Technical Report

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SMS Nababeep Shaft Water Quality:

Geochemical Baseline Assessment

Prepared for: Sound Mining Solutions (Pty) Ltd

January 2014

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Compiled by RN Hansen

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Notations and terms

Coefficient of variation is the ratio between the standard deviation and the average expressed in percentage terms and is an indication of data variability.

Model is a theoretical construct that begins with a concept (the conceptual model) and might be portrayed mathematically or diagrammatically or physically or by analogy. It is always a simplification, an idealisation, a picture of how we think about some aspect of physical phenomena. In one sense, it is always incorrect, because it is never complete or exact. In another sense it may be correct, because it might be our best understanding or approximation of something at a particular time in history.

Standard deviation (σ) is the sum of the square root of the differences of the mean.

The *quantities of interest* are the quantities of those parameters in the geochemical model output, which are most of interest.

Total dissolved solids (TDS) is a term that expresses the quantity of dissolved material in a sample of water.

Uncertainty is limited (incomplete or imperfect) information about current or future environmental, social, economic, technological, political and institutional conditions, states and outcomes and the implications or consequences of these current, or future conditions, states or outcomes. It can also be defined as the confusion around variation of reality surrounding and optimal model.

LIST OF ABBREVIATIONS

Abbreviation	Description
ABA	Acid Base Accounting
AGES	Africa Geo Environmental Services Gauteng Pty Ltd
AMD	Acid Mine Drainage
AP	Acid production Potential
BPEO	Best Practicable Environmental Option
COV	Coefficient of Variation
DWA	Department of Water Affairs
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMPR	Environmental Management Programme Report
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
LiDAR	Light detection and ranging
MAMSL	Meter Above Mean Sea Level
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MEND	Canadian Mine Environment Neutral Drainage program
mg/ℓ	Milligrams per litre
NAG	Net Acid Generation
NEMA	National Environmental Management Act
NNP	Net Neutralisation Potential
NP	Neutralisation potential
NPR	Neutralisation potential ratio (NP:AP)
NWA	National Water Act
PFS	Pre-Feasibility Study
ppm	Parts per million
QOI	Quantities of interest
REE	Rare earth elements
SANS	South African National Standard
TDS	Total Dissolved Solids
TCLP	Toxicity Characteristic Leaching Procedure
TWQR	Target Water Quality Range
USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
WGS84	World Geodetic System of 1984
wt%	Weight percent
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

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1 INTRODUCTION

Sound Mining, under a current prospecting right, is looking to explore the old copper mine in the Okiep Copper District to determine whether the ore in the mine left from the previous mining activities can be extracted economically. However, the shaft contains water, which needs to be pumped out before exploration can commence.

AGES Gauteng was requested by Sound Mining to conduct a water quality baseline assessment to determine management strategies for the exploration program.

1.1 Project Objectives

The objectives of the project are:

1. Determine the requirements for the dewatering of an existing mine shaft.
2. Determine the water quality and determine possible management options and impact on the downstream environment.

2 SCOPE OF WORK

2.1 Phase A: Site visit, hydrocensus and water quality determination

The purpose of this phase is to determine the downstream environment in terms of receptors and sample the shaft water:

1. Review of existing groundwater and geological data and reports.
2. Site visit and hydrocensus
3. Sampling and analysis of surface water and groundwater to determine the baseline conditions
4. Compilation of GIS maps
5. Hydrogeological data interpretation and reporting

2.2 Phase B: Regulatory requirements

The purpose of this phase is to verify what regulatory requirements would be applicable:

1. Review of regulatory requirements in terms of NWA, MRPDA, NEMA, etc. for the dewatering or testing of the shaft.
2. Specialist legal opinion from EdwardNathanSonnebergs (ENS)

3 METHODOLOGY

Samples were collected from the water in the Nababeep shaft as well as from three surface water locations and one groundwater location. The town of Nababeep receives its water from the town of Okiep and therefore does not have any groundwater abstraction points. The boreholes that could be sourced are private. The borehole for which access could be acquired was sampled for a groundwater baseline sample.

