored monthly. The Operations Manual should describe procedures in the event that flows or levels fall outside expected values. These could include the installation of piezometers to determine the phreatic surface, inclinometers to monitor slope movements, or slope buttresses.
- Water quality and flows should be monitored in accordance with the SWMP. It is recommended that such monitoring occurs at least once per month. Values obtained should be incorporated in the water and salt balance for the mine and could serve as early warning indicators if potential malfunctions or mismanagement.
- Regular water management training should be provided by the mine.
- Samples should be taken at watercourses during the wet season and analysed for water quality. Given the arid climate, samples should be taken when practicable (i.e. when watercourses flow). Pools in the Inselberg kloof should be sampled and tested on a monthly basis for the indicators listed in the Pre-feasibility report.

7.3 Decommissioning Phase

- A mine closure plan should be prepared in accordance with the provisions of the MPRDA and its Regulations. This closure plan will be incorporated into the closure EMP.
- All MRD should be left, at closure, in such a state where these facilities are able to withstand the effects resulting from the maximum probable precipitation with minimal detrimental consequences.
- All decommissioned MRD should have regular inspections as defined in the closure plan. These inspections should be carried out by a suitably qualified person and findings presented in Aftercare Reports.
- The closure plan should describe the intended fate of PCD, which may be demolished, retained for beneficial use, or capped.
- Penstocks and outfall pipes should be in a state at closure where these structures do not constitute a potential failure to risk and hence unacceptable impact to persons or the environment. All penstocks and outfall pipes should be in such a condition (or be modified) so that these do not constitute a route whereby residue or uncontrolled water may discharge from the MRD.
- Filter drain outlets and solution trenches should be in a state where these structures are able to function effectively on a long term basis and without deterioration. Solution trenches should be designed to discharge any seepage into suitable evaporation dams or sumps.

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APPENDICES