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ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN (ESMP)

APP: 005046

FOR THE PROPOSED MULTI-METAL RECYCLING (MMR) PROJECT AT SINOMINE TSUMEB SMELTER, TSUMEB, OSHIKOTO REGION

Sinomine Tsumeb Smelter (Pty) Ltd

14 February 2025

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DOCUMENT INFORMATION		
Title	Environmental and Social Management Plan (ESMP) for the proposed **Multi-Metal Recycling (MMR)** Project at Sinomine Tsumeb Smelter, Oshikoto Region	
ECC Application number	**APP- 005046**	
Listed Activities (EIA Regulations, GN: 30 of 2012)	**Activity 1. Energy Generation, Transmission and Storage Activities** 1.2 The construction of facilities for – (b) the transmission and supply of electricity **Activity 2. Waste Management, Treatment, Handling and Disposal** 2.1 The construction of facilities for waste sites, treatment of waste and disposal of waste **Activity 4: Forestry Activities** 4. The clearance of forest areas, deforestation, afforestation, timber harvesting or any other related activity that requires authorization in terms of Forest Act, No. 12 of 2001, or any other law **Activity 8: Water Resource Development** 8.1 The abstraction of groundwater or surface water for industrial or commercial purposes 8.2 The abstraction of groundwater at a volume exceeding the threshold authorized in terms of a law relating to water resources 8.6 Construction of industrial and domestic wastewater treatment plants and related pipeline systems. **Activity 9: Hazardous Substance Treatment, Handling and Storage** 9.1 The manufacturing, storage, handling or processing of hazardous substance defined in the Hazardous Substances Ordinance, 1974 **Activity 10. Infrastructure** 10.1 The construction of the contractor camp (temporary accommodation facility for about 150 workers close to the Smelter)	
Location	Sinomine Tsumeb Smelter, Smelter Road, Tsumeb	
Proponent	Sinomine Tsumeb Smelter (Pty) Ltd Client Representative – Mr. Abraham Kanime Office: 067 – 223 4127 E-mail: abraham.kanime@sinomine.na	
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1. INTRODUCTION

1.1. Background

The Tsumeb smelter is owned and operated by Sinomine Tsumeb Smelter (Pty) Ltd. The smelter is located 2 km outside the town of Tsumeb, Oshikoto Region, and approximately 430 km north of the capital city Windhoek, Namibia.

Sinomine Tsumeb Smelter is a subsidiary of SINOMINE Resource GroupCo – the world's largest producer and supplier of cesium and rubidium products, as well as the leading producer and supplier of battery-grade lithium fluoride in China.

The smelter was originally constructed in the early 1960's to process concentrates from the Tsumeb Copper Mine and other mines in the country. However, since the closure of the Tsumeb Copper Mine in 2008, complex copper concentrate has been imported / sourced from outside Namibia, which remain a practice to date. The Tsumeb smelter is one of the few specialty smelters in the world that can treat complex copper concentrates with high arsenic content. The current smelter treats complex copper concentrates to produce blister copper (98.5%) as well as sulphuric acid (H_2SO_4) that is sold to uranium and copper mining enterprises in Namibia.

To date, the Tsumeb Smelter complex had undergone several transformation and upgrades some of which were listed activities, hence the smelter is currently operating under a valid consolidated Environmental Clearance Certificate (ECC) that covers its operations, related activities as well as the phased-ongoing smelter expansion project.

The proposed Multi Metal Recycling Project was not originally part of the approved Smelter Expansion Project, hence as is a listed activity in accordance with the Environmental Management Act. No. 7 of 2007, an ECC is required before project commencement.

1.2. Project description

The proposed **Multi-Metal Recycling Plant** is part of the new business venture which is not part of the already approved smelter expansion project. The proposed Multi-Metal Recycling Plant aims to reprocess the historic stockpile of Zinc Slag (as main raw material) and produce final products such as zinc ingots, lead ingots, zone refined germanium ingots and high-purity gallium. The by-products include copper slag and Gypsum residues (flue gas desulphurization residue) that can be sold. The wastes are a cleaned slag from the furnaces, an iron-arsenic residue and a defluorination and heavy metal removal residue.

a) Input / Raw material

- zinc slag (generated by historical copper-lead smelting)

b) Reagents

Coke (for rotary kiln), Limestone (rotary kiln), Coal, Lime, Iron powder, Ammonium Chloride, Zinc powder, Flocculant #3, Copper sulphate, Sodium Hydroxide, Activated Carbon, Concentrated hydrochloric acid, P204, YW-100, N503, Sec-octyl alcohol, Solvent oil, Ammonia water (20%), Sodium carbonate, Strontium carbonate, Bone glue, Cathode plate, Anode plate, Hydrofluoric acid (40%), Nitric acid (40%), Caustic soda flakes, Nitrogen, Hydrogen and Steam

c) Products

- Zinc ingot,
- Germanium ingot,
- Gallium metal and
- Lead ingot

d) Waste /Residue

- Slag from Rotary kiln and Slag from fuming furnace
- Lead Blast furnace slag and Gypsum from offgas desulphurization
- FeAs cement and Gypsum from effluent treatment (heavy metals removal)
- Industrial Wastewater and Domestic Wastewater

1.3. Project Rationale

The proposed Alkali Metal Salts project forms part of the new business venture which is not part of the already approved smelter expansion project, but with the aim to diversify the current operation and fully align with Sinomine Resource GroupCo strategic business portfolio. One of the inputs to the proposed project is the sulphuric acid which is already produced onsite by the current copper smelter. The plant will also be tied to the current water and power utilities supply.

The proposed project aims to diversify the current business operation and is identified as a business saver as to generate additional revenue stream for the long-term continuity and sustainability of the Tsumeb Smelter operations. The existence of the Smelter operation is vital for the economic sustainability of the country and Tsumeb in particular, by creating Shared Value through opportunities such as employment, supply chain and community development.

Currently, about 1,432 people are directly depended on the Smelter for their livelihoods (663 employees and 769 contractors or sub-contractors).

1.4. Project Location

The Tsumeb smelter site is located approximately 2 km northeast of the Tsumeb town, Oshikoto Region, north central Namibia (see Figure 2) (19°13’24.6’’S, 17°43’33.4’’E) (see Figure 2-1). Access to the smelter is via an access road at the junction of the M75 and B1 Roads as well as by rail (good delivery and dispatch only). The proposed Multi Metal Recycling project will be contained within the current smelter footprint.

Figure 1.1: Location of Sinomine Tsumeb Smelter (STS), and MMR Project site

2. FOOTPRINT

2.1 Available Waste Material and Volumes

(229 000 t/a fuming furnace slag and Pb Blast furnace slag, 900 t/a effluent treatment residues, 7000 t/a AsFe residue, 9000 t/a gas desulphurization residue (gypsum)

Total Material processed Mass per year	Coverage Area	Timeframe	Waste
200 000 t/a	28 ha	15 years	245 900 t/a

2.2 Transportation and Traffic Management

The mode of transport being considered is the conveyor belts as the first option and also transportation by the onsite haul trucks which is estimated to be 16,500 loads per annum.

It is important to note that the raw material is already on site. Only the reagents and other consumables which be imported.

Further, a total of 10870 t/a of Zinc product will be transported to the port using existing transportation agreement with TransNamib and other service providers.
All 3 processes, from the port to smelter:
Raw material: 350 000 t/a (7000 waggon loads)
Coal & coke: 92000 t/a (2000 waggon loads)
From smelter to port:
Copper + Zink + Cs products + by products: 75 000 t/a (1500 waggon loads)

2.3 Surface Area – Footprint

45.9 ha (includes TSF – Tailings storage facility)
Phase 1: 1 ha
Phase 2: 16.9 ha
TSF: 28 ha (a new TSF will be constructed)

2.4 Water Requirements

The process is expected to consume 4387 m^3/d fresh raw water from the mine shaft.
1413 m^3/d of wastewater is produced which is stored in a dam and partially treated for recycle and partially evaporated.
The pumps, pipelines will be upgraded to ensure more pumping capacity.
Sinomine will request for amendment of the water abstraction permit to add the additional expected water consumption.

2.5 Energy Requirements

Phase 1: 2MW, Phase 2: additional 23.42 MW, Total Phase 1 & 2: 25.42 MW
Power source is Nampower, annual energy consumption is 128000 MWh and waste heat power recovery of 39000 MWh will be installed.
There is insufficient capacity at the substation for all 3 processes. Nampower will need to install a second 132 kV supply line for the second 40MW (132/11 kV) transformer and ideally another standby system in case one transformer fails. Further upgrades required on Nampower side to deliver the total 53 MW on the 132 kV side need to be confirmed

2.6 Environmental and Social Safety

2.6.1 Environmental Safety

Dust emissions will be a concern.
The raw slag contains heavy metals.
Dust suppression need to be implemented during loading of the material. This will be by means of moisturizing the material on the surface.

2.6.2 Occupational Exposure

The health effects are mainly related to dermal exposure and inhalation with irritant properties. The use of appropriate personal protective equipment and observation of safe handling procedures of chemicals will reduce the likelihood of exposure (uptake of chemical by the recipient).
Material safety monitoring systems for employees will include hygiene monitoring where the workplace air concentrations of the material will be measured. The medical surveillance including the required biological monitoring of employees will be informed by the risk as quantified by the workplace air quality sampling.
In summary, the current occupational health and safety risk management program will extend to this plant factoring the new risk factors.

2.6.3 Community Safety and Zone of Influence

Current environmental monitoring programs (air, water, soil and waste) will be reviewed and updated to cover the potential contaminants from this project (arsenic, Lead, Zinc, Cadmium, sulfur dioxide (SO_2), dust etc), however with improved technologies (able to recycle some waste) and lined waste facilities for final disposal, impact would be reduced in comparison with current smelter technology.

Additional Hazards:
Organic substances used for solvent extraction,
Various reagents (acidic and alkaline used for the hydrometallurgical process,
Community exposures – the system design is meant to reduce the occurrence of airborne pollutants through the high efficiency bagging system, thus minimal community exposure
The zone of influence will be similar the current copper smelting operation. Key concerns will be related to particulate matter (dust) and SO_2).

3. ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN (ESMP) CONTEXT

This document constitutes the Environmental and Social Management Plan (ESMP), for the proposed Alkali-Metal Salts project at the Sinomine Tsumeb Smelter.

3.1 Legal Requirements

The Environmental Management Act (also referred to as the EMA), stipulates that for each developmental project, which is listed under the EIA regulations, an Environmental Impact Assessment (EIA) should be conducted.

The EMP should conform to the provisions of the Environmental Management Act (EMA), Act No. 7 of 2007 and EIA regulations of 2012 (Government Notice: 30). The EIA Regulations defines a '*Management Plan*' as:

"…a plan that describes how activities that may have significant environments effects on the environment are to be mitigated controlled and monitored."

Table 3:1: EMP Requirements as outlined in Section 8 of the EIA Regulations

Requirement
(j) a draft management plan, which includes – *(aa) information on any proposed management, mitigation, protection or remedial measures to be undertaken to address the effects on the environment that have been identified including objectives in respect of the rehabilitation of the environment and closure;* *(bb) as far as is reasonably practicable, measures to rehabilitate the environment affected by the undertaking of the activity or specified activity to its natural or predetermined state or to a land use which conforms to the generally accepted principle of sustainable development; and* *(cc) a description of the manner in which the applicant intends to modify, remedy, control or stop any action, activity or process which causes pollution or environmental degradation remedy the cause of pollution or degradation and migration of pollutants.*

3.2 What is an ESMP?

The Environmental and Social Management Plan (ESMP) is a tool used to mitigate potential environmental risks associated with the proposed project / activity, and provides a risk management strategy and logical framework for implementation of the activities associated with the proposed project.

The ESMP recommends mitigation measures in order to ensure that the proposed activities are conducted in an environmentally friendly manner, and in accordance with the provisions of the Environmental Management Act and EIA regulations.

In-addition, the ESMP outlines specific roles and responsibilities for role-players and non-compliance is punishable.

3.3 ESMP Objective

The objective of the ESMP is to prevent / minimize, unacceptable and adverse environmental, social or economic impacts identified during the ESIA process. Overall, the ESMP aims to minimise negative impact/s (real, potential or perceived) that may result from the proposed activities, throughout the project lifespan.

The aim of the EMP is to ensure that the proposed activities are conducted in accordance with the following:

i. Environmental Management Act (No. 7 of 2007),
ii. EIA regulations of 2012 (GN: 30), and
iii. International standards, and
iv. Best environmental practices (benchmarks)

3.4 ESMP Scope

The ESMP does not only focus, and it is not limited to the proposed activities, but it includes the bigger picture, and serve as the guiding tool to protecting the natural, bio-physical and socio-economic environment on both the specific site and the surrounding area. The bigger picture is important because, some impacts may not be confined to the project site.

3.5 Possible adjustments to the EMP

The EMP is an open-ended document and maybe considered inconclusive. In other words, the EMP should allow room for adjustments if new information becomes available at a later stage, in which new / additional mitigation measures may become necessary.

The necessity of possible adjustments to the ESMP at a later stage may be attributed to:

a) Lack of information at the time of drafting the initial ESMP,
b) Evolution or addition of new activities, or
c) Unintended omission of potential impacts during the initial EIA scoping exercise and development of the initial EMP.
d) Development of industry best practice.

This implies that, in-addition to the information contained herein, any other relevant information that may surface during the construction activities, through internal monitoring or auditing by the Environmental Compliance Officers (ECOs), can be added to the EMP (evolution of activities), and such changes or inclusions will be binding to the proponent and all contractors / sub-contractors.

3.6 Implementation Framework and Accountability to the EMP

For effective implementation of the ESMP, the Institutional roles are presented below. However, the specific roles and responsibilities are defined and broken down as presented in Sections 4 and 5, respectively.

Table 3:2: Role players, Institutional Framework

Role-player	Company / Institution	Role
Proponent	Sinomine Tsumeb Smelter (STS)	Compliance to the ESMP
Environmental Consultant	Tortoise Environmental Consultants (TEC)	Development of the ESMP
Environmental Compliance Officer/s (ECO)	Ministry of Environment &Tourism (MET) – Department of Environmental Affairs (DEA)	Monitoring Compliance to EMP: ➢ Un-announced spot checks, ➢ Corrective measures, warning, penalties / fines, license suspension, etc
Public	Interested and affected parties (I&APs)	Report to the ECOs, any activity of environmental concern (e.g Pollution, safety risks, etc)

4. IDENTIFIED ENVIRONMENTAL AND SOCIAL IMPACTS

4.1 The Environmental Impact Assessment process

An Environmental and Social Impact Assessment (ESIA) was conducted at a scoping assessment level in accordance with the Namibian Environmental Management Act 7 of 2007 (EMA) and its EMA Regulations of 2012 (GN. No 29 of 2012 and GN. No.30 of 2012).

4.2 Key Impacts

The proposed Alkali-Metal Salts project was found to have both positive and negative impacts which are rated between low to high before mitigation and after mitigation all negative impacts could be re-rated down to low if not negligible. Further for positive impacts, these could be all rated between medium to high after mitigation.

4.2.1 Positive impacts include

- New employment opportunities
- Sustaining current employment (workforce)
- Sustaining and improvement in community investment
- Sustaining and improvement in support to local and national supply chain (procurement)
- Sustaining and improvement in support to small and medium enterprises (purchasing power of workforce)

4.2.2 Negative impacts include

Design and Construction related impacts

- Excavation – dust emission and noise pollution
- Excavation – impact to biodiversity (removal of protected species)

Operation related impacts

- Bulk material handling and interim storage in Walvis Bay Port – material spillage and dust emission
- Resource consumption (e.g. water and electricity demand)
- Onsite bulk material handling and storage – material spillage, dust emission and occupational exposures
- Solid waste treatment and disposal
- Wastewater treatment and disposal (both domestic and industrial/process water)

5. ROLES AND RESPONSIBILITIES

5.1 Roles and Responsibilities

Assignment of responsibilities is necessary to ensure that key procedures are followed. Ultimately, the overall responsibility for the implementation of the ESMP rests with the proponent (Sinomine Tsumeb Smelter – STS).

To ensure accountability, it is necessary to assign responsibilities. The key role-players for project implementation are;

a) The **Environmental Compliance Officer (ECO):** representing the Environmental Commissioner, or an appointed independent environmental officer, who is responsible for monitoring and auditing.

b) **The Proponent**: **Sinomine Tsumeb Smelter (STS)**:

c) **The Project Manager** the person responsible for the management of the project activities and implementation of the Environmental and Social Management Plan.

5.1.1 The Environmental Compliance Officer (ECO):

The ECO refers to the party responsible for the environmental monitoring and auditing to ensure that the provisions of the ESMP are complied with.

The ECO shall have adequate environmental knowledge to understand and interpret the ESMP and pertaining environmental aspects associated with the project. The specific tasks of the ECO are as follows:

- To undertake all monitoring and auditing activities in-order to ensure compliance with the ESMP.
- Conduct inspections and monitoring at reasonable intervals (e.g. quarterly, bi-annually and or ad hock), during project lifecycle. Depending on the risks, some projects may require more frequent regulatory inspections.
- Issue compliance orders to the proponent, contractors / sub-contractors for non-compliance inspection or audit findings.
- Compile compliance Reports pertaining to any non-compliance incident/s, and a Rehabilitation Report following the conclusion a specific activity.
- Liaise closely with all key stakeholders i.e. the Project Manager.
- Provide guidance on any environmental management issues, incidents or emergencies that may arise throughout the project lifespan.
- Assist in providing recommendations for remedial action in the event of non-compliance.
- Auditing or monitoring activities may involve investigation, as well as structured observation, measurement, and evaluation of environmental data over a certain period.

5.1.2 The Proponent:

The proponent (Sinomine Tsumeb Smelter), hereinafter referred to as STS, upon receiving approved ECC, would immediately assume overall responsibility to ensure implementation of the ESMP is done throughout project life cycle and specifically assign identified staff members who will be held accountable for implementation of the remedial measures outlined in this ESMP.

It is recommended that the client should appoint a Project Manager who will be responsible for monitoring of daily operations.

The specific responsibilities of The Proponent are as follows:

- Appoint a Project Manager (PM) to oversee the daily onsite activities.
- Liaise closely with the PM and ECO on any environmental management issues, incidents or emergencies.
- Ensure that all activities in and around the site are conducted in accordance with the requirements of the ESMP at all times.
- Ensure that all sub-contractors and visitors to the site are conversant with the requirement of the ESMP, relevant to their roles on site.
- Shall develop a **communication strategy** between The Proponent, Project Manager, workers, the ECO and any other relevant stakeholder.
- Shall develop an **organisational structure** to ensure that:

  - There are clear channels of communication
  - There is an organisational hierarchy for effective implementation of the ESMP; and
  - Conflicting or contradictory instructions are eliminated;
  - Ensure that all instructions and official communications regarding environmental matters shall follow the organisational structure as determined
  - Ensure that that ESMP requirements are assigned to specific people / positions with the capacity and experience required for implementation.

5.1.3 The Project Manager:

The **Project Manager (PM)** should:

- Ensure that each team recruited to work at the site, adheres to the ESMP
- Ensure that a <u>**copy of the ESMP is kept on site at all times and as it may be requested by authorities conducting spot checks at any time**</u>.
- Ensure that all staff attend an induction session before commencement of any work on site and that they are adequately informed of the requirements of the ESMP
- Take special care to prevent irreversible damage to the environment.

5.2 Instructions

All instructions and official communications shall follow the organisational structure as determined by the Proponent. Based on the adopted structure, it is essential that responsibilities outlined are assigned to specific parties with adequate capacity and experience required to implement the ESMP.

5.3 Disciplinary Actions

The ESMP is a legally binding document. Non-compliance with the ESMP may result in disciplinary action. Such actions may take the form of;

- Financial penalties, Legal action, fines, and/or Suspension of work.

The disciplinary action shall be determined according to the nature and extend of the non-compliance, and exact penalties are to be weighed against the severity of the incident.