The samples were analysed via ICP-MS at the accredited laboratory Setpoint.

4 LOCATION

The study area is located 6 km north of the town of Nababeep, in the Northern Cape province (Figure 5-1).

4.1 Climate and Rainfall

The project area is situated in a semi-arid region with a mean annual precipitation (MAP) of 153 mm/a and a mean annual evaporation (MAE) of 2 201 mm/a (WR2005). The area falls in a winter rainfall region, with most of the precipitation occurring in the months from May to August. The driest months coincide with the hottest and are from December to March.

4.2 Topography and drainage

The project area consists of a hilly landscape. The peak elevations are around 800 to 1000 mamsl and the valleys around 730 mamsl. The hills are formed by rounded granite outcrop. Due to the relatively low MAP, all drainage channels in the area are non-perennial, sand-filled streams. Occasionally thorn trees and other flora can be seen in the stream beds.

The study area falls in the F30E quaternary catchment, which falls in the Lower Orange River water management area. The drainage channels in the area drain in a westerly direction, towards the Atlantic Ocean.

5 GEOLOGICAL CONTEXT

The study area is dominated by the intrusive Concordia Granite rocks, belonging to the Spektakel Suite (Figure 5-2). The Concordia granite consists of quartz, microcline and plagioclase as the major mineral constituents. Biotite and garnet occurs as secondary minerals (Cornell et al., 2006).

The copper sulphide deposits are hosted in the mafic to ultramafic rocks of the Koperberg Suite. The following description relies heavily on the work of Lombaard et al. (1986).

The Koperberg suite of rocks consists mostly of diotrite and anorthosite. Mineralogically these rocks contain plagioclase, ranging from andesine to labradorite and hypersthene as major mineral components. Secondary minerals are biotite, phlogopite and magnetite. Trace minerals are hornblende, quartz, ilmenite, spinel and hematite. The most important ore minerals are chalcopyrite and bornite. Chalcocite occurs exclusively as an alteration product of bornite. Pyrrhotite and pyrite are important in specific deposits, although small amounts of pyrite are ubiquitous throughout the copper district.

