**SOCIAL AND ENVIRONMENTAL IMPACT ASSESSMENT OF RÖSSING MINE EXPANSION PROJECTS – WATER MANAGEMENT**

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# 1. Introduction

As mentioned in the main SEIA report, three specific components of Rössing's expansion project are the subject of the present impact assessment:

- a sulphuric acid plant, sulphur storage and transport facilities
- a radiometric ore sorter plant and associated waste rock disposal site
- mining of the SK4 ore body and waste rock disposal.

The projects listed above are referred to as Phase 1 projects and the purpose of this report is to describe their impact on water management aspects, especially water use, runoff and groundwater quality.

# 2. Impact of Phase 1 Projects on Freshwater Consumption

## 2.1 Water Supply Background

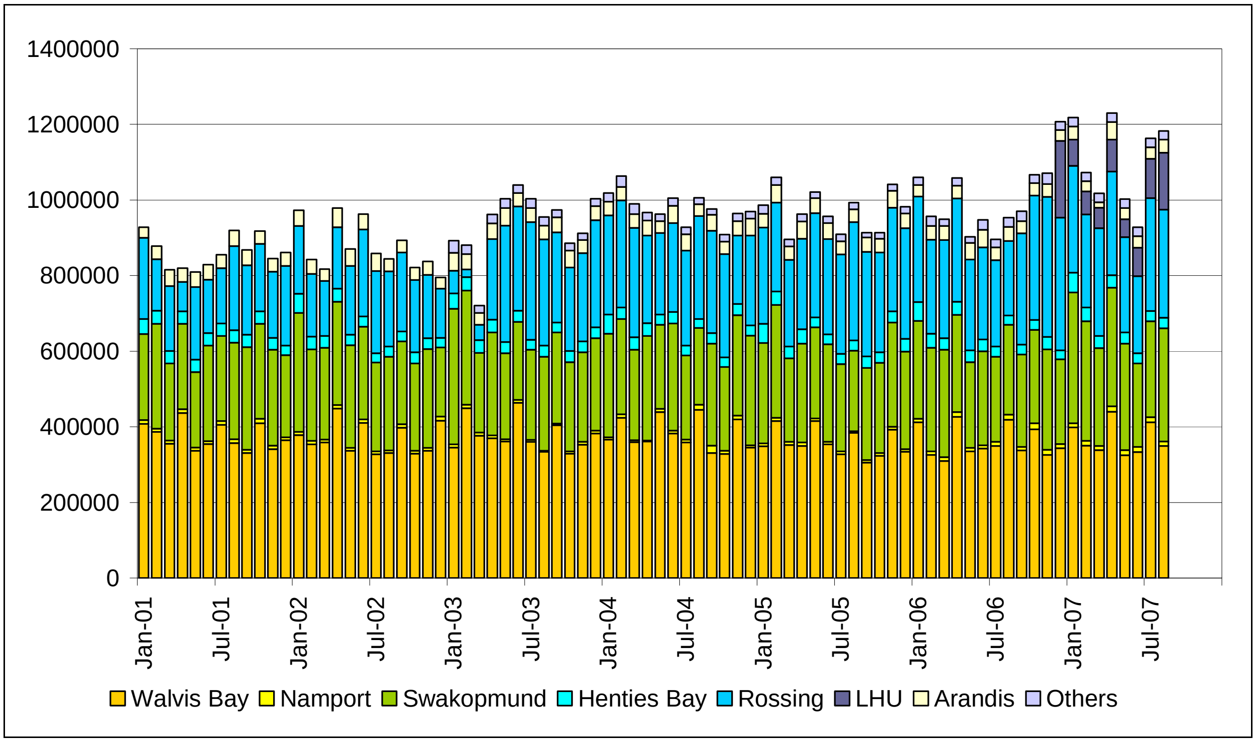
Water in the Central Namib area is sourced from two large alluvial aquifers, namely, the west flowing Kuiseb and Omaruru Rivers. The wellfields operated by NamWater can sustain a supply of up to 15.9 $Mm^3$ per annum according to the currently available information (Table 2.1).

**Table 2.1: Yield of Central Namib Scheme Aquifers (Source: NamWater, March 2006)**

| Source | Yield $m^3/a$ |
|---|---|
| Omdel at present level of development | 5 900 000 |
| Kuiseb at present level of development | 7 000 000 |
| ***Sustainable yield at present level of development*** | ***12 900 000*** |
| Artificial recharge at Site II (under construction) | 1 300 000 |
| Interception of outflow to sea (under construction) | 1 700 000 |
| ***Sustainable yield 1 year from now*** | ***15 900 000*** |
| | |

The NamWater wellfields in the Kuiseb and Omaruru deltas supply the municipalities of Swakopmund including the owners of small-holdings along the Swakop River, Walvis Bay, Henties Bay and Arandis, as well as the large industrial users, Namport, Rössing and Langer Heinrich Uranium mine. Figure 2.1 shows the monthly consumption of these users during the last seven years.

**Figure 2.1: Central Namib Water Consumption in Cubic Metres per Month**




Groundwater from the Khan and Swakop rivers has previously been used for water supply, but high salinity levels render the water unsuitable for human consumption. Rössing mine abstracts water from the Khan River for industrial purposes such as dust suppression. These abstractions currently account for 4% of the total water usage at Rössing mine. Under a Ministry of Agriculture, Water & Forestry abstraction license, Rössing mine may abstract a maximum volume of 0.87 $Mm^3$ per annum, provided that water level drawdown does not exceed 15 m below the surface and that vegetation monitoring occurs on a regular basis. In compliance with this requirement, Rössing mine undertakes a biannual survey of the Khan River riparian vegetation by assessing the vitality, growth rate, productivity or decay together with the sub-surface water levels to assist in the sustainable management of this resource. The last significant recharge of the Khan River aquifer occurred in 2000, as a result of this and the findings of the monitoring programme, Rössing mine has limited the annual abstraction to approximately 0.25 $Mm^3$.

## 2.2 Status of the Coastal Aquifers

The lower courses of the Kuiseb and Omaruru rivers form important linear oases providing food and shelter to wildlife in the Namib Desert. NamWater is required by law to operate the wellfields in a sustainable manner to ensure that sufficient resources are available in future and to prevent negative impacts on the ecosystem.

### *2.2.1 Kuiseb River*

Water from the Kuiseb River is presently used almost exclusively by consumers in Walvis Bay and surrounding areas. In 1976-78 however, Rössing's entire water demand was supplied from the Kuiseb River, resulting in a maximum abstraction of 17 $Mm^3$ in 1977. The sustainable yield of the aquifer is estimated at 3.5-7.0 $Mm^3$/a depending on the frequency of recharge (dry and wet cycles). The sustainable yield had been over-estimated when the wellfield was developed because the mid-1970s were in a wet cycle.

Excessive abstraction has lowered the water table from its original average depth of 8 m below surface to a minimum of 17 m below surface in 1996. Recharge in 1997 and 2000 helped to maintain the water table at 15-16 m since then. Besides a ±50% reduction in stored reserves there are socio-economic and environmental impacts of over-abstraction. The water table decline has caused the shallow wells of the local Topnaar people, who are subsistence farmers, to dry up and they now struggle to pay for piped water.

The vegetation has been affected because the roots of mature trees are not able to follow a rapidly dropping water table. As a consequence less fodder is available for livestock and wild animals that rely on the riparian vegetation of the Kuiseb River during the dry season. It has also been found that recharge rates can be reduced by a thick unsaturated layer.

Sustainable management of the resource was hampered by Walvis Bay's rising water demand and the absence of demand reduction measures. This has improved recently and Walvis Bay's demand is stable. Local communities feel that Rössing is responsible for the status of the Kuiseb aquifer, even though the bulk of the mine's supply has come from the Omaruru River since 1980.