6. ENVIRONMENTAL / SOCAL IMPACTS AND MITIGATION MEASURES

Systematic Approach

To enable a systematic approach, impact and associated mitigation measures have been classified into different categories. For each impact, specific and appropriate mitigation measures have been identified and outlined in the respective Tables.

The recommended mitigation measures should allow flexibility of acceptable adjustments which maybe triggered by the following scenarios:

a) Limited information available at the time of drafting the initial ESMP
b) Evolution or addition of new project activities, or
c) Unintended omission of potential impacts during the initial project design and development of the ESMP
d) Benchmarking of industry best practice.

Impacts and corresponding mitigation measures are categorised as follows:

a) Planning Phase

- Feasibility Studies
- ESIA
- Regulatory framework: supplementary regulatory permits and licenses
- Employment, procurement and community investment

b) Construction Phase

- Excavation - Vegetation Clearing Excavation – dust emission and noise pollution
- Excavation – impact to biodiversity (removal of protected species

c) Operational Phase

- Bulk material handling and interim storage in Walvis Bay Port – material spillage and dust emission
- Resource consumption (e.g. water and electricity demand)
- Onsite bulk material handling and storage – material spillage, dust emission and occupational exposures
- Solid waste treatment and disposal
- Wastewater treatment and disposal (both domestic and industrial/process water)

d) Closure

- Rehabilitation
- Closure

6.1 Planning Phase

6.1.1 Feasibility studies and compliance to other regulatory requirements

Table 6:1: Mitigation measures pertaining to independent verification MSDS and operational permits

Aspect	Impact	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
Material Safety Data Sheets (MSDS)	Concerns relating to independent verification of the Material Safety Data Sheets (MSDS) for the Input Materials (Zinc Slag)	1. Conduct regulatory verification of MSDSs	• MSDS Certificates provided by the Proponent • External MSDS Audit Report and or Regulatory Audit Confirmation Report	STS[1] External Auditor / EC[2]
Licenses / Permits	Operating without appropriate operational Licenses / Permits	1. Obtain all relevant Licenses / Permits	• Water abstraction Permit/s • Wastewater discharge permit/s • Import and Export Permit/s • Fitness (HSE) Permit/s • Power related permit	STS

[1] STS – Sinomine Tsumeb Smelter
[2] EC – Environmental Commissioner

6.1.2 Socio-economic positive impacts

Table 6:2: Mitigation measures pertaining to sustaining current employment, new employment, sustain support to local and national economic through procurement and community investments

Aspect	Impact (Positive)	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
Socio-Economic	1. Sustaining the current STS work force, and contractor employees	• Prolong the smelter operation life through diversification of business revenue streams • Employee retention, upskill current workforce to meet requirements for the new project	• % of employment retention • % of workforce completed special upskill program and understudy program	STS
	2. New employment opportunities (both during construction and operation of the project)	• Create new employment opportunities, both short and long-term, during Construction and Operation of project	• Number of new employment opportunities created • Demonstrated preference of local residents of Tsumeb for job opportunities	STS
	3. Sustain current buying power for STS staff to support small and medium business enterprises	• Retain employees and employ more employees from local to help continue support the local business • Sustain income and buying power to support the local economy	• Number of current employments saved and retained • Monthly income and buying power, thereby sustaining the town of Tsumeb	STS
	4. Support to the Local Economy and Supply chains through local procurement	• Sustain local economy through supply chains • Continue procurement of materials and services from local supply chains (e.g Cement, steel, security companies, cleaning companies, entertainment, etc)	• Value of STS direct annual procurement from local supply chains and overall impact on the local economy	STS

Aspect	Impact (Positive)	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
	5. Community Investments through Corporate Social Responsibility	• Maintain support to the Sinomine Tsumeb Community Trust and other Community Investment Initiatives	• Overall socio-economic impact of STS CSR on the local economy	STS
	6. Maintain support to local and national transportation services	• Sustain the use of Transnamib and other service providers for material transport between Walvis Bay and Tsumeb	• Value of STS annual Transportation budget between Walvis Bay and Tsumeb	STS
	7. Sustain Port Services and other Supply Chains	• Sustain services and supply chains at the port in Walvis Bay (additional services required / provided during the importation of raw materials and exportation of products)	• Value of STS port services and fees budget • Job loses (port services companies)	STS

6.2 Operation Phase

6.2.1 Material Handling

Table 6:3: Mitigation measures pertaining to material spillage, dust emissions and occupational exposure

Aspect	Impact (Negative)	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
Material handling of the Zinc Slag	Material spillages and staff exposure during material handling and processing	1. Develop Standard Operating Procedure (SOP) for Material Handling	• Standard Operating Procedure (SOP) for Material Handling	STS
	Dust emission	1. Identify and implement appropriate Personal Protective Equipment (PPEs) as a result resort to prevent or reduce exposure to workers 2. Dust suppression	• Management Plan on Material Handling	STS
	Occupational and public exposures	1. Adherence to site standard/safe operating procedure	• Management Plan on Material Handling	STS

6.3 Construction Phase

6.3.1 Excavation work

Table 6:4: Mitigation measures pertaining to dust emission, noise and removal of protected species

Aspect	Impact (Negative)	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
Excavation activities	Unselective removal of protected species	1. Adherence to site vegetation clearance checklist/procedure 2. Avoid removal of protected tree species which do not directly affect the construction 3. explore option to relocate and replant some plants such as aloe plants	• Forestry permit or clearance • Number of trees species removal versus species saved • Number of trees or plant species relocated and successfully replanted	STS
	Loss of top fertile soil	1. Identify area for stockpile of topsoil 2. Develop and implement excavation procedure for topsoil soil trimming and stockpile	• Overburden for possible rehabilitation	STS
	Dust emission	1. Adherence to site standard/safe operating procedure 2. Identify and implement appropriate Personal Protective Equipment (PPEs) as a result resort to prevent or reduce exposure to workers 3. Dust suppression 4. Speed limit as per existing site policy	• Dust fallout and dust chemical program and implementation	STS

6.3.2 Health and Safety

Table 6:5: Mitigation measures pertaining to Health and Safety

Aspect	Impact (Negative)	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
General Safety at WorkPlace	Compromised and Poor safety of workers	1. Adhere to the Health and Safety Regulations, Government Notice 156/1997 (GG 1617) 2. Develop a Health and Safety Plan 3. Identify potential hazards and develop responses to eliminate sources of risk or minimize workers' exposure to hazards 4. Provide adequate and appropriate personal protective equipment for all workers 5. Provide training to all workers on relevant aspects of occupational health and safety associated with their daily work	Health and Safety Plan Hazard risk report Safe work condition audit Distribution and issue register for Personal protective gear for all staff Training schedule and attendance register	STS / Health Inspector
Accidents and incidents	Un-safe working conditions	1. Report occupational injuries, illness and fatalities, including near misses. 2. Investigate causes and take appropriate action to eliminate risks where possible 3. Provide adequate access to first aid and medical assistance in cases of work-related accidents or injuries	Accidents & incidents register (including near misses) cause and hazard elimination First aid kit availability and adequacy audit report	STS / Health Inspector
Ablution	Reduce health risks and environmental pollution	1. Ensure adequate, hygienic (clean) and user-friendly ablution facilities for all staff. 2. Provision of separate Male and female toilets 3. Inspect ablution facilities regularly	availability, cleanliness and hygienic ablution facilities Incidents or complaints of waste discharge into the environment	STS / Health Inspector

Aspect	Impact (Negative)	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
Dust and Noise	Excessive dust and noise exposure to both staff and the public during the construction phase.	1. Adopt applicable dust suppression measures to mitigate dust impacts. 2. Provide dust masks and earmuffs to all employees operating in a dusty or noisy environment. 3. Alert the community and public of noisy undertakings prior (e.g blasting).	Dust and Noise Incident Reports. Monitoring of dust and noise levels using modern equipment such as: *Galvimetric Dust Sampler, Personal Dust Monitor, Data Ram, Sound Level Meter, etc*	STS / Health Inspector
Fire Risk / Hazard	Fire risk	1. Contain fire used for cooking purposes and apply caution to prevent un-controlled fires 2. The same fire caution should be adopted by smokers (smother the cigarette bud before disposing in appropriate waste bin or burry underground. 3. Provide / install Fire extinguishers in accordance with safety regulations	Staff induction to demonstrate the use of fire extinguishers and fire hydrants Adequate and Service records	STS / Health Inspector
Hazardous elements	Exposure to hazardous elements	1. Continuously monitor the potential presence of hazardous elements and determine requirement	Records	STS / Health Inspector

6.3.3 Pollution Control and Waste Management

Table 6:6: Mitigation measures pertaining to Pollution

Aspect	Impact (Negative)	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
Oil Spills	Oil spills and leak from vehicles and Machinery	1. There must be an oil spill response kit on site 2. Ensure all vehicle and machinery must be well serviced and leak inspection are done. 3. Provide drip trays to stationary vehicle and machinery 4. The onsite re-fuelling area must be on concrete bund 5. Storage of fuel, oil and lubricants must be kept on bunded structure 6. If an oil spill occurs, collect the contaminated soil, store in drums and dispose at appropriate waste disposal site	Physical verification and routine monitoring	STS ECO
Solid Waste	Littering, pollution, contamination of water and general environmental health hazards	1. All waste produced on site should be contained and disposed as required by law. 2. There must be sufficient temporally ablution facility at the site for designated for males and female.	Scattered waste, Littering and any other unsightly waste at the site (eyesore)	STS ECO

6.3.4 Heritage And Archaeology

Table 6:7: Mitigation measures pertaining to Heritage and Archaeology

Aspect	Impact (Negative)	Action Required	Monitoring Indicator	Responsible Party
Heritage Resources / artefacts	Damaging of heritage resources / artefacts	1. Heritage remains or artefacts discovered on site must be reported to the National Museum (+264 61 276800) or the National Forensic Laboratory (+264 61 240461). 2. No artefacts must be removed or be interfered with prior to authorisation from the Namibian National Heritage Council (NHC) 3. Recovery of heritage remains or artefacts discovered and removal thereof should be directed by the National Museum	Sighting report/s of heritage resources / artefacts	STS Heritage Council

6.4 Operational Phase

6.4.1 Input Material

Table 6:8: Mitigation measures pertaining to Input Materials

Input Material	Impact (Negative)	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
Zinc Slag	Staff exposure during material handling Risk for groundwater pollution through Leaching of heavy metals e.g Arsenic	• Appropriate protective gear for workers • Mitigate leaching of heavy metals into water systems • Develop safe operating procedure (SOP)	• SOP • Protective gear • Risk awareness training (records)	STS
Water	Increased groundwater abstraction	• Calculate sustainable yield (aquifer) • Obtain water abstraction permit • Install flow meter	• Groundwater / aquifer modelling • Install flow meter	STS
Electricity	Increased energy demand and Safety risk (electrocution)	• Increase energy supply • No loose electrical wires • Insulation • Risk Awareness	• Risk awareness training (records)	STS

6.4.2 Combined and Cumulative Water and Energy Requirements

Input	Source (Borehole, Municipality, etc)	Current Demand (Copper Smelter) (M^3 p/a or MW)	New Demand (AMS Project) (M^3 p/a or MW/h/a)	New Demand (MMR Project) (M^3 p/a or MW/h/a)	Sum Current + New (AMS + MMR) (M^3 p/a or MW/h/a)
Water	No.1 shaft (Raw water) and municipal supply (domestic water)	1.3 Mm^3 p/a	365,000 M^3 p/a	1,277,500 M^3 p/a	2,942,500 M^3 p/a
Energy (Capacity or Requirement)	Nampower Station (40 MW)	24 MW	3.5 MW	25.4 MW	52.9 MW
Energy Consumption (Electricity)	Nampower Station	165,000 MW/h/a	24,564 MW/h/a	173,053 MW/h/a	362,617 MW/h/a

Current Water abstraction Permit (MAWLR) **1.3 Mm^3 – 2,9 Mm^3 = -1,6 Mm^3** (New water Permit Required)

Current Stub station (NAMPOWER) **40 MW – 52.9 MW = -12.9 MW** (Sub Station upgrade required)

6.4.3 Reagents

Table 6:9: Mitigation measures pertaining to Reagents

Reagents	Negative Impact	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
All other reagents Coke (for rotary kiln), Limestone (rotary kiln), Coal, Lime, Iron powder, Ammonium Chloride, Zinc powder, Flocculant #3, Copper sulphate, Sodium Hydroxide, Activated Carbon, Concentrated hydrochloric acid, P204, YW-100, N503, Sec-octyl alcohol, Solvent oil, Ammonia water (20%), Sodium carbonate, Strontium carbonate, Bone glue, Cathode plate, Anode plate, Hydrofluoric acid (40%), Nitric acid (40%), Caustic soda flakes, Nitrogen, Hydrogen and Steam	To be procured from the market • Health and environmental Risks if any mishandling and spillage incident occurs	• Reagent spillage incident response protocol • Incident response toolkits • Protection gear for workers • Clean-up, Safety handling and disposal procedure	• Spillage incident response toolkit • Safety Operating Procedures (SOP)	STS ECO

6.4.4 Products

Table 6:10: Mitigation measures pertaining to Products

Products	Impact (Negative)	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
All Products • Zinc ingot • Germanium ingot • Gallium metal • Lead ingot • Coper -Arsenic Residue • Copper slag	These are the intendent outputs or products to be exported to different market • However, health and environmental Risks if any mishandling or spillage incident occurs	• Mishandling or spillage incident response protocol • Incident response toolkits • Clean-up, Safety handling and disposal procedure • Appropriate protective gears for workers • Do not empty in drains or watercourses • Stored or dispose in a lined facility (dry and well ventilated) • Avoid moisture and isolate from incompatible materials to avoid further chemical reactions • The storage facility must be strictly monitored with sensors • Develop safety operating procedure (SOP) to guide handling of product	• Safety operation procedure (SOP) • Analytical Schedules • Laboratory tests • XRD and XRF analysis • Chemo-Sensors • Chemical analysis	STS ECO

6.4.5 Waste / Residue

Table 6:11: Mitigation measures pertaining to Waste / Residue

Waste / Residue	Waste Classification (Leachability)	Impact	Mitigation Measures and Potential Uses	Indicators for Monitoring and Compliance	Respon-sible Party
Slag from Fuming and Rotary Kiln	Low risk waste	• Water Contamination • Soil degradation through Leaching • Exposure may cause respiratory, skin and eye irritation • Harmful if swallowed	• Adherence to site standard/safe operating procedure • Provide Personal Protective Equipment (PPEs) for workers • Granulated slag is used as a cement replacement and can also be used as a sand substitute, can improve concrete durability, and reduce the amount of ozone depleting substance and energy needed to create the concrete. • Slag can increase soil pH, which can help mobilize nutrients and improve plant productivity.	• Tailings volume measurement records • Dust fallout and dust chemical analysis • Slag activity, moisture, composition	STS ECO
Slag from Lead Blast Furnace	Medium risk waste	• Water Contamination • Soil degradation through Leaching • Exposure may cause respiratory, skin and eye irritation • Harmful if swallowed	• Adherence to site standard/safe operating procedure • Identify and implement appropriate Personal Protective Equipment (PPEs) as a resort to prevent or reduce exposure to workers • Do not empty in drains • Store product in lined facility Consider reprocessing to recover residual metals	• Tailings volume measurement records • Groundwater monitoring • Dust fallout and dust chemical analysis • Slag activity, moisture, composition	STS ECO

Calcium Sulphate hydrate (CaSO4) or Gas desulphurization Residue	low risk. Main environmental risk is total dissolves solids (TDS) and sulphate when leaching	• Exposure may cause respiratory, skin and eye irritation, Gastrointestinal issues and allergic reactions • Reduced Plant growth due to acidification • Acute toxicity: LD50 oral (Rat)- 50000mg/kg	• Appropriate protective gear for workers • The waste compound $CaSO_4$ must be stored in a lined disposal facility, dry place. • Isolate from incompatible materials and avoid further chemical reactions in the settled storage. • $CaSO_4$ is a key ingredient in cement production (opportunity to sell the product)- store it in a way that it can be recovered. • Prevent dust generation on the storage facility (keep moisture in the material >10%)	• Tailings volume measurement records • Groundwater monitoring • Dust fallout and dust chemical analysis	STS ECO
FeAs Cement and Effluent treatment and heavy metals removal	Very high-risk wastes. Expected leachability of heavy metals and Fluorine is > LCT1 or LCT2	• Water Contamination • Soil degradation through Leaching • Exposure may cause respiratory, skin and eye irritation • Harmful if swallowed	• Adherence to site standard/safe operating procedure • Provide appropriate Personal Protective Equipment (PPEs) • Do not empty in drains • Waste residue must be stored in a well-designed triple lined facility •	• Laboratory chemical residue tests • Waste quantification • Groundwater monitoring • Dust fallout and dust chemical analysis	STS ECO
Calcium-Magenesium (Ca-Mg) waste	Low risk (main concern is TDS and sulphate)	• Exposure may cause respiratory, skin and eye irritation, • Can be harmful if swallowed	• Provide Personal Protective Equipment (PPEs) • Isolate from incompatible materials and avoid further chemical reactions in the settled storage. • Storage in a lined facility if re-processing is not feasible. • Calcium and magnesium are essential nutrients for plants	• Waste quantification - measurement records • Groundwater monitoring • Dust fallout and dust chemical analysis	STS ECO

Dust (Smelting Dust) ZnO product	Very high risk (but not a waste – this is a product)	• Exposure to heavy metals from smelting dust may lead to various health problems including respiratory illnesses, reproductive issues Allergic reactions • Dust can accumulate in surrounding areas over time	• Wear protective gear and strictly adhere to the standards on handling chemical substances • Store the product in sealed containment to prevent emissions • Dust collection system and recycling • The residue consists of element that can be recycled to obtain chemicals and metallic element for important applications	• Air sampling pumps • High volume air sampler • Passive sampler • Chemical speciation analysis	STS ECO
Industrial Waste-water	Industrial Wastewater / Hazardous wastewater	• Surface and ground water contamination • Leachate • Harmful if ingested	• Storage in pollution control dam for evaporation as a means of disposal • Evaporate excess wastewater, with salts finally deposited in a HWDF (either when pond fill up or at closure) • Cleaning the wastewater to a standard for re-use and then evaporate brine and dispose salts in hazardous disposal facility • Cleaning the wastewater to effluent discharge quality *(as per the Namibian wastewater discharge standards).* • *In summary: Wastewater will be reused, remaining portion will be stored in pollution control dam for evaporation, and any excess water will be treated to a discharge limit standard (Namibian wastewater discharge* • *Deter biodiversity access to wastewater ponds to prevent mortality and loss*	• Quantification through Flow meters • Leakage and points sources of pollution • Groundwater monitoring • Biodiversity monitoring	STS ECO

Domestic Wastewater	Sewage / hazardous wastewater	• Surface and ground water contamination • Odour • Human health (contain pathogens such as E.Coli) • Harmful if ingested	• Treat in sewage treatment plant before directing into reed dam. • Further explore option for reuse of treated effluent e.g. Use for site garden and landscape • Cleaning the wastewater to effluent discharge quality *(as per the Namibian wastewater discharge standards).*	• Flow meters • Leakage and points sources of pollution	STS ECO
Contractor Camp	Contractors' Temporary Camp Domestic Waste (Solid and Wastewater)	• Lack of ablution facilities – leading to open defecation, environmental pollution (scattered human waste), engulfing smell and leaching of human faecal waste into water bodies • Long-drop toilets – not suitable for bigger groups (e.g 150 people) over long period of time (e.g 12 months) • Littering – due to lack of waste bins, lack of waste collection and disposal, lack of staff orientation and awareness	• Induction, orientation and awareness of staff on waste management *(importance of toilets, cleanliness, hygiene, maintenance, and impacts of open defecation, engulfing smell, used toilet papers all over the place, food contamination by flies, potential water pollution through leaching of human faecal waste, impact of littering, etc)* • Flushing toilets with provision of a containerized septic system, with capacity to handle the volumes, honey sucked and emptied frequently for disposal at the municipal oxidation ponds • Engage municipality and obtain permission for wastewater disposal into the Municipal oxidation ponds or processing in dedicated sewage waste treatment facility	• Ablution facilities (Flushing toilets) • Containerised septic tank • Wastewater collection schedule and records • Waste bins, collection schedule and records	STS ECO

6.4.6 General Waste Management

Table 6:12: Mitigation measures pertaining to General Waste Management

Aspect	Impact	Action Required	Indicators for Monitoring and Compliance	Responsible Party
Solid Waste	Littering, pollution, contamination of water and general environmental health hazards	1. All waste produced on site should be contained and disposed as required by law. 2. There must be temporally ablution facility at the site for designated for males and female.	Scattered waste, Littering and any other unsightly waste at the site (eyesore)	STS ECO
Oil Spills	Oil spills and leak from vehicles and Machinery	1. There must be an oil spill response kit on site 2. Ensure all vehicle and machinery are serviced and leak inspections are done. 3. Provide drip trays to stationary vehicle and machinery 4. Concrete budding for onsite re-fuelling 5. Storage of fuel, oil and lubricants must be kept on bunded structure 6. If an oil spill occurs, collect the contaminated soil, store in drums and dispose at appropriate waste disposal site	Physical verification and routine monitoring	STS ECO
Domestic Wastewater	To avoid any potential water contamination or pollution from leachate	7. Refer to the adequate handling of wastewater and project waste streams 8. Train Employees on appropriate measures to handle waste streams 9. No discharge is applicable, all wastewater to be recycled/consumed in the process	Leakage and points sources of pollution	STS ECO
Ground Water	To avoid contamination of ground water	1. Regular collection of water samples from groundwater monitoring boreholes	Water samples from monitoring boreholes	STS ECO

7. REHABILITATION

7.1 Importance of Rehabilitation

Socio-economic development is very important for our livelihood and provides services, income and employment opportunities, and hence activities such as mining and mineral processing are vital and necessary for development.

