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5. Environmental Baseline

5.1. Introduction

This chapter describes the environmental baseline of the KMT Concession Area (including topography, soils, land capability, land use, climate and air quality, surface and ground water and noise and fauna and flora) prior to the commencement of the proposed Kingamyambo Musonoi Tailings Project mining activities. It should be borne in mind that this is not a green field site but is in an area which bears the legacy of around 100 years of mining activity.

Kolwezi town and the mines associated with it are located approximately 240 km west of Lubumbashi, the capital of the Katanga province of the DRC, at 10°40’ latitude and 25°30’ longitude. As a result of mining and metallurgical activities, the area around the town of Kolwezi today has numerous open pits, waste rock, ore and slag dumps, tailings dams, concentrators and other mining-related infrastructure, which has led to extensive impacts on the environment.

The baseline descriptions in the sections below also contain details of the issues identified as possible liabilities during an audit of the site carried out by SRK before the ESIA process began and is reported in the Environmental Audit and Scoping Study (EASS). The quantification of these liabilities are included in the baseline description for each biophysical aspect of the environment. These potential liabilities, which arise from the legacy of previous industrial land uses, are identified in Table 5-1 below. Further details on the existing environmental impacts identified during the audit have been collected during the baseline studies and in many cases the data obtained underlines the existing degraded condition of extensive areas of the KMT Concession. This is emphasised in the text where appropriate, such as in the discussion of groundwater quality monitoring results.

5.2. Environmental liabilities

An Environmental Audit and Scoping Study (EASS) for the Kingamyambo Musonoi Tailings Project was prepared by SRK in January 2004. The work comprised a review of preliminary information supplied by KMT, followed by a field visit by a small team of specialists in the company of KMT representatives. The methodology for the audit was based on SRK audit guidelines and previous experience, good international practice, particularly with regard to the requirements of financial institutions, and the requirements of KMT. The audit concentrated only on those aspects considered to directly or indirectly impact the new project.

The environmental audit comprised the field inspection of the existing mine and plant infrastructures including ancillary facilities such as water disposal and tailings, the taking of water quality readings using field meters, field observation of ecological features and natural history, collections of plant species, examination of records and facilities, and interviews with site personnel. The proposed plant and tailings sites for the KMT operations were broadly evaluated in terms of potential impacts these facilities could have on the environment in the future.

Figure 5-1 illustrates the finalised KMT concession area, together with the boundary in force at the time of Phase I of this study. This figure also depicts the locations of other environmental concerns that could impact on or be impacted by the KMT.

The findings of the physical environment audit are summarised in Table 5-1 which considers the audit findings, their implications with regard to existing liabilities, and the way these issues have been dealt with during baseline studies. The areas investigated during the audit were those that were considered, at the time, to have the potential to affect the KMT development proposals, as listed below. Figure 5.1 shows the location of these areas in relation to the KMT concession area.

Within indicative concession area:

- Kingamyambo tailings impoundment
- Musonoi River tailings impoundment
- Proposed KMT tailing dam sites
- Proposed KMT processing plant site

Outside indicative Concession Area:

- UZK Zinc Plant
- Kolwezi Cu/Co Concentrator
- Kolwezi pit lake and township
- KOV pit
- Sulfide Tailings area
- Waste rock dumps
- Footprint of a uranium stockpile that has since been removed.

Table 5-1: Summary of Findings of the Physical Environmental Audit

SITE DESCRIPTION	EXISTING ENVIRONMENTAL IMPACTS	BASELINE COVERAGE
KINGAMYAMBO TAILINGS FACILITY		
The Kingamyambo Tailings Facility is a conventional dam that contains 42.3 Mt of oxide tailings, over an area of 2 km x 1.5 km and height of 20 m.		
The tailings are saturated below the surface, and standing water is ponded in the western corner.	Limited contamination of the underlying main Roan aquifer and the shallow phreatic weathered aquifer may have occurred from localised mounding and seepage from the saturated tailings.	Ground water and surface water quality monitoring programme initiated in July 2004 does indicate contamination of groundwater (BH2). Surface water impacts are evident (SW05) but contamination is also contributed from the KOV pit and Kolwezi plant (See Sections 0 and 0 in this chapter).
The Sulfide Tailings could be a source of acid rock drainage (ARD) and leaching of heavy metals to the groundwater and surface water.	Runoff of contaminated water to the Musonoi is possible if there are no stormwater controls around the tailings, or there is no means to treat ARD.	Acid Base Accounting (ABA) carried out on Musonoi, Kingamyambo and sulfide tailings samples indicates that only the UZK tailings has significant acid generating potential.
Field measurements of runoff and seepage from the Tailings Dam confirm the neutral pH and low TDS of 70 mg/l		Ground water and surface water quality monitoring programme initiated in July 2004 indicates neutral pH but TDS of 270 mg/l and 310 mg/l in groundwater and surface water, respectively (See Sections 0 and 0 in this chapter).
Water and wind erosion of the dam walls is evident. Dust emissions occur from May to October, but monitoring data has not been analysed, so the impact has not been quantified.	Contamination of soil and water from dust deposition and surface runoff.	Data from dust monitoring network analysed and reported. Modelling also carried out (See Sections 0 and 0 in this chapter).
Surface runoff from the tailings dam is uncontrolled towards the Musonoi River as no stormwater controls are in place.	Contamination of the Musonoi River with tailings material and leachates.	Project design requires cut off drains to divert clean water away from the tailings dam and storm water management around

SITE DESCRIPTION	EXISTING ENVIRONMENTAL IMPACTS	BASELINE COVERAGE
		the dam itself.
MUSONOI RIVER TAILINGS		
The Musonoi River Tailings consists of 70.5 Mt of tailings deposited in the Musonoi River valley, retained by the Kasobantu Dam wall. The footprint of the tailings is 11 kmx1.5 km with a	Extensive losses of water are encountered along the river where the Musonoi tailings are situated due to reversal of the natural hydraulic gradient	A water balance has been set up for the Musonoi tailings dam for different scenarios, in monthly time steps using the period 1953 to 2002 (See Section 5.11 in this chapter).
Silting of the Musonoi River has occurred.	Riverine ecology in this area is largely destroyed.	Aquatic macro invertebrate survey carried out (See Sections 5.14 in this chapter).
Whilst the pH of the Musonoi River is neutral (7.8) within the concession area, the TDS (total dissolved solids) increases from 120 mg/l upgradient of all contaminant sources, to 330 mg/l. at the start of the concession area, remaining relatively constant to the Nzilo spillway	The Kakifuluwe River has elevated TDS (>300 mg/l) due to the reversed flow from the Musonoi, indicating an existing impact. The reversed flow decants into the groundwater via a karst system. The increased salt load has impacted on the groundwater quality from this point source of contamination.	Ground water and surface water quality monitoring programme initiated in July 2004 for all major aniomns and cations and heavy metals (See Sections 0 and 0 in this chapter).
The Sulfide Tailings could be a source of acid rock drainage (ARD) and leaching of heavy metals to the groundwater and surface water.	Runoff of contaminated water to the Musonoi is possible if there are no stormwater controls around the tailings, or there is no means to treat ARD.	Acid Base Accounting (ABA) carried out on Musonoi, Kingamyambo and sulfide tailings samples indicates that only the UZK tailings has significant acid generating potential. (See Section 3.2 especially Table 3.4)
The anthropogenic elevation of the surface water/groundwater interface has resulted in the formation of artificial wetlands and springs, which are used by villagers as a water supply.		Hydrological survey undertaken and development of conceptual hydro geological model, including a water balance for the hydro geological system (See Sections 5.9 and 5.11 in this chapter).
Flow in the Kakifuluwe River has been reversed due to silting of the outflow.	An artificial wetland has been created.	Hydrological survey undertaken and development of conceptual hydro geological model, including a water balance for the hydro geological system (See Sections 5.9 and 5.11 in this chapter).
Black staining of the rocks at the Kasobantu spillway was observed.	The black staining at the Kasobantu spillway, confirmed as an iron manganese oxide precipitating from solution in the Kasobantu Dam,) is an indication that heavy metals may be transported in solution, in spite of neutral pH.	Ground water and surface water quality monitoring programme initiated in July 2004 indicates metal levels in surface water above WHO guidelines for iron, manganese, lead, zinc, aluminium and antimony. (Refer to Sections 0 and 0 in this chapter).
An unlined canal was constructed to supply water from Kasobantu to the Nzilo Lake and Hydroelectric Scheme and is still in operation. The date of commissioning is not known.		
The Kasobantu Dam wall was breached in 1999, and seepage from the tailings dams decanted to the Musonoi River. The dam wall now appears to be in a stable condition.	Contamination of the Musonoi River. Downstream of the dam with tailings material and leachates.	Surface water quality monitoring programme initiated at the Nzilo spillway in July 2004 for all major anions and cations and heavy metals. Results indicate elevated manganese and lead. Aquatic macro invertebrate survey carried out (See Sections 0 and 5.14 in this chapter).
The Kasobantu Dam wall was breached in 1999, and seepage from the tailings dams decanted to the Musonoi River.	Contamination of the Musonoi River. Downstream of the dam with tailings material and	Surface water quality monitoring programme initiated at the Nzilo spillway in July 2004 for all major anions and

SITE DESCRIPTION	EXISTING ENVIRONMENTAL IMPACTS	BASELINE COVERAGE
The dam wall now appears to be in a stable condition.	leachates.	cations and heavy metals. Results indicate elevated manganese and lead. Aquatic macro invertebrate survey carried out. (See Sections 0 and 5.14 in this chapter).
The dry tailings beaches are exposed with no wind protection. They are sprayed with water to control dust but at the time of the site visit were dry.	Dust generation from dry surface of tailings during the windy season (May to October). Potential contamination of soils and surface water upon deposition.	Data from dust monitoring network analysed and reported. Modelling also carried out (See Section 0).
UZK ZINC PLANT		
Zinc pellets originating from the Kipushi area are processed further at this plant. It is currently not operating at full capacity, treating only 120 t/day instead of the 5000 t/day processed in the past.		
The plant process consists of 4 extractions aimed at recovering zinc, germanium, arsenic, lead, copper, cadmium and cobalt.	Contaminated seepage due to hydraulic loading of the tailings, leached into the underlying shallow phreatic aquifer.	Groundwater quality monitoring at the plant (BH04) initiated in January 2005 for all major anions and cations and heavy metals. BH4 is the most contaminated borehole in the area (See Section 0). Soil samples collected to determine existing historical contamination (See Section 0).
Tailings with high concentrations of Zn, Pb, As, Cu, Cd from the final extraction are discharged into a series of unlined dams on the banks of the Musonoi River.	Contamination of the Musonoi River and the aquatic environment due to the acidic plant effluent and contamination from the breached tailings dams. The iron manganese oxide causing black staining of the rocks in the Kasobantu spillway could be originating from this source.	Surface water quality monitoring at the plant (SW04) initiated in July 2004 for all major anions and cations and heavy metals. SW04 is the most contaminated surface water site along the Musonoi River and its tributaries. .Aquatic macro invertebrate survey carried out (See Sections0, 0 and 5.14).
At least two unlined canals with acidic (pH 4) plant effluent discharge into the Musonoi River. The TDS is >5000 mg/l consisting presumably of sulfate and heavy metals.	Contamination of Musonoi River.	Ground water and surface water quality monitoring programme initiated in July 2004 for all major anions and cations and heavy metals. SW04, downstream of the plant indicates neutral pH, TDS ranging from 50 to 4900 mg/l, sulfate from 2.5 – 2700 mg/l and elevated heavy metals. Aquatic macro invertebrate survey carried out (See Sections 0, 0 and 5.14).
The dry tailings surface are exposed with no wind protection	Dust generation from dry surface of tailings during the windy season (May to October). Potential contamination of soils and surface water upon deposition.	Data from dust monitoring network analysed and reported. Modelling also carried out (See Sections 0 and 0).
KOLWEZI CU/CO CONCENTRATOR		
High grade ore from the KOV pit and other nearby mines has been processed at this facility since 1952.		
Poor housekeeping at the KZC plant (leaking palm oil containers, diesel) is evident and the plant and storm water controls are generally in a state of disrepair.	Contamination of Musonoi River and shallow aquifer with sulfates, flocculants, diesel, and possibly solvents is likely to have occurred.	Ground water and surface water quality monitoring programme initiated in July 2004 for all major anions and cations and heavy metals. Monitoring for organics has been undertaken but is not part of the routine monitoring. Borehole P55, near the plant, and SW5, downstream of the plant on the Musonoi, indicate TDS values > 300

SITE DESCRIPTION	EXISTING ENVIRONMENTAL IMPACTS	BASELINE COVERAGE
		mg/ but no phenols, semi-volatiles or volatile organics were detected in the KZC concentrator discharge (See Sections 0 and 0). Soil samples collected to determine existing historical contamination (See Section 0)
Overflows of tailings (oxides and Sulfides) from the concentrator (pH 7) are currently discharged via a pipe directly into the Musonoi River upstream of the KMT concession area. The plant is only semi-operational and currently only 2000t/day is decanted into the Musonoi River.	Contamination of Musonoi River with tailings material and leachates	Ground water and surface water quality monitoring programme initiated in July 2004 indicates an increase in TDS from 120 mg/l upstream of mining activity on the Musonoi River to 320 mg/l at the start of the concession area (See Sections 0 and 0).
URANIUM STOCKPILE		
A Uranium stockpile did exist in the past at a location in close proximity to the Kingamyambo Tailings concession area.	Radioactive contamination of the soil beneath the footprint is likely. If mobile daughter compounds are present, they could have leached into the shallow groundwater. Airborne emissions are also possible during the windy season.	Radiation survey carried out at site and risks to site users reported. Uranium and thorium are included in the routine water quality monitoring programme. No uranium or thorium was detected except for trace levels of uranium in the KOV pit discharge (See Section 0).
The footprint of the Uranium stockpile is not known. The bulk of the Uranium has been removed but radioactive parent and daughter compounds may persist in the soil and shallow groundwater.	As this site is in close proximity to the Musonoi River, baseflow to the River could be contaminated.	Radiation survey carried out at site and risks to site users reported along the Musonoi River downstream of the KOV pit discharge. These values were below the WHO Guidelines (See Section 0).
KOLWEZI TOWN AND PIT LAKES		
The Kolwezi town and pit lakes are located in close proximity to the Musonoi River.	Contamination of the groundwater from the pit lake is unlikely due to the buffering capacity of the host rocks.	Not monitored.
Septic tanks overflow directly into the drainage system, which is in disrepair. Stormwater (including untreated sewage) flows directly or indirectly into the Musonoi River.	Waterborne diseases are a major concern to downstream water users.	No microbiological monitoring on the Musonoi River is undertaken. Increases in nitrate downstream of sewage inflows are slight (1.2 – 1.8 mg/l).
Kolwezi pit is flooded but overtopping is unlikely because the water level is at least 50-100 m below ground level. The impounded water in the pit lake is a source of recharge to the underlying aquifer.		
Industrial waste (disused transformers, scrap iron) was observed near the pit.	Leaking transformers near the pit are a potential source of contaminants to the shallow groundwater.	Monitoring for organics has been undertaken but is not part of the routine monitoring programme. No phenols, semi-volatiles or volatile organics were detected in the Kolwezi town discharge
KOV PIT		
The KOV and nearby Kamoto mines are currently the only mines semi-operational in the Kolwezi area.	Groundwater pumped from the pit into the Musonoi River contributes to contaminant levels in the river.	Ground water and surface water quality monitoring programme initiated in July 2004 indicate a TDS of 600 mg/l in the KOV, contributing to the increase in TDS from 120 mg/l upstream of mining activity on the Musonoi River to 320 mg/l at the start of the concession area (See Sections 0 and 0).

SITE DESCRIPTION	EXISTING ENVIRONMENTAL IMPACTS	BASELINE COVERAGE
The KOV opencast mine is partially flooded, a situation that is deteriorating as only 3 out of 7 dewatering boreholes are currently in operation The abstracted water is the potable water supply for the Kolwezi town.	The abstraction of groundwater for at least 50 years of mining has resulted in the drawdown of the regional water table of up to 200 m in the vicinity of the pit perimeters.	Water level measurements were taken as part of the hydro geological investigation in order to define the piezometric surface of the regional aquifer within the concession area (See Section 0).
Water from sumps within the pit is pumped to the Musonoi River upstream of the Kingamyambo Concession area. The quality is good with pH 7 and TDS slightly elevated at 600-800 mg/l showing minor impact due to mining activities.		Ground water and surface water quality monitoring programme initiated in July 2004 (See Sections 0 and 0).
SULFIDE TAILINGS		
Little information was obtained on the Sulfide tailings dump which originated from the processing of Sulfide ores at the Kolwezi Concentrator. It was not audited during the site visit.	Seepage may have contaminated the shallow weathered aquifer. The deeper Roan aquifer should be protected by the relatively impermeable RGS formation which underlies the tailings deposit. However, hydraulic connectivity may exist between these aquifers due to faulting and fracturing.	Ground water and surface water quality monitoring programme initiated in July 2004 for all major anions and cations and heavy metals indicates TDS levels of 550 mg/l in groundwater (BHP2UZK) and 330 mg/l in the Musonoi River at the start of the concession area (downstream of Sulfide tailings). (See Sections 0 and 0).
The Sulfide Tailings could be a source of acid rock drainage (ARD) and leaching of heavy metals to the groundwater and surface water.	Runoff of contaminated water to the Musonoi is possible if there are no stormwater controls around the tailings, or there is no means to treat ARD.	Acid Base Accounting (ABA) carried out on Musonoi, Kingamyambo and sulfide tailings samples indicates that only the UZK tailings has significant acid generating potential.
The Sulfide ore could be a source of Pb, Ge, and Cd depending on the mineralogy of the Sulfides and ARD.	Dust generation from dry surface of tailings during the windy season (May to October). Potential contamination of soils and surface water upon deposition.	Data from dust monitoring network analysed and reported. Modelling also carried out (See Sections 0 and 0).
WASTE ROCK DUMPS		
Numerous waste rock dumps occur in the Kolwezi area, and although most of the ore is an oxide deposit and therefore not very reactive, waste rock from the Sulfide and mixed ore zones are present.	ARD can occur from the waste rock dumps if the neutralizing capacity of the waste rock is insufficient. This could have impacts on both the shallow groundwater and surface runoff from the dumps.	ABA carried out on the waste rock indicates that the waste rock has low potential to form acid. Ground water and surface water quality monitoring data confirms these results. (See Section 3.2 especially Table 3.4).
ARTISANAL MINING AREAS		
Artisanal re-working of heterogenite for cobalt is taking place at the waste rock dumps within the KMT concession area.	Artisanal mining may re-expose waste material and increase generation of ARD. Runoff may contaminate surface watercourses.	ABA carried out on the waste rock indicates that the waste rock has low potential to form acid. Ground water and surface water quality monitoring data confirms these results.
Artisanal re-working of tailings for gold is taking place in the Musonoi River tailings.	Artisanal mining may re-expose waste material and increase generation of ARD. Runoff may contaminate the Musonoi River.	ABA carried out on the Musonoi tailings indicates that the tailings have low potential to form acid. Ground water and surface water quality monitoring data confirms these results.
LUILU RIVER		

SITE DESCRIPTION	EXISTING ENVIRONMENTAL IMPACTS	BASELINE COVERAGE
The Luilu River flows from the Plateau of Manika, SW of Kolwezi in a northerly direction where it joins the Musonoi River below the Kasobantu Dam, and finally decants to the Lualaba River.	The Luilu River was historically used not only as a source of water for the Luilu Concentrator but also for disposal of effluent from both the Luilu and Kamoto Concentrators. The breached Poto-Poto Tailings dam and Luilu Discharge dams have visibly degraded this water course due to tailings deposition. Raw sewage from the village of Kapata also enters this river. The Dikuluwe pit was excavated in the original river course and is currently flooded.	A survey of the river was carried out in November 2005 to evaluate the state of the aquatic ecosystem and the impact of the degraded Luilu River on the Lualaba River after their confluence. Surface water samples have been taken in the wet and dry seasons (although not on a monthly basis) from the Luilu Upper Dam, (upgradient of mining activities) as well as from the Luilu Discharge Dam at the lowest point of mining activities.

Radiation survey

Following the environmental audit carried out by SRK, a further former uranium stockpile was brought to the attention of KMT. Although this was covered by the survey it is outside the concession area and is not reported here. The radioactivity associated with the site originates mainly from the uranium-238 series. The survey has been carried out in order to assess the risks associated with possible exposure of KMT workers to radiation arising from the site. The average surface contamination and radiation levels are summarised in Table 5-2 below.

Table 5-2: Average survey results

Average Alpha surface contamination levels (Bq/cm2)	Average Beta surface contamination levels (Bq/m2)	Average gamma dose rate at 1 m (µSv/h)
0.73	55.56	3.7

The survey also showed that a stream flowing past the stockpile footprint shows significant levels of contamination. Airborne activity was also measured and is presented in Table 5-3 below:

According to the International Basic Safety Standards, agreed by the World Health Organisation, radiation limits for the general public should be no more than 1mSv/yr, and occupational exposure should not exceed 20 mSv/yr averaged over five consecutive years, or an effective dose of 50 mSv in any single year.

Table 5-3: Results of Airborne Activity Measurements

Location	Alpha Activity Concentration [Bq.m-3]	Beta Activity Concentration [Bq.m-3]
Stockpile 261 centre (E3)	0.35	0.05
Stockpile 261 side (E4)	0.03	0.02

A composite sample of the uranium stockpile was collected and analysed for its radionuclide composition at the Necsa Radioanalysis Laboratory. The results are indicated in Table 5-4 below:

Table 5-4: Radionuclide Concentrations of Soil Samples

Nuclide	Opposite Stockpile 261	Stockpile 261
U-238 [mBq/g]	8670	15700
Ra-226 [mBq/g]	4990	13500
U-235 [mBq/g]	399	723
Th-232 [mBq/g]	42.2	39.3
Ra-228 [mBq/g]		165
Gross alpha [Bq/g]	28.3	100
Gross beta [Bq/g]	75.8	139

Radionuclide Concentrations of Water Samples

A water sample was collected from a stream of water running through the concession area near the stockpile area. Samples were also collected from a borehole in UZK village and from the Musonoi River. These were analysed for its radionuclide concentrations, which are presented in Table 5-5.

Table 5-5: Radionuclide Concentration of Water Samples

Nuclide	Stream near Stockpiles	UZK Village Borehole	Musonoi River
U-238 [mBq/L]	1860000	186.1	470.2
U-234 [mBq/L]	1600000	342.1	442.9
Th-230 [mBq/L]	28.1	3.5	0.4
Ra-226 [mBq/L]	2470	63.4	233.9
Pb-210 [mBq./L]		64.0	57.2
Po-210 [mBq./L]	130	0.6	1.4
U-235 [mBq/L]	85500	8.6	21.6
Th-227 [mBq/L]	-20.8	4.4	6.4
Ra-223 [mBq/L]	75.6	-5.8	-0.6
Th-232 [mBq/L]	47.1	4.9	1.0
Th-228 [mBq/L]	126	8.2	2.4
Ra-224 [mBq/L]	15.2	1.3	2.4
Gross alpha [Bq/L]	1610	0.37	0.97
Gross beta [Bq/L]	14.7	0.13	0.20

Exposure of workers to radiation

A source-pathway-receptor analysis was carried out which considered exposure to a variety of populations such as future workers and members of the public. As the area will be fenced off and warning signs erected to prevent public access, only the exposure to workers will be reported.

The following pathways were considered:

- External exposure to gamma radiation levels.
- Dust inhalation based on airborne activity concentrations derived from the measured dust fall-out data and from air-sample data collected during the on-site survey.

- Soil ingestion for persons who may be in contact with radioactive materials without wearing gloves.
- Radon emanating from the stockpile footprints at the measured on-site Ra-226.

It was assumed that KMT workers would be exposed to external gamma radiation and dust inhalation. As workers will be provided with Personal Protective Equipment (PPE) (discussed further in Articles 88 – 94) no soil ingestion is assumed.

External exposure

The field readings showed a large variation with the maximum readings at around 50 µSv/h. The measured values agree well with calculated values. This allows extrapolation of the dose rates to the Kingamyambo tailings dam, for which only analysed nuclide concentrations are available. On-site workers are presently regarded as informal visitors rather than occupationally exposed persons. A public dose limit of 1 mSv/a should apply to them. The workers are located on the Kingamyambo tailings dam and the assessed external doses for the tailings are all below this limit above. The working conditions should hence be regarded as acceptable without any control.

Dust inhalation

Dust inhalation doses determined from averaged fall-out data west of the tailings dams were used for assessing dust inhalation doses for the off-site public. The assessed doses are all below 1 mSv/a, and are hence acceptable. Extrapolated dust inhalation doses for KMT workers on the tailings are also within limits and acceptable. Soil ingestion is considered negligible as a source of exposure and is not considered further.

Water consumption

Water samples from the borehole at the UZK Village and from the Musonoi River were used for public dose assessments. Assessed doses for both water sources are well below the public dose limit, indicating the water to be acceptable for drinking. Measurements at the stream adjacent to the stockpile, however, show nuclide concentrations to be very high. Therefore this area will also be fenced off and warning signs erected to prevent use of this water for drinking, washing or recreational purposes.

In summary, the exposure of KMT workers is believed to fall within acceptable limits, but occupational exposure will be further assessed during the DFS and any necessary exposure control implemented during construction and operations.

Although KMT will erect warning signs around the old Uranium stockpile (261) which falls inside the KMT concession area; KMT is in no way liable for any damages relating to this stockpile under the terms of the Certificate of Release (see Chapter 2, section 2.2).

Assessment of risks of breaching of zinc tailings dam

The audit identified the discharge of effluents emanating from the zinc plant and its tailings dam and discharging into the Musonoi River tailings deposit as a potential environmental hazard. The tailings dam was found to have been breached in a number of places and thus to be discharging contaminated runoff into the Musonoi. It has emerged that this discharge may pose problems for the processing of the Musonoi tailings; this issue has been reported on separately by the DFS engineers. The potential environmental risks associated with the mixing of the zinc tailings runoff into the Musonoi are discussed in further detail below.

Tailings with elevated concentrations of Zn, Pb, As, Cu, Cd from the final plant extraction are discharged into a series of unlined dams on the banks of the Musonoi River. At least two unlined canals, carrying plant effluent and runoff from the breached tailings dams, with acidic (pH 4) plant effluent, discharge into the Musonoi River. The TDS is >5000 mg/l consisting presumably of sulfates and heavy metals. Discharge volumes during the dry season were estimated at 10 000 m^3/mth, but this was based on an instantaneous flow. Discharge during the wet season will be substantially higher. Contamination of the Musonoi River and the aquatic environment results from the acidic plant effluent and contamination from the breached tailings dams.

The concentrations of metals in solution in the Musonoi River are generally fairly low due to the alkalinity of the water, so dissolution of metals is minimal. The various discharges along the Musonoi system are responsible for raising the trace metal contamination levels above the WHO guidelines for drinking water, the KOV pit and UZK (zinc) plant discharges being the major contributors to this situation. At the start of the concession area, Musonoi River water exceeds the WHO Guidelines for manganese and lead. The UZK discharge contributes aluminium, manganese, lead, antimony and zinc. [Zinc was also elevated in the rain sampled in December 2004 suggesting that wet deposition from fall out in the air is occurring.] Water quality sampling of surface and ground water in the area also demonstrates the UZK plant and KOV pit to be the major sources of elevated salts in the ground water. The black staining of the rocks in the Kasobantu spillway is composed of iron manganese oxides in the water, some of which originates from this source. However, once in the Musonoi, the effects of these inputs are integrated with all the other pollution inputs into the river. Furthermore, dilution of the zinc plant pollution is enormous. The median flow (occurs 50% of the time) in the Musonoi is 300 000 m^3/mth, while during the wet season the monthly average is 5,7 million m^3 and the dry season monthly average is 1,6 million m^3. This means that the median dilution would be thirty fold, while the dry season dilution would be of the order of 160 times. During the wet season, when the volume of zinc plant runoff would be greatest, the dilution would be even greater.

Aquatic habitat integrity and macro-invertebrate surveys in the Musonoi valley tailings have shown that the aquatic environment has been severely impacted by mining activities and discharges, and there is very little biotic aquatic life present. The aquatic environment does not distinguish between sources, of course, it integrates them. Hence risks associated with the zinc plant discharges are indistinguishable from risks associated with the general pollution of the Musonoi engendered by discharges from all upstream mining activities, including the KOV pit, Kolwezi concentrator, tailings deposits, uranium stockpiles, etc. Zinc has sub-lethal effects on biota at low concentrations (0.05 to 0.2 mg/l) and lethal effects from 0.3 upwards (species dependent). Meanwhile the Kasobantu dam acts as a filter so that immediately downstream of the dam wall, in the Musonoi River where seepage from the dam sustains the stream, the highest habitat integrity and macro invertebrate diversity was found. The downstream environment of Nzilo dam, accessed via the artificial canal, has been found at the canal discharge point to have a reduced biotic diversity. Consumption of fish from the Nzilo dam is an important local source of protein, but there are no reports of health effects due to bioaccumulation of toxins in fish.

The above discussion highlights the fact that the zinc plant/ tailings dam discharges are, along with the KOV pit discharges, a major source of trace metal and salt pollution of the Musonoi, which has resulted in extensive damage to the aquatic ecosystem. Actions will need to be taken to limit the liabilities associated with this risk.

It is proposed that one way of doing this is to build a riverside berm to prevent direct discharge from the tailings dam breaches into the Musonoi, to re-shape the tailings dam surface to decant away from the river, and to cap the tailings dam to minimize the penetration of rainwater into the tailings. This will allow for controlled discharge of runoff with a reduced contaminant load and should largely eliminate any risks from this source in the future.

However, the zinc plant may resume operations and/or the tailings may be reworked to recover the significant levels of metals found therein.

The liability associated with these tailings rests with Gécamines as owner/operator and not with KMT, under the terms of the Certificate of Release (Section 2.2). A letter has been sent to Gécamines asking them to address the problem of runoff and discharge, plus possible future failures. However, if the zinc plant tailings become an operational liability (after 2 and 5 years operations when mining of the Musonoi begins) KMT may execute the necessary engineering works.

5.3. Overview of Specialist studies

The specialist studies undertaken for the Project and the responsible experts are listed in Table 5-6 below. The relevant baseline information has been extracted from the specialist reports and included here. The impacts identified by the specialist studies and mitigation measures proposed are discussed in Chapter 7 of the ESIA and Volume III: ESMP respectively.

Table 5-6: Specialist studies undertaken for the Kingamyambo Musonoi Tailings Project

	Specialist Study	Expert	Company
PHYSICAL ENVIRONMENT	Radiation	Mr Neels Boshoff	Necsa
	Geology	Ms. Diane Duthe (Pr.Sci Nat) (MSc)	SRK Consulting
	Soils, Land Capability and Land Use	Mr. James Lake (Pr.Sci.Nat) (MSc)	SRK Consulting
	Climate and Air Quality	Mr. Vis Reddy (Pr.Sci. Nat) (MSc)	SRK Consulting
	Surface Water	Mr. Peter Shepherd (Pr.Sci.Nat)	SRK Consulting
	Ground Water	Ms. Diane Duthe (Pr.Sci Nat) (MSc)	SRK Consulting
	Aquatic Biomonitoring	Dr JL Rall	Ecosun
	Noise	Mr. Francois Malherbe	Accoustic Consulting cc.
	Traffic	Mr Mike Van Tonder	MMC Engineers
BIOLOGICAL ENVIRONMENT	Fauna and flora	Prof. Francois Malaisse	Gembloux Agricultural University, Belgium

The terms of reference for the specialist studies were determined on the basis of the Phase 1: Environmental Audit and Scoping Study and were supplemented, where necessary, following public consultation. Specialist studies were initiated in July 2004 and initial site visits undertaken during the dry season (May to October) 2004. Specialists were briefed on site and introduced to the tribal authority. Each specialist had a copy of a letter documenting the study they were responsible for and providing them with permission to conduct their studies. Some of the specialists (noise, fauna and flora) undertook a further site visit in the wet season (January 2005) in order to accurately present seasonal variation within the project area. Dust monitoring and water quality and flow monitoring has been ongoing since the ESIA specialist studies commenced in July 2004. Field data has been collected by staff on site.

5.4. Topography

The concession area comprises a shallow valley dropping gently into the Musonoi River, rimmed by low ridges, which to the south-west mark the location of the mineralised zone and to the north mark a distinct change in topography, from the plateau of Manika to a zone of rolling hills known as the Kibarian Belt.

The Kibarian Belt consists of a series of north-north-east trending ridges to the northwest of Kolwezi at an elevation of 1200 - 1300 metres above mean sea level (mamsl). The Manika plateau is made up of the sand dunes of the Kalahari Formation at an altitude of around 1400 to 1500 mamsl and covers a surface area of approximately 150 km^2. The Musonoi and Luilu Rivers have their origins in the high lying areas of the Plateau of Manika to the south of Kolwezi. The river valleys are flat and drain towards the north.

Contours of the concession area, which ranges from 1340 to 1440 mamsl, are shown on the 1:20 000 topographical map attached in Chapter 1.

5.5. Geology

The extent, formation and location of each rock type are described below both at a regional level and for the KMT concession area. The geology of the area is illustrated in Figure 5-2. The Geological study was undertaken by Ms. Diane Duthe (SRK Consulting).

Geology of South Central Africa, DRC and Katanga

The geological foundation of Central and East Africa is ancient crystalline rocks consisting of sediments, lavas and intrusives, intensely altered by repeated metamorphism. The younger formations have been designated the Katanga system, the Karroo system and finally (the youngest) the Kalahari system.

The structure of this area of Africa has been described as a rigid block of pre-Cambrian basement rock, bounded to the North West by the Upemba rift and to the south east by the Lunangwa rift. The block is sub-divided into the Kasempa block to the south west and the Banguela block to the North West by the Lufilian arc. This formation of folded Katangan sediments runs from the Zambian Copperbelt, through Katanga (Shaba) province to Angola. The portion of the Lufilian Arc within DRC curves from Lubumbashi through Likasi and Fungurume to Kolwezi in the west. The complex is dominated by folds trending and generally plunging to the north west, and by domes and basins, and is host to most of the major copper deposits of DRC. Deposits are spread over an area of around 400km^2 and outcrop at surface at many points.

Regional Geology

The carbonate hosted ore bodies of the Central African Copper belt occur as stratabound deposits within a broad, strongly folded and faulted arc from Kolwezi in the west through Likasi and Lubumbashi into Zambia in the southeast. Major copper-cobalt deposits are located in the most strongly deformed zones along the axis of the arc. Deposits are spread over an area of around 400km^2 and outcrop at surface in many locations leading to its description as a “geological scandal” by Belgian geologist Jules Cornet in 1892. Refer to Figure 5-2 for a map of the regional geology.

The Kolwezi Nappe (fold) is situated at the extreme western end of the folded belt known as the Lufilian Arc in the province of Katanga. The regional geology of the Kolwezi District has been described in great detail by François (1963, 1973) and a brief resume is provided below.

Stratigraphy

In chronological order from the most recent to the oldest, the general stratigraphy is three sedimentary sequences separated by unconformities:

- The **Kalahari Sequence** (Cenozoic) is composed of recent semi-consolidated aeolian sandstones and gravels deposited in depressions of karstic origin under semi-arid climatic conditions. The thickness varies from 50 m to a maximum depth of 165 m in the Kolwezi Depression.
- The **Katangian Sequence** (Precambrian Neoproterozic) comprises a concordant sedimentary sequence deposited between 1000 and 620 million years (ma) ago. Although stromatolitic horizons are present, there is an absence of fossil record, so it is not possible to date these rocks in terms of biostratigraphic horizons. However, there are two laterally continuous glacial tills which allow for the classification of the Katangian into three series (facies) separated by the tillites:
  - **Upper Kundelungu Series** – Pelites, Diamictites and sandy dolomitic schists 2600 m thick with basal “petit conglomerate” essentially detritic in nature;
  - **Lower Kundelungu Series**– Detritic pelites, siltstone with horizons of limestone and dolomite. Series up to 600 m thick and the “grand conglomerate” at the base;
  - **Roan Series** – Dolomite, shales and dolomitic sandstones 1500 m thick, mostly formed through chemical precipitation with occasional detritic deposition.
  - The **Kibarian Sequence** (Precambrian Mesoproterozoic) consists of NNE trending metasediments (gneisses, quartzites and schists) dating from 1300 to 1000 ma and overlying the older crystalline basement rocks (Cratons comprising of gneiss and granites > 2000 ma).

The Katangian Sequence was deposited discordantly onto the older rocks of the Kibarian and a basal conglomerate or “Poudingue de Base” with extremely variable thickness, occurs between these distinct Sequences. It is very well represented in the Kolwezi area forming the Promontoire de Zilo, a series of hills of massive orthocongolomerate of which 95% of the clasts are quartzite. The Katangian sequence was subjected to complicated tectonic forces resulting in a series of complex overturned folds and over thrusting of the sedimentary sequences. The Kolwezi Nappe (or fold) comprises an elliptical fold basin (syncline) with a long axis of 20 km and a short axis of 10 km and orientated NE-SW. Within the fold, several faulted blocks (scales) belonging to the Roan series have been thrust onto the Upper Kundelungu strata at the top of the Katangian sequence.

Paleo-alteration of the dolomitic horizons of the Roan Series resulted in the leaching of carbonate minerals and was accompanied by a change in physical and chemical properties with most of the siliceous material remaining in situ (silicification). This process resulted in the formation of karsts, cavities and dissolution channels, which on surface may be manifested as depressions or sinkholes. Alteration was a significant process, not only as it allowed for super-concentration of the sulfide mineralization to oxide mineralization but it also altered the hydraulic properties. Preferential flow paths allowed for supergene enrichment within the karsts and brecciated cavities particularly along fold axes and fault zones.

A summary of the Katangian stratigaphy is shown in Table 5-7. Only the facies occurring within the KMT concession areas have been described in this table, as they are relevant to this study.

The ore bodies (OB) occur predominantly within two formations of the Roan Series, namely at the base of the Schiste Dolomitique (SD) and within the stratified dolomites of the RSF/ DSTRAT, separated by a thick siliceous stromatolitic dolomite (Roche siliceuse cellulaire or RSC). Figure 5-3 shows a simplified stratigraphical column of the Roan Series and the occurrence of the ore bodies.