### *2.2.2 Omaruru River*

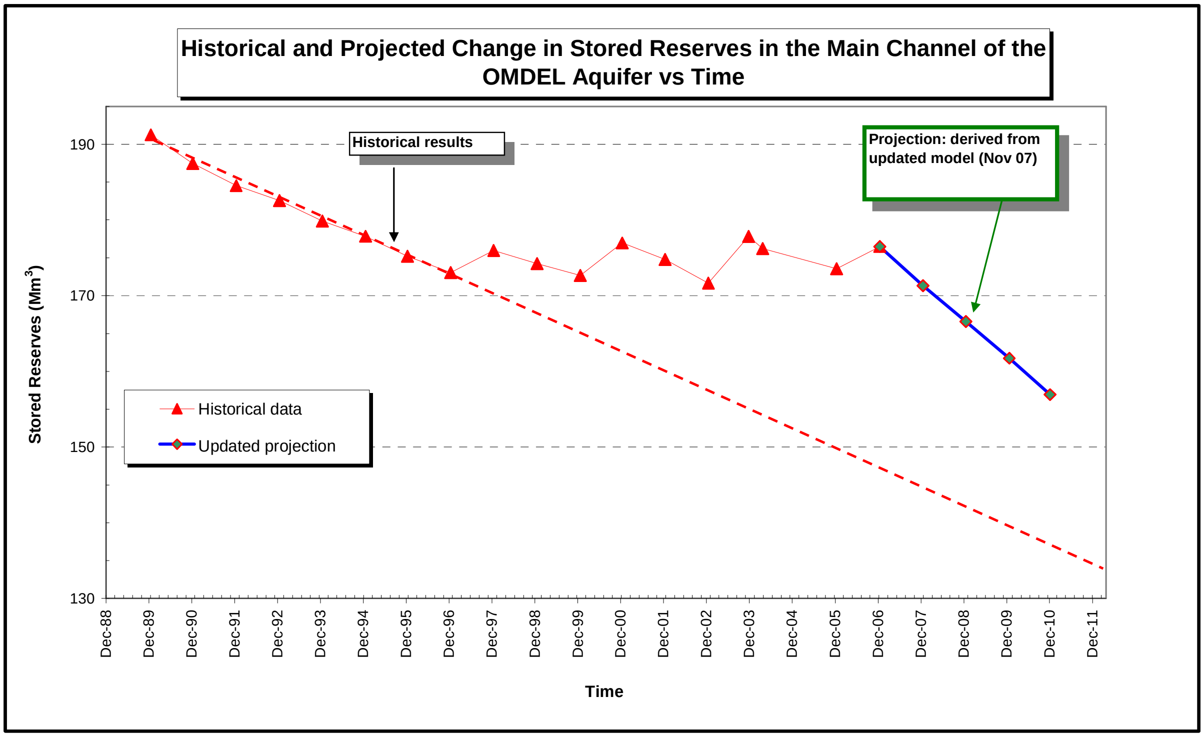
The Omdel wellfield is situated north and north-east of Henties Bay in a palaeochannel of the Omaruru River. The difference between the historic pumping rate and sustainable yield is not as big as in the Kuiseb aquifer, especially in the 1990s, but the high pumping rates have lowered the water table in the Omdel aquifer as well. The only recharge event occurred in 1985 and a flood event of this magnitude has a frequency of 1 in 50 years. Smaller floods do not contribute much water to the aquifer as most of the flood water evaporates from the riverbed.

The Omdel aquifer consists of two sand and gravel layers, separated by an aquitard of cemented sand. The upper aquifer is unconfined, while the lower aquifer is semi-confined. The water table that was originally in the upper layer has been drawn down into the lower aquifer. Groundwater models of the Omdel aquifer have been prepared by NamWater. The model predicts that the stored reserves will decrease from 170 $Mm^3$ in 2007 to 155 $Mm^3$ in 2010 at the projected abstraction rates in the absence of recharge (Figure 2.2).

### *2.2.3 Central Namib Water Scheme*

The supply capacity of the Central Namib water scheme (Table 2.1) can be increased to some degree by installing additional boreholes and infiltration basins in the Kuiseb and Omdel aquifers. Other water supply sources have been investigated, but seawater desalination was found to be the only viable alternative. A desalination plant will be constructed close to Swakopmund and should be completed by 2010.

**Figure 2.2: Water Reserves in the Omdel Aquifer and Predicted Decline (Data and Graph supplied by NamWater)**




## 2.3 Freshwater Consumption of Phase 1 Projects

### *2.3.1 Acid Plant*

It has not yet been decided whether the acid plant will be cooled with air or water. Air cooling is more expensive, but might be preferable due to the high cost of desalinated water. If the acid plant is fitted with a cooling tower, it will consume approximately 1000 $m^3$/day of fresh water at full production. This volume can be saved by installing a dry cooling system. Water availability is not a concern because the acid plant will be completed at the same time as the seawater de-salination plant. The decision between the two cooling alternatives can be based on economic factors alone, since the use of desalinated water will prevent any environmental impact on the coastal aquifers.

### *2.3.2 Ore Sorter*

The ore sorter will need fresh water for dust suppression. According to the equipment supplier each of the ten units uses 5 litres per minute. This adds up to a daily consumption rate of 72 $m^3$ based on the ore sorter plant running 24 hours per day. Observations at the pilot plant show that most of the dust suppression water sticks to the rocks, so that a water collection sump would not be required for this application. A sump will however be needed to collect washdown water, even though the structures will be washed down infrequently, because most of the fines that contribute to dust generation are removed at the prescreening plant. Recycled water may be used for washdown purposes, if the required volumes justify the construction of a supply system.

### *2.3.3 SK4 and SJ Open Pits*

Increased mining activity in the existing SJ open pit and the new SK4 pit will increase the industrial water demand for dust suppression from the current level of 700 $m^3$/day to 1300-1500 $m^3$/day in 2008. The additional water demand can not be met by increasing the abstraction from the Khan River, because the sustainable yield of the aquifer is only 500-600 $m^3$/day (Table 2.2).

Other water sources are treated sewage effluent stored in the Mine Pond and groundwater abstracted from the seepage control systems, which is currently pumped to Ericson Dam. The following volumes of water can be made available for dust suppression in the mining area:

**Table 2.2: Availability of Water for Open Pit Dust Suppression**

| **Source** | **Volume ($m^3$/day)** |
|---|---|
| Khan River groundwater | 500-600 |
| Mine Pond treated sewage effluent | 400-500 |
| Ericson Dam clean seepage water | 400 |
| **Total supply** | **1300-1500** |

Mine Pond water can be supplied with the current infrastructure, while the seepage supply to the open pit needs a new pumping system. This project is currently in the design phase. The reallocation of seepage from its current use in the processing plant to the open pit will create a shortfall in the plant that has to be made up by adding 0.26 $Mm^3$ per annum of fresh water.

## 2.4 Cumulative Impact

The expected total increase in freshwater consumption of up to 2000 $m^3$/day (depending on the cooling system of the acid plant) will raise the mine's annual water demand from 3.3 to 4.0 $Mm^3$. The increase is within the maximum of 4.5 $Mm^3$/annum provided for in the current water supply contract with NamWater. As mentioned in 2.3.1, the acid plant will be supplied from the seawater desalination plant and have no effect on the coastal aquifers. The additional abstraction of 0.26 $Mm^3$ per annum for dust suppression in the mining area will however start in 2008, before the desalination plant is in place, and it will contribute to the earlier depletion of the Omdel aquifer.

## 2.5 Impact Mitigation

Rössing has identified several options to offset the additional demand by reducing the water consumption or losses in other areas of the mine. The achievable savings are in the order of 2000 $m^3$/day and the most likely projects are listed below.