However, such developmental activities should be conducted in a thoughtful and forward-looking manner. In other words, developmental activities, should consider the future land use after such activity has come to an end. Therefore, to ensure that the land remains valuable for other land uses in the future, rehabilitation should be part and parcel of such developmental activity right from the beginning and throughout the project lifespan.

7.2 What is Rehabilitation?

Rehabilitation is the process of repairing and taking all the necessary actions to limit, minimize and mitigate the damage caused by the developmental activity, in-order to make the land suitable for other uses or to simply beautify the affected area (so that it does not become an eyesore). Rehabilitation can also be referred to as the measures taken to repair damaged environments (example refilling of excavated pits with the overburden, re-vegetating, removal of unwanted infrastructure, cleaning up pollution etc).

7.3 Designing a Rehabilitation Plan

A rehabilitation plan refers to a set of steps or measures to be taken in-order to ensure that negative impacts associated with the development at hand are mitigated. This however requires prior planning and integration of rehabilitation activities throughout the project lifespan. Meaning, rehabilitation measures should be taken right from the beginning of the project.

The environmental characteristics of an area where a project is located plays a vital role in designing a rehabilitation plan.

7.4 Conclusion

Construction activities should be undertaken in a responsible and environmentally friendly manner. Although balancing the demands of development and nature is not always clear cut, the importance of minimal disturbance to the natural environment is of utmost importance to safeguard the environment

7.5 Mitigation for Closure and Rehabilitation

7.5.1 Rehabilitation and animal Exposure

Table 7:1: Measures pertaining to Rehabilitation, animal exposure and Closure

Aspect	Impact	Mitigation Measures	Indicators for Monitoring and Compliance	Responsible Party
Rehabilitation	Lack of Rehabilitation (eyesore of environmental scars, contamination, no vegetation etc)	1. Stockpile the topsoil overburden, to be re-used during rehabilitation after construction operations and to aid the re-establishment of vegetation 2. All areas disturbed as a result of the project activities should be cleaned up and rehabilitated	• Physical verification	STS ECO
Habitat alteration and permanent environmental scars	To minimize habitat alteration and environmental scars	1. Limit environmental damages and re-use e.g. the overburden may be collected and piled and used for re-filling of pits 2. Plant indigenous trees / grass to fill the gaps for trees removed during construction.	• Re-filling of and construction pits with the overburden • Plant indigenous vegetation (grass and trees)	STS ECO
Biodiversity (Fauna)	Wildlife poisoning due to accessibility of Hazardous waste accessible by animals (birds, mammals, reptiles, etc)	1. Contain and ensure that hazardous waste is not accessible by animals to prevent poisoning of animals (wildlife and domestic animals)	• Physical Inspections, Monitoring and incident reports (incident book)	STS ECO
Closure Impacts	Project abandoned and hazardous waste scattered all over the site	2. Ensure implementation of mitigation measures from the Planning stage, Construction and Operational and throughout the project lifespan	• Physical verification	STS ECO

8. CONCLUSION

8.1 ESMP requirements and Procedures

The aim of the ESMP is to ensure legal compliance to prevent environmental fatal flaws. Various best practice and mitigation measures have been identified to avoid and reduce effects as far as reasonably practicable across the proposed project, as well as ensure the environment is protected and unforeseen effects are avoided.

On condition that mitigation measures specified in this ESMP are fully implemented, an Environmental Clearance Certificate (ECC) is recommended.

However, Non-compliance is punishable.

The key role-players are defined under section 4 should:

- ***Read*** the ESMP (particularly the Project Manager) and ensure that they are fully conversant with provisions of the ESMP,
- If need be, ***Ask for clarity*** from the Environmental Assessment Practitioner (EAP), Environmental Compliance Officer (ECO) or relevant authority,
- Ensure implementation of the recommended mitigation measures, and
- Communicate defaults / challenges to the ECO as soon as possible.

The ECO should monitor (conduct periodic and unannounced ESMP audits) in-order to ensure compliance against the recommended mitigation measures.

8.2 Compliance to the ESMP

Once approved by the Environmental Commissioner, ESMP become binding to the proponent, and all contractors / sub-contractors. This implies that each and every entity that may have any kind of engagement or involved in / with the proposed project activities ought to familiarise themselves with the mitigations measures as outlined in the ESMP, as these as part of the license conditions.

GROUNDWATER FLOW AND CONTAMINANT TRANSPORT - MODEL UPDATE 2020

Tsumeb Smelter

Prepared for: Dundee Precious Metals Tsumeb

Authority References:

SLR Project No.: 733.04040.00020
Report No.: 2020-WG16
Revision No.: 2
January 2021

DOCUMENT INFORMATION

Title	Groundwater Flow and Contaminant Transport - Model Update 2020
Project Manager	Winnie Kambinda
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Author	Markus Zingelmann (BEAK) & Winnie Kambinda
Reviewer	Arnold Bittner
Keywords	Aquifer, Groundwater, Flow, Abstraction, Contamination, Plume, Cone of depression, Borehole, Monitoring
Status	Final Report
DEA Reference	
DMR Reference	
DWS Reference	
Report No.	2020-WG16
SLR Company	SLR Environmental Consulting (Namibia)(Pty)Ltd

DOCUMENT REVISION RECORD

Rev No.	Issue Date	Description	Issued By
0	November 2020	First draft issued for internal review	Winnie Kambinda
1	November 2020	Second draft -Client draft- submitted to DPMT	Winnie Kambinda
2	January 2021	Final report after client comments incorporated	Winnie Kambinda

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EXECUTIVE SUMMARY

SLR Environmental Consulting (Namibia) (Pty) Limited (SLR) together with Beak Consultants GmbH (BEAK)was appointed by Dundee Precious Metals Tsumeb (Pty) Limited (DPMT) to firstly update the existing 3D groundwater flow model to assess sustainability of water abstraction from Shaft No. 1 by DPMT to support permitted groundwater abstraction, and secondly to extend the transport model solution to a reactive transport solution to estimate a more realistic plume extension around the DPMT operations.

As a result of the 2020 model update, the following is concluded in terms of assessing sustainable abstraction from Shaft No. 1:

- There is still an uncertainty with water volumes which are abstracted by farmers and other users.
- Drawdown and abstraction from the shaft and municipality wells can be observed in the model, but only has a local impact on groundwater levels.
- Groundwater abstraction does not have a significant impact on regional groundwater levels, due to the high potential of the aquifer.
- The maximum radius of influence from abstraction of 1.3 Mm^3/annum is approximately 500 m. Thus, aimed abstraction (roughly 1.3 Mm^3/a) from the shaft is predicted to be sustainable.
- The hazardous waste disposal site is located close to the cone of depression and could therefore impact on groundwater levels to the south west of the site where currently no monitoring boreholes exists to validate influence from pumping at the shaft.

As a result of the 2020 model update, the following is concluded in terms of extension of the 2018 transport model solution to a reactive transport solution to estimate a more realistic plume extension around the DPMT operations:

- Only parts of the active tailings dam, the evaporation ponds, the arsenic /calcine legacy site and parts of the smelter site are regarded as pollution sources at this stage.
- All others including the eastern tailings dam as well as the hazardous waste disposal site do not show any signs of pollution, hence they could not be regarded as source, unlike in the previous 2018 model update.
- Although there is currently no pollution detected in the shaft from the DPMT operations, there is a risk of contamination to the shaft from the hazardous waste site that is located close to the cone of depression induced by abstraction.
- Arsenic is amongst all contaminants the most mobile, it is reduced relatively fast; 1 km from the pollution source (e.g. As 380 mg/l) and thereafter only an arsenic concentration of below 4 mg/l detectable. Beyond this, arsenic concentrations are then dropping relatively fast to natural background concentrations.

The following recommendations are arising from the groundwater contamination potential investigations:

- Water abstraction is subject to variables and thus needs to be reviewed on an annual basis. Water levels monitoring should also include the Dewet Shaft for future correlation of any potential impact of abstraction from No.1 Shaft.
- The numerical groundwater flow and contaminant transport should be updated regularly to support the abstraction permit renewal.
- Although there are no signs of contamination in the shaft at this stage, the groundwater quality in the shaft should be monitored on a Quarterly basis (especially after longer dry periods when simultaneously abstracting water from shaft).

- It is strongly recommended to have drill one (1) additional monitoring boreholes between the hazardous waste disposal site and the shaft.
- Additional three (3) monitoring boreholes, downstream the pollution sources are strongly recommended to further monitor the plume and validate the wider extent of the 2018 potential plume.
- Considering the extent of the current plume, groundwater level and quality monitoring should be revised and streamlined to allow for effective monitoring and analysis of groundwater samples. Further, a schedule for monitoring should be maintained in order to ensure a consistent record keeping that will set a standardised evaluation or interpretation of data especially in terms of external laboratories, analysis methods and detection limits.

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ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
Beak	Beak Consultants GmbH
BC	Boundary condition
GCS	GCS Environmental Engineering (Pty) Limited
DPMT	Dundee Precious Metals Tsumeb (Pty) Limited
EPL	Exclusive Prospecting License
ESIA	Environmental and Social Impact Assessment
EW	Electro winning
HRU	Hydrological research Unit
k	Coefficient of hydraulic conductivity
km	Kilometre
m amsl	Metres above mean sea-level
MAP	Mean Annual Precipitation
ML	Mining License
mm	Millimetre
NCS	Namibia Custom Smelters (Pty) Limited
RCC	Roads Contractor Company Ltd
SLR	SLR Environmental Consulting (Namibia) Pty Limited

1. INTRODUCTION

1.1 BACKGROUND

SLR Environmental Consulting (Namibia) (Pty) Limited (SLR) together with Beak Consultants GmbH (BEAK) were appointed by Dundee Precious Metals Tsumeb (Pty) Limited (DPMT) first to update the existing 3D groundwater flow model to sustainability of water abstraction from Shaft No. 1 by DPMT to support permitted groundwater abstraction, and secondly to extend the transport model solution to a reactive transport solution to estimate a more realistic plume extension around the DPMT operations.

The smelter is located on the outskirts of Tsumeb in the Oshikoto Region of Namibia, approximately 2 km northeast of the Tsumeb town centre. Constructed in the early 1960s, the smelter is one of only five commercial-scale smelters in Africa capable of processing concentrates with a high arsenic content. Figure 1-1 shows the infrastructure on DPMT property.

Groundwater is the only water source in the Tsumeb area. DPMT sources groundwater for its operations from the flooded old Shaft No. 1 of the abandoned Tsumeb Mine situated just in the northern part of the Tsumeb Town area. Water used for Domestic purposes at DPMT is supplied by the Tsumeb Municipality. Groundwater abstraction is permitted by the Ministry of Agriculture Water and Land Reform under Permit No.11294 issued in 2020 for a volume of 1.3 Mm^3/a. The groundwater model update was necessitated due to conditions in Permit 11294 that obligated DPMT to show how abstraction from Shaft No. 1 would impact other water users as well as an opportunity to include new information from recently drilled monitoring boreholes into the model to update the potential groundwater pollution plume.

In that regard, this report elaborates on the outcomes of the model update looking at the aspect of groundwater abstraction and the migration of the potential groundwater pollution plume beyond the DPMT property boundary.

1.2 MODEL OBJECTIVES

According to the proposed scope of work, the deliverables of this model update:

- Collect and update the information database for the groundwater model;
- Engage with relevant stakeholders including farming communities and authority in order to collect monitoring and other required information;
- Evaluate, analyse, collate and interpret the collected monitoring information from the new boreholes;
- Update the groundwater model to a calibrated reactive transport model which depicts a realistic simulation of the plume extent;
- Update the groundwater model to incorporate a sustainability assessment of the Tsumeb Aquifer or a portion of Tsumeb Aquifer as translated and impacted by the continuous abstractions at No.1 mine shaft as well as abstractions by the Tsumeb Municipality and surrounding farming communities - the model should predict sustainability scenarios for the following period measured from date of model update: 5, 10, 25, 50, and 100 years,
- Produce a final model report which clearly talks to the sustainability of current and future abstraction rates; and
- Present the findings of the model to the authority on behalf of DPMT when required in future, in so far as the renewal application for abstraction permit is concerned.

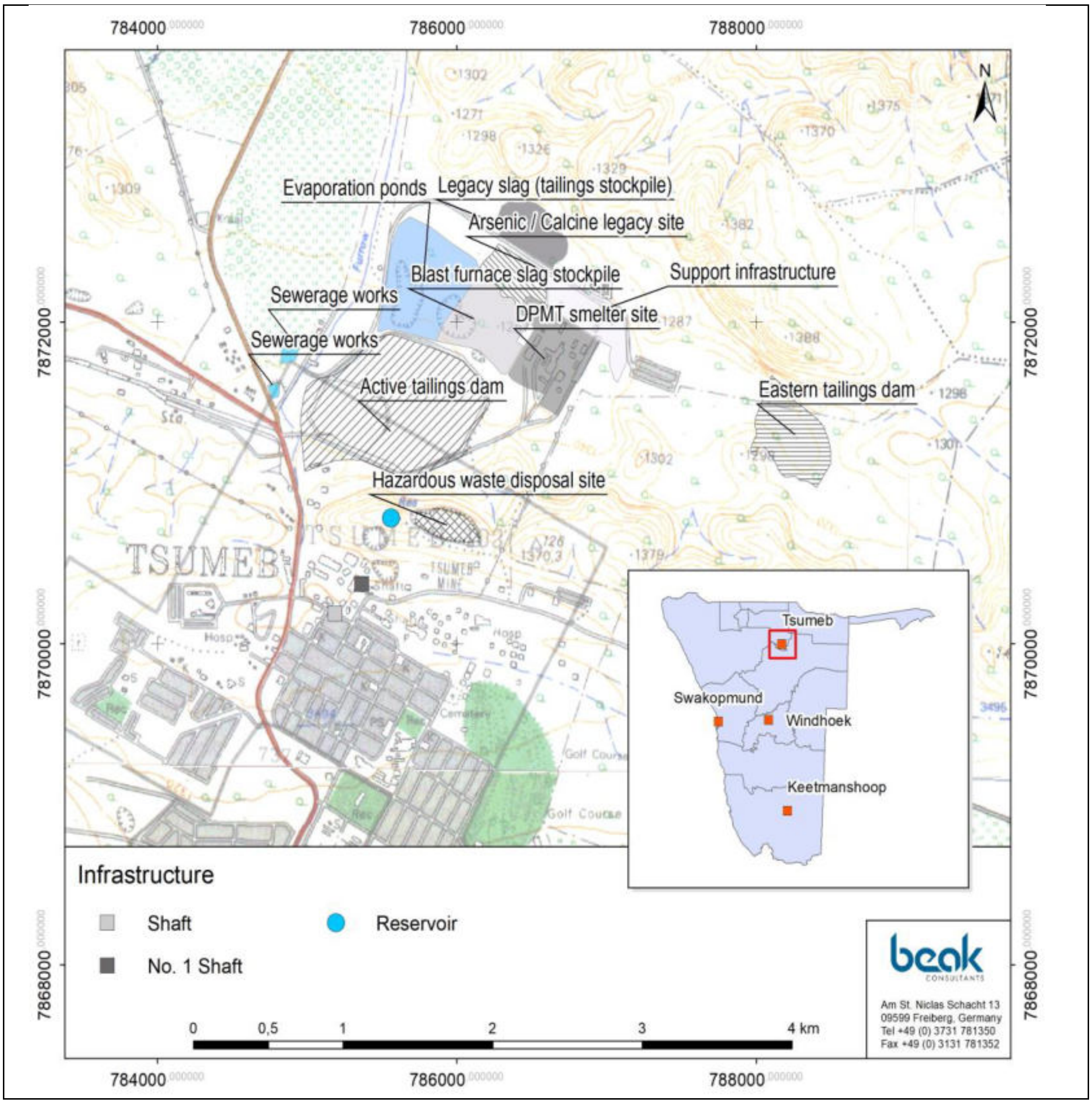

Figure 1-1: Location of Infrastructure associated to the Tsumeb Smelter (after SLR 2018)

1.3 SOFTWARE AND MODEL FUNCTION

As part of the 2020 model update, the 2018 model was extended using the modelling software FEFLOW 7.3 (Finite-Element-Subsurface-Flow-System, DHI-Wasy GmbH, 2020), which is based on a finite-element solution. This means that the model area or domain is represented by a number of nodes and elements. Hydraulic properties are either assigned to these nodes or elements depending on the nature of the input data. An equation is developed for each node, based on the surrounding nodes. A series of iterations are then run to solve the resulting matrix problem, and the model is said to have "converged" when errors reduce to within an acceptable range. The 2018 model was also extended to a transient solution to fulfil the requirements and show changes in water levels after 5, 10, 25, 50 and 100 years. Thus, the results do not show a steady state situation with average water levels, but water levels which vary in time. Under the 2020 model update, the so-called SAMG-solver, an algebraic-multigrid for symmetric and asymmetric matrix, was chosen. According to a widely accepted agreement (by scientist and associated professional), a transient flow model is said to be calibrated within an acceptable range when errors reduce to < 10%; this was the case with this model update.

2. ASSESSMENT OF SUSTAINABLE GROUNDWATER ABSTRACTION FROM SHAFT NO. 1 FOR INDUSTRIAL PURPOSES

2.1 TOPOGRAPHY AND HYDROLOGY

Tsumeb is located on the eastern side of the Etosha Basin catchment, which is an endoreic drainage system where runoff flows from the north via the Cuvelai Ephemeral River system into the Etosha Pan from where it then evaporates. The area around Tsumeb is predominantly karstic, due to the dissolution of soluble base rock mainly dolomite and limestone in this area, characterised by underground drainage systems with sink holes and caves. It is observed that areas proximal to Tsumeb are of high elevation, up to 1550 m amsl, in comparison to areas further north of the town where elevation goes down to 1150 m amsl. Due to the geology of the area, there is no well-defined drainage pattern in the Tsumeb-Grootfontein area, but rather many small individual drainage systems, dependant on the local geology. No major surface runoff is observed due to rapid intake of water by the karstic features in most areas.

