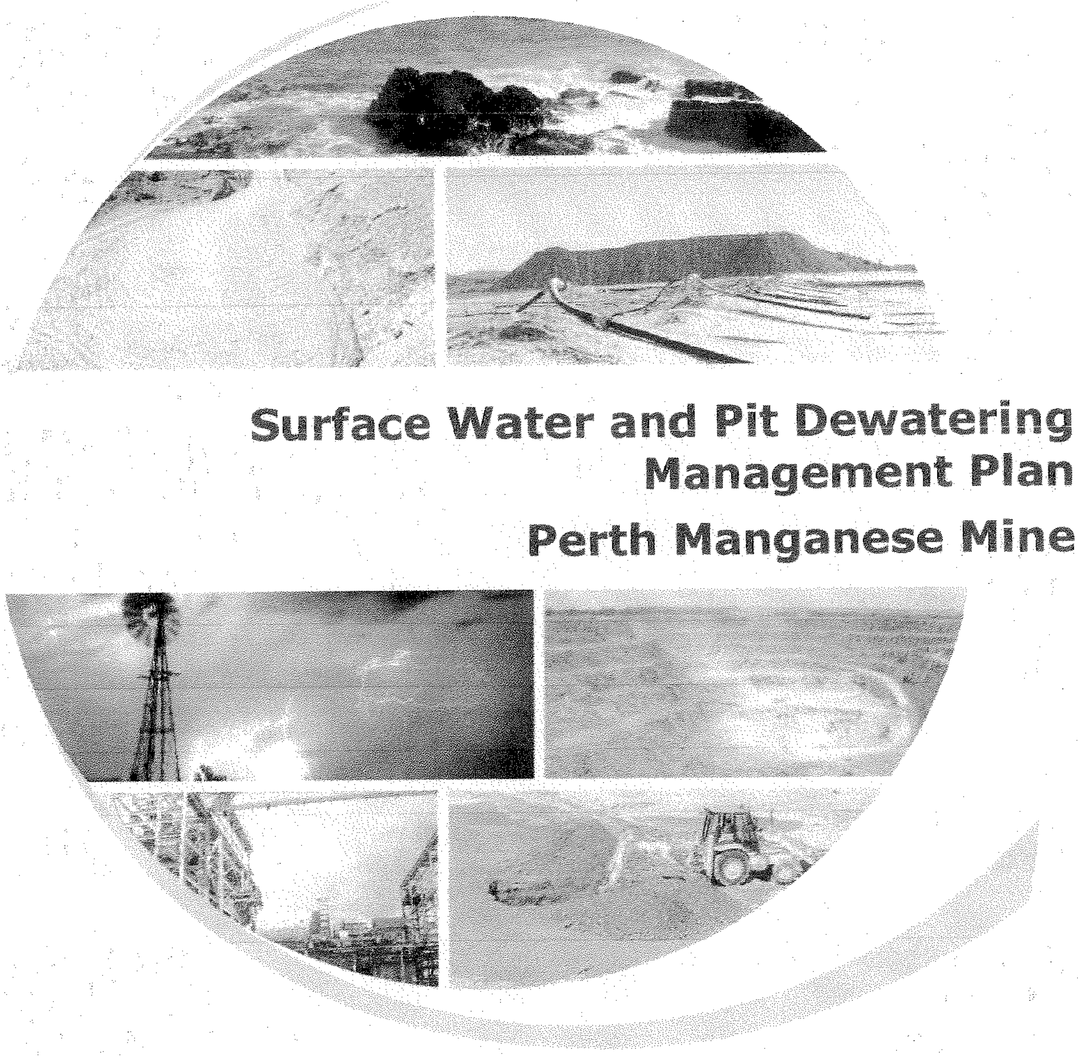

Surface Water and Pit Dewatering Management Plan

Perth Manganese Mine

epoch
resources pty ltd

mine residue and environmental engineering consultants

PROJECT No 000-168 REPORT NO 000-168-01 April 2012

Surface Water and Pit Dewatering Management Plan

Perth Manganese Mine

Prepared For

Sebilo Resources (Pty) Ltd

PROJECT NUMBER 000-168
REPORT NO.000-168-01
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DEFINITIONS

The following terms are used in his report and are defined as detailed in GN704 published in terms of the National Water Act, 1998 (Act No. 36 of 1998

Activity	a) any mining related process on the mine including the operation of washing plants, mineral processing facilities, mineral refineries and extraction plants, and b) the operation and the use of mineral loading and off-loading zones, transport facilities and mineral storage yards, whether situated at the mine or not, (i) in which any substance is stockpiled, stored, accumulated or transported for use in such process; or (ii) out of which process any residue is derived, stored, stockpiled, accumulated, dumped, disposed of or transported;
Clean Water System	includes any dam, other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of unpolluted water
Dam	includes any settling dam, slurry dam, evaporation dam, catchment or barrier dam and any other form of impoundment used for the storage of unpolluted water or water containing waste
Dirty Area	means any area at a mine or activity which causes, has caused or is likely to cause pollution of a water resource;
Dirty Water System	includes any dam, other form of impoundment, canal, works, pipeline, residue deposit and any other structure or facility constructed for the retention or conveyance of water containing waste
Environmental Management Programme	means an environmental management programme submitted in terms of section 39 of the Minerals Act, 1991 (Act No. 50 of 1991);
Facility	in relation to an activity, includes any installation and appurtenant works for the storage, stockpiling, disposal, handling or processing of any substance;
Manager, Mine and Mineral	have the meanings assigned to them in the Mine Health and Safety Act, 1996 (Act No. 29 of 1996);
Person in control of a Mine or Activity	in relation to a particular mine or activity, includes the owner of such mine or activity, the lessee and any other lawful occupier of the mine, activity or any part thereof; a tributer for the working of the mine, activity or any part thereof; the holder of a mining authorisation or prospecting permit and if such authorisation or permit does not exist, the last person who worked the mine or his or her successors-in-title or the owner of such mine or activity; and if such person is not resident in or not a citizen of the Republic of South Africa, an agent or representative other than the manager of such a mine or activity must be appointed to be responsible on behalf of the person in control of such a mine or activity
Residue	includes any debris, discard, tailings, slimes, screenings, slurry, waste rock, foundry sand, beneficiation plant waste, ash and any other waste product derived from or incidental to the operation of a mine or activity and which is stockpiled, stored or accumulated for potential re-use or recycling or which is disposed of
Residue Deposit	includes any dump, tailings dam, slimes dam, ash dump, waste rock dump, in-pit deposit and any other heap, pile or accumulation of residue
Stockpile	includes any heap, pile, slurry pond and accumulation of any substance where such substance is stored as a product or stored for use at any mine or activity
The Act	means the National Water Act, 1998 (Act No. 36 of 1998);
Water System	includes any dam, any other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of water

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mine residue and environmental engineering consultants

April 2012

Project No. 000-168

Report No. 000-168-01

SURFACE WATER AND PIT DEWATERING MANAGEMENT PLAN
PERTH MANGANESE MINE

1. INTRODUCTION

Sebilo Resources (Pty) Ltd (*Sebilo*) are assessing the viability of resuming mining operations at the Perth Manganese Mine located on the farm Perth 276 in the magisterial district of Kuruman approximately 10km south of the town of Hotazel (Ref : Figure 1). The mine was previously operated by Assmang who ceased operations on the site in the 1970s.

The process of transferring ownership of the mine and it's associated rights from Assmang to Sebilo requires that Sebilo prepare and submit an Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP). Epoch Resources (Pty) Ltd (*Epoch*) have been commissioned to assist in the compilation of the EIA and EMP by compiling a pit dewatering and surface water management plan for the proposed resumption of mining and associated activities.

FIGURE 1 : LOCALITY PLAN – PERTH MANGANESE MINE

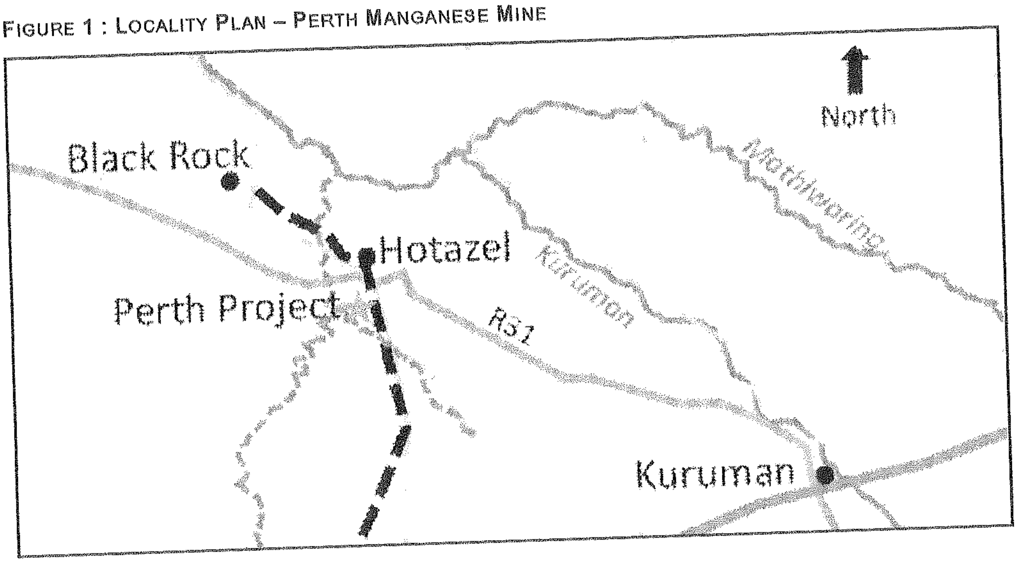
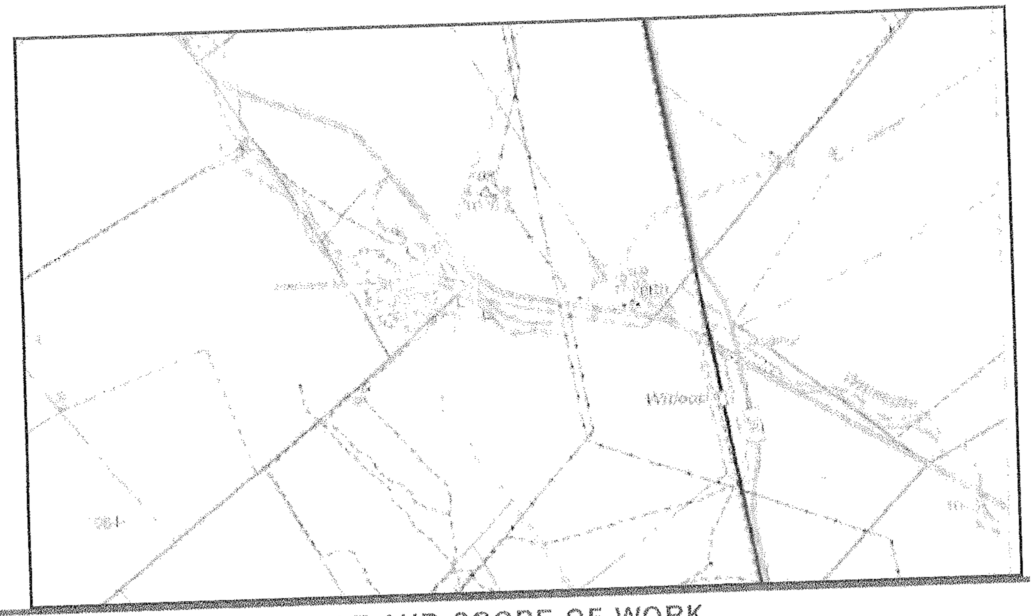


FIGURE 2 : SITE LAYOUT – PERTH MANGANESE MINE

Physical Address	Building 22A, The Woodlands, Woodlands Drive, Woodmead, 2148, Johannesburg, South Africa
Postal Address	PO Box 6, The Woodland, 2080, South Africa
Telephone	+27 (11) 656 0380/1
Facsimile	+27 (11) 802 3654
Web Address	www.epochresources.co.za
Company Registration	Epoch Resources (Pty) Ltd, No 2005/007908/07
Directors	GJ Wiid, G Papageorgiou, A Savvas, SJP Coetzee



2. TERMS OF REFERENCE AND SCOPE OF WORK

The terms of reference for the surface water study call for:

- The compilation of an operational mine water balance
- The development of a conceptual storm water management plan including the sizing of dams and diversion works as necessary
- The development of a conceptual pit dewatering plan

The objective of the study is to develop the necessary plans to a level of detail such that they will support the compilation and submission of an Environmental Management Plan (EMP) for the mine. Feasibility designs of the mine and processing plant are however in the early stages of development which has required that certain assumptions be made. It is expected that changes to the site layout may occur as detailed plans for the implementation of the project are developed.

The scope of work carried out in addressing the terms of reference has comprised:

- An inspection of the mine and review of information supplied to confirm that the information supplied reasonably accurately reflects the actual conditions on site
- Development of a conceptual mine dewatering and water treatment plan
- Development of a conceptual mine water balance
- Conceptual sizing and design of surface water containment and diversion works (including the pollution control dam)
- Compilation of a report on the pit dewatering and surface water management plan.

3. PROJECT SETTING

Descriptions of the surface water environment and proposed mining activities are presented below to place in context the designs and proposed management plans.

3.1. SUMMARY DESCRIPTION OF THE SURFACE WATER ENVIRONMENT

The proposed mine is located in the Northern Cape Province approximately 2km west of the farm Perth and 10km south of the town of Hotazel. In the context of surface water hydrology this places the project in the D41K quarternary sub-catchment of the Orange (D) primary drainage area. (Ref : WRC Report No. 298/3.1/94 First Edition and WRC Report No. 298/3.2/94 First Edition).

- The D41K Quarternary Sub-catchement has a gross catchment area of 4,216km2, net catchment area of 2,664km2.

- The Mine is situated in the D4A rainfall zone, with Mean Annual Precipitation (MAP) of 334mm, Mean annual Runoff (MAR) of 1.1 mil m³, Gross MAR of 4.4 mil m³ and a net MAR of 2.8 mil m³.
- The Mine is situated in the 8A Evaporation zone with a Mean Annual Evaporation (MAE) of 2,070mm.

A summary of the expected average monthly rainfall and evaporation at the mine site is presented in Table 1 with a summary of potential storm events as a function of recurrence interval and duration presented in Table 2.

TABLE 1 : AVERAGE MONTHLY RAINFALL AND EVAPORATION

MONTH	AVERAGE MONTHLY RAINFALL AS PERCENTAGE OF MAP (%)	AVERAGE MONTHLY RAINFALL (MM)	AVERAGE MONTHLY EVAPORATION AS PERCENTAGE OF MAE (%)	AVERAGE MONTHLY EVAPORATION (MM)
January	17.00	59.5	13.60	286.3
February	18.01	63.0	10.45	220.0
March	19.03	66.6	9.02	189.9
April	9.95	34.8	6.30	132.6
May	4.05	14.2	4.54	95.6
June	1.30	4.6	3.45	72.6
July	0.79	2.8	3.99	84.0
August	1.65	5.8	5.44	114.5
September	2.04	7.1	7.53	158.5
October	5.08	17.8	10.07	212.0
November	8.52	29.8	11.90	250.5
December	12.57	44.0	13.71	288.6
TOTAL	**100.0**	**350**	**100.0**	**2104.8**

TABLE 2 : SUMMARY OF EXPECTED RAINFALL AS A FUNCTION OF RECURRENCE INTERVAL AND EVENT DURATION

EVENT DURATION (DAYS)	RECURRENCE INTERVAL (YRS)							MIN ANNUAL MAX	MAX ANNUAL MAX
	2	5	10	20	50	100	200		
	POCCURRENCE FOR SPECIFIED LIFE OF MINE OF15YRS								
	100%	96%	79%	54%	26%	14%	7%		
1	47.8	68	82.2	96.5	116.0	131.4	147.5	16	162
2	56.7	81.6	99.3	117.4	142.4	162.5	183.7	18	162
3	62.0	89.4	109.0	129.1	157.0	179.5	203.3	24	190
7	75.9	110.2	134.9	160.3	195.6	224.0	254.2	24	200

The Witleegte dry water course which runs through the mine area in a north westerly direction is a tributary of the Ga-mogara dry water course, which in turn drains into the Kuruman river. There is no available streamflow data for the Kuruman river or its trubutaries. The Witleegte and Ga-mogara are shown as dry water courses on the 1:50 000 topographical maps of southern Africa (2722 BD) indicating that they run dry during winter months. The surface water catchments in the area are characterised by very gentle gradients and sandy soils, with the end result that only fairly heavy rain is expected to induce any significant surface runoff.

3.2. SUMMARY DESCRIPTION OF THE MINE

The proposed mining activities are expected to include:

- A resumption of opencast mining, commencing in the existing open pit which will expand in a northerly direction
- The establishment of underground workings to access the deeper sections of the orebody to the west of the open pit. It is expected that the underground resources will be accessed by decline shafts in the open pit
- The establishment of a waste rock dump to accommodate excess material from the open pit
- Re-mining and processing of the existing waste dump
- Processing of the waste dump and ore in a crushing and wet screening processing plant
- The disposal of tailings arising from the processing plant into a tailings disposal facility
- Ore stockpiles and loading facilities associated with the processing plant

The surface water works expected to be required to facilitate these operations are expected to require a combination of pollution containment, surface water diversion and abstraction and treatment facilities comprising:

- A Pollution Control Dam (PCD) sized to contain runoff from the plant area
- A surface water diversion and containment works to manage flows associated with the Witleegte perennial stream
- Pit dewatering and treatment infrastructure expected to include:
    - ➢ A pumping station in the open pit
    - ➢ A water treatment plant
    - ➢ A lined storage facility to store brine residues associated with the water treatment process

3.3. LEGISLATION

The design of surface water works associated with mining operations are must comply with the requirements of GN704 published in terms the National Water Act, 1998 (Act No. 36 of 1998) which specify Regulations on the Use of Water for Mining and Related Activities Aimed at the Protection of Water Resources. The most relevant of the requirements are summarised in Table 3.

TABLE 3 : SUMMARY OF LEGISLATION PERTAINING TO DESIGN OF SURFACE WATER WORKS (GN704)

CATEGORY	REGULATION
RESTRICTIONS ON LOCALITY	No person in control of a mine or activity may- (a) locate or place any residue deposit, dam, reservoir, together with any associated structure or any other facility within the 1:100 year flood-line or within a horizontal distance of 100 metres from any watercourse or estuary, borehole or well, excluding boreholes or wells drilled specifically to monitor the pollution of groundwater, or on water-logged ground, or on ground likely to become waterlogged, undermined, unstable or cracked; (b) except in relation to a matter contemplated in regulation 10, carry on any underground or opencast mining, prospecting or any other operation or activity under or within the 1:50 year flood-line or within a horizontal distance of 100 metres from any watercourse or estuary, whichever is the greatest; (c) place or dispose of any residue or substance which causes or is likely to cause pollution of a water resource, in the workings of any underground or opencast mine excavation, prospecting diggings, pit or any other excavation; or (d) use any area or locate any sanitary convenience, fuel depots, reservoir or depots for any substance which causes or is likely to cause pollution of a water resource within the 1:50 year flood-line of any watercourse or estuary.
CAPACITY	Every person in control of a mine or activity must-

TABLE 3 : SUMMARY OF LEGISLATION PERTAINING TO DESIGN OF SURFACE WATER WORKS (GN704)

REQUIREMENTS OF CLEAN AND DIRTY WATER SYSTEMS	(a) confine any unpolluted water to a clean water system, away from any dirty area; (b) design, construct, maintain and operate any clean water system at the mine or activity so that it is not likely to spill into any dirty water system more than once in 50 years; (c) collect the water arising within any dirty area, including water seeping from mining operations, outcrops or any other activity, into a dirty water system; (d) design, construct, maintain and operate any dirty water system at the mine or activity so that it is not likely to spill into any clean water system more than once in 50 years; and (e) design, construct, maintain and operate any dam or tailings dam that forms part of a dirty water system to have a minimum freeboard of 0.8 metres above full supply level, unless otherwise specified in terms of Chapter 12 of the Act. (f) design, construct and maintain all water systems in such a manner as to guarantee the serviceability of such conveyances for flows up to and including those arising as a result of the maximum flood with an average period of recurrence of once in 50 years.
PROTECTION OF WATER RESOURCES	Every person in control of a mine or activity must take reasonable measures to- (a) prevent water containing waste or any substance which causes or is likely to cause pollution of a water resource from entering any water resource, either by natural flow or by seepage, and must retain or collect such substance or water containing waste for use, re-use, evaporation or for purification and disposal in terms of the Act; (b) design, modify, locate, construct and maintain all water systems, including residue deposits, in any area so as to prevent the pollution of any water resource through the operation or use thereof and to restrict the possibility of damage to the riparian or in-stream habitat through erosion or sedimentation, or the disturbance of vegetation, or the alteration of flow characteristics; (c) cause effective measures to be taken to minimise the flow of any surface water or floodwater into mine workings, opencast workings, other workings or subterranean caverns, through cracked or fissured formations, subsided ground, sinkholes, outcrop excavations, adits, entrances or any other openings; (d) design, modify, construct, maintain and use any dam or any residue deposit or stockpile used for the disposal or storage of mineral tailings, slimes, ash or other hydraulic transported substances, so that the water or waste therein, or falling therein, will not result in the failure thereof or impair the stability thereof; (e) prevent the erosion or leaching of materials from any residue deposit or stockpile from any area and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from entering and polluting any water resources; (f) ensure that water used in any process at a mine or activity is recycled as far as practicable, and any facility, sump, pumping installation, catchment dam or other impoundment used for recycling water, is of adequate design and capacity to prevent the spillage, seepage or release of water containing waste at any time; (g) at all times keep any water system free from any matter or obstruction which may affect the efficiency thereof; and (h) cause all domestic waste, including wash-water, which cannot be disposed of in a municipal sewage system, to be disposed of in terms of an authorisation under the Act.
SECURITY AND ADDITIONAL MEASURES	Every person in control of a mine or activity must- (a) cause any impoundment or dam containing any poisonous, toxic or injurious substance to be effectively fenced-off so as to restrict access thereto, and must erect warning notice boards at prominent locations so as to warn persons of the hazardous contents thereof; (b) ensure access control in any area used for the stockpiling or disposal of any residue or substance which causes, has caused or is likely to cause pollution of a water resource so as to protect any measures taken in terms of these regulations; (c) not allow the area contemplated in paragraph (a) and (b) to be used for any other purpose, if such use causes or is likely to cause pollution of a water resource; and (d) protect any existing pollution control measures or replace any existing pollution control measures deleteriously affected, damaged or destroyed by the removing or reclaiming of materials from any residue deposit or stockpile, and establish additional measures for the prevention of pollution of a water resource which might occur, is occurring or has occurred as a result of such operations.

4. PIT DEWATERING PLAN

Removal of the accumulated water in the open pit is required in order to allow access to the open pit such that mining can recommence. The removal of this water from the old workings is crucial to the mining project and will determine the reserves available for mining as well as the access point to the underground ore body.

4.1. VOLUME AND QUALITY OF OPEN PIT WATER

It is estimated by the owners of the mine that approximately 114 million litres of water is present in the old mine workings. The quality of the water is poor with Total Dissolved Solids (TDS) concentration in excess of 8000 mg/l. The dominant cations and anions in the water are chloride (Cl), Calcium (Ca), Magnesium (Mg), Fluoride (F), Sodium (Na) and Nitrogen (N). Acid-base accounting undertaken on the ore and waste rock show that excess neutralising capacity exists, with no threat for acidification and generation of Acid Mine Drainage (AMD). The pH of the pit water is 7.9 which is typical of the BIF geology.

4.2. WATER TREATMENT PLANT

It is proposed that water would be pumped from the open pit to a treatment plant located on or adjacent to the plant terrace. The dewatering of the open pit will in all likelihood precede the commencement of mining and processing operations, implying that the water would have to be treated to a standard suitable for release to the environment or sale to the municipality.

4.2.1. WATER TREATMENT PROCESS

The water treatment process is described in Appendix A and will include pre-treatment, membrane filtration and post treatment processes. Key features of the proposed treatment plant are as follows:

- The membranes are high recovery membranes suitable for the type of waters found within the pit and are designed to minimise brine generation by increasing the recovery of water to approximately 98%. By comparison, conventional membrane technologies would recover approximately 75 % of the water treated, thereby generating significantly larger volumes of brine.
- The chemicals/ reagents utilized within the treatment plant have been specially formulated for the unique manner in which the treatment plant operates and are commonly referred to as GRAS (Generally regarded as safe) for use as referred to by the FDA in the USA
- The waste stream consisting of the Brine is approximately 2% of the total volume treated and is the smallest brine stream produced compared to conventional processes that generate a 25% brine stream that has to be dealt with resulting in larger Evaporation dams and cost to implement.