- Tailings paddy double-deposition to reduce evaporation losses
- Replace hydraulic gland seals on slurry pumps with mechanical seals
- Supply recycled water for dust control at the fine crushers and leach tanks

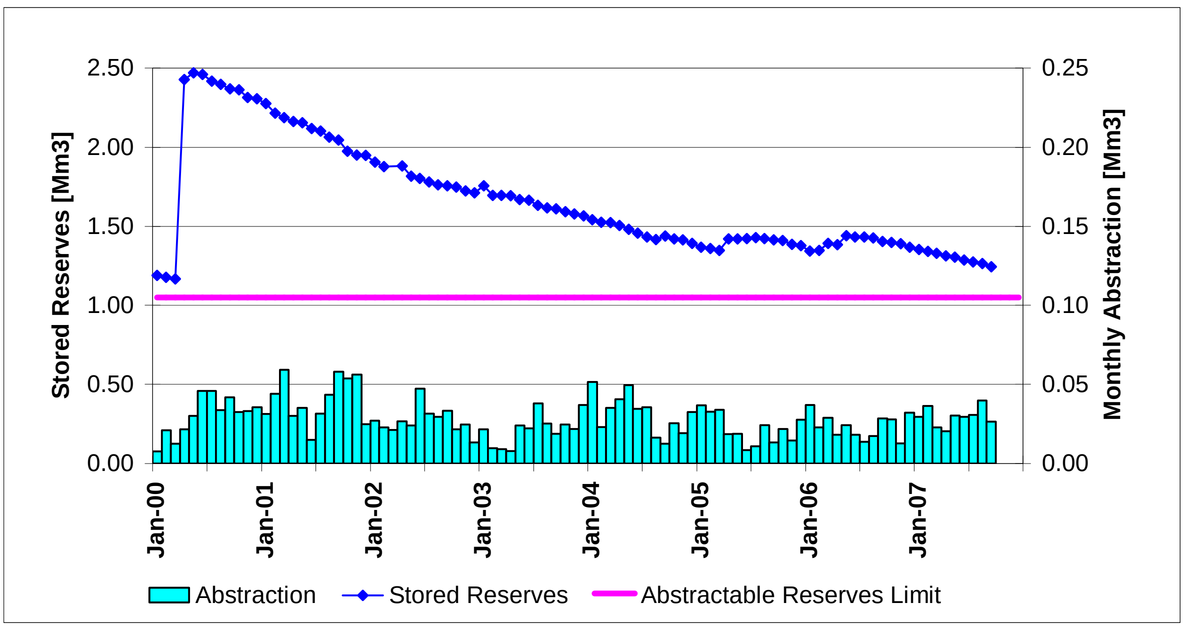
An action plan is in place to ensure that these projects are designed, evaluated and implemented, if they are feasible. This plan should become part of the formal EMP for the Phase 1 SEIA.

## 3. Impact of Dust Suppression Water Use on the Khan River

### 3.1 Status of the Aquifer

The Khan River aquifer was last recharged in 2000 (Figure 3.1) when the stored groundwater reserves were topped up to 2.5 $Mm^3$. Since then the reserves declined continuously until early 2005. Two minor recharge events in 2005 and 2006 kept the reserves steady at about 1.3-1.4 $Mm^3$ during the last two years. The stored groundwater reserves in the Khan wellfield were 1.38 $Mm^3$ in December 2005 and 1.37 $Mm^3$ in December 2006. The total abstraction of 0.28 $Mm^3$ (771 $m^3$/day) in 2006 was provided by recharge (0.096 $Mm^3$) and groundwater inflow from upstream (0.184 $Mm^3$).

**Figure 3.1: Khan River Water Reserves and Abstraction**




There was no recharge in the 2006/7 season and the reserves currently stand at 1.23 $Mm^3$. The maximum abstraction set for 2007 was 600 $m^3$/day, but the target was exceeded due to the mine's high water demand for dust suppression and diamond drilling. If the recent trend (Figure 3.1) continues the abstractable reserves will be depleted in early 2008. Pumping has to stop when the abstractable reserves limit of 1.05 $Mm^3$ is reached. The stored water below this limit is required to sustain the vegetation during times of drought.

### 3.2 Status of the Vegetation

The Khan River vegetation surveys carried out in the last few years showed that most of the trees at the monitored transects were in a satisfactory to good condition except for Transects 3 and 6, which have deteriorated. The progressive deterioration observed at these transects indicates that recharge to the aquifer downstream of the wellfield was not sufficient. The trees at

Transect 3 were damaged by excessive pumping of borehole 7 at the Pinnacle Gorge confluence. Transect 6 is situated half way between the mine and the Swakop River in an area where there is currently no groundwater in the alluvium. A major recharge event would be required to top up the aquifer in the downstream area and make a difference to the vegetation at these transects. Pumping from boreholes 7 and 8 in the downstream wellfield remains suspended in the meantime.

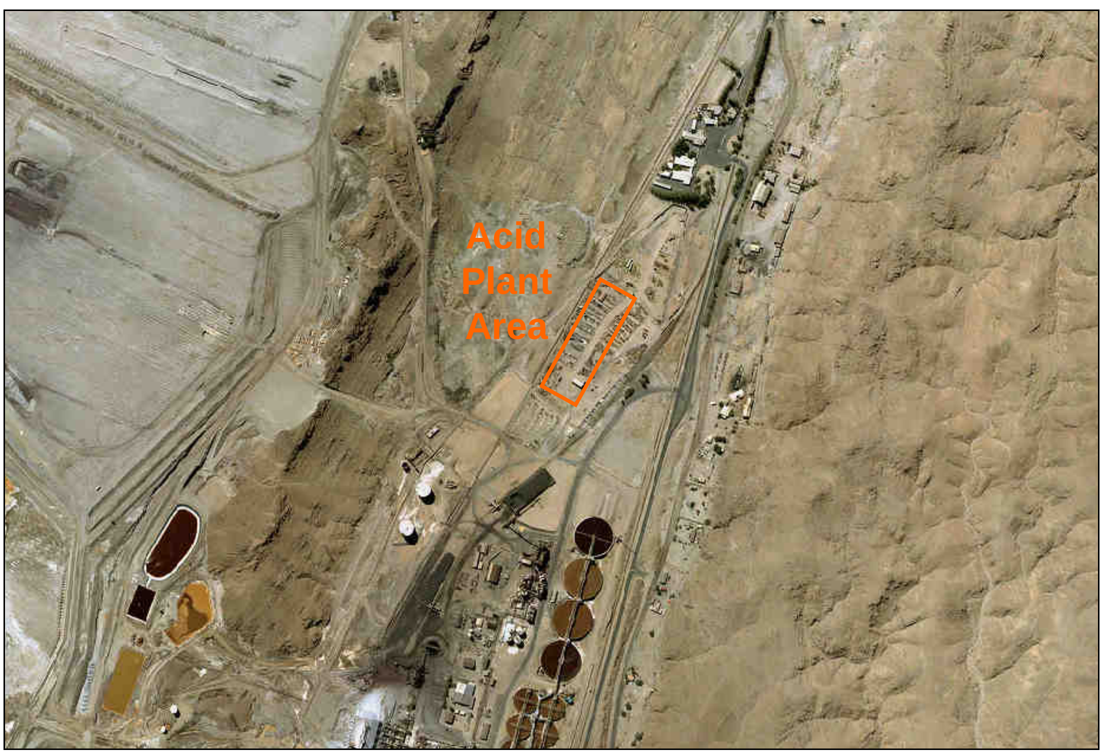
### 3.3 Predicted Abstraction Capacity

The aim of aquifer management is to make the remaining 0.3 $Mm^3$ last until the next major recharge event or otherwise stop abstraction when the abstractable reserves limit of 1.05 $Mm^3$ has been reached. A maximum of 500-600 $m^3$/day can be made available for dust suppression and diamond drilling in the Open Pit during the next few years. As reported in 2.3.3, a project to establish an alternative water supply from Ericson dam to the Open Pit is currently at the design and costing stage. The implementation of this project will begin in early 2008 to alleviate the pressure on the Khan aquifer. In the meantime the water supply is supplemented from the Mine Pond and elevated dust levels are reluctantly tolerated for the duration.

## 4. Water Quality Impact of the Acid Plant

The storage and transport of imported elemental sulphur at Walvis Bay harbour and to Rössing mine is the subject of a separate environmental impact assessment commissioned by Grindrod Namibia. The import of acid will continue at a reduced rate and the acid-loading facilities as well as the tank farm at the harbour will be used as necessary. Inspection and maintenance procedures are in place to prevent water contamination from these activities. The acid-offloading and storage facilities at the mine need to be upgraded (see 4.3).

**Figure 4.1: Location of the New Acid Plant**



## 4.1 Runoff

The acid plant will be constructed just north of the acid off-loading facility on a site that is currently used to store re-useable items (Figure 4.1). The potential for contaminated runoff and effluent generation has been investigated and discussed with the acid plant engineers. Considering the low annual rainfall at Rössing the design does not include any collection of rainfall around the plant. A hydrological study carried out in 1997 shows however that a small runoff channel traverses the site. The upstream area will be graded and berms provided to divert runoff around the plant towards the nearest stormwater drainage. It will be important to ensure that stormwater channels are large enough for the expected maximum flood.