The parent rock types have been subjected to deep weathering under the tropical climate and the geological profile typically consists of up to 2m of residual soil, underlain by iron rich lateritic regolith followed by a zone of up to 30m thick of clay rich saprolite (decomposed parent rock but retaining the fabric of the parent rock).

e 5-7: Stratigraphy of the Katangan System in the Kolwezi KMT concession areas

on	No	Subdivisions		Summary Description
DELUNGU (Kyavye Facies)				
tone	Ks 2	2.1		Fine grained sandstone or siltstone, feldspathic, pink grey in colour and grey-purple argillaceous shale with minor of pink impure limestone near base. The formation is generally truncated at 100m by the over thrust faulting of th nodules characteristic in weathered zone.
	Ks 1	1.3	1.3.2	Alternating fine grained pink to grey sandstone and siltstone with occasional interformational conglomeritic horizo planes. Weathers to purple argillaceous shale.
hique			1.3.1	Limestone (slightly impure with only 10-15% insolubles) 70-80% carbonates with ratio of calcite to dolomite varyin interbedded Macigno (fine calcareous marine sandstone). Weathers to brown to purple soil or fine argillaceous s depressions (Muvumai valley).
		1.2	1.2.2	Argillaceous or gritty shale with carbonate (15-40%), non micaceous, grey green or lilac grey. Weathers to a yello violet, micaceous. With bands of purple/grey Macigno weathers to purple shale.
			1.2.1	Dolomite (80%), lightly calcareous pink to grey in colour, ratio of calcite to dolomite 0 to 0.1. Weathers to brown a outcrops.
nerate		1.1		Tillite – clasts 1 -3cm in diameter of quartz, shale and occasional crystalline rocks in an argillaceous shale matrix. orientation of sub-rounded clasts. When weathered, feldpaths alter to kaolin.
IDELUNGU (Kilenge Facies)				
	Ki 2			Fine grained sandstone to siltstone, arkosic, slightly chloritised, massive layers with stratification, dark grey in col brown yellow or orange porous sandstone
	Ki 1	1.3		Arkosic siltstone, slightly dolomitic (10%) very fine grained, with muscovite. Massive but with fine laminations, ma change much when altered.
		1.2	1.2.1	Argillaceous shale, alternating with shale sandstone. No carbonates yellow brown to grey, Limestone of Kakontwe south east of Kolwezi.
e		1.1		Tillite of Arkose and orthoconglomerates with quartzitic, gneiss, granitic, schistic and magnetite clasts up to 50cm shale, 5-25% dolomites except when altered.
Facies)				
	R4	4.1		Argillaceous shale, stratification regular and pronounced, pale grey green colour with occasional red iron oxide la
	R3	3.1	RGS	Roche Greseuse Superior - Silty shale, feldspathic slightly dolomitic (15%) with a massive texture, steel grey or li chlorite, sterile
	Mine series R2	2.3	CMN	Calcaire a Mineraux Noir. Impure dolomite with grains of quartz and sericitised chlorite, two horizons of stromato of carbonaceous shale. Manganese rich mineralization is distinctive.
ody		2.2	SD	SD – Schist dolomitique, silty shale and impure dolomite, very mineralised at basal contact with underlying RSC, grey, purple, stromatolitic

on	No	Subdivisions		Summary Description
			2.1.3 RSC	RSC – Roche Siliceuse Cellulaire, very siliceous stromatolitic limestone, with bands of mineralised shale, many d weather easily due to siliceous structure, forms hills of white siliceous limestone
ody		2.1	2.1.2 RSF	RSF – Roche siliceuse feuillete, siliceous dolomite, abundant chalcosine and carrollite, grey
			2.1.1 DSTRAT	At least bands of Stratified dolomite and one of arkose, with pyrite and chalcopyrite, nodules of carrolite and bor light grey
	R1	RAT		Quartzitic dolomite, always sterile, massive texture, grey and lilac, weathers to argillitic siltstone, strongly tectonis

Structural geology

Towards the end of the orogenesis of the Kibarian Sequence (circa 1000 ma), tectonic activity within the ancient crystalline basement rocks (>2000 ma) resulted in an aborted rift separating the Kalahari Craton in the south from the Congo Craton in the north (Okitaudji 2001). The resulting localised depression orientated southeast - northwest created a shallow epicontinental sea into which the sediments of the Katangian Sequence were deposited. The environment was evaporitic allowing for the deposition of the carbonates and sulfates with interspersed detritic and volcanodetritic sediments.

These sedimentary formations were then subjected to major Pan African tectonic phases (600 -500 ma) resulting in a folded belt of overturned anticlines and synclines. Thrusting and faulting have broken and displaced the folded sediments of the Roan Series into rotated and isolated blocks (“ecailles”) thrust onto the Upper Kundelungu strata (sandstones, siltstones and conglomerates) at the top of the Katangian sequence. Most of the structures (faults and fold axes) are regionally orientated E-W. The tectonic events and diagenesis intensely altered the sediments and resulted in repeated metamorphism of all rock types (alteration to quartzites, pelites, talc, and schists). Erosion has subsequently left predominantly synclinal remnants on a peneplaned surface.

The Upper Kundelungu series (Ks 2.1) is generally truncated by over thrust faulting of the Roan formation manifested by the Kolwezi nappe with the outlying Klippe Nord orebody. The Kolwezi nappe or syncline thus comprises an elliptical structural basin (Kolwezi nappe) with a long axis of 20km and a short axis of 10km with the main trend of the fold axes and faults within the syncline oriented NE-SW.

To the northeast of Kolwezi, the Kundelungu Series is folded further along the Mamfwe anticline with a fold axis oriented locally NNW-SSE and thereafter trending E-W. To the south of Kolwezi, the lower Kundelungu Series is folded along the Kazembe and Manika anticlines, separated by the Kamukonga syncline with the fold axes oriented ENE-WSW.

Paleo-alteration of the dolomitic horizons of the Roan Series resulted in the leaching of carbonate minerals and was accompanied by a change in the physical and chemical properties with most of the siliceous material remaining in situ. The process resulted in the formation of karsts, cavities and dissolution channels which on surface may be manifested as depressions or sinkholes.

Geophysical anomalies

In 1969, at the height of the cold war, an airborne geophysical survey was undertaken by Hunting Geology and Geophysics with the aim of exploring for new uranium ore bodies (Hunting 1970). An area of 15 000 km^2 was flown using a gamma ray spectrometer and magnetometer. The magnetometer was used to identify near vertical structures such as dykes and faults and assist in the structural interpretation of geological features. Ore bodies within the Copperbelt are frequently associated with faults and fold axes due to remobilisation of fluids along these structures.

The magnetic anomalies have been superimposed on the structural geological map shown in Figure 5-3. The most significant anomaly is to the northwest of the Kolwezi nappe shown by the Grand Conglomerate (Ki 1.1) with an orientation parallel to the outcropping Kibarian formations. This anomaly is due to the inclusion of magnetite and other iron rich clasts (originating from the adjacent Kibara and crystalline basement rocks) within the conglomerate matrix. This anomaly is also present south of the Kolwezi nappe where the Kazembe and Manika anticlines have uplifted the Grand conglomerate, although this area is mostly covered by the Kalahari sands.

No interpretation of data could be made within the Kolwezi Nappe due to interference from the mining infrastructure.

The spectrometric survey was flown at an altitude of 660 m and the background level was maintained at 620 counts per second (cps). An anomaly was identified as any reading 100 cps above background. The spectrometric survey indicated that the Grand Conglomerate or Ki 1.1 has elevated radioactivity due to the accumulation of feldspars, micas and heavy minerals (zircon, monazite) within this formation. The radioactive signal is due to the decay of minerals containing potassium (K) Uranium (U) and Thorium (Th) in clasts originating from the crystalline basement rocks (granites and gneiss). The "Petit Conglomerate" of the upper Kundelungu (Ks1.1) and the Mwashye of the Roan Group also show a radiometric anomaly; although to a lesser extent. Other radioactive anomalies exist where uranium has been stockpiled in the past and along roads, rivers and railway lines due to contamination of the surface soils and water.

It was concluded from this study that these anomalies are not indicative of an exploitable uranium deposit within the Kolwezi area.

Mineralization

Several models to explain the genesis of the copper-cobalt mineralization of the Central African Copper belt have been proposed but to date there is no general agreement. The syndiagentic model does appear to address the lithostratigraphic control (i.e. mineralization confined to stratigraphical units), source of the metals, factors controlling mineralization and concentration processes (Okitaudji 2001) and is described briefly below.

According to Meyer (1981), prior to 1800 Ma all major copper deposits were volcanogenic. Following the change from a reducing to oxidising atmosphere at approximately 1800 Ma, metals could be transported great distances in solution to be precipitated in favourable environments at the interface between oxidising/reducing conditions within an inter continental basin. Stratabound sulfide copper – cobalt deposits are defined as those occurring within a sedimentary sequence and having no close spatial association with volcanics. Mineralization is usually concentrated towards basin margins associated with the wedging out of sedimentary formations against fault bounded paleotopographic highs where marine transgressions and regressions favoured the establishment of the oxidising/reducing interface.

With the evolution of blue green algae (sulfate reducing bacteria-cyanobacteria) and the formation of stromatolites within the sub-tidal zone, bacterial activity resulted in syngenetic enrichment through the reduction of sulfates from the volcanodetritic sediments which were rich in copper and cobalt. Most of the economic stratabound copper-cobalt deposits are therefore clustered either in the Upper Proterozoic or Permian formations confined to shallow lagoonal or lacustrine environments and restricted to tectonically active continental basins.

Mineralization is usually in the form of dissemeninated chalcopyrite, bornite, pyrite, carrolite and chalcocite grains scattered throughout the host sediments frequently accentuating sedimentary features e.g. bedding planes, stromatolite structures, and stylolites. Remobilisation and supergene enrichment of metals may occur along joints, fault planes, fold axes or filling karst cavities.

The original Sulfide mineralization alters to oxide minerals by weathering so within the weathered oxide zone, the main copper minerals are malachite and chrysocolla with heterogenite as the main cobalt mineral. In the transition zone (known as the mixed zone) chalcocite and digenite are the major minerals.

The mineralised zones within the Kolwezi Nappe occur within the R2 Formation of the Roan Series (also known as the Serie des Mines) as depicted in the Stratigraphical Column (Figure 5-3). There is an upper orebody within dolomitic to sandy schists of the "Schist Dolomitique" (SD) separated from the lower orebody by a 20-50m thick massive siliceous dolomite known as the Roches Silisceuse Cellulaire (RSC). The lower orebody is contained within stratified dolomite (D Strat) and the Roche Siliceuse Feuilltee (RSF). These ore bodies are underlain by the Roche Argilo Talquese (RAT) and overlain by the argillaceous dolomitic schists of the Calcaire a Mineraux Noir (CMN). The overlying Dipeta Formation consisting of sandy schists, (also known as the Roches Greseuse Superior (RGS)) is sterile. Within the Kolwezi Nappe, the Musonoi and Dikuluwe facies of the Roan R2 Series de Mines are far more mineralised than the Long Facies which occurs within the outer limits of the KMT concession area, and no uranium is associated with the Long Facies.

In terms of the syndiagentic model, mineralization of the R2 was favourable as the residence time at the interface between oxidising/reducing conditions was sufficiently long under stable evaporitic conditions to allow for the permanent establishment of the sulfate reducing bacteria and the precipitation of metals from solution. The sterile sequences (detritic rather than dolomitic) were deposited under oxidising conditions above the oxidising/reducing interface which was unfavourable to the sulfate reducing bacteria, and the metals were therefore not precipitated within these sediments (e.g. the lilac RAT and the RGS).

In places where the Serie de Mines has very little mineralization (e.g. the Long Facies), it was proposed that:

- the residence time at the oxidising/reducing interface was too short;
- too little confinement (i.e. washed away rather than accumulation as a deposit);
- the sulfate and metal concentration in the depositional waters/sediments were low;
- Decreased activity of the sulfate reducing bacteria.

Seismicity and stability of geological formations

The structure of this area of Africa has been described as a rigid block of pre-Cambrian basement rock, bounded to the north-west and south-east by two rift systems. This block is divided into two by the Lufilian arc of folded Katangan sediments, which is a continuation of the Zambian copper belt and which runs through Katanga province into Angola. Tectonic features are associated with these two rift systems and the Lufilian arc.

Two possible major sources of earthquake risk have been identified, namely:

- indeterminate structure, with insufficient seismic history to determine fault patterns
- extensions of the African Rift System, associated with three particular zones

Contemporary practice requires that major structures be designed to resist:

1 an Operating Basis Earthquake (OBE)
2 a Maximum Credible Earthquake (MCE)

A seismic risk analysis will be undertaken as part of the Final DFS.

In the predominantly dolomitic terrain of the Kolwezi nappe, subsidence associated with the development of karsts (sinkholes) is manifested in the Kolwezi environment as localised depressions filled with recent Kalahari sands.

Due to the relatively flat topography, landslides are not a concern except within the open cast pits where the saturated high walls have slumped since the dewatering systems are not operational.

Methodology for assessing the Geology of the KMT concession area

The geology was developed using available geological maps from Gécamines, supplemented by the following:

- Mapping of aerial photos of the KMT concession area to identify structural features or lineaments;
- Geophysical survey within proposed Plant site and tailings dam area
- Drilling and logging of boreholes within the proposed plant sites, tailings dam and railway line;
- Definition of limits of exploitable resources
- Conceptualise geological model based on collated data.

Aerial photographic mapping

Aerial photographs were taken of the KMT concession area on the 22/10/2001 and 23/10/2001 from an altitude of 1,224 m at a scale of approximately 1:8000. The photos were taken at the beginning of the rainy season prior to excessive vegetative growth.

The following observations are noted from the stereoscopic pairs (60% overlap) of aerial photos covering the proposed plant and tailings dam areas:

- The only laterally consistent geological outcrop within the concession area is the NE-SW trending Kibara quartzites at the extreme north western corner of the concession and adjacent to the Kasobantu dam wall. A quarry within this formation and within the concession area is clearly visible. Due to the gradient of this topographically hilly formation, it is well vegetated with no agricultural development.
- Parallel to the Kibara quartzites are the well exposed hills of the basal conglomerate or "Poudingue de base" and enormous conglomeritic blocks scattered on the slope are apparent in the photos. Minor excavation of this formation has taken place.

- The Kundelungu Formation does not outcrop at surface and the terrain is very flat (sloping gently towards the Musonoi river) with most of the area under agriculture (cassava lands). Within the Kundelungu Formation, there is one large dambo (typical of Miombo environments), a seasonally flooded shallow depression created by preferential weathering.
- The tall termitaria cover the area in approximately equal spacing except they cluster more frequently at the margins of the large dambo which can be readily mapped using this distinction and the abundant agricultural plots that have been developed within the dambo.
- The siliceous limestones of the RSC of the Roan Formation form prominent ridges defining the outer limits of the Klippe Nord, and the Kakifuluwe ore bodies which belong to the Long Facies of the Kolwezi Nappe. The southern side of the ridges are marked by a lack of vegetation that has been interpreted to be indicative of copper toxicity (Upper orebody SD formation) whereas the northern slopes are well vegetated.
- Previous site visits during Phase 1 of the project noted that the Kakifuluwe stream flows in the reverse direction due to damming up of the Musonoi with tailings. A localised depression along this water course is due to the development of a karst or sink hole into which the Kakifuluwe flows from both directions.
- The general trend of all the sub-tributaries (Kanamwamwa, Kakifuluwe and dambo) has an orientation of SW to NE, following the general strike of the geological formations in this area.
- No dykes or faults could be determined from the aerial photographs due to the extensive development of slash and burn plots which have destroyed the natural vegetation, typically used to identify lineaments.
- The proposed tailings dam and plant site areas are bounded to the NE and SW by the AC and DC power lines which are part of the INGA hydroelectric scheme. These power lines are clearly visible on the aerial photographs.

Geological mapping

There are virtually no outcrops of the Kundelungu sediments on surface with the exception of the shales of the Ks1.2.2 which are exposed in a small laterite quarry at the location indicated in Figure 5-3. The exposed face shows the saprolitic nature of the rock and remnant folding and distortion of these metasediments is still clearly visible.

Laterite deposits are fairly common throughout the concession area consisting of rounded pellets (pisoliths) of iron, manganese, titanium and aluminium ores cemented together by iron oxide. In tropical climates, laterite develops beneath the surface in unconsolidated sediments or decomposed rocks where interaction between groundwater, soil and topography are favourable. Other small laterite quarries are also indicated on Figure 5-3.

The Basal Conglomerate or the Puodingue de Base is exposed as the rounded hills at the northern boundary of the concession area. The large unsorted angular clasts are predominantly quartzites and gneiss within a quartzitic matrix. The exposed conglomerate is shown in the following photograph

Exposed Basal Conglomerate

There is also an abandoned quarry within the Kibarian quartzites which shows clearly the general SW-NE strike of the stratigraphy and dipping steeply (70 - 80°) to the SE.

The near vertical siliceous RSC of the Roan Formation is well exposed as the hills of the northern limits of the Klippe Nord and Manga ore bodies. The remainder of the concession area consists of soils deep red in colour. As in most tropical regions, the soils are so highly leached that all silicate minerals are completely altered leaving the soil enriched in aluminium and iron oxides.

Geophysical survey

Apparent conductivity and magnetic field data were collected from the 11 to 24th July 2004 on the proposed Plant Site A and tailings dam area with the aim of identifying structural features to be targeted for drilling. Due to the numerous fields cultivated with cassava, it was not possible to undertake a geophysical survey on a grid, as the coils have to be laid flat which is impossible within the mounded cassava fields. The surveys were undertaken along existing paths and tracks which traverse the plant and tailings dam areas. Magnetic field measurements were unreliable due to interference from the 550 V DC power supply to INGA which is located NE of these sites.

No anomalies indicative of sub-vertical conductors such as dykes, faults or fracture zones within the plant area and tailings dam were identified along the lines surveyed. Apparent conductivity levels are typically below 10 mS/m and broad increases in background suggest an increase in sub-surface water content.

One survey line was undertaken near the overthrust fault zone between the Manga orebody of the Kolwezi nappe and the Kundelungu sediments in order to determine the nature of this contact. Apparent conductivity decreased towards the north east with increasing distance from the potentially mineralised orebody contact. However, no vertical conductor is associated with this zone.

Limits of exploitable resources

The Kundelungu Formation is generally regarded as being sterile in the Kolwezi area unless there is secondary mobilisation along faults and fold axes. Minor syngenetic mineralization has been reported by Francois (1973) in the Petit Conglomerate (Ks 1.1) at Kisangeshi with a copper content of up to 0.39%. The Grand Conglomerate (Ki 1.1) reportedly also has occasional mineralization (<1 % Cu), namely at Tombolo and Tilwezembe. He has also reported mineralised horizons (less than 1 metre in thickness) in the Ks 1.3 and Ks 2.1 near Mutoshi on the eastern limb of the Kolwezi fold. However, even if the grades are locally very high, they are not of economic interest as they are not laterally extensive and the tonnage is therefore insignificant.

To ensure that there is no exploitable copper and/or cobalt mineralization underlying the proposed plant sites, tailings dam site and railway line route, a sterilisation drilling programme was implemented in conjunction with the hydro geological investigation and samples from each borehole were assayed by SGS Lakefield in Johannesburg. Details of the results of the assays for the percussion samples are included in the Sterilisation Drilling Report (SRK Report No. 342211) and only a summary is given here.

For a copper - cobalt deposit to be of economic interest, the average grade should be at least 2% copper and 0.2 % cobalt. However as an indication that mineralization could be present, any samples with a grade greater than 0.1 % (1000 ppm) copper or 0.05 % (500 ppm) cobalt were flagged in the analytical reports. Using these conservative limits, the only Cu – Co mineralization identified was in the samples from BH1 and at depth in BH18 (29-55 m).

BH1 was drilled through the CMN and into the SD formation of the Manga orebody as part of the hydro geological investigation for water resources and these results were expected. BH18 is located in close proximity to the outer limits of the Klippe Nord orebody at the southern boundary of Plant Site A. A composite sample from a depth of 29 – 55m had grades of 9800 ppm Co and 4100 ppm Cu. High manganese is generally associated with the Co/Cu ores and is >10 000 ppm in this sample. There are many heterogenite diggings in this area and whilst it does not appear to be economically viable at the current cobalt price, hydrothermal alteration and displacement along fractures or joints appears to have mobilised mineralization along the contact between the Roan and Kundelungu Formations.

High residual concentrations of iron, aluminium and titanium are typical of lateritic environments where most of the silicates, alkalis and alkali earth metals have been leached from the parent rock, leaving behind a red saprolite. Specular hematite (identified from its red/brown streak on unglazed porcelain) is visible as shiny platy flakes in many of the percussion samples, particularly in the proposed tailing dam area where it is associated with quartz veins. The magnetic anomaly associated with the Grand Conglomerate is due to the abundance of these iron rich minerals. Whilst the maximum concentrations of these metals is greater than the maximum detection limit of >1% (> 10,000 ppm), it is unlikely that these deposits are economically exploitable. Where the laterites are capped by a hardened crust (duricrust), they may contain 30 to 80 % Fe and/or Al oxides, and may be enriched in titanium and manganese. Depending on the thickness of these duricrusts, they can be significant sources of iron and aluminium (bauxite) ore. However, analyses allowing a higher maximum detection limit would be required to verify this.

Zinc concentrations of up to 1700 ppm (0.17%) determined in samples from BH4 show that zinc has been leached from the tailings dams of the UZK and precipitated out of solution at short distances from the slimes dams.

Conceptual geological model of KMT Concession area

Figure 5-5 shows an adaptation of the more detailed Kolwezi geological map (Francois 1973) and the positions of the proposed plant site, tailings dam and railway line are also included. A geological cross section A-B shown as Figure 5-6, has been constructed from the geological plan and borehole logs to show the conceptual geological model through the KMT Concession area.

The KMT concession is located on the northern limb of the Kolwezi nappe mostly within the Kundelungu sediments. The strata have a SW-NE orientation and dip at least 60^{o} towards the SE. A secondary phase of folding along an N-S axial plane has resulted in the fold hinge that appears to be a preferential flow path for part of the Musonoi River course.

Overthrust faulting has thrown the Roan sediments into the truncated Ks 2.1 of the Kundelungu formation manifested as the Kolwezi orebody. The outlying Klippe Nord ore body also lies within this axial plane along the fold hinge. Portions of the Manga and Klippe Nord ore bodies lie within the KMT concession area as well as the Kingamyambo orebody which is overlain by the Kingamyambo tailings deposit.

The SW-NE orientation of the Kananwamwa River and dambo are a manifestation of preferential weathering of carbonate rich strata (i.e. Ks 1.2.1 and Ks 1.3.1). Minor folding or faulting of the Ks1.3.1 formation as interpreted on the geological map may have resulted in the outlying cusp of the dambo which is clearly visible in the aerial photographs.

Geology underlying the proposed KMT infrastructure

The geology within the concession area is presented in Figure 5-5 and described below. Most of the geological profiles consist of weathered laterite underlain by saprolites of the parent sedimentary rock formations.

Plant Site

The proposed plant site has an available flat (with less than 5m elevation change) surface area of approximately 40 ha, bounded by the power lines to the NE and SW and to the NW by the Kananwamwa River. The plant site covers an area of 60 ha and as shown in Figure 5.5 the north-western boundary is located adjacent to the Kananwamwa River on a slope and the south-eastern boundary is located close to the dambo. Two boreholes were drilled at the proposed plant site; BH11 near the NE power lines and BH20 near the Tshala cemetery. The site D) is underlain by the argillaceous shales of the Ks 1.2.2. A band of grey Macigno was intersected from a depth of approximately 40 m as confirmed from the ICP scan by the higher Ca content at this depth. Chips of quartz intersected at 31-40 m could be from a quartz vein or a localised intraformational conglomerate. Intraformational conglomerates occur at depths >50 mbgl. No mineralization was present in the percussion samples from BH11 and BH 20 and this formation appears to be sterile.

The dambo adjacent to the south-eastern boundary of the plant is the surface expression of the pink oolitic limestone horizon (Ks 1.3.1) occurring at the base of the Ks 1.3. Due to the high $CaCO_3$ content, it weathers preferentially and has a shallow phreatic aquifer associated with it. The plant infrastructure should be designed to avoid placement over this formation as the water table is high and consequently the aquifer is very vulnerable to contamination. It could also represent stability issues for the any concrete foundations as the pH of this aquifer is low.

Proposed Tailings Dam

The proposed tailings storage facility (TSF) covers an area of 420 ha and is largely underlain by two distinct stratigraphical units, namely the Ki 1.1 and the Basal Conglomerate or “Poudingue de Base”. The Ki 1.1 also known as the “Grand Conglomerate” has a thickness of up to 600 m and consists of a weathered conglomerate with clasts of quartzite, arkose, shale and granite in a carbonate rich shale matrix. The Basal Conglomerate is an orthoconglomerate with more than >95% angular quartzite clasts in a coarse grained (1-2 mm) gritty quartzite matrix with no carbonate. BH7, BH12 and BH13 were drilled into the Ki 1.1 and the remnant conglomeritic fabric of the rock is evident within the saprolite from 6 to 20 m. Clasts of siltstone, gneiss and quartzites are well rounded or angular and specular hematite is abundant as platy fragments and in open fractures associated with quartz veins. The aerial radiometric survey undertaken in 1969 by Hunting and Associates identified a radioactive anomaly associated with this formation. For this reason a hand held scintillometer was used to determine if the percussion samples were radioactive.

BH 8 was drilled through the Basal Conglomerate and is highly weathered to a depth of 39 m, which is surprising given the quartzitic composition. Specular hematite is abundant associated with hydrothermal alteration and quartz veining.

No mineralization (apart from iron as hematite and other iron aluminium oxides) was determined in any of the samples from the boreholes drilled in the tailings dam area.

The downgradient retaining wall is located over the Ki 1.2 and Ki 1.3 formations consisting of argillaceous shale and arkosic siltstone respectively. These formations should be relatively impermeable.

Proposed Railway Route

Most of the proposed railway route is not within the KMT concession area and it traverses the Kakifuluwe orebody and the Upper Kundelungu sequences as can be seen from the geological map (Figure 5-5).

Boreholes BH16, BH17, BH 21 and BH22 were drilled with a view to determining the geology and to evaluate the route in terms of potential mineralization and geotechnical stability. BH16 and BH 17 were drilled within the Kakifuluwe orebody of the Kolwezi Nappe whereas BH 21 and BH 22 were drilled within the Kundelungu formations. BH 16 intersected the CMN formation whereas BH 17 was drilled through the silty shales of the sterile RGS. Slightly elevated Co (500 to 900 ppm) and Cu (1000 to 2200 ppm) were determined in BH16. The Kakifuluwe ore body belongs to the Long facies of the Kolwezi Nappe and is generally regarded as being sterile (not economically viable) and only the Lower orebody (RSF and DSTRAT) is sporadically mineralised.

BH21 and BH22 were drilled through the highly weathered purple brown shales/siltstones of the Ks 1.3.2. BH21 intercepted an interformational conglomerate from a depth of 38 m. No mineralization was determined in the samples from these boreholes.

Kingamyambo Tailings

The Kingamyambo Tailings is located above the Kingamyambo ore block directly overlying the RGS formation, with the ore bearing units (SD and RSF/DSTRAT) occurring at depth below it. The KOV pit and Kamoto Underground mines are adjacent to the Kingamyambo Tailings Dam and are the only mines partially operational.

BH2 was drilled downgradient and adjacent to the Kingamyambo Tailings deposit to a final depth of 52 m. Weathered silty shale of the RGS occurs below the lateritic profile to a depth of approximately 40 m and thereafter it is intercalated with CMN identified from the siliceous and dark manganese rich fragments. The increased Ca and Mn concentrations shown in the analyses from the ICP scans confirm this change in lithology. No mineralization occurs at these shallow depths (the upper orebody SD occurs below the CMN) and the water table is very deep due to the cone of drawdown around the KOV open cast pit.

Musonoi River Tailings

The Musonoi River Tailings is located within the Kundelungu formations and is presumably devoid of mineralization with depth below the entire tailings deposit. Samples from all boreholes drilled elsewhere within the Kundelungu formation did not show any mineralization. Unless there is secondary mobilisation along the fold axis, which is a preferential flow path for the Musonoi within the KMT concession, the underlying geology of the Musonoi Tailings is deemed sterile.

No cross sections are available for this area, as it has not been drilled.

Quarries

Two potential quarries have been investigated to the north-west and north-east, respectively of the tailings dam. The north-west quarry is an existing, though presently disused quarry while at the site of the north-eastern one there has also been limited excavation of material at some time in the past. Both quarries lie in the prominent ridge behind the tailings dam formed by parallel formations of the Kibara quartzites and Basal Conglomerate or the Poudingue de Base. The NW quarry is in Kibara quartzite while the NE quarry lies within the Basal Conglomerate. The NW quarry would yield aggregate for building, while conglomerates are sought from the NE quarry.

5.6. Soils and Land Use

This section describes each soil type found in the concession area; its extent, formation and location. The soils of the concession area are illustrated in Figure 5-5. The soils and land capability/ land use specialist investigation was undertaken by Mr James Lake (SRK Consulting).

The results discussed below highlight the disturbance to the site created by former mining activity, although soils do not appear to be contaminated as a result of the former mining activities.

Methodology for assessing the soils

The focus of the soil and land capability classification was on the proposed footprints of the new infrastructure that is to be associated with the re-mining activities in the concession area at Kolwezi. This new infrastructure includes the proposed tailings storage facility, located in the north-west of the concession area, the proposed plant and the proposed new management camp. Excluded are the possible river diversion of the Musonoi and soil borrow pits where soils for construction may be obtained. These two items are not included as details on them have not yet been developed.

In each of these areas intrusive investigations were made to confirm that the subsurface soil types were the same as those observed in the termitaria. Augering was also used to determine soil depths. The intrusive investigations that were undertaken included shallow soil augering (to a maximum depth of 1200 mm) and the digging (by hand) of shallow test pits (to a depth of between 500 to 750 mm). In some instances earthworks had been historically undertaken on site. Where these were present, observations of the soil profile were made.

The intrusive investigations that were undertaken were then used to “ground truth” the observations made from termitaria, the Landsat Image and from the FAO soils map. This information was all used to produce the soils distribution map. As described in the following section, only a single major soil type was identified in the concession area. A sample of this soil was collected and submitted to a laboratory for analysis of the following parameters:

- pH and EC;
- Particle size distribution;
- Exchangeable cation and anion capacity (CEC and AEC respectively);
- Concentrations of heavy metals.

Regional soils

According to the Food and Agriculture Organisation (FAO) soils map, the soils that are typically found in the Katanga Province of the DRC fall into one of the following soil forms:

- Ferralsols;
- Nitrisols; or
- Acrisols.

Based on the field work that was undertaken on site, the soils in the Kolwezi area are those belonging to the Ferralsol soil form. These soils are classified as having a ferralic[1] B horizon at some depth between 250 and 2500 mm (from soil surface), they lack a nitic[2] B horizon within 1000 mm (from soil surface) and they lack a layer which fulfils the requirements of an argic[3] B horizon and which has in the upper 300 mm, 10% or more water-dispersible. The ferralic soils in the region can be divided into two different categories:

- those that have a yellow brown colour,
- Those that have a red colour.

The primary difference between these two soils is the species of iron oxide that dominates the soil mineralogy. In the red soil, haematite (Fe_2O_3) is the dominant species of iron, while in the yellow soils goethite ($FeO(OH)$) is the dominant species. These soils typically form in a well drained oxidising environment, with the redder soils typically forming under drier conditions. The soils are typically dominated by non-swelling 1:1 clay mineral suite. The dominance of either haematite or goethite is influenced by the moisture status of the soils, with goethite typically forming under higher moisture conditions. The presence of organic matter also influences iron speciation, with organic matter (and its soluble product) limiting haematite formation or converting haematite to goethite.

The soils in the remainder of the area belong to the Planosol and Gleysol soil forms. The Planosols are typically those from which clay and free iron oxides have been removed or where the oxides have become segregated to the extent that the colour of the horizon is determined primarily by the colour of the uncoated sand and silt particles. These soils typically have a light colour and form where there is an underlying impermeable layer forming a perched water table. Gleysols are very wet soils formed in unconsolidated materials. The characteristic horizon is an organic-rich A horizon (up to 28% organic matter).

[1] The ferralic horizon is a subsurface horizon resulting from long and intense weathering, in which the clay fraction is dominated by low activity clays, and the silt and sand fractions by highly resistant minerals, such as iron-, aluminum-, manganese- and titanium oxides.

[2] The nitic horizon is a clay-rich subsurface horizon with as its main feature a moderately to strongly developed polyhedric or nutty structure with many shiny ped faces, which cannot or can only partially be attributed to clay illuviation.

[3] The argic horizon is a subsurface horizon which has a distinctly higher clay content than the overlying horizon. The textural differentiation may be caused by an illuvial accumulation of clay, by predominant pedogenetic formation of clay in the subsoil or destruction of clay in the surface horizon, by selective surface erosion of clay, by biological activity, or by a combination of two or more of these different processes. Sedimentation of surface materials which are coarser than the subsurface horizon may enhance a pedogenetic textural differentiation. However, a mere lithological discontinuity, such as may occur in alluvial deposits, does not qualify as an argic horizon.

Soils in the Concession Area

The distribution of the different soil types in the concession area is indicated in Figure 5-5. The different areal proportion occupied by the soil forms are tabulated in Table 5-8. Included in this table is an estimate of soil depth based on observations made from auger holes, test pits and open cuttings.

Table 5-8: Soil mapping units

Soil Type	Soil Map Unit[1]	Area (ha)	Soil Depth[2]	Proportion of total (%)
Ferralsol	FR	2 920	>1 000 mm	43.8
Gleysol	GL	380	<500 mm	5.7
Planosol	PL	1 300	> 750 mm	19.5
Other mining[3]	N/A	1 090	Unknown	16.3
Musonoi Tailings	N/A	990	Unknown	14.8
TOTAL		6 680		

1. soil map units abbreviations as per the FAO classification system
2. soil depth based on limited soil augering, not possible to determine remotely as remote techniques did not penetrate surface
3. includes area south of Sulfides tailings dam, towards the Kingamyambo tailings dam and KOV pit

The two proposed quarry sites in the ridge north of the tailings dam fall within the ferralsol soil types, but on the ridges soils are shallow and very rocky, due to the prominence of rock strata.

There are two areas within the concession area where it is not possible to identify soil types. These areas are along the Musonoi River under the existing Musonoi tailings dam and the area to the south of the concession area, starting at the Sulfide tailings dam and moving southwards under the Kingamyambo tailings dam towards the KOV Pit. Soil types cannot be identified in these areas as the overlying infrastructure prevents access. It is speculated, based on observations made in the immediate proximity of these areas that the soil probably belongs to the Ferralsol form.

The only area on the KMT concession where non-climatic alluvial soils would be expected to occur is in the Musonoi River, however, since the river is currently filled with tailings it is not possible to investigate the soils found beneath the tailings.

As indicated in Table 5-8, the majority of the area (44%) has soils deeper than 1 000 mm (Ferralsols). These deep soils should be relatively well draining, preventing water logging and have a deep effective rooting depth. These soils will allow effective root penetration, which is desirable for many plant species. The Planosols, while not as deep as the Ferralsols, are also relatively deep (>750 mm) which allows good root penetrations. Rooting depth is limited in the Gleysols by the relatively shallow depth of these soils. This rooting depth could potentially have an impact on plant growth. However, this lack of rooting depth will be outweighed by the saturated status of these soils, which would limit oxygen transfer to the roots growing in these soils. Therefore, the combination of lack of effective rooting depth as well as saturation status of these soils will limit the types of plants that will successfully grow in these areas.

In terms of agricultural potential, the Ferralsols and Planosols theoretically have a higher potential than do the Gleysols.

Permeability

Permeability testing of soils at the proposed tailings dam area was carried out by infiltration tests. The tests were carried out by putting a known volume of water into saturated hand augered holes of between 1.66 and 3m depth and 96mm diameter. The falling head (sinking water) was measured and recorded at set time intervals.

Permeability values obtained by this test are restricted to a small radius around the tested hole, but at least give an indication of the hydraulic conductivity (K). The results were analysed using the Porchet method. However, the permeability of the soils underlying the tailings dam fall within the range of $1 \times 10^{-6} < k < 1 \times 10^{-4}$ cm/s thereby prescribing additional modelling required to assess the risks to human health and the aquatic environment associated with the location of the proposed tailings dam.

Soil Permeability under the Tailings Storage Facility

Results of the permeability tests of the top 3 m of undisturbed soils in the TSF area are summarized in Table 5-9.

Permeability measurements of the top 3 m of undisturbed soil give a range of 10^{-6} to 10^{-4} cm/s. In terms of the DRC Mining Code Regulations, this requires additional modelling to evaluate the risks to human health and the aquatic environment as the underlying soil is not completely impervious and leakage to the subsurface will occur. However, as the geochemical test work above indicates low risk for the Kingamyambo and Musonoi tailings, this modelling is not deemed necessary.

Permeability values obtained by this test are restricted to a small radius around the tested hole, but at least give an indication of the hydraulic conductivity (K). The permeability of the saprolitic soils at the proposed TSF area ranges from $7.16\ 10^{-6}$ cm/s close to the proposed return water dam to $2.29\ 10^{-5}$ cm/s at the south west corner of the proposed tailings dam.

Table 5-9: Summary of permeability testing for the proposed Tailings Dam site

Hole ID	Coordinates		Depth (m)	Profile	Conductivity (K)	
	S	E			(cm/s)	(m/day)
HA-BH13	10.61741	25.40268	3	Sandy silt	2.28 E-05	0.019
HA-BH14	10.62555	25.39057	3	Sandy silt	2.29 E-05	0.019
HA-BH14B	10.62558	25.39000	3	Sandy silt	1.86 E-05	0.016
HA-BH15	Next to BH 15		1.66	Sandy silt	1.96 E-05	0.017
HA-BH15B	Next to BH 15		1.66	Sandy silt	1.99 E-05	0.017
HA-BH7	10o 36'' 49.3'	25o 24''42.5'	3	Sandy silt, lateritic	1.51 E-05	0.013
HA-BH7B	Next to HA-BH7		3	Sandy silt, lateritic	7.16 E-06	0.006
HA-BH7C	Next to HA-BH7		3	Sandy silt, lateritic	8.55 E-06	0.007
HA-BH7D	Next to HA-BH7		3	Sandy silt, lateritic	8.87 E-06	0.008

These results are lower than the laboratory tested results for saprolites which vary from 0.086 to 86.4 m/day for the top 3 m. This is probably due to the different lithology as the tailings dam is largely underlain by the weathered conglomerates, rather than limestone and shales.

Methodology for assessing the land capability

The FAO Framework (FAO, 1976 and subsequent guidelines) were utilised to determine the land capability of the concession area.

The FAO system is based on the following concepts:

i) The land is qualified, not only the soil.

ii) Land suitability must be defined for a specific soil use (crop and management).

iii) Land evaluation was to take into account, both the physical conditions as well as economic ones;

iv) The concept of land evaluation is essentially economic, social and political.

v) The evaluation requires a comparison between two or more alternative kinds of use.

vi) The evaluation must propose a use that is sustainable.

In the scheme, four categories are recognized. The highest category is the order that it reflects, in broad features, whether a soil is suitable or not for a given use (in this instance use for subsistence agriculture which is the dominant land use in the area). Two orders are recognized:

- *S = Suitable*. Land in which the benefits exceed the costs and sustained use does not incapacitate the soil over a sufficiently long period of time.
- *N = Not suitable*. Land can be classified as not suitable for a certain use for diverse reasons. The use proposed may be deemed technically impractical, as in irrigation of abrupt rocky terrain, or that it causes serious environmental degradation, as in cultivation on steep slopes. Frequently, however, the reason is economic, in that the profit expected does not justify the cost required.

The second category is the class that reflects degrees of suitability (for use as subsidence agriculture) within the order. These are numbered consecutively in Arabic numerals. For the order S, three classes are considered:

- *S1 = highly suitable*. Without limitations for sustained use or minor limitations that do not affect productivity nor appreciably increase costs.
- *S2 = moderately suitable*. Moderately serious limitations that reduce profits or involve risks of degradation in the sustained use of the soil.
- *S3 = marginally suitable*. The limitations for the sustained use are serious and the balance between the costs and benefits make the use only marginally justifiable. Its use is normally justified on other than economic grounds.

In the order N, three classes are also recognized:

- *N1 = Not currently suitable*. Land with limitations that could be eliminated by technical means or investment, but that these changes are at present unfeasible.
- *N2 = permanently unsuitable*. Serious limitations of generally a physical nature, which are assumed to be beyond solving over the long term.

- *X = Land for conservation*. Unsuitable for exploitation, being lands of special protection, due to their conservation, wildlife, of special scientific, ecological or social interest (e.g., parks, reserves or recreational zones).

The limits between the orders (S and N) and between the different classes (S1, S2, S3 and N1, N2) are established by the presence of limiting factors. One limiting factor is a characteristic of the soil that hampers its use, reduces productivity, increases costs and implies degradation risk, or all of the above.

These limiting factors are used to define the third category of the system, which is the subclass. In the symbol of each subclass, the number of limitations involved should be kept to the minimum one letter, or, rarely, two. The limitations proposed include:

- *t*, slope;
- *e*, erosion risk;
- *p*, depth;
- *s*, salinity;
- *d*, drainage;
- *c*, bioclimatic deficiency;
- *r*, rockiness;
- *i*, flood risk.