The treatment process is flexible both in terms of the rate at water can be treated and in the quality of water that can be produced. The size of water treatment plant that would be installed would depend on the time allowable for the dewatering of the pit and the re-establishment of mining operations. The estimated time required for dewatering of the pit is as follows:

- 15.6 months at a treatment rate of 10m^3/hr and 24 hr/day
- 6.3 months at a treatment rate of 25m^3/hr and 24 hr/day
- 3.1 months at a treatment rate of 50m^3/hr and 24 hr/day

4.2.2. WATER TREATMENT PLANT INFRASTRUCTURE

It is expected that the water treatment plant would be located on or adjacent to the process plant terrace on an area of 20m by 30m. The plant would be erected on a 150mm thick reinforced concrete slab. Infrastructure required to support the installation and operation of the plant is expected to include:

- The dewatering pumps and pipeline required to pump the water from the pit to the treatment plant
- A receiving water tank to be supplied as part of the water treatment plant into which pit water will be pumped and from which the water treatment plant will be supplied
- Supply of power to the water treatment plant (est 300kW) and pit dewatering pump station

The concentrate (Brine) discharge water from the treatment plant will be pumped to an evaporation dam no more than 100m away from the plant. The treated compliant water will be discharged from the plant to a holding tank situated next to the treatment plant for discharge to the environment by overflow or for reuse either in the water treatment plant or the ore processing plant.

4.2.3. Water Treatment Options

The proposed water treatment technology is flexible in that it can vary the quality of water produced depending on the requirements at the time. Variations in the quality of water will impact on the cost of water treatment as well as the rate of brine production.

The production of industrial quality water would be approximately 10% to 20% cheaper to produce than producing potable quality water due to reductions in reagent consumptions for the treatment of the water within the pretreatment stage and solids reduction between stages within the treatment.

The production of industrial quality water will result in a reduction in the volume of brine produced of by approximately 20 % as only the concentration of contaminants that exceed the allowable limits for discharge will be removed to provide an environmentally acceptable discharge water quality. Excess contaminants would be discharged as a brine and be disposed of to the evaporation dam.

Should there be a need to supply potable water to the site this would be done by treating the required quantity of water and pumping it to a separate water tank or dam for use as required.

While the volume of brine produced can be reduced by producing water to a lower quality specification it is unlikely that the generation of brine could be eliminated completely.

4.2.4. Brine Disposal

Brine from the water treatment plant will be pumped to an HDPE lined pond where it will be allowed to evaporate. The pond has been sized based on two considerations (Ref : Appendix B), namely:

- The surface area required to ensure that the rate of evaporation from the pond matches the rate of brine disposal
- The storage capacity required to contain all of the brine expected to be produced by the treatment of the specified volume of water

Based on the understanding that the treatment of water will cease after the dewatering of the pit is complete, it is considered appropriate to size the pond to store the entire production of brine. This will require the establishment of a pond with a storage capacity of:

- 2 850m^3 at a treatment efficiency of 97.5%
- 5 700m^3 at a treatment efficiency of 95.0%
- 11 400m^3 at a treatment efficiency of 100%

It is recommended that a pond with a storage capacity of between 2 850 and 5 700m^3 be constructed to allow for lower than expected efficiencies or the treatment of additional water if required. The brine pond is expected to comprise:

- An excavated pond, with the excavated material shaped and compacted to form a perimeter wall to the pond to achieve the required storage capacity and isolate the pond from the surrounding surface water environment
- A liner to the inside face of the excavated pond and wall anchored into an earth filled trench on the crest of the wall and comprising:
    - ➢ Shaping, compaction and removal of stones from the basin of the pond
    - ➢ A heavy duty geofabric protective layer
    - ➢ 1.5mm HDPE liner or similar approved
- Safety ropes and anchor blocks installed at no greater than 25m centres to the perimeter of the pond
- A 6 strand barbed wire perimeter fence and warning signage

4.3. Installation of Water Treatment Infrastructure

The timeline for the installation of the water treatment plant and related infrastructure will be dictated by the time allowed for dewatering of the pit as well as the time required for:

- Installation of the water treatment plant itself (2 months) and the construction of the required terrace and concrete foundation (1 month)
- Installation of the pit dewatering pump station and pipeline (2 months)
- Construction of the brine pond (2 months)

4.4. REHABILITATION AND CLOSURE

Based on the information available it is not expected that there would be a continued ingress of groundwater into the open pit. It is unlikely therefore that the water treatment plant would be operational in the long term unless there were significant inflows of surface water into the open pit (see 5 below). It is expected therefore that at some stage during the operation of the mine the water treatment and associated infrastructure would be removed from site and that pipe supports and foundations would be demolished and disposed of to a designated waste disposal area. The water treatment plant itself would be sold or returned to its owner depending on how it was acquired and pit dewatering pumps and pipelines would either be sold or put to some other use on the mine.

It is expected that the water in the brine pond would be left to evaporate. At closure the pond would be filled with selected waste or tailings to create a domed landform which could then be rehabilitated by covering with soil and topsoil and the establishment of vegetation to form a sustainable free draining landform.

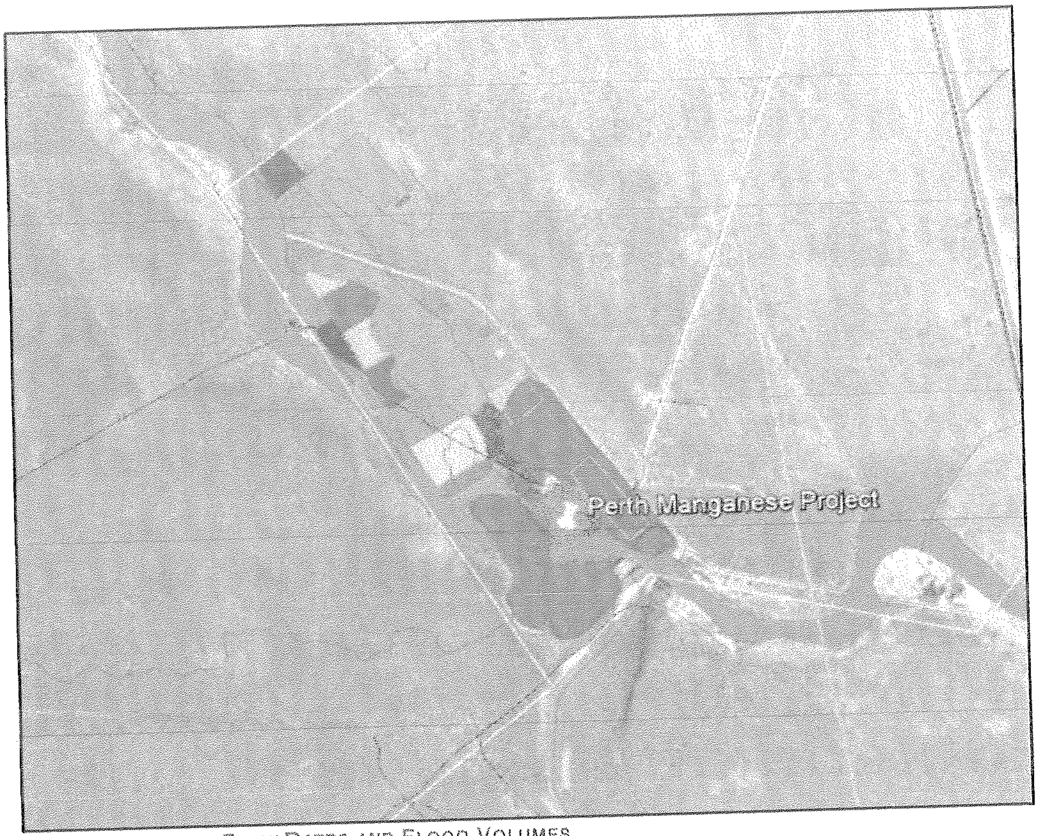
5. SURFACE WATER DIVERSION

The proposed open pit mine and surface infrastructure will impact on the Witleegte River as shown in Figure 3. While the river is perennial and flows only in the event of significant rainfall events the permitting of the project will require that its potential impacts of the river are addressed. From it can be seen that:

- The proposed plant layout encroaches on the river
- The waste dump straddles the river
- The existing open pit has been mined through the river
- The proposed extensions of the open pit to the north and west will encroach on the river

The estimated flow rates and flood volumes expected to be experienced at the mine are discussed below together with options considered for the management of the mine's potential impacts on the river.

FIGURE 3 : SITE LAYOUT SHOWING PROPOSED MINE LAYOUT AND WITLEEGTE DRAINAGE LINE



5.1. ESTIMATED FLOW RATES AND FLOOD VOLUMES

Estimates of the Mean Annual Runoff and Average Monthly Runoff for the Witleegte river are presented in Table 4 (Ref : Surface Water Resources of South Africa, 1994). While it should be noted that the figures apply to the whole of the catchment, the mine is close enough to the bottom of the catchment for the estimates to give a reasonably accurate estimates of expected flows at the mine. As the situation currently stands, unless a diversion is constructed around the open pit, these flows would report to the pit.

Estimates of peak flow rates and associated flood volumes associated with events of specific recurrence intervals have also been compiled and are presented in Table 5. The flood peaks have been calculated with the RMF Method (K=2.8 and 3.4) and flood volumes were calculated using the SCS's method's hydrograph shape and the flood peaks from the RMF method. The flood peaks have been calculated for "K" values of both 2.8 and 3.4 as the catchment lies in an area of some uncertainty with regard to the values. It is recommended that if under estimation of the flood peaks can result in loss of life and economic value, it would be advisable to carry out a much more detail flood hydrology study or adopt the flood peaks calculated using a "K" value of 3.4 which would be conservative.

TABLE 4 : ESTIMATED MONTHLY SURFACE WATER RUNOFF IN WITLEEGTE CATCHMENT

RIVER NAME		GAMOGARA	WITLEEGTE	VLERMUISLEEGTE
MAR (10^6 M3)		**6.0**	**0.73**	**0.54**
CATCHMENT AREA (KM^2)		**5182**	**661**	**487**
MONTH	**% MAR**	**AVERAGE MONTHLY RUNOFF (10^6 M3)**		
January	32.80	1.97	0.24	0.18
February	22.90	1.37	0.17	0.12
March	19.70	1.18	0.14	0.11
April	8.90	0.53	0.06	0.05

May	1.30	0.08	0.01	0.01
June	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00
October	0.90	0.05	0.01	0.00
November	4.60	0.28	0.03	0.02
December	8.70	0.52	0.06	0.05

***Ref** : Surface Water Resources of South Africa 1994, Volume 3*

TABLE 5 : ESTIMATED PEAK FLOW RATES AND FLOOD VOLUMES FOR WITLEEGTE CATCHMENT

EVENT DESCRIPTION	PEAK FLOW RATE (M³/S) (K = 2.8)	PEAK FLOW RATE (M³/S) (K = 3.4)	ALT. RATIONAL METHOD
Regional Maximum Flood	187	382	
Q 200 (RMF Method)	103	211	187
Q 100 (RMF Method)	77	157	152
Q 50 (RMF Method)	56	114	116

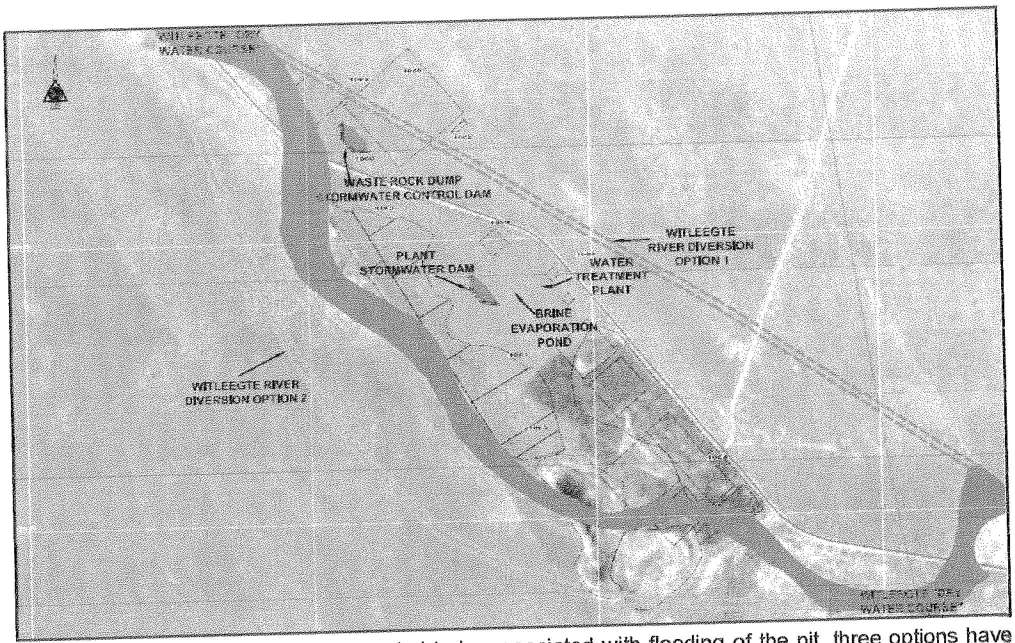
***Note** : Calculation of flood peaks based on Qt/QRMF relationship for Kovács regions*

5.2. OPTIONS FOR DIVERSION OF WITLEEGTE DRAINAGE LINE

Based on the estimated flow rates and flood volumes as described above it is expected that measures would have to be put in place to divert surface water flows around the open pit. These would be required both to protect the operations in the pit and in the proposed decline shafts to be established to access adjacent underground resources.

Surface water runoff reporting to the open pit would by definition be classified as contaminated and would probably have to be treated before it could be released into the environment. This is likely to be costly and delay the resumption of mining significantly. If the underground workings are flooded there would probably be significant damage to underground infrastructure

FIGURE 4 : SITE LAYOUT SHOWING POTENTIAL ALIGNMENT OF SURFACE WATER DIVERSION WORKS



In view of the potential problems expected to be associated with flooding of the pit, three options have been considered for preventing surface water inflows to the pit. These options are shown in Figure 4 and are described in summary as follows:

- Option 1. The Witleegte is diverted the north and east of the mine site. This would require the installation of substantial culverts under the road crossing to the north of the site. The advantage of this option is that it does not encroach on the ore reserves to the west. It does however affect the surface rights owners to the east.
- Option 2. The Witleegte is diverted to the south and west of the site. There should not be any road crossings associated with this option but it may interfere with westward expansions of the open pit or the underground workings. This option will definitely be opposed by the mineral rights holders to the west
- Option 3. The Witleegte is maintained on, or as close as possible, to its natural alignment. This option has the advantage of minimising the impacts on the adjacent landowners but would require:
    - ➢ A short term diversion while the river area is mined, followed by its re-establishment on its original as the pit is backfilled
    - ➢ Relocation of the drainage line to the west of the proposed open pit expansion slightly westward or its temporary diversion and eventual re-established on its original alignment as backfilling of the pit is completed
    - ➢ Relocation of the plant site slightly to the north from its currently proposed position
    - ➢ Integration of the diversion, backfilling and drainage line re-establishment into the sequencing of the mining operations

None of these solutions can be seen in isolation and would require detailed planning and design in conjunction with the mine and plant design as well as consultation with the adjacent landowners.

5.3. PREFERRED OPTION FOR SURFACE WATER DIVERSION

Based on the information available at the time of compiling this report Option 3 as outlined above is the preferred option for preventing surface water inflows to the open pit. This is because:

- Surface and mineral rights holders have indicated that they would oppose the diversion of the river around the site
- The preliminary estimates of costs associated with the surface water diversions (Options 1 and 2) are considered to be unaffordable for a project on the scale of the proposed mine

The pre-feasibility stage design of the project is therefore expected to focus on the development, permitting and implementation of Option 3 with specific reference to confirmation of the expected peak flow rates and volumes from the catchment based on a detailed catchment study to determine whether there are any potential upstream attenuation or control structures that would affect the stream flows. The design of the works would have to be carried in conjunction with the mine planning process to ensure that the drainage line can be reinstated and also that the decline portals can be protected in the long term.

While the scale of the diversion works are expected to be significant it is expected that, if properly planned and executed, the required works can be incorporated into the mining and backfilling operations at very little additional overall cost to the mine.

The diversion works to the west of the proposed open pit expansion would also require:

- The approval of the surface and mineral rights holders to the west
- Confirmation that the works do not pose any risk to the high wall stability in the open pit or to the proposed underground workings to be accessed via the decline portals

6. SURFACE WATER CONTAINMENT

In terms of the requirements of GN704 the mine will be required to contain runoff from all disturbed areas on their property. Based on the currently proposed surface layout it is suggested that this be accomplished by the construction of:

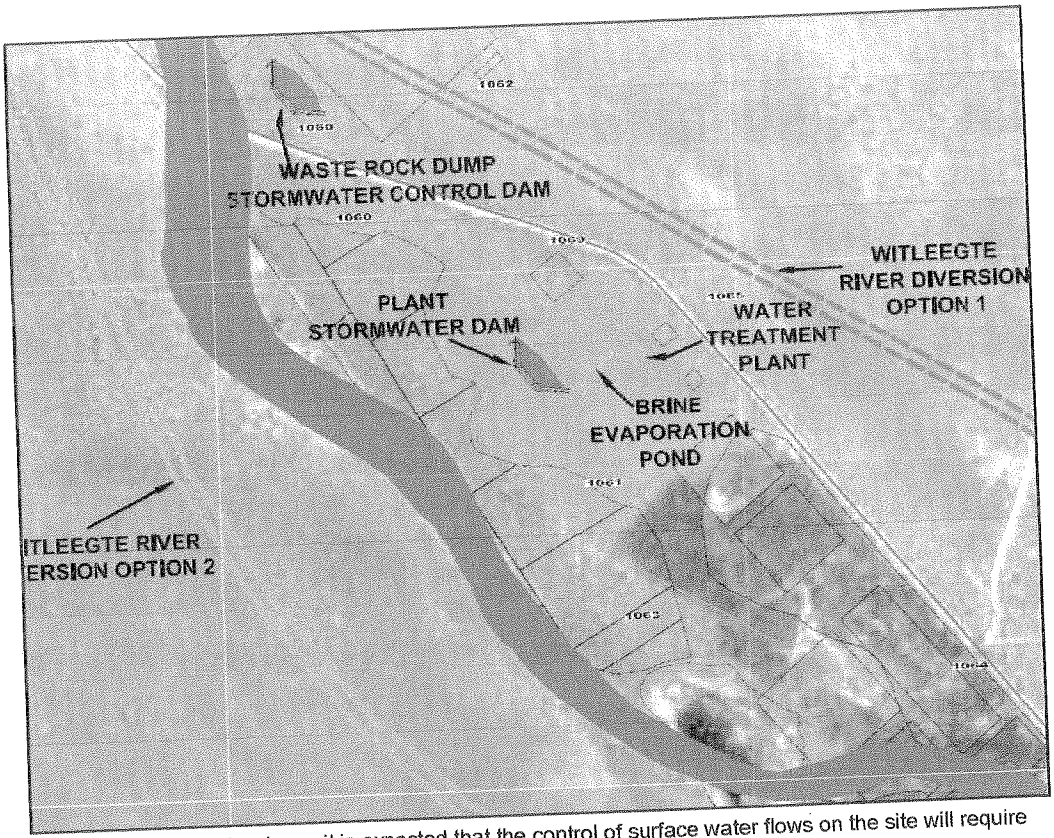
- A plant storm water control dam
- A waste rock dump storm water control dam

6.1. Location Surface Water Containment Works

Suggested locations for both of these dams are shown in Figure 5 below. The reasons for their suggested placement are as follows:

- The site is elongated and is bisected by a road which would complicate the direction of all surface water runoff to a single location
- The waste rock dump storm water control dam is located such that it can collect all surface water runoff from the area north east of the road bisecting the mine site. If no development or surface disturbance takes place on that side of the road the need for the dam would fall away
- The plant storm water control dam is located such that it can collect runoff from the entire area south and west of the road, including potential spillages from the water treatment works, brine pond and tailings storage facility

Figure 5 : Site Layout Showing Proposed Location of Storm Water Control Dams



In addition to the works shown it is expected that the control of surface water flows on the site will require the construction of diversion and containment channels to:

- Divert runoff away from areas affected by mining and associated operations
- Ensure that runoff from disturbed areas is directed towards the dams

It is expected that the site topography will be used so as to minimise the scale of such channels. All channels constructed should be wide and flat and be designed as permanent features so as to minimise the amount of work required at closure.

6.2. SIZING OF SURFACE WATER CONTAINMENT WORKS

The required storage and spillway capacities for the respective catchments are summarised in Table 6 and have been determined based on Rational Method calculations of runoff from their respective areas as well as evaluation of variations in rainfall depth as a function of recurrence interval and event duration as shown in Appendix C. The dams have been sized to contain runoff associated with an event of approximately 150mm which equates to (Ref Table 2):

- An event with recurrence interval of 200 years, duration of 1 day and a probability of occurrence in the 15 year life of mine of 7% (i.e. 147.5mm)
- An event with recurrence interval of 20 years, duration of 7 days and a probability of occurrence in the 15 year life of mine of 54% (160mm)

TABLE 6 : SUMMARY CONFIGURATION OF STORMWATER CONTAINMENT DAMS AND SPILLWAYS

NAME OF DAM	CATCHMENT AREA (M2)	RATIONAL METHOD RUNOFF COEFFICIENT	DESIGN STORAGE VOLUME (M3)	PEAK FLOW RATE / SPILLWAY CAPACITY (M3/S)
PLANT STORM WATER CONTROL DAM	409 000	0.65	40 000	6.44

- The installation of a water treatment plant and associated infrastructure including pit dewatering pumps and pipelines and brine pond to enable dewatering of the existing open pit
- The construction of two small storm water control dams and associated diversion and collection channels and spillways to the mine site
- The management and diversion of flows associated with the Witleegte river so as to enable mining in the open pit

It is concluded also that the quantities of water required to operate the mine and treatment plant would have to be determined based on a mining and processing plan and that a reliable source of process water supply would have to be secured to enable the project to proceed.

9. RECOMMENDATIONS

Based on the assessment of surface water impacts and management requirements as describe above it is recommended that the design of the necessary surface water management works proceed in tandem with the feasibility assessment of the overall project. It is expected that this assessment will result in the generation of:

- A detailed life of mine plan specifying the rate and duration of mining
- Feasibility level designs of mine residue disposal facilities (Tailings storage facility and waste rock dump)
- Finalisation of the site layout

Particular attention should be paid to ensuring that plans are in place to manage surface water flows associated with the Witleegte river so as to avoid interruptions to mining operations and also to ensure the safety of everyone working in the pit and decline shafts. This will require that the design of the preferred surface water diversion be integrated into the design of the open pit mine and that the sequence of mining is adjusted, if necessary, to allow for the construction of the necessary temporary and permanent diversion works

Report Author	**Project Manager**	**Reviewer**
GJ Wiid PrEng	GJ Wiid PrEng	SJP Coetzee Pr.Sci.Nat

Waste Rock Dum Storm Water Control Dam	121 000	0.42	8 000	1.31

6.3. Construction of Surface Water Containment Works

The methods applied to the construction of the surface water containment works should be dictated by the nature of available construction materials and the low rainfall climate. Due to the expected shortages of water in the area it is expected that any runoff accumulating in the dams would quickly be recovered for use in the processing plant. Dams are therefore expected to comprise excavated storage compartments with excavated material used to construct low flat dam walls to the down grade side of the excavation so as to optimise the available storage capacity.

It is not expected that the dams would be lined as they will probably require frequent cleaning of eroded and windblown sand. This, together with the very low rainfall in the area would make lining unnecessary unless the dams were expected to receive particularly bad quality water. All seepage flows from the dams are expected to report to the open pit from where they can be retrieved, treated and reused or released as necessary.

At closure all accumulated silt and fines washed down from the plant should be removed from the dams and deposited to the tailings storage facility. Once clean the dams should be left intact so as to serve the post closure land use.

7. MINE WATER BALANCE

The design and planning of the mining and processing operations are at this stage in the early stages of development which make it impossible to develop a detailed mine water balance. It can be stated however that:

- The use of surface water runoff is unlikely to contribute significantly to the mine water requirements
- Little if any ground water inflows are expected to the open pit and underground workings which are also not expected to contribute significantly to the mine water requirements
- The treatment of accumulated water in the pit would have to be completed before operations in the pit or plant commence. Unless a large dam is constructed to store this water it would also not contribute to the mine's operating water requirements

It is probable therefore that all the mine's water requirements would have to be sourced externally. Large water uses on the mine are expected to include:

- The process plant and associated disposal of tailings
- Dust suppression in the open pit and haul roads to the plant and waste dump

8. CONCLUSIONS

Based on the assessment of the proposed mine plan and the local and surface water hydrology it is concluded that additional work will be required to finalise details of the surface water management measures associated with the mine and associated infrastructure. The majority of this work will however depend on the completion of the detailed sizing and design of:

- The waste rock dump
- The tailings storage facility
- The process plant and terrace
- The open pit and associated decline shafts

It is expected however that the management of surface water impacts associated with the mine and processing plant operations will require:

APPENDIX A : WATER TREATMENT PLANT

MiWaTek

Mine Water Treatment Technologies (Pty) Ltd.
Registration Number: 2011/001050/07.

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2191.