Any rainfall that falls into the bunded area around the acid section of the plant (the three towers, acid circulation tank, acid coolers and acid drain pumps) will flow into the acid sump in the corner of the bunded area. This will be handled together with any acid spillage that occurs in this area. Any acid spillage or acid leakage from the plant will be collected in the acid drain sump in the corner of the bunded area. This can be pumped away to an acid neutralisation stage, as yet undefined.

From time to time there may be acid condensation in the gas/gas heat exchangers. This will be drained off into a plastic bucket. The acid in the bucket can be poured into the acid circulation tank, as it is normally 85-100% concentrated acid. This will occur under upset working conditions in the plant, such as poor air drying in the drying tower, or water/steam leaks in the boiler, economiser or superheater. When this occurs, the cause of the acid condensation should be investigated and steps to rectify the situation should be taken immediately.

The bund around the acid area of the plant is not normally sized to take all the acid that could be spilled, but this could be done, if required by the Rio Tinto environmental standards. The bunded area normally has an acid-resistant drain channel leading to an acid brick lined sump to collect the acid spillages. The rest of the bunded area will consist of a concrete slab graded to fall into the drain channels. The remainder of the acid plant area is covered with a 100-150 mm thick concrete slab to minimise acid drainage into the ground. The expansion joints will be sealed with expansion loops to render them acid-proof. The concrete surface will be sealed with 3 mm thick epoxy and fibre coating.

## 4.2 Effluent

Acid spillage or acid leaks from the plant will occur from time to time. The bunded area has an acid drain sump where spilled acid will be collected. This can be pumped away to an acid neutralisation stage or drained into the spillage collection system (‘snake pit’) of the processing plant. There may be acid condensation in the gas/gas heat exchangers, which will be drained off into a plastic bucket. The acid in the bucket can be poured into the acid circulation tank, as it is normally 85-100% concentrated acid. This will occur under upset working conditions in the plant, such as poor air drying in the drying tower, or water/steam leaks in the boiler, economiser or superheater. When this occurs, the cause of the acid condensation should be investigated immediately, and steps to rectify the situation should be taken.

According to Rio Tinto standards the bunding of the acid plant must be large enough to contain all the acid that could potentially be spilled. The current design provides for a bunded area with an acid-resistant drain channel leading to an acid brick-lined sump to collect any acid spillages. The rest of the bunded area consists of a concrete slab graded to fall into the drain channels.

There is an option to line the whole bunded area with acid bricks, but this is expensive and needs a lot of maintenance.

The designers propose to cover the remainder of the acid plant surface area with a 100-150 mm thick concrete slab to minimise acid infiltration into the ground. As the slabs normally contain expansion joints, this is not 100% acid proof. A concrete slab is usually regarded as suitable for carbonate-free soils, like those at Rössing. A risk assessment has to be carried out so that the decision about bunding and concrete-lining can be based on the expected environmental impact, standard compliance and cost implications.

### 4.3 Impact Assessment

Infiltration of acid could lead to a potentially significant environmental impact on soil and groundwater. Geological maps and site inspections showed that the bedrock at the acid plant site consists of banded gneiss of the Khan formation with minor intrusions of alaskite. Alluvium and soil are absent except for some sand fill that was brought in to level the area. The permeability of Khan banded gneiss and associated alaskites is very low with pumping test results varying from 0.004 to 0.09 m/day and an average of 0.04 m/day. In hydrogeological terms the formation is classified as an aquitard, i.e. it transmits too little water to qualify as an aquifer. The permeability for concentrated sulfuric acid will be even lower due to the higher viscosity of the acid.

A review of Rössing metallurgical studies from the early 1980s was carried out to find information on the neutralisation capacity of various rock types. The ore at the mine contains about 1.5% carbonate, mainly in form of calcite ($CaCO_3$). Other rock-forming minerals, such as quartz, mica and feldspar, do not readily react with sulphuric acid. This means that due to the low carbonate content one tonne of rock can only neutralise 15 kg of acid. The chemical equation for the neutralisation of sulphuric acid through reaction with calcium carbonate and water is as follows:

$$CaCO_3 + H_2SO_4 + 2\ H_2O \rightarrow CaSO_4 \ .\ 2\ H_2O + CO_2 + 2\ H^+$$

The formation of gypsum ($CaSO_4 \ .\ 2\ H_2O$) leads to a mass increase. For instance, the dissolution of 2.5 kg of carbonate uses 2.5 kg of water and leads to a mass increase of 5.65 kg. Similar reactions occur when banded gneiss is exposed to acid, as long as there is some carbonate present.

The mass increase mentioned above is the reason for geotechnical problems caused by acid spills. Prolonged reaction of acid with soil and water (rain) leads to ground instability, lifting or buckling of roads, railway lines and cracks in walls and buildings. Examples of these incidents can be observed at the Rössing rail offloading station and around the acid plant. However, being of a geotechnical nature, they are outside the scope of this water management report.

A hydrogeological and chemical investigation to assess the water quality impact of the existing acid tanks was carried out in 2002. It confirmed that the current impact of many small acid spills since the start of operation is noticeable in form of soil and groundwater contamination. The affected soil layer is easily identified by its powdery texture and yellowish colour. Water samples from a borehole (AT1, see Figure 4.2) drilled close to the tanks showed elevated sulphate concentrations compared to other sites unaffected by acid contamination.

A pH of 6.8 was measured in two samples from borehole AT1. The samples were analysed to determine whether the sulphate concentration downstream of the tanks was higher than at a control borehole (N1A) upstream of the tanks (Table 4.1). Higher sulphate contents would indicate groundwater contamination due to acid spills from the tanks. The sulfate concentration at N1A varied between 1080 and 1460 mg/L with an average of 1210 mg/L during the last 5 years. The sulfate content in the two samples from AT1 was almost twice as high at 2738 and 2682 mg/L.

**Figure 4.2: Locality Map of Boreholes near the Acid Tanks**

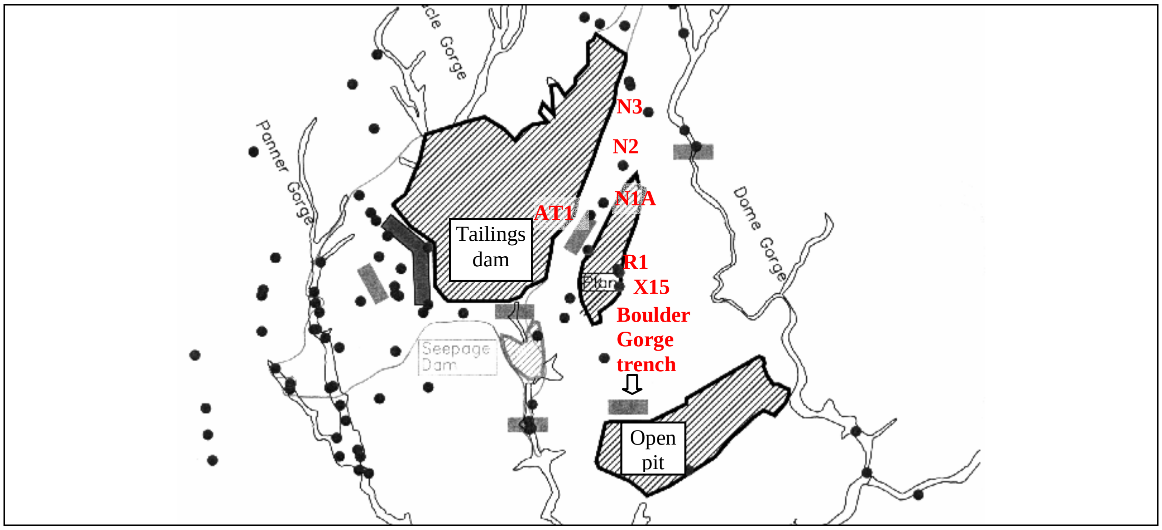



**Table 4.1: Sulphate Concentration in Boreholes near the Acid Tanks**

| Borehole | Year analysed | pH | Sulphate (mg/L) |
|---|---|---|---|
| AT1 | 2003 | 6.8 | 2710 |
| N1A | 2002 | 6.8 | 1460 |
| N2 | 2000 | 7.0 | 1100 |
| N3 | 2000 | 7.0 | 1207 |
| R1 | 2001 | 6.8 | 1280 |
| X15 | 2001 | 6.9 | 1270 |

Other boreholes in Khan formation east of the tailings dam (Figure 4.2) have sulphate concentrations similar to N1A in the range of 1100-1300 mg/L. The high sulphate values at AT1 must have been caused by infiltration of acid or acid-neutralisation products to the water table. However, to put the impact into perspective, ambient groundwater north of the tailings dam contains up to 2800 mg/L sulphate.