Finally, the fourth category is the unit that establishes the differences within the subclasses as a function of the desired use. All of the units within a subclass (S2rA, S2rM,) have the same degree of suitability at the subclass level (S2) and analogous characteristics of limitation at the subclass level (r). The units differ from each other in their characteristics of production or in secondary aspects of their management demands. Their examination enables a detailed interpretation at the planning level of the exploitation. The units are distinguished by upper-case letters that are placed at the end. There is no limit at all for the number of units examined within a subclass. These defined are:

- *A*, intensification in the agricultural use without need of great improvements;
- *M* intensification in the agricultural use with need of major improvements (irrigation, etc.);
- *P*, use for pasture for livestock;
- *F*, forestation.

The land capability according to the FAO classification system is illustrated in Figure 5-8 and Table 5-10. According to the FAO system land should be classified in terms of its suitability for a specific use. As the main use in the area (other than mining) is subsistence agriculture (slash and burning agriculture) the soils have been classified in terms of its suitability to support this type of activity.

Table 5-10: Land Capability Distribution

FAO Class	Summary	Area (ha)	Proportion of Total (%)
N2	Not suitable	2 070	31.1

S1iA	Highly suitable	20	0.4
S2dM	Moderately suitable	240	3.6
S2tM		210	3.2
S3cM	Marginally suitable	3 970	59.7
S3sM		140	2.1

Theoretically, the deeper Ferralsols and Planosols would have a high agricultural potential relative to the shallow, waterlogged Gleysols. However, poor farming practices, such as slash-and-burn agriculture, have had a significant impact on the topsoil horizons, the A horizon overlying the B horizons described above, with this horizon being almost destroyed over the concession area. This is, as a results of the burning used to clear the area destroying vegetation that would contribute to the O horizon, followed by the working of the soil, with the O being mixed with the A horizon, during the preparation of the cassava fields.

The lack of an organic A horizon significantly reduces the nutrient cycling that would normally occur in soils. Nutrient cycling involves organic matter supplying nutrients to the soils, as the organic matter decomposes. The nutrients provided by decomposition of organic matter is then utilised by plants growing on the soil. When these plants die, they in turn fall to the soil where they begin to break down to form organic matter which then starts to decompose, re-releasing the nutrients to the soil. In slash-and-burn agriculture the burning of the growing plants results in a loss to the atmosphere of the nutrients as the plants are turned to ash, thereby interrupting the cycling process.

This lack of organic material is the primary reason that the majority of land is classified as marginally suitable (S2 in Table 5-10) for agricultural purposes. The land which is classified as N2 (31% of the areas) does so as this area is overlain by either tailings or other mining related infrastructure, such as plants, open pits and rock dumps. The land with the highest land capability S1iA in Table 5-10 is the undisturbed gallery forest on the western side of the Musonoi Tailings dam. This area has not been subjected to slash-and-burn agriculture, with the result that there is a sufficient build-up of organic matter to ensure that nutrient cycling still occurs. Although not tested, it is suspected that this soil has a nutrient status that will support good productivity. The areas that classify as S3 are the dambo's (seasonal wetlands) that are potentially productive due to the high organic content of the soils. However, the classification of these soils as marginal (S3) is due to the fact that they are waterlogged and would need significant draining before they could be used in a sustainable manner on a large scale. They are currently drained and used locally for the growing of vegetables.

Evidence of Misuse

Table 5-11 reports the results of the fertility analyses that were undertaken on the soils. As there are no available in country standards for soil fertility, use has been made of generic guidelines to indicate the soil fertility. These guidelines are included in Table 5-11

Table 5-11: Results of soil fertility analysis

	Guideline	Surface soils	Sub-Surface Soils
pH Value	6.2-7.2	6.4	5.0

Conductivity, mS/m	<10	18.1	1.92
Calcium, Ca (%)	60-70	25	8.2
Magnesium, Mg (%)	8-20	15.1	2.2
Sodium, Na (%)	3-8	5.6	4.1
Potassium, K (%)	0.25-3	40	2.9
Available S (ppm)	>20	<0.1	<0.1
Nitrate as N (ppm)		0.9	0.7
Manganese, Mn (ppm)	35	2.0	0.70
Iron, Fe (ppm)	75	28	18.6
Zinc, Zn (ppm)	2-50	0.38	0.22
Copper, Cu (ppm)	0.5-30	0.64	0.20
Boron, B (ppm)	0.5-3	0.10	0.08

These soils have low nitrogen content (nitrate < 5ppm), low available phosphate content, a low cation exchange capacity and a very low organic matter content. These values indicate that the soil fertility is low. It is suspected that the slash-and-burn subsistence agriculture that has occurred over the concession area has resulted in a loss in soil fertility, which has reduced the land capability of the concession area. The effects of slash-and-burn agriculture on the soils are compounded by the heavy rainfall that is experienced in the region during summer months, leaching constituents from the soil profile, further effecting fertility.

No significant signs of erosion were observed in the concession area.

Effects of the existing tailings dam on soil quality

Potentially the existing Kingamyambo and Musonoi tailings dams have an impact on the soils below the footprint as well as the soils around the toe where tailings may have sloughed/eroded onto or leached into the soils and soils in the vicinity may be affected by wind-blown dust from the tailings dam. As it is not possible to accurately sample the soils below the dam as they are covered in tailings, it is only possible to sample the soils at the toe and make extrapolations as to the expected quality below the dam. To this end a composite soil sample was collected around the toes of the two dams. The results of the analyses on a 1:1 water extract prepared from these samples are presented in Table 5-12: Also included in this table is the analysis of a 1:1 water extract prepared from the soil sample that is considered background in that it was collected in an area not known to be impacted by mining activities. This has been used as a comparison of the impact of the respective tailings dams on the soil. The highlighted values in the table indicate where the concentration of the constituent in the soils around the tailings dam exceeds that in the background sample, indicating possible contamination of the soils at the toe of the dam.

Table 5-12: Results of the soil analyses conducted on the soil samples collected at the toe of the respective tailings dam (results in mg/l unless otherwise indicated)

	Musonoi	Kingamyambo	Surface
pH Value @ 23ºC	4.7	6.6	6.4
Conductivity, mS/m @ 25ºC	8.9	214	90.5
Calcium, Ca	0.5	210	125

	Musonoi	Kingamyambo	Surface
Magnesium, Mg	<0.5	155	75.5
Sodium, Na	10.5	21.5	28
Potassium, K	<0.5	250	200
Total Alkalinity as $CaCO_3$	15	970	380
Bicarbonate, HCO_3	20	1 185	465
Carbonate, CO_3	Nil	Nil	Nil
Chloride, Cl	25.5	92.5	185
Sulfate, SO_4	13.5	<0.5	1
Nitrate as N	19.5	<0.5	4.5
Arsenic, As	<0.1	<0.2	<0.3
Titanium, Ti	0.7	0.25	3.15
Aluminium, Al	7	9	195
Nickel, Ni	0.05	0.1	0.2
Manganese, Mn	0.1	21.5	10
Iron, Fe	3.8	13	140
Vanadium, V	0.02	0.1	0.3
Zinc, Zn	0.4	0.55	1.9
Lead, Pb	0.05	0.05	0.05
Cobalt, Co	0.25	17.5	7
Copper, Cu	0.1	10	3.2
Chromium, Cr	0.05	0.05	0.25
Cadmium, Cd	<0.05	<0.05	<0.05
Molybdenum, Mo	<0.05	0.7	<0.05

The results of the comparison of the soils collected at the toe of the two tailings dams with the background sample indicate that the samples at the toe show some indication of being enriched with elements relative to what may be expected for the background samples. The implication of this is that there does not appear to be leaching or running off from the tailings onto the soils. It should be noted that the soils collected around the toe of the Musonoi tailings dam appear to have significantly, and abnormally, lower concentrations of the various constituents, relative to the background sample. This could be due to the position of the Musonoi toe samples in the landscape, i.e. at the base of the catena adjacent to the river, with these soils having being leached over geological time as well as the soils being currently leached by fresh water or water not impacted on by the tailings. Therefore, even though there may be some contaminants being deposited on the soils, ongoing leaching by fresh water moving down the catena towards the river under the natural water gradient, could leach contaminants from the soils.

The results of the analyses indicate that the soil at the toe of the dams is slightly impacted. The existing conditions within the tailings may limit some downward leaching, although it may be assumed that the soil below the dam may be contaminated to some extent over time and dependent upon the ability of natural run-off to dissipate and remove the elements from the soils, as particularly indicated by the abnormally low elemental leaching of the Musonoi toe soils. It is thus recommended that once the tailings have been lifted during the mining process, it will be sufficient to cover the footprint of the remaining area with a layer of topsoil or soil forming materials and allow natural vegetation to re-establish.

Effects of Processing Activities on Soil Contamination

Soil samples were collected at the UZK Plant to determine the existing historical contamination associated with the two plants. It must be noted that sampling in the UZK Plant was limited as large portions of the plant is covered by hardstanding or the soils have been removed and the base compacted. Therefore, sampling was mainly focussed on the perimeter of the plant.

Samples were collected at surface (0-100 mm) and sub-surface (100-500mm) either by hand excavating a test pit or by using a soil auger. The samples were submitted to a laboratory where a 1:5 (solid to water) water extract was prepared. The extract was analysed for:

- pH, Electrical Conductivity, Alkalinity;
- Cations – Ca, Mg, Na, K
- Anions – Cl, F, SO_4 and NO_3
- 23 different heavy metals or metalloids.

In the absence of World Bank, IFC or DRC guidelines on soil contamination, recourse has been made to the Dutch Intervention Values (DIV). The DIV represent the maximum tolerable concentration above which remediation is potentially required (depending upon assessed risk) and is therefore a good indication of liability. The results of the analyses are presented in Table 5-13 It must be noted that the concentrations measured in the 1:5 extract have been mathematically converted to represent mg/kg of the various analytes, this is necessary for comparison to the DIV, which are presented as mg/kg. An exceedance of the DIV has been highlighted in grey in the two tables.

Results from the UZK Plant area

During the site assessment, it was observed that the soils of the UZK Plant appeared to be contaminated, with precipitated salts being evident on surface throughout most of the plant. These observations are confirmed by the analytical results which indicate that the salts observed on surface are likely to be gypsum, as the results indicate elevated concentrations of sulfate and calcium and probably derived from historical plant activities rather than natural formation. The heavy metal concentrations in the soils in the plant are elevated with the concentrations of Cd, Cu and Zn being several orders of magnitude above the DIV. The exceedance of the DIV would imply that remediation could be required on the site, depending on the risk.

Given the proximity of the plant to the Musonoi River, there is the potential that contaminants in the soils could leach and enter the Musonoi River. The results of the assessment indicate that the area adjacent to the river is significantly contaminated, with elevated salt and metals concentrations measured in the soils at the toe of the sludge pond. The ingress of contamination into the river from the UZK Plant could increase the salt and metal load. This increase in loading could impact on users of the river. The likely users are the local communities who have been observed to be using the river for drinking water, bathing and washing of clothes. The communities also take fish from the river for their consumption. The fact that there are users of the river, indicate that there are receptors that may be impacted by the contamination in the UZK Plant area. The implication of this is that the contamination in this area represents a risk. Therefore, as a risk exists, management of the contaminated soils in the UZK Plant is indicated, to achieve an acceptable risk profile.

It must be noted that as there is an absence of mechanical equipment to undertake deeper soil sampling in the Kolwezi area, no samples were collected at a depth greater than 500 mm. Given the high rainfall in the region, it is possible that contamination could potentially have leached to greater depths than 500 mm in the area of the UZK plant.

Table 5-13: Comparison of soil quality to DIV in the plant areas (concentrations in mg/kg)

						UZK Plant		
	Dutch Intervention Values	Sludge Pond – surf[1]	Sludge Pond Sub-surf[2]	Railyard - surf	Bag house dust disposal	Uranium Area – sub-surf	Toe of Sludge Pond @ Musonoi- surf	Toe of Sludge Pond @ Musonoi – sub-surf
pH		6.8	7.4	6.9	6.7	5.8	5.6	5.6
EC, mS/m		350	49	73	50	128	2,535	1,520
Ca		215	38	97	19	82	2,380	2,715
Mg		125	13	24	31	38	155	5.5
Na		195	12	19	22	23	51	15
K		20	4	1.5	4.5	3.5	120	27
ALK*		200	120	70	140	20	80	60
Cl		66.5	25	46	31	21	82	41
SO_4		1,375	100	325	79	475	19,310	9,700
NO_3 (N)		25	1	2	3	2	9	11
Al		<0.045	0.15	0.1	0.05	0.5	0.1	0.15
Sb	15	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
As	55	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ba	625	0.5	1.9	0.75	0.55	0.35	0.25	0.35
Be	30	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bi		0.03	0.03	0.03	0.03	0.03	0.03	0.03
B		<0.03	0.15	<0.03	0.04	0.6	0.75	0.2
Cd	12	0.03	0.02	0.04	0.01	1.5	180	38
Cr	380	<0.15	0.02	0.02	0.04	<0.15	<0.15	0.04
Co	240	45	20	36	8.5	0.75	8	1.2
Cu	190	0.65	0.1	0.65	0.03	0.15	670	510
Fe		<0.05	0.04	0.1	0.15	0.3	0.02	0.5
Pb	530	<0.05	<0.05	<0.05	<0.05	<0.05	17	3.9
Mn		15	5.5	1.9	1.15	1.5	205	20

						UZK Plant		
	Dutch Intervention Values	Sludge Pond – surf[1]	Sludge Pond Sub-surf[2]	Railyard - surf	Bag house dust disposal	Uranium Area – sub-surf	Toe of Sludge Pond @ Musonoi- surf	Toe of Sludge Pond @ Musonoi – sub-surf
Mo	200	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ni	210	0.02	0.05	0.03	0.05	0.1	0.4	0.1
Se	100	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	0.35
Si		38	29	17	68	11	370	325
Ag	15	<0.02	<0.02	<0.02	<0.02	<0.02	0.1	0.04
Sr		0.55	0.2	0.15	0.03	0.25	12	30
Sn	900	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ti		<0.005	<0.005	<0.005	<0.005	0.02	<0.005	<0.005
V	250	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Zn	720	2.15	1.4	5.5	0.55	92	15,010	2,850

* - Alkalinity as mg/kg $CaCO_3$

1 – Surface soils (0-100 mm)

2 – Sub-surface soils (100-500mm)

Land Use

The land use mimics the land capability, with almost all suitable utilisable areas being utilised for slash-and-burn subsistence agriculture, with the “farmers” typically growing cassava in these cleared areas. The *dambo’s* are also utilised for agricultural purposes, with the local community growing root vegetables, such as carrots and sweet potatoes, in these saturated soils. The proposed effluent pipeline route to the Luilu River runs through ferralsols on gently undulating land subject to subsistence agriculture, similarly to the bulk of the concession area.

The FAO does not provide a classification for land use, therefore, use was made of the DRC mining regulations (Annex VII – “Le Plan d’attenuation et de Rehabilitation” which relates to the environmental report required for exploitation projects and temporary quarries) where land is divided into the categories indicated in Table 5-14. Included in this table are the different proportions of the mining area that are utilised for the different land use activities. Figure 5-9 indicates the distribution of the different land uses.

Table 5-14: Land use as per the DRC mining regulations

Land Use	Area Occupied (ha)	Percent of total	Nature of activity[4]
Agriculture	3509	52.7	Intermittent/ temporary
Industrial	2193	32.9	Permanent
Natural	842	12.6	Permanent
Residential	112	1.7	Permanent

The risk of land slides, flowslides or other natural disasters is negligible due to the flat topography. The site is not seismically active. An assessment of seismic risk will be done as part of the detailed design. Flood risks have been assessed as part of the hydrological studies and the results have been incorporated into the design and location of infrastructure and are confirmed by the Final DFS.

5.7. Climate and Air Quality

Climatic conditions of the DRC

Two broad climatic areas can be distinguished in the DRC. The Congo River basin, which lies on the equator and forms around one-half of the country's area, consists of low-lying rain forest, which receives rainfall all year round. Temperatures are not as high as might be expected at the equator, but humidity is generally high.

The remainder of the country, comprising the area around Kinshasa, and Kivu, Kasai and Katanga provinces, experiences distinct rainy and dry seasons. Katanga province, lying largely at an elevation of 1000 m or greater, experiences a very agreeable climate with cooler, drier air than the majority of the country.

At only 10° latitude, daylight and night hours are almost equal, daylight lasting broadly between 0600 and 1800 hours. Rapid temperature drops occur after sunset during the dry season as a result of lack of cloud cover.

Five distinct seasons can be readily distinguished, namely:

1	Cool dry season	May - July
2	Hot dry season	August - September
3	Early rainy season	October - November
4	Full rainy season	December - February
5	Late rainy season	March - April

Regional climate

Meteorological observations in Katanga province were first carried out in 1899, and a significant network of meteorological monitoring stations was established in 1911. A continuous data set is available for Lubumbashi for the period 1913-1974, compiled from the records of various government bodies, NGOs and individuals.

Meteorological data were analysed to characterise the atmospheric dispersion potential of the proposed site. Meteorological parameters taken into account included wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature, precipitation and mixing depth. Long

[4] Whether this activity is temporary or permanent, intermittent or regular.

term site specific meteorological data for this study were not readily available, hence characteristics of the meteorology of the site were obtained from various sources. However, the primary sources were a meteorological station within the concession area that is currently being operated by KMT[5], information from the meteorological station at Kolwezi airport and an internet site www.weatherbase.com/weather. A more detailed description of conditions in the Kolwezi area is presented in the following sections.

Measuring of climatic conditions in the KMT Concession Area

A weather station has been operating in the concession area since March 2000. The station is equipped with sensors to provide the following information:

- External temperature
- External humidity
- Dew Point
- Rainfall
- Barometric pressure
- Wind speed and direction
- Solar radiation
- Sunshine hours

The equipment can provide automatic downloading of data to one of the administration offices.

Temperature

Average Monthly Temperatures

Average monthly temperatures for the site weather station were calculated for the period 2000 to 2004 (Table 5-15). This information does not provide long term trends of temperatures in the area. The average air temperature remains very similar throughout the year averaging between 17 and 22°C during the year. Although there is no distinct winter and summer temperature regime, average temperatures peak during September and October at 30ºC, with minima occurring during June and July with an average level of 10°C. Except for the period from September to October, average daytime temperatures are relatively similar during the year.

Table 5-15: Average temperature trends (derived from KMT weather station data)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Maximum	26	26	26	26	26	25	26	28	30	30	26	26	27
Minimum	15	15	15	15	13	10	10	12	14	15	15	15	14

Extreme Temperatures

Temperatures for Lubumbashi and Kolwezi for 1953 to 1977 were obtained from Gécamines records and are presented in Table 5.5-16.

[5] This site has been in operation since March 2000

Table 5.5-16: Temperatures for Lubumbashi and Kolwezi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lubumbashi												
Max	28	28	28	28	27	26	26	28	38	33	31	28
Avg	22	22.5	22	21	18.5	16.5	16	18	21.6	28.5	28.5	22.5
Min	16	17	16	14	10	7	6	8	14	14	16	17
Kolwezi												
Max	24.5	25.4	25.5	26.9	27	26.1	26.7	27.5	29.5	29	25	23.7
Avg	18.8	19.6	20.4	19.9	18.6	17.8	18.5	19.5	20	22.3	18.8	18.2
Min	15.8	16.8	15.4	14.5	11.4	10.2	10.4	12.2	12	15.2	15.3	15.3

Rainfall

The tropical climate of the area is characterised by distinct wet and dry seasons. The wet season (summer) starts in October and November and ends in April with the heaviest rainfall occurring from November to January. The dry season occurs from May to September (winter). The long term average monthly rainfall for Kolwezi is presented in table 5.17.

Rainfall data collected from 11 stations in the Kolwezi area were obtained from Gécamines. The list of rainfall stations is presented in Table 5-17 below. The positions of the rainfall stations are indicated in Figure 5-10.

Table 5-17: Rainfall Stations

	Lambert Projection		Station Data	
	X	Y	From	To
DE KOV (KTOWEST) at the KOV pit	327724.7633	8815748.8637	Aug 1977	Dec 2002
DE DIKULUWE (not indicated on the map)			Aug 1977	Dec 2002
DE LUILU (plant)	324601.0046	8818850.2800	Aug 1995	Dec 2002
DE MASHAMBA QEAST (not indicated on the map)	320590.1064	8811685.8861	Aug 1978	Dec 2002
DE MUPINE	325669.6913	8817774.7697	Aug 1977	Jun 1986
DE UZK (zinc plant)	330842.7280	8820723.8233	Sep 1993	Dec 2002
DE MUTOSHI (not indicated on the map)			Aug 1977	May 1987
DE MUSONOI (pit)	328666.8355	8814767.2789	Aug 1981	Apr 1999
DE KOLWEZI (pit)	332760.0681	8814830.0135	Aug 1977	Dec 2002
DE TI7 (not indicated on the map)			Dec 2000	Nov 2002

Mean Monthly and Annual Rainfall Rates

The monthly rainfall data for Kolwezi was also abstracted for the period 1956 to 1977 from reports and an electronic rainfall dataset was obtained from the Gécamines office. A monthly rainfall data set from 1956 to 2002 is summarised in Table 5-18.

Table 5-18: Monthly Rainfall Data (mm)

		Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total

1956 to Dec 2002	Adopted Long Term Rainfall Data	211	189	216	80	10	2	0	3	23	90	180	216	1219

Rainfall statistics for the remaining stations including the actual monthly rainfall, maximum daily rainfall for each month and number of days of rainfall is presented in Table 5-19.

Table 5-19: Monthly Statistical Rainfall Data

*Percentile	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Max	397	367	344	205	69	36	0	39	131	259	403	443	
10%	303	270	287	137	43	0	0	8	56	170	259	312	
30%	232	238	246	103	7	0	0	0	28	93	215	238	
50%	206	189	212	76	0	0	0	0	11	81	177	201	
Avg	211	189	216	80	10	2	0	3	23	90	180	216	1219
70%	170	139	181	47	0	0	0	0	4	68	152	175	
90%	132	104	142	28	0	0	0	0	0	33	92	144	
98%	99	70	108	5	0	0	0	0	0	11	57	100	
Min	91	64	75	0	0	0	0	0	0	0	0	0	

*Percentage of time that a value is equalled or exceeded (i.e. approximately 30% of the time 93 mm or more occurs during October)

Storm Rainfall

The daily rainfall data recorded in the Kolwezi area has been used to calculate the 24-hour storm rainfall for the region. The maximum 24-hour rainfall for each year was abstracted from each of the 10 rainfall stations and this then created an "annual maximum series" data set. The data set for each of the rainfall stations was input into the Regflood program. The Regflood program is a statistical program, which is used to calculate the 24-hour storm rainfall for the area. The general extreme value statistical fit for De Mashamba was adopted for this area and the 24-hour storm rainfall values for various recurrence intervals are presented in Table 5-20. The shorter duration recurrence intervals are estimates based on curves as no continuous rainfall measurements are available at the site. These data need to be updated as more data is collected on site.

Table 5-20: Storm Rainfall (mm) for Kingamyambo Musonoi Tailings Project

	1:2	1:5	1:10	1:20	1:50	1:100	1:200	1:500	1:1000	1:10000
24 hour	76	99	112	124	137	146	155	165	171	190
12 hour	71	93	105	117	129	137	146	155	161	179
8 hour	68	89	101	112	123	131	140	149	154	171
6 hour	66	86	97	108	119	127	135	144	149	165
2 hour	55	71	81	89	99	105	112	119	123	137
1 hour	46	59	67	74	82	88	93	99	113	114
30 min	35	46	52	57	63	67	71	76	79	87

Note: the results for the larger storms in excess of 1:20-year should be used with caution due to the record period of 30 years. These data were also used to estimate the peak flow rates for various rivers near the Project.

Annual Evaporation

Evaporation data were obtained from site reports. The exact source of the data and the length of the record are unknown thus this data need to be treated with caution. The data are presented in Table 5-21.

Table 5-21: Evaporation Data for Kolwezi (assumed A Pan evaporation)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
95	120	168	186	230	229	214	146	142	190	132	116	1968

Wind

The wind field for an area is an important parameter with respect to air quality. Whilst rainfall and temperature attenuate the behaviour and concentration of a pollution plume after the release of a pollutant into the atmosphere, wind can generate dust emissions and thereafter control the dispersion of a pollution plume. The degree to which the winds have an influence on dispersion depends on wind speed, with higher winds speeds resulting in longer travel distance and dilution of the pollutants. Lower more stable wind conditions result in shorter travel distance and build-up of pollutant levels (especially gases) over a smaller area.

Annual wind roses for the site are presented in Figure 5-11 to Figure 5-14. The wind roses describe the prevailing wind conditions within the KMT concession area.

The prevailing wind directions for the area can be characterised as being on a narrow vector from east-northeast to east-southeast. A similar pattern is observed during the night and day with higher wind speeds being observed during the day. This is not unexpected since the higher daytime temperatures will result in more unstable conditions and hence higher wind speeds over the southerly through to north westerly sectors.

However the average conditions are generally not representative of all of the prevailing wind conditions. During the period October to March the prevailing winds also have a north-westerly and an easterly component, distinctly north-easterly in January and reverting to a north- westerly-easterly pattern in March and thereafter reverting to a distinctly easterly wind from May to September. It is important to note that the wet season coincides with the winds that prevail from the north-west indicating that moisture from the equatorial regions and the Atlantic Ocean to the west brings rains to the region. The easterly winds are dry and usually barren of any moisture.

The average wind speed is 2.7 ms^{-1}. The winds that prevail form the east and north east are usually stronger and this is important from a dust generation and dispersion perspective since this occurs during the dry season when dust emissions peak. The north-westerly winds are usually less than 2.5 ms^{-1} with calm conditions prevailing for up 17.5% of the time.

Risk and probability of meteorological disasters such as sand or dust storms, hail, pouring rains, hurricanes, cyclones, tornados, floods, drought

The risk and probability of meteorological disasters such as sand or dust storms, hail, intense rains, hurricanes, cyclones, tornados, floods, drought have been assessed. According to the limited information available it appears that the only major meteorological risks are heavy rains and flooding during the wet season (October to March), and droughts, especially with the possibility of late rains at the beginning of the wet season (October). The others only have a negligible chance of occurring.

Ambient Air Quality

Air quality varies with the season, reflecting variations in temperature, humidity and rainfall. During the dry season any smoke and dust which arises, lingers in the near-ground air layers and causes frequent, but not significant, hazes and reduced visibility. However, during the wet season, heavy rainfall quickly disperses smoke and dust, and maintains air quality.

During the dry season, the KMT concession area and Kolwezi environment is characterised by very dry and dusty conditions with large quantities of windblown dust visible in the atmosphere. The major sources of dust and other pollutants of the air are described below. Although dust is blown from a number of different surfaces the Kingamyambo tailings dam, which has not been rehabilitated or revegetated at all, is a major source of windblown dust in the concession area. This was identified during the audit of the site which was carried out, which also noted the tailings ponds at the Zinc plant (UZK), the Sulfide tailings dam and waste rock dumps as sources of dust. The data collected are generally unable to distinguish between dust from different sources, but simply because of its size (approximately 3km^2) Kingamyambo is the largest contributor.

Baseline pollution sources

Kolwezi is a large town with a considerable infrastructure including that associated with many years of mining. The environment is generally degraded and the existing facilities old and poorly maintained. The existing sources of air pollution are summarised in Table 5-22.

Table 5-22: Summary of baseline sources of air pollution

Source	Location	Pollutant	Comment
Kingamyambo and Musonoi River tailings dams	Within the KMT concession area.	Dust	Major sources of particulate matter.
Waste rock and ore stockpiles	Within and outside of the KMT concession.	Dust	Scattered around the old mine workings and could be a major source of dust when high speed winds prevail.
Motor vehicles	Within and outside of the KMT concession.	Dust, SO_2, NO_x, Volatile organic compounds (VOCs) and greenhouse gases.	Source of particulate matter resulting from the re-suspension of dust from the unpaved road surfaces. Although there is a low vehicle count in the area there has been an increase in vehicle activity in the area with baseline dust concentrations increasing along the main access roads around the site since 2004. Nevertheless the impacts from this source are expected to be limited to distance of less than 100m from the roads edge.
Existing Quartzite Quarry	East of proposed tailings dam	Dust	This quarry has not been use for the past 10 years and hence it is not considered to be a dust source for the purposes of this assessment. At present

			the quarry is largely overgrown with vegetation and any potential for dust emissions from discarded waste rock and aggregate stockpiles is considered to be negligible.
Kolwezi Concentrator	Outside of the KMT concession	Dust, SO_2	Could be a significant dust source and minor source of SO_2.
Luilu Plant including the Felco smelter	Outside of the KMT concession	Dust, SO_2	Could be a significant dust source and minor source of SO_2.
Mining activities associated with mining of the open pits around Kingamyambo Tailings dam	Outside of the KMT concession	Dust, VOCS and green house gases	Mining operation sin this area are just commenced with emissions from these operation on an increasing trajectory going forward.
Slash and burn of vegetation	Regional source	Particulate matter, SO_2, VOCs and greenhouse gases	Seasonal in occurrence usually at the end of the dry season (May to September)

Quantification of existing liabilities

The existing monitoring information and the limited analysis that were done in an attempt to apportion sources of dust at the various dust fallout monitoring points were inconclusive primarily because the Kingamyambo tailings have a similar mineralogy to that of materials from the surrounding areas i.e. dust that is characterised as being alumina and iron rich. Furthermore the procedure used for the quantification of dust fallout required that the samples be preserved with copper sulfate and this eliminated that potential opportunity to distinguish between dust from the Kingamyambo and Sulfide tailings dams.

Hence the only way that baseline liabilities relating to air quality issues can be identified is by determining the footprint of the impacted areas as a result of the dust emissions from existing sources. These baseline conditions were modelled i.e. the emissions from the major dust sources within the concession area and it was predicted that exceedances of the World Bank IFC guidelines currently do occur in areas up to 6 km from the Kingamyambo tailings dam and up to 4 km from the Musonoi river tailings deposit. This suggests that there could be liabilities as a result of respiratory health impacts related to dust emissions from existing sources in villages within and beyond the boundaries of the concession areas.

Existing air quality monitoring

Dust Monitoring

KMT has been monitoring total dust fallout within the KMT concession area since March 2000. The original locations of the dust monitoring points were selected by Annegarn Environmental Research (Pty) Ltd in January 2000. The procedures used for the collection and quantification of dust fallout follows those procedures set out in the ASTM guideline D1739-94, Standard test method for the Collection and Measurement of Dustfall (Settleable and Particulate Matter). The primary purpose of the existing dust monitoring network was to establish a baseline of dust fallout levels in the area and identify the impacts of dust emissions from the existing dust sources in the area i.e. tailings dams, waste rock dump and the roads network. The locations of the dust monitoring points are presented in Figure 5.15. A description of the locations and reasons for the location is presented in Table 5-23.

The results of the dust fallout monitoring for the period March 2000 to April 2004 are summarised in Table 5-24 and a graph of the average dust fallout is given in Figure 5-16. This data set has been supplemented by more recent data from the KMT network and other networks from other mining companies in the area (Table 5-25). A discussion of the dust fallout monitoring results is presented in Table 5-26.

It should be noted that the latest IFC Environmental Health and Safety (EHS) Guidelines of April 2007 (IFC 2007) do not stipulate guidelines for dust fallout. There are no DRC guidelines for dust fallout and therefore the South African guidelines are used for comparison. No other ambient air quality data for the area are available.

Table 5-23: Description of dust fallout monitoring points.

Site ID	Site Name	Description and Comment
KOLW01	Weather Station/New plant site	Baseline measurement for new tailings dam
KOLW02	Kingamyambo Village	600 m NE of KTD, highly sensitive site
KOLW03	Kingamyambo Tailings Dam (KTD) North East	1.7 km NE of KTD, in the direction of the Zinc Smelter
KOLW04	Arsenel Ferroviarie	In the open are marked Arsenel Ferrovaire 1 km west and NW of KTD downwind in the dry season. Heaviest dust falls expected here.
KOLW05	Luilu	Village of Luilu, 5.3 km NW of KTD. Downwind in the most sensitive direction at the point of first significant habitation.
KOLW06	Kolwezi	Western end of Kolwezi, closest to KTD 3.1 km SSE of KTD. Closest densely populated village but not on a prevailing wind direction, hence less sensitive to dust.
KOLW07	Musonoi River East	At a village on the east bank of Musonoi River. Monitors dust from tailings in the river course.
KOLW08	Kasobantu East	NE corner of Kasobantu Dam, within security fence.
KOLW09	Kasobantu West	West of Kasobantu Dam. Monitors baseline conditions for the new tailings dam.
KOLW10	New Tailings dam	Background dust monitor. Monitors pre-conditions for new tailings dam

Table 5-24: Average dust fallout in mg/m²/day units for the KMT concession area – March 2000 to April 2004

Dust monitoring Points	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
KOLW01 N	61	44	111	94	127	191	129	57	230	194	78	157
KOLW02 N	251	163	200	108	188	277	237	150	209	248	280	106
KOLW03 N	65	61	60	214	257	294	329	201	220	289	163	49
KOLW04 N	49	125	499	480	***1434***	***1393***	***2100***	***1434***	***1577***	*1121*	318	94
KOLW05 N	100	114	175	361	596	*693*	*1190*	*709*	*689*	***2088***	178	89
KOLW06 N	243	224	218	158	152	183	226	133	163	299	135	61
KOLW07 N	189	202	290	268	428	508	410	283	267	384	*603*	39
KOLW08 N	38	53	197	199	365	392	275	176	209	578	180	41
KOLW09 N	46	32	176	70	221	342	335	226	309	*809*	416	43
KOLW10 N	155	89	221	120	153	137	127	99	106	548	501	96
SA guideline Values												
*Residential	600	600	600	600	600	600	600	600	600	600	600	600
*Industrial	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
*Alert	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400

* Since SRK is unaware of any guidelines for the DRC in terms of dust fallout, the SA guidelines for dust fallout have been used. Values shown in italics are above the residential guidelines, values indicated in bold are above the industrial guideline values; no readings were obtained above the Alert guideline value of 2400 mg/m²/day, although two readings were obtained of over 2000 mg/m²/day.

Table 5-25: Average daily dust fallout (mg/m²/day) for 2000 - 2006 (Data supplied by First Quantum Minerals)

Year	Kolw01N	Kolw02N	Kolw03N	Kolw04N	Kolw05N	Kolw06N	Kolw07N	Kolw08N	Kolw
2000 (1)	106.88	208.48	176.60	919.80	491.54	138.57	243.16	231.69	320.7
2001	61.90	156.13	135.38	819.03	756.88	115.55	278.45	166.63	133.7
2002 (2)	200.19	183.07	193.73	1162.86	453.82	283.80	436.17	271.29	380.0
2003 (3)	168.91	245.31	301.26	1294.43	794.33	204.35	438.70	357.95	216.4
2004	131.28	206.83	238.08	Not in place	469.54	196.58	294.10	125.24	78.39
2005	56.52	112.10	132.81	Not in place	273.13	513.48	253.34	317.29	38.94
2006 (4)	22.94	57.26	62.07	Not in place	152.26	33.33	82.35	57.94	18.40
SA Guideline Values									
Residential	600	600	600	600	600	600	600	600	600
Industrial	1200	1200	1200	1200	1200	1200	1200	1200	1200
Alert	2400	2400	2400	2400	2400	2400	2400	2400	2400

Notes:

1 – Monitoring period: March - December 2000

2 – Monitoring period: January - October 2002

3 – Monitoring period: May - December 2003

4 – Monitoring period: January - April 2006, Limited data and therefore not comparable to other years

The 2007 – 2008 and the 2000 – 2006 dust fallout results cannot be directly compared as they were not located at identical positions. However it is possible to conclude that the results are in the same order of magnitude or are higher at certain locations, which is the expected outcome due to the increased activity.

Table 5-26: Discussion of dust fallout data

Site Location	Discussion
KOLW01 Plant Site A	The dust fallout at this point is the generally the lowest for all points monitored and remains low throughout the year and is currently viewed as a background monitoring point. Average daily dust fallout levels do not exceed 200.19 mg/m^2/day for the period 200 to 2006. For the period March 200 to April 2004 peak concentrations usually are observed during the dry season especially during the period May to September. The elevated level observed during October is due to low (<30 mm) rainfall levels during 2002 and 2003. Dust levels do not exceed the South African residential guideline value of 600 mg/m^2/day.
KOLW02 UZK Village	Although KOLW02 is placed close to the Kingamyambo tailings dam (KTD) dust levels at this point is amongst the lowest at all of the points that were monitored. This is the case because this point is located upwind of the prevailing wind direction especially during the dry season. The highest average dust levels (245 mg/m^2/day) are observed in 2003, for the period 2000 to 2006. This is probably due to fact that this point is downwind of the prevailing winds during the wet season.
KOLW03 Zinc Plant	The dust levels at this point are similar to those that are observed at KOLW02. It should be noted that although this point is located upwind of KOLW02 is close to the Musonoi River Tailings Dam and hence occasionally levels are observed. Since 2000 dust levels have increased and decreased but they have remained within data set maximum and minimum levels.
KOLW04 North west of Kingamyambo Tailings Dam	This point tends to have the highest dust fallout levels with peak concentrations occurring during the period May to October. This is not unexpected since this point is directly downwind from the KingamyamboTailings Dam for the prevailing winds during the dry season. Dust levels at this point exceed the SA Industrial guideline limit of 1200 mg/m^2/day during the dry season. This point has not been active since 2004
KOLW05 Luilu	This point tends to have the second highest dust fallout levels and is also downwind of KTD during the dry season. Dust levels exceed the SA residential guideline of 600 mg/m^2/day. This is significant since this point is in a residential area and may have a nuisance and health impact on the residents in Luilu village. It is important note that not all of this dust may be due to dust from KTD since there are other dust sources viz. Luilu plant and the waste rock dumps situated upwind and within a 2.5 km of radius of Luilu village. It is significant to note dust levels have been decreasing since the peak that was observed in 2003.
KOLW06 Kolwezi Town	The dust fallout trend at this point is similar to that observed at upwind (dry season) monitoring points KOLW02 and KOLW03 with decrease since the peak in 2002 and s spike in concentrations observed during 2005.
KOLW07 Kamimbi Village	Dust levels at this point are the highest amongst the dry season upwind monitoring points. Dust levels have steadily decreased since 2003. Wet season dust levels tend to be higher at this point since it is downwind of the Musonoi River tailings area during this period with the highest average dust levels recorded during November for the period 200 to 2004 (Table 5.24).
KOLW08 Kashala Village	Dust fallout trends at this point are similar to that which was observed at KOLW07 and for similar reasons as well. The primary dust source in this area is the Musonoi River tailings area.
KOLW09 Kalulu	Dust fallout levels at this point are generally below 350mg/m2/dayexcept for the period during 2002. However levels increase in October to 809 mg/m2/day (>SA residential level) (Table 5.26). This point is downwind of potential dust sources throughout the year but it is primarily affected by dust emissions from the Musonoi River tailings area.
KOLW10 New Tailings Dam Site	This point has a similar dust fallout trend to that observed at KOLW09. The main difference is that the dust levels are slightly lower. This is not unexpected since this point is further away from the Musonoi River. This confirms that the Musonoi River tailings are the primary dust source in this area.

Chemistry of the fallout dust

Five dust samples collected during May 2004 were submitted for chemical analysis. The samples were sent to Echalaz and Osborne, an ISO 9001 certified laboratory based in Durban South Africa. The samples that were analysed were selected on the basis of dust masses and spatial representativity. The samples were chosen for the period May 2004 since they had some of the higher loadings and were recently collected. The results of the analysis are presented in Table 5-27.