Our Ref: SebiloPMn 23412
Your Ref:

Perth Manganese Project
C/O Epoch Resources
Ground Floor, Uplands 13
The woodlands Office Park
Woodlands Drive
Woodmead

23 April 2012

Attention: Mr .G.Wiid

RE : MiWaTek Opencast Pit discharge water treatment process description

The treatment process recommended by MiWaTek has been specifically designed to treat the Perth Manganese non-compliant pit water that has to be pumped out of the pit to an acceptable quality for discharge to the environment or used as decided by the client to allow the client to proceed with mining operations within the pit. The treatment process has been designed to minimise operational cost with minimal reagent consumption and to maximise the treatment and recovery of the water (98% recovery) as well as reducing the volume of concentrate (Brine) water (2%) that is produced and requires to be dealt with in the most cost effective manner such as an evaporation pond. The recommended plant has been designed to operate at 98% water recovery at 95% plant availability. Any by-products removed from the water by the MiWaTek recommended process will be generated as a reduced moisture content sludge that can be easily handled and transported to the solids waste material dumping site for disposal.

The MiWaTek recommended Perth Manganese pit discharge water treatment plant basic process flow is as follows:

- The water is pumped from a pontoon containing the transfer pumps situated within the pit to the raw untreated pit water tank.
- The water from the Raw untreated pit water tank is pumped to the pre-treatment stage where the necessary raw water quality adjustment is made producing two discharge streams, a) solid reduced moisture sludge and b) adjusted water to be transferred to the 1^{st} Membrane.
- The 1^{st} membrane produces two discharge streams, a) Permeate (treated water) that is pumped to the perm holding tank and b) concentrate (Brine) is pumped to the 1^{st} post treatment stage.
- The 1^{st} post treatment stage makes the necessary water quality adjustments and produces two by products, a) a post treated water that is transferred to membrane 2 and b) a solid sludge that can be disposed of.
- The 2^{nd} membrane produces two discharge streams a) a permeate that is transferred to the perm tank and b) concentrate that is transferred to the 2^{nd} post treatment stage.
- The second post treatment stage adjusts the quality of the water again producing two by products, a) post adjusted water to be transferred and b) solid sludge for disposal
- The 3^{rd} membrane produces two discharge streams, a) Permeate stream to be transferred to perm tank and b) a concentrate stream to be transferred to the evaporative pond.

APPENDIX B : CONCEPTUAL DESIGN OF BRINE POND

PERTH MANGANESE MINE
CONCEPTUAL PIT DEWATERING PLAN
CONCEPTUAL SIZING OF BRINE DISPOSAL / EVAPORATION POND

1 DESIGN CRITERIA

.1 Estimated Quantity of Brine Storage Required as a Function of Treatment Efficiency

Volume of Water to be treated	m^3	114,000		
Treatment Efficiency		97.5%	90%	75%
Total Waste Water (Brine) Production	m^3	2,850	11,400	28,500

.2 Estimated Brine Production Rate and Duration of Dewatering

		Option 1	Option 2	Option 3
Treatment Rate	m^3/hr	10	25	50
Treatment Efficiency		97.50%	97.50%	97.50%
Waste Water (Brine) Production Rate	m^3/hr	0.25	0.63	1.25
	m^3/mnth	183	456	913
Operating Hrs/day	hrs/day	24	24	24
Operating Efficiency	days	95%	95%	95%
Time Required to treat specified volume of water	days	500	200	100
	months	16.4	6.6	3.3

2 SIZING OF BRINE DISPOSAL / EVAPORATION POND

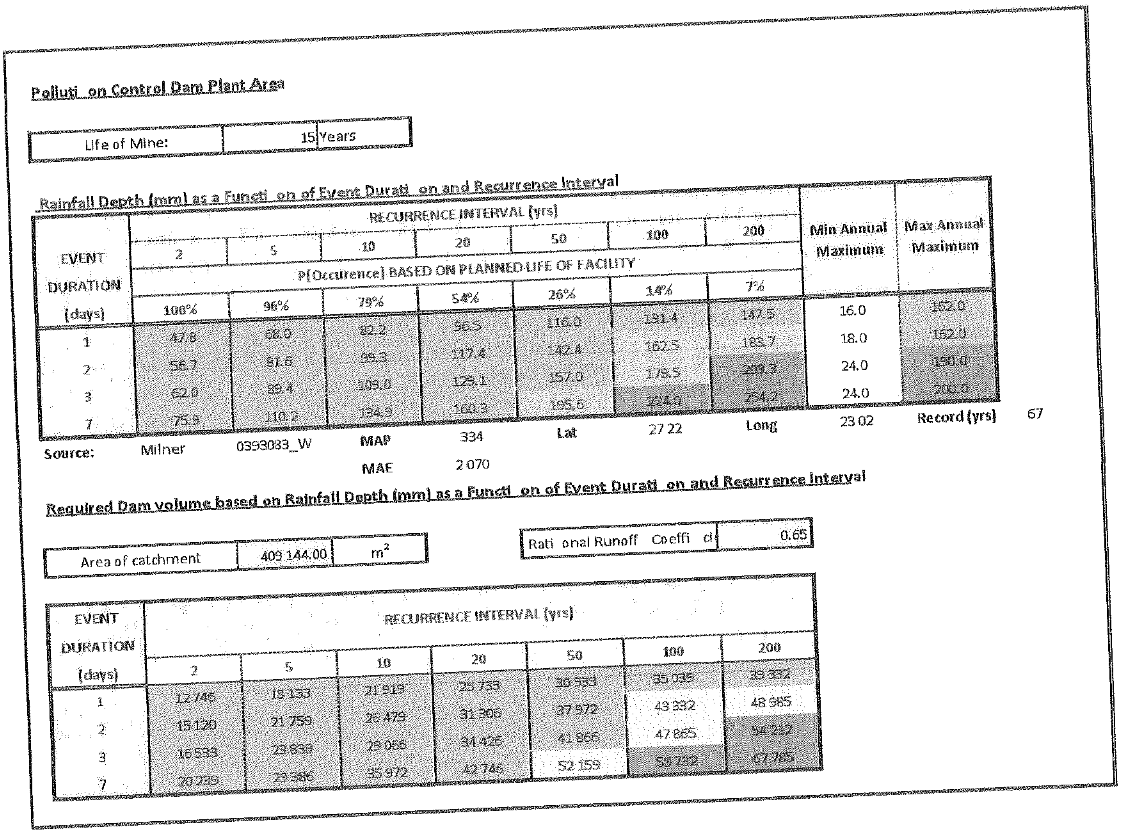
.1 Sizing of Brine Evaporation Pond based on Evaporative Capacity

Month	Monthly Evap (mm)	Brine Production Rate (m^3/mnth)		
		Option 1	Option 2	Option 3
		183	455	913
		Reqd Evaporative Area (m^2)		
January	286	638	1,594	3,188
February	220	830	2,074	4,149
March	190	961	2,403	4,806
April	133	1,376	3,441	6,881
May	96	1,910	4,775	9,549
June	73	2,513	6,283	12,566
July	84	2,173	5,433	10,865
August	115	1,594	3,985	7,969
September	158	1,151	2,879	5,757
October	212	861	2,153	4,305
November	250	729	1,822	3,643
December	289	632	1,581	3,162
		Average Area Required (m^2)		
ANNUAL	2,105	1,040	2,601	5,202
		Maximum Area Required (m^2)		
		2,513	6,283	12,566
Pond Side Slopes		3	3	3
Average Depth	m	2	2	2
Aspect Ratio		1	1	1
Bottom Length	m	50	79	112
Bottom Width	m	50	79	112
Bottom Area	m^2	2,513	6,283	12,567
Wall Crest Length	m	62	91	124
Wall Crest Width	m	62	91	124
Crest Area	m^2	3,860	8,329	15,401
Storage Volume	m^3	6,325	14,565	27,920

2.2 Sizing of Brine Pond based on Brine Storage Capacity

	Option A	Option B	Option C
Contaminated Water Volume (m^3)	114,000	114,000	114,000
Treatment Efficiency	97.5%	90%	75%
Required Storage Capacity (m^3)	2,850	11,400	28,500
Pond Side Slopes	3	3	3
Average Depth	2	2	2
Aspect Ratio	1	1	1
Bottom Length	35	80	125
Bottom Width	35	80	125
Bottom Area	1,225	6,400	15,625
Wall Crest Length	47	92	137
Wall Crest Width	47	92	137
Crest Area	2,209	8,464	18,769
Storage Volume	3,386	14,816	34,346
Actual vs Reqd Storage	119%	130%	121%

APPENDIX C : CONCEPT DESIGN OF SURFACE WATER CONTAINMENT WORKS



Pollution Control Dam Plant Area

Life of Mine:	15	Years

Rainfall Depth (mm) as a Function of Event Duration and Recurrence Interval

EVENT DURATION (days)	RECURRENCE INTERVAL (yrs)							Min Annual Maximum	Max Annual Maximum
	2	5	10	20	50	100	200		
	P[Occurence] BASED ON PLANNED LIFE OF FACILITY								
	100%	96%	79%	54%	26%	14%	7%		
1	47.8	68.0	82.2	96.5	116.0	131.4	147.5	16.0	162.0
2	56.7	81.6	99.3	117.4	142.4	162.5	183.7	18.0	162.0
3	62.0	89.4	109.0	129.1	157.0	179.5	203.3	24.0	190.0
7	75.9	110.2	134.9	160.3	195.6	224.0	254.2	24.0	200.0

Source:	Milner	0393083_W	MAP	334	Lat	27 22	Long	23 02	Record (yrs)	67
			MAE	2 070						

Required Dam volume based on Rainfall Depth (mm) as a Function of Event Duration and Recurrence Interval

Area of catchment	409 144.00	m^2

Rational Runoff Coeffici	0.65

EVENT DURATION (days)	RECURRENCE INTERVAL (yrs)						
	2	5	10	20	50	100	200
1	12 746	18 133	21 919	25 733	30 533	35 039	39 332
2	15 120	21 759	26 479	31 306	37 972	43 332	48 985
3	16 533	23 839	29 066	34 426	41 866	47 865	54 212
7	20 239	29 386	35 972	42 746	52 159	59 732	67 785

Pollution Control Dam Waste Rock Dump Area

Life of Mine:	15	Years

Rainfall Depth (mm) as a Function of Event Duration and Recurrence Interval

EVENT DURATION (days)	RECURRENCE INTERVAL (yrs)							Min Annual Maximum	Max Annual Maximum
	2	5	10	20	50	100	200		
	P[Occurence] BASED ON PLANNED LIFE OF FACILITY								
	100%	96%	79%	54%	26%	14%	7%		
1	47.8	68.0	82.2	96.5	116.0	131.4	147.5	16.0	162.0
2	56.7	81.6	99.3	117.4	142.4	162.5	183.7	18.0	162.0
3	62.0	89.4	109.0	129.1	157.0	179.5	208.3	24.0	190.0
7	75.9	110.2	134.9	160.3	195.6	224.0	254.2	24.0	200.0

Source:	Milner	0393083_W	MAP	334	Lat	27.22	Long	23.02	Record (yrs)	67
			MAE	2 070						

Required Dam volume based on Rainfall Depth (mm) as a Function of Event Duration and Recurrence Interval

Area of catchment	120 727	m²

Rational Runoff Coeffici	0.42

EVENT DURATION (days)	RECURRENCE INTERVAL (yrs)						
	2	5	10	20	50	100	200
1	2 418	3 440	4 158	4 881	5 868	6 647	7 461
2	2 868	4 128	5 023	5 939	7 203	8 220	9 292
3	3 136	4 522	5 514	6 530	7 942	9 080	10 284
7	3 839	5 574	6 824	8 109	9 894	11 331	12 859

Rational Method

Description:	Sebilo, Perth Manganese. (Plant Area)	Date:	04 May 2012
Calculated By:	L. Venter		

Physical Characteristics

Size of Catchment (A)	0.409144	km^2
Longest Watercourse (L)	1.305	km
Overland Flow (OF)	0	km
Average Slope WC(Sav)	0.008	m/m
Average Slope OF(Sav)	0.000	m/m
Dolomite Area (D%)	0	%
Mean Annual Rainfall (MAR) 0	334	mm

Rainfall Region		
Area Distribution Factors		
Rural (α)	Urban (β)	Lakes (γ)
0.50	0.50	

Rural 1

Surface Slope	%	Factor	Cs
Vleis and pans	5	0.01	0.0005
Flat Areas	90	0.06	0.054
Hilly	5	0.12	0.006
Steep Areas	0	0.22	0
Total	100		0.0605
Permeability	**%**	**Factor**	**Cp**
Very Permeable	0	0.03	0
Permeable	7.5	0.06	0.0045
Semi-Permeable	7.5	0.12	0.009
Impermeable	85	0.21	0.1785
Total	100		0.192
Vegetation	**%**	**Factor**	**Cv**
Thick Bush and Plantation	0	0.03	0
Light Bush and Farm-Lands	0	0.07	0
Grasslands	10	0.17	0.017
No Vegetation	90	0.26	0.234
Total	100		0.251

Urban 2

Description	%	Factor	C2
Lawns			
Sandy, flat (<2%)	0	0.10	0
Sandy, steep (>7%)	0	0.20	0
Heavy Soil, flat (<2%)	0	0.17	0
Heavy Soil, steep (>7%)	0	0.35	0
Residential Areas	**%**	**Factor**	**C2**
Houses	0	0.50	0
Flats	0	0.70	0
Industry	**%**	**Factor**	**C2**
Light industry	100	0.80	0.8
Heavy Industry	0	0.90	0
Business	**%**	**Factor**	**C2**
City Centre	0	0.95	0
Suburban	0	0.70	0
Streets	0	0.95	0
Maximum Flood	0	1.00	0
Total (c2)	100		0.8

Notes:

Time Of Concentration (Tc)

Overland Flow 3		Defined Watercource	
Surface Description r value		0.3	
0.000	Hours	0.512	Hours
Total Tc	0.512	Hours	

Run-off Coefficient

Return Period (years), T =	2	5	10	20	50	100	MAX
Run-off Coefficient, C1 (C1=Cs+Cp+Cv)	0.5035	0.5035	0.5035	0.5035	0.5035	0.5035	
∑Dfactor*Cs%	0						
Adjusted for Dolomite Areas, C1d (=C1(1-D%)+C1D%(∑(Dfactor*Cs%)) 4	0.504	0.504	0.504	0.504	0.504	0.504	
Adjustment Factor for Initial Saturation, Ft5	0.75	0.80	0.85	0.90	0.95	1.00	
Adjusted Run-off Coefficient, C1T (=C1d *Ft)	0.38	0.40	0.43	0.45	0.48	0.50	
Combined Run-off Coefficient CT (αC1T+βC2+γC3)	0.589	0.601	0.614	0.627	0.639	0.652	

Rainfall

Return Period (years), T =	2	5	10	20	50	100	MAX
Point Rainfall (mm), Pt 6	12.00	17.00	22.00	27.00	37.00	45.00	
Point Intensity (mm/hour), PIT (=Pt/Tc)	23.44	33.20	42.96	52.73	72.26	87.88	
Area Reduction Factor (%), ARFt7	0.99	0.99	0.99	0.99	0.99	0.99	
Average Intensity (mm/hour), It (= PiT * ARFt)	23.20	32.87	42.54	52.20	71.54	87.00	
Return Period (years), T =	**2**	**5**	**10**	**20**	**50**	**100**	**MAX**
Peak Flow (m^3/s), Q = (Ct*It*A)/3.6	1.55	2.25	2.97	3.72	5.20	6.44	0.00

Rational Method

Description:	Sebilo, Perth Manganese (Waste Rock Dump Area)	Date:	04 May 2012
Calculated By:	L. Venter		

Physical Characteristics

Size of Catchment (A)	0.120727	km^2
Longest Watercourse (L)	0.681	km
Overland Flow (OF)	0	km
Average Slope WC(Sav)	0.003	m/m
Average Slope OF(Sav)	0.000	m/m
Dolomite Area (D%)	0	%
Mean Annual Rainfall (MAR) 0	334	mm

Rainfall Region		
Area Distribution Factors		
Rural (α)	Urban (β)	Lakes (γ)
1.00	0.00	

Rural 1

Surface Slope	%	Factor	Cs
Vleis and pans	0	0.01	0
Flat Areas	95	0.06	0.057
Hilly	5	0.12	0.006
Steep Areas	0	0.22	0
Total	100		0.063
Permeability	**%**	**Factor**	**Cp**
Very Permeable	25	0.03	0.0075
Permeable	25	0.06	0.015
Semi-Permeable	25	0.12	0.03
Impermeable	25	0.21	0.0525
Total	100		0.105
Vegetation	**%**	**Factor**	**Cv**
Thick Bush and Plantation	0	0.03	0
Light Bush and Farm-Lands	0	0.07	0
Grasslands	10	0.17	0.017
No Vegetation	90	0.26	0.234
Total	100		0.251

Urban 2

Description	%	Factor	C2
Lawns			
Sandy, flat (<2%)	0	0.10	0
Sandy, steep (>7%)	0	0.20	0
Heavy Soil, flat (<2%)	0	0.17	0
Heavy Soil, steep (>7%)	0	0.35	0
Residential Areas	**%**	**Factor**	**C2**
Houses	0	0.50	0
Flats	0	0.70	0
Industry	**%**	**Factor**	**C2**
Light industry	100	0.80	0.8
Heavy Industry	0	0.90	0
Business	**%**	**Factor**	**C2**
City Centre	0	0.95	0
Suburban	0	0.70	0
Streets	0	0.95	0
Maximum Flood	0	1.00	0
Total (c2)	100		0.8

Notes:

Time Of Concentration (Tc)

Overland Flow 3		Defined Watercource	
Surface Description r value		0.3	
0.000	Hours	0.466	Hours
Total Tc	0.466	Hours	

Run-off Coefficient

Return Period (years), T =	2	5	10	20	50	100	MAX
Run-off Coefficient, C1 (C1=Cs+Cp+Cv)	0.4190	0.4190	0.4190	0.4190	0.4190	0.4190	
∑Dfactor*Cs%	0						
Adjusted for Dolomite Areas, C1d (=C1(1-D%)+C1D%(∑(Dfactor*Cs%)) 4	0.419	0.419	0.419	0.419	0.419	0.419	
Adjustment Factor for Initial Saturation, Ft	0.75	0.80	0.85	0.90	0.95	1.00	
Adjusted Run-off Coefficient, C1T (=C1d *Ft)	0.31	0.34	0.36	0.38	0.40	0.42	
Combined Run-off Coefficient CT (=αC1T+βC2+γC3)	0.314	0.335	0.356	0.377	0.398	0.419	

Rainfall

Return Period (years), T =	2	5	10	20	50	100	MAX
Point Rainfall (mm), Pt 6	12.00	17.00	21.00	28.00	36.00	44.00	
Point Intensity (mm/hour), PiT (=Pt/Tc)	25.77	36.50	45.09	60.12	77.30	94.48	
Area Reduction Factor (%), ARFt 7	0.99	0.99	0.99	0.99	0.99	0.99	
Average Intensity (mm/hour), It (= PiT * ARFt)	25.51	36.14	44.64	59.52	76.53	93.54	
Return Period (years), T =	2	5	10	20	50	100	MAX
Peak Flow (m^3/s), Q = (Ct*It*A)/3.6	0.27	0.41	0.53	0.75	1.02	1.31	

APPENDIX D : CONCEPT DESIGN OF SURFACE WATER DIVERSION WORKS

STREAM DIVERSION OPTION 1 CHANNEL SIZING

UNLINED

Channel Slope, So =	0.007 m/m	1: 139.8
Channel base width, b =	25.00 m	
Flow depth, y =	1.50 m	
channel side slopes, 1:x =	3.00	
Channel breadth, B =	34.00 m	
Channel sides	4.74	
Wetted perimeter, P =	34.49 m	
Flow c/s area, A =	44.25 m^2	
Hydraulic radius, R =	1.28	
Absolute roughness, ks =	0.010 m	Figure 4.8, SANRAL drainage manual
Mannings n =	0.029	Figure 4.8, SANRAL drainage manual
Flow capacity of channel =	**152.38** m^3/sec	
Velocity, v =	3.44 m/sec	

Regional Maximum Flood	381.5	m^3/sec
Q50	116.0	m^3/sec
Q100	152.0	m^3/sec
Q200	187.0	m^3/sec

Depth	Area	Wetted Perimeter	Hydraulic Radius	Flow	Velocity	Channel Armourment
0.10	2.53	25.63	0.10	1.58	0.62	Velocity OK
0.20	5.12	26.26	0.19	5.02	0.98	Velocity OK
0.30	7.77	26.90	0.29	9.90	1.27	Velocity OK
0.50	13.25	28.16	0.47	23.38	1.76	V>1.5m/sec - channel armour required
0.60	16.08	28.79	0.56	31.80	1.98	V>1.5m/sec - channel armour required
0.70	18.97	29.43	0.64	41.29	2.18	V>1.5m/sec - channel armour required
0.80	21.92	30.06	0.73	51.79	2.36	V>1.5m/sec - channel armour required
0.90	24.93	30.69	0.81	63.23	2.54	V>1.5m/sec - channel armour required
1.00	28.00	31.32	0.89	75.77	2.71	V>1.5m/sec - channel armour required
1.10	31.13	31.96	0.97	89.21	2.87	V>1.5m/sec - channel armour required
1.20	34.32	32.59	1.05	103.60	3.02	V>1.5m/sec - channel armour required
1.30	37.57	33.22	1.13	118.93	3.17	V>1.5m/sec - channel armour required
1.40	40.88	33.85	1.21	135.19	3.31	V>1.5m/sec - channel armour required
1.50	44.25	34.49	1.28	152.36	3.44	V>1.5m/sec - channel armour required
1.60	47.68	35.12	1.36	171.50	3.58	V>1.5m/sec - channel armour required
1.70	51.17	35.75	1.43	189.53	3.70	V>1.5m/sec - channel armour required
1.80	54.72	36.38	1.50	209.46	3.83	V>1.5m/sec - channel armour required
1.90	58.33	37.02	1.58	230.36	3.95	V>1.5m/sec - channel armour required
2.00	62.00	37.65	1.65	252.15	4.07	V>1.5m/sec - channel armour required
2.10	65.73	38.28	1.72	274.87	4.18	V>1.5m/sec - channel armour required
2.20	69.52	38.91	1.79	298.51	4.29	V>1.5m/sec - channel armour required
2.30	73.37	39.55	1.86	323.08	4.40	V>1.5m/sec - channel armour required
2.40	77.28	40.18	1.92	348.57	4.51	V>1.5m/sec - channel armour required
2.50	81.25	40.81	1.99	375.03	4.62	V>1.5m/sec - channel armour required
2.60	85.28	41.44	2.06	402.57	4.72	V>1.5m/sec - channel armour required
2.70	89.37	42.08	2.12	430.67	4.82	V>1.5m/sec - channel armour required
2.80	93.52	42.71	2.19	459.92	4.92	V>1.5m/sec - channel armour required
2.90	97.73	43.34	2.25	490.11	5.01	V>1.5m/sec - channel armour required
3.00	102.00	43.97	2.32	521.26	5.11	V>1.5m/sec - channel armour required

Note: Refer to Figure 5.15 in SANRAL Drainage manual
For permissible velocities in channels

Preliminary Cost Breakdown			
Description	**Option 1**	**Option 2**	**Additional Info**
Excavation			
Cross-sectional area of excavation (m^2)	44	52	
Length of Stream Diversion (m)	2 796	3 285	
Sloped Area of Channel (m^2)	166 325	195 414	
Excavation Volume (m^3)	123 723	169 999	
Estimated Excavation cost Per m^3 (Rands)	50	50	Cost does not make provision for blasting
Excavation Costs	R 6 186 150	R 8 499 938	Cost does not make provision for blasting
Contingencies	R 618 615	R 849 994	At 10% of Excavation Costs
Total Cost For Excavation	**R 6 804 765**	**R 9 349 931**	
Armourment of Channel			
AMORFLEX 180 (Blocks only)	R 22 242 667	R 26 132 747	Cost Per m^2 excl VAT, fixing wire, fixing pins, freight to site, etc
Freight Costs @ R19,200 per Freight (Freight contains 179m^2, constraint due to weight and size)	R 19 513 011	R 22 925 694	Cost Excl VAT (based on 34 ton truck without crane, 179m^2 has a weight of ± 30 tons, mat size equal to 6.2m X 2.4m X 0.115m)
Total Cost for ARMORFLEX 180	**R 41 755 678**	**R 49 058 441**	
Contractors P&G's	**R 14 568 133**	**R 17 522 512**	At 30% of cost
TOTAL Cost for Stream Diversion	**R 63 128 575**	**R 75 930 884**	

STREAM DIVERSION OPTION 2 CHANNEL SIZING

UNLINED

Channel Slope, So =	0.006 m/m	1: 164.25
Channel base width, b =	30.00 m	
Flow depth, y =	1.50 m	
channel side slopes, 1:x =	3.00	
Channel breadth, B =	39.00 m	
Channel sides	4.74	
Wetted perimeter, P =	39.49 m	
Flow c/s area, A =	51.75 m²	
Hydraulic radius, R =	1.31	
Absolute roughness, ks =	0.010 m	Figure 4.8, SANRAL drainage manual
Mannings n =	0.029	Figure 4.8, SANRAL drainage manual
Flow capacity of channel =	**166.75** m³/sec	
Velocity, v =	3.22 m/sec	

Regional Maximum Flood	381.5	m³/sec
Q50	116.0	m³/sec
Q100	152.0	m³/sec
Q200	187.0	m³/sec

Depth	**Area**	**Wetted Perimeter**	**Hydraulic Radius**	**Flow**	**Velocity**	**Channel Armourment**
0.10	3.03	30.63	0.10	1.74	0.58	Velocity OK
0.20	6.12	31.26	0.20	5.55	0.91	Velocity OK
0.30	9.27	31.90	0.29	10.94	1.18	Velocity OK
0.50	15.75	33.16	0.47	25.80	1.64	V>1.5m/sec - channel armour required
0.60	19.08	33.79	0.56	35.07	1.84	V>1.5m/sec - channel armour required
0.70	22.47	34.43	0.65	45.49	2.02	V>1.5m/sec - channel armour required
0.80	25.92	35.06	0.74	57.02	2.20	V>1.5m/sec - channel armour required
0.90	29.43	35.69	0.82	69.63	2.37	V>1.5m/sec - channel armour required
1.00	33.00	36.32	0.91	83.29	2.52	V>1.5m/sec - channel armour required
1.10	36.63	36.96	0.99	97.97	2.67	V>1.5m/sec - channel armour required
1.20	40.32	37.59	1.07	113.68	2.82	V>1.5m/sec - channel armour required
1.30	44.07	38.22	1.15	130.38	2.96	V>1.5m/sec - channel armour required
1.40	47.88	38.85	1.23	148.07	3.09	V>1.5m/sec - channel armour required
1.50	51.75	39.49	1.31	166.75	3.22	V>1.5m/sec - channel armour required
1.60	55.68	40.12	1.39	186.40	3.35	V>1.5m/sec - channel armour required
1.70	59.67	40.75	1.46	207.02	3.47	V>1.5m/sec - channel armour required
1.80	63.72	41.38	1.54	228.61	3.59	V>1.5m/sec - channel armour required
1.90	67.83	42.02	1.61	251.15	3.70	V>1.5m/sec - channel armour required
2.00	72.00	42.65	1.69	274.66	3.81	V>1.5m/sec - channel armour required
2.10	76.23	43.28	1.76	299.13	3.92	V>1.5m/sec - channel armour required
2.20	80.52	43.91	1.83	324.55	4.03	V>1.5m/sec - channel armour required
2.30	84.87	44.55	1.91	350.94	4.14	V>1.5m/sec - channel armour required
2.40	89.28	45.18	1.98	378.28	4.24	V>1.5m/sec - channel armour required
2.50	93.75	45.81	2.05	405.59	4.34	V>1.5m/sec - channel armour required
2.60	98.28	46.44	2.12	435.85	4.43	V>1.5m/sec - channel armour required
2.70	102.87	47.08	2.19	466.08	4.53	V>1.5m/sec - channel armour required
2.80	107.52	47.71	2.25	497.28	4.62	V>1.5m/sec - channel armour required
2.90	112.23	48.34	2.32	529.44	4.72	V>1.5m/sec - channel armour required
3.00	117.00	48.97	2.39	562.58	4.81	V>1.5m/sec - channel armour required

Note: Refer to Figure 5.15 in SANRAL Drainage manual
For permissible velocities in channels

APPENDIX E : DRAWINGS

Future Flow
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2008/094325/23

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MEMBER:
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Future Flow Reference: EPR.11.044
Client Reference:

30 April 2012

Sebilo Resources
121 Mendelsohn street
Roosevelt Park
2129

Irene Lea Environmental & Hydrogeology
3 Herbert Baker st
Sharon Park
1496

Attention: Tebogo Louw / Irene Lea

SEBILO MANGANESE MINE

GROUNDWATER IMPACT STUDY

Good day Tebogo / Irene,

Please see attached the report for the conceptual groundwater impact study conducted at the Sebilo Perth Manganese Mine. Please do not hesitate to contact me should you require any additional information.