In case of acid infiltration from the new acid plant it is expected that chemical reactions between the acid and carbonates in the bedrock will neutralise a small quantity of acid and form a gypsum crust. The crust will reduce the further spread of acid, both sideways into adjacent areas and downwards into the bedrock. The degree of vertical infiltration of spilt sulphuric acid depends on the time that the acid is allowed to stand after spilling. If the bulk of a large spill is rapidly pumped into containers and the remainder neutralised with marble dust, it is unlikely to infiltrate deeper than half a metre. The soil profile at AT1 showed the main contamination within the upper 0.5 m. Due to the formation of a crust limiting the infiltration of acid into the soil and deeper formations and the possibility of early spill recovery the magnitude, probability and risk of soil and groundwater contamination are regarded as low in this environmental impact assessment.

### 4.4 Mitigation

Procedures and equipment must be in place to handle any major spills that could occur during the operation of the new acid plant. It is understood that minor acid infiltration may take place through expansion joints in the concrete slab. These will lead to a degree of soil contamination, which has to be cleaned up when the mine closes. The closure plan will provide for decontamination of the site and removal of the contaminated material to a hazardous waste site. Infiltration to groundwater could occur and would mainly result in higher sulfate concentrations as shown at borehole AT1. The flow direction of the contaminated groundwater is towards Boulder Gorge, where it will ultimately discharge to the Boulder trench. The trench will continue to be pumped after mine closure as long as there is any inflow and the water will be collected for safe disposal. Any remaining groundwater flow in the underlying fractured bedrock will be cut off by the northern wall of the open pit, where the water will evaporate.

## 5. Water Quality Impact of the Ore Sorter

### 5.1 Effluent

The ore sorter plant will be situated west of the conveyor that runs from the coarse ore stockpile to the fine crushing plant (Figure 5.1). It will use water for dust suppression, but it is expected that most of this water will evaporate. A spillage sump with a water transfer facility must be provided to collect any excess water, also in case of a pipe break. The elevated uranium concentration of the ore sorter dust will contaminate the dust suppression water, so that it may not be discharged into the environment.

### 5.2 Waste Rock Disposal

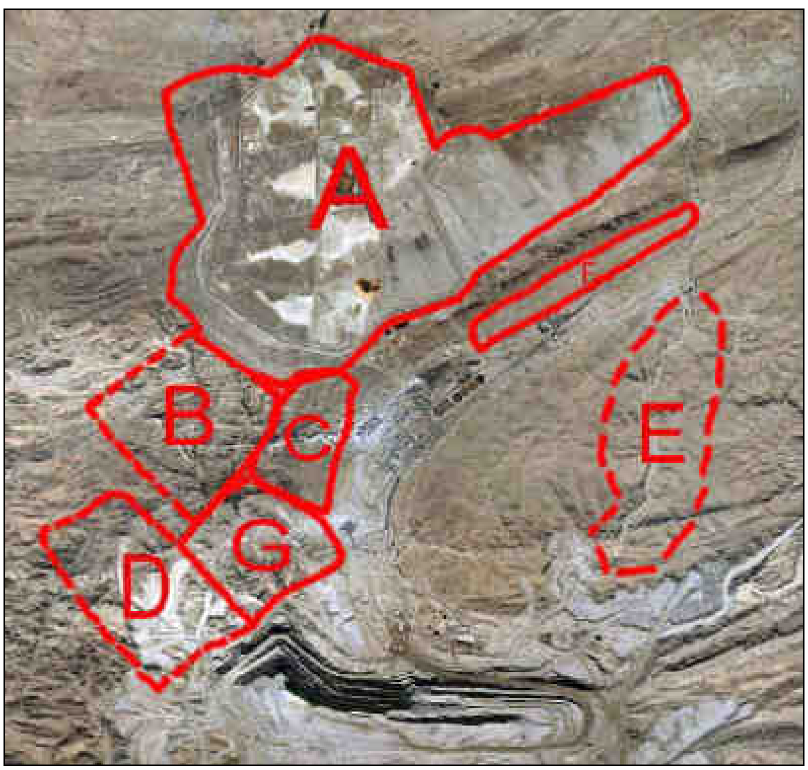
The most significant environmental impact associated with the ore sorter plant will be caused by the storage of reject material. The current plan includes seven possible locations (Figure 5.1):

- Location A ~ Tailings dam
- Location B ~ Below the southern toe of the tailings dam
- Location C ~ The valley and areas adjacent to the grit-blasting yard
- Location D ~ Existing open pit Waste 5 dump
- Location E ~ The upper area of Dome Gorge
- Location F ~ Northwest of the salvage yard on the slopes of the Berning Range
- Location G ~ South of the Seepage Dam access road.

In this report the locations will be ranked according to their potential impact on water quality. Environmental and visual constraints are mentioned elsewhere in the SEIA report.

**Figure 5.1: Location of the Ore Sorter Plant**


**Figure 5.1: Possible Locations for Ore Sorter Waste Storage**



### 5.3 Impact Assessment

The ore sorter waste rock can affect the groundwater quality by releasing leachates. Rössing has investigated the impact of the large waste rock dumps around the open pit, which are similar in composition to the proposed ore sorter waste. Observations show that leachates containing sulphate, nitrate and uranium can form after intense rainfall of more than approximately 20 mm per event. Nitrate is derived from the explosive used at Rössing, while sulphate and uranium originate from minerals in the waste rock itself.

Laboratory leach tests on waste rock carried out over several days showed that nitrate was mostly dissolved on the first day. The total amount of nitrate, sulphate and uranium leached from the samples increased with time.

Historic data demonstrate the impact of waste rock leaching on the water quality in Dome Gorge, where the nitrate concentration downstream of the dumps increased from around 70 mg/L in the 1980s to 120 mg/L in the mid-1990s. The maximum appears to be related to higher than average rainfall in 1993 and 1995.

The impact on the Khan River water quality was assessed by mixing calculations. The predicted volume of leachate resulting from a specific rainfall event of 92 mm with an average composition as shown in Table Y was mixed with Khan River water of the typical composition upstream of Dome gorge (BH1.4A). If the Khan River is in flood at the time of rainfall on the waste rock dumps, the severity of the impact is low due to dilution. If there is no runoff in the Khan River during the local rainfall event, leachates can infiltrate into the aquifer. A storm event of 92 mm can raise the sulphate concentration in the Khan River above the Namibian limit for stock watering of 1000 mg/L over a short distance downstream of the confluence (Table 5.1).

**Table 5.1: Leachate Quality and Impact on the Khan River**

| Determinant (mg/L) | Average leachate composition | Predicted impact from 92 mm rainfall | Recent BH1.4A (upstream of mine) | Recent BH1.6A (downstream of mine) |
|---|---|---|---|---|
| Nitrate | 166 | 78 | 17 | 43 |
| Sulphate | 1692 | 1036 | 583 | 775 |
| Uranium | 0.35 | 0.20 | 0.09 | 0.15 |

To test the predicted impact against water quality data collected so far the recent figures for nitrate and sulphate in the Khan River were compared to the calculated effect of leachates (Table 5.1). The actual long-term impact of the waste rock dumps on the entire Khan River along the mine frontage is much smaller than the predicted figures suggest. The most likely explanation for the relatively low observed impact of leachates is that heavy rain on the mine is usually accompanied by runoff in the Khan River.