Table 5-27: Chemical analysis of selected dust fallout samples

Sample Location	KLOW03	KLW04	KWO05	KLW07	KLW10
Sampling Month	**May 2004**	**May 2004**	**May 2004**	**May 2004**	**May 2004**
Sample Mass (g)	0.26	1.11	0.41	0.39	0.12
Sodium (%)	0.30	0.07	0.21	0.26	0.75
Magnesium (%)	0.14	0.50	0.17	0.11	0.08
Calcium (%)	0.18	0.23	0.33	0.33	0.37
Chloride (%)	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate (%)	2.79	0.91	1.99	1.94	5.49
Aluminium (%)	1.00	0.27	0.92	0.82	0.33
Arsenic (%)	<1	<1	<1	<1	<1
Cadmium (%)	<1	<1	<1	<1	<1
Iron (%)	1.14	0.56	1.61	1.14	0.42
Lead (mg/kg)	309	27	121	51	83
Manganese (mg/kg)	382	377	271	315	308
Zinc (mg/kg)	1088	96	416	330	867
Mercury (mg/kg)	<1	2.0	2.7	1.1	<1
Total Chromium (mg/kg)	<1	11	56	64	158
Cobalt (mg/kg)	463	2180	418	2.6	83
Copper (%)[1]	7.65	3.33	6.02	6.41	13.36
Nickel (mg/kg)	19	11	27	13	<1

1 – The copper concentration may be misleading since copper sulfate was used as an algaecide in the dust monitors and this has increased the copper and sulfate concentrations. Hence no comment will be given on the copper and sulfate concentrations.

* - The reader must note the values presented in Table 5-27 are not expressed in a concentration that can be compared against an ambient guideline value. Hence the chemical data presented only gives an indication of the chemical characteristics of the dust in the areas.

The dust in this area can be characterised as being alumina and iron rich. Other heavy metals such as lead, manganese, zinc, chrome and cobalt are present as minor elements with nickel present in trace amounts. Sample KOLW3 taken from areas close to the Zinc smelter has the highest level of zinc with elevated levels of lead, manganese and cobalt. The dust from KOL04W a point representative of dust emanating from the KTD tailings dams has a relatively high level of cobalt and manganese relative to those measured at the other monitoring points.

The dust at Luilu village tends to have an 'average' chemical fingerprint containing most of the target parameters which are within the ranges on concentrations that were measured in all of the samples.

Except for the sample at KOLW04 all off the samples have a characteristic zinc concentration suggesting either that the zinc smelter has had an impact on the soils in the surrounding areas or the soils in the area are naturally high in zinc. Overall the dust contains base metals such as zinc, cobalt and lead suggesting that this is a natural condition for the soils. From an air pollution perspective the presence of some of these metals may pose a health risk especially metals such as lead, mercury, manganese, cobalt and nickel.

Mineralogical analysis of dust samples

Three dust samples were selected and submitted to Mintek in Randburg, South Africa, for mineralogical characterisation using X-Ray diffraction. The mineralogical analysis was undertaken so as to determine whether there are any minerals that could be used to determine the source of the dust. Once again the sample selection was based on location and dust loading. Due to the nature of the samples only a semi-quantitative analysis was conducted. The results are tabulated in Table 5-28.

Table 5-28: Mineralogical analysis of selected dust fallout samples

Mineral	Chemical Formula	KOLW05	KOLW07	KOLW09
Brochantite	$Cu_4(SO_4)(OH)_6$	5 - 20 %	5 - 20 %	Trace
Posnjakite	$Cu_4(SO_4)(OH)_6 .H_2O$	5 - 20 %	Trace	Not detected
Langite	$Cu_4(SO_4)(OH)_6 .2H_2O$	Not detected	5 - 20 %	>50%
Quartz	SiO_2	>50%	>50%	Trace
Kaolinite	$AlSi_2O_5(OH)_4$	5 - 20 %	5 - 20 %	Not detected

The results of the mineralogical analysis indicate that the dust in the area especially those close to the mining area consists primarily of quartz and kaolinite clay. The presence of the copper bearing minerals should be ignored since it is possible that these minerals may have formed from the addition of the copper sulfate algaecide.

Although silica was not targeted in the bulk chemical analysis the XRD indicates that the matrix of the soils consists of quartz and aluminium silicates. From an environmental health perspective the presence of quartz is a concern since prolonged exposure via the respiratory pathway can cause silicosis. It is important to note that the two points KOLW05 and KOLW07 are areas that are affected by the tailings that have the highest levels of silica.

Dust Modelling

It should be noted that no remodelling was done. However, it is the specialist opinion that the proposed changes to the project within the KMT concession area will not be materially affect ambient dust levels as a result of the proposed changes to the project. Areas outside of the KMT concession area will be affected as a result of the increased vehicle movement in the Kolwezi area especially the area roads between Kolwezi and Luilu. In addition to this the proposed use of road transport between Zambia and Kolwezi will add to increased dust levels along the road especially in areas where the road is not paved and passing through villages. This aspect will have to be addressed as part of the management plan.

The data from the dust monitoring network has been analysed in Section 5.7.8. The following figures (Figure 5-16 to Figure 5-20) show the existing levels of dust i.e., Total Suspended Particulates (TSP) and PM10's (particulate matter <10µm) which have been calculated by the air quality model. These figures illustrate the effects of the prevailing winds and how the nearby settlements are affected by existing dust levels. Reference should be made to these figures when viewing the isopleths (dust contours) for construction and operational conditions as shown in the Impact Assessment Chapter of this report (See Chapter 7 of this report). This project will have a positive impact on ambient dust levels (decrease) on removal of the Kingamyambo and Musonoi River Tailings Dams.

SO_2 and NO_2 Monitoring

Since there is no long-term SO_2 and NO_2 monitoring data for the area, one-off dry season and wet season baseline monitoring runs were conducted during August 2004 and February 2005. Although these samples were taken to represent SO_2 and NO_2 levels during the dry and wet seasons respectively, they are not truly indicative of the long term dry and wet season trends. The results represent a 'snap shot' of the monitoring period. Nonetheless, the area does not currently have any major sources of SO_2 and NO_2 and those sources that are present are unlikely to change significantly on a daily basis, as would be the case in an industrialised urban environment. These data have been supplemented by subsequent sampling that was undertaken during the period April 2007 to January 2008 by other mining companies operating in the Greater Kolwezi area (Table 5.30). The samples were taken over a 24-hour period using Radiello diffusive monitors. These monitors are passive monitors that are made of mycroporous polyethylene which are coated with triethanolamine (TEA). SO_2 and NO_2 are chemiabsorbed onto TEA as nitrite and sulphite ions respectively. Nitrite is quantified by visible spectrophotometry while sulfite and sulfate are analysed by ion chromatography. Sampling is selective for gaseous molecules i.e. any airborne nitrite, sulfite or sulfate will not cross the diffusive membrane.

The samples were submitted for analysis to Protechnik Laboratories in South Africa. The laboratory is an ISO 17025 certified laboratory. Although the method for the quantification of NO_2 and SO_2 is not accredited, the sample handling and quality control procedures are in accordance with ISO 17025 requirements.

Dry Season Monitoring

All of the passive monitors were collected over a 24-hour period from 24 to 25 August 2004 and the results are tabulated in Table 5-29 together with reasons why the sampling locations were chosen. The laboratory certificates are included in Appendix 5.1 of the Air Quality Impact Assessment report. The equivalent 2007 and 2008 data are presented in Table 5.30.

These results indicate that SO_2 and NO_2 levels are well below the respective DRC limit values as well as the respective World Bank/IFC ambient air quality guidelines. This is not surprising since there are no significant sources of SO_2 and NO_2 in the area other than the motor vehicle emissions and emissions from the Felco electric arc furnace at Luilu, the burning of wood for domestic purposes and regional scale slash and burn of forests and grassland areas.

Wet Season Monitoring

A second set of SO_2 and NO_2 samples were collected over a 24-hour period during 10 to 11 February 2005. These results are tabulated in Table 5-29 and the laboratory certificates are included in Appendix 5.1 of the air quality impact assessment report. The equivalent 2007 and 2008 data are presented in Table 5.30.

The wet season monitoring results indicate that, relative to the dry season, SO_2 levels are lower with all of the samples reporting levels that were below the detection limit of 2.23 µg/m^3. This is not unexpected since the primary source of SO_2, is regional scale burning of forests and grasslands that occur during the dry months. Furthermore, during the rainy period SO_2 is 'washed' out of the atmosphere and deposited onto the surrounding environment.

Although the NO_2 levels increased during the wet season the change in concentration is not considered significant and remains well below the DRC guideline level of 200 µg/m^3. The IFC April 2007 guidelines do not list a 24-hour guideline for NO_2. Of significance is that fact that the points where NO_2 concentrations were observed were at points between the Musonoi and Luilu rivers. Based on these results the source of NO_2 could not be confirmed, but a likely source of NO_2 could be the natural biogenic processes that release nitrogen gases into the atmosphere at higher rates during the wet season.

These results indicate that SO_2 and NO_2 levels are well below the respective DRC limit values and the World Bank/IFC guidelines where applicable.

Table 5-29: 24-Hour NO_2 and SO_2 results

Site Location	SO_2 (µg/m^3)		NO_2 (µg/m^3)		Comment
World Bank/IFC	125		Not specified		
DRC Limit	500		200		
Sample Date	**08/04**	**02/05**	**08/04**	**02/05**	
KOLW01	2.93	<2.23	<18.54	23.73	This point was sampled to represent baseline conditions at the proposed new plant as well as represent a present day background level.
KOLW02	3.52	<2.23	<18.54	21.66	Representative of conditions around KTD and downwind of the Kolwezi Concentrator Plant.
KOLW05	<2.23	<2.23	<18.54	23.73	Baseline conditions at the site of the new tailings dam and downwind of the proposed new plant and Luilu Plant.
KOLW07	2.54	<2.23	<18.54	<18.54	Baseline conditions at an upwind location at Kamimbi village.
KLW08	ns	<2.23	ns	<18.54	Baseline conditions at Kashala village which is upwind of the new sulphuric acid plant.
KOLW10	4.69	ns	<18.54	ns	Baseline conditions at the new tailings dam site

Note: ns - not sampled

Table 5-30: SO_2 results for April, July and September 2007 – 24- hour readings in µg/m^3.

Monitoring period	Luilu refinery	Luilu City	Kapata City	Musonoi Village	Tshamudende Clinic
Apr-07	3.32	3.09	4.3	2.83	No monitoring
Jul-07	0.61	3.09	1.81	1.62	No monitoring
Sep-07	0.06	0.3	stolen/lost		1.5
Jan-08	BDL	BDL	BDL	BDL	BDL

SO_2 Modelling

The SO_2 modelling results of the original study showed that the predicted ambient SO_2 levels as a result of emissions from the sulfuric acid plant would be negligible relative to the IFC 24-hour guideline of 125µg/m^3.The maximum predicted off-site concentration was 1.3µg/m^3. For the new project the stack height of the acid plant will be increased from 40m to 70m and with emissions levels that will meet World Bank IFC guidelines. The increased stack height will result in further decreases in contributions to ambient SO_2 levels as a result of enhanced dispersion and dilution of SO_2 emissions, despite the increase in sulphuric acid production which is about 17%.

Greenhouse Gas Emissions

Whilst greenhouse gas (GHG) emissions are expected to increase, the additional load is expected to be negligible in around the mining operations. Except for the use of diesel generators in remote locations and as backup in the event of power failures, all of the electricity required will be supplied by the DRC National Electricity Supply Company (SNEL) by the project. The electricity supply from SNEL is 99% clean i.e. hydroelectric generated and as such additional GHG emissions resulting from the increased in electricity demand for the proposed operation will be negligible. There may be a significant change in GHG emission levels as a result of switching to road transport. However this has not been quantified. As is the case with motor vehicles, the GHG emission from the diesel generators needs to be quantified.

5.8. Surface Water

The positions of the Musonoi River and its tributaries are presented in Figure 5-21 The Musonoi River has its source approximately 6 km north of Kolwezi town on the Plateau Manika. Runoff seems to be minimal and infiltration at the Plateau is as high as 60 %. The runoff and seepage flows in all directions off the plateau.

A dam called the Golf Dam is situated upstream of the town near the Golf Club. Immediately downstream of the Golf Dam, the Musonoi has its confluence with the Katanga River. The Katanga River drains the bulk of the town including Manika city, Kolwezi industrial and Kanina city. The Kabongo Dam is situated on the Katanga River upstream of the Kolwezi pit (now filled with water) The outflow from the Kabongo Dam is a canal 8 m wide with sluice gates. The canal diverts the river away from the Kolwezi open pit and discharges back into the Musonoi River downstream of the Golf dam.

The Musonoi River then flows past the Kolwezi concentrator (KZC) and then the Kingamyambo tailings, where it is partially covered by the tailings in this area. The Kingamyambo canal to the south of Kingamyambo tailings dam drains into the Musonoi River upstream of the Sulfide tailings dam. The main source of water is discharged from the KOV pit tank, immediately south of the Kingamyambo tailings facility, as it is continuously leaking. The canal flows past an area that was used historically for the stockpile of uranium rich minerals. Although the stockpile has been removed, the remaining footprint has high radioactivity and is the subject of a separate specialist study.

The Musonoi River is then joined by another significant tributary called the Dilala River. The Dilala River drains the northern part of Kolwezi town. After the Dilala River and Musonoi River confluence, the Musonoi River flows past the Usine Zink village (UZK Ville) and the Sulfide Tailings into the existing Musonoi Tailings dam upstream of the UZK zinc plant.

The Kakifuluwe River then joins the Musonoi River, but because of the tailings build-up, reverse flow from the main Musonoi River into the Kakifuluwe River occurs through a culvert (1.5 m x 2 m high). A wetland has thus formed and discharges into a karst (sinkhole) which opened up along a southwest–northeast trending fissure in the late 1980s. This event probably coincided with the drying up of the Kakifuluwe River Pumphouse, which had supplied water to the UZK town in the past. The upstream sections of the Kakifuluwe River, which flows past the Tshala village, also flows into the fissured depression but into a different cavity. It is not clear where the water in the karst daylights - isotope tests in BH6, located at proposed Plant Site A, (refer to Section 0) confirmed that the Kakifuluwe water draining into the karst does not decant into the dambo located to the northwest of the KOV pit.

The Musonoi is hydraulically connected to the dambo located near plant site A. The Kanamwamwa River flows into the Musonoi River nearer the Kasobantu Dam. The proposed site for the new tailings dam falls within the Kanamwamwa River catchment. A small sub-tributary to the Kananwamwa is the Muninga Stream which was dammed to supply water to the Muninga Farm in the past.

The Musonoi River flows into the Kasobantu Dam, which has two outlets. The principal outlet discharges into the Nzilo Dam via a man-made canal. This carries the normal flows from the dam. The Nzilo Dam lies on the Lualaba River. The emergency outlet (Kasobantu outflow) is for storm conditions only and discharches into the original riverbed below the dam wall. (The original channel below the dam wall, however, carries only a very small seepage flow during normal periods).

Seepage through the earthen Kasobantu Dam wall flows into the original Musonoi watercourse downstream of the wall and an iron rich orange coloured precipitate is apparent. Thereafter, the Musonoi River joins the Luilu River and later the Luilu River joins the main Lualaba River, which later becomes the Congo River. The Luilu River has it's origins to the west of Kolwezi also within the Plateau Manika. The Dikuluwe pit was developed in the old channel of the Luilu River at the confluence with the Kabulungu and Luilu rivers. The river channel was diverted with a canal from the Upper Luilu Dam to the Poto-Poto River downgradient of the Poto-Poto Tailings Dam. The Luilu River also joins the Poto-Poto River 3 km downgradient of the Dikuluwe Pit. The Poto-Poto tailings dam was breached in the past, resulting in the deposition of tailings all along these two rivers as far as the Luilu discharge dam wall. Copper rich effluent is also discharged to the Luilu River from the Kamoto and Luilu refinery. The degradation of these rivers is apparent in the satellite and photographic images.

The Lualaba River flows northwards to Kinshasa and has its source in Zambia. The catchment area of the Lualaba at the major Nzilo dam is approximately 17,000 km² and the flow downstream of the hydroelectric power station is usually in excess of 80 m^3/s.

Floodline Determination

The floodlines were calculated using the HEC-RAS model, which determines the flood levels for various peak flows using standard Manning based hydraulic equations. The 1:50 and 1:100-year floodlines are graphically presented in Figure 5-22. The input required to run the model includes:

- cross sectional data, which is obtained from the topographical data;
- “roughness” of the watercourse, which is obtained from a site visit;
- hydraulic control (culverts, dams), which is obtained from a site visit;

The following should be noted for the Musonoi River reach immediately upstream of the Kasobantu dam to the confluence with the Kanamwamwa River (SW09 to SW10):

- the 1:100 year velocities in the stream are approximately 0.1m/s and generally erosion is not a cause for concern;
- The proposed infrastructure and existing infrastructure are situated outside the 1:100 year floodline.

The following should be noted along the Musonoi River upstream of Kanamwamwa River confluence to a point where the Kakifuluwe River and the Musonoi River joins SW10 to SW11:

- the 1:100 year velocities in the stream are between 0.1 and 0.6m/s and generally erosion is not a cause for concern;
- The proposed infrastructure and existing infrastructure are situated outside the 1:100 year floodlines.

The following should be noted for the Musonoi River reach at a point immediately upstream of the confluence with the Kakifuluwe River to the point where the Chingana River joins the Musonoi River SW12 to SW11:

- The 1:100 year velocities in the stream are between 3.0 and 10.0m/s and generally erosion is a cause for concern.
- The proposed infrastructure and existing infrastructure are situated outside the 1:100 year floodlines.

The following should be noted for the Musonoi River reach upstream of the Chingana Stream to the end of the concession area SW12 to SW03:

- the 1:100 year velocities in the stream are between 0.6 and 3.3m/s and generally erosion is not a cause for concern;

- The proposed infrastructure and existing infrastructure are situated outside the 1:100 year floodlines.

The following should be noted for the Muninga River:

- the velocities are generally between 0.2 and 2.0 m/s and erosion is not expected to be substantial;
- The proposed infrastructure and existing infrastructure are situated outside the 1:100 year floodlines.

The following should be noted for the Kanamwamwa River reach upstream of the confluence with the Muninga River:

- velocity is greater than 2 m/s and erosion will be anticipated for any controls within the river;
- The proposed infrastructure and existing infrastructure are situated outside the 1:100 year floodlines.

The following should be noted for the Kanamwamwa River reach downstream of the confluence with the Mwanga River:

- the velocities are generally between 0.6 and 2.1 m/s and erosion is not expected to be substantial;
- The proposed infrastructure and existing infrastructure are situated outside the 1:100 year floodlines.

The following should be noted for the Kakifuluwe River:

- The velocities are generally between 0.04 and 2.3 m/s and erosion is not expected to be substantial.

Surface water use

Surface water use in the concession area and immediate surrounds is described below.

- Domestic use (water and food supply, recreation and washing)
    - People from villages within the concession area obtain potable and agricultural water from hand-dug wells located in wetlands along the Muninga and Kananwamwa streams and along the banks of the Musonoi River.
    - Washing and swimming in the Muninga Dam is common.
    - Fishing from dugout canoes and in traps is an additional food supply from the Kanamwamwa River and in the wetland created by the reverse flow conditions in the Kakifuluwe River.
    - Villages are located along the course of the Luilu River where tributaries join the Luilu. Villagers state that the Luilu River has been too contaminated from mining in Kolwezi to use for fishing, bathing or crops for as long as can be remembered, and so they draw their water supplies from the tributaries.

- Process water supply: In previous years there was abstraction from the Musonoi River for use in the Kolwezi plant (KZC plant). The offtake scheme involved an intake structure, which was controlled with sluice gates. The pumphouse was large but is no longer in operation and water for the plant is now sourced from the Kabongo Dam.

Musonoi River

- 2000 m^3/h to 3000 m^3/h of KOV pit water discharges via 2 pipes directly into the river; FQM is likely to request this flow to be rerouted to the Luilu river
- Untreated sewage is discharged from the hospital and surrounds directly into the river (KZC Ville);
- Excess water from the KZC plant is discharged into the river. One larger discharge and two smaller point discharges were observed. Runoff from the plant also discharges directly into the river;
- Effluent from the UZK zinc plant is discharged directly to the river but in variable volumes depending on the functioning of the plant.

Dilala River

- Untreated sewage from Kolwezi town discharges directly to the river. Agricultural use: There are extensive vegetable fields along the margins of the Plant Site A dambo and Kanamwamwa River. Crops include cabbage, pineapples, tomatoes, spinach, sugar cane and others. Water is supplied from wetlands as described under domestic use above.
- Ecosystem maintenance: The watercourses support aquatic and riparian fauna and flora, for example, Muninga Stream, which supports a gallery forest and abundant birdlife.

Luilu River

- At the height of the DIMA mining operations in the 1970's 2200 m^3/h -0.6 m^3/s was pumped from the Luilu River for use in the Luilu Concentrator. This was approaching the maximum limit of the river for dry season flows. (Placet, 1975).
- The mining effluent was then disposed of into the Luilu discharge dam for re-use (120 m^3/hr).
- There are settlements in the Luilu catchment, but there is presently no evidence of human consumption of river water or of irrigated cultivation. It is reported that local residents are aware of the "acid" water in the river and avoid using it.
- Riparian vegetation along the Luilu River is severely impaired.

Surface water quality

Historical analytical data (1975) confirms that while the water quality in the upper Luilu River was uncontaminated, once it had passed the confluence with the Poto Poto River where the pump station was located, the water quality was significantly degraded due to inputs from the Cité Kapata, underground water from Kamoto, the concentrate from Kamoto and tailings from Kamirombe.

The collection of surface water quality data is based on the water monitoring protocol (this is outlined in the ESMP: Volume III of this document). The monitoring points are presented in Figure 5-23. The analytical results for the period June 2004 to September 2005 have been validated and the data are summarised in Table 5-31 and Figure 5-24. The mean (average) and range (maximum and minimum) of the chemical analyses for each sampling point has been reported with the number of samples used in computing the average. The maximum and minimum indicate the variability of the data.

Major ion chemistry

Generally the water quality is good with all major ions complying with the guidelines although the pH in the Muninga Stream at SW12 tends towards being acidic. Although the water quality complies with the guidelines for the major ions, water flowing down the Musonoi River is changed significantly by inflows from:

- the overflow from the Kabunga dam (SW14), which receives urban drainage from the town of Kolwezi, which contributes to elevated nitrate levels in SW14;
- the KOV pit dewatering exercise;
- discharges from the Kolwezi concentrator (SW2);
- periodic discharges from the UZK plant (SW4) – the periodicity of the discharges is evident in the variability of the data;
- suspended material from the washing of heterogenite in the river by artisanal miners (SW5);
- Urban drainage down the Dilala River (SW10), a tributary of the Musonoi River.

By the time the river flow has reached the culvert at the start of the concession area (SW3), the total dissolved salts (TDS), and thus electrical conductivity (EC)has typically increased almost three-fold, mainly through the addition of magnesium and sulfate from the various discharges (refer to Figure 5-24). The water flowing in the Musonoi is then further contaminated by Musonoi tailings, particularly with respect to sulfate, before it leaves the Kasobantu dam over the spillway and away through the Nzilo outflow (SW9).

e 5-31: Surface water quality data

D	SampleID	pH_Lab	Total Dissolved solids_ppm	Nitrate_NO3_ppm	Sulfate_SO4-2_ppm*	Chloride_Cl-_ppm*	Fluoride_F_ppm	TotalAlkalinity_CaCO3_ppm	Orthophosphate_ppm	Phosphorus_P_ppm	Calcium_Ca_ppm	Magnesium_Mg_ppm	Sodium_Na_ppm*	Potassium_K_ppm	Iron_Fe_ppm*	Aluminium_Al_ppm	Nickel_Ni_ppm	Manganese_Mn_ppm	Zinc_Zn_ppm*	Copp Cu_
vaules: DRC Mining		6-9													6		1		10	1.
e Values: IFC/World Bank		6-9													2		0.5		1	0.
	Count	9	9	8	8	9	9	8	4	3	9	9	9	9	9	4	8	9	8	
	Max	8.4	694	3.0	287	5.2	1.4	194	0.05	0.14	92	64	6.3	3.7	0.06	0.110	0.006	0.280	0.050	0.3
	Minium	7.8	455	0.05	170	0.050	0.005	170	0.050	0.10	31	50	4.0	0.60	0.001	0.005	0.001	0.100	0.003	0.0
	Average	8.1	592	1.1	214	2.9	0.33	187	0.050	0.12	62	57	5.1	1.7	0.023	0.040	0.003	0.180	0.023	0.1
	Count	11	11	11	11	11	11	11	6	5	11	11	11	11	10	7	10	10	10	
	Max	8.2	378	3.0	109	4.6	0.10	132	0.20	0.020	39	33	8.3	2.7	**0.50**	**0.210**	0.004	0.010	0.050	0.0
	Minium	6.8	53	0.05	1.0	0.50	0.050	12	0.050	0.020	2.7	0.6	1.2	0.05	0.030	0.020	0.002	0.004	0.003	0.0
	Average	7.3	120	1.2	12	2.5	0.055	41	0.075	0.020	12	4.8	3.1	1.2	0.205	0.099	0.002	0.009	0.023	0.0
	Count	11	11	11	11	11	11	11	4	5	11	11	11	11	10	5	9	10	9	
	Max	8.2	514	5.0	165	6.2	0.70	148	0.20	0.19	56	72	12	5.3	**18.0**	**0.490**	0.010	**3.0**	0.009	**1**
	Minium	7.3	116	0.30	6.1	1.5	0.050	36	0.050	0.020	6.0	1.6	2.5	1.2	0.001	0.005	0.002	0.001	0.003	0.0
	Average	7.9	329	1.6	79	3.9	0.13	107	0.13	0.10	30	27	5.4	2.7	**1.9**	0.102	0.003	**0.441**	0.003	**1.**
	Count	8	8	8	8	8	8	8	1	4	8	8	8	8	7	4	5	7	5	
	Max	8.0	4868	2.7	**2653**	10	2.0	66	0.050	0.22	34	24	4.7	6.1	1.8	1.100	0.060	22	1237	2.1
	Minium	6.5	55	0.05	2.5	0.050	0.050	32	0.050	0.020	2.0	1.0	0.40	0.50	0.050	0.070	0.002	0.050	**1.4**	0.1
	Average	7.4	835	1.2	408	3.3	0.58	49	0.050	0.10	19	14	3.2	2.1	**0.35**	**0.343**	0.016	**4.5**	**253**	**0.5**
	Count	11	11	11	11	11	11	11	4	4	11	11	11	11	10	6	9	10	9	
	Max	8.3	486	3.5	205	13	0.80	142	0.20	0.13	50	83	8.9	4.0	**15.0**	0.020	0.007	**2.0**	0.700	**4.0**
	Minium	7.2	98	0.70	6.2	2.0	0.050	20	0.050	0.010	5.0	4.7	2.2	1.0	0.001	0.005	0.002	0.003	0.003	0.0
	Average	7.9	313	1.8	90	4.5	0.12	98	0.088	0.050	29	31	4.6	2.2	1.5	0.011	0.003	0.279	0.082	0.5
	Count	10	10	10	10	10	10	10	4	4	10	10	10	10	9	6	9	9	9	
	Max	8.3	428	2.6	88	5.2	0.10	158	0.10	0.13	39	36	10	5.9	0.13	0.120	0.004	**1.3**	0.260	0.0
	Minium	7.1	224	0.05	5.9	1.5	0.050	80	0.050	0.060	14	13	3.4	2.6	0.001	0.010	0.002	0.110	0.070	0.0
	Average	7.5	309	1.0	48	3.7	0.055	116	0.063	0.10	26	24	6.0	3.5	0.06	0.062	0.002	**0.559**	0.126	0.0
	Count	11	11	11	10	11	11	11	4	4	11	11	11	11	10	6	9	10	9	
	Max	7.3	272	4.1	10	5.2	0.70	26	0.050	0.040	7.8	2.1	4.4	3.8	0.80	0.160	0.004	0.050	0.110	1.0
	Minium	6.3	15	0.05	0.70	0.20	0.050	6.0	0.050	0.020	0.05	0.40	0.05	0.10	0.060	0.005	0.002	0.005	0.003	0.0
	Average	6.9	96	1.1	4.4	2.7	0.11	18	0.050	0.025	3.5	1.4	2.2	1.4	**0.35**	0.066	0.002	0.024	0.045	0.1
	Count	10	10	10	10	10	10	10	4	3	10	10	10	10	9	5	8	9	8	
	Max	8.4	450	2.6	174	6.2	0.60	142	0.050	0.70	51	42	8.3	3.6	**2.2**	0.070	0.010	**0.770**	0.290	**3.0**
	Minium	7.2	235	0.05	30	2.0	0.050	40	0.050	0.050	12	7.9	3.0	0.70	0.00	0.010	0.002	0.190	0.003	0.0
	Average	7.8	327	0.94	79	3.9	0.11	94	0.050	0.27	28	24	5.7	2.6	0.28	0.046	0.004	0.421	0.148	0.3
	Count	11	11	10	10	11	11	11	4	4	11	11	11	11	10	5	9	10	9	
0	Max	8.7	434	4.0	10	12	0.80	128	0.10	0.090	30	19	6.6	5.1	**2.3**	0.120	0.004	0.200	0.150	**2.0**
	Minium	6.5	115	0.05	1.0	2.6	0.050	60	0.050	0.020	5.0	6.7	3.0	1.8	0.030	0.005	0.002	0.020	0.003	0.0
	Average	7.4	258	1.1	3.7	6.6	0.19	108	0.063	0.043	20	15	5	3.8	**0.32**	0.047	0.002	0.095	0.039	0.2
	Count	9	9	9	9	9	9	9	4	4	9	9	9	9	9	6	9	9	9	
2	Max	6.3	127	3.7	4.3	5.2	0.050	8	0.050	0.020	1.1	1.2	2.0	1.6	0.34	0.120	0.004	0.030	0.130	0.0
	Minium	**4.3**	22	0.05	0.80	1.0	0.050	Bdl	0.050	0.020	0.05	0.05	0.70	0.10	0.040	0.040	0.002	0.007	0.003	0.0
	Average	**5.7**	50	0.59	2.4	2.3	0.050	6.4	0.050	0.020	0.6	0.46	1.4	0.57	0.19	0.073	0.002	0.012	0.037	0.0
	Count	11	10	11	11	11	11	11	4	4	11	11	11	11	10	5	9	10	9	
4	Max	7.8	282	7.6	5.8	13	1.0	80	0.10	0.12	27	8.9	9.2	9.9	**1.9**	0.140	0.004	0.120	0.100	**0.6**
	Minium	7.1	168	0.30	1.4	6.0	0.005	64	0.050	0.050	1.0	5.0	1.9	6.7	0.020	0.020	0.002	0.005	0.003	0.0
	Average	7.3	211	2.7	3.7	11	0.13	75	0.063	0.070	15	7.7	7.8	8.4	0.26	0.064	0.002	0.033	0.029	0.0

The historical data indicates an increase in salt loads of at least one order of magnitude from the source (EC = 2.5 mS/m) to the Kasobantu Dam (EC = 25 mS/m). The current data for Kasobantu Dam at SW8 (not part of the routine monitoring program as the dam is now monitored at the Nzilo spillway - SW9) indicates an average value for EC of 35 mS/m (TDS of 360 mg/l), representing a 40 % increase in salt loads over the last 30 years. The salt load increase in the Musonoi River increases is due to:

- loading from the UZK effluent discharge (mostly sulfate);
- the KZC concentrator discharge;
- The Kingamyambo canal (pumping from the dewatering boreholes and pit sump).

Note however, that despite the increases, the quality (in terms of major ions) generally complies with the WHO 2006 Drinking Water Guidelines.

Although not sampled routinely, the impact of the historical and current mining activities are still apparent in the water quality of the Luilu River. Sampling undertaken at the start of the dry season (27/04/06) showed that the EC increases from 4.6 mS/m in the upper Luilu dam to 160 mS/m at the Luilu discharge dam. The pH decreases from 6.4 to 2.2; the sulfates increase from 3.5 mg/l to 475 mg/l and Mg from 1.8 mg/l to 12.6 mg/l. Sampling in the wet season (30/11/2005) confirms this trend with sulfates 680 mg/l, calcium increasing to 233 mg/l and magnesium to 28 mg/l at the Luilu discharge dam. Note this point was sampled above the discharge point from the Luilu plant. The impact of the Luilu River after the confluence with the Lualaba River is not apparent due to the dilution from this river. The pH of the Lualaba River above and below the confluence with the Luilu River is static at 7.8 and the TDS is about 130 mg/l, significantly lower than the Luilu River below the discharge dam (345 mg/l).

Trace heavy metals

The concentrations of metals in solution in the Musonoi are generally fairly low due to the alkalinity of the water (dissolution of metals is minimal). There are, however several exceedances of the health-based guidelines for trace heavy metals. The various discharges along the Musonoi system are responsible for raising the heavy metal contamination levels above the WHO Guidelines for drinking water. The background samples (SW1, 7, and 12) all show negligible traces of heavy metals, but SW3 at the start of the concession exceeds the WHO Guidelines for manganese and lead. SW12 has an acidic pH (averaging 5.7) probably due to the very low electrical conductivity, which is generally around 1 mS/m, as there are currently no human induced impacts in the area and humid acids from the decomposition of plant matter in the forest which lines the stream. The low concentration of total dissolved salts is due to the infiltration of rainwater through the leached saprolitic profile, where there are no more ions to be exchanged/dissolved. The low pH may contribute to dissolution of metals from mining activities, if mine water seepage and runoff is not adequately controlled, although the mining activity is likely to result in an increase in pH. The UZK discharge contributes aluminium, manganese, lead, antimony and zinc. Zinc was also elevated in the rain sampled in December 2004 suggesting that wet deposition from fall out in the air is occurring. The outflow into the Nzilo channel contains manganese and lead at levels above the WHO Guidelines (maximum values measured). Black encrustations along the shoreline of Kasobantu Dam indicated high iron and manganese values confirming that an iron manganese oxide is precipitating from solution in the Kasobantu Dam. Iron values, however generally comply with or show slight exceedance of the aesthetic guideline value (0.3 mg/l) based on average values except for SW3 (1.9 mg/l) and SW5 (1.5 mg/l). Trace quantities of uranium were detected along the Musonoi River downstream of the KOV pit discharge. These values were below the WHO Guidelines. No thorium was detected in any of the samples.

Copper and cobalt were below detection limit in the sample from the upper Luilu dam and 35 mg/l and 5.7 mg/l respectively in the sample from the Luilu Discharge Dam taken at the start of the dry season. These metals remain elevated in the wet season i.e. 12.6 mg/l for Co and 29.5 mg/l Cu in the Luilu discharge dam. Other metals attributable to the mining activities in the Luilu Discharge Dam are aluminium (1.2 mg/l), Manganese (1.2 mg/l) iron (7.2 mg/l). Nickel, lead, zinc and chromium also are noted in the down gradient Luilu samples.

Seasonal variation

Seasonal variation in the data is evident (refer to Figure 5-24). The more contaminated downstream samples indicate a peak at the start of the rainy season, most likely due to contaminated runoff entering the watercourses. This peak is followed by a decrease in contaminant levels, which can be attributed to the dilution effects of the midsummer rains. This is followed by an increase in contaminant levels during the winter season due to concentration effects of lower flows in the watercourses. Seasonal effects are less pronounced in the background samples with TDS ranging from 22 to mg/l 127 mg/l for SW12, in Muninga Stream (best quality background sample) and 53 to 378 mg/l for SW1 on the Musonoi.

Organic compounds

No phenols, semi-volatiles or volatile organics were detected in the three samples taken from surface water at the start of the Musonoi concession area, and the discharges from the Kolwezi town (and hospital) and the KZC concentrator discharge. These facilities are not operating at full capacity and single samples are snap shots of the surface water at an instant in time.

Bis 2 ethyl hexyl phthalate was identified in all three samples, but this is a chemical usually associated with plasticizers, and is very often due to laboratory contamination.

Piper plots

Piper plots are a plot of the major anions (chloride, sulfate and carbonate) and cations (calcium, sodium and magnesium) to indicate the geochemical dominance of environmental water. The dominance is used in the assessment of ground-surface water interactions and impacts from mining, which tends to shift dominance away from that of background samples. The piper plot for surface water is presented in Figure 5-26.

Samples from the KOV pit lake and SW 4 (UZK discharge) plot towards the top apex of the diamond shape, which is indicative of contamination. There is a clear mixing line between the relatively uncontaminated samples from the Musonoi River upstream of mining activity (SW1) and the contaminated KOV and SW4, which indicates gradual contamination of these samples. SW3, SW5, SW6, SW8 and SW9, all samples from the Musonoi River, plot along the mixing line. SW12 on Muninga Stream indicates the least contamination and falls within the saprolite aquifer composition presented in the groundwater piper plot in Figure 5-32. The saprolite aquifer is the base flow to Muninga Stream and the dambo next to the plant site A.

Biomonitoring

A biological monitoring survey on the aquatic system has also been carried out at site. The major objectives of this study were to characterize the aquatic environment, habitat, related biota, magnitude and extent of existing site related effects and determine the current ecological status, in order to identify possible problem areas as well as to identify possible sensitive areas.

Invertebrate habitat assessments (IHAS), macroinvertebrate assessments, water quality measurements and whole effluent toxicity (WET) were performed during both the wet and dry seasons at a total of 11 sites, which ranged from upstream of Kolwezi town away from any mining activity, through the concession to areas downstream of the Kasobantu dam.

During this survey no reference site could be identified, due to the high levels of contamination through the entire Musonoi catchment. Results of the habitat and macroinvertebrate assessment and of the whole effluent toxicity testing identified the KOV pit and the KZC processing plant discharge as a significant negative impact on the water quality further downstream. The deposit of tailings into the Musonoi River valley was identified as a significant impact on habitat diversity due to sedimentation. Nevertheless the tailings dam showed a possible positive impact on water quality by accumulating potential pollutants from the sewage and KOV pit discharge.

The highest macro invertebrate diversities were recorded downstream from the tailings dam in the old Musonoi channel (flow sustained by seepage through the wall), indicating that the Kasobantu dam may have a positive impact on the water quality in this section of the river. However, instream habitat and biological integrity are severely impaired downstream where the Luilu River joins the Musonoi River below the Kasobantu Dam.

5.9. Ground Water

A borehole census was conducted on 20 July 2004 around the concession area to measure rest water levels, investigate groundwater use and where possible to collect groundwater samples for chemical analyses. Most boreholes found during the hydrocensus are located around or within the KOV Pit, and were drilled for pit dewatering purposes. Three boreholes are located at the INGA power station located adjacent to the Musonoi River.

No boreholes were found in the proposed tailings and plant sites respectively, although two hand-dug wells estimated to be approximately 10 m deep were located downgradient of the proposed tailings dam. Data obtained from the borehole census is summarized in Table 5-35.

Additional boreholes (a total of 23) were drilled, within and around the concession area, as part of the hydrogeological investigation and sterilization drilling program (SRK Report No 342211). Relatively shallow rest water level depths in the boreholes compared to water strike depths are indicative of the confined to semi-confined nature of the aquifer systems at the site. The locations of the boreholes and monitoring boreholes are presented in Figure 5-23.

Aquifer Lithologies

The main aquifers associated with the stratigraphic sequences are discussed below:

Kalahari

The sands of the Kalahari covering the Plateau Manika and large parts of the Kolwezi region (Mutoshi, Cite Mwadi), are considered to be superficial and perched aquifers. They are exploited as potable water supplies from small boreholes. Recharge is from runoff and infiltration of precipitation (Gécamines 1975). These aquifers are susceptible to contamination and in particular bacteriological contamination from shallow pit latrines.

Katangian

The Katangian stratigraphy is divided into the Kundelungu and Roan aquifer systems. Very little is known about the Kundelungu from a hydrogeological point of view. Although the synclinal structures are favourable for the development of aquifers from a structural standpoint, the lithologies consisting mainly of metamorphosed fine grained siltstones and sandstones are not conducive to high permeability and are therefore not high yielding formations. However, the weathered saprolitic profile has a relatively high permeability and subsurface flow can be important within the decomposed parent rock, especially within the storm flow zone as shown in Figure 5-27 below.

In contrast, the Roan formation is extremely favourable for the development of major aquifers. The large synclinal ore block structures (covering up to 10 km^2) consist of massive multi-layered altered siliceous and dolomitic horizons, which have formed highly permeable traps (due to karstic morphology) associated with the synclinal axes and wedging out of layers. Most of these ore blocks were originally isolated aquifers, but mining activities have resulted in the hydraulic connection of many of these hydrogeological units, resulting in complex interaction between different structural blocks.