2.2 GEOLOGY AND HYDROGEOLOGY

The area is situated in the Otavi Mountainland (OML). In hydrogeological terms, relevant groundwater flow is restricted to the dolomites of the Tsumeb Subgroup and minor to other meta sediments. All geological formations acting either as aquifer, aquitard or aquiclude are summarised in stratigraphical order:

- **The Nosib Group** unconformably overlies the Basement Complex. It consists of the Nabis and Varianto formations. The environment of deposition progressively developed from predominantly fluvial to marine when finer grained shales were deposited (Kamona & Gunzel, 2006). Aquifers of the Nosib Group are generally of moderate potential.
- **The Otavi Group** consists of Abenab and the Tsumeb Subgroups which are unconformably overlying the Nosib Group and the Basement Complex (Hedberg, 1979). The Group's sediments form major aquifers in the area utilised for bulk water supply. The Tsumeb Subgroup, is subdivided into 8 litho-zones (T1 to T8) from the clastic Ghaub Formation to the carbonate dominant Maieberg, Elandshoek as well as the Hüttenberg Formations elaborated on below:
    - The Ghaub Formation, referred to as T1, is a glacio-marine tillite with lenses of dolomite and schist. The Maieberg Formation is a platform slope, deep water deposit and overlies the Ghaub Formation. The lower Maieberg Formation (T2) consists of slump brecciated and laminated carbonate and argillaceous sediments. The upper Maieberg Formation (T3) comprises bedded and finely laminated carbonates.
    - The Elandshoek Formation conformably overlies the Maieberg Formation. It covers most of the northern limb of the Otavi Valley north of Kombat Mine. The lower Elandshoek Formation (T4) comprises of massive dolomite and is responsible for the rugged geomorphologic terrain of the northern limb of the Otavi Valley. The brecciation is generally intensive and therefore T4 is regarded as an important aquifer (Van der Merwe, 1986). The upper Elandshoek Formation (T5) is fairly thin and not easily distinguishable from T4.
    - The Hüttenberg Formation marks the change from the deep-sea environment observed in the Elandshoek Formation to shallow lagoon shelves. The high potential aquifer consists of a grey bedded basal dolomite, stromatolite rich (T6), overlain by two upper units, a massive dark and bedded dolomite with chert and with phyllite (T7) and T8 is marked by pisolite and oolite.
- **The Mulden Group** is characterised by the Kombat Formation in the southern part of the OML, which consists of a siliciclastic molasses (poorly graded phyllite, arkose, argillite and siltstone) deposited syntectonically during the early stage of the Damara Orogeny, and the Tschudi Formation (Arkose and

feldspathic sandstone) in the northern part of the OML, and is separated from the Tsumeb Subgroup by an angular disconformity.

- **Quarternary cover** is mainly composed by sediments of the Kalahari Supergroup form a thin cover in most areas around Tsumeb, it can be thicker can be thicker to the north and northwest of the town. The super Group forms calcrete deposits around Otavi and they locally important aquifers.

A stratigraphic column for the OML is shown in detail in SLR 2016, with the regional geology depicted. The town of Tsumeb lies on the northern edge of the OML and the dolomites of the Otavi Group characterise the area. The sandstones of the Mulden Group have been preserved in the Tschudi Syncline which extends in an east-west direction and is the representative geology of most of the area covered by the town. This syncline was depicted within the GCS 2016 report (see Figure 2-1 and Figure 2-2).

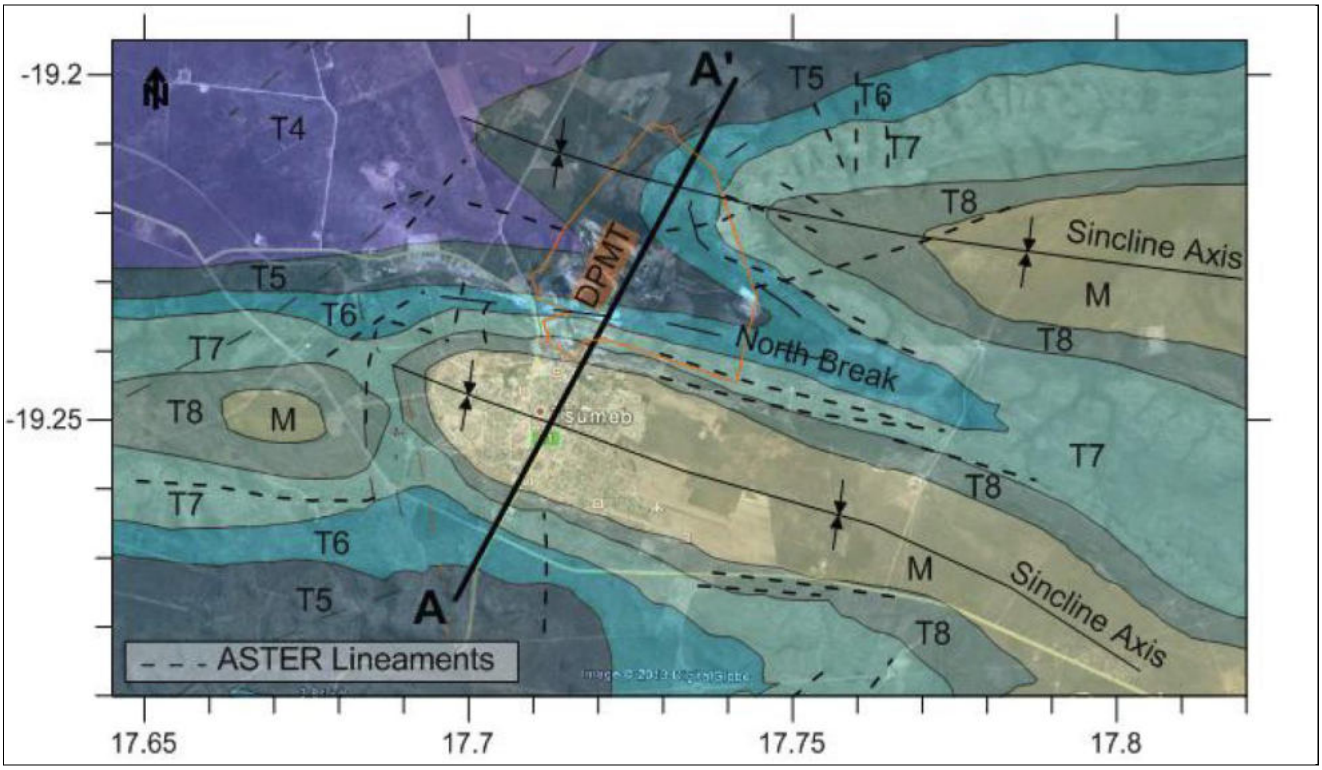

Figure 2-1: Geological Map and Location of the Cross Section

The town falls within the Etosha Basin Hydrogeological Region. Groundwater occurs in the Tsumeb Dolomitic Aquifer with the Mulden Sandstone/Shale acting as an aquiclude. The Smelter site is located on the Elandshoek and Hüttenberg Formation litho-zones, both are aquifers, in an ESE-WNW sloping valley formed as part of an anticlinal structure. The groundwater is expected to move in fold axes, pressure relief joints, faults or on lithological contact zones (see Figure 2-1 above). The average natural groundwater levels in Tsumeb are at approximately 1 210 m amsl (60 m below the land surface in the town area) with little seasonal fluctuation in the levels.

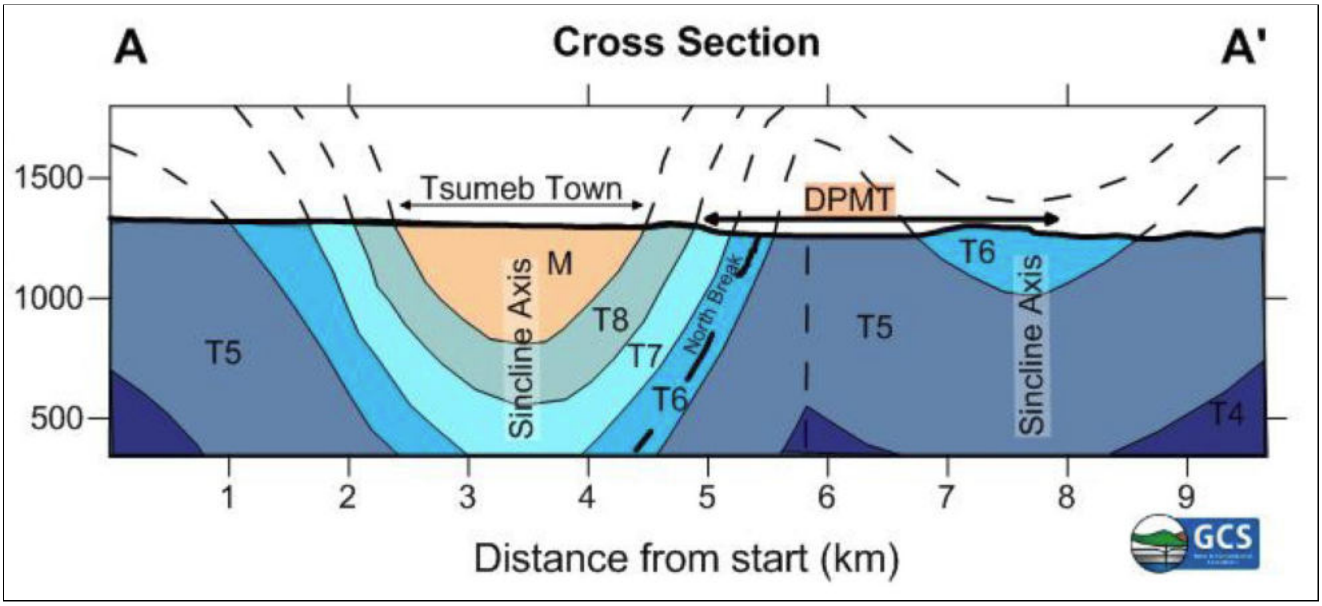

Figure 2-2: SW-NE Cross section through the Tsumeb Town and Smelter Site area

The natural groundwater flow from Tsumeb is in a northerly direction. The dolomite of the Hüttenberg Formation has high transmissivity and it is estimated that water migrates at a rate of approximately 1.08 m/day or 360 m/annum (GCS, 2013), although secondary fracture flow in the area may result in localised acceleration of the groundwater flow rates. The high elevations areas are considered as recharge zone for the groundwater. Noteworthy, groundwater flow is predominantly happening within the Tsumeb subgroup. The Kalahari aquifer is acting with its thin layered sand and calcrete as perched water table.

The Tsumeb Mine was operational from 1907 to 1996, temporarily closed until 2000 then recommissioned for a short period. (GCS, July 2013). Dewatering occurred at Shaft No.1 (approximately 1 600 m deep) at the old Tsumeb Mine, south-west of the smelter. In 2000, water was pumped from the shaft for mining of mineral specimens from the upper levels of the mine (approximately 250 m below ground surface) at a rate of 350 m^3/hr (WSP Walmsley, 2004). It is understood that during actual mining operations the water was pumped from a much greater depth.

2.3 GROUNDWATER ABSTRACTION MONITORING

DPMT is located within B2 Subterranean Water Control Area under the Water Act No. 54 of 1956, therefore drilling boreholes and abstracting groundwater requires a permit. To this effect, Permit No.11294 issued in 2020 for a volume of 1.3 Mm^3/a. DPMT is obligated under the permit to monitor and record monthly abstraction for No.1 Shaft. This record is submitted on a quarterly basis to DWA and it becomes the part of the basis through which DPMT's compliance to permit conditions is measured. Further details of groundwater abstraction are discussed in subsection 2.7.3 below.

2.4 GROUNDWATER LEVEL MONITORING DATA

The DPMT conducts groundwater level monitoring on a consistent basis. This is conducted on a network of nineteen (19) boreholes including the twelve (12) additional monitoring boreholes drilled following recommendations from the 2018 model update (Figure 2-3). Thus, this database has been taken as basis for further incorporation into the model, e.g. such as assessing groundwater recharge rates, and for the transient model calibration. It should be noted that water level monitoring should be continuous to create long-term database and thus provide better understanding of how the aquifer responds to natural or anthropogenic factors overtime. Before the groundwater level database was manipulated for use in the model update, quality control was done to determine errors or inconsistencies in the database. A number of missing and erroneous records of water level readings were noted. Once identified, the database was synthesized and corrected.

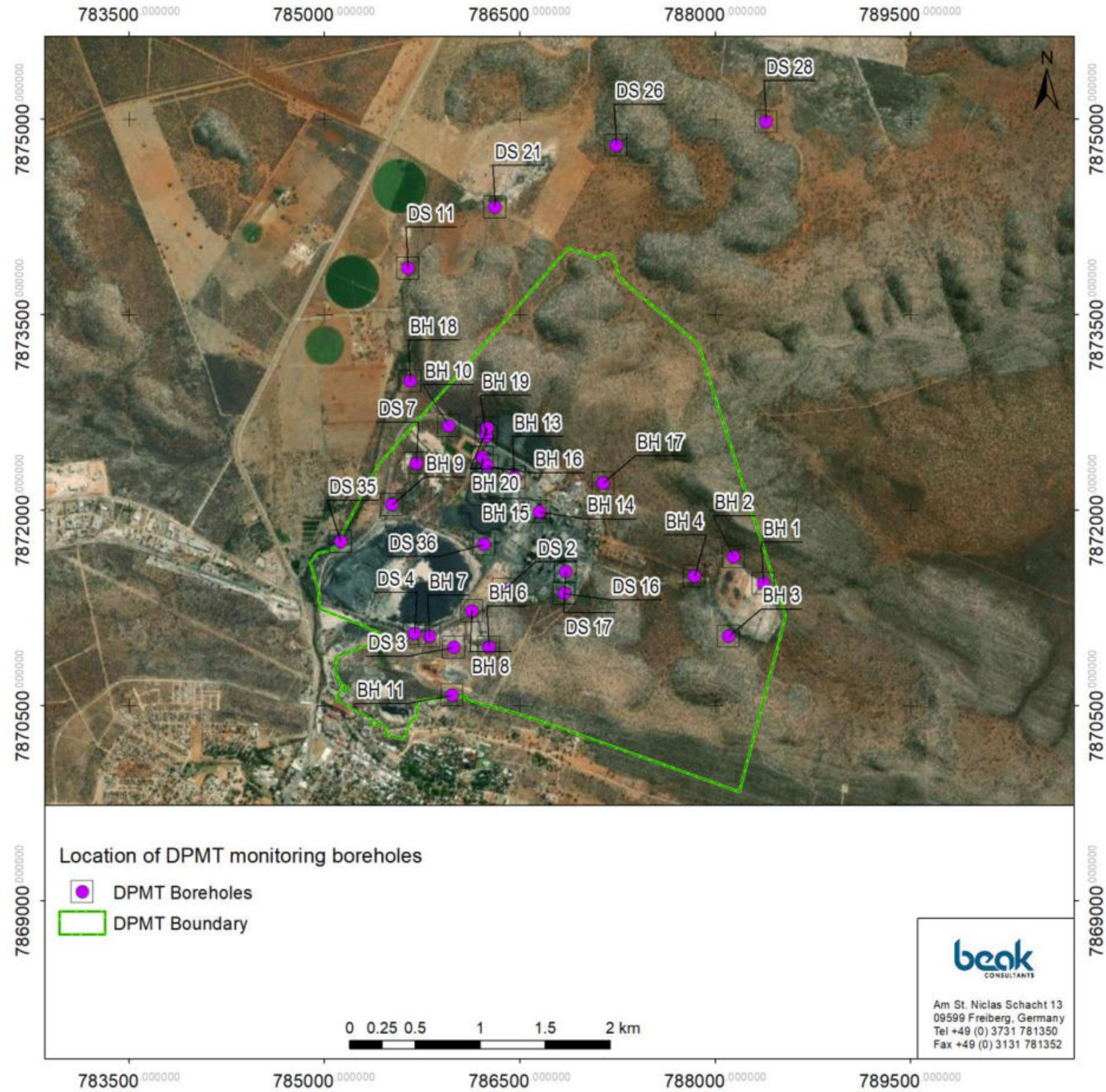

Figure 2-3: DPMT Groundwater monitoring network

Figure 2-4 depicts corrected water level records of the DPMT monitoring boreholes between 2017 and 2020. It was observed that groundwater levels range between 83 m in BH 11 and 43 m in BH 18 located at the Roads Contractor Company Ltd (RCC) quarry and north-west of the DPMT property boundary respectively. Overall, groundwater levels in the main monitoring network are on a declining trend. This is despite several recharge peaks in between the rainy season most recent of which was the between January 2020 to May 2020 where water level rise in boreholes was observed. A discontinuity in water level records in BH2 and BH 12 was noted.

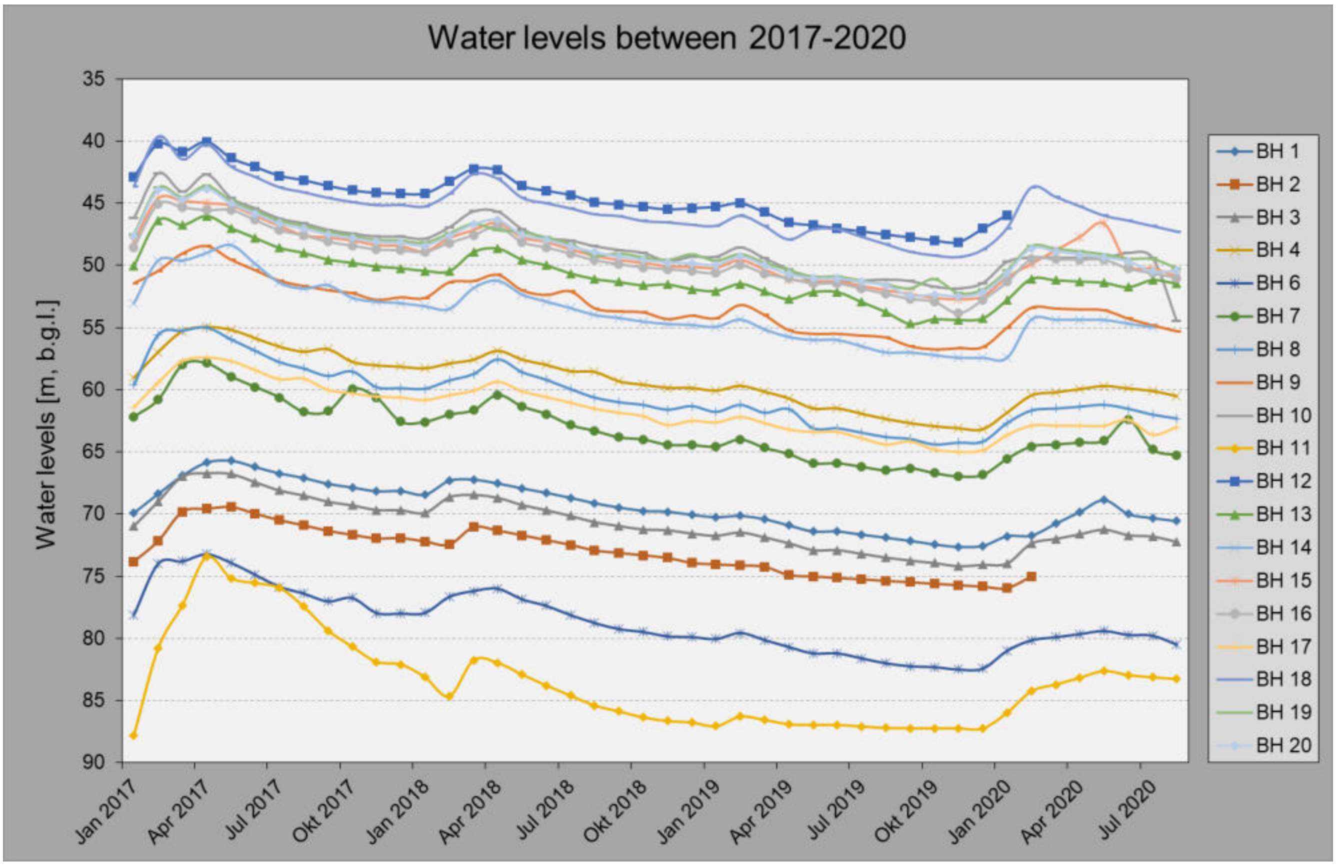

Figure 2-4: Water level records between 2017-2020 (DPMT monitoring boreholes)

For all new monitoring boreholes, drilled after 2018, a separate interpretation of groundwater levels was carried out (see Figure 2-5). The new monitoring boreholes thus have a relatively short period over which they were monitored from March 2019 to August 2020. From these boreholes, groundwater level ranges between 27 m and 75 m in DS26 and DS3. Overall, groundwater levels were observed to respond to rainfall events during this period with DS21 and DS17 showing the highest peaks while the rest of the new boreholes show stable groundwater levels.