Best regards,

Martiens Prinsloo Pr.Sci.Nat
Future Flow GPMS cc

Future Flow
GROUNDWATER & PROJECT MANAGEMENT SOLUTIONS

Future Flow Reference: EPR.11.044
Client Reference:

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SEBILO MANGANESE MINE

GROUNDWATER IMPACT STUDY

For

Sebilo Resources

and

Irene Lea Environmental & Hydrogeology

Future Flow Document: EPR.11.044 / Conceptual Impact Report
30 April 2012

SEBILO MANGANESE MINE

GROUNDWATER IMPACT STUDY

For

Sebilo Resources

and

Irene Lea Environmental & Hydrogeology

Report Issue	Final		
Reference Number	EPR.11.044		
Title	Sebilo Manganese Mine - Groundwater impact study		
	Name	**Signature**	**Date**
Author	Martiens Prinsloo (Pr.Sci.Nat)		30 April 2012

This report has been prepared by Future Flow Groundwater and Project Management Solutions with all reasonable skill, care and diligence within the terms of the contract with the client, and taking into account of the resources devoted to it by agreement with the client.

We disclaim any responsibility to the client and any other in respect of any matters outside the scope of the project.

This report is confidential to the client and we accept no responsibility of whatsoever nature to third parties to whom this report, or any part thereof, is made known. Any such parties relies on the report at their own risk.

The water level in the historic Perth Pit is equivalent to the surrounding, and regional, groundwater levels and the system is in equilibrium. Based on this, and the high net evaporation from the area, it can be concluded that there is a net inflow into the pit, and the pit does not recharge into the surrounding aquifers.

The groundwater level contours and flow patterns for the weathered rock aquifer are shown in Figure 4.3. Groundwater flows are directed from the east towards the topographical lows representing the Witleegte stream bed. Flow gradients are calculated at 1:100 to 1:350.

Groundwater use and classification

Groundwater forms the sole source of water supply to the local landowners for both domestic use and agricultural (stock watering) purposes. No measured water use volumes are available. Using standard minimum use volumes of 25 l per person per day for domestic use it is calculated that less than 10 m^3 of water is used per day for domestic use. Agricultural water use from the 12 agricultural use boreholes is estimated at 120 m^3/day (10 m^3/day from each borehole).

Following the Parsons Classification system the aquifers in the area is classified as a **minor** aquifer based on the low yields from the aquifer. However, the aquifers are of **high importance** to the local landowners due to the fact that it forms the sole source of water supply.

Groundwater quality

The regional groundwater quality in general is relatively poor with almost all samples having elements within the SANS241 domestic use guideline Class II and exceeding Class II. The main elements that show elevated concentrations include chloride, nitrate, calcium, magnesium and sodium.

Plotting the chemical analysis results on a Piper diagram show that all the samples plot within the upper portion of the diamond indicating static water. The water generally has a magnesium / chloride or calcium / chloride dominant character.

Comparison to Perth pit water quality show that the pit was character is magnesium chloride dominant, which is comparable to a number of groundwater samples, including samples PD, PS1, and UMK14.

Water quality from all the new boreholes drilled around the historic mine area and into the ore body show elevated manganese concentrations. Sample SB02, which is drilled into the historic underground mine, is considered to provide an indication of the expected long term groundwater quality after mine closure. The sample show highly elevated concentrations of chloride, sulphate, nitrate, fluoride, calcium, magnesium, sodium, manganese, and zinc

Aquifer transmissivity

The aquifer transmissivity of the fractured rock material ranges between 0.25 and 0.7 m^2/day. The newly drilled monitoring boreholes targeted geological structures that could act as potential groundwater flow pathways, and the transmissivity of these boreholes are considered to be higher than the average transmissivity of the general competent, fractured, host rock. The general aquifer transmissivity of the un-fractured host rock is considered to be less than 0.1 m^2/day. This is confirmed by the very low transmissivity seen in borehole P5 which yielded extremely little water. At 72 hours after completion of the drilling only 2 to 3 m of water had accumulated in the borehole.

The hydraulic conductivities of the fractured rock aquifer are calculated to range around 0.012 and 0.021 m/day. This means that groundwater migrate at a rate of between 0.012 and 0.021 m/day through the aquifers. These are very low numbers and not conducive to large flow volumes through the area.

Acid base accounting and static leach testing

Results from ABA test performed on two samples indicate that:

- NNP: The NNP of samples "Waste" and "/LEH" exceed 20 kg $CaCO_3$/tonne and can be considered safe;
- NPR: The NPR of the samples far exceeds the neutralising guideline of 3 and ranges between 450 and 510. Based on this the material can be classified as acid neutralising;
- Sulphide S and NAG pH: The Sulphide-S ratio for both samples is less than 0.01, while the final NAG pH is measured at between 7.7 and 8.0. Based on Price's guidelines no further ARD testing is required provided there are no metal leaching concerns; and
- The sulphide percentages in all the samples fall below 0.3 %.

Final NAG pH values for the roof material range around 8 to 9. This corresponds to the NPR ratios of between 23 and 83 which are much greater than the guideline value of 3, indicating that the rock material is acid neutralising.

It is unlikely that the material will be acid forming. Should some acid conditions form it will be buffered and neutralised by the high neutralising capacity of the rock material. In addition, any such acid conditions that form will only be sustainable in the short term due to the very low Sulphur-S percentages.

Static leach testing results show that in general there is no concern around the element leach concentrations. Cadmium, Mercury, and Manganese do indicate some elevated concentrations. However, cadmium and mercury is reported at the limit of the detection capability of the analysis method. Therefore, there is uncertainty around the actual concentration values for these two elements and whether they do in fact exceed the Class II guideline values. Manganese is the only element where it can be said with certainty that the leach concentrations are expected to exceed domestic use guidelines. This is expected due to the natural elevated manganese concentrations in the area associated with the ore body.

Conceptual impact assessment

Construction phase

The historic mine area will be dewatered causing a drawdown in the surrounding groundwater levels. It is expected that the historic mine will be completely dewatered, thus to a level of approximately 100 m below surface. The groundwater level will therefore be drawn down by approximately 72 m. The maximum zone of influence of the drawdown cone in the general competent rock is around 110 m.

Surface construction of the discard and tailings dumps, settling and evaporation ponds, pollution control dams, haul roads and offices will not breach the groundwater level and is therefore not expected to have any notable impact on the groundwater levels.

In general it can be said that the impacts during the construction phase will be small.

Operational phase

Groundwater level drawdown and zone of influence

The mining areas will have to be actively dewatered to ensure a safe working environment. Pumping groundwater that seeps into the mine area to surface will cause dewatering of the surrounding aquifers and an associated decrease in groundwater level within the zone of influence of the dewatering cones. The maximum zone of influence in the general competent rock is expected to be around 25m. The calculated zone of influence in the individual groundwater bearing range up to 110 m from the mining area. A value of 200 m is assumed to be conservative.

The Witleegte stream has non-perennial flows. Therefore, even though the channel represents a topographical low, it is considered that the drawdown cone can develop to the opposite side of the topographical depression due to a combination of:

- The depth of the mining and groundwater level in the area;
- The apparent poor hydraulic connection between the stream and the underlying aquifer due to the very low hydraulic conductivity of the rock material; and
- The non-perennial nature of the stream.

Water inflows into the mine area

Direct recharge from rainfall: The calculated direct rainfall onto the pit area range between 7 and 63 m^3/day depending on the size of the open pit. Direct rainfall into the pit during the rainy season will be higher than the values shown in Table 5.1. The direct rainfall into the pit could possibly as high as 150 m^3/day during January 2018 when the open pit area is at its largest with a total combined area of 65 760 m^2 for the pits opened during 2016, 2017, and 2018 (keep in mind that rehabilitation only begins three years after mining started). January is also the month with the highest average rainfall at 70 mm.

Recharge onto the rehabilitated area: The calculated values represent the worst-case scenario as a notable portion of the recharging rainwater will be retained within the rehabilitated material (possibly up to 20 %) thus decreasing the dewatering requirement. The water retained within the rehabilitated material will lead to a rising water level in the rehabilitated material.

Groundwater inflow volumes: Using average hydraulic conductivities the groundwater inflow volumes into the pit area range between 10 and 120 m^3/day over the life of mine. As expected, the inflow volumes are initially relatively low and then increase over time with an increasing mine area. At the end of the life of mine groundwater inflows are expected to be 120 m^3/day when using the average hydraulic conductivity values.

Groundwater contamination

Groundwater flows around the mining area, within the zone of influence of the mine dewatering cone, will be directed towards the mine area. Water will be pumped from the pit to surface water management structures and therefore very little to no contamination is expected to reach the surrounding aquifers from the opencast pit area.

The waste, topsoil, and tailings storage facilities are located mostly outside the zone of influence of the drawdown cone around the mining area. Any contamination from these sources will not necessarily be drawn towards the mining area and could leave the mine area.

The sandy gravel that overlies the area around the proposed mine inherently has a relatively high hydraulic conductivity compared to the competent rock and can have a conductivity in the order of 1 to 5 m/day. This could lead to significant contaminant migration away from surface infrastructure should there be vertical seepage from these infrastructure towards the underlying sandy gravel.

Decommissioning phase

Mine dewatering will stop during the decommissioning phase and the groundwater level in the aquifers surrounding the mine will start to recover as the water level in the mined-out area rises. However, it is considered that during the time span of the decommissioning phase (assumed to be less than 6 months) there will be little measurable rise in the water levels due to the fact that the underground area will require a large volume to be flooded.

Groundwater flows around the mining area, within the zone of influence of the mine dewatering cone, will remain directed towards the mine area even though mine dewatering has stopped. This is due to the fact that the decommissioning phase is not expected to last more than 6 months which is not sufficient time for the water level in the pit area to recover significantly.

The waste, topsoil, and tailings storage facilities are located mostly outside the zone of influence of the drawdown cone around the mining area. Any contamination from these sources will not necessarily be drawn towards the mining area and could leave the mine area.

Long term post-operational phase

Recovery of the groundwater level

The water level in the pit area is expected to rise once mine dewatering stop. Using the groundwater inflow rates and void space in the rehabilitated material and underground mine it is calculated that recovery of the groundwater levels to the level of the regional groundwater level (28 mbgl) will take approximately 40 years using average inflows from the surrounding aquifers. Applying the maximum and minimum groundwater inflow rates (based on minimum and maximum aquifer hydraulic conductivities) it is shown that this time line for groundwater level recovery has a range of a maximum of 75 years, and a minimum of 25 years.

Contamination of the surrounding aquifers

The groundwater level in the rehabilitated material of the opencast pit will recover to near pre-development levels around 30 to 40 years after closure. As the groundwater flow patterns are re-established through rising water levels in the rehabilitated area the plume will migrate from the mine in a down gradient direction, towards the west where the Witleegte stream channel forms a topographical low. Once the contamination accumulates here, the migration direction will change towards the northwest, along the stream channel. Contaminant migration from the mining area through the fractured rock aquifer will be limited. It is not expected that the plume will extend more than 700 to 1 000 m from the mining areas.

The waste, topsoil, and tailings storage facilities are located mostly outside the zone of influence of the drawdown cone around the mining area. Therefore, any contamination from these sources will not necessarily be drawn towards the mining area and could leave the mine area. The sandy gravel that overlies the area around the proposed mine inherently has a relatively high hydraulic conductivity that could lead to significant contaminant migration away from surface infrastructure should there be vertical seepage from this infrastructure towards the underlying sandy gravel. It is assumed that the sandy gravel will be excavated (average thickness of 5.6 m), or sealed off using a synthetic liner and leakage detection system, especially at the tailings and waste facilities, which will prevent contamination of the underlying aquifers.

It is assumed that the tailings and waste facilities will be sloped, capped, and vegetated in order to reduce oxygenation and rainfall recharge into the facilities. In the long term this will reduce the vertical seepage from the facilities towards the underlying sandy gravel and fractured rock aquifers.

Decant potential

At no point is the floor elevation of the underground mine above the topographical levels around the perimeter of the opencast area. Therefore, no decant directly from the underground mine is expected.

Decant from the rehabilitated opencast area is more difficult to evaluate. The natural groundwater level in the vicinity of the area is on average around 28 mbgl. It is possible that the groundwater level can continue to rise in the rehabilitated area after the elevation of the surrounding regional groundwater level has been reached. Under ideal conditions the water level in the rehabilitated material can reach surface around 10 to 15 years after the regional groundwater level was reached, thus around 40 to 55 years after mine closure. Once the water reaches surface elevation, decant onto surface could occur.

The probability of decant occurring it is currently unsure and it is recommended that on completion of the mine operations a monitoring borehole be installed at the north-western corner of the rehabilitated opencast area at coordinates: 4 980 E; -3 018 700 S. This borehole will serve to monitor the rate of rise, and quality, of the water in the rehabilitated material. The borehole will serve as an early warning system for potential decant. The water quality data can also be used to determine the decant water quality and the impacts on the surrounding environment.

In the event that the water level in the rehabilitated material rise to the reach the elevation of the sandy gravel it is possible that a dispersed seepage front will develop somewhere down gradient from the mine, in the area between the Witleegte stream and the mine area.

Impact management recommendations

Dewatering of the aquifers

The surrounding aquifers will be dewatered due to mine dewatering. This process cannot be stopped. It is also impractical to attempt to reduce the inflows.

The groundwater seeping into the mined-out area will have to be pumped to surface to ensure safe working conditions. The water pumped from the underground area will be classified as "dirty" water and as such will have to be managed by the mine. The water will be pumped to a pollution control dam from where it can be re-used in the plant.

Control surface water inflows

Installation of surface berms and diversion trenches will reduce the surface inflows into the mine area during rainfall events, and therefore the volume of "dirty" water that will have to be managed.

Monitoring of contamination of the surrounding aquifers

It is recommended that the groundwater monitoring program be continued after mine closure to monitor for any contamination migrating away from site. Monitoring boreholes should include not only dedicated mine monitoring boreholes, but also privately owned boreholes that could potentially be impacted, including:

- Owner – Mr Eben Anthonissen: P7, P6, P5;
- Owner – Mr Henk Venter: PK01;
- Owner – Mrs Koba Albagten: PD.

The monitoring program should allow for:

- Monthly monitoring:
  - Depth to groundwater level in all boreholes;
  - Field pH, EC, TDS measurements in all boreholes;
- Quarterly monitoring:
  - Depth to groundwater level in all boreholes; and
  - Sampling of all boreholes and submitting the samples to an accredited laboratory for chemical analysis. The elements that should be analysed for are shown in Table 4.2.

Contamination of the aquifers underlying the surface infrastructure

Seepage from the tailings and waste facilities can contaminate the underlying aquifers as discussed in Section 5.4.2. It is recommended that:

- The high transmissivity sandy gravel that underlies the target areas for the facilities should be excavated. This will reduce the risk to the surrounding environment due to potential widespread, and relatively rapid, migration of poor quality seepage from the surface infrastructure;
- If possible, a liner system or under drain system (herringbone drain system) should be installed underneath the tailings and waste facilities together with a leak detection system in order to reduce and manage vertical seepage into the underlying aquifers;
- The tailings and waste facilities be sloped, capped, and vegetated as part of the rehabilitation plan in order to reduce oxygenation and rainfall recharge into the facilities. In the long term this will reduce the vertical seepage from the facilitates towards the underlying sandy gravel and fractured rock aquifers;
- The newly installed mine specific monitoring boreholes should be monitored on a regular basis for changes in groundwater levels and quality that could indicate seepage from the surface infrastructure and contamination of the aquifers; and
- Additional monitoring boreholes should be installed at the tailings and top soil storage areas.

Installation of an additional monitoring borehole

It is recommended that on completion of the mine operations a monitoring borehole be installed at the north-western corner of the rehabilitated opencast area at coordinates:

Easting: 4 980 ; Northing: -3 018 700 (WGS84, LO23).

This borehole will serve to monitor the rate of rise, and quality, of the water in the rehabilitated material. The borehole will serve as an early warning system for potential decant. The water quality data can also be used to determine the decant water quality and the impacts on the surrounding environment. It is recommended that should the water level in the proposed monitoring borehole reach the sandy gravel lithologies active monitoring of the area between the mine and the stream be implemented to monitor for any shallow, poor quality seepage daylighting from the sandy gravel.

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1. Introduction and terms of reference

Future Flow GPMS cc is contracted by Sebilo Group (Pty) Ltd – Mining & Resources (Sebilo) to perform a hydrogeological impact study for the Sebilo Perth Manganese Mine Project. Irene Lea from Irene Lea Environmental & Hydrogeology (*i*LEH) is the project manager. The project area is located on the farm Perth 276; approximately 10 km south of the town of Hotazel, Northern Cape (please refer to Figure 3.1).

The current environment on site is dominated by the historical mining footprint left behind after Assmang finished mining during the 1970's. This includes an old flooded pit and underground workings, a waste rock dump and an old manganese ore floor. Available information suggests that the water in the pit is of poor quality.

Sebilo proposes that both opencast and underground mining methods are used to extract the manganese ore. Mining is planned to commence during 2013 and will be completed by 2026. At the start of the operations, only opencast mining will be conducted. Underground mining is expected to commence in 2023. Mining is expected to cease during 2026. The ore will be crushed and screened on site and will be transported via rail to Durban for export.

The aim of the study is to characterise the groundwater regime in the project area and construct a conceptual groundwater flow and contaminant transport model of the study area. Also included is a conceptual quantification of the possible impacts to the receiving environment including the surrounding aquifers as well as the surface water systems in the study area.

This report details the outcomes of the best practice methods used to characterise the conceptual hydrogeological environment for the proposed Sebilo Perth mining project.

2. Scope of work

The scope of work includes:

- Project initiation:
    - Collect and evaluate all available data including site specific information supplied by the client as well as public domain information (geological, hydrogeological maps etc.); and
    - An initial site visit to visually inspect the study area and evaluate grey areas or data gaps identified during the desk study.
- Field investigation:
    - Hydrocensus of the study area to collect current information on the groundwater environment (depth to groundwater level, current use type and volume etc.);
    - Ground geophysical investigation to identify geological structures such as dykes, sills, and faults that could act a preferential groundwater flow pathways;
    - Drilling of five hydrogeological boreholes during which the relevant information (depths and yields of water strikes, lithologies, etc.) are collected;

  - Aquifer testing of the newly drilled boreholes in order to determine the aquifer parameters (transmissivity and storage);
  - Collection of groundwater samples for chemical analysis to determine the pre-development groundwater character; and
  - Collection of rock samples for geochemical analysis to determine the acid mine drainage potential and identify elements that are expected to be present in elevated concentrations in the post-mining environment. This phase of the project has been completed by *i*LEH.
- Conceptual groundwater model:
  - Analyse the data and construct a conceptual groundwater flow and contaminant transport model. For the purpose of this document reference is made to the available data and other studies done in the area in the past; and
  - Determine conceptual impacts on groundwater flows and quality due to the proposed mining activities. These impacts are calculated based on the available information.
- Report on results from the study:
  - Compile a report detailing the findings of the study.

3. General site description

3.1 Site locality

The study area is located approximately 10 km south of Hotazel in the Northern Cape Province of South Africa. Maps relevant to the study area include:

- 1:50 000 scale topographical maps (2722BB, 2722BD, 2723AA, and 2723AC);
- 1:250 000 scale geological map (2722 – Kuruman);
- 1:500 000 scale hydrogeological map (Kimberley);
- Satellite image of the area (Google Earth);
- Other published data on the study area.

A general locality map is shown in Figure 3.1.

3.2 Topography

The site topography is best described as being relatively flat with little topographical features. Locally, the natural topography dips slightly towards the stream beds of the non-perennial Witleegte and Ga-Mogara streams. Topographical elevation at the farm Perth, in the portion of the farm west of the gravel road – thus in the area where mining is proposed, is recorded at between 1 070 and 1 060 metres above mean sea level (mamsl). The higher lying (1 070 mamsl) areas occur on the eastern side of this portion of the farm (thus along the gravel road) while the low lying areas occur along the boundary of Perth 276 and Botha 313 which lies to the west of Perth. The low lying area that runs along this boundary forms the Witleegte stream.

On this portion of the property the natural topography is disturbed by ore and discard stockpiles from the 1970's Assmang mining activities. It is understood that these areas will be rehabilitated.

The natural topographical gradient on site is calculated to be around 1:60 to 1:70.

3.3 Surface water bodies

The project is situated in the Ga-Mogara River catchment which drains into the Kuruman River. The Ga-Mogara River is non-perennial that flows immediately west of the project boundary. Both rivers are tributaries of the Molopo River Basin, a sub-catchment of the Orange River System, which eventually drains into the Orange River between Wabrand and Blouputs in the Riemvasmaak area below the Augrabies Falls.

As mentioned in Section 3.2 the non-perennial Witleegte stream runs along the western boundary of Perth with the Farm Botha 313. The stream drains towards the north. Approximately 4 km northwest of the proposed mining area the two streams join, and is then known as the Ga- Mogara stream.

3.4 Climate and rainfall

The project area falls within the summer rainfall region of South Africa, in which more than 80 % of the annual rainfall occurs from October to April. A total of 85 % of the rainfall occur during summer. Following the scoping report the closest weather station to the project area is the Olifantshoek weather station and the precipitation data was derived from this station (please refer to Table 3.1). The average annual precipitation is 349 mm/a. Annual average evaporation rates are in the order of 2 026 mm/a.

Temperatures in this climate zone are generally moderate to high, although low minima can be experienced during the winter months due to clear night skies. Temperature can vary between 38 degrees (maximum) to 0 degrees (minimum) in summer and 30 degrees (maximum) to -5 degrees in winter.

The annual prevailing wind direction during the day for summer and winter months is from the south.