The main water bearing strata identified in the Roan formations are the Schistes Dolomitique (SD), Calcaire a Mineraux Noir (CMN) and the Ore Body (OB) units which are frequently associated with karstic structures and solution channels. These aquifers are usually confined to semi-confined when they are overlain by less permeable formations. The less permeable formations, namely the Roches Argilo Tarqueuses (RAT) and Roche-Greseuse-Siliceuse (RGS) can form marginal phreatic aquifers due to secondary fractures (Viviers 1997).

Kibarian

Very little is known about the hydrogeological conditions of the Kibarian formation. The pelites and quartzites of this sequence have the best characteristics for recharge due to their lithological and structural properties.

Aquifer Parameters

No hydraulic parameters were found for the Kundelungu, Kibarian and Kalahari aquifers from available literature.

Hydraulic parameters for the Roan aquifers is summarised from various Gécamines reports (1984) in Table 5-32 The syndiagentic alteration (silicification) of the SD, CMN and the OB units has increased the horizontal (Kh) and vertical hydraulic conductivities (Kv) at least ten fold. Consequently, the preferential flow paths within the major mineralised horizons that allowed for supergene enrichment are also the main water bearing strata. Storativity for unconfined aquifers is 5-15% and greater than under confined conditions.

Table 5-32: Hydraulic Parameters of the Roan Aquifers for the KOV mine at Kolwezi (Gécamines 1984)

Formation	Lithology	Transmissivity (m2/d)	Kh (m/d)	Kv (m/d)	Confined Storativity	Unconfined Storativity
ALTERED	RAT	10	0.009	0.00011	1.00E-06	0.05
	RGS	30	0.1	0.0013	1.00E-05	0.05
	CMN	470	0.3 -6.2	0.078	1.00E-04	0.15
	SD	470	0.3 - 6.2	0.078	1.00E-04	0.15
	OB	470	0.3 -6.2	0.078	1.00E-04	0.15
DOLOMITIC	RAT	10	0.009	0.00011	1.00E-05	0.05
	RGS	30	0.1	0.0013	1.00E-05	0.05
	CMN	30	0.1 - 0.5	0.0063	1.00E-04	0.10
	SD	100	0.1 -10.5	0.0063	1.00E-04	0.10
	OB	100	0.1 - 0.5	0.0063	1.00E-04	0.10

No hydraulic parameters were found for the Kundelungu, Kibarian and Kalahari aquifers from available literature. However, as all of these formations have weathered to saprolites, hydraulic properties of saprolites were deemed more appropriate.

The saturated hydraulic conductivity of saprolites is a function of lithology, frequency of root holes and fractures (macropores), extent of infilling of macropores with iron and manganese oxides. Abrupt changes in hydraulic conductivity, at least partly controlled by macropore infilling, are a common feature of sedimentary rock saprolite. The saprolite profile for limestone is generally deeper than for the shale saprolite. The hydraulic properties of saprolite are presented in Table 5-33.

Table 5-33: Hydraulic Properties for Shale/Limestone Saprolites (http://web.utk.edu/hydro/saprolite)

Lithology	Saturated Hydraulic conductivity (m/day)	Porosity	Comment
Shale/ Limestone	0.086 to 86.4	Up to 60%	Rapid storm flow zones at shallow depths with abrupt decrease below this

The transmissivity value obtained for the saprolitic Ks1.3.1 of 323 m^2/day is comparable to the mean of 400 m^2/day determined by Gécamines for the altered dolomitic/limestone formations of the Roan aquifers within the KOV orebody. Horizontal conductivity is 14 m/day but falls within the literature range of .0.08 to 86 m/day for a limestone saprolite.

One high yielding borehole (BH 6) located at Plant Site A was test-pumped to determine aquifer parameters at the site. The testing included pumping the borehole at variable rates (Step Test) for 1 hour each and at a constant rate (Constant Discharge Test) for 24 hrs at a pumping rate of 30 m^3 per hour. This was followed by a Recovery Test. Results of the test pumping are summarized in Table 5-34.

Table 5-34: Summary of test pumping analysis for borehole BH 6

Parameter	Values
Water Strike (mamsl)	1372.6
Rest Water Level (mamsl)	1375.2 (Jan 05)
Aquifer Thickness (m)	23.5 Approximate
Test Period (h)	24
Pumping Rate (m3/h)	30
Transmissivity m2/d (CJ)	323
Conductivity (m/d)	13.8
Aquifer location	Saprolitic Ks 1.3.1

Mamsl: metres above mean sea level

Test-pumping of the Manga orebody (BH1) to evaluate this aquifer as a potential water supply for the project, was not possible as the blow yield of >101 m^3/hr at 90 m depth was too high (refer to Section 5.10).

Plant Site

BH20 intercepted a water strike at 34 m with a blow yield of 2 m^3/hr and has a final rest water level of 5-8 meters below ground level showing confined conditions. The relatively higher TDS of 120-340 mg/l and isotope analyses indicate slightly older water with less recent recharge within the deeper fractured shale sandstone aquifer. BH11 was drilled in the shallow saprolite aquifer.

Tailings Storage Facility (TSF)

BH7 has a very low TDS of 50 mg/l, low pH, no uranium or thorium and is typical of a shallow saprolitic aquifer with recent and abundant recharge percolating through a leached profile. The water table in BH7 is at 7 mbgl but the water levels in BH12 and BH13 could not be measured with the dip meter due to the low electrical conductivity (EC).

BH 8 had a high blow yield of >10 m^3/hr. Specular hematite is abundant associated with hydrothermal alteration and quartz veining. When sampling this borehole, the groundwater is clear as it is brought to surface in the bailer, but within 10 minutes turns orange/brown due to oxidation of the ferrous iron. The iron concentration determined in the samples is as high as 70 mg/l. The TDS of > 100 mg/l is probably due to the ferrous iron in solution.

BH14 at the south-western corner of the tailings dam site was drilled through the Kibarian quaritzites, but remains dry at a final depth of 50 m. BH15 drilled adjacent to the Muninga Stream and downgradient of the Tailings Dam site intercepted the fractured rock aquifer rather than the shallow saprolite aquifer as confirmed by the higher EC (200 mS/m).

Groundwater levels and flow directions

Groundwater flow is a combination of fracture flow and matrix flow in the variably weathered formations. The piezometric map of the concession area was interpolated from groundwater levels obtained from borehole water level measurements. This was compiled from available borehole information from Gécamines and the boreholes drilled as part of the current investigation. Where there are no borehole level data, the assumption is made that the water table intersects surface topography in water courses and this information has been used to interpolate the contours as shown in Figure 5-27. The conceptual hydrogeological model of the KMT concession is shown on Figure 5-28.

The Kolwezi area has been hydrologically disturbed due to extensive mining activities since 1943 when the Musonoi pit was initiated. The original pre-mining hydrogeological conditions are not recorded. Generally, groundwater levels follow the topography but with a lesser gradient. Modelling of pre-mining levels showed that groundwater flowed northeast and northwest towards the Musonoi and Luilu Rivers, respectively (Viviers 1984). The current investigation indicated localized reversed groundwater flow within the radius of influence of the mining operations.

The proposed TSF site is located at the top of the small hills of the Poudingue De Base and although BH14 drilled through the Kibara Quartzites at the extreme western corner was dry, it is probable that once the TSF is commissioned, mounding from the saturated tailings may result in two groundwater flow directions; one towards the Musonoi River and Muninga Stream to the east and one across the hydraulic divide to the northwest and towards the streams of the adjacent catchment.

Interpretation of the pre-mining hydrogeologic regime has been undertaken in the past using groundwater models. The potentiometric surface (regional water table) was probably near surface (approximately 10 mbgl) at an elevation of approximately 1410 mamsl in the vicinity of Kolwezi mines (KOV, Kolwezi, Musonoi pits). However, due to decades of dewatering, the potentiometric surface was lowered to at least 1240 mamsl within the cone of drawdown of the KOV pit.

Water level measurements were taken as part of the hydrogeological investigation in order to define the piezometric surface of the regional aquifer within the concession area. The findings are as follows:

- the water table is generally approximately 5 to 10 mbgl within the saprolitic aquifer of the Upper Kundelungu, but deeper within the Roan Formation, probably due to the cone of drawdown around the mined open pits.
- rest water levels within and near KOV Pit decrease from 1290 metres below ground level (TW3 outside the pit) on the perimeter to approximately 1260 mamsl at the pit lake, following recovery of the water table due to malfunctioning of the dewatering system;
- Localised mounding within the Kingamyambo tailings (and presumably the Sulfide tailings deposit) is evident from the shallow water table (2 mbgl) in the centre of Kingamyambo equivalent to a piezometric elevation of approximately 1382 mbgl. This has resulted in bulging of the contours and seepage into the KOV pit highwalls from this source;
- The KOV pit is currently being dewatered and once complete the dewatering cone is predicted to extend to the Musonoi River in the east and below the Kingamyambo tailings dam to the north of KOV. Current predictions indicate a loss of 1800 m^3/hr from the Musonoi River (Viviers 2007), but these predicted losses are to be confirmed.
- The water level at the power station borehole (WW3) is at 6.19 metres below ground level. No reliable elevation data was obtained, but the elevation of INGA is approximately 1370 mamsl indicating that the water table is at approximately 1364 mamsl;
- The water level in Kasobantu dam is currently at approximately 1340 mamsl.

The mining operations will not impact on groundwater quantities, as there will be no opencast pit or underground workings. For this reason it is not necessary to develop a numerical flow model of the entire concession area. If a wellfield is developed to supply groundwater for the project, and extracts more than 175,000 m^3/a (i.e. 20 m^3/hr), then dedicated peizometers will be installed and a numerical flow model developed to monitor the cone of drawdown and potential impacts on other groundwater users.

Groundwater Recharge

Groundwater recharge has been assumed in past reports to be between 5 to 10 % of the Mean Annual Precipitation (MAP) or approximately 60 – 120 mm/a using a MAP of 1200 mm/a. The main recharge to the aquifers is within the Plateau Manika, which has a surface area of approximately 150 km^2. Stable isotope and tritium analyses were undertaken to confirm the above values and determine the component of recharge to the aquifers.

As chloride is a conservative tracer and because it is introduced into an aquifer by the rainfall recharging the aquifer, the chloride concentration of groundwater in relation to that of rainfall can be used for quantitative estimation of recharge (Bredenkamp 2000), providing that no chloride has been added by dissolution of aquifer material, pollution or by evaporation. Although only one rainfall analysis was obtained during this study, the low concentration of chloride generally in the aquifers is an indication that a high percentage of recharge (30 - 60%) is occurring in the shallow saprolitic profiles (BH6, BH17, BH22). This is in agreement with the isotopic results, which indicated that the aquifers are of recent recharge (<60 years) with very little evaporation prior to infiltration. This confirms that the aquifer resources are sustainable, due to the annual replenishment from precipitation.

This implies that as much as 360 to 729 mm/a of the MAP could be infiltrating with minimal losses to evaporation due to the very high humidity. It also explains the highly leached soil profile resulting in very low conductivity in this hydrogeological unit. Using the more conservative recharge figure of 30% MAP, annual recharge for the aquifers in the Musonoi catchment is calculated as:

Catchment area (226 km^2) x MAP (1200 mm) x infiltration (30% of MAP) = 81,4 Mm^3/a

This figure is probably much higher, as recharge within the Kalahari sands of the Plateau Manika (150 km^2) is estimated at 60% and recharge into the open pits is even higher. The fractured rock aquifers (BH15, BH18, BH20) are typical of an actively recharged aquifer with a mean residence time of 60 year. BH1 in the Roan aquifer also shows recent recharge, and it does not appear to be a fossil aquifer, increasing the likelihood of sustainability if exploited as a wellfield for the KMT project.

Groundwater use

Groundwater is used to supply domestic and process water:

- Groundwater is used as potable water supply to Kolwezi Town and environs. Historically, the potable water supply to the towns was via dewatering boreholes around the various pits developed as wellfields and collected at REGIDESO for treatment and reticulation. Currently, the only functional borehole for water supply to Kolwezi Town is located adjacent to the KZC concentrator (P55) in the KZC wellfield. P55 is supplemented with water from the Nioka and Mutoshi wellfields, located in the Nioka and Mutoshi ore bodies to the south and northeast of Kolwezi respectively.

- In the past the UZK village was supplied by water from the pumphouse on the Kakifuluwe River and a borehole named Long P1. However, the Kakifuluwe source dried up in the 1980s (probably due to the fissure and karst development), and the village is now supplied by one borehole located upgradient of the town (UZK P2). This borehole is approximately 100 m downgradient of the Sulfide tailings and also supplies Luilu village.
- The annual consumption of water supplied to the Kolwezi town is currently approximately 4 Mm^3/a (or around 450 m^3/h), supplied by boreholes in Nyoka and Mutoshi wellfields. Assuming an additional 200 m^3/h is pumped from boreholes (P55, INGA, BH UZKP2 and others in the Kalahari formation), it is estimated that 28 Mm^3/a is abstracted for groundwater consumption.
- The equipped boreholes (INGA WW1 to WW3) at the power station supply potable and industrial water to the power station.
- Water for the proposed project is to be supplied from the Manga wellfield, within the CMN formation on the eastern side of the Musonoi River near the UZK zinc plant (refer to Section 5.10).

Ground water quality

Groundwater quality within and around the concession area has been monitored on a routine basis since July 2004. The location of the monitoring boreholes is presented in Figure 5-23. These sampling points have been selected on the basis of existing facilities identified in the audit (such as the Zinc plant) as well as proposed future facilities. The results thus reflect the existing groundwater contamination, which has arisen as a result of past activities at the site.

In order to compare the concentrations with a suitable reference, the DRC and IFC requirements, and the third edition of the World Health Organisation (WHO) Drinking Water Quality Guidelines (2006) have been included in Table 5-35 and shaded where these values are exceeded. The DRC and IFC requirements are only prescriptive for pH. The WHO values included for sodium, sulfate, chloride, iron and zinc are based on acceptability in terms of aesthetics (palatability or staining potential in the case of iron) rather than as limits as there is no direct link to adverse health impacts from these constituents.

Field measurements of temperature vary between 21 and 24ºC. REDOX measurements were not determined as the samples were taken with a bailer and so measurements would not be representative of in-situ aquifer redox conditions.

No microbiological analyses have been undertaken to date due to the difficulties associated with transporting the samples to a reliable laboratory within the short holding time (24 hours) for these samples. On site extraction of DNA should be undertaken instead.

Major ion chemistry

Most borehole samples have low conductivity (low TDS) with neutral to slightly acid pH ranges. The water is typically soft, carrying very low concentrations of calcium, magnesium, sodium and potassium bicarbonates, with insignificant traces of sulfate, chloride, fluoride and nitrate. TDS are typically within the 50 – 200 mg/l range, except for BHP2UZK, near the sulfide tailings, which has an average TSD of 550 mg/l and BH4, below the UZK plant, which has an average of 4,900 mg/l. The salt loading in the two boreholes is largely contributed by sulfate and to a lesser extent magnesium and calcium in seepage from the UZK plant and tailings basins. Nitrate levels comply with the WHO guidelines but elevated concentrations are evident in BH3, BH4, BHP2UZK and P55 and are possibly due to contamination from human effluent. These results are presented in the charts in Figure 5-30.

Trace heavy metals

Boreholes P55 and BHP2UZK, which are used for drinking water, comply with the WHO Guidelines except for lead in P55. The concentrations of metals in solution are generally fairly low due to the alkalinity of the water. Heavy metal concentrations in the ground water are generally negligibly low. Notable exceptions are iron and manganese in:

- BH1 drilled into the Manga orebody, identified as the most likely water source for mining and domestic use on the concession, by virtue of its extraordinarily high yield;
- BH8 drilled in the proposed TSF area within the deeper fractured rock aquifer.

Samples from these boreholes have iron concentrations in the 40 – 70 mg/l range, and manganese in excess of 1 mg/l. If BH1 is typical of the wellfield that could be developed in the area, treatment would need to be provided to remove both the iron and manganese before use. (SRK would recommend drilling one or two additional boreholes in this area before the design of the water treatment system is finalised to confirm that iron and manganese are problems in this area). The origin of the high iron is presumably natural as abundant specularite (shiny hematite) was observed in the percussion chip samples when these boreholes were drilled. Specularite was also noted in BH7 and BH10, which also have slightly elevated iron concentrations. Manganese in BH1 is due to the MnO frequently associated with the CMN formation.

When sampling these boreholes, the groundwater is clear when taken out with the bailer but quickly oxidises and turns orange brown. The origin of the high iron is presumably natural as abundant specularite (shiny hematite) was observed in the percussion chip samples when these boreholes were drilled. Specularite was also noted in BH7 and BH10, which also have slightly elevated iron concentrations. Manganese in BH1 is due to the manganese oxide always occurring with the CMN formation (calcaire a mineraux noire or limestone with black minerals as the direct translation).

The borehole used to supply the power station (INGA) located downgradient of the UZK plant also has elevated iron, but at the 10 mg/l with manganese < 1.0 mg/l.

The groundwater from BH4 is the most severely impacted in terms of heavy metals. BH4 samples contain significantly high concentrations of zinc, copper, lead, aluminium, manganese, nickel and selenium indicative of leaching from the tailings basins from the UZK plant. This is due to the acidity of the groundwater causing corrosive seepage from this facility. Cobalt and copper precipitating as salts along the banks of the Musonoi adjacent to the tailings basins are evident as pink to green encrustations in this area.

High concentrations of copper and cobalt were determined from the Kingamyambo piezometer seepage (as would be expected) but trace quantities of uranium are also associated with this seepage and groundwater abstracted from the KOV pit lake. No thorium was detected in any of the samples.

It is not possible to contour the chemical composition for each salt as there are not enough data points. The major ion compositions are shown as radial plots in Figure 5-32, as this is the most effective method of displaying the water composition across the site. Surface water samples are shown in green and groundwater in blue. Samples with similar shapes have similar origins and the effects of mixing of different sources are more easily identified.

Organic compounds

Boreholes, which should be sampled for phenols and hydrocarbons are BH UZK, INGA, P55 and BH 4, which may have remnant contamination from historical plant operations or spills.

Seasonal variation

Not unexpectedly, seasonal variation is not often apparent in the ground water system.

e 5-35:Groundwater quality

ID	SampleID	pH_Lab	Total Dissolved solids_ppm	Nitrate_ NO3_ppm	Sulfate_ SO4-2_ppm*	Chloride _Cl- _ppm*	Fluoride _F_ppm	TotalAlkalinity_CaCO3_ppm	Orthophosphate_ppm	Phosphorus_P_ppm	Calcium _Ca_ppm	Magnesium_Mg_ppm	Sodium _Na_ppm*	Potassium_K_ppm	Iron_Fe _ppm*	Aluminium_Al_ppm	Nickel_ Ni_ppm	Manganese_Mn _ppm	Zinc_Z _ppm
e values: DRC Mining		**6-9**													**6**		**1**		**10**
e Values: IFC/World Bank		**6-9**													**2**		**0.5**		**1**
inking water guidelines (3rd ed, 2004)				**50**	**500**	**250**	**1.5**						**200**		**0.3**	**0.2**	**0.02**	**0.4**	**3**
	Count	9	9	9	9	9	9	9	4	6	9	9	9	9	9	7	9	9	
	Max	7.4	228	6.3	7.7	7.3	0.10	38	0.10	0.070	10	5.7	7.2	14.7	73	0.060	0.008	2.000	0.420
	Minium	**5.7**	38	0.050	0.050	0.500	0.050	12	0.050	0.020	0.50	1.2	0.80	2.5	0.21	0.005	0.001	**0.810**	0.010
	Average	6.5	91	0.99	2.9	4.0	0.056	26	0.067	0.040	2.6	2.3	2.1	5.8	**49**	0.027	0.003	**1.3**	0.130
	Count	8	8	8	8	8	8	8	3	5	8	8	8	8	8	6	8	8	
	Max	7.9	322	4.8	17	12	0.30	178	0.050	0.16	48	24	9.2	6.7	**4.6**	0.090	0.007	**1.3**	**2.0**
	Minium	6.9	218	0.050	5.6	7.3	0.20	124	0.050	0.020	21	15	3.0	2.9	0.060	0.020	0.004	0.280	0.040
	Average	7.2	269	1.2	11	9.2	0.24	152	0.05	0.08	33	19	7.7	4.7	2.1	0.048	0.005	0.834	0.496
	Count	8	8	8	8	8	8	8	3	5	8	8	8	8	8	6	8	8	8
D	Max	7.7	394	7.0	1.9	148	1.4	74	0.05	0.14	14.2	9	93	4.1	0.410	0.150	0.008	0.080	0.200
	Minium	6.0	89	0.50	0.20	2.1	0.050	20	0.05	0.02	3.4	1.5	1.6	1.5	0.030	0.020	0.004	0.040	0.020
	Average	6.6	230	2.2	1.0	61	0.23	49	0.05	0.086	8.2	5.4	41	2.8	0.143	0.062	0.007	0.064	0.108
	Count	9	9	9	9	9	9	9	4	5	9	9	9	9	9	7	9	9	9
S	Max	7.9	338	4.1	4.6	69	0.10	116	0.1	0.21	23	13	39	4.3	0.260	0.110	0.010	0.300	0.220
	Minium	5.5	67	0.20	0.05	2.1	0.050	14	0.05	0.02	1.7	0.90	2.3	0.90	0.030	0.002	0.003	0.020	0.050
	Average	6.1	147	2.2	1.4	21	0.056	36	0.075	0.12	5.9	4.6	13	2.6	0.117	0.069	0.007	0.092	0.117
	Count	3	3	3	3	3	3	3	1	2	3	3	3	3	3	2	3	3	
	Max	**4.4**	5252	6.2	**2925**	11	1.2	4.0	0.050	15	249	153	40	6.4	**6.9**	**16**	**0.34**	**103**	**1257**
	Minium	**4.2**	830	2.4	362	5.2	0.20	Bdl	0.050	0.47	28	13.9	2.2	2.1	0.12	**1.7**	**0.020**	**15**	**350**
	Average	**4.2**	4934	3.7	**2840**	9.0	1.1	Bdl	0.050	7.5	202	149	40	5.1	**0.31**	**9.1**	**0.32**	**103**	**1077**
	Count	10	10	10	10	10	10	10	5	5	10	10	10	10	10	7	10	10	
	Max	7.5	214	3.1	6.2	37	0.050	46	0.20	0.28	13	4.4	22	1.9	2.5	0.240	0.020	3.8	0.280
	Minium	**5.8**	61	0.050	0.20	2.6	0.050	12	0.050	0.020	5.6	0.050	1.4	0.5	0.010	0.005	0.007	0.170	0.070
	Average	6.4	97	0.95	1.9	9.9	0.050	28	0.080	0.13	7.6	1.8	6.2	1.1	**1.2**	0.067	0.013	**1.3**	0.164
	Count	8	8	8	8	8	8	8	3	5	8	8	8	8	8	6	8	7	
	Max	**5.8**	96	3.1	1.3	4.2	0.050	8.0	0.050	0.050	1.5	1	3.8	1.5	**12**	0.080	0.007	**0.530**	0.340
	Minium	**4.9**	15	0.050	0.050	0.50	0.050	4.0	0.050	0.020	0.050	0.050	0.40	0.050	0.040	0.005	0.002	0.090	0.003
	Average	5.3	53	0.80	0.49	2.3	0.050	5.8	0.050	0.032	0.91	0.33	1.3	0.64	5.3	0.044	0.005	0.243	0.098
	Count	8	8	8	8	8	8	8	3	5	8	8	8	7	**8**	**6**	**8**	8	
	Max	6.6	340	3.1	4.2	6.2	0.10	38	0.050	0.050	7.6	2.9	2.8	3.2	**70**	0.060	**0.020**	**2.0**	0.190
	Minium	**5.6**	15	0.050	0.050	1.5	0.050	12	0.050	0.020	0.70	0.60	0.40	0.500	0.11	0.005	0.002	0.290	0.003
	Average	6.0	105	0.64	2.1	3.2	0.056	21	0.050	0.030	3.5	1.4	1.7	2.1	**28**	0.036	0.011	**1.2**	0.068
	Count	6	6	6	6	6	6	6	3	3	6	6	6	6	6	5	6	6	
	Max	7.7	1280	0.50	68	147	0.20	86	0.70	0.150	26	21	132	8.3	**1.7**	**0.600**	**0.040**	**1.0**	0.180
	Minium	**6.0**	146	0.050	4.5	9.7	0.050	51	0.050	0.050	5.7	6.3	9.5	5.0	**0.45**	0.005	**0.020**	0.320	0.100
	Average	6.7	655	0.18	23	74	0.13	67	0.32	0.083	15	14	69	6.1	**1.0**	**0.245**	**0.030**	**0.815**	0.138
	Count	7	7	7	7	7	7	7	3	4	7	7	7	7	7	5	7	7	
5	Max	7.6	260	3.3	3.8	4.1	0.050	100	0.050	0.130	19	8.4	13.6	2.9	0.89	0.110	0.004	0.190	2.3
	Minium	6.1	164	0.050	0.30	1.0	0.050	86	0.050	0.020	15	5.8	10.9	0.7	0.090	0.010	0.002	0.130	0.003
	Average	6.7	203	1.4	2.5	2.6	0.050	93	0.050	0.085	16.3	7.1	12.4	1.7	**0.34**	0.050	0.003	0.150	0.369

ID	SampleID	pH_Lab	Total Dissolved solids_ppm	Nitrate_NO3_ppm	Sulfate_SO4-2_ppm*	Chloride_Cl-_ppm*	Fluoride_F_ppm	TotalAlkalinity_CaCO3_ppm	Orthophosphate_ppm	Phosphorus_P_ppm	Calcium_Ca_ppm	Magnesium_Mg_ppm	Sodium_Na_ppm*	Potassium_K_ppm	Iron_Fe_ppm*	Aluminium_Al_ppm	Nickel_Ni_ppm	Manganese_Mn_ppm
ne values: DRC Mining		**6-9**													**6**		**1**	
ne Values: IFC/World Bank		**6-9**													**2**		**0.5**	
rinking water guidelines (3rd ed, 2004)				**50**	**500**	**250**	**1.5**						**200**		**0.3**	**0.2**	**0.02**	**0.4**
9	Count	10	9	9	9	10	10	10	5	5	10	10	10	10	10	6	10	10
	Max	6.4	110	5.1	3.0	7.2	0.050	8.0	0.050	0.36	7.2	0.50	2.6	2.0	0.21	0.140	0.005	0.350
	Minium	**4.3**	18	0.050	0.050	1.0	0.001	Bdl	0.050	0.030	0.4	0.050	1.2	0.050	0.030	0.030	0.002	0.030
	Average	5.2	59	1.7	1.2	4.1	0.046	5.2	0.050	0.136	2.0	0.24	1.9	0.69	0.1	0.083	0.003	0.071
0	Count	9	9	9	9	9	9	9	4	5	9	9	9	9	9	7	9	9
	Max	6.8	344	2.80	3.4	158	0.10	66	0.050	0.14	11	8.7	101	5.6	**6.6**	0.770	**0.020**	**3.000**
	Minium	6.1	132	0.050	0.20	1.7	0.050	4.0	0.050	0.020	1.3	0.8	1.4	0.60	0.001	0.005	0.003	0.260
	Average	6.3	196	0.83	1.6	40	0.061	51	0.050	0.078	7.1	5.6	29.6	2.2	**2.4**	0.138	0.006	**0.718**
GA	Count	8	8	8	8	8	8	8	2	5	8	8	8	8	8	5	8	8
	Max	7.4	230	7.7	6	4.1	0.050	66	0.050	0.090	17	10	**218**	3.2	11.7	0.090	0.005	1.700
	Minium	**5.6**	64	0.05	3	1.0	0.050	32	0.050	0.020	6.4	4.9	0.80	0.70	**0.30**	0.010	0.002	**0.420**
	Average	6.4	136	1.9	5.0	2.7	0.050	50	0.050	0.054	10	7.4	30	1.6	**7.0**	0.034	0.002	**0.760**
UZ	Count	**5**	5	5	5	5	5	5	2	2	5	5	5	5	5	2	5	5
	Max	8.8	632	7.1	206	8.3	0.10	198	0.40	0.26	86	52	14	5.2	0.10	0.050	0.002	0.010
	Minium	7.0	436	1.6	120	4.5	0.050	168	0.050	0.19	48	41	6.0	2.4	0.001	0.040	0.002	0.001
	Average	7.5	546	3.7	166	6.1	0.070	189	0.23	0.23	61	48	12	3.4	0.048	0.045	0.002	0.005
	Count	10	10	10	10	10	10	10	3	5	10	10	10	10	10	6	9	10
	Max	8.8	364	6.5	20	6.7	0.90	188	0.70	0.13	43	32	25	1.1	0.16	0.100	0.004	0.050
	Minium	7.0	190	1.4	5.0	2.0	0.050	176	0.050	0.020	11	25	4.0	0.05	0.001	0.005	0.002	0.001
	Average	7.6	315	2.7	16	4.0	0.14	181	0.27	0.072	29	31	7.6	0.51	0.040	0.042	0.002	0.014

5.10. Water Supply Potential

Surface and groundwater resources have been investigated to identify the most suitable supply source.

Water requirements

Quantity

Water requirements interpreted from the process flow sheets and mass balance indicate that the total make up requirement averages 390 m^3/h.An additional amount of potable water for the peak staff complement of 500 persons at 120 l/person/d is 60 m^3/d, or about 3 m^3/h.

Quality

Process designers have specified a preference for the water quality provided by Rand Water in South Africa. This request is interpreted as:

Constituent	Concentration as mg/l where applicable	BH1
pH	7.2 – 7.8	6.5
TDS	<200	91
Total hardness (as $CaCO_3$)	<100	26
Sulfate	<20	2.9
Chloride	<20	4.0
Nitrate (NO_3)	<10	0.99
Iron + manganese	<0.1	50.3
Total heavy metals	<0.5	51
Total suspended solids	<3	Not analysed
Total organics as COD	<10	Not analysed

This water quality is suitable for general plant use, and can be readily adapted for cooling and for a feed stream to a demineralisation plant. It is also suitable for domestic use provided it has been adequately disinfected. Comparison with the average water quality determined for groundwater from BH1 (the proposed water resource), shows that the total dissolved salts is well within the required limit of 200 mg/l. However, total heavy metals are in excess of the recommended 0.5 mg/l due to the excessive concentrations of iron and manganese (50.3 mg/l).

Groundwater Balance

Recharge was conservatively estimated at 81,4 Mm^3/a. The hydrogeological system loses 0.6l/s/km^2 as baseflow to the Musonoi River as determined from the general calibrated water balance i.e. the Musonoi River is essentially a gaining stream. The length of the Musonoi River is approximately 16 km from the source to Kasobantu Dam, which represents a loss of groundwater of 4 mm^3/a along the length of the Musonoi River. This is in direct contradiction to the AGES model, which reports a loss of 1800 m^3/hr from the Musonoi as pit inflows to the KOV.

The annual consumption of water supplied to the Kolwezi town is currently approximately 4 Mm^3/a (or around 450 m^3/hr), supplied by boreholes in Nyoka and Mutoshi wellfields. Assuming an additional 200 m^3/hr is pumped from boreholes (P55, INGA, BH UZK and others in the Kalahari formation), it is estimated that groundwater abstracted for domestic supply is approximately 6

Mm^3/a. In addition, barges are pumping approximately $2500m^3/hr$ from the KOV pit into the Musonoi so in total it is estimated that 28 Mm^3/a is abstracted for groundwater consumption.

Total losses due to existing use and baseflow to the river is estimated at **32 Mm^3/a.**

Based on estimates of groundwater recharge and existing use, a conservative estimate of surplus groundwater available for development is calculated as:

81.4 Mm^3/a – 32 Mm^3/a = **49.4 Mm^3/a**

If the requirements of the project are 400 m^3/hr this equates to approximately 3,5 Mm^3/a which could readily be supplied from the surplus groundwater.

Potential sources

The potential groundwater sources include BH1 in the Manga ore body in the CMN formation, BH5 and 6 at plant site A. The potential surface water sources are the Golf Dam, KOV pit and Kasobantu Dam. The Manga orebody is the most feasible for development of a well-field for the following reasons:

- The high yielding borehole BH1 showed that at least 100-200m^3/h per borehole could be abstracted from the CMN formation in this area, providing the borehole dimensions are sufficiently large (17" in diameter). The sustainability of this abstraction rate has not been proven as it was not possible to test-pump this borehole due to the capacity of the pump on site.
- There are no other users exploiting this aquifer and no villages close to the site.
- On the basis of the current dataset, the water quality (after filtration) complies with the preferred quality specification in all respects with the exception of the high concentrations of ferrous iron and manganese present. Contamination from other sources is unlikely.
- The source lies within the KMT concession area, well placed for use in monitoring at Kingamyambo Tailings and the upper reaches of the Musonoi Tailings.

5.11. Water Balance

A water balance was set up for the Musonoi tailings dam to understand the volumes of water that the mining process will need to deal with. The water balance has been undertaken in monthly time steps using the period 1953 to 2002 for a number of scenarios, which are outlined below.

Present Day Scenario

The present day scenario outlines the situation where no mining of the tailings occurs and discharges into the dam are as they are at present. This is done so that the water balance can be calibrated based on the gauge flow data, which is collected weekly on site. At this stage the continuous monitor at SW09 (spillway at Kasobantu dam) measured 3 300 000m^3 of flow for the period 15 July 2004 to 15 August 2004 and 3 000 000 m3 for the period 16 August 2004 to 16 September 2004. These values are substantially higher than the original reported numbers as additional information is now available and more confidence can be attributed to the present numbers. The hourly hydrograph is presented in Figure 5.33 and the following should be noted from the data:

- baseflow which leaves the dam is simulated at approximately 1 500 000 m^3 /mth;

- A rainfall event of 20 mm causes a sudden peak within an hour and the hydrograph tail takes about 8 days before the effect of the rainfall is no longer felt. This indicates that there is a delay in the release of the water, which can be attributed to the many storage facilities in the area that release the water over a longer period of time;
- The tail of the second hydrograph indicated on the 27 August 2004 is an anomaly as the hydrograph falls within 1 hour, which is highly unlikely. It is possible the float (element of the continuous monitor) got stuck in the pipe and dropped from its original height on the 1 September. A more likely scenario is that the tail of the hydrograph was similar to that of the first (28 July 2004) hydrograph. Again it can be seen that the catchment is responsive to the rainfall and the tail of the hydrograph takes 5 days to get back to its original baseflow;
- on the 18 August 2004 the KOV pit was not pumping water into the Musonoi River and the drop in the water discharge was approximately 3600 m^3 /hr;
- This period of monitoring is during the dry season and during the wet season rainfall is high and it is likely that the tail of the hydrograph will not have recovered before the next rainfall event.

The water balance for a medium month is presented in Table 5-36. It indicates the discharge of water that is expected through the Nzilo spillway (SW09). The inflow into the Musonoi tailings dam is also presented in Table 5-37 and indicates substantially higher flow than what is exiting the Kasobantu Dam.

The water balance for the medium, wet and dry months are presented in Figure 5-34 to Figure 5-36 respectively, and the following can be drawn from the present day water balance:

- The discharge of water from the Kasobantu Dam to the Nzilo canal is highly variable from 1 400 000 m^3/mth to in excess of 16 million m^3/mth.
- Approximately 90,000 m^3/mth of water enters the Kakifuluwe wetland from the Musonoi River.
- Baseflow is extensive in this area.
- Extensive losses of water are encountered along the river where the Musonoi tailings are situated.

e 5-36: Discharge of water through the Nzilo spillway as m^3/month

rcenti le	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
x	2 533 392	6 345 137	10 738 621	16 452 451	17 976 515	16 334 323	15 360 539	14 347 382	8 950 622	3 794 729	2 414 639
	1 687 023	3 248 869	7 656 595	11 112 846	13 141 143	12 854 306	11 563 654	12 044 891	6 453 895	2 838 835	1 403 839
	1 443 974	2 367 252	4 698 937	9 488 715	10 384 155	10 233 927	10 381 929	10 520 125	5 167 769	1 603 269	1 403 839
	1 443 974	1 760 621	4 226 031	8 031 845	9 021 024	9 265 446	8 561 954	9 276 427	4 160 045	1 403 355	1 403 839
	1 535 189	2 184 211	4 544 044	8 168 280	9 560 387	9 453 770	8 583 820	9 423 454	4 319 146	1 720 118	1 448 935
	1 443 974	1 552 705	3 582 374	7 101 437	8 051 062	7 934 895	6 721 988	8 137 646	3 104 193	1 403 355	1 403 839
	1 443 974	1 446 150	2 349 115	4 929 522	6 923 759	6 552 513	5 418 092	6 664 192	2 389 679	1 403 355	1 403 839
3	1 443 974	1 446 150	1 725 376	3 657 960	5 270 703	5 294 672	4 150 477	5 405 107	1 564 796	1 403 355	1 403 839
	1 443 974	1 446 150	1 422 698	1 450 937	1 458 867	5 031 672	3 919 463	4 188 197	1 424 632	1 403 355	1 403 839

e 5-37: Expected flow in the Musonoi River as it enters the Kolwezi tailings as m^3/month

rcenti le	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
x	2 258 752	4 962 722	7 847 169	11 803 614	12 842 494	11 742 995	10 922 705	10 224 597	6 703 568	3 194 972	2 213 709
	1 808 096	2 760 645	5 826 614	8 193 515	9 573 306	9 390 160	8 504 291	8 804 887	5 015 534	2 548 693	1 634 596
	1 634 596	2 200 075	3 821 305	7 095 442	7 709 310	7 618 526	7 705 329	7 773 995	4 145 987	1 749 132	1 634 596
	1 634 596	1 814 765	3 475 617	6 084 649	6 787 700	6 963 737	6 474 846	6 933 132	3 464 666	1 634 596	1 634 596
	1 687 847	2 096 181	3 678 773	6 198 521	7 151 555	7 090 663	6 485 676	7 028 017	3 572 716	1 833 267	1 660 433
	1 634 596	1 695 644	3 046 604	5 475 008	6 131 910	6 064 154	5 230 848	6 163 204	2 750 806	1 634 596	1 634 596
	1 634 596	1 634 596	2 176 060	4 012 979	5 369 742	5 129 528	4 349 286	5 167 004	2 267 724	1 634 596	1 634 596
3	1 634 596	1 634 596	1 808 008	3 152 747	4 251 306	4 279 103	3 492 253	4 315 739	1 714 900	1 634 596	1 634 596
	1 634 596	1 634 596	1 634 596	1 634 596	1 634 596	4 101 289	3 336 065	3 492 988	1 634 596	1 634 596	1 634 596

5.12. Traffic

The traffic study was conducted bu Mike van Tonde of MMC Engineers.

The following assumptions and limitations for this specialist study are noted:

1. From observation, existing peak hour, daily and weekend traffic volumes on the road network that the re-treatment operations generated traffic will have an impact on, are very low and whilst a significant increase in these traffic flows are expected in the short to medium term, the vast majority of this will be re-treating activity generated traffic.
2. Many sections of road network that the re-treating activity generated traffic will use, currently require to be rehabilitated and once rehabilitated these roads will provide more than sufficient road capacity even for the longer term forecast accumulative traffic. The gravel roads have wide formations and the asphalt road widths are also wide, in some cases four-lane dual carriageway roads. Most junctions that carry or are expected to carry higher volumes of traffic are roundabouts.
3. From observation high volume pedestrian routes were easily identified and recorded as well as routes where pedestrian flows impacted on the road capacity by walking within the roadway.
4. On the basis of these observations and a baseline analysis, area wide traffic and pedestrians counts were deemed unnecessary as once rehabilitated, the roads and intersections would provide more than sufficient capacity for future accumulative traffic and pedestrian volumes. Some existing traffic counts for other mining projects were, however, included in the review and analysis for this study.
5. Whilst the local municipality, Provincial and National Road Authorities do have plans (and in one case a contract) to rehabilitate or upgrade the local, regional and national road network, there appears to be no funding available and hence it is assumed that these roads will remain in there existing condition for the foreseeable future unless they are maintained privately by the large users. A project to re-habilitate the Likasi – Kolwezi road which reportedly had funding was due to commence in 2005 but to date has not yet commenced.