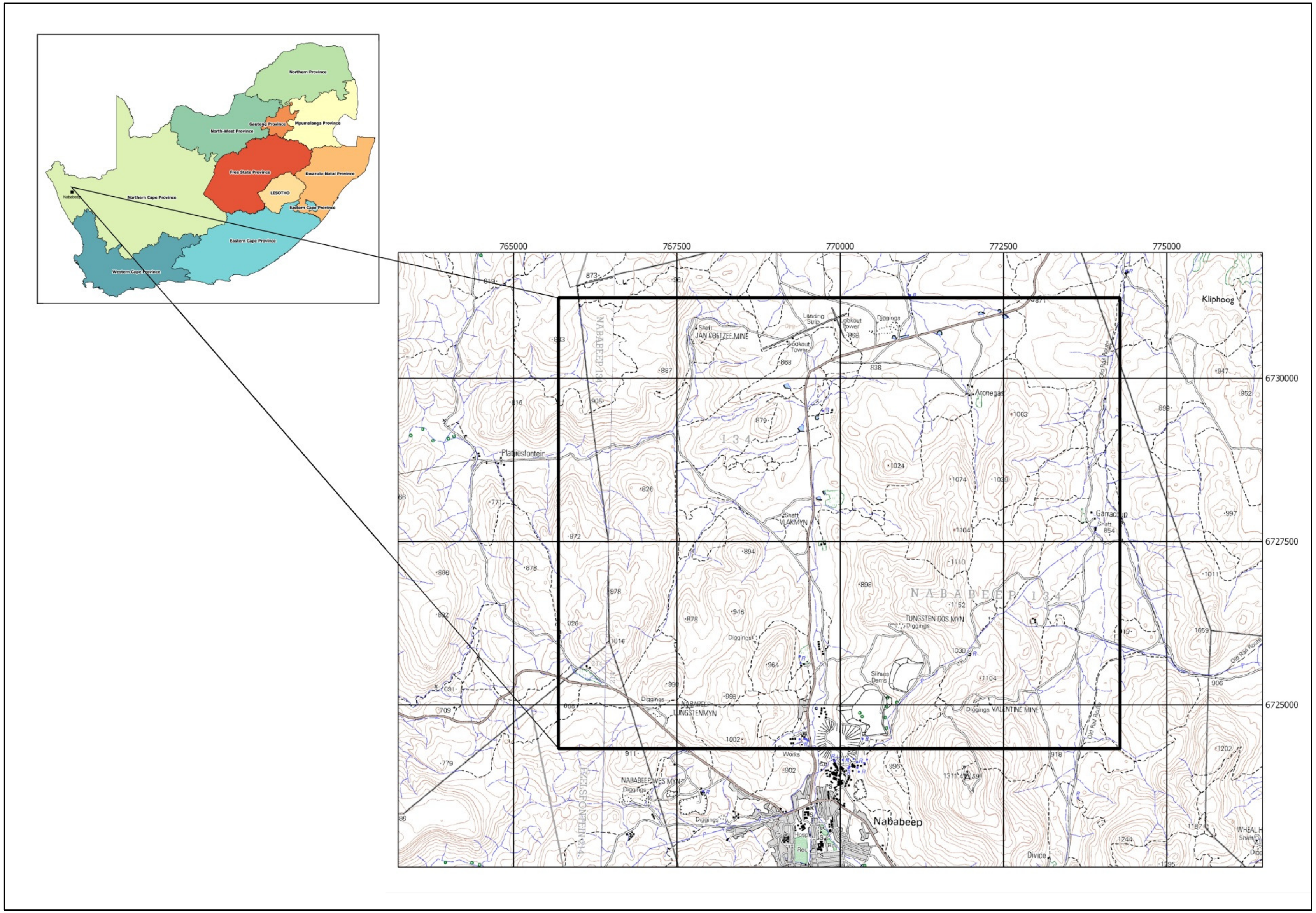

Figure 5-1 Project location

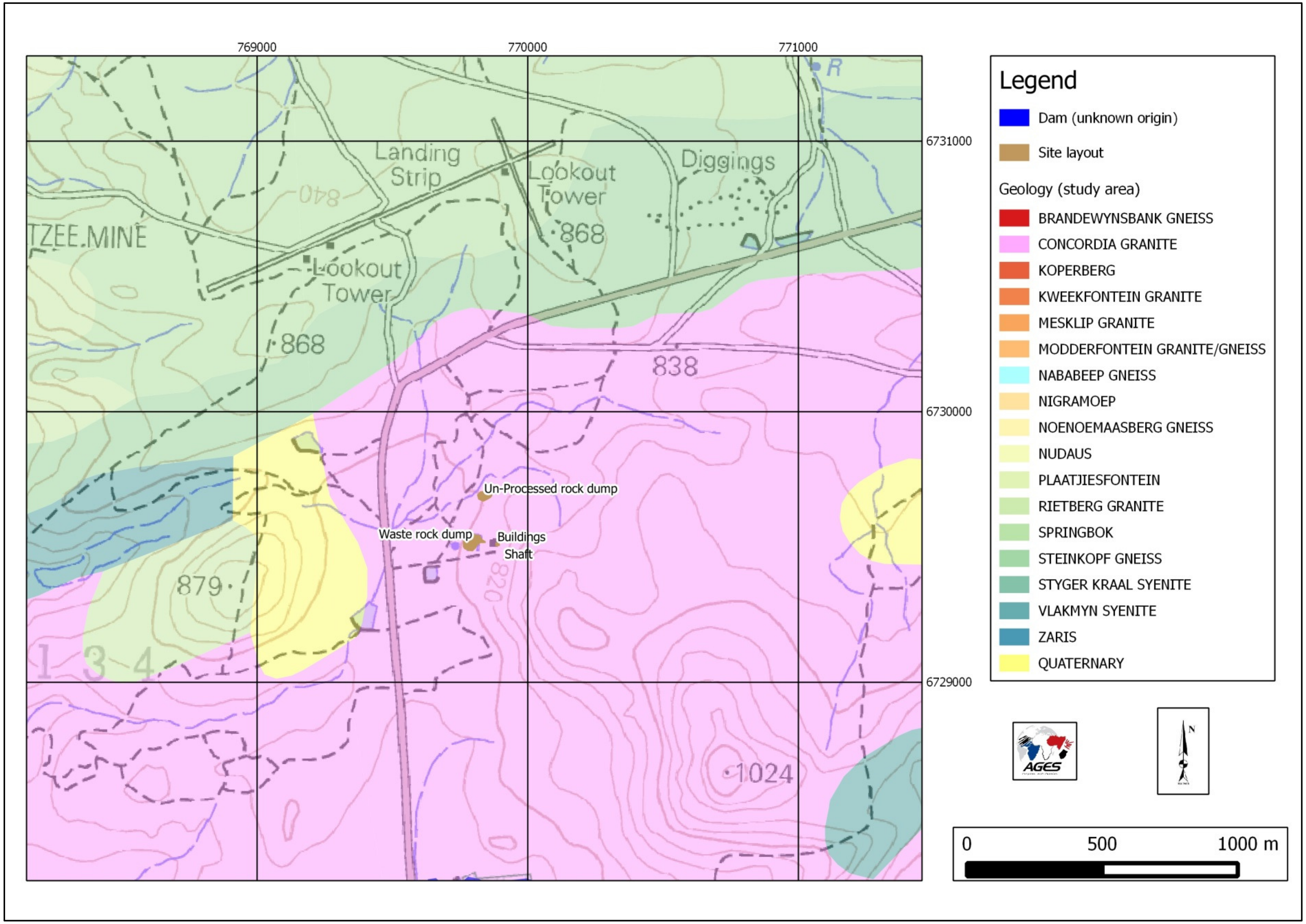

Figure 5-2 Study area geology

Other sulphides which have been recorded in trace amounts throughout the copper district are pentlandite, sphalerite, galena, valleriite, millerite, niccolite, molybdenite, linnaeite, melonite, sylvanite, hessite, coloradoite and tetradymite.

6 INTERPRETATION OF LABORATORY DATA

6.1 Sample analysis results

Samples were collected from the shaft, in which the water level is 64.5 m below ground level, from one surface water point downstream from the Nababeep shaft (SW1), one surface water samples upstream from sampling point SW1 (SW3) and a borehole groundwater sample on the farm Jakkalswater (Figure 6-1). The laboratory results were compared to the SANS (2011) drinking water quality standards as well as to Department of Water Affairs water quality data for the F30E quaternary catchment (Table 6-2). The legend to the SANS assessment is shown in Table 6-1.

Table 6-1 SANS water quality assessment legend

Aesthetic	Determinand that taints water with respect to taste, odour and colour and that does not pose an unacceptable health risk if present at concentration values exceeding the numerical limits specified.
Operational	Determinand that is essential for assessing the efficient operation of treatment systems and risks to infrastructure.
Acute Health - 1	Routinely quantifiable determinand that poses an immediate health risk if consumed with water at concentration values exceeding the numerical limits specified.
Acute Health - 2	Determinand that is presently not easily quantifiable and lacks infomration pertaining to viability and human infectivity which, however, does pose immediate unacceptable health risks if consumed with water at concentration values exceeding the numerical limits specified.
Chronic Health	Determinand that poses an unacceptable health risk if ingested over an extended period if present at concentration values exceeding the numerical limits specified.
(orange)	Exceeds Acute health - 1, Acute health - 2 and Chronic health guideline values
(yellow)	Exceeds only Operational and Aesthetic guideline values