Table 3.1: Olifantshoek weather station average monthly climatic figures

Month	Precipitation (mm)	Evaporation (mm)	Temperature (°C)
January	70	272	25.1
February	56	220	25.3
March	62	186	20.7
April	33	135	18.2
May	12	112	13.6
June	6	91	10.2
July	2	107	9.2
August	3	143	12.9
September	8	203	17.0
October	23	249	20.5
November	31	265	22.8
December	55	293	24.8
Total	**349**	**2 026**	-

3.5 Geology of the study area

The Kalahari Manganese Field is a compact (approximately 30 km by 15 km) deposit located in the Northern Cape Province of South Africa which houses 70 % to 80 % of the world's high grade manganese resource. The Kalahari Manganese Field (KMF) has the shape of a tilted saucer with a sub-outcrop at approximately 45 m below surface in the east and more than 1 000 m in the west. The manganese deposits hosted in the Hotazel Formation at the top of the Griqualand West Sequence are vast, containing 13 billion tons of ore at a cut-off of 20 % (MDM Engineering, 2009).

The Hotazel Formation comprises of Banded Ironstone Formation inter-bedded with three manganese horizons termed the Upper, Middle and Lower Manganese Ore bodies. The lower body varies in thickness from 5 to 45 m in the area and constitutes the main ore body. The middle body is only 1 to 3 metres thick and is often considered uneconomic. The average thickness of the upper body is 5 meters but it can be as thick as 30 m. Of these, the lower 5 to 6 meters of the lower body normally represents the economic ore horizon (MDM Engineering, 2009).

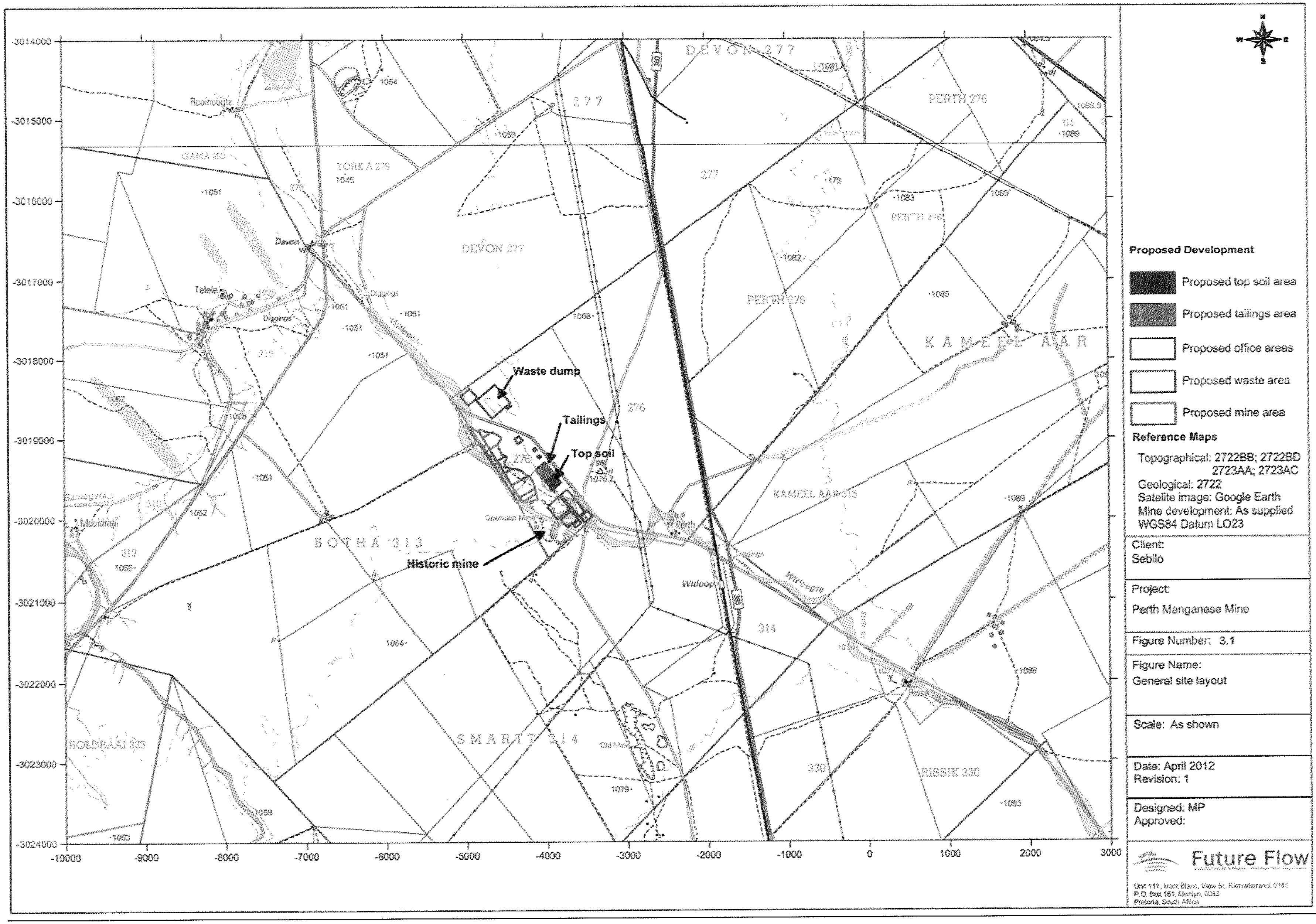
The lower ore body is characterized by a braunite assemblage. This is referred to as Mamatwan-type ore and represents approximately 79 % of the total manganese resource in the field. The main contaminants in Mamatwan ore are calcium and magnesium carbonates. Whilst the average economically exploitable Mamatwan ores have a 35 % Mn content, sintering results in Mn values exceeding 44 %. Along the north-western margin of the field intense faulting, thrusting and associated hydrothermal activity enriched the ore through the removal of carbonates and silica. This ore type is known as Wessels Ore and has manganese content in excess of 40 %, but only constitutes approximately 21 % of the Kalahari Manganese Field (MDM Engineering, 2009).

The major rock types that occur in the study area include dolomite, limestone and chert of the Ghaap Group, Banded Iron Formation within the Griquatown West Sequence and shales and schists of the Ecca Group of the Karoo Supergroup. These rocks were deposited about 2 200 –

2 300 million years ago in an oceanic environment. The source of the iron and manganese is thought to have been submarine volcanic activity. Subsequently, during the formation of the Namaqua Metamorphic Province approximately 1 000 – 1 300 million years ago, the valuable high-grade ores formed as a result of hydrothermal reconstitution of the original low-grade sedimentary ores.

Approximately 12 km to the east of the proposed Sebilo Perth mine area the Makganyene (Vm) and Danielskuil (Vad) Formations outcrop. The Makganyene Formation comprises diamictite, banded jasper, siltstone, mudstone, sandstone, grit, and dolomite with chert. The Danielskuil Formation is represented by yellow-brown banded or massive jaspilite with crocidolite, flat-pebble conglomerate (potsherd marker) and an upper speckled marker.

The hydrogeological maps of the area show the presence of north-south trending regional fault lines that divide the Makganyene and Danielskuil Formations into blocks with north / south displacement noted along these faults. The presence of these faults is also confirmed from the results of the ground geophysical investigation. The north / south offset between opposite sides of the faults can be up to 6.75 km. Based on the size of the regional faults and the large displacement along the fault lines it is assumed that the faults will extend below the sandy gravel cover and possibly reach the proposed Sebilo Perth mining area.


Waste dump
Tailings
Top soil
Historic mine
Opencast Mine
DEVON 277
277
DEVON 277
PERTH 276
PERTH 276
276
KAMEEL AAR
KAMEEL AAR 315
314
BOTHA 313
313
SMART 314
RISSIK 330
330
YORK A 279
GANA 280
HOLDRAAI 333
Rooihoogte
Devon
Telele
Diggings
Perth
Witloop
Witsegte
Mooidraai
Old Mine
-3014000
-3015000
-3016000
-3017000
-3018000
-3019000
-3020000
-3021000
-3022000
-3023000
-3024000
-10000
-9000
-8000
-7000
-6000
-5000
-4000
-3000
-2000
-1000
0
1000
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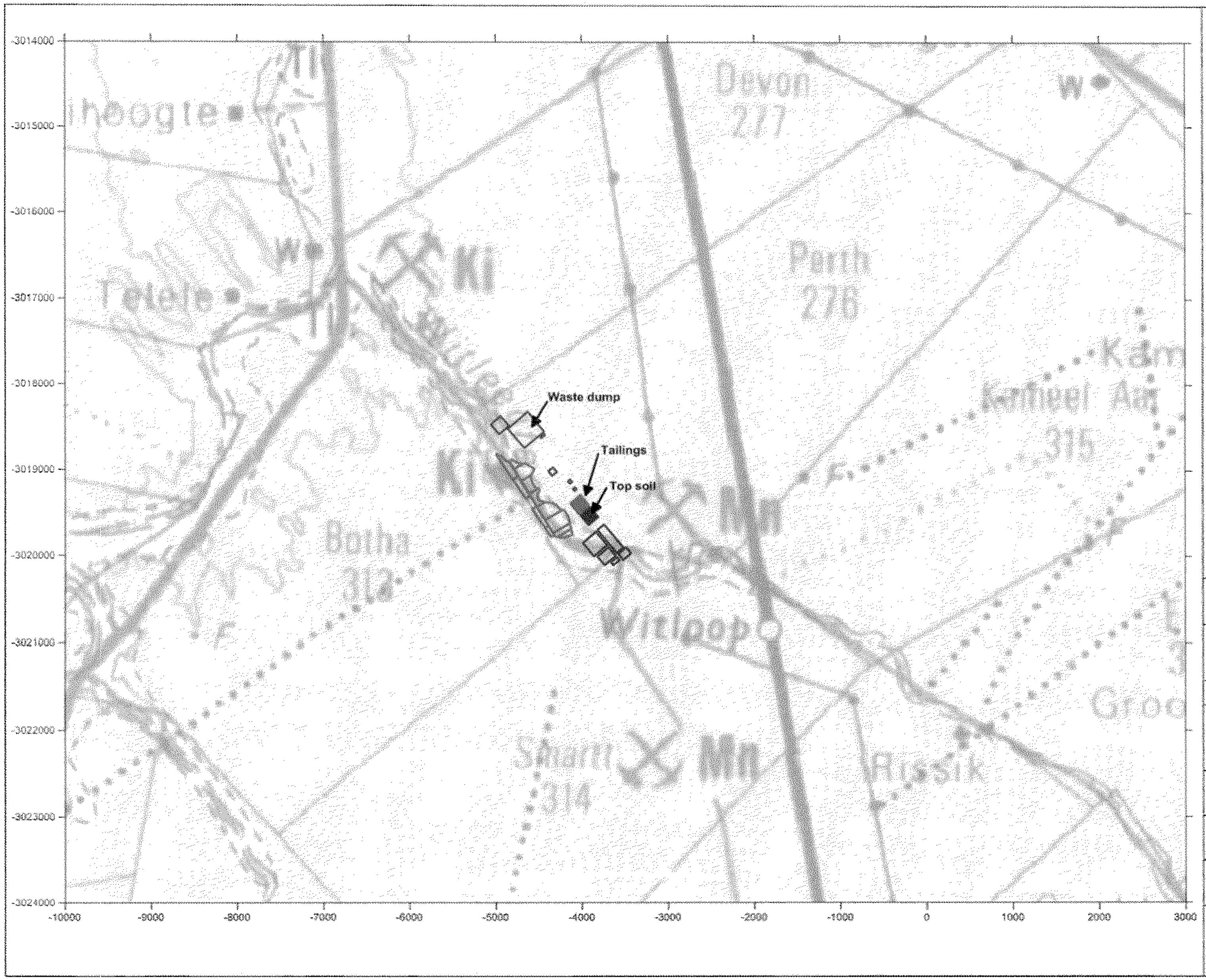
3000
N
E
S
W
Proposed Development
Proposed top soil area
Proposed tailings area
Proposed office areas
Proposed waste area
Proposed mine area
Reference Maps
Topographical: 2722BB; 2722BD 2723AA; 2723AC
Geological: 2722
Satellite image: Google Earth
Mine development: As supplied
WGS84 Datum LO23
Client: Sebilo
Project: Perth Manganese Mine
Figure Number: 3.1
Figure Name: General site layout
Scale: As shown
Date: April 2012
Revision: 1
Designed: MP
Approved:
Future Flow
Unit 111, Mont Blanc, Vale St. Rietvalleirand, 0181
P.O. Box 161, Menlyn, 0063
Pretoria, South Africa



Proposed Development

■	Proposed top soil area
▨	Proposed tailings area
☐	Proposed office areas
☐	Proposed waste area
☐	Proposed mine area

Reference Maps

Topographical: 2722BB; 2722BD
2723AA; 2723AC
Geological: 2722
Satelite image: Google Earth
Mine development: As supplied
WGS84 Datum LO23

Client:
Sebilo

Project:
Perth Manganese Mine

Figure Number: 3.2

Figure Name:
General geology of the study area

Scale: As shown

Date: April 2012
Revision: 1

Designed: MP
Approved:

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Pretoria, South Africa

4. Hydrogeology of the study area

The hydrogeology of the study area is described at the hand of data collected during the desk study and the field investigation. The field investigation included a hydrocensus, geophysical investigation to identify faults and fractures that can act as preferential groundwater flow paths, installation of five monitoring boreholes, aquifer testing of the newly drilled boreholes, and hydrochemical analyses.

4.1. Aquifer description

Three aquifers occur in the area. These three aquifers are associated with a) the primary sandy gravel material, b) the fractured rock and leached banded iron formation aquifer, and c) the dolomitic aquifers of the Griqualand West Sequence.

The fractured rock aquifers are not high yielding, but the dolomitic karst aquifer is well known for its high potential (Van Dyk and Jones, 2006). The following is a description of the natural aquifer systems in the area:

4.1.1 Upper primary sandy gravel aquifer

The upper aquifer forms due to the vertical infiltration of recharging rainfall through the primary sandy gravel material being retarded by the lower permeability of the underlying competent rock. Exploration borehole log data shows that this aquifer ranges between 3 and 10 m in thickness and is on average 5.6 m thick. Groundwater collecting above the sandy gravel / competent material contact migrates down gradient along the contact to lower lying areas. In places where the contact is near surface the groundwater can daylight on surface as springs. Such areas where the groundwater level in the sandy gravel material is close to surface can also be expected to be near the streams where it contributes baseflow to the streams.

However, it has to be cautioned that drilling results show this aquifer to be dry in large portions of the study area. It is considered that this aquifer is seasonal and mostly carries water only during and shortly after rainfall events when rainfall recharges into the material. The relatively high transmissivity of the sandy gravel material allows the recharging water to migrate quickly through and out of the material. This combined with the high positive evaporation rates in the area (please refer to Table 3.1) lays the material dry for large portions of the year.

It is considered that up to 5 or 7 % of the mean annual rainfall (MAR) recharges into this material However, taking into consideration evaporation and other losses possibly as little as 1 to 3 % of the MAR reaches the saturated zone in the underlying fractured rock aquifer.

4.1.2 Fractured rock and leached banded iron formation aquifer

Although the lower permeability of the competent rock material will retard vertical infiltration of groundwater some of the water in the upper aquifer will recharge the lower aquifer. The geological map does not show major faults or fractures in the area which will also help recharge the lower aquifers. However, large portions of the area is covered by the sandy gravel discussed in Section 4.1.1, therefore surface mapping of fault and fractures are hampered. The hydrogeological map of the area does show the presence of some regional faults in the Makganyene (Vm) and Danielskuil (Vad) Formations that outcrop 12 km to the east.

Drilling results from previous projects in the area have shown that the flat-pebble conglomerate (potsherd marker) that is intercepted in the Danielskuil Formation is the only water bearing zone in the area.

Groundwater flows in the fractured rock aquifer are associated with the secondary fracturing in the competent rock that was formed by the major north / south striking faulting seen from the hydrogeological maps and confirmed by the ground geophysical survey (please refer to Figure 3.2 and Appendix A). As such groundwater flows and contaminant transport will be along discrete pathways associated with the fractures. The general transmissivity of the competent rock material is considered to be around 0.1 m^2/day or less.

Aquifer testing performed on the newly drilled boreholes (SB01 to SB05) show that the transmissivity of individual fractures range between 0.25 and 0.7 m^2/day. Drilling results show that aquifer strikes can occur down to 80 m in this area. Using the borehole depths and the aquifer transmissivities stated above the hydraulic conductivity of the non-fractured, competent material is calculated to be around 0.001 m/day, and that of the individual fractures up to 0.021 m/day as discussed in more detail in Section 4.5.

4.1.3 Dolomitic aquifer

Dolomitic aquifers are recognised to potentially be of concern to mining activities due to the potential large inflow volumes in areas where karstic dolomite is intersected. The dolomitic karst aquifer in the region is well known for its high potential (Van Dyk and Jones, 2006). A number of springs have been mapped in the area (van Dyk & Jones, 2006) of which the Kuruman, Klein Karoo, and Manyeding are perennial.

Smit (1978) and Wiegmans (2006) defined compartments within the dolomite in separate groundwater management units. The project area falls within the D41K groundwater management area. Wiegmans (2006) also calculated recharge to each of the compartments and the associated management criteria in terms of sustainable abstraction volumes.

Inspection of exploration drilling core on neighbouring farms show that the dolomite in the area appears to be competent with no indication of weathering or karstification. Karstic dolomite is highly variable in competence and transmissivity over short distances and this is no guarantee that karstic dolomite won't be found on site, however, based on the general constant high competence and total absence of indications of karstic dolomite it can be concluded that the likelihood of intercepting karstic dolomite is very low.

4.2. Depth to groundwater level and flow patterns

The depth to groundwater level was measured during the hydrocensus that was performed as part of the study (please refer to Figure 4.3 for the borehole positions) where eighteen boreholes were identified. In addition to this, the depth to groundwater level was measured in the newly drilled monitoring boreholes. The recorded data are summarised in Table 4.1 and shown graphically in Figure 4.1. From Table 4.1 it can be seen that the depth to groundwater level generally range between 14.60 and 36.70 mbgl. The average depth to groundwater is calculated to be 28 mbgl, with the groundwater level around the pit specifically (boreholes SB01, SB03 and SB04) calculated at 27.3 mbgl.

Borehole PK indicates an anomalous deep depth to groundwater when compared to the other boreholes (indicated in red on Figure 4.1). The borehole is used for mining purposes at Amari and it is possible that the depth to groundwater was influenced by pumping shortly before the measurement was taken.

In areas where there are no large scale external impacts on the groundwater environment, such as the lowering of groundwater level through mine dewatering, and where the geology and aquifer interactions are not excessively complex it is expected that the groundwater level contours reflect topographical contours, although at a moderated gradient. Plotting groundwater level elevation versus topographical elevation for this area (and omitting the anomalous depth to groundwater in borehole PK) yields a 94.6 % correlation for the fractured rock aquifer. From these correlation figures it can be concluded that there are no large scale impacts on the groundwater levels in the area. When PK is included a correlation of 90 % is still achieved.

Considering the average depths to groundwater level, Figure 4.1 and Figure 4.2 it is concluded that the water level in the historic Perth Pit is equivalent to the surrounding, and regional, groundwater levels and the system is in equilibrium. Based on this, and the high net evaporation from the area, it can be concluded that there is a net inflow into the pit, and the pit does not recharge into the surrounding aquifers.

Regional groundwater level contours are calculated using Bayesian interpolation based on topographical elevation and the good correlation between groundwater levels and topography as shown above. The groundwater level contours and flow patterns for the weathered rock aquifer are shown in Figure 4.3. From the figure it can be seen that groundwater flows are directed from the east towards the topographical lows representing the Witleegte stream bed. Flow gradients are calculated at 1:100 to 1:350.

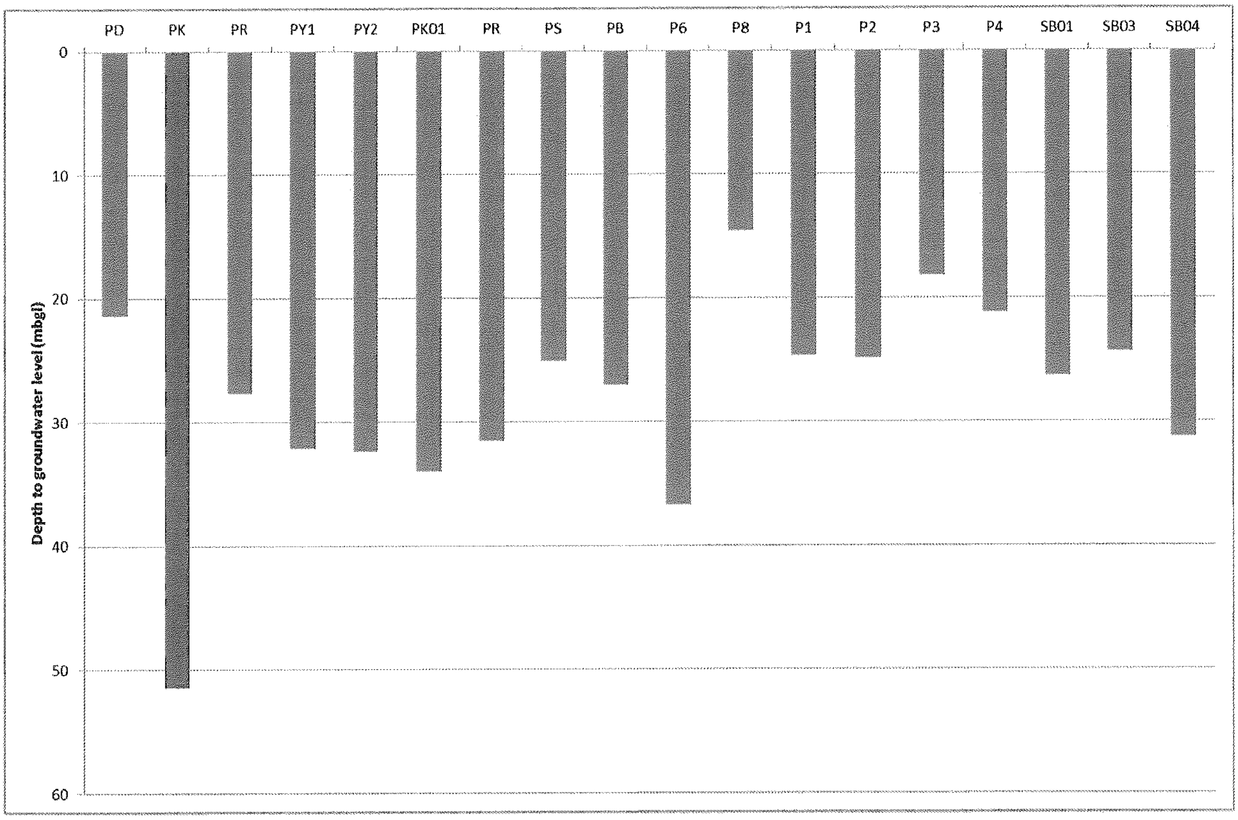


Figure 4.1: Depth to groundwater level

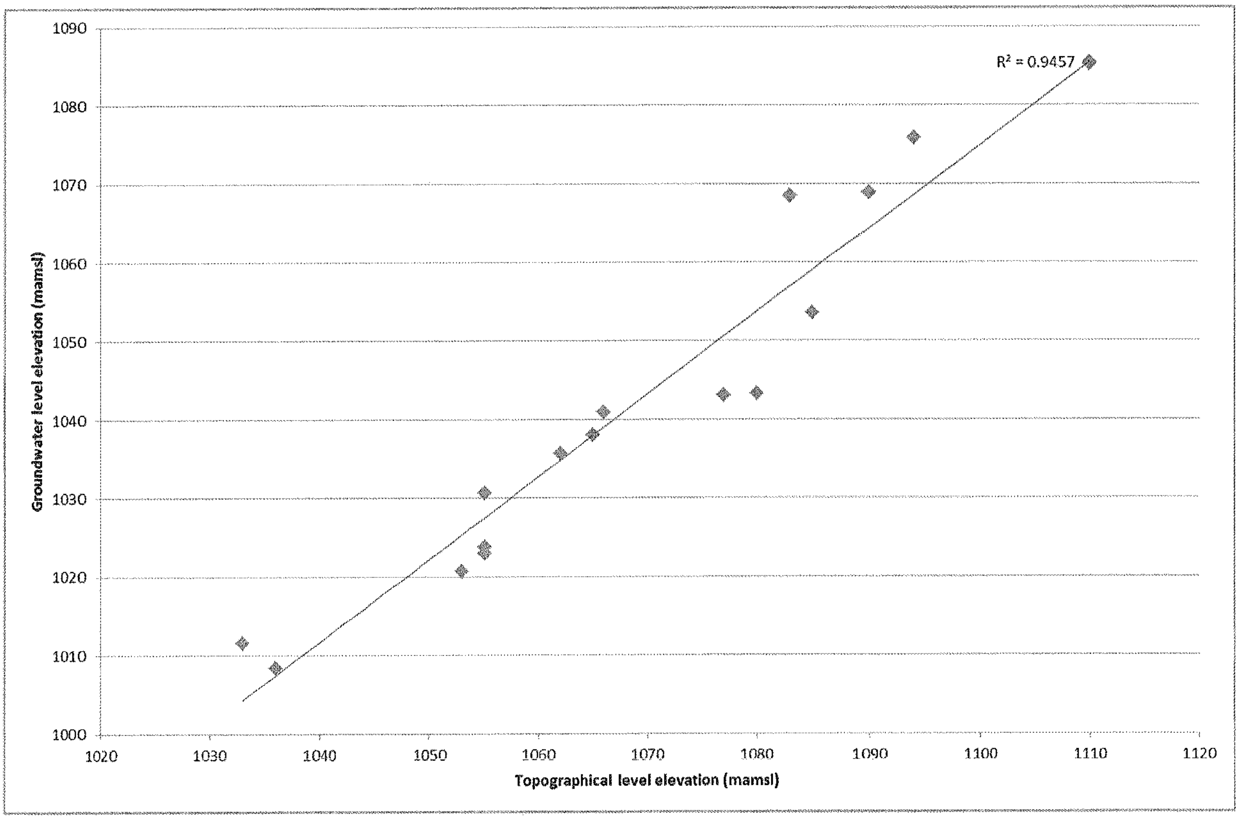


Figure 4.2: Topography vs. groundwater level elevation plot

4.3. Groundwater use and aquifer classification

Groundwater forms the sole source of water supply to the local landowners for both domestic use and agricultural (stock watering) purposes. No measured water use volumes are available. Using standard minimum use volumes of 25 l per person per day for domestic use it is calculated that less than 10°m^3 of water is used per day for domestic use.