Overview of Relevant Legislation and Standards

There is no specific DRC legislation that governs traffic impact and transportation planning studies. The study has, however, been undertaken in accordance with the following where applicable:

- Democratic Republic of Congo law and regulations
- IFC Policy and Performance Standards
- World Bank Environmental, Health and Safety Guidelines

This specialist traffic and transportation study has been undertaken using the following guideline documents:

- South African National Department of Transport's Guidelines for Traffic Impact Studies
- The Southern African Road Traffic Signs Manual
- Southern African Road Safety Manual
- South African National Guidelines on Traffic Calming.

The following lists the key sections of the local and regional road network surrounding and serving the KMT concession area in Kolwezi that the proposed First Quantum Minerals re-treating operation generated traffic is likely to impact on.

Lubumbashi – Likasi Road

The Lubumbashi - Likasi route is functional, but narrow bridges at km 173.9 and 190.2 may require reinforcement and widening, and depending on loads, the road requires widening in certain areas.

There is a road bridge across the Lufira River (98.4 km from Lubumbashi) with no alternative diversions, place the following restrictions on vehicle movement:

- Max width: 3.2m
- Max height: 5.0m
- Max GVM: 65t

Likasi to Fungurume

This road is gravel surfaced and is generally in very poor condition with some sections completely impassable by all vehicles during the summer months with a 500 m section of road approximately 3,0 km west of Likasi in the worst condition. The formation width varies considerably and drainage along this section of road is very poor or non-existent. Through Fungurume the road narrows down considerably to around 6,0 m in some places, with trading along both sides, close to the road edges as well as heavy vehicles parked along both sides of the road within the village. Some sections of this road through Fungurume village are asphalt surfaced and have speed humps to slow the traffic down. Just to the east of Fungurume there is a single lane bailey bridge which is a constriction point along this road. The horizontal and vertical alignments of this section of road are of a high standard.

Fungurumi to Bazano Mining Turn-Off

This road is gravel surfaced and has a narrow formation width. Some sections of this road are in very poor condition with rutting and potholes even though it is maintained by Swanepoels on behalf of DCP. Some sections of the road have acceptable drainage and others have no drainage at all. The horizontal and vertical alignments of this road are of an acceptable standard.

Bazano Mining Turn-Off to Lualaba Village

This section of road is gravel surfaced with a very wide formation of up to 15,0 m and has formal drainage. The road is in good condition as it is maintained by Bazano. The horizontal and vertical alignments of this section of road are of a high standard. The road crosses Lake Lualaba via a narrow bailey bridge (281 km from Lubumbashi) which places the following restrictions on vehicle movement:

- Max width: 3.2m

- Max height: 5.0m
- Max GVM: 35t

There is a barge that can be used to transport vehicles larger and heavier than the above restrictions between the east and west banks of the lake, operated by the DCP and KOL mining operations. In order to access this barge there are two access roads off the Likasi – Kolwezi Road, one on each side of the lake. As the bailey bridge is a single-lane bridge and it is an additional constriction point along this route.

Barge Access Road West of Lake through Lualaba Village

The barge access road west of the lake is a gravel surfaced road in very good condition with good horizontal and vertical alignments. The road is generally fairly wide, however it does narrow down to 6,0m along some sections and it passes through the middle of the village of Lualaba.

Barge Access Road East of Lake Direct Access onto Likasi Road

The barge access road east of the lake is an informal gravel surfaced road aligned directly off the Kisali - Kolwezi and only passes a small shop. The width of the road varies but is acceptable for the type of heavy vehicle traffic it is required to carry.

Lualaba Village to Tilwezembe Access Road Intersection

This section of road is gravel surfaced with a wide formation and has formal drainage. The road is in good condition as it is maintained by Bazano. The horizontal and vertical alignments of this section of road are of a high standard.

Tilwezembe Access Road Intersection to Kolwezi Town Road Network

From the Tilwezembe Access Road to around the airport turnoff this road is gravel surfaced with a very wide formation of up to 12,0 m and formal drainage. The road is in good condition as it is maintained by DEM Mining (contract miners for DCP). The horizontal and vertical alignments of this section of road are of a high standard. The last section of this road from around the airport turn-off to Kolwezi is narrow and asphalt surfaced with evidence of edge erosion. The horizontal and vertical alignments of this section of road are also of a high standard.

Kolwezi Town Road Network

Boulevard Lumumba

The Lubumbashi Road – Likasi – Kolwezi Road national road connects to Boulevard Lumumba which is the main road through Kolwezi New Town and extends up to Boulevard du 30 Juin. Even though this road is a wide 4-lane dual carriageway road, it is in very poor condition resulting in slow vehicle speeds. Currently all of the ore that is being mined at Tilwezembe by DCP is transported by DEM Mining along this dual carriageway to the crusher in the Kolwezi mine complex. DEM Mining is maintaining this road by filling potholes and watering the road to keep the dust down.

Road 1 (Kolwezi New Town to Luilu)

Known locally as Road 1, this road forms part of National Road 3 between Kolwezi and Angola and is the extension of Boulevard Lumumba to the northwest from Boulevard du 30 Juin in Kolwezi Newtown. This road used to be an asphalt surfaced road, but is now in exceptionally poor condition with deep and extensive potholing and is virtually impassable for all travellers except by 4 X 4. The cross section of this road is fairly wide and the horizontal alignment and the vertical alignment of this section of road are of a high standard. This road has no existing drainage. Through the village of Luilu the road is in much better condition with the section west of Luilu having recently been upgraded by DCP Mining.

Concession Internal Road Network

Kolwezi Town to Project Site Road

This access road known as Road 2 is the main access road off Road 1 (Kolwezi – Luilu Road) that serves the existing construction operations within the concession (including the construction village) and is planned to serve the future plant site including the senior management village.

Internal Access and Distribution Roads

Apart from the main access road (Road 2), there are a further 10 roads or tracks that make up the re-treatment operations internal road network as follows:

Road 5 - Access to TSF

Road 6 - Lime quarry access road

Road 7 - Aggregate quarry haul road

Road 8A - Access to pipeline maintenance road: Upper Musonoi reclaim area

Road 8B - Access to pipeline maintenance road: Middle Musonoi reclaim area

Road 8C - Access to pipeline maintenance road: Lower Musonoi reclaim area

Road 9 - Powerline maintenance track

Road 10 - Borefield maintenance track

Road 12 - Access and pipeline maintenance road to Luilu River

The location of these roads is shown on the overall site layout plan.

Existing Traffic Flows

Existing traffic flows on the key road network were obtained from extensive observation over several average weekdays including during the morning and afternoon peak periods where necessary. As indicated above, all of the roads in the greater Kolwezi area that the proposed FQM re-treatment operation generated traffic is likely to impact on, currently carry low traffic volumes even during peak periods and therefore extensive traffic counts for capacity analysis purposes were not deemed to be necessary.

The following traffic counts were, however, used to assist in describing the baseline traffic conditions on the road network described above:

- Classified 24-hour traffic count on the Kolwezi to KTL road at the bus stop in the village on Wednesday, 15 August 2007 and Saturday 18 August 2007.
- Classified 24-hour traffic count on the Kolwezi – Luilu road at security container on Wednesday, 15 August 2007 and Saturday 18 August 2007.
- Classified 12-hour traffic count on the Kolwezi – Likasi Road at the Kalumbwe Mine / Kisanfu Mine Access Road intersection on Thursday, 7 February 2008.

The results of these traffic counts are contained in Appendix C and the existing AM peak hour, PM peak hour and 12-hour traffic volumes at the Kalumbwe Mine / Kisanfu Mine Access Road intersection on the Kolwezi – Likasi Road are shown schematically in Figure 1. An analysis of these counts has been undertaken for the applicable section of road below, for the remainder of the road network where no counts are available, a qualitative assessment of baseline traffic conditions has been made.

Lubumbashi – Likasi Road

Traffic volumes along this section of road are low due to the poor condition of the road surface. The vast majority of these vehicles are light delivery vehicles, heavy vehicles or 4 X 4 vehicles.

Likasi Road – Kolwezi Road

Likasi to Fungurume

Traffic volumes along this section of road are also very low mainly due to the poor condition of the road surface. The vast majority of these vehicles are also light delivery vehicles, heavy vehicles or 4 X 4 vehicles. An off-peak hourly count indicated less than 30 veh/h two-way travelling along this road. Just outside the urban edges of Likasi and Fungurume the traffic volumes do increase with a higher proportion of sedans, however, the traffic volumes are still very low. The only public transport activity along this section of road is the long haul buses.

Fungurume to Bazano Mining Turn-Off

Traffic volumes along this section of road between the town of Fungurume and the TFM mining complex to the north of the town are higher than the previous and following sections of the Likasi to Kolwezi Road due to the TFM mine generated traffic. Within the urban area of Fungurume there is increased vehicular activity including some sedans, however traffic densities are still very low.

Between the TFM mining complex and the Bazano mining turn-off, the traffic volumes are very low again due to the relatively poor condition of the road surface. The 12-hour traffic count at the Kalumbwe Mine / Kisanfu Mine Access Road intersection confirmed that existing traffic volumes along this road are very low with less than 35 veh/hr two-way recorded during the highest peak hour and less than 230 veh/12hr two-way recorded during the survey period.

Virtually all of the vehicles travelling along this section of road are light delivery vehicles, heavy vehicles, 4 X 4 vehicles and buses / minibuses although the odd sedan was observed. There is some public transport activity along this section of road with the long haul buses, minibuses and minibuses making up just less than 20% of the total vehicle volumes.

Bazano Mining Turn-Off to Lualaba Village

Due to the Bazano mining activity the volume of traffic increases significantly along this section of road with hourly volumes increasing to around 50 veh/hr two-way and daily volumes estimated at 500 veh/24hr. The vast majority of vehicles travelling along this section of road are light delivery vehicles, heavy vehicles or 4 X 4 vehicles. The only public transport activity along this section of road is the long haul buses.

Barge Access Road West of Lake through Lualaba Village

This section of road only carries heavy vehicles that exceed 35 tons and some of the local Lualaba village traffic and therefore both light and heavy vehicle volumes are low. This road is not a known public transport route. Vehicle speeds along this road are generally low.

Barge Access Road East of Lake Direct Access onto Kisali Road

This section of road also only carries heavy vehicles that exceed 35 tons and hence is used a maximum of 2 to 3 times a day. This is due to the poor condition of the Kisali – Lualaba road. The low volume of extra heavy vehicles is due to the poor condition of the Kisali – Lualaba road.

Lualaba Village to Tilwezembe Access Road Intersection

Due to the Bazano mining activity and the improved road surface of this section of road the volume of traffic increases further along this section of road to above 50 veh/hr two-way. Within the urban area of Lualaba there is increased vehicular activity including some sedans and minibus / midibus taxis, however, traffic densities along this road are still very low. The vast majority of vehicles travelling along this section of road are light delivery vehicles, heavy vehicles or 4 X 4 vehicles although some sedans, minibuses and midibuses were also observed. The only public transport activity along this section of road is the long haul buses and the few minibuses / midibuses that travel between Lualaba and Kolwezi as well as some additional minibus / midibus activity in and around Lualaba.

Tilwezembe Access Road Intersection to Kolwezi Internal Road Network

The volume of traffic along this section of road and particularly the heavy vehicle traffic increases substantially from the previous section due to the DCP mining activity at Tilwezembe. There are currently 100 000 tons of ore being mined at Tilwezembe and transported to the Kolwezi crusher. With a pay load of 35 tons, this equates to around 100 trips to the crusher and 100 return trips per day (24 hours) for a seven day week. The average peak hour traffic thus increases to around 60 veh/hr with the daily traffic increasing to around 750 veh/24 hr.

The proportion of heavy vehicles also increases substantially for this section of road and public transport services include the long haul buses as well as minibus and midibus services between Lualaba and Kolwezi.

Kolwezi Internal Road Network

Boulevard Lumumba

Traffic volumes increase noticeably along Boulevard Lumumba as the longer distance traffic mixes with local town traffic. The two-way volume of traffic is, however, still well below 200 veh/hr two-way along Boulevard Lumumba which is a 4-lane dual carriageway and therefore provides plenty of road capacity for these existing traffic volumes. All major junctions are effectively roundabouts and even though traffic speeds are generally slow there is no congestion at all along Boulevard Lumumba. The proportion of heavy vehicles reduces along this section of road network and the proportion of public transport vehicles (minibuses and midibuses) increases.

Road 1 (Kolwezi New Town to Luilu)

Sections of this road carry very low volumes of traffic due to its very poor condition. Closer to Kolwezi New Town (Caroline City and Kasulo City) traffic volumes increase noticeably, however, so do the volume of pedestrians and cyclists that walk within the roadway and therefore affect the capacity of this section of road. Traffic volumes between the First Quantum Minerals main access road and Kolwezi are, however, higher than west of this access road. Within the village of Luilu where the road has recently been rehabilitated by DCP, traffic volumes are noticeably higher including light vehicles, minibuses, midibuses and heavy vehicles. This section of road within the village of Luilu forms part of the public transport route between Kolwezi and Luilu. Vehicle speeds are generally low along this road due to high pedestrian and cyclist activity and open channel drains along both sides of the roadway.

Concession Internal Road Network

Kolwezi Town to Project Site Road

This main access road only carries a low volume of project generated traffic throughout the day. The volume of traffic travelling along this road is currently not high as re-treatment and construction activity is still limited.

Internal Access and Distribution Roads

Existing traffic volumes on the other 10 internal access and distribution roads are negligible with most of these roads currently not used much at all during an average weekday.

An indication of the existing pedestrian and cycle activity along each section of road that is likely to be used by the First Quantum Minerals re-treatment operations was obtained from extensive observation during both peak and off-peak periods of an average weekday.

Lubumbashi – Likasi Road

There is very little pedestrian and cyclist activity along this section of road except on the outskirts of the towns and villages where pedestrian and cyclist activity does occur. All of these pedestrians and cyclists walk and cycle within the roadway, however, they do give way for vehicles.

Likasi – Kolwezi Road

Likasi to Fungurume

There is also very little pedestrian and cyclist activity along this section of road except on the outskirts of Likasi and Fungurume where pedestrian and cyclist activity does occur. As with the section of road above, all of these pedestrians and cyclists walk and cycle within the roadway although they do give way for vehicles.

Fungurume to Bazano Mining Turn-Off

Within Fungurume there is extensive pedestrian activity with a very high concentration of pedestrians including children walking on either side of this road associated with the informal trade activity that occurs within the town. Pedestrians walk within the roadway and alongside the roadway for virtually its entire length through the town. There is also some cyclist activity within the town.

Between the Fungurume town and the TFM mining complex there is also some pedestrian and cyclist activity along this road. From the TFM mining complex to the Bazano mining turnoff there is very little pedestrian and cyclist activity along the road. All of these pedestrians and cyclists walk and cycle within the roadway although they do give way for vehicles.

Bazano Mining Turn-Off to Lualaba Village

There is very little pedestrian and cyclist activity along this section of road except on the outskirts of Lualaba village where some pedestrian and cyclist activity occurs. All of these pedestrians and cyclists walk and cycle within the roadway although they do give way for vehicles.

Barge Access Road West of Lake through Lualaba Village

There is some pedestrian activity along this road but very little cyclist activity. Children were observed playing in the roadway within the Lualaba village.

Barge Access Road East of Lake Direct Access onto Kisali Road

There is very little pedestrian and cyclist activity along this road.

Lualaba Village to Tilwezembe Access Road Intersection

Within Lualaba village there is pedestrian activity along the road including children particularly at some of the intersections and trading areas. There is also some cyclist activity along the road within the village.

Between the Lualaba and the Tilwezembe Access Road intersection there is very little pedestrian and cyclist activity along the road. All of these pedestrians and cyclists walk and cycle within the roadway although they do give way for vehicles.

Tilwezembe Access Road Intersection to Kolwezi Internal Road Network

At the Tilwezembe Access Road intersection there is a concentration of pedestrian activity associated with public transport. There is, however, very little cyclist activity at this intersection. Between Tilwezembe and the outskirts of Kolwezi there is some pedestrian and cyclist activity in the vicinity of the villages and small settlements mainly associated with road side trade or public transport. Pedestrian and cyclists activity increases noticeably as the distance to Kolwezi decreases.

Kolwezi Internal Road Network

Boulevard Lumumba

There are consistent volumes of pedestrians and cyclists walking and cycling along the entire length Boulevard Lumumba with concentrations of pedestrians at the commercial activity along the road. This road is an effective 4-lane dual carriageway road and has sidewalks and a wide central median island. As such pedestrians walk along the sidewalks and within the central median island and cyclists are able to cycle within the roadway without impeding the free flow of traffic which in any event is slow due to the poor condition of the road surface.

Road 1 (Kolwezi Newtown to Luilu)

Within Luilu there is extensive pedestrian activity with a high concentration of pedestrians including children walking on either side of this road associated with the informal trade activity that occurs within the village. Pedestrians walk within the roadway and alongside the roadway for virtually its entire length through the town which affects the free flow of through traffic. There is also extensive cyclist activity within the village which is a combination of those transporting logs and Luilu residents travelling to, from and within Luilu via cycle.

From Luilu to Kolwezi New Town there is some pedestrian and cyclist activity along this road as it is the shortest route between Luilu and Kolwezi. Even though the road virtually impassable by vehicle, pedestrians can walk along the edges and there is also a reasonable cycle path for cyclists.

Within Kolwezi Newtown there is extensive pedestrian activity with a high concentration of pedestrians walking on either side of this road associated with the informal trade activity that occurs alongside this road. Pedestrians walk within the roadway and alongside the roadway through Kolwezi Newtown. There is also some cyclist activity along this road within Kolwezi Newtown.

Concession Internal Road Network

Kolwezi Town to Project Site Road

There is some pedestrian and cyclist activity along this main access road associated with the existing limited re-treatment and construction activity within the concession area.

Internal Access and Distribution Roads

Existing pedestrian and cyclist activity along the other 10 internal access and distribution roads are negligible or non-existent with most of these roads currently not used at all by pedestrians and cyclists during an average weekday.

Existing Animal Activity

There is some domestic animal activity along the Lubumbashi – Likasi – Kolwezi Road associated with the herding of cattle to the abattoir at Likasi. These herds are usually controlled by several herd men who have red flags to warn approaching vehicles. Within all of the villages and towns along this road, there are pigs, goats, domestic dogs and chickens that walk within the roadway.

There are also many pigs, goats, domestic dogs and chickens that walk in the roadway within some sections of Kolwezi and within the village precinct of Luilu.

There was no evidence of wild animal activity along any of the roads evaluated as part of this study although there have been reports of small buck crossing the Likasi – Kolwezi road at night.

Existing Road Safety Conditions

An indication of the existing road safety conditions along each section of road that is likely to be used by the proposed First Quantum re-treatment operations was obtained from extensive observation during both peak and off-peak periods of an average weekday.

Lubumbashi – Likasi Road

Due to the very low volumes of traffic, pedestrians and cyclists along this section of road as well as the low vehicle speeds there are no adverse road safety conditions on the road between Lubumbashi and Likasi. Dust generated by vehicles travelling along the road does restrict visibility, however, due to the low vehicles speeds this is not problematic.

Likasi Road – Kolwezi Road

Likasi to Fungurume

Similarly, due to the very low volumes of traffic, pedestrians and cyclists along this section of road as well as the low vehicle speeds there are no adverse road safety conditions on the road between Likasi and Fungurume. Dust generated by vehicles travelling along the road does restrict visibility, however, due to the low vehicles speeds this is not problematic.

Fungurume to Bazano Mining Turn-Off

Within Fungurume there is conflict between pedestrians / cyclists and vehicles, particularly heavy vehicles as there is a high concentration of pedestrians including children walking on either side of the road. Even though this section of road is traffic calmed by means of speed humps this conflict is still hazardous for both pedestrians and vehicles.

From Fungurume past the TFM mining complex to the Bazano mining turnoff there is not much conflict between pedestrians / cyclists and vehicles. Vehicle speeds are not noticeably high along this section of road and no major adverse road safety conditions were observed. Dust generated by vehicles travelling along the road does restrict visibility, however, due to the relatively low vehicles speeds this is not problematic.

Bazano Mining Turn-Off to Lualaba Village

Even though the volume of heavy vehicle traffic increases significantly along this section of road and the heavy vehicle speeds are higher than the previous sections of road, there is not much conflict between pedestrians / cyclists and vehicles. Dust generated by vehicles travelling along the road does, however, restrict visibility which is hazardous for vehicles travelling at fairly high speeds. Due to this dust vehicles and particularly heavy vehicles cannot see pedestrians and cyclists who are then very vulnerable to passing traffic.

Barge Access Road West of Lake through Lualaba Village

Heavy vehicles travelling along a local village road on which local village pedestrians currently walk and on which village children currently play is a potential road safety conflict.

Barge Access Road East of Lake Direct Access onto Kisali Road

There are no existing adverse road safety conditions along this road.

Lualaba Village to Tilwezembe Access Road Intersection

Within Lualaba village there is conflict between pedestrians / cyclists and vehicles and between domestic animals and vehicles, particularly the Bazano mine vehicles and other heavy vehicles that tend to travel at fairly high speeds through the village. There is, however, space on either side of the road for these pedestrians to walk and cyclists to cycle.

Between the Lualaba and the Tilwezembe Access Road intersection there is not much conflict between pedestrians / cyclists and vehicles. Even though vehicle speeds are quite high along this section of road, no major adverse road safety conditions were observed. Dust generated by vehicles travelling along the road does, however, restrict visibility which is hazardous for vehicles travelling at fairly high speeds. Due to this dust vehicles and particularly heavy vehicles cannot see pedestrians and cyclists who are then very vulnerable to passing traffic.

Tilwezembe Access Road Intersection to Kolwezi Internal Road Network

The heavy vehicle traffic increases significantly from the Tilwezembe Access Road intersection to Kolwezi due to the DCP mining operations at Tilwezembe. DEM Mining’s ore trucks travel at excessive speeds along this section of road which is hazardous to all other road users. This is exacerbated by the dust generated from these vehicles which reduces visibility for passing and approaching motorists. Due to this dust vehicles and particularly heavy vehicles cannot see pedestrians and cyclists who are then very vulnerable to passing traffic, particularly high speed traffic.

Kolwezi Internal Road Network

Boulevard Lumumba

Even though the road surface along this dual carriageway is poor, the DEM Mining vehicles transporting ore for DCP Mining travel at high speeds along this road which is hazardous for other road users, particular light vehicles. This road is watered by DEM Mining to reduce dust within the town of Kolwezi.

Road 1 (Kolwezi Newtown to Luilu)

Within Luilu there is high conflict between pedestrians / cyclists and vehicles, particularly heavy vehicles as there is a high concentration of pedestrians including children walking on either side of the road. This is considered to be hazardous for both pedestrians and vehicles.

From Luilu to Kolwezi New Town existing traffic volumes are low and traffic speeds are very low due to the poor road surface and therefore there is very little conflict between pedestrians / cyclists and vehicles.

Within Kolwezi Newtown there is high conflict between pedestrians / cyclists and vehicles, particularly heavy vehicles as there is a high concentration of pedestrians including children walking on either side of the road. This is considered to be hazardous for both pedestrians and vehicles.

Concession Internal Road Network

Kolwezi Town to Project Site Road

As the existing traffic volumes, pedestrian flows and cyclist activity along this road are currently low and the alignment of the road is good, there are no existing road safety concerns along this road.

Internal Access and Distribution Roads

As existing traffic volumes, pedestrian flows and cyclist activity along the other 10 internal access and distribution roads are negligible or non-existent with most of these roads currently not used at all during an average day, there are no existing road safety concerns along these roads.

5.13. Noise

The noise specialist study was conducted by Francois Malherbe of Accoustic Consulting cc.

Methodology

In order to undertake noise modelling for the proposed construction and operation activities, baseline ambient noise levels needed to be verified. Site visits were made during both the dry (August 2004) and the wet (January 2005) seasons and the ambient noise levels were measured in accordance with methodology outlined in articles 1 to 6 of Annexure XIII of the DRC Mining Regulations as described below.

Noise Intensity Measurement

Measurements were taken of the current, pre-development ambient A-weighted[6] sound pressure levels in communities nearest to the proposed development since these were assumed to be the most sensitive receptors to the noise anticipated from the proposed project.

Post-development noise levels were calculated using an internationally accepted calculation procedure[7].

Noise Evaluation Method

The noise level attributable to an operation or to the environmental noise is evaluated as per the following formula:

$$L_e = P + 10 \times Log_{10}\left\{\left[(0{,}0014 \times m) \times 10^{\frac{(L_i+5)}{10}}\right] + 10^{\frac{L_x}{10}}\right\}$$

Where:

Le = noise level at noise evaluation point;

L_i = equivalent level impact noises (Calculation of the exponential mean of peak levels of impact noises that are produced during the reference period and that are perceived at the point of reference);

L_x = noise equivalent level;

P = 5 for any disturbance noise containing verbal or musical elements;

P = 0 for any noise containing no verbal or musical element;

The formula to be used for Li calculation is the following:

$L_i = 10 \log_{10} [(1/m) \sum 10^{dBn/10}]$

dBn = peak level of n^{th} impact noise during the reference period; and

m = total number of impacts during the reference period. If the number of impacts is higher than 720 / hour, m= 720.

The formula to be used for L_x calculation is the following:

$L_x = 10 \log10 [(1/100) \sum fi\ 10^{Li/10}]$

Where:

fi = time interval (as a percentage of the reference time) during which the noise level is within the limit of class i. When the company is not in operation, the corresponding fi are equal to 0.

6 The 'A' of dBA referes to the A-weighting applied to measurements and calculations. The A-weighting, or A-filter is applied in order to simulate the frequency characteristics of the human ear, i.e. our ears are not equally sensitive to all frequencies of sound. Internationally all measurements and calulations relating to human responses to noise are given in dBA.

7 The future ambient noise levels were calculated using the so called Concawe method, developed by CONCAWE - (The Oil Companies' European Organization for Environmental and Health Protection) for calculating the noise caused by oil refineries over long distances. As such it has been thoroughly tested and has also been referred to by ISO.

And:

L_i = noise level in dBa corresponding to the average point of class i.

The extent of class i is set to a value equal or less then 2 dBA and the sampling period must be equal to or less than 0,1 second.

The calculations for the noise modelling were carried out according to the specifications of Article 2 outlined above. The result at each point on the map was calculated as the energetic sum of the noise contributions from the different noise sources that were assumed to form part of the noise emissions from the KMT plant. The reference period was 60 minutes, i.e. it was assumed that there would be two train trips per hour to and from the KTM plant (this is a very conservative assumption since there is likely to be one to two trains a day). No corrections for impulsive noise were included since, according to the information available at the time of reporting, the noise emissions were characterized by continuous noise emissions. Furthermore, the noise levels which were recorded were sampled at 0,1 second intervals.

Evaluation Period

For the purpose of this evaluation method, the reference period is of 60 consecutive minutes. If the evaluation is based on a period of less than 60 minutes, an adjustment is carried out, so that the relation between operation and rest periods are the same. All measures are in dBA.

The reference period for assessing the noise impact was 60 minutes during the day or night. All measurements and calculation results were expressed in dBA.

Noise Evaluation Points Selection

The four locations were chosen for the following reasons:

- The environment where the noise emissions from the KMT plant are most likely to cause a negative noise impact are the communities that live in villages in relative proximity to the plant site.
- The locations were chosen for being representative of communities in the larger villages, such as UZK and Luilu, where there is significant infrastructure, e.g. infrastructure and some road traffic, as well as more rural villages without electricity and no road traffic.
- At each location a point was chosen were the general community noise could be captured without causing too much noise disturbance by one’s presence in the village.
- Another important factor was to try and capture the different locations at more or less the same period of day, e.g. afternoon or evening or night. In order to do this the locations could not be too far apart since travelling between them required some time, especially at night.
- The requirements of article 4 specifically refer to a situation where the noise caused by an existing source has to be quantified. However, for this investigation the noise levels had to be calculated since the source, the KMT operation, does not yet exist. The noise levels were calculated for the nodes of a 13x16 grid (208 points) that included both densely and sparsely populated areas.

The ambient noise levels were measured during representative periods specified for the day and night and at the four representative measurement sites listed below:

- ***Measurement Point 1 (MP1):*** At the eastern edge of **UZK Village**, opposite the new technical training college. UZK is one of the larger villages in the area with some infra structure in place, e.g. some tarred roads, schools, churches. It lies immediately east of the Kingamyambo Tailings.
- ***Measurement Point 2 (MP2):*** At the northern edge of **Tshala Village**. Tshala is a more rural type of village with very little infrastructure. It lies south of and probably is the closest to the site of the new KMT plant.
- ***Measurement Point 3 (MP3):*** Near the centre of **Luilu Village** west of the proposed KMT development site. Luilu is also a larger village like UZK, and was developed as a mining town for the neighbouring Luilu mine and plant.
- ***Measurement Point 4 (MP4):*** Next to the main road running from north to south through **Kamimbi Village**, east of the KMT development site. Kamimbi is a village with a character in between that of a very rural and a larger mining village.

In addition to the above measurement points the ambient noise level was also continuously measured over the period of approximately 24 hours at the KMT office in Kolwezi Town (the 5th location mentioned in Table 5.37). This measurement was taken in accordance with the procedures specified in SANS 10103[3] and the DRC regulations.

The abovementioned sites were then classified according to the three terrain types a), b) and c); as specified in the DRC Mining Regulations and shown in Table 5-38.

Table 5-38: DRC regulation noise limits compared with IFC Guidelines.

Land category	Description	Noise level, Le dBA		IFC Guidelines dBA	
		Night (19h00 to 07h00)	Day (07h00 to 19h00)	Night (19h00 to 07h00)	Day (07h00 to 19h00)
a	Land on which there are numerous residential dwellings constituting a community or a village, a school or a hospital or similar health institution.	40	45	45	55
b	Land which there are permanent commercial, hunting, fishing or recreational activities. However, the noise level prescribed for the night only applies on the border with residential properties. Everywhere else the day and night thresholds are the same.	50	55	None	None
c	Land on which there are predominantly industrial or agricultural activities. However, at the location of an existing residential dwelling on this terrain the thresholds are 50 dBA during the night and 55 dBA during the day.	70	70	70	70

The villages were classified into land categories according to the ambient noise levels measured during the day (07:00 to 19:00) and night (19:00 to 07:00) and further to discussions with DPEM representatives during the wet season site visit in January 2005 as shown in Table 5-39.

Table 5-39: Noise limits for the measurement locations

Village	Description	Terrain Type	DRC noise level dBA	
			Day (07h00 to 19h00)	Night (19h00 to 07h00)
UZK	This is a fairly large, electrified village with paved roads, churches, schools and some commercial activities. It is in close proximity to the face of the Kingamyambo Tailings.	b	55	50
Tshala	This village is the nearest to the KTM plant site. It has no electricity and a very rural character.	b	55	50
Luilu	This is also a large, electrified village with planned roads, churches, schools and some commercial activities. It is associated with the neighbouring Luilu Plant and mining area.	b	55	50
Kamimbi	This is a large village, but without electricity and a rural character.	a	45	40
Kolwezi	This is the main town in the area. Electrified, commercial activities etc.	b	55	50

The location of the selected measurement points are illustrated in Figure 5-37.

Noise Measuring Conditions at Impact Points: equipment, location, equipment location and meteorological conditions.

All the measurement instrumentation that was used for this investigation conforms to the specifications of a Class 1 instrument, as specified in IEC 61672-1. The requirements in terms of microphone placement and calibration check were fulfilled. Although noise caused by the wind often contributed to the measurements, no measurements were taken under conditions where the wind speed exceeded 20 km/h (5,5 m/s).

Methodology of Environmental Noise Measurement of the Sector

The pre-development ambient noise level at each location was measured during two independent periods of 20 minutes (40 minutes in total) during the day (07:00 to 19:00) and two independent periods of 20 minutes (40 minutes in total) during the might (19:00 to 07:00). The results are considered to be representative of the present, pre-development ambient noise climate at each of the locations. Therefore, the ambient noise levels under pre-development conditions were measured in full compliance with the requirements of Article 6 of Annexe XIII of the DRC Mining Regulations.

The noise emissions from the future KMT plant and other processes were calculated in accordance with the Concawe prediction method described in SANS 10357[6]. This is an internationally recognised and trusted method for the calculation of sound propagation over long distances under a large variety of meteorological conditions. Based on this method a detailed noise model for the KMT operation was developed. The model requires the following input parameters:

- The typical ground conditions, i.e. acoustically hard or soft conditions.
- The noise emission levels of mining equipment and processes, specified in terms of the octave band sound power levels, L_{Wi}.
- The operational detail of the mining operation during the construction and operational phases.
- The different conditions for sound propagation during the day and night.
- The typical meteorological conditions during the day and night.

The average meteorological conditions assumed for the calculations are summarised in Table 5-40.

Table 5-40: Summary of the assumptions made for the calculations

Parameter	Assumed value
Temperature	29 °C max
	13 °C min
Wind	2 m/s
	East
Humidity	92% RHD max
	44% RHD min
Static air pressure	86 kPa
Acoustically soft ground conditions	50%

There a number of hills in the area, and the effect of the topography of the area on the propagation of sound was included in the modelling.

The assumptions that were made regarding the equipment for the KMT operation are given in Table 5-41 below.

Table 5-41: Assumptions made for the equipment of the KMT operation

Equipment	Noise sources	Number
KMT plant	Pumps	44 12x 132 kW 5x 110 kW 2x 90 kW 5x 75 kW 9x 55 kW
	Cooling tower	1
	Blowers	2
	General broad band source	1
Sulphur/Acid plant	FEL	2
	Feed hopper	1
	General broad band source	1
	Cooling towers	2
Access Road	Transport truck	14 trips per hour i.e 1 truck every 4 minutes
Per hydraulic monitoring unit	Water nozzle	1
	Vibrating screen	1
	Slurry pumps	1

No specific data on the noise emission levels of specific equipment were available. Therefore, the typical equipment noise emission levels available in the consultants' data base and in technical literature were used.

Expression and assessment of noise impacts in terms of IFC guidelines

The DRC Mining Regulations do not provide any criteria for assessing a noise impact in terms of the increases in ambient noise levels as, for instance, SANS 10103 does. Furthermore, the IFC guidelines (Environmental Health & Safety General Guidelines, April 2007) do provide such a criterion in stipulating that the increase in ambient noise level during the noisiest hour at the nearest noise sensitive receptor is not more than 3 dBA. This 3 dBA-criterion has its origin in the fact that the person with average hearing acuity will just be able to detect a change of 3 dBA in the general ambient noise level.

However, the assessment of noise impacts in very rural environments in terms of increases in noise levels is often quite difficult, since the introduction of mechanised processes and equipment will almost without exception cause large increases in the existing, very low ambient noise levels. This may then lead to an overly critical evaluation of a noise impact. Therefore, it is proposed that for the purposes of this study the estimated increases in ambient noise levels should be assessed in conjunction with the resulting total ambient noise level.

According to the guidelines given by SANS 10103 these large increases may lead to complaints in the affected rural communities. However, this is often not the case. The reasons for this are definitely very complex but are probably linked to the fact that, despite the large increases, the total resulting ambient noise levels do not exceed, or do not exceed by much the guideline levels of 55 dBA and 45 dBA during respectively the day and night. These are also the guideline levels specified by the IFC for residential areas in general.

In order to simplify the assessment of the magnitude of noise impacts in terms of increases, it is suggested that the increase Δ be calculated in the following manner:

$\Delta = L_{Aeq}\ (1\ hr)_{post} - L_{Aeq}\ (1\ hr)_{pre}$ dBA

where

$L_{Aeq}\ (1\ hr)_{post}$ = Ambient noise level determined for the noisiest hour under operational conditions, dBA

$L_{Aeq}\ (1\ hr)_{pre}$ = Ambient noise level determined for the noisiest hour before the development under investigation, dBA

All else being equal the noisiest hour is very likely to be during the night, when noise meteorological conditions favour the propagation of noise from source to receiver. The Δ-level can then be used as the IFC assessment criterion in the manner summarised in Table 5-42.

Table 5-42: Criteria for assessing the magnitude of a noise impact in a rural environment.

Increase (Δ dBA)	Assessment of impact magnitude
$\Delta \leq 0$	Very low
$0 < \Delta \leq 5$	Low
$5 < \Delta \leq 10$	Medium
$10 < \Delta \leq 15$	High
$15 > \Delta$	Very High

Ambient Noise Levels

The measured ambient noise levels at the four sites in the Concession area are summarised in Table 5-43.

Table 5-43: Measurement results, all levels in dBA

Village	Time	Measurement results 1	2	Avg.	Guideline levels DRC	WHO	IFC	Comments
UZK	Day	46,3	48,1	**47,3**	55	55	55	Community noise - local traffic
	Night	44,2	42,5	**43,4**	50	45	45	Pump station dominates noise level - Community noise - Local traffic
Tshala	Day	51,5	40,8	**48,8**	55	55	55	Wind in foliage causes high level on day 1 - Community noise - Vehicles on main road
	Night	46,0	31,9	**43,2**	50	45	45	Frogs cause high noise level night 1 - Some community noise - No frogs on night 2 - Very quiet, but distant droning of fans at elec. supply station audible
Luilu	Day	52,0	53,2	**52,6**	55	55	55	Community noise - Local traffic
	Night	43,0	40,8	**42,0**	50	45	45	Music played loudly in nearby bars night 1 - Community noise - Luilu plant noise clearly audible both nights

Village	Time	Measurement results			Guideline levels			Comments
		1	2	Avg.	DRC	WHO	IFC	
Kamimbi	Day	48,9	49,3	**49,1**	**45**	**55**	**55**	Community noise - Some traffic on main road
	Night	44,2	42,3	**43,4**	**40**	**45**	**45**	Very quiet - Dogs start barking later on - People talking - Corona noise high voltage overhead lines
Kolwezi	Day	**55,0**			**55**	**55**	**55**	Traffic on road, community noise, vehicles arriving and departing at office
	Night	**42,4**			**50**	**45**	**45**	Community noise, natural sounds

The following remarks can be made for the results of Table 5-44:

- All the average measured ambient noise levels fall within the limits specified by the WHO, SANS 10103 and the IFC.
- During the day the average measured ambient noise levels conform to the criterion of the DRC Regulations.
- The exception is Kamimbi, where the results are slightly in excess of the DRC limits. A person with average hearing acuity will not be able to detect a difference of less than 3 dBA in the general ambient noise level. The DPEM representative agreed in writing that for all practical purposes the conditions of the DRC Regulations have been met. This was achieved by re-classifying Kamimbi from terrain type a to terrain type b (Table 5.38).
- During the night the results at Kamimbi are significantly in excess of the lower limit of 40 dBA.
- They do, however, conform well to the higher criterion level of 50 dBA.

The results do, therefore, indicate that a night time criterion level of 45 dBA, as is accepted internationally, would be a good choice.

Table 5-44: Summary of the ambient noise levels measured in January 2005 compared to August 2004.

Period	Year	Day/Night	L_{Aeq} (20 min) BA				Legend
			Luilu	Tshala	UZK	Kamimbi	
DAY	2004	Day 1	52,0	51,5	46,3	48,9	Wind
		Day 2	53,2	40,8	48,1	49,3	No Wind
		Average	**52,6**	**48,8**	**47,3**	**49,1**	
	2005	Day 1	51,9	41,8	49,5	50,7	
		Day 2	54,1	39,4	46,1	40,2	
		Day 3	55,5	39,7	44,0	45,3	
		Average	**54,1**	**40,4**	**47,1**	**47,3**	
		□	1,4	-8,4	-0,2	-1,8	
		2004 - 2005		-0,4			
NIGHT	2004	Night 1	43,0	46,0	44,2	44,2	
		Night 2	40,8	31,9	42,5	42,3	
		Average	**42,0**	**43,2**	**43,4**	**43,4**	
	2005	Night 1	45,7	Rain	Rain	42,0	
		Night 2	49,5	37,5	48,6	39,2	
		Night 3	Rain	43,7	48,6	Rain	
		Average	**48,0**	**41,6**	**48,6**	**40,8**	

			6,0	-1,5	5,2	-2,5	
		2004 - 2005					
OVERALL AVERAGES							
		Day	53,4	46,4	47,2	48,3	
		Night	46,0	42,5	46,7	42,3	

The following comments can be made on the wet season measurements in comparison to earlier noise readings:

- The measurement results obtained during January 2005 compare well with those in August 2004.
- The overall averages confirm the compliance to the DRC Regulations, as discussed above.