Table 6-2 Water quality comparison

Parameters	Abbreviations	Units	SANS	Risk	Nababeep shaft	SW1	SW3	Jakkalswater	F30E Quaternary Catchment	
									Average	95th Percentile
pH	pH	pH units	5 - 9.7	Operational	8.4	7.1	7.6	6.9	7.57	6.95
Electrical conductivity	EC	mS/m @ 25°C	n.g.v.		116	741	550	54	n.d.	n.d.
Total dissolved solids	TDS	mg/ℓ @ 180°C	n.g.v.		613	5900	3993	330	n.d.	n.d.
Total alkalinity	T Alk	mg/ℓ $CaCO_3$	n.g.v.		63	122	222	193	104.17	193.62
Bicarbonate	HCO_3	mg/ℓ	n.g.v.		76.86	148.84	270.84	235.46	n.d.	n.d.
Carbonate	CO_3	mg/ℓ	n.g.v.		<6	<6	<6	<6	n.d.	n.d.
Chloride	Cl	mg/ℓ	300	Aesthetic	219	1365	786	46	421.25	1353.22
Fluoride	F	mg/ℓ	1.5	Chronic health	1.7	2.9	1.8	<0.1	1.44	3.74
Nitrate	NO_3	mg/ℓ	50	Acute health-1	<0.4	2.2	27.0	<0.4	10.4	33.92
Orthophosphate	PO_4	mg/ℓ	n.g.v.		0.3	0.6	4.3	0.3	0.06	0.11
Sulphate	SO_4	mg/ℓ	500	Acute health-1	101	3174	2864	6	176.3	389.78
Ammonia	NH_4	mg/ℓ	1.5	Aesthetic	2.1	4.3	6.7	12.6	0.08	0.27
Chromium (hexavalent)	Cr(VI)	mg/ℓ	0.05	Chronic health	<0.005	<0.005	<0.005	<0.005	n.d.	n.d.
Aluminium	Al	mg/ℓ	n.g.v.		<0.15	<0.15	<0.15	<0.15	n.d.	n.d.
Boron	B	mg/ℓ	n.g.v.		<0.35	<0.35	<0.35	<0.35	n.d.	n.d.
Calcium	Ca	mg/ℓ	n.g.v.		14.63	500	380	24	104.49	224.98
Iron	Fe	mg/ℓ	2	Chronic health	<0.10	0.4	<0.10	16.4	n.d.	n.d.
Magnesium	Mg	mg/ℓ	n.g.v.		0.995	309.885	502.34	19.4	n.d.	n.d.
Potassium	K	mg/ℓ	n.g.v.		28.02	111.04	135.74	6.67	5.11	14.9
Silicon	Si	mg/ℓ	n.g.v.		1.13	3.55	8.37	18.7	n.d.	n.d.
Sodium	Na	mg/ℓ	200	Aesthetic	227	937.56	742.62	41.9	202.87	589.78
Telerium	Te	mg/ℓ	n.g.v.		<0.04	<0.04	<0.04	<0.04	n.d.	n.d.
Zinc	Zn	mg/ℓ	5	Aesthetic	<0.06	0.06	<0.06	<0.06	n.d.	n.d.
Antimony	Sb	µg/ℓ	20	Chronic health	<0.50	<0.50	<0.50	<0.50	n.d.	n.d.
Arsenic	As	µg/ℓ	10	Chronic health	3.03	7.44	7.92	0.65	n.d.	n.d.
Cadmium	Cd	µg/ℓ	3	Chronic health	<0.10	<0.10	<0.10	<0.10	n.d.	n.d.
Chromium (trivalent)	Cr(III)	µg/ℓ	n.g.v.		<3.00	<3.00	<3.00	<3.00	n.d.	n.d.
Chromium (total)	Cr(T)	µg/ℓ	50	Chronic health	<3.00	<3.00	<3.00	<3.00	n.d.	n.d.
Cobalt	Co	µg/ℓ	500	Chronic health	<0.20	4.77	1.28	0.278	n.d.	n.d.
Copper	Cu	µg/ℓ	2000	Chronic health	8.15	8.57	22	1.29	n.d.	n.d.
Lead	Pb	µg/ℓ	10	Chronic health	<1.00	<1.00	<1.00	1.21	n.d.	n.d.
Manganese	Mn	µg/ℓ	500	Chronic health	12.3	9125	87.1	204	n.d.	n.d.
Mercury	Hg	µg/ℓ	6	Chronic health	<0.50	<0.50	0.498	<0.50	n.d.	n.d.
Molybdenum	Mo	µg/ℓ	n.g.v.		<1.00	9.67	23.1	1.8	n.d.	n.d.
Nickel	Ni	µg/ℓ	70	Chronic health	<1.00	21.6	4.6	11.4	n.d.	n.d.
Selenium	Se	µg/ℓ	10	Chronic health	4.42	3.56	12.4	<2.00	n.d.	n.d.
Thorium	Th	µg/ℓ	n.g.v.		<0.20	<0.20	<0.20	<0.20	n.d.	n.d.
Uranium	U	µg/ℓ	15	Chronic health	1.81	16.5	5.05	0.427	n.d.	n.d.
Vanadium	V	µg/ℓ	200	Chronic health	4.1	5.5	8.42	0.37	n.d.	n.d.