Agricultural water use from the 12 agricultural use boreholes is estimated at 120 m^3/day (10 m^3/day from each borehole).

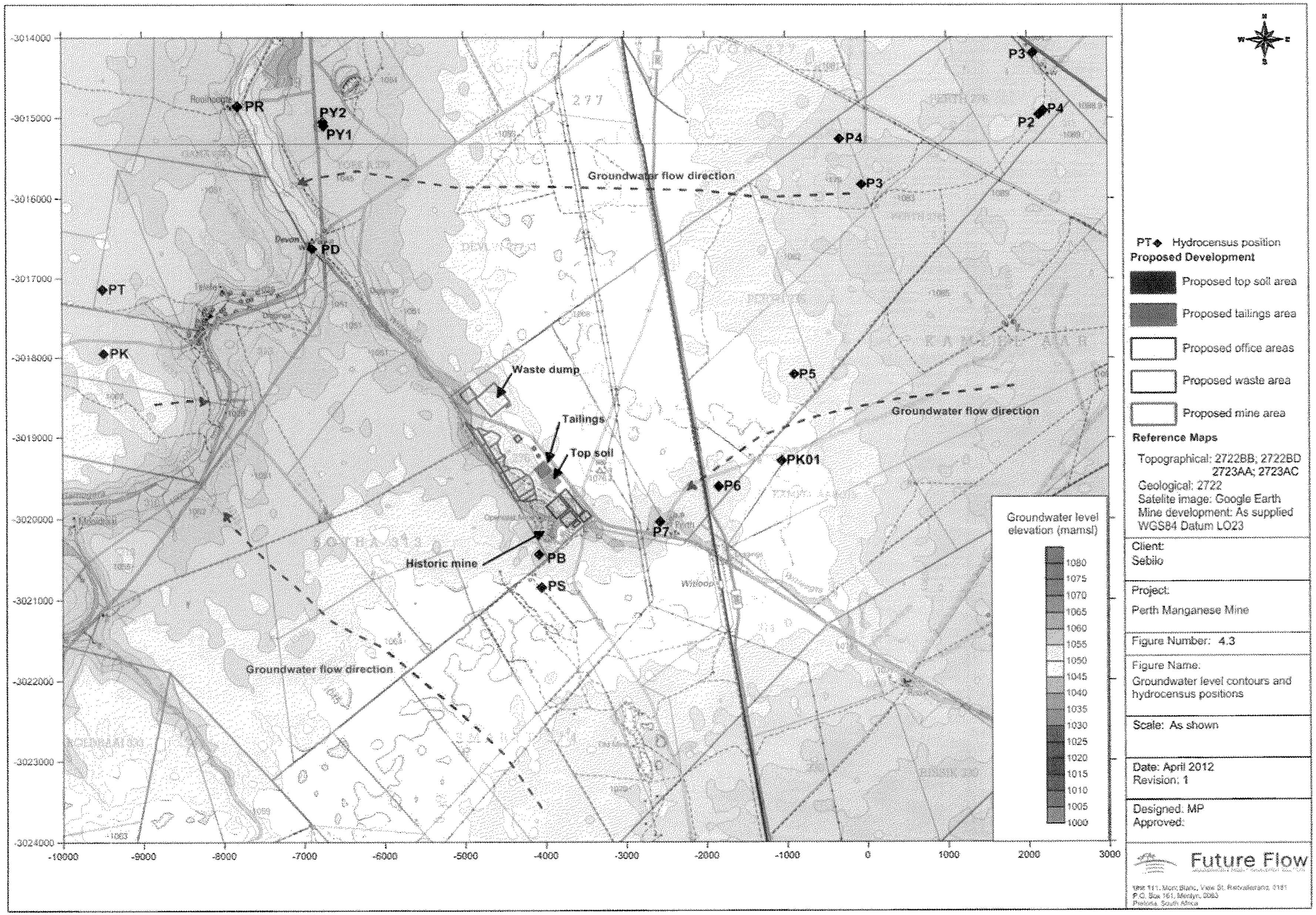
Mine water use at Amari from borehole PK is unknown.

Following the Parsons Classification system the aquifers in the area is classified as a **minor** aquifer based on the low yields from the aquifer. However, the aquifers are of **high importance** to the local landowners due to the fact that it forms the sole source of water supply.

Table 4.1: Hydrocensus results

BH	Owner	Contact	Easting	Northing	Elevation	Collar	Water level			Depth	Use	Comment
			WGS84, LO23	WGS84, LO23	mamsl	magl	mbc	mbgl	mamsl	mbgl		
PD	Mrs Koba Albagten	Unknown	-6 885	-3 016 632	1 033	0.24	21.65	21.41	1 011.59	Unknown	Agricultural	Spoke to Nick Bosh, Devon
PK	Amari Mine	Unknown	-9 486	-3 017 952	1 063	0.5	51.92	51.42	1 011.58	Unknown	Mining	Spoke to Johannes Mmessi, Kongoni
PT	Andries Bursman	082 550 7242	-9 492	-3 017 148	1 062	0.58	Unknown	Unknown	Unknown	Unknown	Agricultural	Mono pump, no access for dip meter.
PR	Japie Steyn	082 458 6864	-7 810	-3 014 854	1 036	0.39	28.04	27.65	1 008.35	Unknown	Agricultural	On Rooihoogte
PY1	Asia minerals	Unknown	-6 745	-3 015 096	1 055	0.2	32.27	32.07	1 022.93	Unknown	Agricultural	On York
PY2	Asia minerals	Unknown	-6 751	-3 015 060	1 053	0.302	32.64	32.338	1 020.66	Unknown	Agricultural	On York
PK01	Henk Venter	082 507 7716	-1 064	-3 019 284	1 077	0.4	34.37	33.97	1 043.03	Unknown	Agricultural	On Kameel Aar
PR	UMK Mine	082 940 1876	-1 734	-3 025 031	1 085	0.72	32.23	31.51	1 053.49	Unknown	Monitoring	Protea (Env manager) UMK10 on Rissik
PS	UMK Mine	082 940 1876	-4 053	-3 020 851	1 066	0.86	25.94	25.08	1 040.92	Unknown	Monitoring	Protea (Env manager) Umk 14 on Smart
PB	UMK Mine	082 940 1876	-4 078	-3 020 445	1 065	0.1	27.10	27.00	1 038.00	Unknown	Monitoring	Protea (Env manager) on Botha
P7	Eben Anthonissen	073 163 4665	-2 577	-3 020 041	1 073	0.05	Unknown	Unknown	Unknown	Unknown	Agricultural	On Perth at UMK office
P5	Eben Anthonissen	073 163 4665	-902	-3 018 216	1 087	0.3	Unknown	Unknown	Unknown	Unknown	Agricultural	On Perth, no access for dip meter.
P6	Eben Anthonissen	073 163 4665	-1 845	-3 019 607	1 080	0.5	37.20	36.70	1 043.30	72	Not in use	On Perth
P8	Eben Anthonissen	073 163 4665	2 077	-3 014 193	1 083	0.4	15.00	14.60	1 068.40	Unknown	Domestic	Supplies water to the farm supply store
P1	Eben Anthonissen	073 163 4665	2 206	-3 014 904	1 110	0.3	25.00	24.70	1 085.30	Unknown	Agricultural	Pumped close to time of measurement
P2	Eben Anthonissen	073 163 4665	2 154	-3 014 959	1 110	0.32	25.20	24.88	1 085.12	Unknown	Agricultural	Pumped close to time of measurement.
P3	Eben Anthonissen	073 163 4665	-55	-3 015 830	1 094	0	18.20	18.20	1 075.80	Unknown	Agricultural	On Perth
P4	Eben Anthonissen	073 163 4665	-327	-3 015 258	1 090	0.1	21.30	21.20	1 068.80	Unknown	Agricultural	On Perth
SB01	Sebilo	011 782 4322	-4 073	-3 019 568	1 062	0.42	26.70	26.28	1 035.72	50	Monitoring	Newly drilled monitoring borehole
SB02	Sebilo	011 782 4322	-4 147	-3 020 048	1 066	-	27.00	27.00	1 039.00	42	Monitoring	Drilled into underground mine
SB03	Sebilo	011 782 4322	-4 683	-3 019 248	1 055	0.30	24.65	24.35	1 030 65	101	Monitoring	Newly drilled monitoring borehole
SB04	Sebilo	011 782 4322	-4 620	-3 019 162	1 055	0.35	31.62	31.27	1 023.73	50	Monitoring	Newly drilled monitoring borehole
SB05	Sebilo	011 782 4322	-4 747	-3 018 894	1 062	-	Dry	Dry	Dry	50	Monitoring	Newly drilled monitoring borehole

All coordinates in WGS84 datum, LO23 projection
mamsl = metres above mean sea level
magl = metres above ground level
mbc = metres below collar
mbgl = metres below ground level



Reference Maps

Topographical: 2722BB; 2722BD
2723AA; 2723AC
Geological: 2722
Satelite image: Google Earth
Mine development: As supplied
WGS84 Datum LO23

Client:
Sebilo

Project:
Perth Manganese Mine

Figure Number: 4.3

Figure Name:
Groundwater level contours and hydrocensus positions

Scale: As shown

Date: April 2012
Revision: 1

Designed: MP
Approved:

Future Flow

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Pretoria, South Africa

4.4. Groundwater quality

4.4.1. Element concentrations

A total of fourteen groundwater quality samples will be collected as part of this study. Nine were collected during the hydrocensus and another five during the drilling and aquifer testing of the five new monitoring boreholes (please refer to Table 4.3). In addition to this, reference is made to previous groundwater studies and groundwater monitoring in the area (please refer to Table 4.2). This includes National Groundwater Data Base (NGDB) data from sampling runs stretching back to 1970 which is quite some time ago and there are some doubts regarding the relevance of the results. However, the water sample taken at Black Rock during October 2010 compares well with the other samples in terms of the groundwater character and element concentrations. The values from the NGDB database used in this report will be compared to the analysis results for the current groundwater study in the final EIA report.

The results from the NGDB sampling are summarised in Table 4.2. The results are compared to the SANS 241:2006 water quality guidelines for domestic use. Both Class I and Class II values are specified. Class I values represent the recommended operational limit whilst Class II represents the maximum allowable levels for a limited duration. All elements that are expected to exceed the guideline ranges are highlighted.

From Table 4.2 it can be seen that the regional groundwater quality in general is relatively poor with almost all samples having elements within Class II and exceeding Class II, with the exception of samples Hotazel, England and the Telele sample taken during May 1976. The main elements that show elevated concentrations include chloride, nitrate, calcium, magnesium and sodium.

The chemical analysis results obtained during the current Future Flow study are presented in Table 4.3. Samples P1-2 and P3-4 represent the combined groundwater quality from boreholes P1 and P2, and P3 and P4 respectively (please refer to Table 4.1 for more details on these boreholes). The boreholes are equipped with wind pumps and piping which do not allow direct collection of groundwater samples from the individual boreholes. Therefore, water samples were collected from the two holding dams in which groundwater from the two pairs of boreholes are stored. Groundwater from the combined boreholes P1 and P2 are pumped into one dam, and combined water from boreholes P3 and P4 into the other dam.

The groundwater samples taken from the new monitoring boreholes (samples SB01 to SB05) that were drilled around the existing pit, and into the extended ore body show a notable difference from all the other boreholes in that they uniformly show elevated manganese concentrations. These concentrations are associated with leaching from the ore body, and possibly the pit water lake. Unfortunately, the "Perth Pit" sample was not analysed for manganese and the manganese concentration in the pit is unknown. It should be taken into consideration that the static leach testing that was done (please refer to Section 4.6.2) show that manganese can be expected to be present in elevated concentrations in the post-mining environment.

Please note that Borehole SB02 was drilled into the existing underground mine. The water sample was taken therefore taken directly from the old underground workings. It is considered that the SB02 water quality and character provides an indication of the expected long-term groundwater quality and character after the Sebilo Perth operations has stopped.

The chemical analysis results show similar trends to those from the NGDB and Black Rock samples shown in Table 4.2. All the collected samples show elevated chloride, calcium, nitrate and magnesium concentrations. From this, it can be deduced that fundamentally the regional groundwater chemistry composition has not changed since the 1970's.

However, further inspection of the data does indicate an increase in element concentrations between the data from the DWA NGDB (1970's) and the current groundwater quality (Future Flow 2012). Because there is no time series data available between the 1970's and the present it is not possible to determine whether the change in element concentrations were gradual, or whether the current increased element concentrations are due to short term seasonal changes (yearly fluctuations in rainfall etc). Comparisons that can be made include:

- Chloride concentration: The general chloride concentration during 1976 ranged between 200 and 450 mg/L, with an individual sample showing a concentration of 845 mg/L. During 2012 the general trend remained at 200 to 450 mg/L. Some individual samples show elevations of 650 to 1 350 mg/L;
- Nitrate concentration: During 1976 there were two distinct ranges in nitrate concentration with around half of the samples showing concentrations between 1 and 7 mg/L, and the rest having an average concentration ranging between 60 to 150 mg/L. During 2012 the concentrations ranged between 30 and 90 mg/L, with individual samples reaching 283 mg/L. None of the sample points show concentrations less than 30 mg/L;
- Calcium concentration: During 1976 more than half of the samples indicated concentrations between 20 and 70 mg/L, with some samples ranging up to 130 mg/L. Individual samples reached 160 to 470 mg/L. During 2012 concentrations in general range between 150 and 500 mg/L, with the lowest concentration being 90 mg/L;
- Magnesium concentration: During 1976 more than half the samples ranged between 20 to 70 mg/L. Individual samples ranged between 120 and 160 mg/L, or even up to 390 mg/L. During 2012 the general concentration ranges between 80 and 300 mg/L, with the lowest concentration measured at 61 mg/L.

The health and aesthetic impacts of the trace elements that exceed the Class I guidelines are discussed in more detail below.

Chloride: The chloride concentrations in almost all the Telele samples, Langdon, Gloria, and Black Rock from the DWA NGDB data are elevated and range between 200 and 800 mg/L. Future Flow samples from 2012 show concentrations between 200 and 450 mg/L. Individual samples reach 65- (P7), 834 (PS1), and 1 330 (P5) mg/L The source is most likely leaching from the local geology.

Chloride is of concern in domestic water supplies because elevated concentrations impart a salty taste to water and accelerate the corrosion rate of metals. Typically, concentrations of chloride in fresh water range from a few to several hundred mg/L. In sea water the concentration is approximately 19 800 mg/L.

Chloride concentrations in the newly drilled monitoring boreholes around the pit range between 250 and 550 mg/L, except for sample SB02 which shows a concentration of 3 500 mg/L. As stated before, borehole SB02 was drilled into the existing underground mine and could be representative of the expected long-term water quality in the post-operational Sebilo Perth mining environment.

The norms used in the guideline for chloride are based principally on aesthetic effects and on the influence of corrosion rates in domestic appliances. Human health is a secondary norm; effects are only observed at very high concentrations.

Chloride is only detectable by taste at concentrations exceeding approximately 200 mg/L. A salty taste becomes quite distinctive at 400 mg/L and objectionable at greater than 600 mg/L. At chloride concentrations between 600 and 1 200 mg/L the water has an objectionably salty taste and will not slake thirst. At concentrations greater than 1 200 mg/L nausea and disturbance of the electrolyte balance can occur, especially in infants where fatalities due to dehydration can occur.

Chloride accelerates the corrosion rate of iron and certain other metals well below the concentration at which it is detectable by taste. The threshold for an increased corrosion rate is approximately 50 mg/L. At chloride concentrations greater than 200 mg/L, there is likely to be a significant shortening of the lifetime of domestic appliances as a result of corrosion. Between 200 and 600 mg/L there is a likelihood of increase corrosion rates in domestic appliances which increases in rate of corrosion to a rapid state between 600 and 1 200 mg/L.

Nitrate / Nitrite: The concentrations are elevated in the DWA NGDB Adams and initial Telele samples, as well as London, Langdon, Perth, Gloria and Black Rock. Results from the Future Flow 2012 study show generally increased concentrations across the board ranging between 30 and 90 mg/L, with sample reaching 283 mg/L. The source could be from agricultural activities.

The newly drilled boreholes around the historic mine workings and the ore body all show elevated nitrate concentrations ranging between 100 and 200 mg/L. Sample SB02, which is drilled into the old underground workings show an anomalously high concentration of almost 600 mg/L which correlates well with that measured in the pit water from the sample taken by *i*LEH during February 2012. This elevated nitrate could be due to a combination of concentration due to evaporation, and also due to the nitrate present in the blasting material used during the historic mining activities.

Nitrate is the end product of the oxidation of ammonia or nitrite. Nitrate in drinking water is primarily a health concern in that it can be readily converted in the gastrointestinal tract to nitrite as a result of bacterial reduction.

Nitrate tends to increase in shallow ground water sources in association with agricultural and urban runoff, especially in densely populated areas. Upon absorption, nitrite combines with the oxygen-carrying red blood pigment, haemoglobin, to form methaemoglobin, which is incapable of carrying oxygen. This condition is termed *methaemoglobinaemia*. The reaction of nitrite with haemoglobin can be particularly hazardous in infants under three months of age and is compounded when the intake of Vitamin C is inadequate.

Methaemoglobinaemia can occur in infants at concentrations between 10 and 20 mg/L. At concentrations above 20 mg/L the risk to infants increases. Mucous membrane irritation can occur in adults.

Calcium: Calcium concentrations are elevated in three of the DWA NGDB samples (Adams, Telele October 1976, and Langdon August 1978) and range between 160 and 470 mg/L. Future Flow 2012 data show calcium concentrations generally ranging between 150 and 500 mg/L.

Calcium concentrations in the new boreholes drilled around the proposed mining area (SB01 to SB05) show elevation calcium concentrations of between 180 and 270 mg/L. Sample SB02, which is drilled into the historic underground mine, show a concentration of around 850 mg/L which correlates to that from the “Perth Pit” sample taken by *i*LEH during February 2012.

The solubility of calcium in water is usually governed by the carbonate/bicarbonate equilibrium and is thus strongly influenced by pH and temperature. Metabolically, calcium interacts with cations, especially those of magnesium, and with both inorganic anions (bicarbonate, sulphate and phosphate) and organic anions (acetate and organic acids). Biologically, calcium exerts an influence on the integrity of cell membranes and thereby strongly influences the absorption and toxicity of heavy metals.

Calcium is an important mineral element in the human diet, the total daily dietary intake being in the range of 500 - 1 400 mg/day. Calcium has been reported as exerting a protective action against cardiovascular disease. However, the available data do not demonstrate an unequivocal causal relationship. There is no conclusive evidence to support claims for the increased incidence of human kidney and urinary tract stones (urolithiasis) resulting from the long-term consumption of water with high concentrations of calcium. Calcium is known to mitigate against the toxicity of certain heavy metals.

Scaling results in less efficient use of electrical power and any other fuel used for heating purposes, and the partial obstruction of pipes. High concentrations of calcium impair the lathering of soap. Biologically, calcium exerts an influence on the integrity of cell membranes and thereby strongly influences the absorption and toxicity of heavy metals.

At concentrations above 80 mg/L severe scaling problems with household appliances occur and lathering of soap is severely impaired. No health effects are expected.

Magnesium: The magnesium concentrations in eight of the DWA NGDB samples exceed the Class I guidelines and range between 70 and 400 mg/L. The affected samples include Adams, Telele April 1976, Telele May 1976, Telele 13th October 1976, Telele 21st October 1976, both Langdon samples, and Gloria. Future Flow 2012 data show generally elevated concentrations ranging between 70 and 300 mg/L.

The newly drilled boreholes around the historic mine workings and the ore body all show elevated magnesium concentrations ranging between 110 and 180 mg/L. Sample SB02, which is drilled into the old underground workings show an anomalously high concentration of 910 mg/L which correlates well with that measured in the pit water from the sample taken by *i*LEH during February 2012.

Magnesium has a bitter taste. This property serves as a natural protection against the ingestion of potentially harmful concentrations. As excess magnesium is readily excreted by the kidney, adverse effects such as the suppression of the central nervous system and heart function are rarely seen. Excess magnesium intake, particularly as the sulphate, results in diarrhoea.

Magnesium, together with calcium, is responsible for scaling problems caused by deposits of carbonates in appliances using heating elements and plumbing which transports hot water, and also for inhibiting the lathering of soap which results in scum formation.

At concentrations up to 400 mg/L severe scaling occurs. Diarrhoea can be expected in all new users. Concentrations of over 400 mg/L can lead to health impacts.

Sodium: The sodium concentrations in four of the DWA NGDB samples exceed the Class I guidelines and range between 200 and 280 mg/L. These samples include Telele July 1976, Telele 06 August 1976, Gloria, and Black Rock. Future Flow 2012 data show an elevated sodium concentration at P7 of 277 mg/L. Borehole SB02 which is drilled into the historic underground mine show a sodium concentration of 450 mg/L.

The taste threshold for sodium in water varies from 135 - 200 mg/L, depending on the associated anion. The common ones include chloride, sulphate, nitrate, bicarbonate and carbonate. Sodium intake can exacerbate certain disease conditions. Persons suffering from hypertension, cardiovascular or renal diseases, should restrict their sodium intake. In the case of bottle-fed infants, sodium intake should also be restricted.

At concentrations between 200 and 400 mg/L the water has a slightly salty taste and is undesirable for persons on a sodium restricted diet. Concentrations between 400 and 600 mg/L cause a distinctly salty taste and are undesirable for infants or persons on a sodium restricted diet. No health effects are expected in healthy adults with short term use.

Manganese: The manganese concentrations in PK01, as well as all the newly drilled monitoring boreholes around the proposed mining area are elevated. The concentrations generally range between 0.2 and 0.8 mg/L, with samples SB02 and SB03 showing concentrations of 1.6 and 2.9 mg/L respectively.

The aquatic chemistry of manganese is closely associated with that of **iron** chemistry. Both elements tend to behave synergistically in their dissolution from sediments under anaerobic conditions and reprecipitation under aerobic conditions. Manganese, once in solution, is more readily stabilised by complexation than iron is, and is often difficult to remove from solution except at high pH, where it precipitates as the hydroxide. Like iron, manganese can be utilised by metallophilic bacteria.

Other water constituents and properties that govern the action of manganese in water are pH, redox potential, turbidity, suspended matter and the concentration of aluminium.

Adverse aesthetic effects limit the acceptability of manganese-containing water for domestic use at concentrations exceeding 0.15 mg/R. An unpleasant taste is imparted to beverages, and staining of plumbing fixtures and laundry occurs.

Uptake of manganese occurs by ingestion from both food and water, but more so from food. Manganese exhibits a low solubility in gastric fluids; only three to four percent of ingested manganese is absorbed from the gastrointestinal tract. Manganese in the body is regulated primarily by excretion through the pancreas, although excretion directly through the gut wall and in the urine also takes place.

It has been suggested that the presence of manganese in drinking water may be inversely related to cardiovascular mortality. Deficiencies result in anaemia, growth impairment and skeletal abnormalities. The absorption of manganese in the digestive tract is closely linked to the absorption of iron. Manganese absorption is also inversely related to the level of calcium in the diet and directly related to the level of potassium.

Neurotoxic effects may occur at high concentrations, but manganese is considered to be one of the least potentially harmful of the elements. Only extreme exposure to manganese, such as may occur from industrial exposure, is likely to lead to manganese poisoning. A causative link between manganese ingestion and Parkinson's Disease has been tentatively suggested but not confirmed.

At concentrations up to 1 mg/L severe staining can be expected and the water will have a poor taste. No health effects are expected at these concentrations. A concentration between 2 and 5 mg/L cause extreme staining and the water is likely to be aesthetically unacceptable to a large proportion of users. No health effects are expected at concentrations up to 5 mg/L.