The calculated pre-development ambient noise levels based on the model are depicted in Figure 5-38 and Figure 5-39 and illustrate that the modelled results conform to the measured ambient levels.

5.14. Aquatic Biodiversity

Methodology

A field survey to collect biological data was conducted by Dr J Rall, an aquatic ecosystem specialist, during the intermediate low-high flow period from the 25th to 28th of October 2004 and during the intermediate high-low flow period from 1st to 3rd of February 2005. In order to facilitate characterization of the aquatic environment, certain ecological indicators were selected to represent each of the responding, habitat and stressor components associated with the aquatic environment. In November 2005 Dr Rall conducted a separate survey which included the Musonoi River downstream of the Kasobantu dam (MUS1) and at the Kasobantu Dam wall (KD1), the Luilu River downstream of the Luilu discharge dam (LUI1) and the Lualaba River both downstream and upstream of the confluence with the Luilu River, LUA 1 and LUA2 respectively.

These included:

Stressor Indicators

- *In situ* water quality

Habitat Indicators

- General Habitat Assessment
- Invertebrate Habitat Assessment System (IHAS, *version 2*)

Response Indicators

- Aquatic Macroinvertebrates (quantitative sampling, EPA 1989)

Of interest here are the habitat assessment and macroinvertebrate surveys. Habitat Assessment can be defined as the evaluation of the structure of the surrounding physical habitat that influences the quality of the water resource and the condition of the resident aquatic community (Barbour ., 1996). The Invertebrate Habitat Assessment System (EPA, 1989) was applied at each of the selected sampling sites in order to assess the suitability of biotopes present. The IHAS was developed for use with rapid biological assessment protocols in the United States (EPA, 1989), and expresses the suitability of biotopes as a percentage, where 100% represents “ideal” habitat availability.

Benthic macroinvertebrates were collected from the most dominant substrate type (preferably cobble with 64 – 256 mm size) at each of the sampling sites, using a 300 mm square net with a pore size of

1000 microns. In cases where the cobble substrate represented less than 30% of the sampling reach in the reference site, alternate habitat(s) had to be sampled. A composite sample was taken from three individual sampling spots in the flowing biotopes, representing different velocities, ending up with a total sample area of 0.45 m^2 per site. The total abundance for a sampled area of $1m^2$ was calculated by multiplying the individuals with 2.22. Identification of the organisms was made to family level, in order to assess the macroinvertebrate diversity and abundance per m^2 at each selected site. A map showing the 11 sample sites is provided in Figure 5-40 below. Sites were selected to characterise the impacts of past and existing mining and other anthropogenic activities on aquatic environments which could be affected by the KMT project.

State of the aquatic environment

Habitat Assessment

The Habitat Assessment scores for the different study sites are shown in Table 5-45 below. No significant difference in the Habitat Assessment Scores between the two flow seasons was observed. Poor aquatic macroinvertebrate habitat availability (low habitat assessment scores) was found at the two sites (M2 and M3) within the Musonoi tailings dam area. The IHAS at the sites further upstream (M4 to M8) recorded higher habitat scores, which were similar to each other, ranging from 43 % at site M5 to 51% at site M8. IHAS values obtained at the Kwanamwamwa River (56 -61%) as well as at the discharge D1 (56%) indicated medium habitat availability. The artificial seepage stream emanating from the dam (site M1) is the only study site where good habitat conditions (habitat assessment score of 68%) was found.

Table 5-45: Invertebrate Habitat Assessment System scores recorded during the October field survey (25.10. – 29.10.2004) and the February field survey (01.02. - 03.02.2005) at selected sites in the study area.

Study site	IHAS (%)	
	Oct 2004	Feb 2005
M 1	72	72
M 2	29	20
M 3	18	17
M 4	44	41
M 5	43	38
D 1	56	56
M 6	47	44
M 7	46	47
M 8	51	51
S 1	60	59
S 2	56	59
Lake Nzilo	**	52

** Not sampled

Aquatic macroinvertebrates

To assess the level of impairment resulting from potential impact zones within the Musonoi River, the biotic integrity (based on taxa richness as well as the EPT metric – richness and abundance of Ephemeroptera, Plecoptera, and Trichoptera) were compared amongst different sites (EPA, 1989). The EPA macroinvertebrate approach to assessing the level of impairment at a site is based on characterizing the presence of EPT (Ephemeropteran, Trichopteran and Plecopteran) taxa richness where a high EPT richness would indicate no or low impairment levels and a low EPT richness indicating high impairment levels. Table 5-46 shows the taxa richness in combination with the total macroinvertebrate abundance and the EPT taxa richness.

Table 5-46: Macroinvertebrate data (Total abundance, taxa richness and EPT taxa richness) recorded during the two surveys at different selected sites.

site	Total Abundance/m2		Taxa richness		EPT taxa richness	
	Oct	Feb	Oct	Feb	Oct	Feb
M1	111	58	15	11	6	3
M2	0	7	0	2	0	0
M3	0	0	0	0	0	0
M4	4	0	1	0	1	0
M5	0	0	0	0	0	0
M6	16	18	4	4	2	3
M7	49	60	8	8	4	1 *
M8	64	69	8	7	3	2
S1	13	115	4	9	1	3
S2	311	285	12	11	3	4
D1	0	0	0	0	0	0
Lake Nzilo	**	11	**	2	**	0

* Sampled Habitat was less suitable for EPT taxa

** Not sampled

Intermediate low-high flow period (October 2004 survey)

A total of 33 macroinvertebrate taxa were sampled in the study area (0-15 taxa per site). During this survey no Plecopteran taxa were sampled from any of the sites in the study area indicating that all sites have been impacted upon through anthropogenic activities. Site M1, (in the Musonoi River) maintained by seepage water from Kasobantu Dam, showed the highest macroinvertebrate abundance, richness and number of EPT taxa. This can partly be explained by the high habitat score (68%) measured for the site, but may also be linked to the level of protection resulting from the setting of the site immediately downstream from the dam. Site M1 was followed by site M8 (reference site) and M7. The two sites within the tailings dam area (site M2 to M3) showed a very low abundance of macroinvertebrates, which can generally be expected given the low habitat score (29% and 18%). Sites M4 and M5 showed much lower abundances and taxa richness than sites M6 and M7, even though the habitat scores were almost the same. This difference could be linked to a difference in the water quality of the two sites. The discharge out of the KOV pit (site D1) showed no evidence of macroinvertebrates even though the habitat score was similar to that at sites S2 and M8. This stream is therefore too non-perennial and unstable to allow for the establishment of a macroinvertebrate community, or the level of water quality impairment is higher than at sites S2 and M8.

Site S1 within the Kwanamwamwa River showed low abundances and taxa richness. This site has more lenthic than lotic characteristics, lenthic character being generally less suitable for certain macroinvertebrates. Site S2, further upstream in the Kwanamwamwa River, showed a high macroinvertebrate abundance, as well as a high number of taxa. The EPT taxa richness was however lower than at site M1 or M8, which suggests less tolerant taxa are prevalent at this site.

Site M1 represents the best biotic integrity measured in the study area, with higher taxa than at sites D1 (KOV pit discharge), M5 (downstream the discharge) indicating the efficiency of the Kasobantu dam in improving water quality downstream from the wall in the Musonoi River.

As shown in Figure 5-41 above the EPT taxa richness is correlated to the Habitat Score (R^2= 0.6985) as well as to the TDS (R^2=0.6216). No correlation was recorded between EPT taxa richness and pH or dissolved oxygen. This indicates that both habitat availability and TDS levels (as one parameter for water quality) contributes to the EPT taxa occurrence at the different sites.

Intermediate high-low flow period (February 2005)

A total of 28 macroinvertebrate taxa were sampled in the study area (0-11 taxa per site). Again no Plecopteran taxa were sampled from any of the sites during this survey either. The only sites showing significant differences to the October survey in total abundance and EPT taxa were site M1, M7 and S1. Site M1 showed a decrease in macroinvertebrate abundance from 111 individuals/ m² during the October survey to 58 individuals/ m² during the February, as well as a decrease in EPT taxa from 6 to 3 EPT taxa. The decrease could be explained by possible mobilization of contaminants in the tailings dam during the rainy season, although the TDS, as a general water quality indicator for pollutants, did not increase from the previous survey.

Due to the high rainfall between the two surveys, the habitat sampled at site M7 during the October survey was flooded and not accessible during the February survey. The habitat sampled consisted mainly of emergent vegetation with lower percentage of cobbles, which is less suitable for EPT taxa. Site M7 showed an increase in macroinvertebrate abundance from 49 individuals/ m² during the October survey to 60 individuals/ m², but a decrease in EPT taxa from 4 to 1 EPT taxa. This decrease can possibly be ascribed to the flood conditions experienced during the February survey.

Site S1 also showed an increase in macroinvertebrate abundance from 13 individuals/ m² during the October survey to 115 individuals/ m², as well as an increase in EPT taxa from 1 to 3 EPT taxa. This increase can probably be ascribed to natural seasonal fluctuations.

During the February survey, a site in the canal discharge point into Nzilo Lake was sampled as an additional site. This site has deposits of tailings derived from the Kolwezi mines and sedimentation from agricultural surroundings. Only 11 individuals and no EPT taxa were sampled at this site.

As depicted in Figure 5-42 above the correlation between EPT taxa richness and Habitat Score remained almost the same with R^2= 0.6004, whereas the TDS as a general driver for EPT taxa richness was increasing in its importance (R^2=0.8332). No correlation was recorded between EPT taxa richness and pH or dissolved oxygen.

Aquatic habitat diversity and macroinvertebrate diversity in the project area is clearly correlated with the impacts of past mining activities. In general in the Concession Area there is little aquatic habitat of good quality, even where riparian habitat is in a reasonable state, such as the Kwanamwamwa stream.

Luilu River Survey – November 2005

During this survey, the most sensitive taxa (Plecopteran) was only found in the Musonoi River at site MUS1, thus indicating that all the remaining sites have been impacted upon through anthropogenic activities.

Site MUS1, located on the Musonoi River downstream of the Kasobantu Dam, obtained the highest abundance of aquatic macroinvertebrates per square metre (78 individuals/m^2) (Table 3). Additionally, site MUS1 was observed to maintain the highest EPT richness in the study area (6 EPT taxa of a total of 15 taxa sampled) (Table 3). Site LUA2, located on the Lualaba River upstream of the confluence with the Luilu River, was observed to be the only other site within the study area supporting EPT taxa (2 EPT taxa of a total of 6 taxa sampled) (Table 3). No other sites surveyed during November 2005 were observed to support EPT taxa, thereby suggesting the severe nature of anthropogenic insults at the mentioned sites (Table 3). The low number of aquatic macroinvertebrate individuals and the presence of only one taxa at site LUI1 may further be the result of the low pH values and high suspended solids observed for the Luilu River.

Table 5.47 shows the macroinvertebrate data for the November 2005 survey of the Luilu River and below the Kasobantu Dam to the junction with the Lualaba River to determine the impact of the highly degraded Luilu River on the aquatic ecosystem of the Lualaba.

Table 5-47 Macroinvertebrate data (Total abundance, taxa richness and EPT taxa richness) recorded during the November 2005 Luilu River survey

Site	Total Abundance (individuals/m^2)	Taxa richness	EPT taxa richness
KD1	20	2	0
MUS1	78	15	6
LUI1	2	1	0
LUA1	0	0	0
LUA2	29	6	2

5.15. Terrestrial biodiversity

The fauna and flora studies were undertaken by Professor Francois Malaisse (Gembloux Agricultural University, Belgium) together with his local field assistant Emile Kibuye Kisimba. Prof. Malaisse is internationally recognised as an expert on *metallophytes* (plants adapted to grow on soils rich in heavy metals) and he has undertaken extensive research in the Katangan province and in the DRC in general over the past 30 years (over 300 papers published on flora of Katanga, DRC and Tropical Africa). Mr. Kisimba has assisted him on a number of these field trips. Two site visits were undertaken to cover seasonal aspects of the site: two weeks during the dry season (August 2004) and a further five days during the wet season (January 2005). The entire Concession Area was superficially surveyed and thereafter the field work focussed on areas considered important in terms of their biodiversity value or sensitivity to the project activities. The fauna and flora occurring in the Concession Area are described separately in the sections below.

Fauna

Regional Faunal Diversity

The expected faunal diversity for Upper Katanga for each of the taxonomic groups is briefly discussed under the subheadings below. Five field interviews were undertaken with people in the local language with inhabitants regarding the presence and absence of several groups of animals (mammals, reptiles, fishes, birds, caterpillars etc.) and the vernacular names noted. Opportunistic animal field observations (direct observations, droppings, nests, burrows, prints, trappings etc.) were made when possible. Local experts were then utilised to gather additional seasonal data over the three months following the dry season site visit.

Fauna occurring in the KMT Concession Area and surroundings

Faunal diversity in the Concession Area is discussed below under separate subheadings for mammals (including rodents), fishes, birds, molluscs and invertebrates. The general degraded nature of natural habitats in the Concession Area and in areas immediately surrounding it, through which linear infrastructure will pass (railway, roads, effluent pipeline), has resulted in a depauperate faunal diversity. This is particularly so for fishes and edible game and the situation is not expected to improve at any time in the foreseeable future. Slash and burn agriculture and local hunting practices have largely depleted the fauna which may have occurred in this area prior to the commencement of mining.

Mammals

Based on fieldwork undertaken in areas of intact miombo woodland in Upper Katangan regions mammal diversity would be expected to be relatively high: approximately 220 mammal species including 38 edible game species and edible rodent species. Mammal diversity in the Concession Area is far lower than this with only 11 mammal species actually recorded as present on site although 32 species are expected to have formerly occurred in this area based on interviews (Table 5-48).

Reptiles

Ten reptile species have been recorded as being eaten in the Upper Katangan regions (as shown in Table 5-49), by contrast only four species were recorded as being present in the Concession. Most of the information dealing with reptiles in the Zambezian wet miombo area is old. No recent studies exist.

For Katanga and Northern Zambia information on reptiles has to be found in De Witte (1941, 1962), Laurent (1956 a-b), Broadley (1971).

As far as the KMT concession in concerned the most comprehensive work is the study carried out by Bourgeois (1964) on a miombo environment in the vicinity of Lubumbashi. She listed some 28 species. Of these *Agama atricollis*, two Chamaeleo (*C. dilepis and C. quilensis*), as well as two *Typhlops* are still present in the area.

Table 5-48: Mammal and rodent species recorded for the KMT concession area

Species	20 km around Kolwezi (presently)	In KMT concession area (formerly)	In KMT concession area (presently)
MAMMALS			
Aepyceros melampus	X	X	?
Adenota vardoni	RR		
Aonyx capensis	X	X	?
Canis masomelas	X	X	X
Cercopithecus mitis	X	X	?
Cercopithecus pygerythrus	X	X	?
Civettictis civetta	X	X	?
Galago crassicaudatus	X	X	?
Gamago senegalensis	X	X	X
Genetta genetta	X	X	X
Mellivora capensis	X	X	?
Mungos mungo	X	X	X
Orycteropus afer	X	?	?
Papio cynocephalus	X	X	?
Phacocherus aethiopicus	?	X	?
Phylotomba coeruleus	RR	RR	?
Potamochoerus porcus	?	X	?
Redunca arundinum	X	X	?
Sylvicapra grimmia	X	X	X
Tragelaphus scriptus	RR	?	?
RODENTS			
Aethomys kaiseri (Noack)	X	X	X
Cricetomys gambianus Waterhouse	X	X	?
Cryptomys hottentotus (Lesson)	X	X	X
Dasymys incomtus (Sundevall)	X	X	?
Graphiurus murinus (Desmarest)	X	X	?
Hystrix africae australis Peters	?	X	-
Lepus saxatilis L.	X	X	X
Lophuromys flavopunctatus Thomas	X	X	?
Manis tricuspis Rafinesque	?	X	?
Mastomys natalensis (A. Smith)	X	X	X
Paraxerus boehmii (Reichenow)	X	X	?
Paraxerus cepapi (A. Smith)	X	X	?
Saccostomus campestris Peters	X	X	X
Tatera leucogaster (Peters)	X	X	X
Thamnomys dolichurus (Smuts)	X	X	?
Thryonomys swinderianus (Temminck)	X	X	?
X = species recorded in the respective area ? = supposed to occur in the area vy further confirmation is required RR = very rare in the area concerned			

The gallery forests contain some diversity regarding snakes, this was confirmed by the site visit in August 2004.

Table 5-49: Diversity of wild edible reptiles in KMT Concession Area (data obtained from interviews on site)

Families	Species	English names	Local names	Remarks
TESTUDINES				
Testudinidae	Kinixys belliana subsp. belliana	Lowveld Hinged tortoise	Fulwe	rare
	Kinixys belliana subsp. spekii	Savannah Hinged tortoise	Fulwe	rare
Pelomedusidae	Pelusios nanus	African dwarf mud turtle		rare
	Pelusios subniger	African mud turtle		rare
CROCODYLIA				
Crocodylidae	Crocodylus niloticus	Nile crocodile	Mamba	disappeared
SQUAMATA				
Sauria				
Vanaridae	Varanus niloticus	Water monitor	Samba	very rare
	Varanus exanthematicus	Rock monitor		disappeared
Serpentes				
Viperidae	Bitis gabonica gabonica	Gaboon viper	Moma	rare
	Bitis arietans arietans	Puff adder	Kikele	very rare
Boideae	Python sebae	African python	Lusato	very rare

Source: Malaisse 1997 (Se Nourrir en Foret Claire Africaine)

Fishes

Fish diversity is presently very poor in contrast with 87 species quoted as inhabiting the Upper-Lualaba river system (Malaisse 1997: 165-178). This is thought to be due to the former high levels of heavy metal contaminants in streams and rivers but probably also due to fishing with nets that have very narrow mesh. Only 3 species were directly observed with a further 4 species quoted as being present in the Concession (Table 5-50). However, observations of the diversity of fishes caught during fishing as well the fish species being sold in the Kolwezi market indicate that some diversity still exists in the Lualaba River but that the Upper Musonoi River is totally impoverished. It was noted that the size of fishes caught was generally small in response to heavy fishing pressure.

Table 5-50: List of fish in the KMT area and vernacular names

Species	P	O	Sanga	Ndembo
Barbus neefi		O		tusense
Barbus sp. 1	P		tuntule	
Clarias sp. 1	P		mutambala	
Ctenopoma multispinis	P		nkomo	
Synodontis sp. 1	P		kikalankonke	
Tilapia melanocera		O	kampome	kikele
Tilapia rendalli		O		
O = direct observation P = presence quoted during interviews				

Birds

The bird diversity of Katanga province is estimated to comprise 676 different species (Malaisse 1997). Of these, at least 101 species are observed in the Katangan miombo open forests (Malaisse 1983).

Table 5-51 lists the diversity noted in the KMT concession and, where possible, suggests the local names. Only 59 species of birds were directly observed on site with a further 25 noted as being present from interviews with local people. Some of the species were both observed and quoted during interviews so a total of 76 species are recorded as present in the Concession Area today. This is considerably lower than what would be expected for an intact miombo woodland area and underlines the level of ecosystem degradation, notably miombo destruction, in the area concerned.

However, bird diversity is considerably higher than that of mammals and fishes. This is partially explained by the diversity of habitats and the species associated with these habitats: 24 water bird species are associated with aquatic and semi-aquatic sites; 26 grassland species are associated with open grasslands vegetation units and a further 26 woodland species associated with the remaining miombo woodlands. Only 3 forest species were recorded. Bird diversity associated with woodland and forest vegetation types is largely depleted. Information on bird breeding and gestation periods has not been included here.

Table 5-51:List of birds in the KMT area and vernacular names in different dialects

Species	P	O	E	Habitat	Distribution	Local names		
						sanga	ndembo	others
Amaurornis flavirostra		O	(E)	ma	afrotrop			
Anas hottentota	P		E	wa	ea-zamb		mayembe	mayembe(2)
Anas undulata		O	E	wa	zamb			
Anhinga rufa	P			wa	afrotrop	kankele		
Ardea melanocephala	P	O		gr	afrotrop			katovu(1)
Ardeola ralloides		O		wa	afrotrop			
Bubo africanus	P	O		mi	zamb-S		ikungu	fwifwi(3)
Bulbucus ibis	P	O	(E)	gr, ca	afrotrop			tshambamba(1)
Butorides striata		O		wa	afrotrop			
Calidris ferruginea	P			wa	afrotrop			katantamatuwa(3)
Campethera abingoni		O		mi	zamb			
Caprimulgus fossii	P			gr	co-zamb	lubwata		tshambamba(2)
Centropus cupreicaudus		O	(E)	ma	end			
Centropus superciliosus	P	O	(e)	ma	end	mukuku		
Ceryle rudis		O		wa	afrotrop			
Chalcomitra amethistina	P	O		mi	zamb	sonsa		
Charadrus pecuarius		O		gr	su-zamb			
Circus macrourus	P			gr	su-zamb		mbulu	
Colius striatus		O		rud	ea-zamb			
Coriacas caudatus		O		gr	ea-zamb			
Coriacas spatulatus		O		mi	zamb			
Corvus albus		O		rud	arotrop			
Coturnix adansonii		O	E	gr	su-zamb			
Coturnix delegorguei	P		E	gr	ea-zamb		kavumbi	fwifwi(3)

Species	P	O	E	Habitat	Distribution	Local names		
						sanga	ndembo	others
Cyanomitra cyanolaema		O		fo	co			
Cypsiurus parvus		O		rud	afrotrop			
Dendropicos griseocephalus	P			fo	end			mubangwapopo(3)
Dendrocygna viduata		O	E	wa	afrotrop			
Dicrurus adsimilis		O		mi	su-zamb			
Egretta ardesiaca	P		(E)	wa	ea-zamb		kananga mpemba	myange(1)
Ephippiorhynchus senegalensis	P			wa	su-zamb	msekwe		
Euplectes ardens		O		gr, rud	su-zamb			
Euplectes hordeaceus		O	(E)	ma	su-zamb			
Gallinago media		O	(E)	ma	su-zamb			
Gallinula chloropus		O	E	wa	su-zamb			
Hirundo dimidiata	P	O		gr	zamb-S		kambimbi	tshakubatwa(2)
Hirundo rufigula		O		wa	end			
O = direct observation P = presence quoted during interviews ? =supposed to exist, need confirmation								
Indicator indicator	P			mi	su-zamb	mayimba		
Kaupifalco monogrammicus		O		mi	afrotrop			
Lamprotornis chalybeus		O		gr, mi	su-zamb			
Lagonosticta senegala		O		mi, wa	su-zamb			
Lanius collaris		O		mi, gr	su-zamb-S			
Macrodipteryx vexillarius		O		mi	afrotrop			
Mandingoa nitidula		O		mi	co-zamb			
Merops pusillus		O		gr, mi	su-zamb			
Mirafra rufocinnamomea		O		mi, gr	su-zamb			
Motacilla aguimp	P	O		wa	afrotrop	katomba matshipa		
Musophaga rossae	P	O		fo	ea-zamb		ndjuwang anga	
Nettapus auritus	P	O	E	wa	afrotrop			dikowa(1)
Numida meleagris	P		E	gr	su-zamb		kanga	
Oriolus larvatus	?		(E)	mi	su-zamb			
Passer griseus		O		rud	afrotrop	msonkw e		
Pelecanus rufescens	P			wa	su-zamb	kiswasw a		
Pernis apivorus		O		mi	afrotrop			
Ploceus ocularis	P		E	gr	afrotrop	nseba		
Poicephalus meyeri		O	(E)	mi, gr	ea-zamb			
Porphyrula alleni		O	E	wa/gr	afrotrop			

Species	P	O	E	Habitat	Distribution	Local names		
						sanga	ndembo	others
Prinia subflava		O		mi	su-zamb			
Pternistis afer		O	E	gr	zamb			
Pycnonotus tricolor		O		rud	afrotrop			
Rhinoptilus chalcopterus		O	(E)	mi	su-zamb			
Serinus mozambicus		O	(E)	mi, gr	su-zamb			
Scopus umbretta	P			wa	afrotrop	kafielele		
Spermestes bicolor		O		gr, rud	co			
Streptopelia capicola		O	E	mi, gr	ea-zamb			
Streptopelia semitorquata		O	E	mi	afrotrop			
Streptopelia senegalensis		O	E	mi, gr	su-zamb			
Tachybaptus ruficollis	P	O	E	wa	afrotrop	kanko		
Terpsiphone viridis	?			fo	afrotrop			
Treron calvus		O	E	mi, gr	afrotrop			
Tringa stagnatilis		O	(E)	wa	afrotrop			
O = direct observation P = presence quoted during interviews ? =supposed to exist, need confirmation								
Tyto alba		O		mi	su-zamb			
Upupa africana		O	(E)	mi, gr	zamb-S			
Uraeginthus bengalus		O		rud	su-zamb			
Vanellus coronatus	?			gr	ea-zamb-S			
Vidua macroura	P	O		gr	afrotrop	sempia		
O = direct observation P = presence quoted during interviews ? =supposed to exist, need confirmation								

Names according to Sinclair, I & Ryan , P (2003). Birds of Africa south of the Sahara, Struik, Cape Town

***Observations**: O = direct observation P = presence quoted during interviews ? =supposed to exist, need confirmation*

***Ethnozoology** - E = birds frequently eaten (E) = rarely eaten*

***Habitat** : ca : associated with cattle, fo : evergreen forests, gr = grasslands, ma = marshes, mi = miombo, rud = ruderal, wa = lake and river, water,*

***Distribution** : afrotrop = tropical Africa, co = congolian, ea-zam : Eastern Africa and Zambezian, end : endemic to Katanga-northern Zambia, su-zamb = sudano-zambezian, zamb = Zambezian, zamb-S : Zambezian and Southern Africa,*

***Local names** : (1) Lwena, (2) Luvale, (3) Chibemba*

Bird Migration around Kolwezi

For Katanga and Northern Zambia information on bird migration routes can be obtained from Lippens & Wille (1976) "Les Oiseaux du Zaïre", as well as in the paper of Ulfstrand & Alerstam (1977).

It appears that some 61 true migrants birds may be found in Katanga during the rainy season (late December to early March). Migrations routes are along the Marungu and Kundelungu plateaus of Katanga, a long distance from the KMT concession thus restricting the migration of avifauna across the Concession Area.

Molluscs

Molluscs involved in bilharzia transmission were sought. No potential host molluscs were observed.

Insects

Only edible insects received some attention (Table 5-52). Local knowledge appears weak in comparison with other areas.

Table 5-52: List of edible insects in the KMT area and vernacular names in different dialects

Species	P	O	sanga	ndembo	others
Coleoptera					
Rhynchophorus phoenicis	P	O			
Hymenoptera					
Camponotus sp.	P		manienzi		
Isoptera					
Macrotermes falciger	P		inswa		
Lepidoptera					
Cirine forda	P		masase		
Elaphrodes lactea	P		tunkubiu		
Hadraphe ethiopica	P		swata		
Gonimbrasia richelmannii	P		misafwa	mapopa	mapopa(4)

O = direct observation P = presence quoted during interviews

Endangered and Threatened Fauna

a) Totally Protected Animals

The only mammals that are completely protected in the DRC that may have occurred in the Concession Area are:

- *Aepyceros melampus* (Impala of Katanga)
- *Orycteropus afer* (Mpendwa of Katanga)

However it is very likely that these two species are no longer in existence in the concession area due to hunting pressure.

b) Partially Protected Animals[8]

Four mammal species and three bird species that have formerly existed or may presently occur in the KMT Concession Area are categorised as partially protected by the DRC Regulations, these include:

Mammals

- *Cercopithecus* mitis (Samango Monkey)
- *Galago crassicaudatus* (Lesser bushbaby)
- *Potamochoerus porcus* (Bushpig)
- *Phacochoerus aethiopicus* (Warthog)

8 The fauna and flora expert was surprised that the latter two bird species were protected and especially since Buphagus africana is a species that is known to be eaten. Cuprimulgidae (nightjars) exist; but generally the birds of this family are not eaten in Katanga, and consequently not directly endangered.

Birds (Aves)

- Cuprimulgidae (all species in this family)
- *Bubulcus ibis* (cattle egret)
- *Buphagus africanus (Yellow-billed oxpecker)*

The deterioration in habitats in the Concession Area is not expected to have severe consequences for those birds linked to grasslands on sandy sites since this vegetation type may become more frequent.

Fauna in relation to the proposed effluent pipeline route and effluent disposal

Although no specific faunal surveys were conducted for the effluent pipeline route, all the indications are that the discussion above for other project affected areas would apply to the pipeline route to the Luilu River. The effluent will be discharged into the Luilu, by which means it will arrive eventually at the Lualaba some 20 km downstream. The lower catchment of the Luilu R runs through a hilly landscape covered in miombo woodland in relatively good condition and with sparse human settlement. The riverine zone is severely degraded, however, and animals are unlikely to utilize the river much. Evidence of trapping was seen in a remote part of the Luilu valley and no animals were seen during a long walk in this area, so even here fauna resources are poor. Samango monkeys (*Cercopithecus mitis*) probably occur in the gallery forest along the Lualaba River. Terrestrial fauna are not regarded as an issue in relation to the pipeline and effluent disposal.

With respect to the aquatic habitat of the Luilu, sampling has shown its integrity to be very poor. The Lualaba by contrast is in relatively good condition, although its biotic composition demonstrates the effects of flow manipulations upstream by the Nzilo power station.

Flora

Regional Floral Diversity

In biological terms the DRC is the most diverse country in Africa. At least 11,000 plant species, of which 29% are found only within the country, have so far been recorded. This is both the highest number of plants and the highest number of endemics recorded for any African country apart from South Africa. This is due partly to the size of the country, and the fact that about half of the country is covered by rainforest, and such forests are well known as centres of biological diversity. Other reasons include the development of the landscape in the last 30,000 years, when parts of the country represented refuges for plants and animals during the most recent ice ages, and the wide range of altitudes present in the country stretching from lowland rain forest to montane forest and Afro-alpine communities, which has resulted in a large number of different habitat types.

The Concession Area lies within a zone of miombo woodland. Miombo is a vernacular term adopted by ecologists to describe the woodland ecosystems dominated by trees of the genera *Brachystegia*, *Julbernardia* and *Isoberlinia* of the family Fabacae, sub family Caesalpiniodeae. Such woodlands extend over about 2.8 million km^2 of the southern sub humid tropical zone from Tanzania and DRC in the north, through Zambia, Malawi and eastern Angola to Zimbabwe and Mozambique in the south. Their distribution largely coincides with the flat to gently undulating African (early Tertiary) and post African I (Miocene) planation surfaces that form the Central African plateau. These woodlands constitute the largest more-or-less contiguous block of deciduous tropical woodlands and dry forests in the world.

Interspersed within the miombo woodlands are broad, grassy depressions known as *dambo's*. These seasonally waterlogged areas are not old river systems, but are formed from differential weathering and leaching by groundwater, and generally form important sites for cultivation. The boundaries between the areas are clearly defined by the vegetation, and the sharp transition between woodland and grassland reflects the point where the wet season water-table reaches the surface. The components of the landscape are related to the movement of water, soil and nutrients down slope, and the return of nutrients upslope through animal activity and atmospheric transport, fire and patterns of land use. A Miombo Network has been set up to study the important ecological and human interactions of the woodlands, which support the livelihoods of about 39 million people in seven Central African countries, including some of the lowest per capita income and highest per capita population growth rates in the world. A further estimated 15 million people living in towns and cities throughout the region (such as Lubumbashi and Likasi) also depend on food, fuel wood and charcoal produced in the miombo. Estimated woody biomass fuel consumption alone amounts to 48 Tg/yr, releasing almost 22 Tg/yr of carbon into the atmosphere. Other natural and anthropogenic processes such as wild land burning, clearance of land for agriculture and the cultivation of wetlands, also contribute trace gases and particulates to the atmosphere as well as altering the nature of the land cover and hydrological processes.

Copper-cobalt Flora

Another habitat type which once occurred in the Kolwezi area, as a result of the underlying geology, is part of the metallogenic Province of South Central Africa. In the province of Katanga, over 100 copper and cobalt deposits totalling some 20 km^2 are scattered across the Copper Arc, an area of about 20,000 km^2. These deposits support distinct vegetation consisting of both endemic and more widely distributed species. In 1983, 42 endemic species had been identified; by 1988 this had increased to a possible 53. A preliminary analysis of the copper-cobalt flora shows that 81% of the species occur in other vegetation types in 'Haut Katanga'.

Vegetation Communities in the KMT Concession Area and surroundings

The vegetation communities found in the KMT Concession Area are shown in Figure 5-43. Approximately 97% of the non-built-up area in the KMT Concession comprises a mosaic of agroecosystems including fields of cassava and corn, both cultivated and fallow and grasslands derived from tree savannas, shrub savannas, steppe-savannas and bracken. This 'vegetation type' is in a significantly degraded state, due to extensive slash and burn subsistence agricultural activities, charcoal-making and past large scale farming activities in some areas. The tree component of what would have been Miombo woodland has been largely lost, and the under storey has been severely disturbed by shifting cultivation. These areas are of little conservation value. Steppes and swards on heavy metal polluted deposits are commonly found around the existing Kingamyambo and Musonoi tailings deposits. The vegetation found in these areas may be useful for rehabilitation of the new tailings dam areas and this is discussed in further detail in the ESMP (Volume III).

Although the majority of the original vegetation has been destroyed or degraded a few remaining pockets of natural habitats[10] do still however exist within the Concession Area. These include two sections of riverine gallery forest. The Muninga forest is situated along the Muninga stream, a tributary of the Kanamwamwa River, at the base of the proposed tailings dam site (shown as vegetation type 3 in Figure 5-43 and sites 2 and 3 in green in Figure 5-43. The Muninga forest contains some important plant species such as *Gardenia imperialis*.

The forest also has cultural/spiritual value (refer to discussions under Archaeological and Cultural Heritage resources in Chapter 6 of the ESIA) and entry into the little forest is forbidden to all except "les délégations en provenance du Chef de Terre Kamimbi" and cutting of wood is formally forbidden in this forest.

The Tshilenge valley situated north-east of the Kasobantu dam wall also contains a section of intact riverine forest (shown as vegetation type 3 on Figure 5-43 and site 4 on Figure 5-44. The north-eastern quarry site, in the Basal Conglomerate ridge just north-east of the proposed tailings dam, bears a fairly intact stand of miombo woodland, due to its poor agricultural potential (steep slopes, rocky, shallow soils).

The cemetery forest comprises miombo woodland (Berlinio-Marquesion type - shown as vegetation type 2a on Figure 5-43 and site ii in yellow on Figure 5-44), although this forest is partially degraded due to the placement of grave sites here, these graves have simultaneously served to protect this section of forest since the trees have not been cut for wood and some of them are up to 20m tall. A section of intact Miombo woodland also exists on the north-facing slopes north-east of the Kasobantu dam wall (shown as vegetation type 2b on Figure 5-43).

The naturally formed seasonal wetlands (dambos) also comprise the remnant natural habitats in the Concession Area. However, these are discussed in more detail in section 0.

The above-mentioned sites represent the last surviving remnant of natural habitats in the Concession Area of original vegetation types. As such they have local conservation importance.

The areas proposed for project infrastructure generally do not contain any species of conservation importance. No *cuprophyte* flora was found to occur naturally in the Concession, however certain species were found on disturbed/transformed sites and these could be used for later rehabilitation of the new tailings dam.

Approximately 306 different plant species were recorded from the site following the dry and wet seasonal surveys. Lists of the plant species found in the natural vegetation communities on site are contained within the Fauna and Flora specialist study. Reference vouchers of dominant and important species have been deposited at the "Jardin Botanique National de Belgique" and duplicates will be deposited in the Lubumbashi and Kinshasa herbaria.

Corridors for project linear infrastructure extending westwards from the Concession – for the railway, roads and effluent pipeline to the Luilu River are in much the same degraded state as the Concession Area. No significant habitats or species have been observed in these project area extensions. Effluent from the pipeline will be discharged into the Luilu, down whose course it will travel to the Lualaba, some 20 km distant. The Luilu River's riparian zone throughout these reaches is severely degraded due to mining effluent discharges and dewatering practices, so that no significant flora resources are likely to be affected by disposal of the saline effluent from KMT. Only once the Lualaba R is reached is riparian habitat integrity restored, but this will not be affected by KMT effluent disposal.

Areas of important vegetation types

Areas considered to have significant biodiversity value are indicated in Figure 5-44. The riparian forest found along the Muninga stream and extending along the Kwanamwamwa River towards the Musonoi has certain sections that are recognised as having high biodiversity (vegetation type 3). The dambo 1 on the western side of the Musonoi has considerable biodiversity value (Figure 5-46).

Dambo 2 on the eastern side of the Musonoi also has an important function in terms of biodiversity and ecosystem services, however since no infrastructure is proposed for this area this site was covered in less detail than dambo 1.

Some of the swards found on heavy metal soils (shown as sites a-d) are considered to have value in terms of the species that could be used for rehabilitation of the new tailings dam. Seven different vegetation communities have been identified on the polluted soils in the Concession Area (sites i – vii) and these may have had considerable biodiversity value in the past, however anthropogenic activities have transformed these areas considerably.

Sensitive ecosystems

Sensitive ecosystems are shown on Figure 5-46. Wetlands (*dambos* in Swahili / *marrecages* in French) are defined as sensitive areas in Annexe XII Article 3 of the DRC Mining Regulations. Two naturally formed seasonal wetlands (*dambos*) exist in the Concession Area, *dambo* 1 is located in the vicinity of the plant and *dambo* 2 is situated west of the Musonoi 'Artificial wetlands' have also been created in the Concession Area such as where the Kakifuluwe and Kanamwamwa rivers are crossed by the old haul road, due to damming by the road embankment and the Musonoi tailings. All the wetlands in the Concession Area provide various ecosystem services, fishing sites and refuges for plant and animal biodiversity in a "sea" of transformed land. The dambos are important resources to communities for cropping, and the dambo near the plant site is intensively cultivated for maize and vegetables. The occurrence of various orchid species in some of the natural and artificial wetlands is an indication of their biodiversity value.

There are no lakes, zones subject to erosion or arid or semi-arid zones subject to desertification in the Concession Area.

The wetlands and sites of potable water of which KMT is aware are shown on Figure 5-46.

Protected plant species

None of the protected species listed in Article 6 of Annexe XIII in the DRC Mining Regulations occur in the KMT concession area. According to the World Conservation Monitoring Centre (WCMC) there are 80 threatened plants in DRC [9]. None of these species mentioned were recorded during the site visit. WCMC lists 1418 plant species as endemic to DRC. Two of the endemic species on this list do occur in the Concession: *Biophytum kassneri* and *Xerophyta demeesmaekerana*. One *Drosera* species is on the list but not *Drosera madagascarensis* which was found on one of the waterlogged areas in the Concession Area. *Crotalaria cobalticola* is on this list but this was found approximately 10 m outside the Concession boundary on the site of the former uranium stockpile.

According to the field surveys, the following plant species are considered to be of conservation significance for the DRC and specifically the Katangan province:

- *Brasenia schreberi*
- *Cyathea dregei*
- *Disa welwitschii subsp. occultans*

9 However, the list is based primarily on a publication pertaining to the Flore du Comgo Belge et du Ruanda-Urundi, mostly published before 1962 and supplemented with literature from Kew. It is suspected that this information has not been updtead much since the 1960's and it is probable that recently discovered rare plants have not been considered in this list.