Additionally, water level records from the Department of Water monitoring network boreholes were evaluated. In Figure 2-6, WW33311 and WW39973 proximal to Tsumeb showed main recharge events during 2010-2011, 2011-2012 and 2013-2014 rainy seasons after which groundwater levels generally declined. Both boreholes have no water level records beyond 2016. Nonetheless, these water level records have been set in proportion to rainfall data on the one hand and have been incorporated as basis for the model calibrations on the other hand.

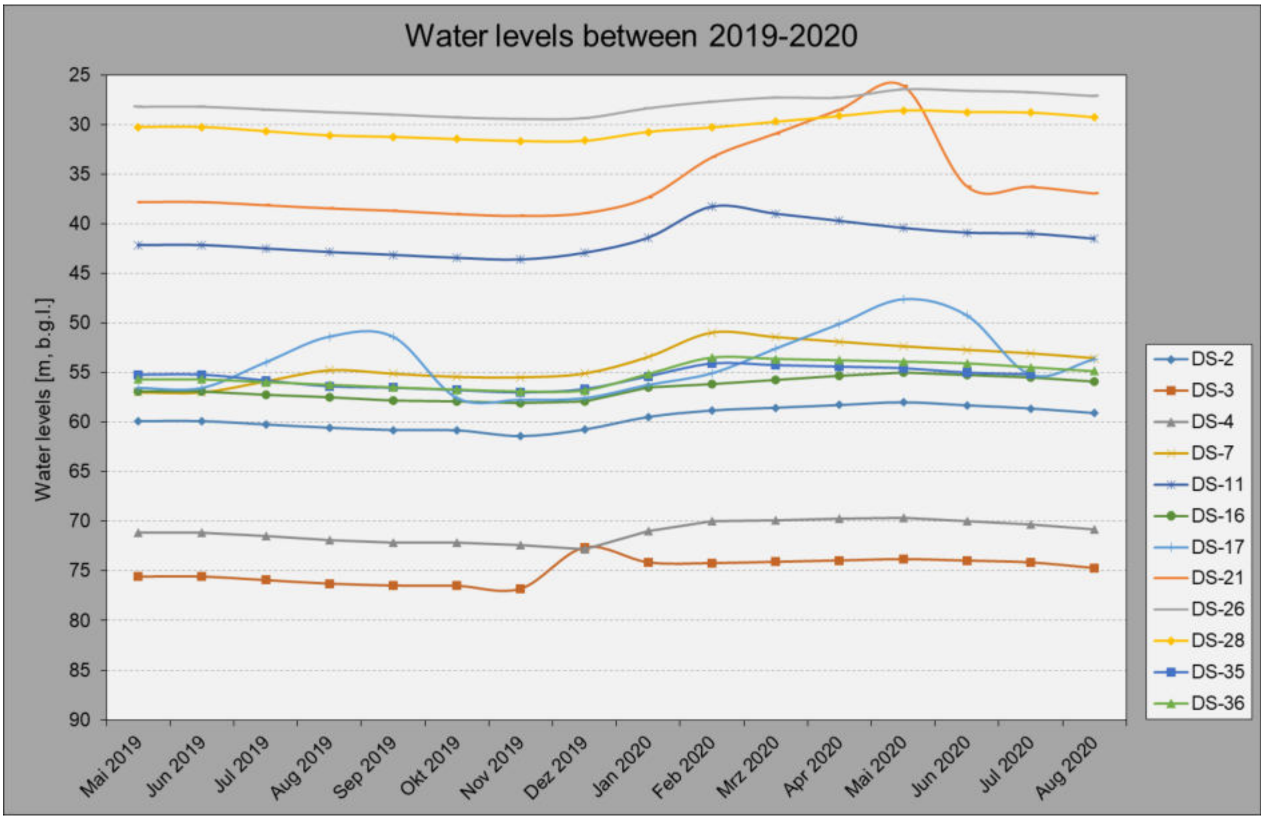

Figure 2-5: Water level records between 2019-2020 (new DPMT monitoring Boreholes)

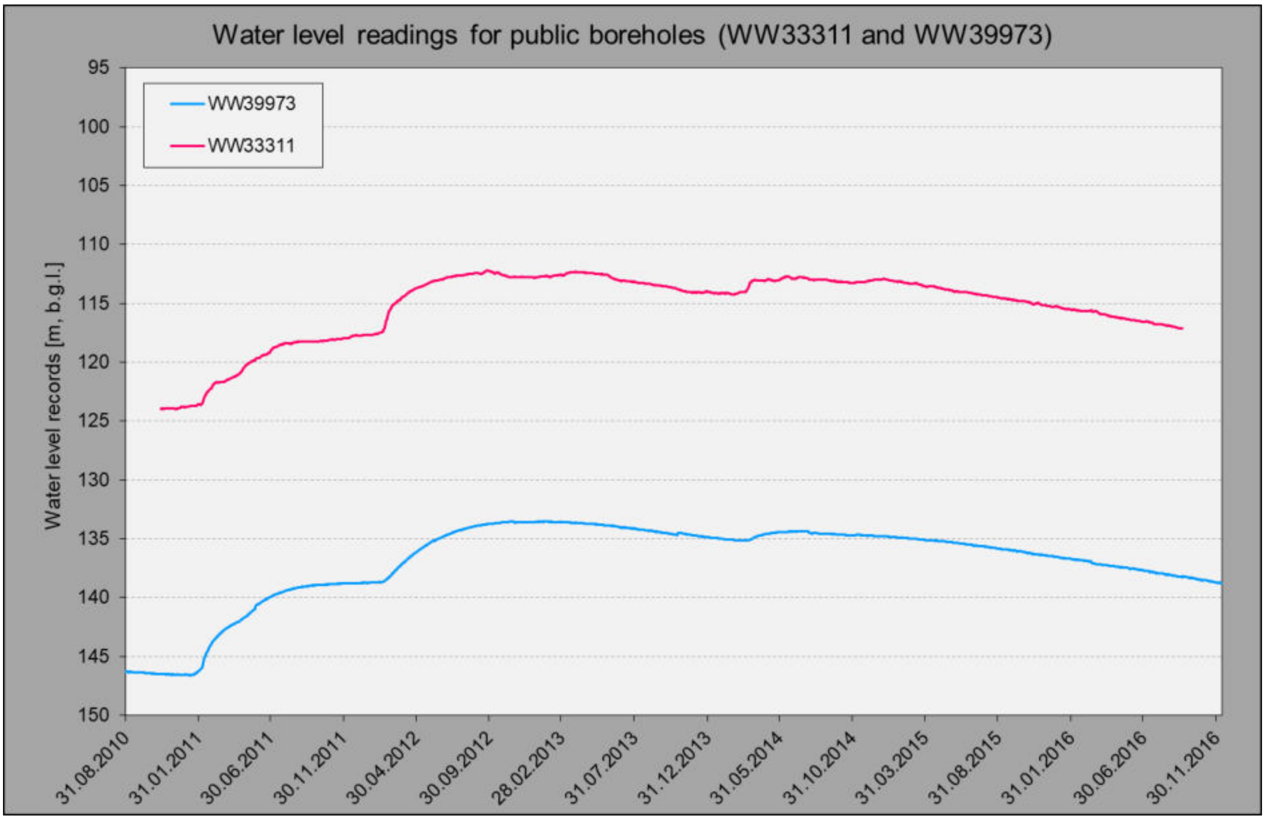

Figure 2-6: Water level records between 2010-2016 (DWA Monitoring boreholes)

2.5 RAINFALL AND RECHARGE

Aquifer recharge resulting from rainfall events is dependent on the temporal and spatial variation in precipitation as well as the host rock surface and subsurface susceptibility in terms of infiltration and storage. By virtue of its surface and subsurface hydrogeological conditions, the dolomite outcrops are potentially a good recharge area. Hence it is also susceptible in terms of pollution. Due to the fact that most of the precipitation in the region is in the form of thunderstorms, it is likely that some of the rain water infiltrates into open fractures and faults to finally reach the groundwater table before evaporating or flowing into the next river bed. Indirect recharge due to flood events in ephemeral rivers is assumed to be of minor importance in the project area since there are no rivers. A large range of recharge rates were reported by several investigations within Namibia and the study area itself (see Bardenhagen 2007). Values vary from 0.01% to 10% of mean annual rainfall, accordingly. Tsumeb has an annual average rainfall of 520 mm (between 500 and 600 mm in the area) with most of the rainfall occurring in the summer months (October to April). Approximately two thirds of the rainfall occurs in the months of January, February and March, with the highest number of productive rainfall days (i.e. days with rainfall of 10 mm and more) registered in January and February. According to the Tsumeb-Groundwater-Study (Bardenhagen 2007), groundwater recharge is extremely variable in the area. Dolomite outcrops are showing relatively high groundwater recharge, whereas basement sub-outcrops are significantly lower. Wherever dolomite and/or other rock types are overlain by Kalahari calcrete or sandy layers, lower recharge values have been observed.

Since the existing flow model was calibrated as steady-state solution in 2017, groundwater recharge data was included as long-term average, taking the hydrostratigraphical units and hydrogeological situation of the different lithologies into account. For the transient model solution, which provides changing water levels in time due to recharge and abstraction, time varying recharge rates have been deviated. Figure 2-7 shows rainfall data and water level records. Groundwater recharge does have a significant impact on water levels, as expected. The longer and intense the rainfall events, the stronger the impact on water levels is (see Figure 2-7).

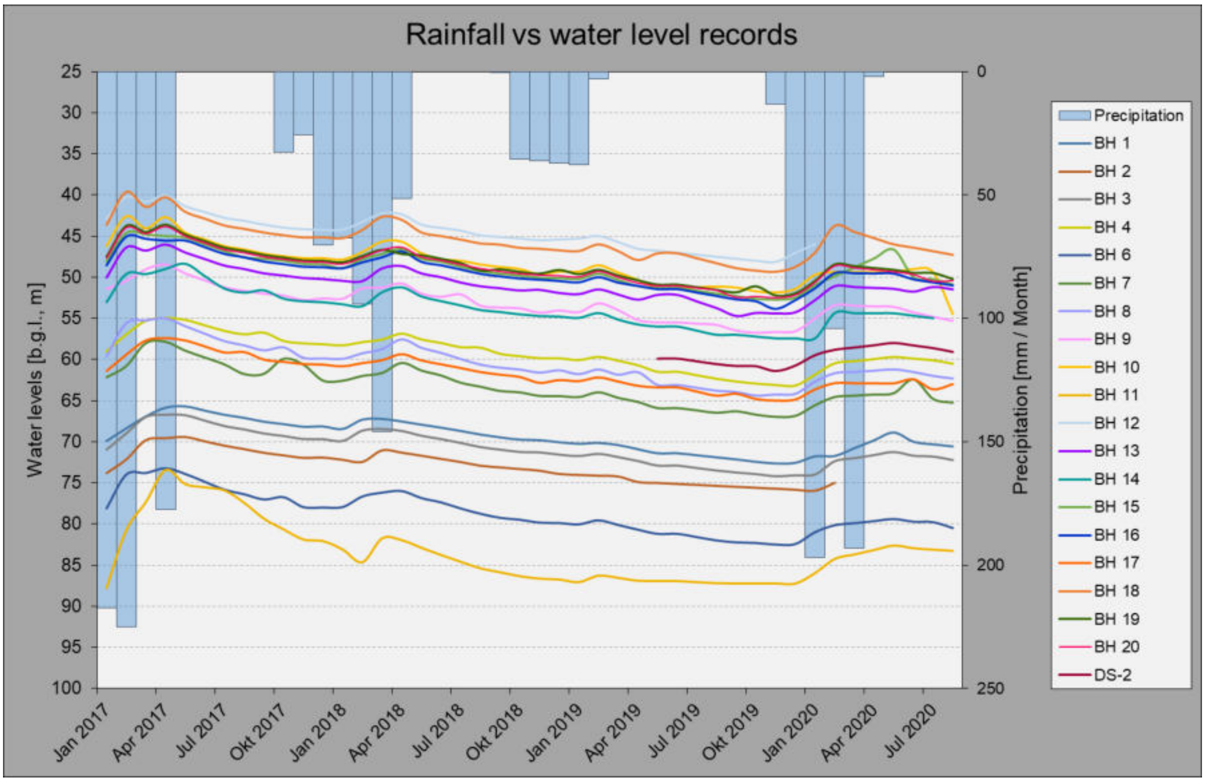

Figure 2-7: Rainfall vs water level records

As a result, realistic groundwater recharge values have been calculated for each specific hydrogeological recharge zone. Table 2-1 shows different groundwater recharge rates as average values, increased recharge after years with more than average rainfall, and recharge rates after dry periods with less than average rainfall.

Table 2-1: Time-Varying Recharge rates, inferred from rainfall and water level data

Type	Recharge in areas with low aquifer potential	Recharge in areas with high aquifer potential
Average rainfall	0.48 – 8.55 mm/a	25.18 – 55.11 mm/a
25% less than average rainfall	0.36 – 6.41 mm/a	18.89 – 41.33 mm/a
25% more than average rainfall	0.59 – 10.68 mm/a	31.47 – 68.89 mm/a

These recharge values have been taken as input data for the transient model calibration.

2.6 MODEL DISCRETISATION

2.6.1 Horizontal Mesh

Various input data have been used to define and create a finite-element-mesh. The following input information and spatial data were taken as a basis for the supermesh (i.e. all input polygons and lines and point data):

- Potentially contaminated areas and groundwater relevant smelter infrastructure;
- No 1 Shaft;
- Monitoring boreholes and abstraction wells;
- Tectonic structures (i.e. faults and fractures), dykes and lineaments;
- Ephemeral rivers and drainage system; and
- Geological units and formation.

One of the biggest advantages of a finite-element solution compared to a finite-difference solution is the possibility to setup a triangular mesh or to work in a totally unstructured mesh. Thus, linear structures can be considered realistically. For this project a regular mesh based on triangles has been developed (see Figure 2-8).

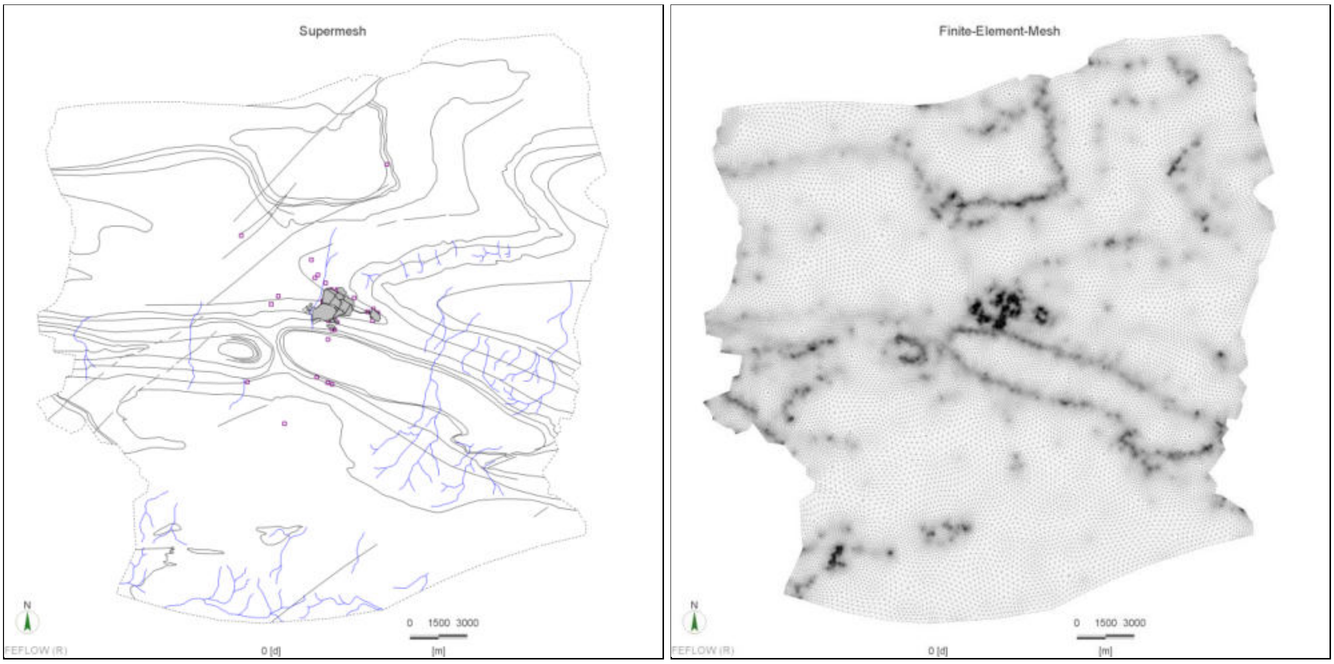

Figure 2-8: Feflow Supermesh and corresponding Finite-Element-Mesh

The numerical groundwater flow model consists of 418,458 elements and 281,192 nodes in 3 layers. The model area covers an area of 697.9 km².

2.6.2 Vertical Discretisation

Based on the finite-element mesh, the model has been expanded to fully 3-D by the inclusion of layers and elevation data. The triangles of the horizontal mesh were changed to triangular prisms (see Figure 2-9).