Lead: Future Flow 2012 data show the lead concentration to be elevated at P5 and PS1. At 0.041 and 0.037 mg/L respectively it exceeds the Class I limit of 0.02 mg/L slightly.

Lead tends to accumulate in sediments and soils in the environment. Metabolically, lead interacts with iron and interferes with haemoglobin synthesis. Lead uptake is affected by the action of calcium and an intake of adequate dietary calcium tends to suppress uptake.

Chronic lead poisoning, which is far more common than acute poisoning, results from intake over a period of months or years, rather than from episodic exposure. Further, single-sample values can fluctuate widely, especially where lead dissolution from the distribution system takes place.

Exposure to lead, particularly of young children, should be minimised as far as possible. At relatively low concentrations, particularly with continuous exposure, lead can cause neurological impairment in foetuses and young children. This can lead to behavioural changes and impaired performance in intelligence quotient tests. The effects are slight at low or intermittent exposure to lead, but become more pronounced as the exposure to lead increases. In adults the neurological effects are much less pronounced and the effects of exposure to toxic concentrations of lead take the form of anaemia and lead colic, that is, acute episodes of abdominal pain. An adult is approximately one order of magnitude less sensitive to lead toxicity than a growing child.

At concentrations between 0.01 and 0.05 mg/L there is no danger of adverse health effects except for a slight risk of behavioural changes and possibility of neurological impairment, where exposure to lead from other sources such as food is not minimised. At concentrations between 0.05 and 0.1 mg/L possible neurological damage can occur where nerve and brain tissues are developing, that is, in foetuses and young children. Young children and pregnant women should avoid exposure.

Zinc: The zinc concentration in sample SB02, which is likely to provide an indication of the long term post-operational groundwater quality in the mine is elevated at 6.7 mg/L.

Humans have a high tolerance level to elevated zinc concentrations, while fish are highly susceptible to poisoning. The most common mineral form of zinc is the sulphide (sphalerite). Zinc is also found as a carbonate, oxide or silicate and may occur in association with many other metal ores such as copper and arsenic. The chloride, sulphate and nitrate salts of zinc are highly soluble in water, but at neutral and alkaline pH they hydrolyse to form relatively insoluble hydroxides which tend to be associated with sediments. On acidification of the water, the insoluble hydroxides are released back into solution. If the water is acidic, zinc leaching caused by dissolution of the protective zinc hydroxide layer of galvanised piping can give rise to relatively high concentrations of zinc in solution.

Elevated zinc concentrations at neutral and alkaline pH arise where zinc occurs largely as a colloidal suspension of zinc hydroxide which imparts a milky white appearance to the water.

At concentrations sufficient to cause gastrointestinal disturbances, zinc imparts a bitter astringent taste, and an opalescent or milky appearance to water. It does not pose a hazard since the vomiting reflex is activated to rid the body of high levels.

At the measured concentration (6.7 mg/L) the water will have a clearly discernible bitter taste and opalescence. No health effects are expected.

Sulphate: The sulphate concentration in Sample SB02 which is likely to provide an indication of the long term post-operational groundwater quality in the mine is elevated at almost 440 mg/L.

Consumption of excessive amounts of sulphate in drinking water typically results in diarrhoea. Sulphate imparts a bitter or salty taste to water, and is associated with varying degrees of unpalatability. High concentrations of sulphate exert predominantly acute health effects (diarrhoea). These are temporary and reversible since sulphate is rapidly excreted in the urine. Individuals exposed to elevated sulphate concentrations in their drinking water for long periods, usually become adapted and cease to experience these effects.

Sulphate concentrations of 400 to 600 mg/L cause diarrhoea in most non-adapted individuals. The water has a definite salty or bitter taste.

Fluoride: The fluoride concentration in sample SB02 is elevated at 2.1 mg/L. The presence of fluoride in drinking water reduces the occurrence of dental caries in adults and children. A small amount of fluoride is necessary for proper hardening of dental enamel and to increase resistance to attack on tooth enamel by bacterial acids. In humans and animals, fluoride accumulates in the skeleton. Fluoride is present in many foods, and water is not the only source thereof. Drinking water is estimated to contribute between 50 % - 75 % of the total dietary fluoride intake in adults.

In natural waters it is thought to be one of the main ions that allows for the solubilisation of beryllium, scandium, niobium, tantalum and tin. Fluoride reacts readily with calcium to form calcium fluoride, which is reasonably insoluble and can be found in sediments. Where phosphate is present, an even more insoluble apatite or hydroxy apatite may form. Fluoride also reacts very readily with aluminium, a property which is made use of in the removal of fluoride from water.

Mean values should be used to compare with the criteria given. If, however, a single sample value exceeds 8 mg/L, it should be treated as a maximum non-exceedance value. The concentration of fluoride should always be interpreted in conjunction with temperature and the concentrations of calcium, aluminium and silicate.

If fluoride is ingested, it is almost completely absorbed, where after it is distributed throughout the body. Discolouration of dental enamel and mottling occurs at concentrations in the range of 1.5 - 2.0 mg/L in persons whose teeth are undergoing mineralisation. Generally, children up to seven years of age are susceptible.

High doses of fluoride interfere with carbohydrate, lipid, protein, vitamin, enzyme and mineral metabolism. Skeletal fluorosis may occur when concentrations of fluoride in water exceed 3 - 6 mg/L and becomes crippling at intakes of 20 - 40 mg/day. This is equivalent to a fluoride concentration of 10 - 20 mg/L, for a mean daily water intake of two litres. Systemic toxicity and interference with bone formation and metabolism occur at high concentrations.

Chronic effects on the kidneys have been observed in persons with renal disorders and rarer problems, including effects on the thyroid gland, which may occur with long-term exposure to high fluoride concentrations. Acute toxic effects at high fluoride doses include haemorrhagic gastroenteritis, acute toxic nephritis and injury to the liver and heart- muscle tissues. Many symptoms of acute fluoride toxicity are associated with the ability of fluoride to bind to calcium. Initial symptoms of fluoride toxicity include vomiting, abdominal pain, nausea, diarrhoea and convulsions.

The threshold for marked dental mottling with associated tooth damage due to softening of the enamel is 1.5 mg/L. No other health effects occur.

4.4.2. Chemical character

The character of the water samples included in the DWA NGDB is illustrated by the Piper Diagram (please refer to Figure 4.4). The chemical character of the water from the 2012 Future Flow study is shown in Figure 4.5. The Piper diagram, introduced by Arthur Piper in 1944, is one of the most commonly used techniques to interpret water chemistry data. This method proposed the plotting of the major cations and anions on adjacent tri-linear fields, with these points then being extrapolated to a central diamond field. Here the chemical character of water, in relation to its environment, can be observed and changes in the quality interpreted. The cation and anion plotting points are derived by computing the percentage equivalents per million for the main diagnostic cations of Ca^{2+}, Mg^{2+} and Na^{+}/K^{+}, and anions Cl^{-}, SO_4^{2-} and CO_3^{2-}/HCO_3^{-}.

Different waters from different environments always plot in diagnostic areas or "hydrochemical facies". The upper half of the diamond normally contains water of static and disordinate environments, while the middle area normally indicates an area of dissolution and mixing. The lower triangle of this diamond shape indicates an area of dynamic and co-ordinated environments. Sodium chloride brines normally plot in the right hand corner of the diamond shape while recently recharged water plots on the left-hand corner of the diamond plot. The top corner normally indicates water contaminated with gypsum (SO_4^{2-} mine impact).

In general the top half of the diamond contains static waters and other unusual waters high in $Mg/Ca\ Cl_2$ and $Ca/Mg\ SO_4$. The lower half contains those waters normally found in a dynamic groundwater basin or surface stream environment. Mixtures of any two waters in any proportion plot along a straight line joining their respective points in each of these diagrams. Water therefore being invaded by e.g. an industrial effluent will plot a vector towards the analysis of the invading fluid.

Water plotting in the upper half of both the cation and anion triangles would be referred to as a magnesium chloride-type water. A water plotting in the lower left hand side of the cation triangle and the lower right hand side of the anion triangle would be a calcium chloride-type water. If both cation and anion compositions plot in the middle of the two triangles, then the waters would be referred to as mixed cation-mixed anion-types. If a water plots near the middle of one of the edges of the triangles, then one might refer to, e.g., a magnesium-calcium sulphate water.

If waters are the result of mixing of two different end member waters, then the compositions of the waters should plot along a straight line in each of the fields of the diagram. On the other hand, if the compositions do not plot along a straight line on the Piper Diagram, then the waters cannot be related by simple mixing between two end members. If the waters do plot along a straight line, this is not necessarily definitive proof that mixing did occur, but it is strongly suggestive and other tests can be designed to prove mixing.

The Piper diagram for both the DWA NGDB data (Figure 4.4) and the current Future Flow study (Figure 4.5) show that in general the groundwater quality plot within the upper half of the diamond indicating static water. This correlates to the general site conditions which include:

- The generally low transmissivity of the aquifers leading to slow groundwater migration through the area (basically static water in terms of flow velocities);
- The low topographical gradients contribution to slow groundwater flow velocities; and
- The low rainfall in the area leading to little recharge of fresh water to the groundwater systems.

From Figure 4.4 it can be seen that DWA NGDB Samples Telele 76/05/13 and Hotazel show some anomalous qualities. However, comparing the Telele 76.05.13 quality to the other six Telele samples indicate that the sample taken on 13 May 1976 might have been subject to erroneous laboratory analysis or sampling methodology.

Figure 4.5 shows that the groundwater samples plot in the upper half of the diamond. The combined P1 and P2 sample show a slightly less evolved character than the rest.

The chemical character of the 2012 Future Flow groundwater samples can be summarised:

- Combined Sample P1 & P2: magnesium / bi-carbonate dominant;
- Combined Sample P3 & P4: calcium / chloride dominant;
- Sample P5: calcium / chloride dominant;
- Sample P6: calcium / chloride dominant;
- Sample P7: sodium / chloride dominant;
- Sample PD: magnesium / chloride dominant;
- Sample PS1: magnesium / chloride dominant;
- Sample UMK14: magnesium / chloride dominant;
- PK01: magnesium / chloride dominant;
- SB01: calcium / chloride dominant;
- SB02: magnesium / chloride dominant;
- SB03: magnesium / chloride dominant;
- SB04: magnesium / chloride dominant; and
- SB05: calcium / chloride dominant.

It should be noted that borehole P6, which has been reported by the local landowner to have a very poor taste, show a notably different cation character than the rest of the samples taken by Future Flow during 2012. The Piper diagram clearly show a more balance contribution from all cations, with an increased contribution from sodium and potassium to the chemical balance. However, the sample still shows a chloride dominant character, which is the same as samples P3&P4, P5, and P7.

4.4.3. Comparison to Perth Pit water quality

The groundwater quality can be compared to the Perth Pit water sample (please refer to Figure 4.5). The surface water quality as analysed by a SANAS accredited laboratory was supplied by the client.

Results show that the pit was character is magnesium chloride dominant, which is comparable to a number of groundwater samples, including samples PD, PS1, UMK14, SB02, SB03, and SB04. All element concentrations are elevated compared to the SANS241 guidelines, and in general compared to the element concentrations measured in the groundwater samples. The increased element concentration is most probably attributable to the effect of the high net evaporation in the area causing high losses of water from the pit, thereby increasing the element concentration in the remaining water.

Table 4.2: Groundwater chemical analysis results - DWA NGDB

Element	Units	SABS 241 guideline		ADAMS	LIZBETH	TELELE 76/04/27	TELELE 76/05/13	TELELE 76/07/23	TELELE 76/08/05	TELELE 76/08/03	TELELE 76/10/13	TELELE 76/10/21
		Class I	Class II									
Sample Date				03/09/1970	03/09/1970	04/27/1976	05/13/1976	07/23/1976	05/08/1976	06/08/1976	10/13/1976	10/21/1976
pH		5 – 9.5	4 – 10	7.9	8.4	7.16	7.6	7.79	7.97	8.08	7.7	7.68
TDS	mg/L	<1000	1000 – 2400	-	-	1435	692	1165	1002	1065	1640	968
Electrical conductivity	mS/m	<150	150 – 370	527.8	51.1	220	96.6	174.8	162.9	163	306.4	163
Sulphate	mg/L	<400	400 -600	504	2	51	110.2	364.7	56	350.3	85.7	41.2
Chloride	mg/L	<200	200 – 600	142	75	299.4	86	206.8	293.8	214.7	845	338.1
Nitrate / Nitrite	mg/L	<10	10 – 20	103.69	7	60.91	2.63	6.63	9.07	3.46	0.62	4.73
Ammonia	mg/L	<1	1 – 2	-	-	0.02	0.02	0.33	0.89	0.22	0.02	0.04
Total Alkalinity	mg/L	NS	NS	59.9	155	367.9	236.4	179.4	256.8	132.9	149.5	231.8
Calcium	mg/L	<150	150-300	470	20	127.6	19.4	66.7	66.7	60.5	174.5	103.9
Magnesium	mg/L	<70	70-100	389	53	120	18.6	64.4	70.1	49.3	149.8	70.3
Sodium	mg/L	<200	200-400	83	21	107.4	152.1	204.9	144.8	203.7	173.8	92
Potassium	mg/L	<50	50-100	-	-	11.35	5.73	8.56	15.41	8.49	25.37	17.87
Fluoride	mg/L	<1	1 – 1.5	0.05	0.4	0.42	0.4	0.82	0.52	0.7	0.46	0.5
Phosphate	mg/L	NS	NS	-	-	0.007	0.007	0.003	0.007	0.003	0.003	0.011
Silica	mg/L	NS	NS	-	-	25.21	6.16	3.1	24.1	2.39	24.92	27.43

Legend:	
Fall within Class II	▨
Exceeding Maximum	■

Table 4.2: Groundwater chemical analysis results - DWA NGDB (continued)

Element	**Units**	**SABS 241 guideline**		**ENGLAND**	**LONDON**	**LANGDON**	**LANGDON**	**PERTH**	**HOTAZEL**	**GLORIA**	**Black Rock**
		Class I	Class II								
Sample Date				08/21/1978	08/21/1978	08/22/1978	08/22/1978	10/26/1983	02/20/1985	01/09/1985	Oct 2010
pH		5 – 9.5	4 – 10	7.25	7.63	7.69	7.81	8.01	8.18	7.67	7.81
TDS	mg/L	<1000	1000 – 2400	273	721	1593	910	720	596	2370	1420
Electrical conductivity	mS/m	<150	150 – 370	3.6	9	241.1	11.7	106.4	77.9	378.5	213
Sulphate	mg/L	<400	400 -600	6.4	39.9	133	45	36.1	51.6	151	290
Chloride	mg/L	<200	200 – 600	11.1	27.7	426	49.2	128.9	36.6	838.9	372
Nitrate	mg/L	<10	10 – 20	4.53	22.41	73.14	22.18	14.32	1.45	142.66	74
Ammonia	mg/L	<1	1 – 2	0.08	0.09	0.09	0.05	0.04	0.05	0.08	NA
Total Alkalinity	mg/L	NS	NS	142.7	316.6	239.7	416.7	249.6	273.5	82.5	140
Calcium	mg/L	<150	150-300	26	84	159.4	88	67.2	3	119.8	112
Magnesium	mg/L	<70	70-100	21	48	145	71	54.5	4.2	279.6	48
Sodium	mg/L	<200	200-400	9.9	33.4	109.9	46.2	63.6	160.2	222	279
Potassium	mg/L	<50	50-100	4.69	1.57	2.99	3.31	1.95	0.15	26.1	NA
Fluoride	mg/L	<1	1 – 1.5	0.11	0.59	0.05	0.78	0.05	0.36	0.33	0.37
Phosphate	mg/L	NS	NS	0.014	0.061	0.23	0.068	0.006	0.008	0.01	NA
Silica	mg/L	NS	NS	10.17	38.72	33.36	41.08	31.54	19.1	30.87	NA

Legend:	
Fall within Class II	▨
Exceeding Maximum	■

Table 4.3: Groundwater chemical analysis results – Future Flow study 2012

Element	Units	SABS 241 guideline		P1&2	P3 & 4	P5	P6	P7	PD	PS1	UMK14	PK 01	SB01	SB02	SB03	SB04	SB05	Perth Pit
		Class I	Class II															
Sample date				2012/03/24	2012/03/24	2012/03/24	2012/03/24	2012/03/24	2012/03/24	2012/03/21	2012/03/26	2012/04/19	2012/04/18	2012/04/18	2012/04/18	2012/04/18	2012/04/19	2012/02/01
pH	pH units	5-9.5	<4 and >10	8.1	7.46	7.3	7.6	7.92	8	7.4	7.78	8.37	7.43	7.41	7.45	7.54	7.49	7.9
EC	mS/m	<150	>150-370	97.2	191.4	328.8	142.1	244.1	202.8	339.1	149.2	113.4	195.3	1176	262.5	205.8	268.8	1 050
TDS	mg/L	<1000	>1000-2400	466	1100	2533	767	1520	1172	2215	727	947	998	6773	1447	1102	1348	9 026
Total Alkalinity	mg/L	NS	NS	267.7	235.5	192.1	284.7	75.8	256.9	201.8	237.7	239	261.9	29.5	218.5	276	208.4	104
Chloride	mg/L	<200	>200 – 600	67.5	436.2	1330.7	230.6	646.5	388.4	833.9	204.2	359.5	267.7	3500	557.5	351.8	452.4	2 311
Sulphate	mg/L	<400	>400 -600	19.2	45.87	152.19	24.9	174.75	91.13	79.15	22.51	55.34	71.95	437.63	72.43	75.74	68.13	350
Nitrate	mg/L	<10	>10 – 20	33.099	64.587	82.573	41.665	72.947	84.756	283.538	67.556	61.642	118.602	592.629	157.462	97.381	193.338	547
Ammonium	mg/L	NS	NS	0.265	0.172	0.469	<0.015	<0.015	<0.015	0.102	<0.015	0.146	0.145	0.75	0.125	0.099	0.298	-
Phosphate	mg/L	NS	NS	<0.025	<0.025	0.029	<0.025	<0.025	<0.025	<0.025	0.046	0.221	0.133	0.133	0.103	0.14	0.127	-
Fluoride	mg/L	<1.0	1 – 1.5	0.511	0.278	0.255	0.211	<0.183	0.337	0.364	0.36	0.44	0.425	2.117	0.733	0.496	0.864	-
Calcium	mg/L	<150	>150-300	87.789	197.817	459.961	144.669	206.114	163.27	480.01	113.495	155.536	197.025	844.687	207.523	183.844	266.634	793
Magnesium	mg/L	<70	>70-100	61.11	109.161	251.036	77.15	93.921	137.665	298.712	93.406	101.599	114.05	910.716	173.38	124.525	153.66	716
Sodium	mg/L	<200	>200-400	34.51	102.15	136.27	74.99	276.61	144.13	108.02	76.77	67.26	66.23	450.47	141.19	96.54	82	402
Potassium	mg/L	<50	>50-100	2.322	3.282	5.017	2.544	3.688	8.752	9.577	6.155	2.844	4.834	19.481	6.693	5.96	6.462	-
Aluminium	mg/L	<0.3	>0.3-0.5	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.026	0.012	<0.006	<0.006	0.015	<0.006	-
Iron	mg/L	<0.2	>0.2-2	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.024	0.03	0.086	0.073	0.014	0.012	-
Manganese	mg/L	<0.1	>0.1-1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.752	0.499	1.618	2.926	0.376	0.23	-
Chromium	mg/L	<0.1	>0.1-0.5	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	-
Copper	mg/L	<1	>1-2	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	0.008	<0.001	<0.001	<0.001	0.148	<0.001	0.008	0.005	-
Nickel	mg/L	<0.15	>0.15-0.35	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.036	<0.003	<0.003	<0.003	-
Zinc	mg/L	<5	>5-10	0.024	0.074	1.038	0.034	0.211	0.027	<0.004	0.04	2.275	2.028	6.721	1.95	2.616	1.537	-
Cobalt	mg/L	<0.5	>0.5-1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	-
Cadmium	mg/L	<0.005	>0.005 – 0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Silver	mg/L	NS	NS	<0.002	0.002	0.005	<0.002	0.002	<0.002	0.006	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	0.002	-
Gallium	mg/L	NS	NS	0.006	0.006	0.012	0.007	0.007	0.007	0.015	0.006	0.008	0.008	0.061	0.007	0.006	0.007	-
Boron	mg/L	NS	NS	0.173	0.378	0.443	0.248	1.871	0.579	0.337	0.766	0.256	0.329	5.894	1.95	0.873	0.361	-
Barium	mg/L	NS	NS	0.121	0.228	0.14	0.185	0.067	0.1	0.228	0.032	0.185	0.073	0.03	0.068	0.06	0.175	-
Beryllium	mg/L	NS	NS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Bismuth	mg/L	NS	NS	0.02	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
Tellurium	mg/L	NS	NS	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023	-
Lithium	mg/L	NS	NS	0.003	0.01	0.011	0.006	0.017	0.016	0.014	0.011	0.006	0.009	0.037	0.023	0.015	0.009	-
Molybdenum	mg/L	NS	NS	0.039	0.039	0.073	0.038	0.052	0.039	0.074	0.038	0.013	0.013	0.104	0.014	0.016	0.014	-
Lead	mg/L	<0.02	>0.02-0.5	<0.001	0.002	0.041	<0.001	<0.001	<0.001	0.037	<0.001	<0.001	<0.001	0.017	<0.001	0.001	<0.001	-
Rubidium	mg/L	NS	NS	0.092	0.085	0.184	0.091	0.088	0.084	0.205	0.05	0.096	0.136	1.102	0.071	0.085	0.084	-
Silica	mg/L	NS	NS	33.544	25.662	23.371	25.853	15.633	17.155	26.502	14.448	20.288	19.384	13.714	14.881	15.378	16.754	-
Strontium	mg/L	NS	NS	0.6	1.12	2.064	0.715	1.248	1.457	2.971	0.785	0.712	1.132	2.974	1.226	1.205	1.512	-
Vanadium	mg/L	<0.2	>0.2-0.5	<0.087	0.004	<0.003	0.006	0.003	0.015	0.004	0.008	0.003	0.007	<0.003	<0.003	0.005	0.005	-
Thallium	mg/L	NS	NS	471	<0.087	<0.087	<0.087	<0.087	<0.087	<0.087	<0.087	<0.087	<0.087	<0.087	<0.087	<0.087	<0.087	-
Total hardness	mg/L	NS	NS	264.5	943	2182	679	901	975	2433	668	807	962	5860	1232	973	1299	4 966
Bi-carbonate	mg/L	NS	NS	8.1	234.8	191.8	283.7	75.2	254.4	201.3	236.3							-