- *Drosera madagascariensis*
- *Eulophia horsfallii*
- *Euphorbia sp;nov.*
- *Habenaria holubii*
- *Ottelia cylindrica*
- *Pandanus sp.*

The areas where these species were found have been indicated as areas of conservation importance on Figure 5-44.

Zones containing threatened plant species

The only threatened vegetation type listed in Article 7 that occurs in the Concession Area is *"la forêt dense sèche du Katanga"*.

The typical dry evergreen forest of Katanga no longer exists in the Concession although some small remnants of this vegetation type may still exist. Nevertheless, downstream of the Kasobantu dam, along the Musonoi river, some steep banks are covered by a vegetation which consist of a large number of the typical species of the Katanga dry evergreen forest (ten woody plants at least). This section of the river is considered to be a sacred grove. No human destruction of the area was observed.

Ethno ecology

Based on interviews, field observations and previous work conducted in the project vicinity a number of plants are used by local people. Wild plants such as orchids are eaten and sold at the Kolwezi market. Certain plant roots are used to concoct a local drink. Common edible fruits include *Anisophylla boehmii*, *Uapaca kirkii* and *Parinari curatellifolia*. The frequent plant uses were also noted: use of *Loudetia simplex* for thatched roofs of houses, of *Imperata cylindrica* for fences of latrines, orchids underground organs for cooking the “kikanda”, of *Potamogeton octandrus* and *Ceratophyllum demersum* to keep fishes fresh, of *Brachystegia boehmii* bark for ropes.

Species suitable for rehabilitation

Article 96 of Annexe IX of the Mining Regulations and good practice states that all sites that have experienced mining activities, including sterile deposits, require revegetation. Plants that currently grow on the existing tailings are considered to be suitable for revegetation purposes of the new tailings deposit. The species composition of the heavy metal (Cu, Co) tolerant plant communities on site were thus investigated in more detail. The occurrence of three main ecological groups was observed, namely

a.- Local cuprophytes

b.- Steppe savanna cuproresistant species

c.- Ruderal heavy-metal-tolerant species.

Seven different ecological sites were selected and the species composition of these areas studied (see):

1.- Temporary waterlogged Cu/Co deposits

2.- Cu/Co deposits mixed with “sterile” rocks

3.- Cu/Co deposit with ruderal conditions

4.- Permanent pond on Cu/Co deposits

5.- Cu/Co deposits with local fine layer of red laterite soils

6.- Thick Cu/Co deposits, dune aspect

7.- Heavy metal polluted alluvial sands

Plant species recorded in these areas are listed in Table 5-53.

Table 5-53: Plant species comprising the heavy metal tolerant plant communities

Types	1	2	3	4	5	6	7
Plant species							
Local cuprophytes							
Rendlia altera	X	X	X	X	X		
Bulbostylis cupricola	X	X	X			X	
Bulbostylis cinnamomea		X	X	XX	X	X	
Bulbostylis pseudoperennis	XX						
Lobelia erinus		X	X			X	
Buchnera sp. 1		X		X		X	
Ascolepis protea var. anthemidiflora	X			XX	X		
Eragrostis boehmii		X	X				
Crotalaria cobalticola	X			X		X	
Anisopappus hoffmanianus		X					
Equisetum ramossisimum							X
Steppe savanna cuproresistant species							
Monocymbium ceresiiforme					X		
Arthraxacon quartinianus		X					
Diheteropogon emarginatus						X	
Vernonia sp. 1		X					
Hypoestes sp. 1			X				
Ruderal cupro-tolerant species							
Bocconia frutescens			X				
Tithonia rotundifolia							
Pityrogramma calomelanos		X					
Cymbopogon densiflorus			X		X		
Imperata cylindrica							
Laggera alata						X	
Eragrostis chapelieri						X	
Haumaniastrum sp.			X		X	X	
Pteridium aquilinum subsp. centraliafricanum			X		X		
Crotalaria sp. 1					X		
Eragrostis chapelieri						X	
Merremia sp. 1		X					
Lantana camara			X				

X = presence, XX = dominant species, dense carpets, closed mats.

A rehabilitation programme involving the species listed in Table 5-53 could involve either conserving the existing plant communities *in situ* or cultivating/multiplying local *cuprophytic* populations in order to obtain a better knowledge of their requirements. The plant species shown in bold above would be the most suitable for cultivation purposes.

Invasive Plant Species

A list of invasive plant species occurring in the Concession Area is shown in Table 5-54. The growth form, abundance and location are also indictead in the Table. Four of these species are very common and are already problems in the old fields. *Tithonia diversifolia* needs to be controlled and manual clearing of the infested area is proposed.

Table 5-54: Problems plants occurring in the KMT concession

Species	English name	Biological type	Present abundance	Remark
Bocconia frutescens L.	Parrotweed	nanophanerophyte	common	Rocky disturbed sites (and heavy metal polluted)
Cleome monophylla	Single-leave cleome	annual	Very common	Invader of (old) field crops
Imperata cylindrica	Silver spike	geophyte	Very common	Invader of (old) field crops
Lantana camara	Common lantana	nanophanerophyte		Disturbed sites
Leersia hexandra	Wild ricegrass	geophyte	common	River banks
Pennisteum setaceum	Fountain grass	hemicryptopyte	common	Along roads
Populus x canescens	Grey polar	mesophanerophyte	rare	Wet sites, river banks, coppice vigorously
Pteridium aquilinum	Bracken	geophyte	Very common	Invader of old field crops
Rumex abyssinicus		geophyte	rare	Along roads, invader of disturbed sites
Setaria pallide-fusca	Red bristle grass	hemicryptophyte	common	Invader of old field crops
Smilax anceps		geophyte	common	Invader of old field crops
Tithonia diversifolia	Red sunflower	chamephyte	Very common	Mainly on termite mounds and disturbed sites

However, *Tithonia diversifolia* has been shown to have the ideal N:P:K ratio to make it useful as a green fertilizer. Trials will be conducted locally as part of the CDP (Annex D to Volume 3) to develop expertise in adding nutrients to the soil without the need for expensive inorganic fertilizers, and to reduce the need for slash and burn agriculture by extending the fertility of the soil.

Figure 5-1: Location of original and final KMT Concession boundaries

Figure 5-2: Regional geology of Kolwezi area

Figure 5-3: Simplified Stratigraphical Column

Figure 5-4: Structural map with overlay of geophysical anomaly

Figure 5-5 : Geological Map of the KMT Concession area

Figure 5-6: Geological cross section A-B through the KMT concession area

Figure 5-7: Soil mapping units in concession area

Figure 5-8: Land capability distribution in Concession Area

Figure 5-9: Land Use Map

Figure 5-10: Positions of rainfall stations

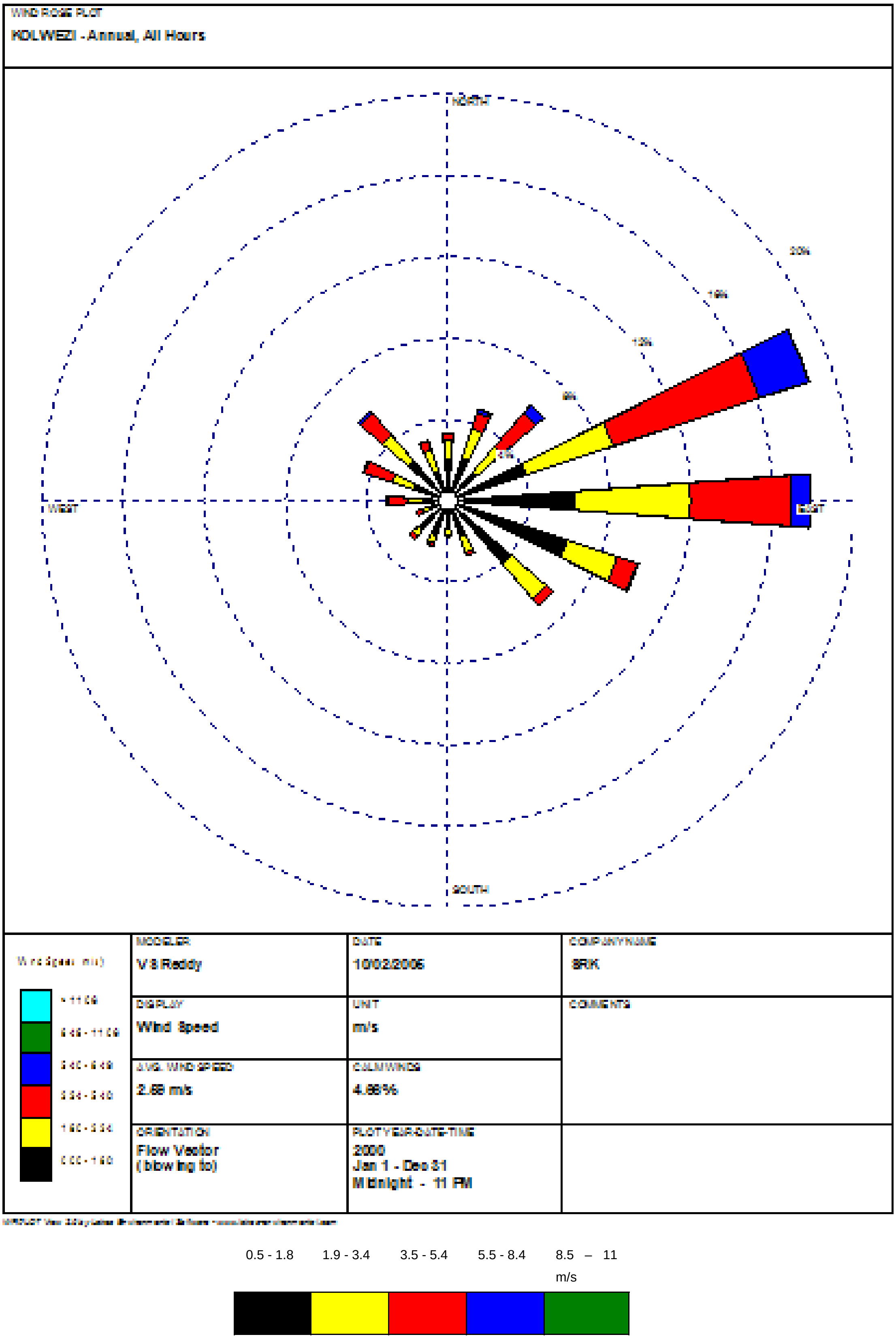


Figure 5-11: All hours wind rose - annual

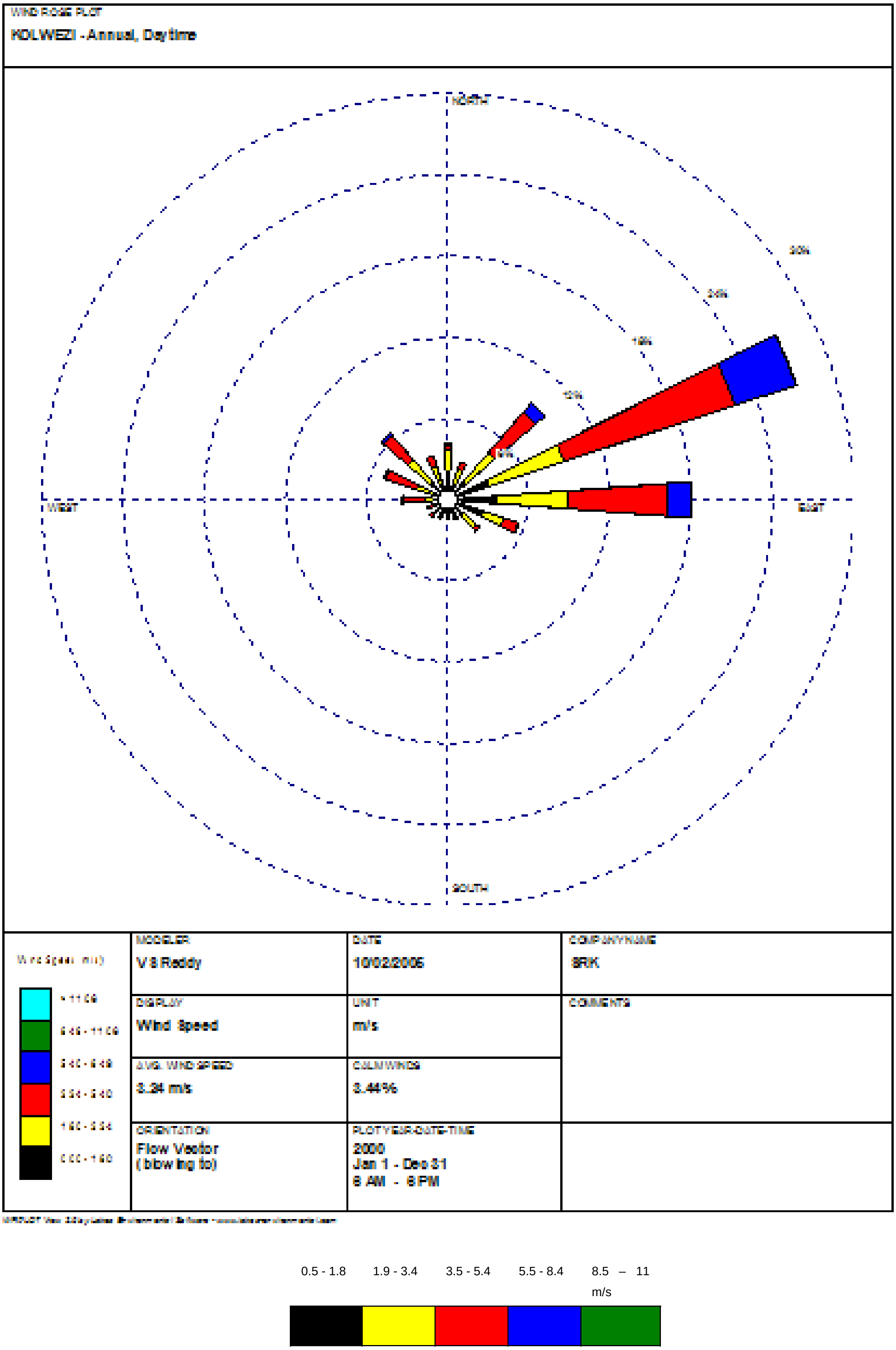


Figure 5-12: Day time wind rose - annual

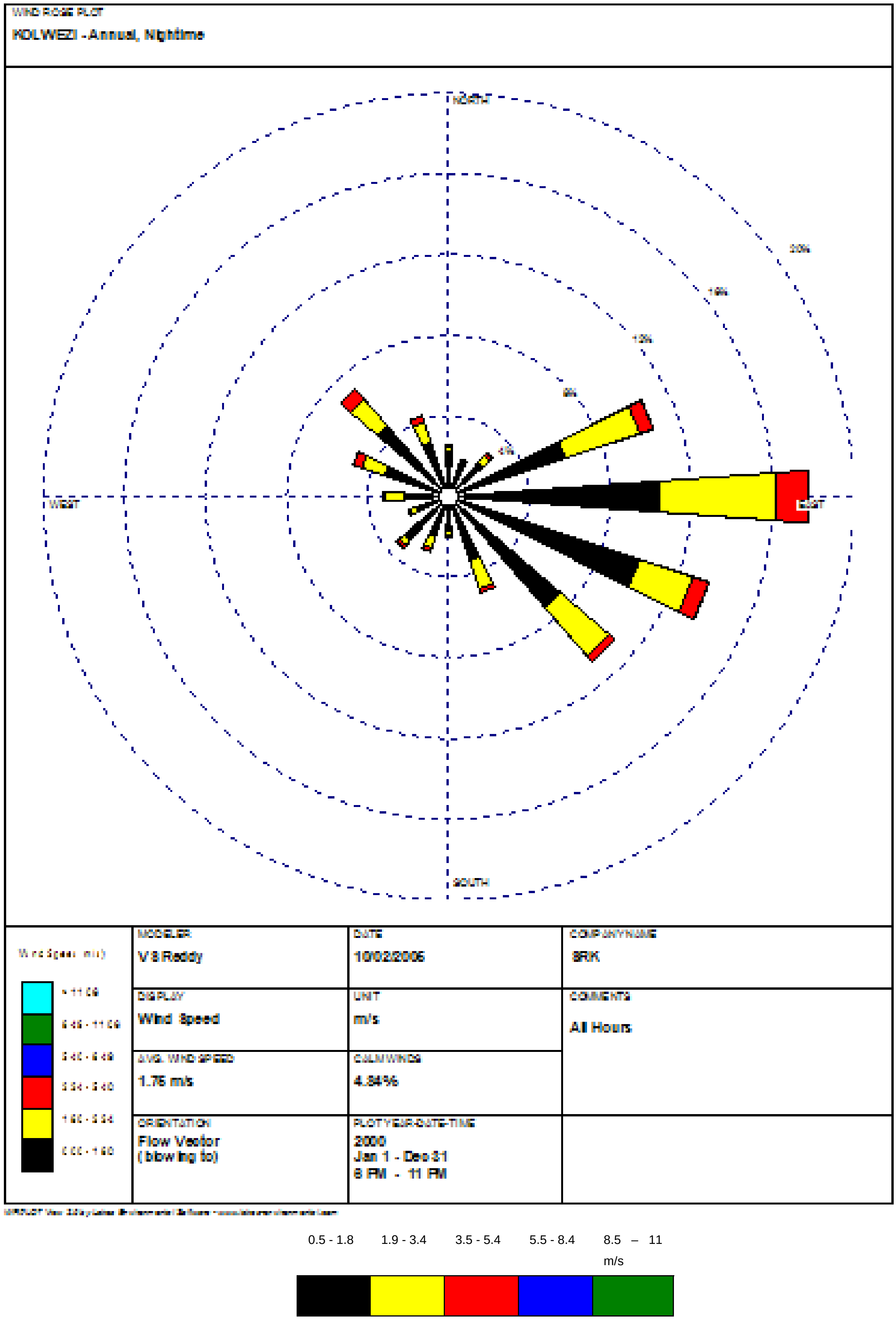


Figure 5-13: Night time wind rose - annual (6 to 11pm)

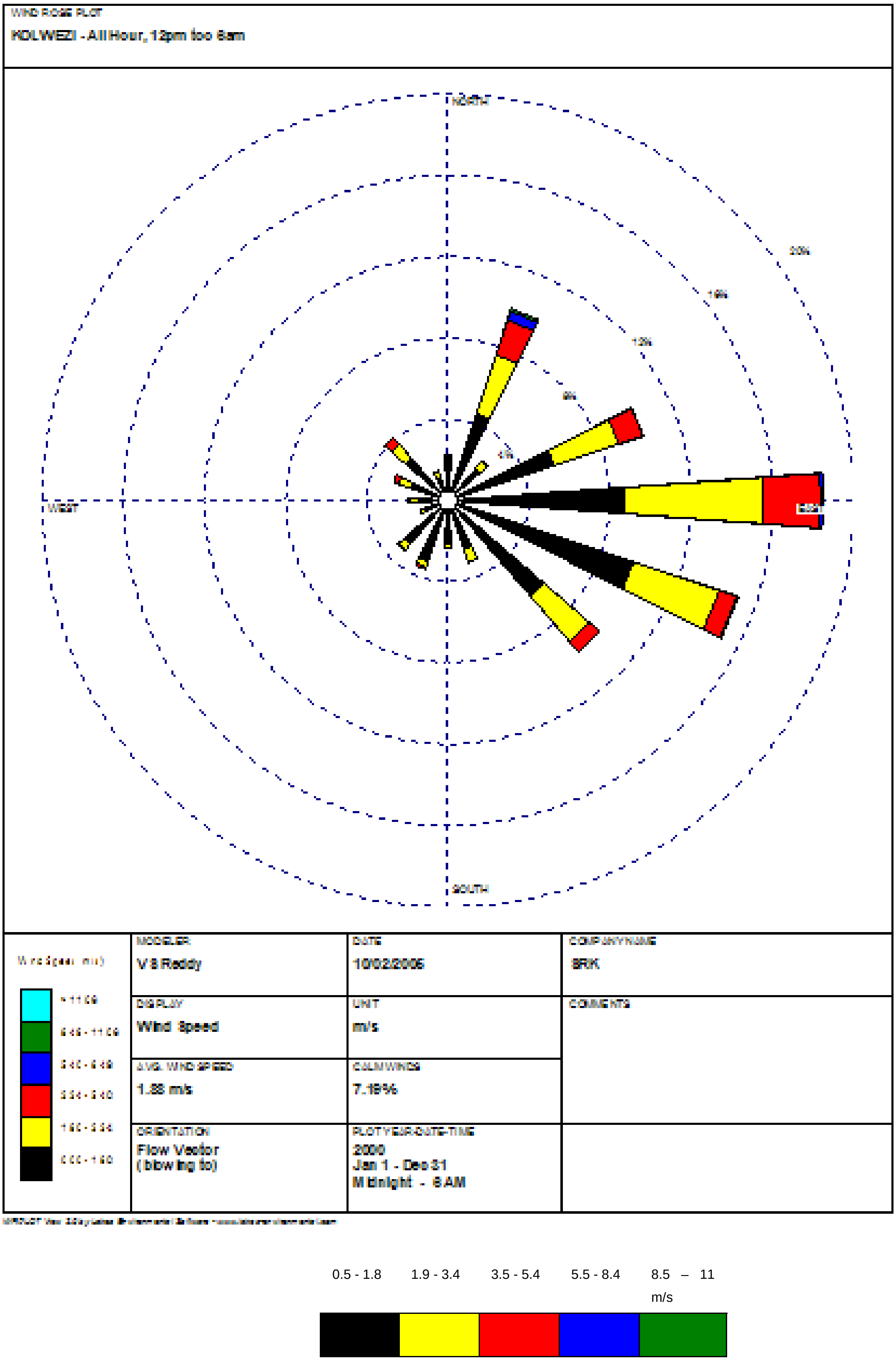


Figure 5-14: Night time wind rose - annual (midnight to 6 a.m.)

Figure 5-15: Dust fallout monitoring points

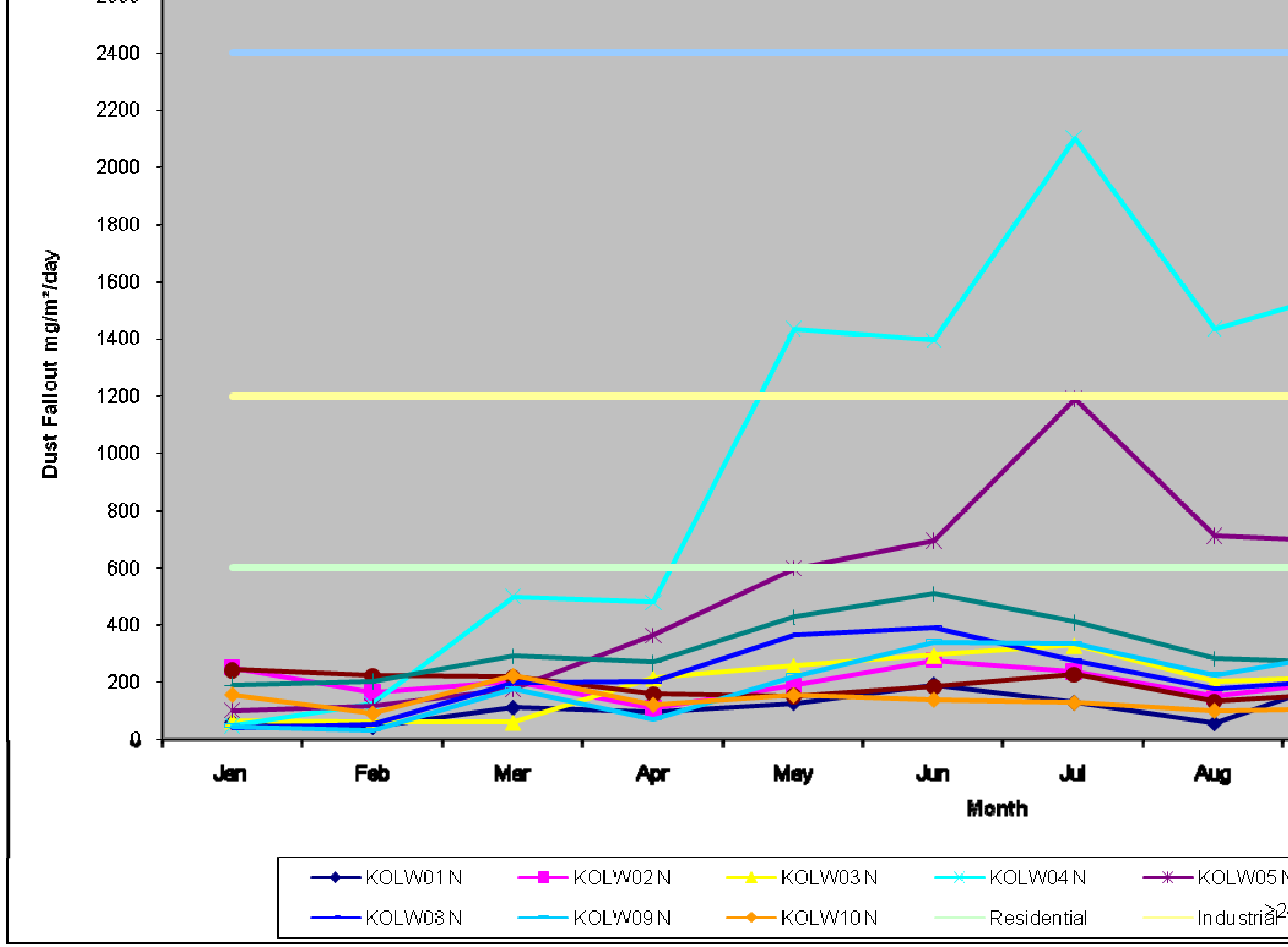


Figure 5-16: Average monthly dust fallout levels for the period March 2000 to April 2004.

Figure 5-17: Average Maximum 24 hr TSP concentrations

Figure 5-18: Average annual TSP concentrations

Figure 5-19: Average maximum 24 hr PM_{10} concentrations

Figure 5-20: Average annual PM_{10} concentrations

Figure 5-21: Position of the Musonoi River and its tributaries

Figure 5-22: 1:50 and 1:100 year floodlines of the Musonoi River

Figure 5-23 : Location of surface and groundwater monitoring points

Figure 5-24: Bar charts of selected water quality constituents

Figure 5-25: Time series plots of selected constituents

Figure 5-26: Surface Water Piper Plot

Figure 5-27 : Conceptual hydrogeological profile for a saprolite profile

Figure 5-28: Conceptual Hydrogeological model of the KMT Concession Area

Figure 5-29: Piezometric surface for Kolwezi region

Figure 5-30: Bar charts of selected water quality constituents

Figure 5-31: Trace heavy metals

Figure 5-32: Ground water piper plots

Figure 5-33: Measured flows discharging from the Kasobantu dam through the Nzilo Spillway

Figure 5-34: Water Balance for Kolwezi – Present Day Situation

Figure 5-35: Present Day Water Balance – Wet Conditions

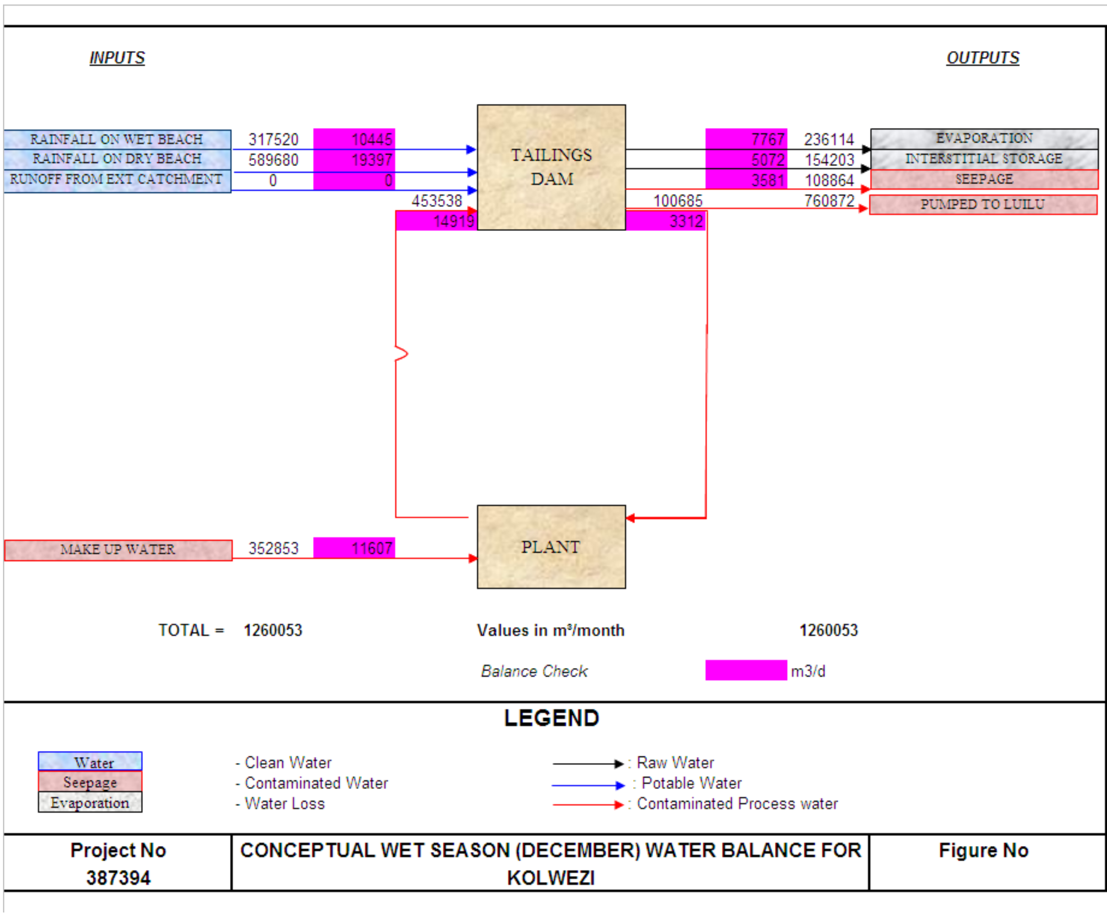
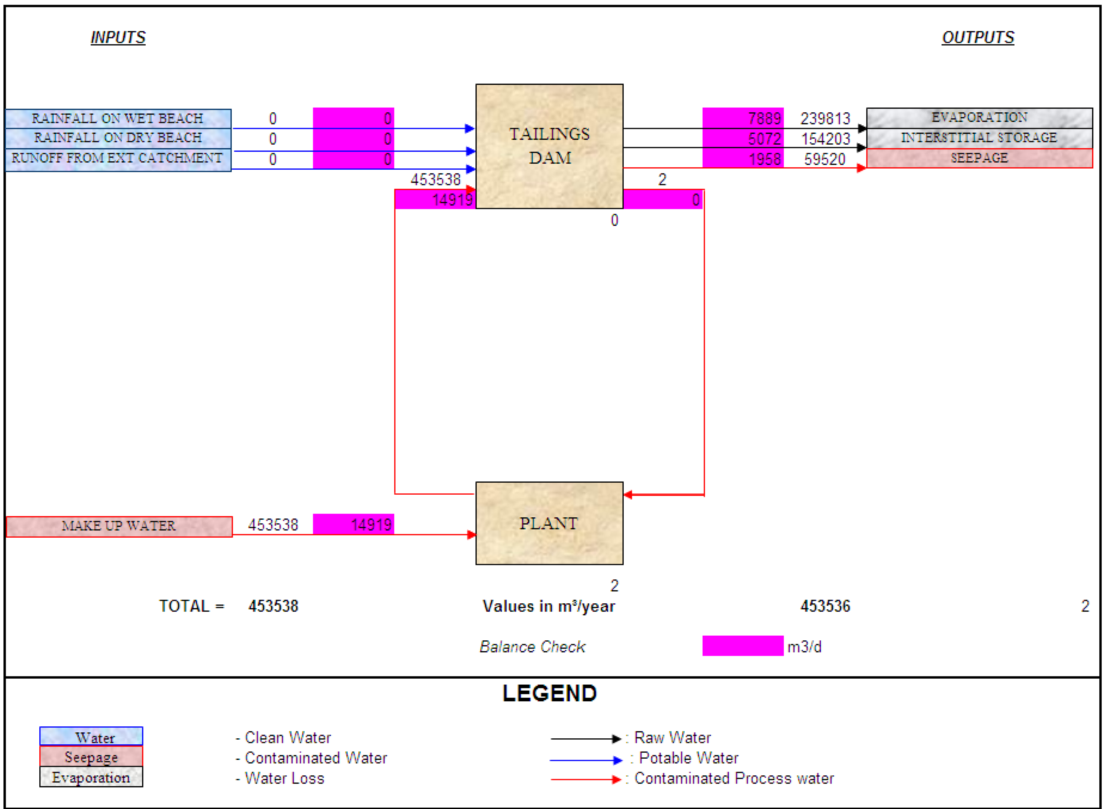


Figure 5-36: Present Day Water Balance – Dry Conditions



Project No 387394	CONCEPTUAL DRY SEASON (JULY) WATER BALANCE FOR KOLWEZI	Figure No

Figure 5-37: Noise measurement sites in relation to the proposed KMT infrastructure.

Figure 5-38: Contours of the present ambient noise levels during the day (07:00 to 19:00)

Figure 5-39: Contours of the present ambient noise levels during the night (19:00 to 07:00)

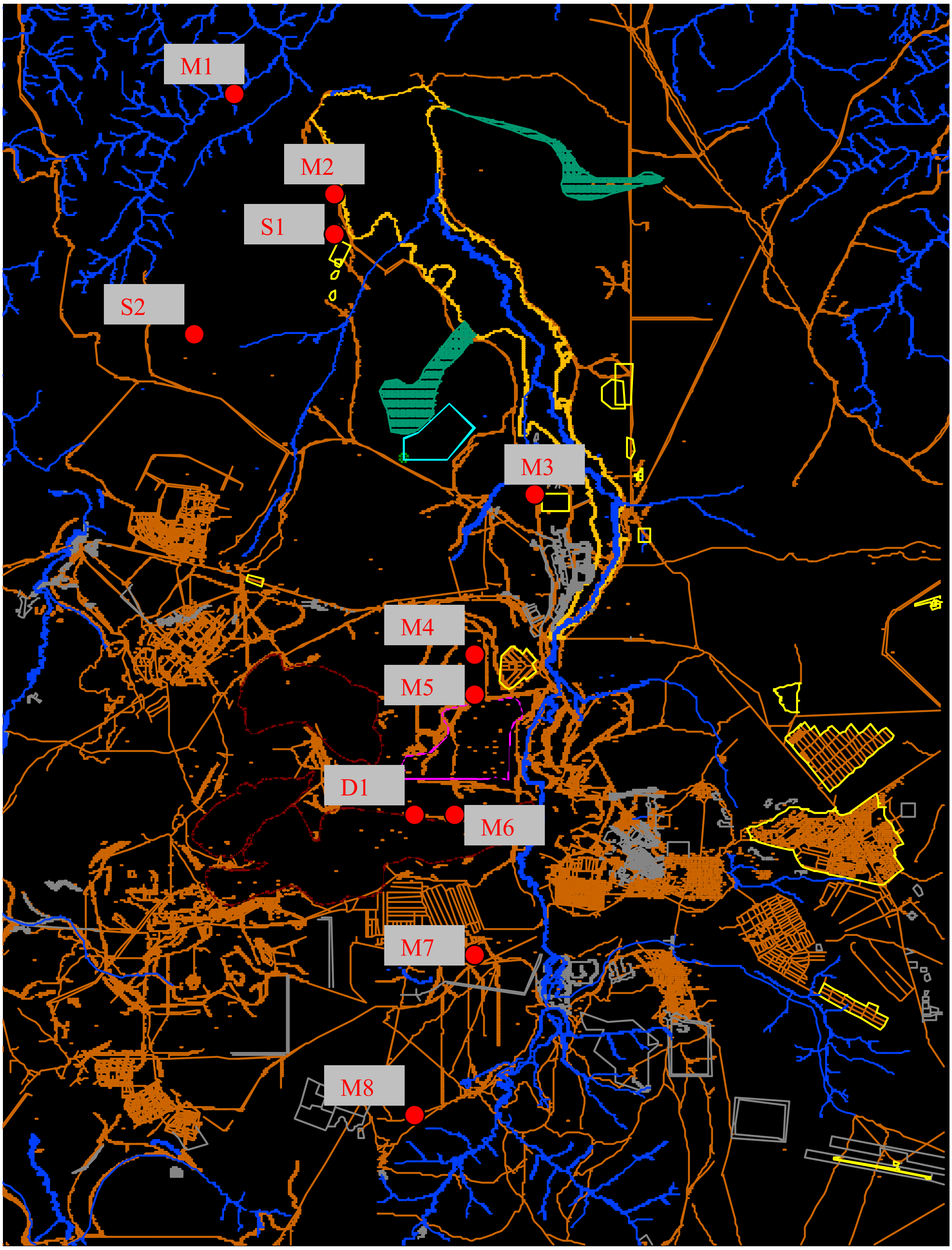


Figure 5-40: Map showing HA and macroinvertebrate sampling sites.

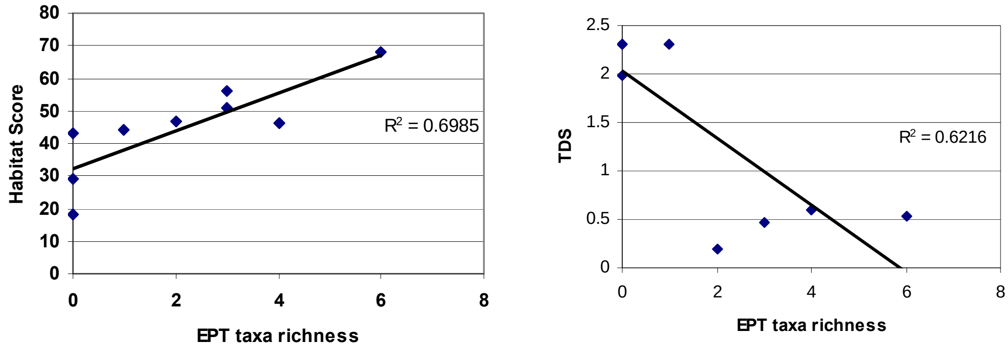


Figure 5-41: Correlation between EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa richness and a) Habitat Assessment Score and b) TDS values at the selected study sites during the October survey. (The following sites are not included into the correlation: Site S1, because it is a wetland and D1, because it is a discharge).

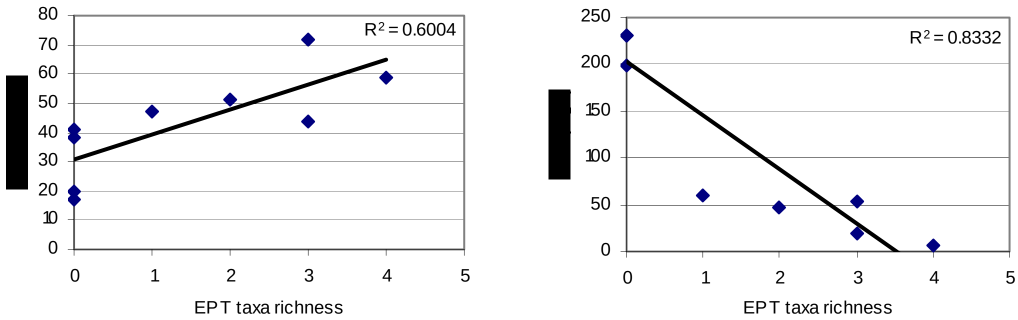


Figure 5-42: Correlation between EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa richness and a) Habitat Assessment Score and b) TDS values at the selected study sites during the February survey. (The following sites are not included into the correlation: Site S1, because it is a wetland and D1, because it is a discharge).

Figure 5-43: Vegetation map of the KMT Concession Area

Figure 5-44: Sites of biodiversity importance

Figure 5-45: Vegetation communities found on heavy metal polluted soils in the KMT Concession Area

Figure 5-46: Sensitive ecosystems in the KMT concession area