It was concluded from the study that the waste rock dumps will continue to contribute small loads of nitrate, sulphate and uranium to the Khan River aquifer during the operational phase. The effect will diminish with time after mine closure as the bulk of the soluble salts will be removed after several rainfall events. The impact of slow weathering and leaching of the remaining sulphides and uranium minerals in the waste rock dumps is expected to be insignificant due to infrequent wetting of the dumps, but this needs to be confirmed by modelling.

When sulphide minerals are present in mineral waste, acid rock drainage can occur. A study was carried out to assess the neutralisation capacity of waste rock and tailings using standard testing methods. The net acid-producing potential of waste rock and tailings samples was found to be as follows:

| | |
|---|---|
| Average ore and waste rock: | - 5.79 kg $H_2SO_4$/tonne |
| High-sulphur waste rock: | -60.74 kg $H_2SO_4$/tonne |
| Tailings | - 3.22 kg $H_2SO_4$/tonne |

Values >20 indicate acid-forming material, while those <-20 are acid-consuming. Between –20 and 20 are potentially acid-forming rocks that may require further evaluation. Most of the Rössing samples fell into this bracket and were further evaluated by performing the net acid-generating test. This test was carried out on a number of waste rock and tailings samples, but none of these generated any residual acid. The study concluded that Rössing waste material had no inherent acid-generating potential due to the surplus of neutralizing minerals.

Rössing will carry out further geochemical characterization studies according to procedures recommended by Rio Tinto experts. The confirmation of the low acid rock drainage potential will form part of these tests. The results are not available in time for the Phase 1 SEIA report, but will be included in the Phase 2 assessment.

## 5.4 Impact Mitigation

In terms of leachate control it would be ideal to place the ore sorter waste in an area that is already affected by groundwater contamination. Such areas have existing seepage control installations that could be enlarged if necessary so that the impact on the surrounding water occurrences would be minimised. Figure 5.2 shows the 2005 extent of the sulphate plume, which is accompanied by nitrate and uranium concentrations above background levels.

**Figure 5.2: Extent of the Sulphate Plume in 2005**

The tailings dam (Location A) would be the preferred option, because the water composition within and beneath the tailings corresponds to contaminated process solution and the incremental effect of the leachates would be very small.

The southern toe of the tailings dam (Location B) is partly contaminated as well, but the seepage dam area is needed for water storage, seepage collection and recycling.

Location C (the valley and areas adjacent to the grit-blasting yard) is suitable in terms of water management. The groundwater in this area is already affected by seepage from the tailings facility and a drainage channel could be provided below the waste rock dump to discharge leachates to the seepage dam.

The existing waste rock dump at Location D is another suitable option as long as the footprint is not extended too far beyond the current toes. Leachates have already affected the quality of groundwater that is present in the alluvium of Pinnacle Gorge and a cut-off trench is in operation downstream of the dumps to collect any leachates.

Locations E and F in Dome Gorge and along the Berning Range have hardly been affected by groundwater contamination in the past and there are no leachate collection systems in place. These areas are regarded as less favourable for ore sorter waste disposal. Dome Gorge may be used for waste storage if the river course is cut off by mining of the so-called north-eastern extension of the current open pit. This would ensure that any leachates emanating from the dumps would be intercepted by the pit.

Location G south of the Seepage Dam access road covers largely unaffected ground, but has access to the seepage dam for leachate collection. Overdumping this area would however remove the possibility of constructing a drainage channel for the disposal of seepage into the open pit after mine closure. If Location G is preferred in terms of other impacts the potential ‘seepage channel’ area should be kept open.

The ranking of the proposed waste sites in terms of water quality and water management impact is as follows:

| Suitable | Partly suitable | Unsuitable |
|---|---|---|
| 1) A | G | B |
| 2) D | E | F |
| 3) C | | |

## 6. Water Quality Impact of the SK4 Pit

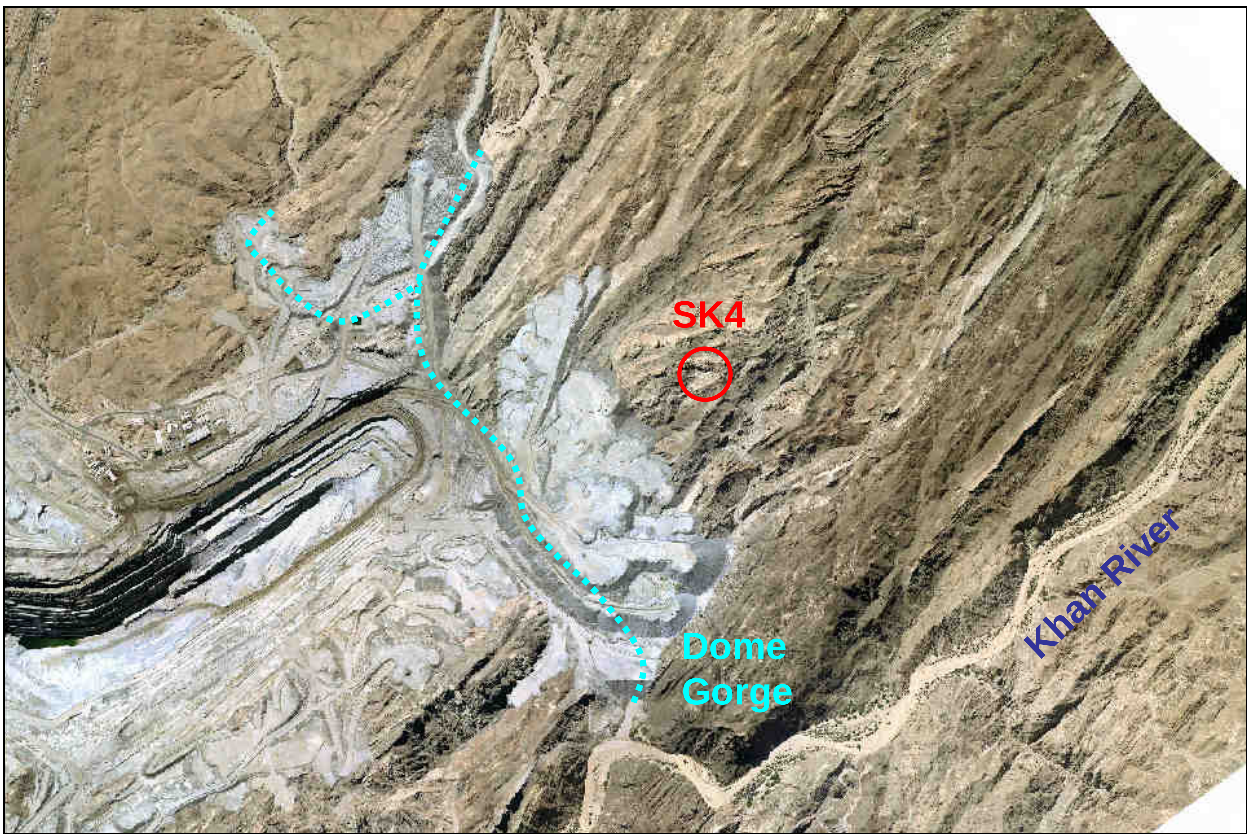
The pioneering work required to allow access to the SK4 site would comprise drilling, some minor blasting and the use of heavy earth-moving plant. Once suitable road access has been created, excavation will be undertaken to provide a drilling platform. The drilling platform will then allow the initial excavation of two 15 m deep benches and access by loading equipment. The usual open-cast mining sequence of drilling, blasting, loading and hauling will be applied. A water cart will be used for dust suppression.

The life of the SK4 ore body mine is anticipated to be approximately three years. It is envisaged that the SK4 pit will eventually have 10 benches, in an excavation of 600 m in length, 300 m in width and 150 m in depth. In the order of 27 Mt of material is likely to be excavated, of which 75% or ±20 Mt will be waste. The waste rock derived from the SK4 pit can be accommodated on the existing waste dump sites, specifically Waste 7.