Following the hydro-stratigraphy of the investigation area the vertical resolution and discretisation can be summarised as in Table 2-2

Table 2-2: Vertical Discretisation and Numerical Parameters

Hydro-stratigraphic Unit	Numerical Layer No.	No. of Zones	Type	Status	Average Thickness
Weathered zone	1	5	Aquifer / Aquitard	Phreatic	~ 10 m
Tsumeb subgroup	2	5	Aquifer / Aquitard	Confined	10 – 1000 m
Basement complex	3	1	Aquiclude	Confined	300 m

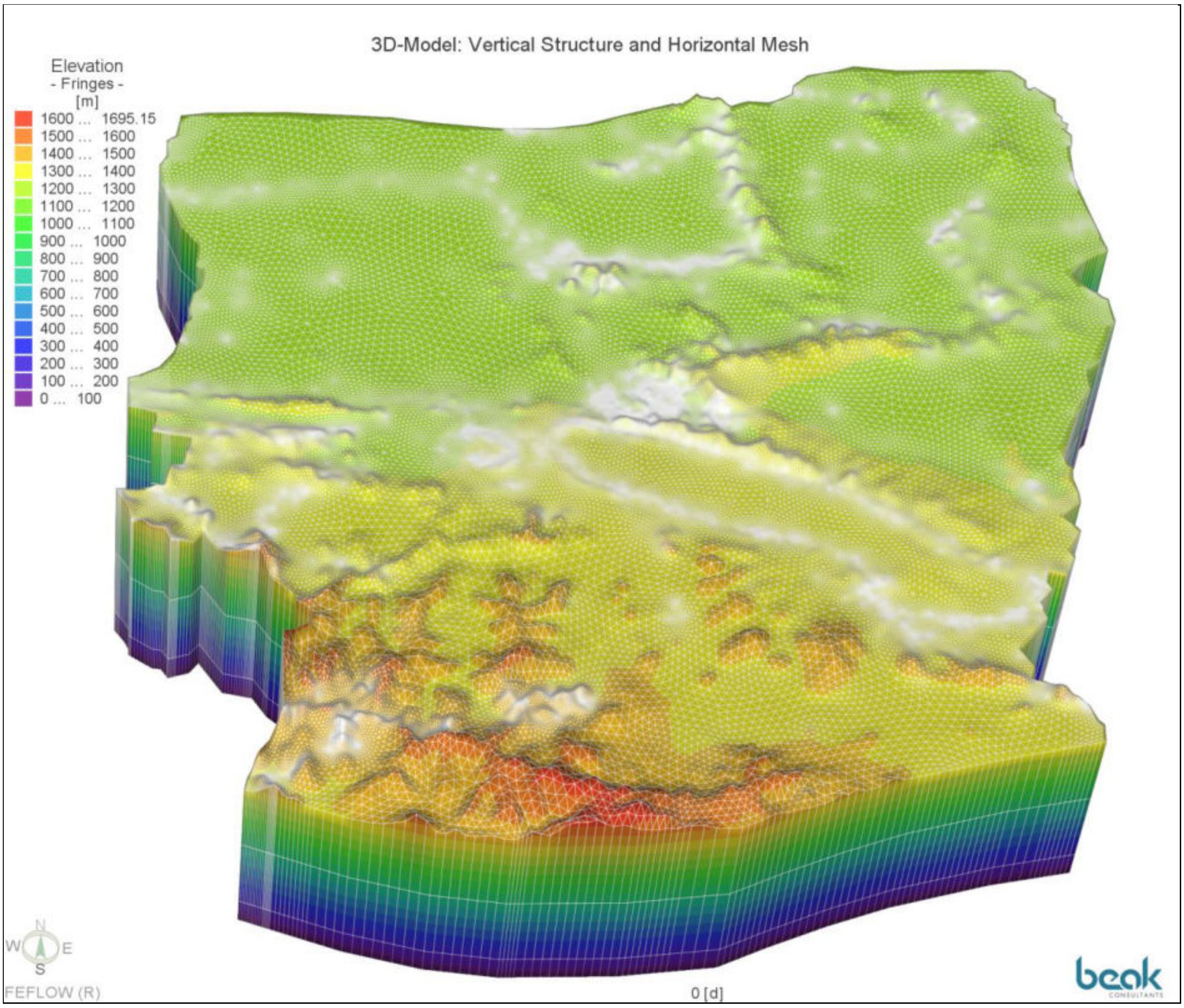

Figure 2-9: 3D-Feflow-Model with vertical Resolution and Horizontal Mesh

2.7 AQUIFER CHARACTERISTIC

2.7.1 Hydraulic Properties

Based on a variety of borehole information (see Bittner 2004), hydraulic- and pumping tests (see Bittner 2004, GKW & BICON 2003), and previous model solutions (see GCS 2013, GKW & BICON 2003) a detailed picture of the k-values can be given (see Table 2-3).

Table 2-3: Hydraulic Properties taken from the Tsumeb Groundwater Study

Hydro-stratigraphic Unit	k [m/d]	Storage Coefficient [-]	Porosity [%]	Characterisation	Description
Tschudi-Formation (Mulden-Group)	0.032	3.0×10^{-04}	1	Aquitard	Fractured aquitard. Fault zone acting as a vertical conduit within low permeable fractured rock. Evaluation suggests bilinear rather than linear flow field indicating a finite conductive vertical fracture zone.
Huettenberg-Formation (Tsumeb-Subgroup)	55.65	1.6×10^{-03}	8	Aquifer	Homogeneously fractured aquifer
Elandshoek-Formation (Tsumeb-Subgroup)	12.60	7.0×10^{-04}	6	Aquifer	Homogeneously fractured aquifer
Maieberg-Formation (Tsumeb-Formation)	1.23	9.0×10^{-05}	2.8	Aquitard or Aquifer	Fractured aquifer. Fault zone acts as a vertical conduit. Length of hydraulically active zone appears to be much smaller than the length of the lineament determined from geophysical data.
Gauss-Formation (Abenab-Subgroup)	4.66	$6.0 \times \cdot 10^{-04}$	3.8	Aquifer	Fractured aquifer. Either homogeneously fractured rock or finite conductive fracture zone with considerable storage properties
Basement-Complex	0.002	0	0.1	Aquiclude	Virtually impermeable rock

Although there is hydrogeological information available, it is heterogeneously distributed in the area. Given the lack of information on extensive hydrogeological characteristics especially for porosity, a literature review on hydraulic properties of rock types in the project area was completed. In this case, guidelines for groundwater modelling approaches (see Barnett et al 2012, Reilly & Harbaugh 1996, and Robertson Geoconsultants & SRK 2012) recommend using average hydraulic property values for hydro-stratigraphical units instead of an interpolated hydraulic property map. Table 2-3 shows the model k-values.

Since k-values, storage coefficient and porosity represent average values, these hydraulic properties have not been changed during the calibration process. Furthermore, it is believed that these hydraulic properties are the only known fixed values in the area. For the model calibration only groundwater recharge (for groundwater flow), advection, longitudinal and transversal dispersion (for the transport solution) were changed within a reasonable range (i.e. ± 10% of the initial values).

2.7.2 Flow Boundary Conditions

For most boundary conditions it is of capital importance to use them as little as possible. The boundary condition has been assigned according to the delineation of the model area (see Figure 2-10) with the groundwater heads of the existing regional model (see Baeumle 2003). The 1st kind boundary conditions (constant head or Dirichlet-BC) create an inflow or outflow, which easily over or underestimates the water budget in case they are located close to the actual prediction area. When applying 2nd kind boundary conditions (fluid-flux or Neumann-BC), a realistic estimation or proof of the in- and outflowing groundwater volume is needed. The 3rd kind boundary conditions (fluid-transfer or Cauchy-BC) typically represent rivers or other water bodies.

For this particular numerical groundwater model only, the northern boundary shall be constrained with a constant head boundary to simulate the outflow of the project area. Since the distance between our prediction area and the northern boundary is long enough we this assures a minimum impact on the available water volume as the only source for groundwater within the model area is recharge from rainfall.

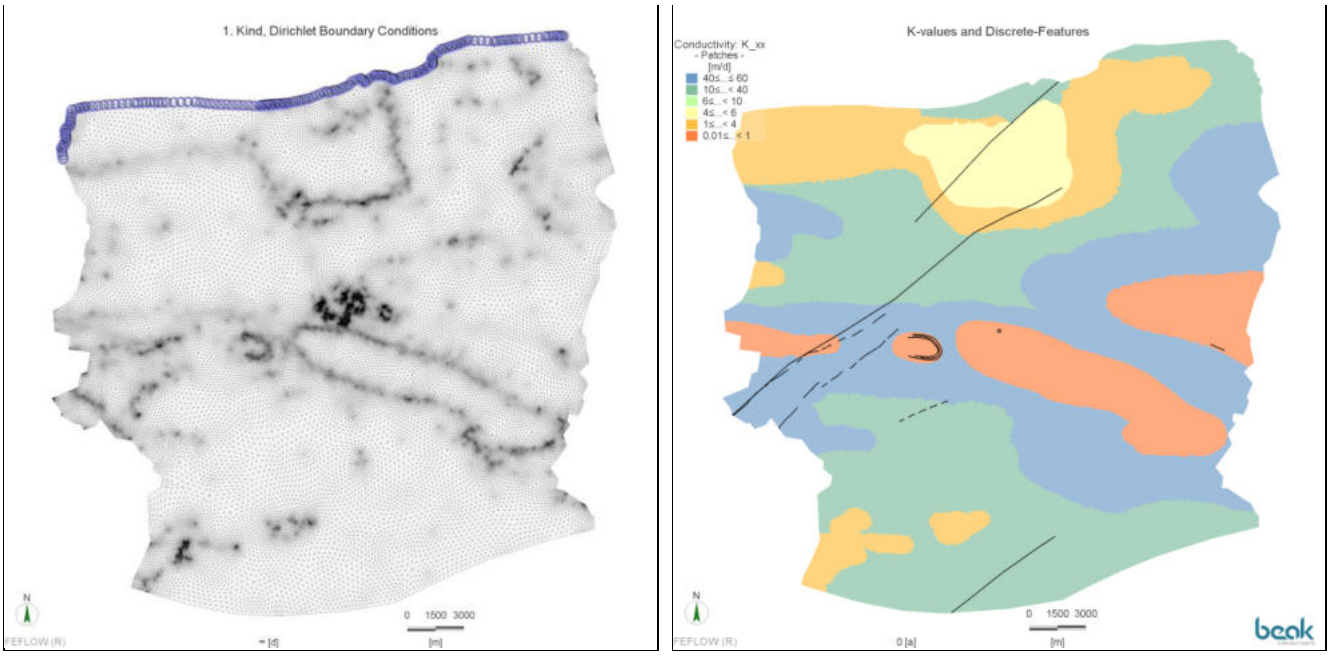

Figure 2-10: Boundary Conditions, Hydraulic Conductivity and Discrete-Features

2.7.3 Discrete-Feature Elements and Abstraction Wells

Discrete Features can be inserted in the model domain to represent high-conductivity features that can be approximated as one- or two-dimensional, such as:

- Conductive faults, fractures and fissures
- Horizontally screened wells
- Shafts, tunnels, pipes and drains

For the Tsumeb model, two different types of discrete-feature have been incorporated (see Figure 2-10):

- Regional faults and fractures were included as conductive lineaments as part of the Tsumeb-Subgroup,
- The Tsumeb No. 1 Shaft has been included as an assumed vertical shaft-feature-element with a diameter of 10 m and depth of 1700 m.

Information and estimations of the conductivity of faults and fractures within the predominantly dolomitic Tsumeb-Subgroup was sourced from Bardenhagen (2007), GKW Consult & BICON Namibia (2003), and Bittner (2005) where available. Thus, the conductivity of these features is elevated compared to the rocks in the vicinity by a factor of 1.

The No.1 Shaft was incorporated as open space with a discharge rate according to DPMT records. Since 2000, for operation of DPMT, 300 m³/h to 340 m³/h translating to 2.63 Mm³/a to 2.98 Mm³/a, respectively, is abstracted from the No.1 Shaft. Water pumped out of No.1 Shaft is from 235 - 250 m below surface. Additionally, other abstraction boreholes operated by the Tsumeb Municipality supply groundwater to the averaging approximately 2.3 Mm^3/a to Tsumeb residents.

A detailed groundwater abstraction data record of the No.1 Shaft starting from 2018 is available, it was incorporated into the model to simulate a time-varying abstraction rate. Figure 2-11 shows abstracted water volumes from the shaft and corresponding water levels. High groundwater abstraction from No. 1 Shaft was observed to correlate with decline of groundwater levels in the shaft. Similarly, lower monthly abstraction from 2019 have resulted in groundwater level increase in the shaft.

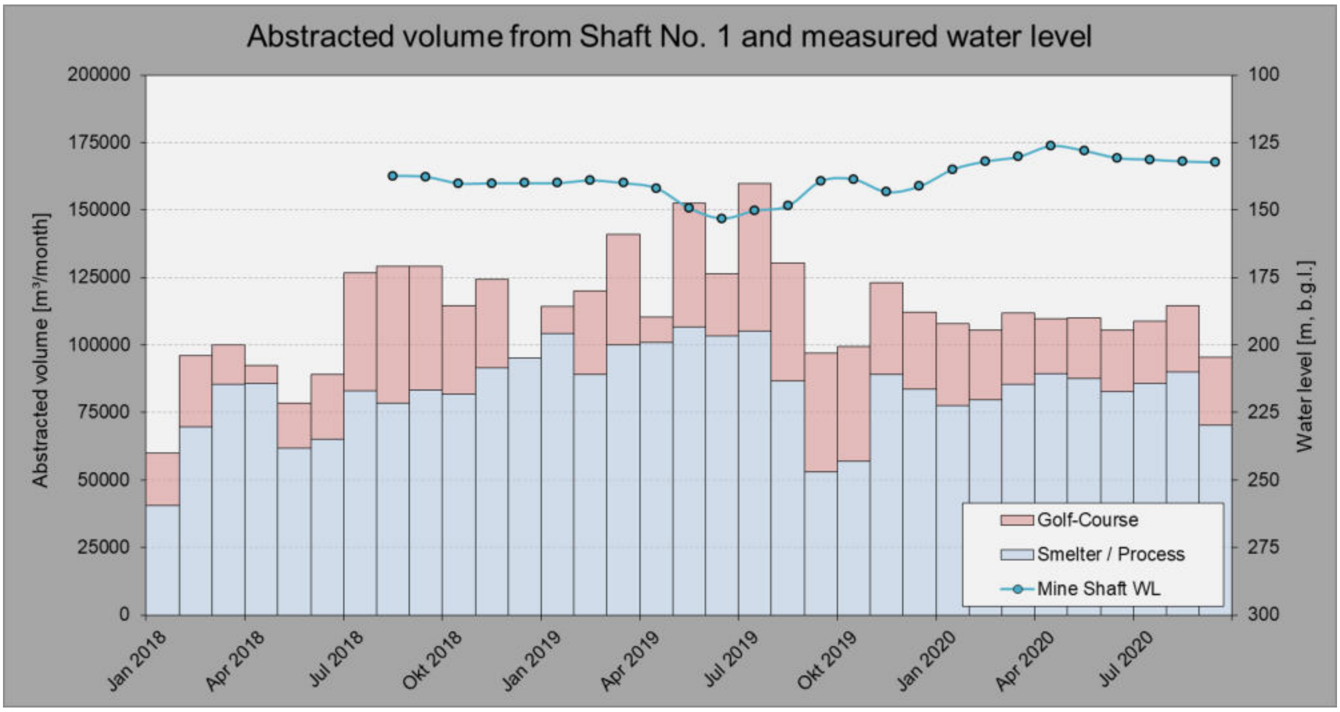

Figure 2-11: Abstracted volume from Shaft No. 1 and recorded water level, between 2018-2020

2.8 IMPACT OF WATER ABSTRACTION ON GROUNDWATER RESOURCES AND AQUIFERS

For the purpose of long-term prediction and an assessment of sustainable abstraction, the calibrated model was first calibrated for the period between 2017-2020. Then, the model was expanded in a way, that prediction results after 5, 10, 25, 50 and 100 years of abstraction from No.1 Shaft can be made. Following the current permitted volumes by DWA, an annual maximum abstraction rate of 1.3 Mm³ was applied. Recharge rates were implemented to range between 25% above and less than average recharge values. Abstraction from municipality and farming boreholes has been taken into account ranging between 6,251 and 15,561 m³/d.

Assumptions were made to best evaluate and predict how water levels would behave when abstracting water from the shaft under various conditions including a worst-case scenario of no recharge. In that regard, the time-steps and conditions were simulated to fulfil these requirements shown in Figure 2-12 to Figure 2-16 as well as tabulated in Table 2-4.

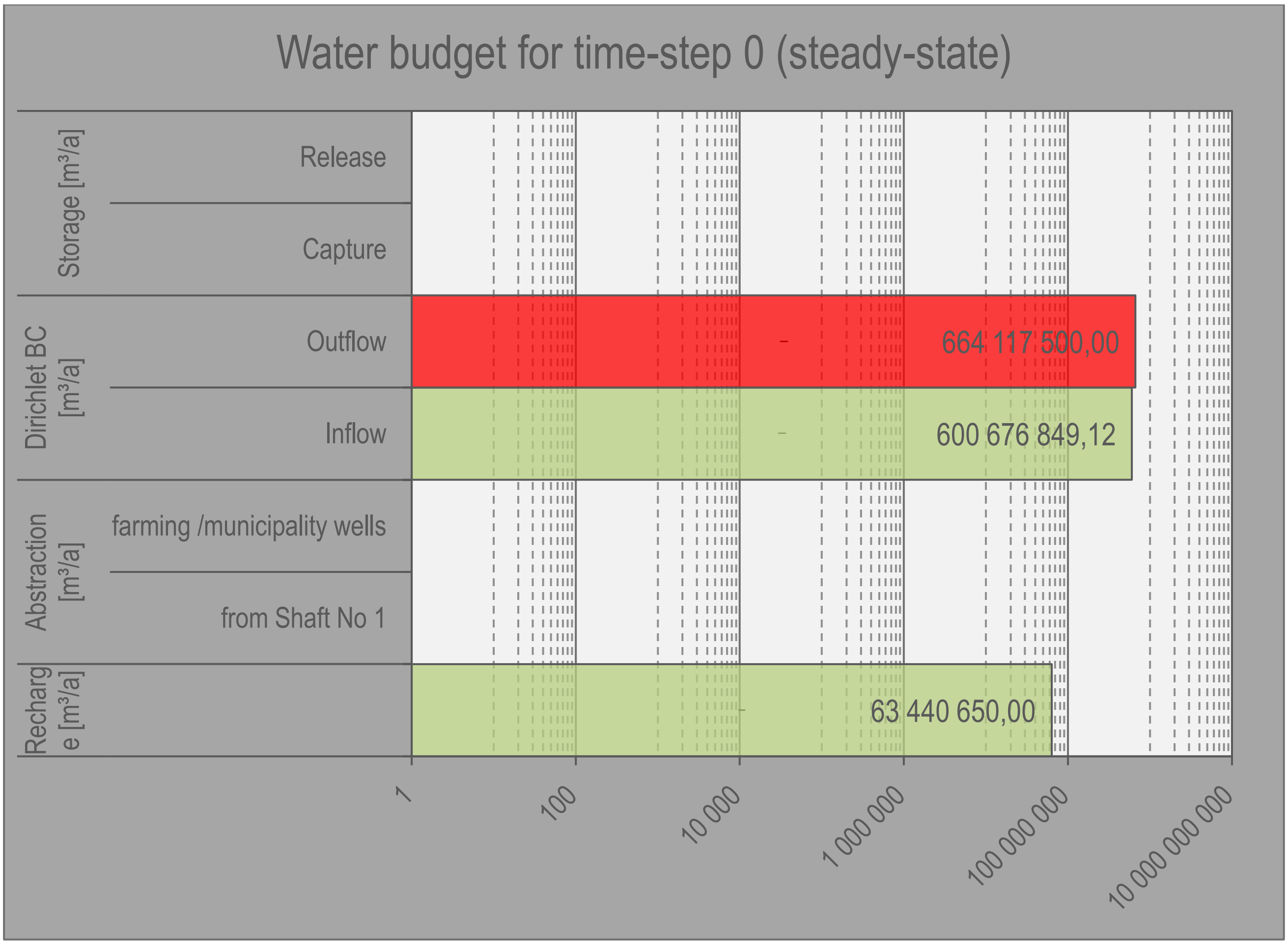

Figure 2-12: Water budget time-step 0 (steady state)