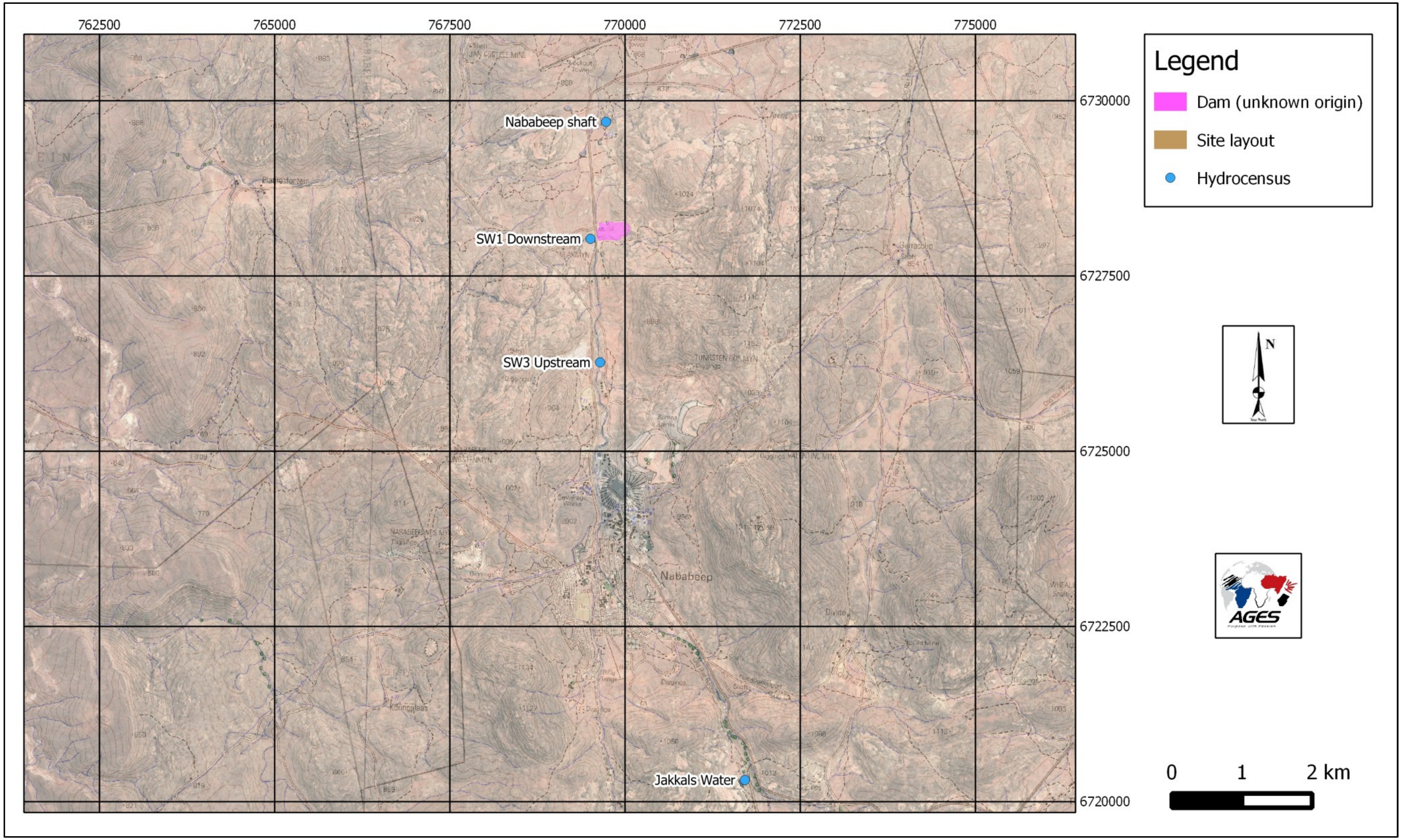

Figure 6-1 Nababeep sample locations

6.1.1 Shaft water quality

The results show that the shaft water sample has a fluoride concentration exceeding the SANS chronic health guideline value. The concentrations of ammonia and sodium exceed the aesthetic guideline values.

6.1.2 Surface water quality

The chronic health guideline values are exceeded for fluoride, sulphate, manganese and uranium in surface water sample SW1 and for fluoride, sulphate and selenium in surface water sample SW3. The aesthetic guideline values for ammonia, chloride and sodium are exceeded in both surface water samples.

6.1.3 Local groundwater background

The chronic health guideline value for iron and the aesthetic guideline of ammonia are exceeded in the Jakkalswater groundwater.

6.1.4 Regional groundwater background

The F30E catchment water quality monitoring data from the Department of Water Affairs shows that the catchment groundwater exceeds the aesthetic guideline values if sodium and chloride on average and that the 95^{th} percentile value exceeds the chronic health guideline value for fluoride.

The fact that the 95^{th} percentile concentration for fluoride in the F30E catchment groundwater exceeds the SANS chronic health guideline value, implies that fluoride is slightly enriched regionally in the F30E catchment groundwater.

6.2 Implications of water quality assessment results

The results indicate that the water in quality of the water quality in the shaft is comparable to baseline groundwater conditions and significantly better quality than the local surface water.