### 6.1 Surface Water

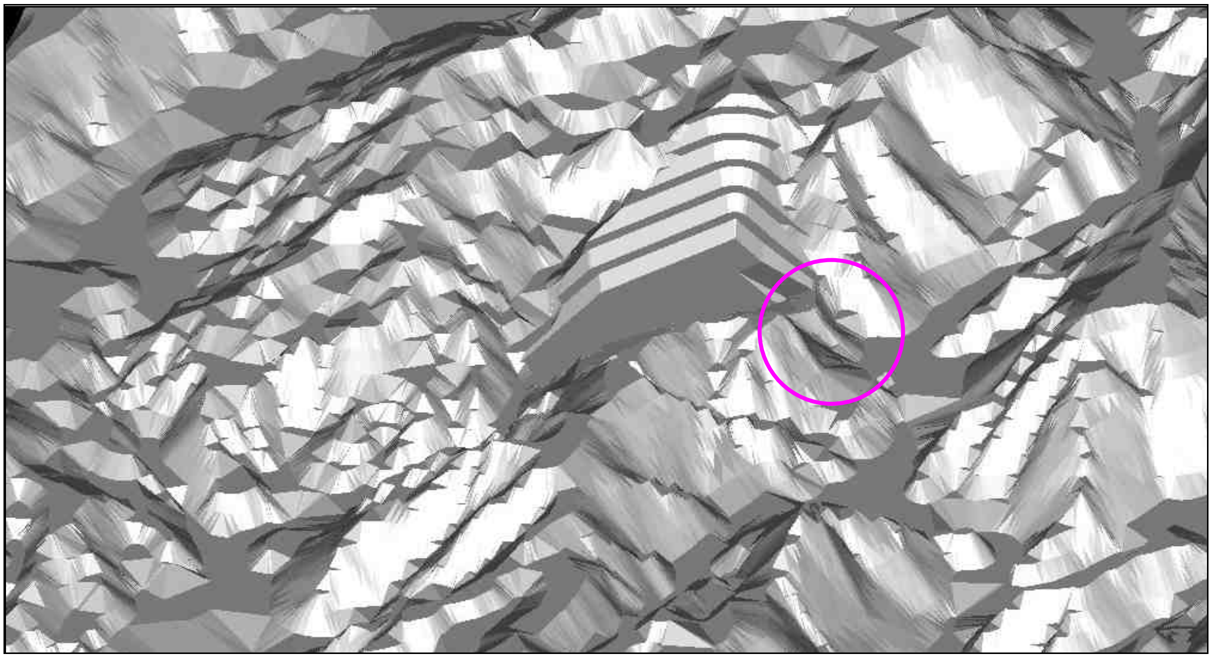
Water will be required for drilling activities and dust suppression in the SK4 pit. The current rate of water usage for these purposes for the entire mine operation is ±700 $m^3$/day. This figure is likely to double with the exploitation of the SK4 ore body and expansion of the mining activities in the active SJ pit. Groundwater is presently abstracted from the Khan River and stored in the Waste 4 pond for use in dust suppression. The Khan water supply of 500-600 $m^3$/day will be supplemented with treated effluent from the waste water treatment works and clean seepage from Ericson Dam. This system will provide the necessary water for SK4. The impact of the dust suppression water quality on the local groundwater will be assessed in 6.4.

**Figure 6.1: Aerial Photo Showing SK4 and Dome Gorge**




Valleys in the SK area are aligned north-east to south-west and drain towards Dome Gorge, which is a tributary of the Khan River (Figure 6.1). The SK4 pit is situated on a watershed and will not intersect any drainage lines. The catchment area of the stream south of the pit is quite large, but the height of the saddle between the valley and the pit is sufficient to prevent inundation of the SK4 pit during the maximum flood (see circled area in Figure 6.2). The impact of surface water contamination by contact with exposed ore and waste rock will be assessed in 6.4.

**Figure 6.2: Model of SK4 Pit Surroundings**



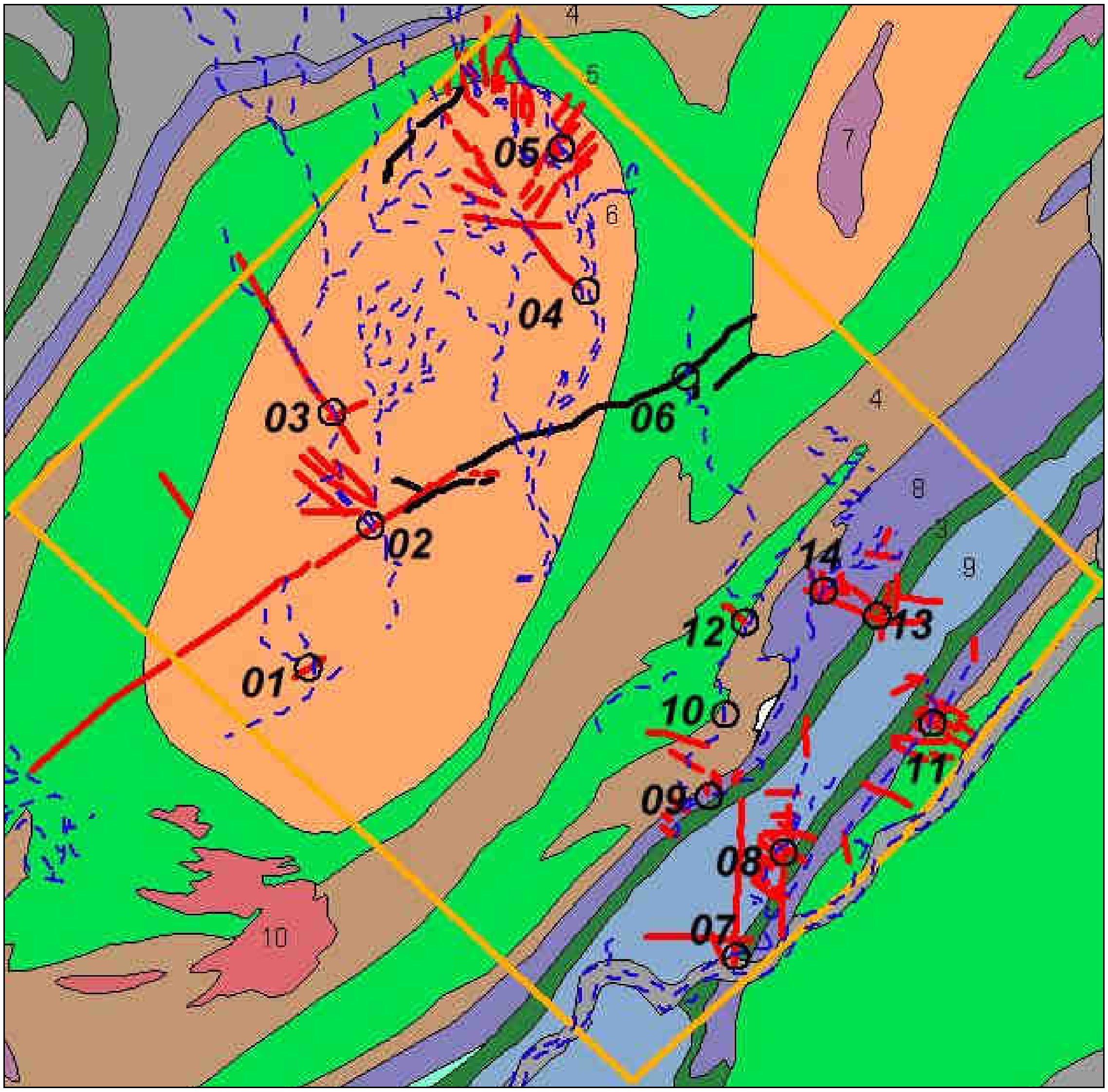
## 6.2 Hydrogeology

A comprehensive hydrogeological study consisting of geophysical borehole siting, drilling of monitoring boreholes, yield testing, water quality sampling and 3D flow modelling is in progress as part of the SEIA. Most of the results will only be available for the Phase 2 report. The Phase 1 report focuses on the SK4 pit and its hydrogeological impact, taking into account any new information that has recently become available.

The geology of the deposit is similar to the existing open pit (SJ) with uranium-bearing alaskite (red area in Figure 6.3) intruded into Khan Formation (bright green) and Rössing Formation (brown) metasediments. Geological maps and a photogeologic interpretation of the area show no major fractures connecting SK4 to the Khan River (Figure 6.3). The location of SK4 is indicated on the map by the bold figure 10. The Khan River appears as a grey band crossing the lower right quadrant of the map.