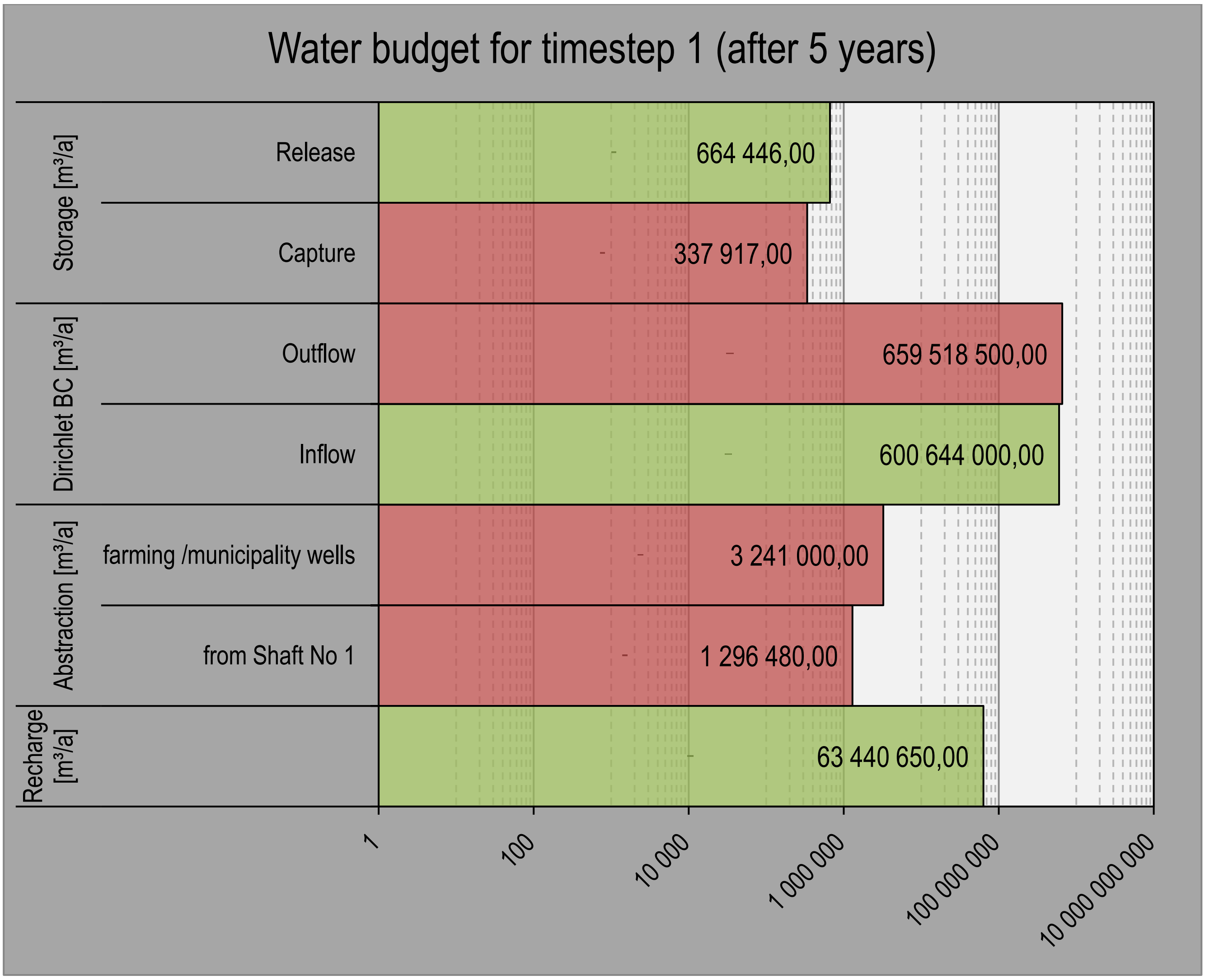

Figure 2-13: Water budget time-step 1 (after 5 years)

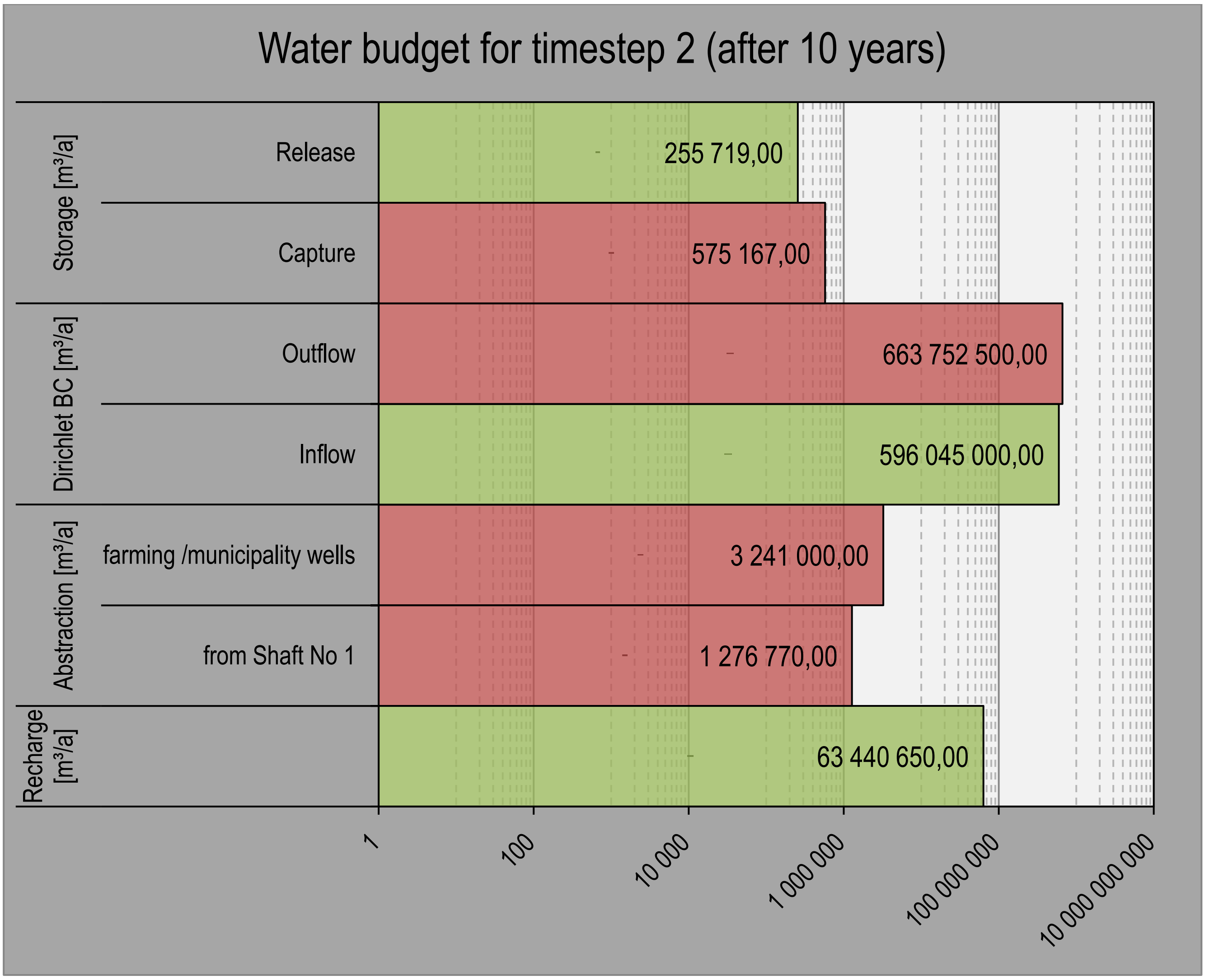

Figure 2-14: Water budget time-step 10 (after 10 years)

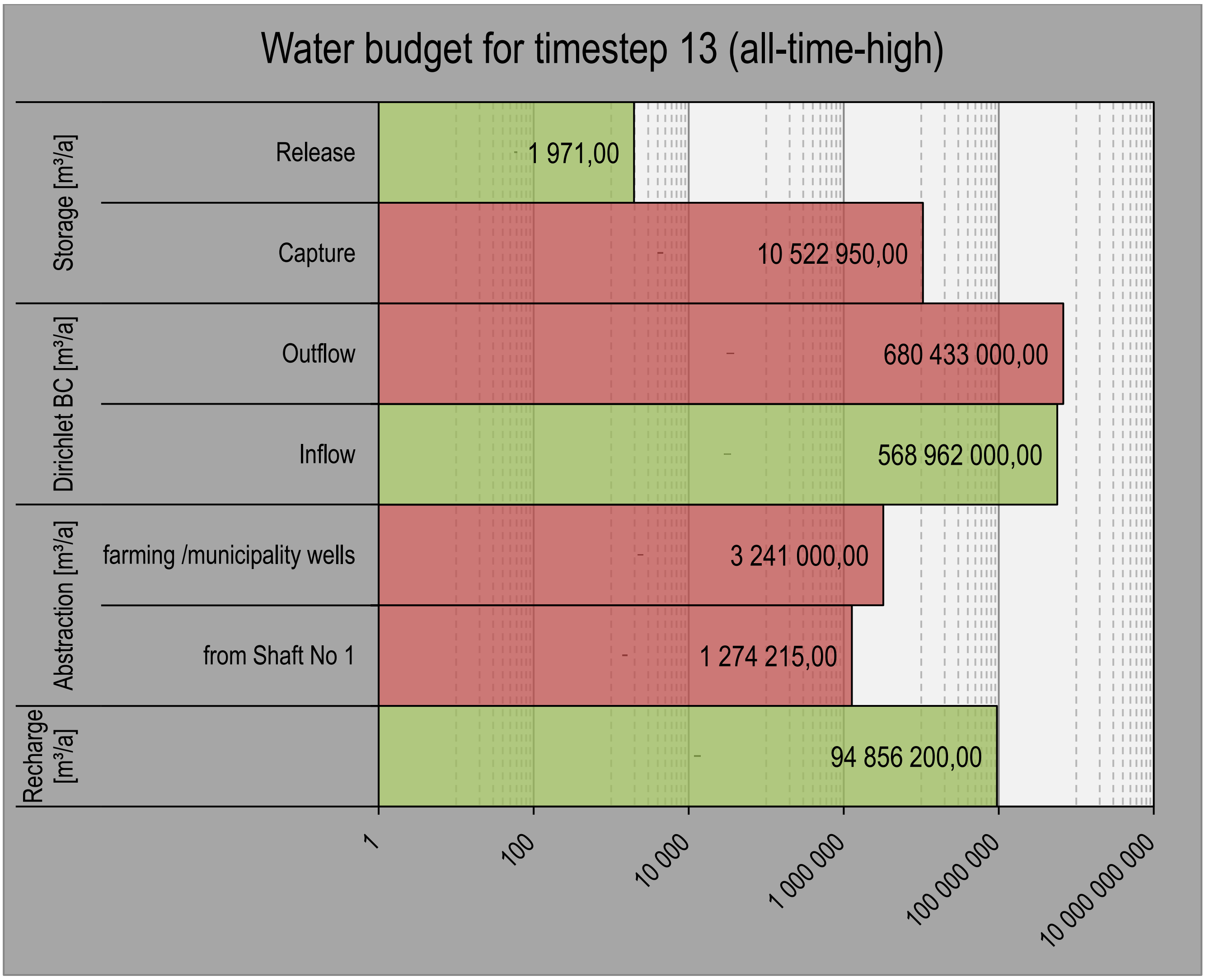

Figure 2-15: Water budget time-step 13 (all time high)

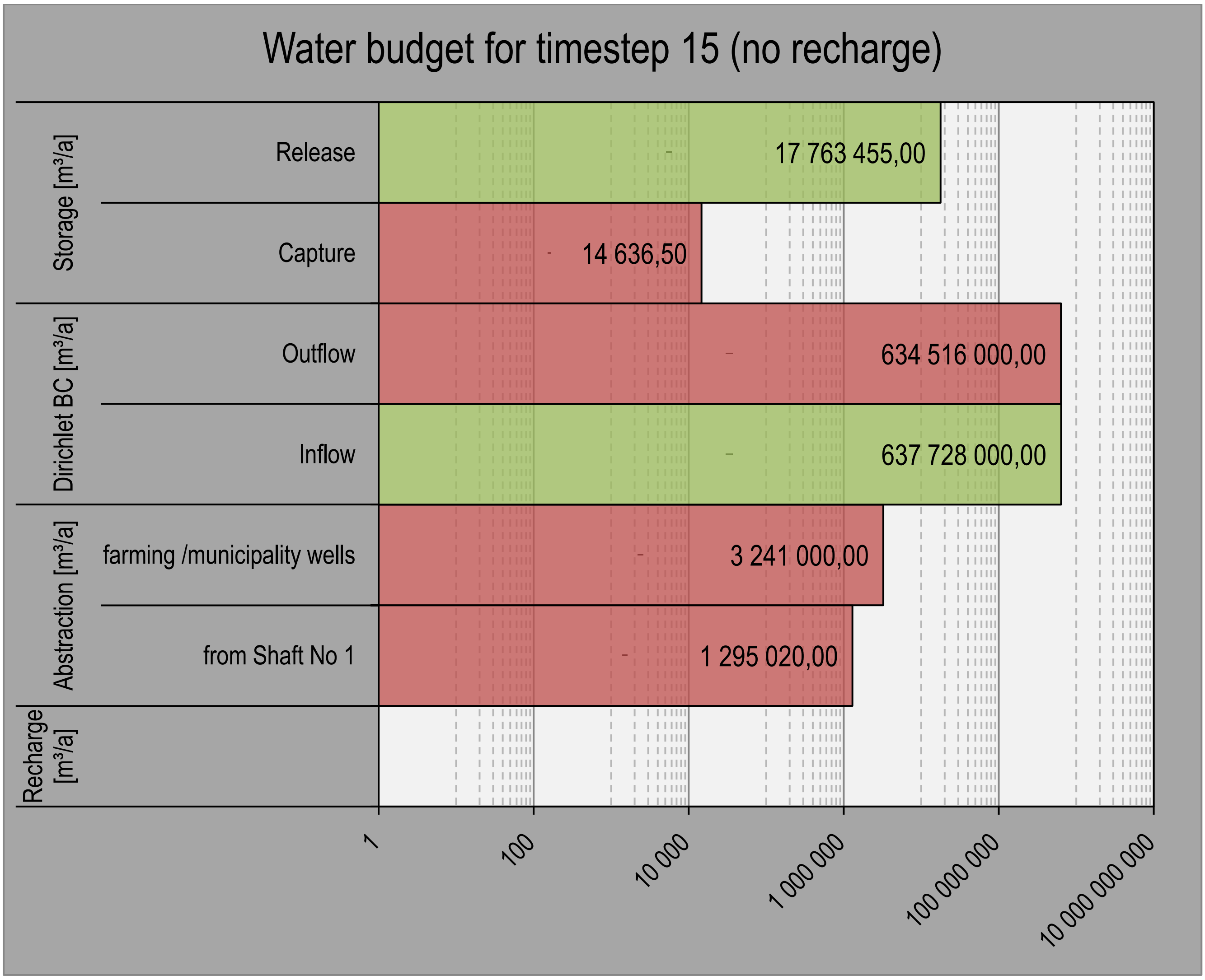

Figure 2-16: Water budget time-step 15 (no recharge)

Table 2-4: Implemented Time-Steps and simulated time-depending abstraction

Step No.	Simulated time [years]	Description	Recharge [m³/a]	Abstraction [m³/a]		Dirichlet BC [m³/a]		Storage [m³/a]	
				from Shaft No 1	farming /municipality wells	Inflow	Outflow	Capture	Release
0	∞	average conditions, initial water levels before abstraction started	63 440 650,00	-	-	600 676 849,12	664 117 500,00	-	-
1	5	average conditions	63 440 650,00	1 296 480,00	3 241 000,00	600 644 000,00	659 518 500,00	337 917,00	664 446,00
2	10	average conditions	63 440 650,00	1 276 770,00	3 241 000,00	596 045 000,00	663 752 500,00	575 167,00	255 719,00
3	15	average conditions	63 440 650,00	1 288 085,00	3 241 000,00	599 950 500,00	659 920 000,00	220 314,00	477 529,50
4	20	average conditions	63 440 650,00	289 910,00	3 241 000,00	596 629 000,00	663 387 500,00	422 195,50	183 861,45
5	25	average conditions	63 440 650,00	1 294 655,00	3 241 000,00	599 439 500,00	660 212 000,00	172 207,00	357 809,50
6	30	25% below average recharge, dry period	28 352 835,00	1 258 885,00	3 241 000,00	625 099 000,00	644 480 500,00	4 781,50	11 389 460,00
7	35	25% above average recharge, wet period	79 300 812,50	1 281 880,00	3 241 000,00	585 861 500,00	667 439 000,00	16 796 935,00	190 822,00
8	40	average conditions	63 440 650,00	1 273 120,00	3 241 000,00	606 338 000,00	657 803 000,00	746 644,00	3 663 140,00
9	45	average conditions	63 440 650,00	1 275 675,00	3 241 000,00	592 030 000,00	664 811 000,00	1 872 997,50	401 755,50
10	50	average conditions	63 440 650,00	1 300 860,00	3 241 000,00	603 345 000,00	658 934 500,00	419 166,00	1 011 123,00
11	55	average conditions	63 440 650,00	1 296 115,00	3 241 000,00	593 672 500,00	664 190 500,00	792 962,50	273 494,50
12	60	average conditions	63 440 650,00	1 275 675,00	3 241 000,00	602 250 000,00	659 445 500,00	290 726,15	575 240,00
13	65	50% above average recharge, all times-high	94 856 200,00	1 274 215,00	3 241 000,00	568 962 000,00	680 433 000,00	10 522 950,00	1 971,00
14	70	average conditions	63 440 650,00	1 280 785,00	3 241 00,00	613 857 000,00	653 569 000,00	182 062,00	12 009 595,00
15	75	no recharge, worst-case scenario	-	1 295 020,00	3 241 000,00	637 728 000,00	634 516 000,00	14 636,50	17 763 455,00
16	80	25% above average recharge, wet period	79 300 812,50	1 274 580,00	3 241 000,00	583 306 500,00	669 191 000,00	22 327 050,00	384 783,00
17	85	average conditions	63 440 650,00	1 282 610,00	3 241 000,00	607 396 500,00	657 219 000,00	1 081 933,00	5 813 355,00
18	90	average conditions	63 440 650,00	1 301 225,00	3 241 000,00	593 015 500,00	664 993 500,00	2 717 936,00	505 342,50
19	95	average conditions	63 440 650,00	1 295 750,00	3 241 000,00	602 031 000,00	658 825 000,00	507 605,50	1 322 066,50
20	100	average conditions	63 440 650,00	1 299 035,00	3 241 000,00	595 205 500,00	664 190 500,00	971 009,50	282 619,50

Appendix A to Appendix G show the highlighted results from the table above while Figure 2-17 shows the cone of depression after five (5) years with no recharge. Simulated model results show that

- There is no big change in water levels due to abstraction from the shaft this is attributed to high aquifer potential. Further, a worst-case prediction scenario with no recharge does not lead to very low water levels if the period is followed by a period of average recharge again after 5 years.
- The cone of depression (see Appendix H & Figure 2-17) is showing a relatively small extent and is restricted to ± 500 m to each direction from the shaft. Thus, a constant water abstraction of 3,552 m³/d or likewise aproximatelly 1,300,000 m³/a from Shaft No. 1 is regarded as being sustainable.

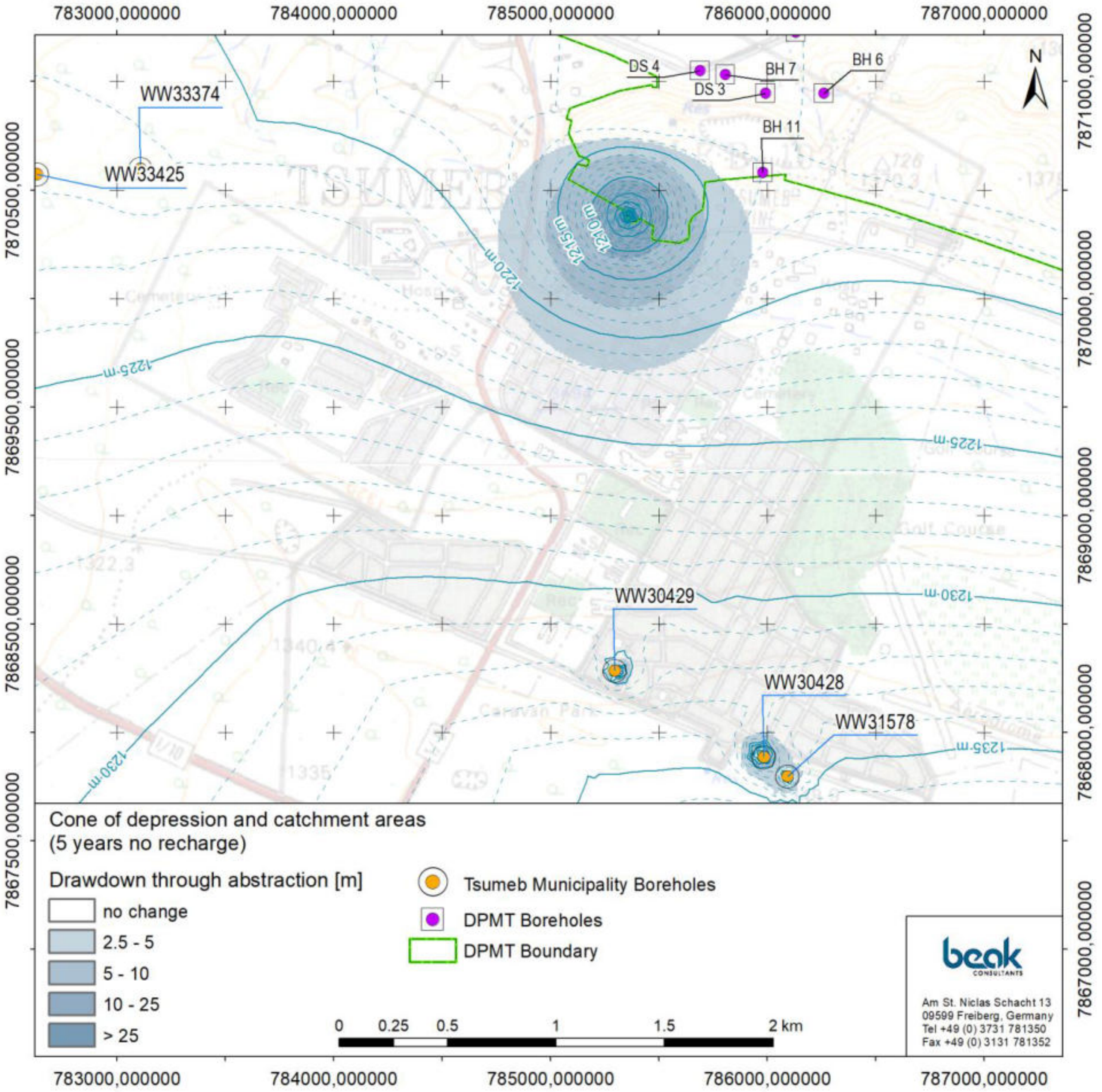

Figure 2-17: Cone of Depression and Catchment Areas (5 Years no Recharge)

2.8.1 Well catchments

Particle tracking in combination has been applied to evaluate the flow paths. Starting locations were set at abstraction wells and they were calculated with the backward method (see Appendix H and Figure 2-18). From each location a number of pathlines indicate the flow field. The catchment area of the shaft is restricted to the Hüttenberg Formation. What is observed is that the shaft has a much wider flow field compared to the municipal borehole.