The sampling point SW1 is located immediately downstream from a constructed dam. The origins of the dam are unknown, but high dissolved solid effluent is evidenced to seep from this brine pond (Figure 6-2 and Figure 6-3). This seepage ends up in the natural drainage channel and is reflected in the SW1 water quality results. The concentrations of sulphate, chloride, sodium, fluoride, manganese and uranium exceed the SANS drinking water quality guideline values. The drainage channel of which SW1 is a representative sample joins up downstream with the drainage channel located to the west of the Nababeep shaft site.

Figure 6-2 Brine pond with salt crust (view towards the northeast)

Figure 6-3 View to the southwest (downstream) of the brine pond

This implies that the water from the shaft would add a significant dilution capacity to the impacted drainage channel thereby providing a measure of mitigation for the deleteriously impacted drainage channel.

6.3 Geochemical speciation modelling

The laboratory results of the Nababeep shaft water sample was used to develop a geochemical speciation model to better understand the hydrochemical dynamics. These dynamics aid in the choice of the correct management decisions regarding the shaft water pump and discharge scenario.

When a speciation model is run using the laboratory results, the model shows that the water is in equilibrium with various minerals, mostly primary and secondary phosphates. Although this is most certainly possible, it does not correlate with the expected mineralogy of the Koperberg suite, host to the copper sulphide paragenesis.

The Nababeep shaft water contains 2.1 mg/ℓ ammonia, but no nitrate. Ammonia and nitrate form a redox pair. Ammonia is oxidised to nitrate over time by the presence of oxygen. An oxygen-pH activity diagram for dissolved nitrogen indicates that the ammonia stability field is at low oxygen concentrations (Figure 6-4).