Hydrogeological parameters of the SK4 rock types are well known from other areas of the mine. It is planned to extend the existing groundwater flow model to incorporate the SK area in early 2008. Most of the required data are available except for exact information on the depth of the water table. Forty percussion boreholes were drilled for exploration in the SK area in mid-2007. The majority did not intersect water before reaching the final depth of 150 m. Only three boreholes had water strikes at 81, 126 and 135 m below surface respectively. The water table measured in one of the boreholes close to SK4 was 112 m below surface (426 m above mean sea level) in December 2007. This indicates that at least the first 100 m excavation of the SK4 pit is unlikely to intersect the water table and require any dewatering. A deep water table also reduces the potential for groundwater contamination.

**Figure 6.3: Geological Map showing Fault Structures in Red**




Drilling of several boreholes for water level and quality monitoring has recently been completed. Water samples of the new boreholes will be taken in January 2008 and analyses will show the baseline water quality information for the area potentially affected by mine expansion projects. The hydrogeological parameters and water levels will provide the necessary input to include the SK area in the existing three-dimensional groundwater flow model of the mine site. The extended model will be used to simulate the impact of the new open pits on the water table. The output of this model will later be transferred to a geochemical transport model that will identify contamination flow paths, velocities and allow for the effective design of the control measures.

The results of the hydrogeological investigation will be summarized in a report that will form part of Phase 2 SEIA.

### 6.3 Impact Assessment

The first concern in relation to the SK4 pit is the use of dust suppression water that is partly recycled from the water treatment and seepage control systems. The chemistry of the dust suppression water must be known in order to assess its impact on the groundwater in the area. Analyses are available for the three water sources that will supply the Waste 4 pond. Table 6.1 shows the data and a calculation of the expected mixed water composition, as well as the water quality in the SH area. Several monitoring boreholes have been drilled in the SK area, but their water quality results are not yet available. For the time being it is assumed that the water quality is similar to the SH area.

**Table 6.1: Quality of Dust Suppression Water**

| Determinants | Khan River | Ericson Dam | Mine Pond | Mixed Water | Groundwater in SH |
|---|---|---|---|---|---|
| Potassium as K mg/L | 49 | 108 | 32 | 63 | 97 |
| Sodium as Na mg/L | 864 | 2220 | 798 | 1294 | 1582 |
| Calcium as Ca mg/L | 449 | 500 | 301 | 417 | 965 |
| Magnesium as Mg mg/L | 208 | 1721 | 51 | 660 | 359 |
| Ammonia as N mg/L | bdl | 106 | 1.5 | 36 | 0.9 |
| Sulphate as SO4 mg/L | 542 | 9166 | 556 | 3421 | 2173 |
| Chloride as Cl mg/L | 2175 | 2116 | 700 | 1663 | 3594 |
| Alkalinity as CaCO3 mg/L | 210 | 825 | 155 | 397 | 119 |
| Nitrate as NO3 mg/L | 23 | 100 | 328 | 150 | 115 |
| Fluoride as F mg/L | 1.0 | 9.6 | 1.1 | 3.9 | 1.1 |
| pH (Lab) (20℃) | 7.1 | 7.1 | 7.0 | 7.1 | 7.3 |
| Conductivity mS/m (25℃) | 798 | 1775 | 312 | 962 | 1274 |
| TDS mg/L calc. from EC | 5343 | 11893 | 2090 | 6442 | 9881 |
| Manganese mg/L | bdl | 10.4 | bdl | 3.5 | 1.8 |
| Uranium mg/L | 0.13 | 2.81 | bdl | 0.98 | 1.11 |

bdl = below detection limit

Application of the mixed water could lower the concentration of total dissolved solids, potassium, sodium, calcium and chloride in the SK groundwater, whereas the concentration of magnesium, ammonia, sulphate, total alkalinity, nitrate and manganese would increase. Uranium levels are similar in both water types. The severity of this impact depends on the volume of dust suppression water that reaches the groundwater. Observations in the existing open pit show that most of the dust suppression water evaporates shortly after spraying.

Rain water and runoff can be contaminated by contact with exposed uranium ore, muckpiles and rock dumps. Infiltration of contaminated rainwater into the ground can in turn affect the groundwater quality. Uranium, sulphate and nitrate are the main contaminants leached out of this material. They are either carried directly into Dome Gorge and the Khan River or infiltrate to the groundwater, which reaches the river more slowly. This process is very similar to the formation of leachates from waste rock dumps as described in 4.3.

The current water levels are close to the maximum depth of the pit, which is at 430 m above mean sea level. Thus no direct impact of the SK4 pit on the local water table, e g by dewatering, is expected to occur. Underground drainage of infiltrated surface water along the geological strike or along fracture zones may reach Dome Gorge and the Khan River. The water quality impact from the small area of the SK4 pit is expected to be insignificant, but this will be confirmed by modelling in Phase 2 (see 6.2).

In the meantime a preliminary assessment has been made based on site knowledge and professional judgement. Factors that will reduce the risk of surface and groundwater contamination during the first few years of mining are as follows:

- Low rainfall of 30 mm/a on average
- High potential evaporation of 2700 mm/a
- Infiltration only occurs after rainfall exceeding 20 mm
- No major fractures connecting SK4 to the Khan River
- Presence of a seepage control system at the mouth of Dome Gorge

Considering all these factors it is concluded that the risk of water contamination from mining the SK4 pit is low.

### 6.4 Impact Mitigation

Rössing‘s policy is to accept responsibility for the quality of surface and groundwater within the mining grant and for the prevention of mine-induced water quality deterioration in the Khan River downstream of the mine. Groundwater should be preserved in a state as close to natural as possible. As groundwater contamination can be a very slow process with long-term impact a precautionary approach to prevent pollution is more effective and economic than later rehabilitation.

The objective of Rössing’s water quality management strategy is to maintain a suitable groundwater quality for the highest beneficial use to which the groundwater resources or occurrences can presently or potentially be put (“differentiated protection of groundwater resources”). This policy is based on an evaluation of groundwater resources in the mining area. The highest beneficial use is usually human consumption, but this does not apply at Rössing due to the natural salinity of the groundwater. The area around Rössing mine contains no freshwater resources and the only beneficial uses are for industrial and ecological purposes, e g dust suppression and maintaining the natural vegetation, while Khan River groundwater is potentially suitable for agricultural use. The goal of the proposed mitigation measures is to maintain an acceptable water quality for industrial, agricultural and environmental purposes.

As set out in 6.3, the use of dust suppression water will have no significant impact on the local groundwater quality. Mitigation measures will therefore not be required.

To prevent surface water contamination the design of the pit and associated dumps should provide for stormwater drainage into the pit or into a storage trench. Uncontrolled runoff of contaminated rainwater into Dome Gorge must be prevented due to the gorge’s proximity to the Khan River.

The groundwater at SK4 is saline and its only potential use is to maintain the ecology. Since the vegetation will be transplanted or destroyed by mining, there is no beneficial use in the immediate surroundings. Khan River water could however be used for stock watering downstream of the mine or in the Swakop River and must be preserved for this purpose. Should modelling show that there is any risk of contaminant release from the SK4 area, seepage control at the mouth of Dome Gorge has to be upgraded. The current installation consists of one production borehole and is probably not 100% effective in collecting the entire groundwater discharge from Dome Gorge.

It is recommended that a reactive barrier be installed at the toe of the waste rock dump in Dome Gorge. A reactive barrier is a trench backfilled with zero-valent iron and organic material, which reacts with contaminants such as sulphate, uranium and heavy metals. The contaminants are reduced to an immobile form and precipitated within the trench fill. The barrier can be designed according to the level of contamination to be effective for several decades. After mine closure, when all the reactive material has been used up, the trench fill can be removed to a hazardous waste site. A project to construct a pilot reactive barrier in Pinnacle Gorge is currently in progress under the supervision of an expert from Canada.

For impact mitigation in Phase 1 the following measures should be included in the Environmental Management Plan for the SK4 pit:

- Drilling of 5-10 monitoring boreholes
- Monthly water level measurements
- Quarterly water quality analyses of the new boreholes and DG1 at the mouth of Dome Gorge
- Detailed investigation of the impact of any proposed new waste rock dumps.

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14 December 2007