Legend:	
Class II	▨
Exceeding Class II	■

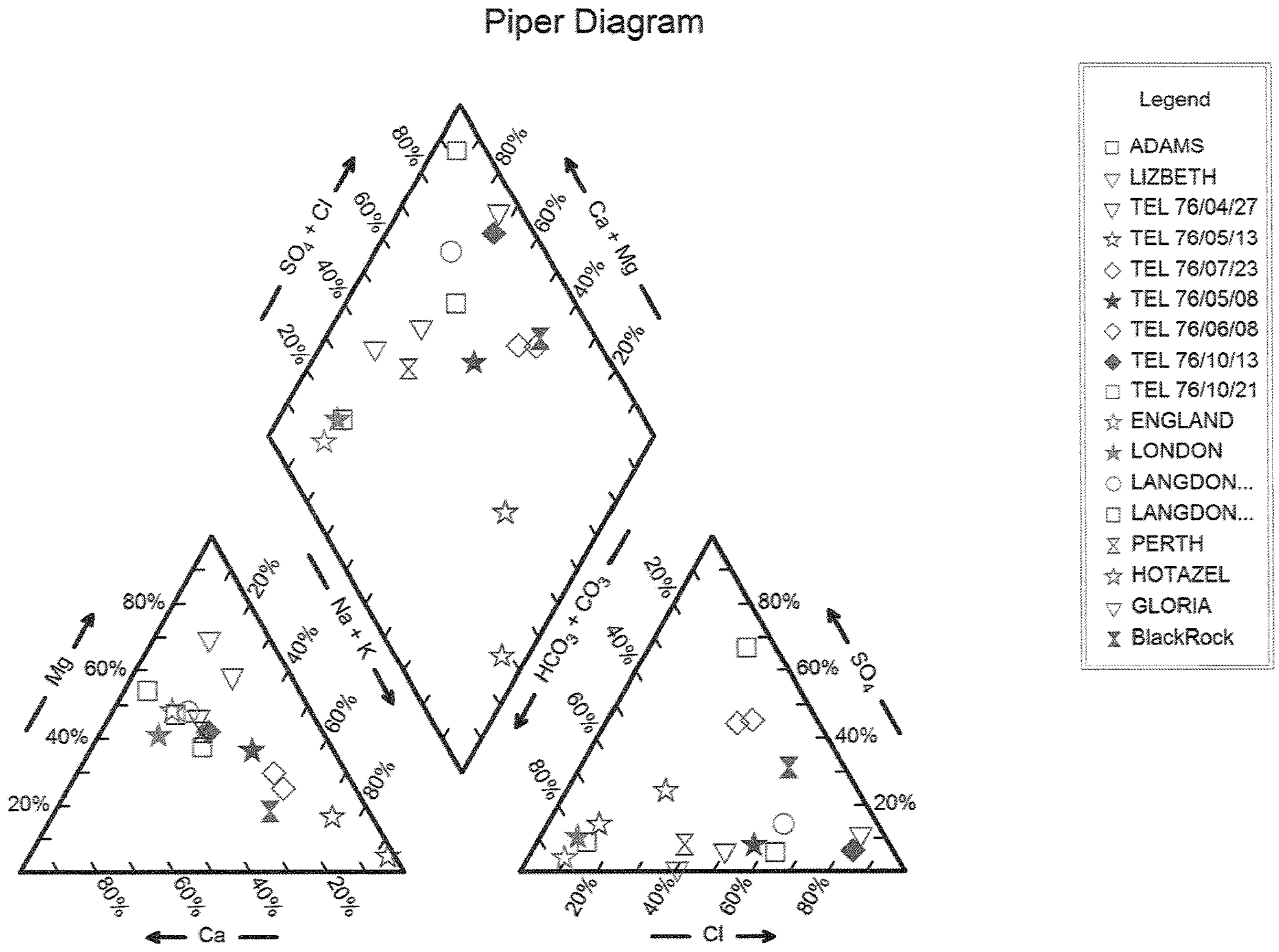

Figure 4.4: Piper diagram – DWA NGDB

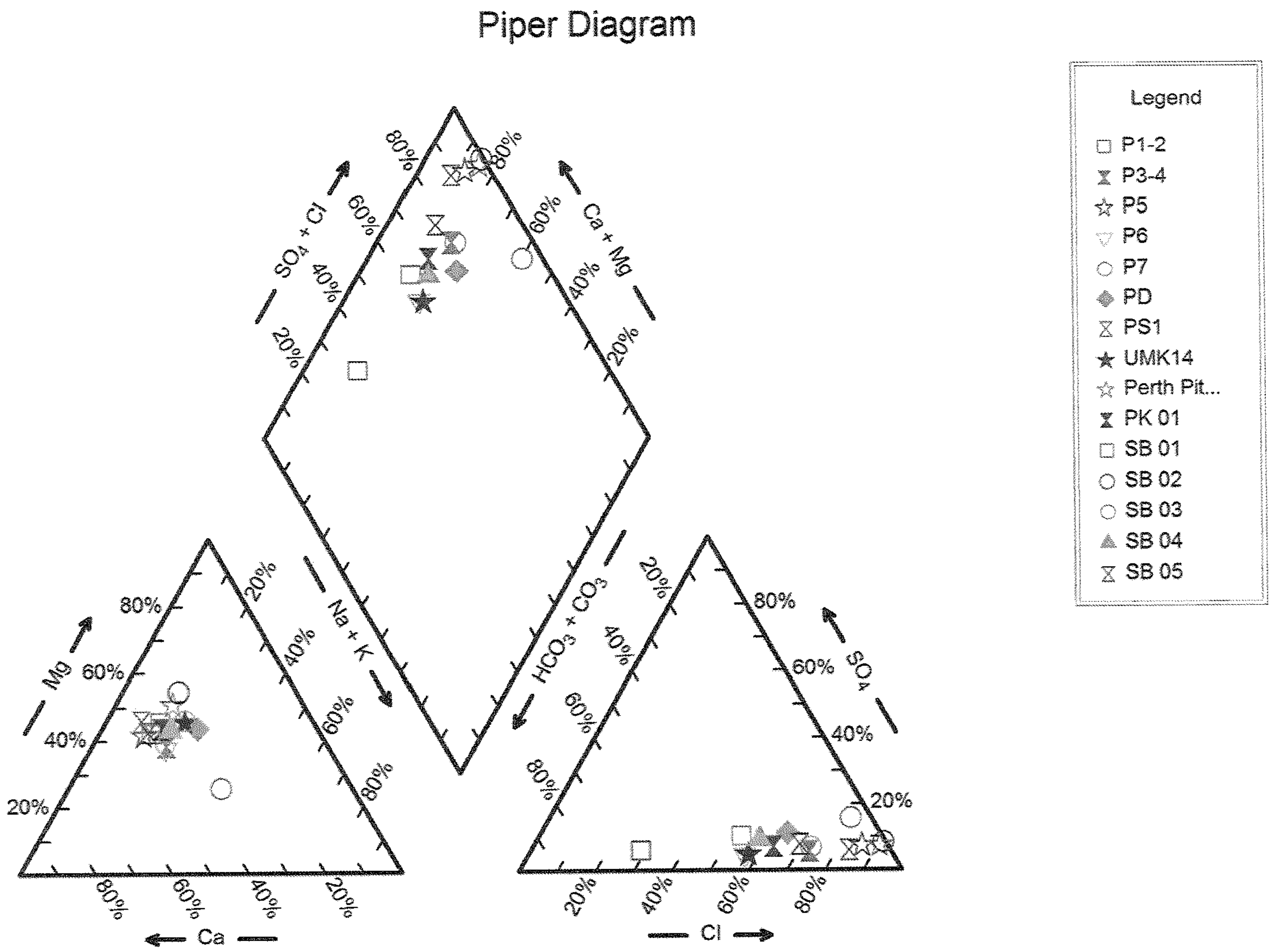

Figure 4.5: Piper diagram – Future Flow study 2012

4.5. Aquifer transmissivity and storativity

Aquifer testing was performed on three of the five new monitoring boreholes that were drilled around the proposed mining area. The results of the data interpretation are summarised in Table 4.4. The transmissivity of the overlying quaternary sand have not been tested in this or other studies through normal pump testing due to the sands being dry outside of rainfall events and therefore not acting as a notable aquifer in the area during the majority of the year. In addition, no falling head tests have been performed on the sands. For the purpose of this study it is assumed that the transmissivity of these sands are between 1 and 5 m^2/day.

From Table 4.4 it can be seen that the aquifer transmissivity of the fractured rock material ranges between 0.25 and 0.7 m^2/day. It has to be noted that these boreholes targeted geological structures that could act as potential groundwater flow pathways, and the transmissivity of these boreholes are considered to be higher than the average transmissivity of the general competent, fractured, host rock. The general aquifer transmissivity of the un-fractured host rock is considered to be less than 0.1 m^2/day. This is confirmed by the very low transmissivity seen in borehole P5 which yielded extremely little water. At 72 hours after completion of the drilling only 2 to 3 m of water had accumulated in the borehole.

The aquifer hydraulic conductivities can be calculated from the obtained data using the equation:

$$T = k \times d$$

Where:

T = aquifer transmissivity (as calculated from the aquifer test results);
k = aquifer hydraulic conductivity; and
d = saturated thickness of the aquifer (which of the purpose of this calculation is assumed to be the depth of the borehole minus the depth to groundwater level in that borehole).

As seen from Table 4.4 the hydraulic conductivities of the fractured rock aquifer are calculated to range around 0.012 and 0.021 m/day. This means that groundwater migrate at a rate of between 0.012 and 0.021 m/day through the aquifers. These are very low numbers and not conducive to large flow volumes through the area.

Aquifer storativity of the rock material is estimated from the aquifer test results. It should be noted that the obtained values are likely to be inaccurate due to the fact that they were calculated from single borehole tests. Ideally storativity of an aquifer is calculated from the groundwater level response to pumping measured in a borehole some distance away from the borehole being pumped. Calculating the storativity from the data collected in the borehole being pumped leads to uncertainty in the obtained results. Unfortunately, there were no boreholes close to each other that could be used as monitoring boreholes during the aquifer tests. The calculated aquifer storativity values range between 1.18E-10 and 2.18E-9, which are very low numbers.

Table 4.4: Aquifer test results

Parameter	Unit	P1	P2	P3	P4	P5
Borehole depth	m	50	42	101	50	50
Water strike	mbgl	None	42 (U/G mine)	82	50	Dry
Static water level	mbgl	26.28	27.00	24.35	31.27	-
Pumping rate	L/s	0.2	No test – Borehole drilled into underground mine	0.5	0.2	No test – borehole is dry
Transmissivity	m^2/day					
Theis		0.25		0.60	0.28	
Cooper-Jacob		0.31		0.67	0.33	
Recovery		0.02		0.33	0.12	
Average transmissivity		0.28		0.53	0.24	
Aquifer hydraulic conductivity	m/day	0.012		0.021	0.013	
Storage capacity (estimate)	-	1.74E-10		2.18E-9	1.18E-10	

m = metre
mbgl = metres below ground level
L/s = litres per second
m^2/day = metres squared per day
m/day = metres per day

4.6. Acid base accounting and static leach testing results

4.6.1. Acid-base accounting

Many South African mines are associated with acid mine drainage conditions developing due to sulphide minerals such as pyrite being present in the host rock or mined ore body. Sulphide minerals are geochemically inherently unstable and will, in the presence of oxygen, spontaneously begin to oxidise to produce undesirable effects such as a low pH, high sulphate concentrations, and significant increases in heavy metals and radionuclide contents. The acidic water produced by pyrite oxidation can be neutralised when it comes into contact with base minerals such as carbonates, hydroxides, oxides and silicates. The potential of the ore and discard products to produce acid and the subsequent buffering capacity is referred to as the Acid Base Potential. Acid Base Accounting (ABA) provides an average of this process over a period of time, during which either acidic or alkaline conditions can dominate.

ABA involves a combined measurement of sulphur contents (total sulphur, sulphuric acid, sulphur, and organic sulphur), neutralisation capacity (NP), paste pH and the calculation of acid potential (AP), net neutralisation potential (NNP) and NP/AP ratio (NPR). The assessment obtained by ABA techniques needs to be refined and calibrated with detailed mineralogical characterisation, site-specific observation and kinetic testing. This assessment should be complimented by geochemical modelling in order to increase the reliability of the ARD prediction study.

In this study, ABA tests have been performed by *i*LEH on two samples as detailed in Table 4.5. Samples were collected from waste and ore material.

Table 4.5: ABA test results

Acid-Base-Accounting (Modified Sobek (EPA-600)	**Waste**	***i*LEH Ore**
Paste pH	7.7	8.0
Total Sulphur % (LECO)	<0.01	<0.01
Acid Potential (AP) (kg/t)	0.313	0.313
Neutralising Potential (NP)	158	143
Net Neutralising Potential (NNP)	158	143
Neutralising potential ratio (NPR) (NP:AP)	507	459
Rock Type	III	III

As shown by Robertson & Broughton (1992) it can be noted that:

- NNP - Greater than 20 kg $CaCO_3$/tonne are considered “safe”;
- NNP - Less than -20 = potentially acidic drainage;
- NNP - -20 to 20 kg $CaCO_3$/tonne = Grey area - prediction is difficult.

- NPR – Less than 1 = potentially acid producing;
- NPR – 1 to 3 – grey area = prediction is difficult;
- NPR – Greater than 3 = potentially acid neutralising

Guidelines from Price *et al* show:

	NAG pH	**NPR**	**ARD Potential**	**Comment**
Sulphide-S <0.3%	>5.5	-	None	No further ARD testing required provided there are no other metal leaching concerns. Exceptions: host rock with no basic minerals, sulphide minerals that are weakly acid soluble.
Sulphide-S >0.3%	<5.5	<1	Likely	Likely to be ARD generating
		1-2	Possibly	Possibly ARD generating if NP is insufficiently reactive or is depleted at a rate faster than that of sulphides
		2-4	Low	Not potentially ARD generating unless significant preferential exposure of sulphides occurs along fractures or extremely reactive sulphides are present together with insufficiently reactive NP
		>4	None	No further ARD testing required unless materials are to be used as a source of alkalinity.

From Table 4.5 the above guidelines can be applied:

- NNP: The NNP of samples “Waste” and “*i*LEH” exceed 20 kg $CaCO_3$/tonne and can be considered safe;
- NPR: The NPR of the samples far exceeds the neutralising guideline of 3 and ranges between 450 and 510. Based on this the material can be classified as acid neutralising;

- Sulphide S and NAG pH: The Sulphide-S ratio for both samples is less than 0.01, while the final NAG pH is measured at between 7.7 and 8.0. Based on Price's guidelines no further ARD testing is required provided there are no metal leaching concerns.

From Table 4.5 and the guidelines outlined above it can be seen that the sulphide percentages in all the samples fall below 0.3 %. Several factors calculated in ABA by Soregaroli and Lawrence (1998) indicated that for sustainable long-term acid generation, at least 0.3% sulphide-S is needed. Values lower than 0.3% can yield acidity but it is only of short-term significance.

Final NAG pH values for the roof material range around 8 to 9. This corresponds to the NPR ratios of between 23 and 83 which are much greater than the guideline value of 3, indicating that the rock material is acid neutralising.

From the above, it is concluded that it is unlikely that the material will be acid forming. Should some acid conditions form it will be buffered and neutralised by the high neutralising capacity of the rock material. In addition, any such acid conditions that form will only be sustainable in the short term due to the very low Sulphur-S percentages.

4.6.2. Static leach testing

Static leach testing done on the two samples taken by *i*LEH shows that in general there is no concern around the element leach concentrations (please refer to Table 4.6). The measured element concentrations are compared to the SANS 241:2006 water quality guidelines for domestic use. Both Class I and Class II values are specified. Class I values represent the recommended operational limit whilst Class II represents the maximum allowable levels for a limited duration. All elements that are expected to exceed the guideline ranges are highlighted.

Cadmium, Mercury, and Manganese do indicate some elevated concentrations. However, cadmium and mercury is reported at the limit of the detection capability of the analysis method. Therefore, there is uncertainty around the actual concentration values for these two elements and whether they do in fact exceed the Class II guideline values.

Manganese is the only element where it can be said with certainty that the leach concentrations are expected to exceed domestic use guidelines. This is expected due to the natural elevated manganese concentrations in the area associated with the ore body.

Table 4.6: Static leach test results

Element	Units	SABS241		Waste	ILEH ore
		Class I	Class II		
Total Dissolved Solids at 180°C	mg/L	<1 000	1 000 – 2 400	168	184
Alkalinity as $CaCO_3$	mg/L	NS	NS	384	328
Total Acidity as $CaCO_3$	mg/L	NS	NS	10	10
Total Hardness as $CaCO_3$	mg/L	NS	NS	412	347
Bicarbonate as HCO_3	mg/L	NS	NS	468	400
Nitrate as N	mg/L	<10	10 – 20	0.2	1
Chloride as Cl	mg/L	<200	200 – 600	<5	<5
Sulphate as SO_4	mg/L	<400	400 -600	<5	<5
Fluoride as F	mg/L	<1	1 – 1.5	<0.2	<0.2
Sodium as Na	mg/L	<200	200-400	<2	<2
Calcium as Ca	mg/L	<150	150-300	144	129
Magnesium as Mg	mg/L	<70	70-100	13	6
Ammonia as N	mg/L	<1	1 – 2	0.5	0.2
Aluminium as Al	mg/L	<0.3	0.3 – 0.5	<0.1	<0.1
Barium as Ba	mg/L	NS	NS	<0.025	<0.025
Boron as B	mg/L	NS	NS	<0.025	0.08
Cadmium as Cd	mg/L	<0.005	0.005 – 0.01	<0.5	<0.5
Total Chromium as Cr	mg/L	<0.1	0.1 - 0.5	<0.025	<0.025
Cobalt as Co	mg/L	<0.5	0.5 – 1	<0.025	<0.025
Copper as Cu	mg/L	<1	1 – 2	<0.025	<0.025
Iron as Fe	mg/L	<0.2	0.2 – 2	<0.025	0.044
Mercury as Hg	mg/L	<0.001	0.001 – 0.005	<0.01	<0.01
Lead as Pb	mg/L	<0.02	0.02 – 0.05	0.02	0.02
Manganese as Mn	mg/L	<0.1	0.1 – 1	0.515	5.69
Molybdenum as Mo	mg/L	NS	NS	<0.025	<0.025
Nickel as Ni	mg/L	<0.15	0.15 – 0.35	<0.025	<0.025
Selenium as Se	mg/L	<0.02	0.02 – 0.05	<0.02	<0.02
Strontium as Sr	mg/L	NS	NS	0.147	0.126
Vanadium as V	mg/L	<0.2	0.2 – 0.5	<0.025	<0.025
Zinc as Zn	mg/L	<5	5 - 10	<0.025	<0.025

░ Uncertain whether the actual concentrations exceed SANS guidelines
▒ Exceed Class I guideline value
▓ Exceed Class II guideline value

4.7. Conceptual model summary

4.7.1. Groundwater flows

The baseline data is analysed and compiled into a conceptual model which is summarised below.

There are three aquifers present in the area, associated with a) the upper sandy gravel material, b) the fractured rock material, and c). the dolomitic material

The upper **sandy gravel material aquifer** can be considered to be present throughout the whole of the study area. The aquifer is heavily dependent on rainfall and therefore yields from the aquifer vary seasonally. However, it has to be cautioned that drilling results show this aquifer to be dry in large portions of the study area. It is considered that this aquifer is seasonal and mostly carries water only during and shortly after rainfall events when rainfall recharges into the material. The relatively high transmissivity of the sandy gravel material allows the recharging water to migrate quickly through and out of the material. This combined with the high positive evaporation rates in the area (please refer to Table 3.1) lays the material dry for large portions of the year.

Drilling results from previous projects in the area have shown that the flat-pebble conglomerate (potsherd marker) that forms part of the **fractured rock aquifer** and is intercepted in the Danielskuil Formation is the only water bearing zone in the fractured rock aquifer area. Groundwater flows in the fractured rock aquifer are associated with the secondary fracturing in the competent rock that was formed by the major north / south striking faulting seen from the hydrogeological maps and confirmed by the ground geophysical survey (please refer to Figure 3.2 and Appendix A). As such groundwater flows and contaminant transport will be along discrete pathways associated with the fractures. The general transmissivity of the competent rock material is considered to be around 0.1 m^2/day or less.

Aquifer testing performed on the newly drilled boreholes (SB01 to SB05) show that the transmissivity of individual fractures range between 0.25 and 0.7 m^2/day. Drilling results show that aquifer strikes can occur down to 80 m in this area. Using the borehole depths and the aquifer transmissivities the hydraulic conductivity of the non-fractured, competent material is calculated to be around 0.001 m/day, and that of the individual fractures up to 0.021 m/day.

The **dolomitic karst aquifer** in the region is well known for its high potential (Van Dyk and Jones, 2006). A number of springs have been mapped in the area (van Dyk & Jones, 2006) of which the Kuruman, Klein Karoo, and Manyeding are perennial. Smit (1978) and Wiegmans (2006) defined compartments within the dolomite in separate groundwater management units. The project area falls within the D41K groundwater management area. Wiegmans (2006) also calculated recharge to each of the compartments and the associated management criteria in terms of sustainable abstraction volumes.

Inspection of exploration drilling core on neighbouring farms show that the dolomite in the vicinity of the proposed Perth mine appears to be competent with no indication of weathering or karstification. Karstic dolomite is highly variable in competence and transmissivity over short distances and this is no guarantee that karstic dolomite won't be found on site, however, based on the general constant high competence and total absence of indications of karstic dolomite it can be concluded that the likelihood of intercepting karstic dolomite is very low.

Groundwater levels recorded during the hydrocensus show relatively homogenous depths to groundwater level in the fractured rock aquifer ranging between 14.60 and 36.70 mbgl, with an average of 28 mbgl. Around the current Pert Pit area boreholes SB01, SB03 and SB04 show that the depth to groundwater level is around 27.5 m.

Considering the average depths to groundwater level, Figure 4.1 and Figure 4.2 it is concluded that the water level in the historic Perth Pit is equivalent to the surrounding, and regional, groundwater levels and the system is in equilibrium. Based on this, and the high net evaporation from the area, it can be concluded that there is a net inflow into the pit, and the pit does not recharge into the surrounding aquifers.

Groundwater flow directions are directed from the east towards the low lying areas in the west associated with the Witleegte stream channel. Calculations show that the groundwater gradient in study area ranges between 1:100 and 1:300.

Based on to the depth of the groundwater level near the Witleegte stream (measured to be 24.35 mbgl in borehole SB03 which is located very close to the stream channel), it is considered that the regional fractured rock aquifer do not contribute to the stream flows. During and directly after rainfall events when there is active recharge to the upper sandy gravel aquifer it is possible that there could be some baseflow contribution to the stream from the aquifer. However, it is considered that overall the stream is a losing stream. Due to the very low aquifer transmissivity as calculated from the aquifer test data river losses to the fractured rock aquifer is considered to be very low.

As mentioned, rainfall recharges into the aquifers. Long term rainfall data show an average rainfall figure of 350 mm/a. Based on the coarse nature of the loose sandy gravel it is considered that gross recharge is in the order of 5 to 7 % of the mean annual rainfall effective recharge. Taking into consideration of evapotranspiration, field capacity etc. on gross recharge) effective recharge is estimated at 1 to 3 % or mean annual rainfall.

Factors that could impact on groundwater flows in the catchment include:

- Drawdown of groundwater levels within and around the proposed mining developments;
- Dewatering of the historic mine areas;
- Recovery of groundwater levels when mining and the associated dewatering stop;
- Seepage from the overburden and discard stockpiles, as wells as ROM and product stockpiles where rainfall accumulates and artificially increase recharge to the underlying aquifers. Research done by Hodgson & Krantz (1998) show that recharge from such areas can be as high as 20% of the annual rainfall in comparison to 1 to 3 % for general areas;

- Seepage from the tailings area and
- Recharge into rehabilitated opencast areas where the recharge can be on average 8 % of the mean annual rainfall (Hodgson & Krantz, 1998). This will accelerate the rate of rise in the rehabilitated pit areas.

4.7.2. Contaminant transport

There are several potential sources of contamination to the aquifers from the proposed mining activities including accidental hydrocarbon and other spills from storage containers on site. For the purpose of this discussion it is assumed that good housekeeping such as storage of potentially hazardous material will be within properly constructed and lined or paved areas. Oil traps will be sized, operated and maintained to contain all discard oil from workshops and service areas etc.

Surface infrastructure that could act as potential pollution sources include:

- Top soil stockpile;
- Waste dump;
- Tailings area;
- Product and ROM stockpiles;
- Pollution control dams; and
- Mined out or rehabilitated pit area;

The water management infrastructure (pollution control dams etc) will be sized to contain storm events and will be lined. Therefore it is not expected that there will be any contamination from these surface points.

The opencast pit can act as a source of pollution to the surrounding aquifers through oxidation of the exposed lithologies. However, as discussed in Section 4.6 no AMD conditions are expected. Only manganese is expected to be present in elevated concentrations (exceeding SANS241:2006 guidelines for domestic use). This should be controlled against the elevated chloride, calcium, magnesium and nitrate concentrations measured in the regional groundwater and current Perth pit water samples that indicate the possibility of those elements also be present in high concentrations in the post-mining environment.

Groundwater seeping into the pit through the affected lithologies, or direct runoff on the pit walls over the lithologies, can lead to accumulation of the water in the mine area with elevated manganese and other concentrations. During the operational phase the groundwater flow directions will be directed towards the opencast pit and underground mine areas due to mine dewatering, thereby containing any contaminants that might form within the mining areas. The water pumped from the mined out area as part of the mine dewatering will be contained within lined water management dams that will be sized and lined to be able to contain 1:50 flood events, and therefore it is not expected that there will be any significant contamination to the surrounding aquifers.

The opencast mine area will be continuous rehabilitated as mining progresses. The rehabilitation will entail backfilling, shaping, top soiling, and re-vegetation of the mined out areas as mining progresses. The groundwater flows in the area will be impacted:

- Recharge into the rehabilitated material can be assumed to be around 8 to 10 % of mean annual rainfall (Hodgson & Krantz 1998);
- There will be inflows into the pit from the surrounding aquifers. The inflow rate will depend to a large extend on the groundwater flow gradient between the surrounding aquifers and the water level in the rehabilitated material; and
- There will be little to no impact from evaporation on the rising water level in the rehabilitated material other than removal of shallow recharging water before it reaches the saturated zone.

The rising water level in the pit will allow the groundwater flow gradients to be re-directed to near pre-development directions. This will allow contaminated water to migrate away from site.

Acid mine drainage and leach testing results indicate that there is virtually no possibility of AMD conditions forming, and in the event that such conditions do form it will not be sustained in the long term. Leach testing results show manganese concentrations to be elevated in the post mining environment as can be expected from the ore body. Nitrate concentrations can also be elevated due to blasting during the mining operations. As mentioned above, it is recommended that the long term pit water quality be monitored for elements such as chloride, calcium and magnesium that from samples taken from regional boreholes and the current Perth pit are naturally present in elevated concentrations in the post-mining environment.

Water accumulating in the waste, tailings, and top soil storage facilities will artificially increase recharge into the underlying aquifers. As mentioned above work done by Hodgson & Krantz (1998) indicates that recharge in these areas can increase up to 20 % of the mean annual rainfall. This increased recharge will form a mounding in the groundwater levels underlying the infrastructure. The mounding in groundwater level will re-direct groundwater levels radially away from the stockpiles. Any poor quality seepage from the stockpiles will therefore migrate away from the stockpiles. Should these stockpiles fall within the zone of influence of the mine dewatering around the mining area it can be expected that contaminants will migrate towards the mining area from where it will be pumped into the water control infrastructure (PCD etc) where it will be managed.