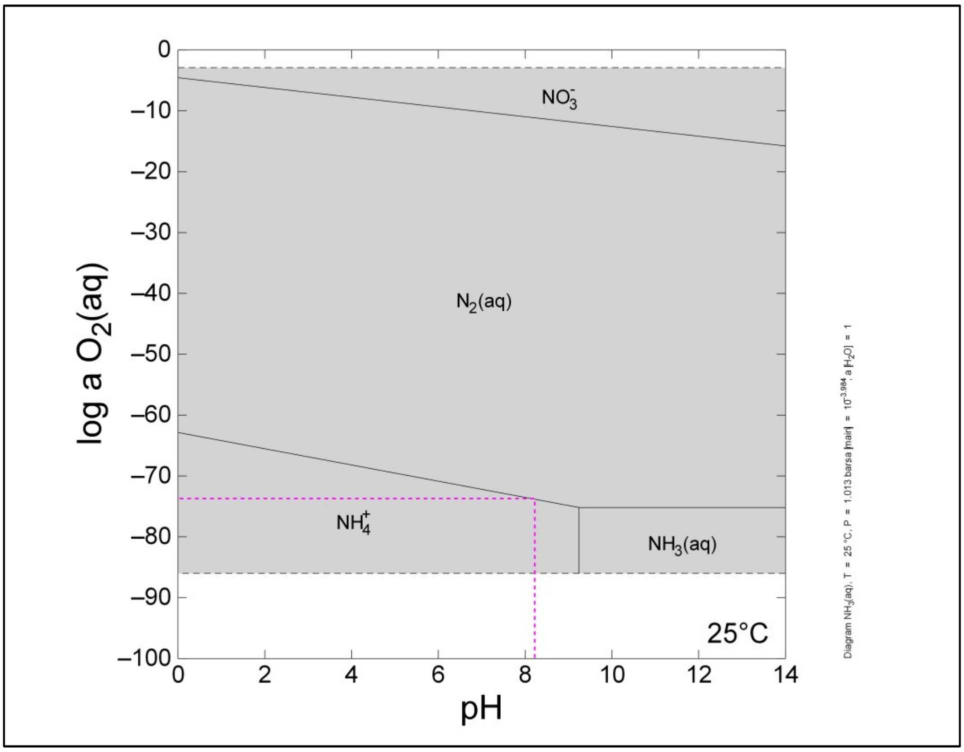

Figure 6-4 Nitrogen stability diagram

The diagram shows that the maximum amount of oxygen (log activity) at the measured pH of the Nababeep shaft water sample of 8.4, is around -74. When this value is input into the speciation model, the model shows that the water is in equilibrium with a range of primary phosphates, but also with a range of sulphides, such as sphalerite, galena, chalcocite and covellite. These results correlate with the known copper ore mineralogy.

These model results show that the Nababeep shaft water is most likely reducing. This is indicative that the geochemical environment of the Nababeep shaft is reducing. Sulphide minerals are unstable in the presence of oxygen, but the reaction rates are relatively slow. This implies that there will most probably be enough time to dewater the underground workings without any significant impact on water quality. However, the dewatering may cause the ingress of oxygen into the system, especially when mining commences, thereby resulting in a slow decrease of water quality with time. Therefore it is recommended that after dewatering, if exploration shows that further work is warranted, that subsequent dewatered mine water be stored in a lined dam, thereby preventing potential contamination of the local groundwater sources with water containing potential contaminants.

7 CONCLUSIONS

The following conclusions can be drawn from this study:

1. The Nababeep Flatmine mine water quality is comparable to groundwater baseline and is better quality than the drainage channel water. Therefore the mine water can be safely discharged into the local stream system.
2. The mine water is most probably reducing and may slowly deteriorate with time. However, the mine dewatering during the exploration phase of the project will occur sufficiently rapidly so that water qualities are not expected to significantly decrease during the exploration phase of the project.
3. From a geochemical perspective, the mine water can be safely discharged during the prospecting phase of the project into the local stream without negative impacts to the local groundwater and surface water systems.

8 RECOMMENDATIONS

The following recommendations follow this study:

1. Water monitoring should form part of the exploration phase of the project on a monthly basis to evaluate the potential change in water quality with time.
2. In the event of mining commencing, the mine water will need to be monitored on a monthly basis and if water quality deterioration is observed the dewatered mine water will need to be fed into a lined process water storage facility and re-used in the mine reticulation circuit.

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