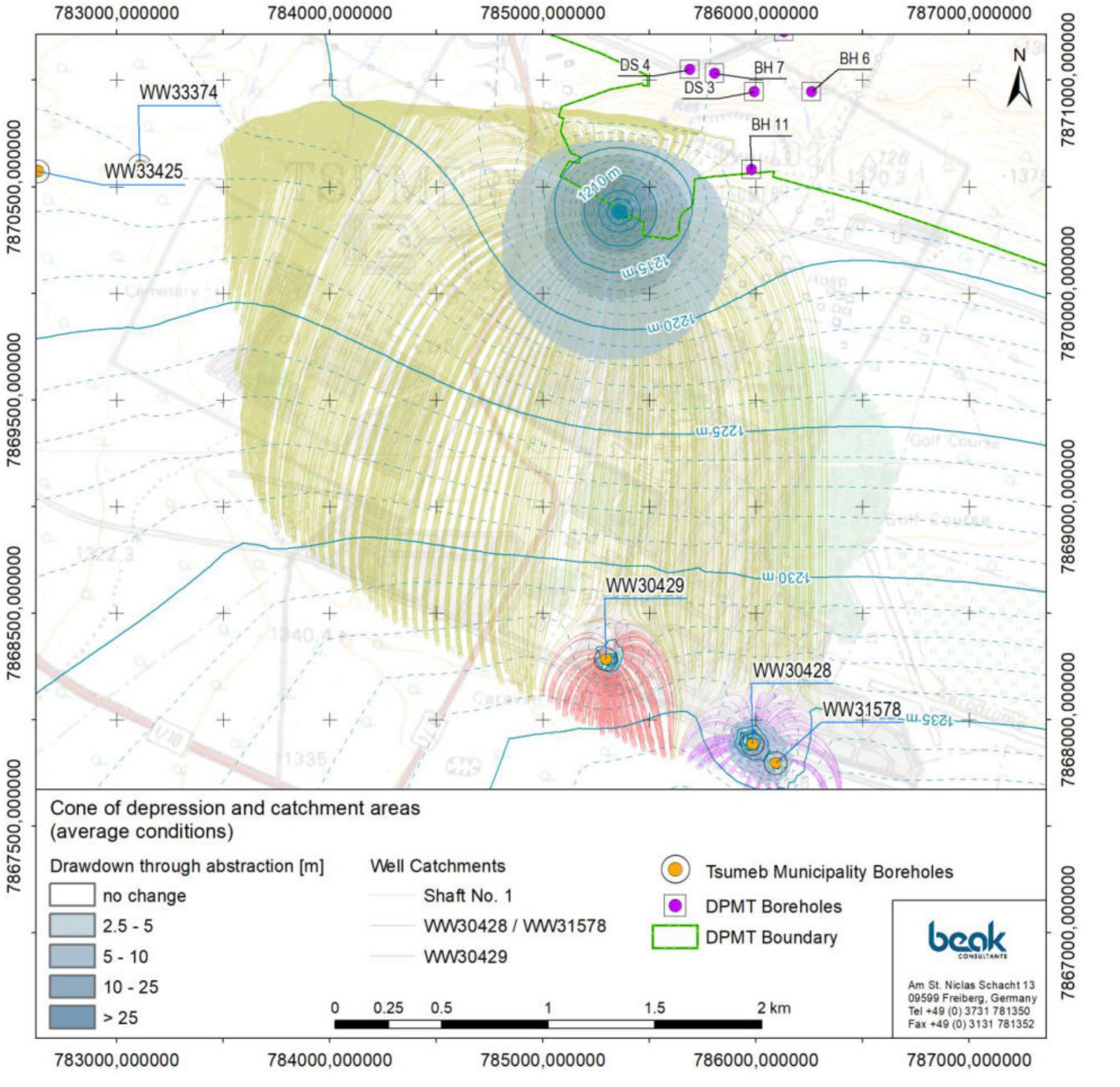

Figure 2-18: Cone of Depression and Catchment Areas from Shaft No. 1 and Tsumeb Municipality Boreholes

3. UPDATE OF GROUNDWATER CONTAMINATION POTENTIAL

3.1 HYDROCHEMICAL DATA

In line with the constant water level monitoring, DPMT is carrying out a separate hydrochemical sampling. The samples are sent to external laboratories for detailed analytics. A range of parameters are analysed for of which those with significance in terms of contamination/pollution will be discussed. For limits from the Namibia Water Quality Guidelines and Standards for Potable Water (Water Act No. 13 of 2014) for the parameters of interest are in Table 3-1.

Table 3-1: Extract from the Water Quality Guidelines and Standards for Potable Water

Determinant	Units	Ideal guideline	Acceptable standard
		Ranges and upper limits Interpretation	
Arsenic	mg/litre	<0.01	<0.05
Cadmium	mg/litre	<0.005	< 0.01
Sulphate	mg/litre	100	< 300
Sodium	mg/litre	< 100	< 300

The observations summarising the important elements with significantly elevated concentrations are as follows:

- Elevated Na and sulphate, which is probably originating from the Arsenic (*As*) / Calcine legacy slag site,
- Elevated cadmium (*Cd*) near the Calcine legacy slag site,
- High concentration of As and molybdenum (*Mo*) in all on-site boreholes, with peak concentrations near the Calcine legacy slag site.

However, potential contaminant sources currently related to the site include more than 100 years of smelter operations with two (2) tailings dams and various storage areas of slag and calcine. It appears that runoff from the site has, occasionally, accumulated away from the site, acting as an additional (secondary) source of groundwater contamination. On site, *As* is regarded to be the most important potential contaminant both in terms of potential length of transport and hazardousness. Figure 3-1 is showing *As*-concentration between 2019-2020. Towards the beginning of 2020 an increase of *As* was observed in boreholes DS-36, BH14, and BH10. This increase is as well observed to correlate with Sulphate (SO_4) concentrations.

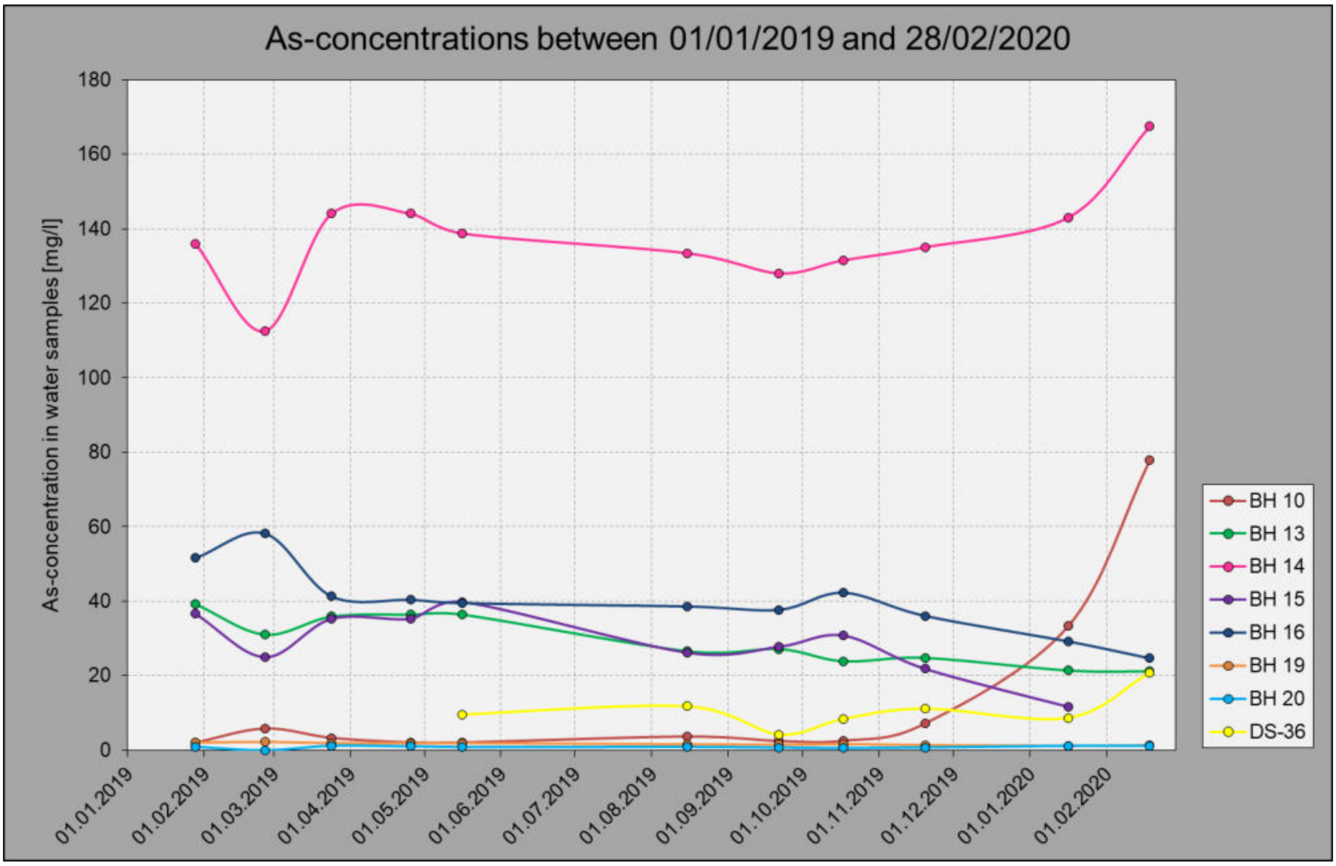

Figure 3-1: Arsenic-concentration between 2019-2020 for selected DPMT monitoring boreholes

However, it is important to view the groundwater quality monitoring results against some background values for the larger karst region, specifically when looking at arsenic pollution. Data from wider area studies do indicate elevated arsenic concentrations in areas not previously affected by mining which may be reflective of naturally high background arsenic levels in the geology.

The Clarke -Value which is the natural concentration of elements in the earth's crust is generally used to distinguish between natural and anthropogenic concentrations. To that effect it was used to distinguish between those boreholes that have been affected by pollution and water from boreholes which only shows natural (geogenic) background concentration in Figure 3-2 were a scatter-plot was produced, showing Arsenic against Sulphate concentrations. It should be observed that samples collected from 2019-2020 are above the Clarke – Value and thus represent an anthropogenic source of arsenic. Some samples were also observed to plot below detection limits. However, due to different detection limits from the laboratories that were used to analyse the samples, a clear distinction between detection limits was observed through the scatter plot.

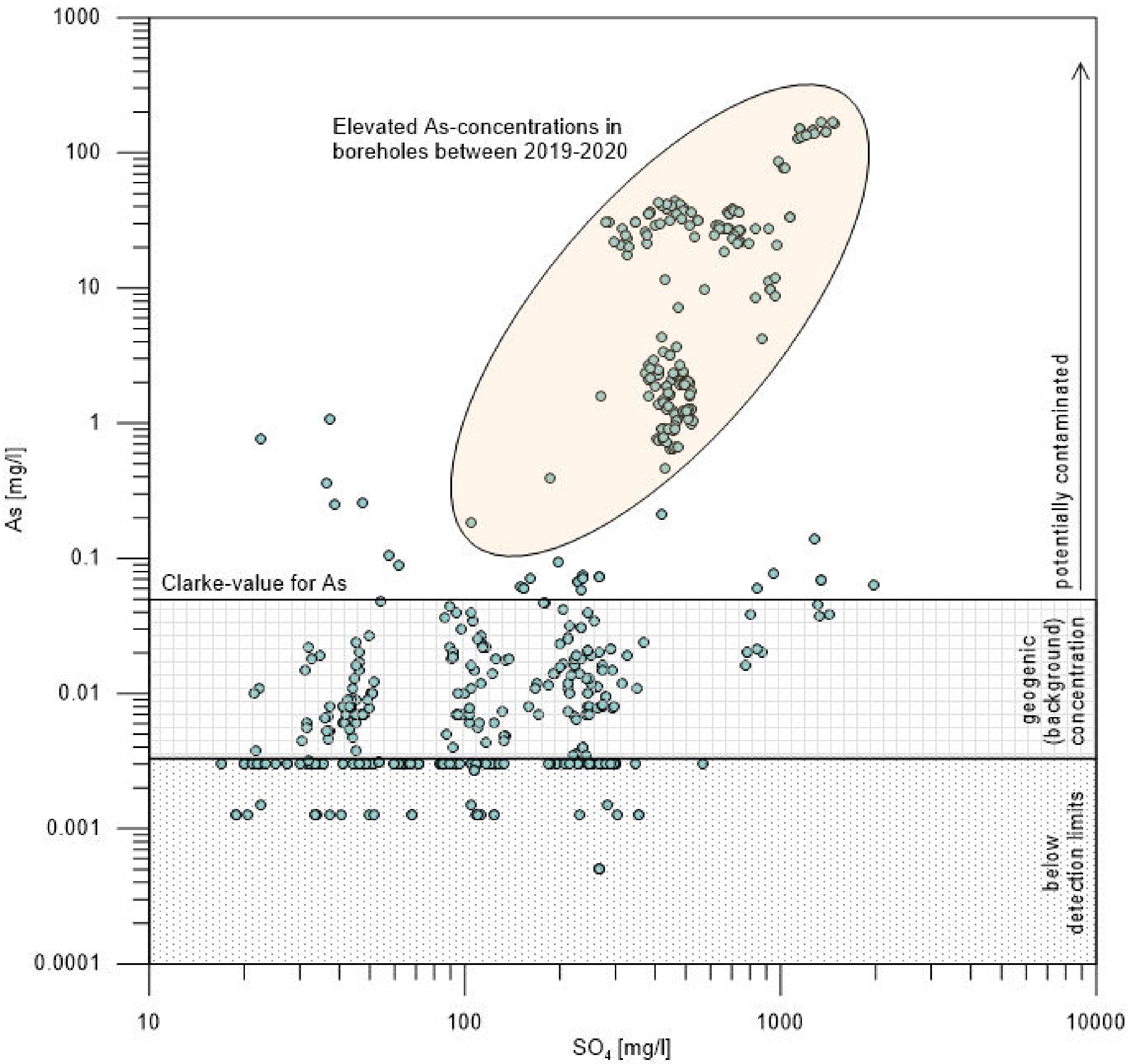

Figure 3-2: Scatter-plot of Arsenic against Sulphate concentrations

3.2 REACTIVE TRANSPORT

A reactive transport model predicts the distribution in space and time of the chemical reactions that occur along a flowpath. Different processes lead to the reduction of elevated metal concentrations and these were incorporated in the model:

- Dispersion / Diffusion (simple processes when contaminated water mixes with fresh water which naturally leads to dilution);
- Advection (transport of contaminants dissolved in water in flow direction);
- Sorption (fixation of contaminants onto e.g. soil particles); and
- Reaction (process in which one or more contaminants are converted to one or more different substances).

To calculate all possible reactions, all analytical results have been imported into the software AquaChem. First of all, Figure 3-3 shows the basic composition of both contaminated and fresh water in the vicinity of the DPMT. This knowledge of the general water characteristics is essential for understanding the later reaction processes.

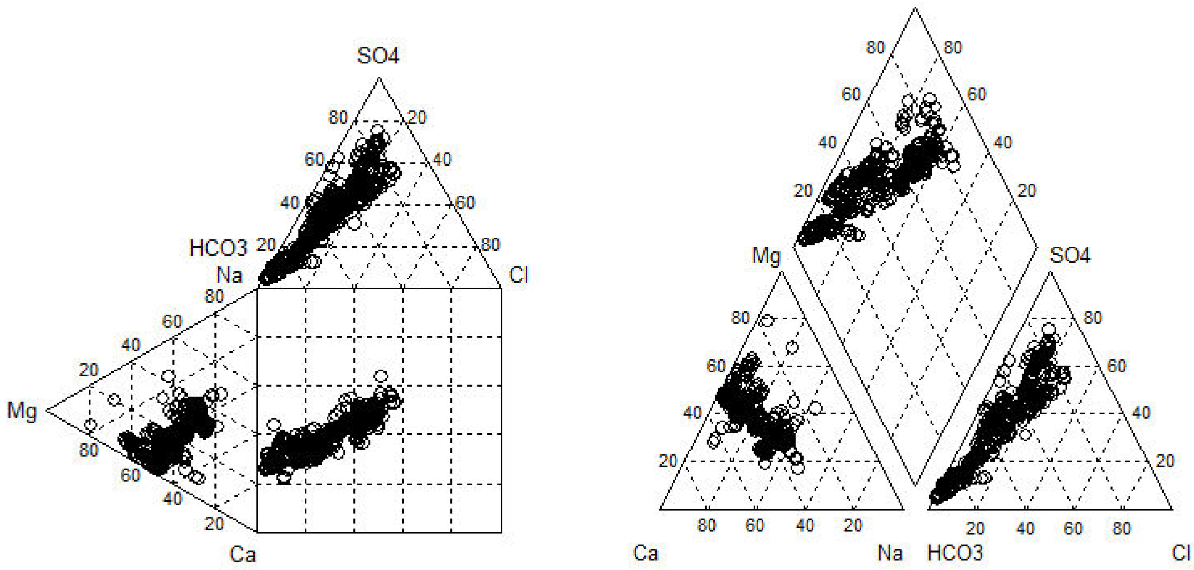

Figure 3-3: Durov- and Piper plot of hydrochemimcal analyses from DPMT boreholes

As there are boreholes that show signs of contamination (see Figure 3-3) different from boreholes with natural conditions, it was possible to summarise the quality of pure natural water in the area. The average of these natural conditions form the baseline and have been uploaded into the software PhreeqC as “freshwater”.

In PhreeqC, the contaminated water at each of the relevant sources were mixed with the average baseline or “freshwater” conditions. Taking average flow velocities and aquifer conditions into account, the reduction of Arsenic due to reaction processes was then calculated (see Figure 3-4). It is observed that most chemical species reduce towards equilibrium about 2 km from the pollution source with arsenic species having a higher tendency of being produced thereby reducing arsenic concentration significantly as the plume migrates.

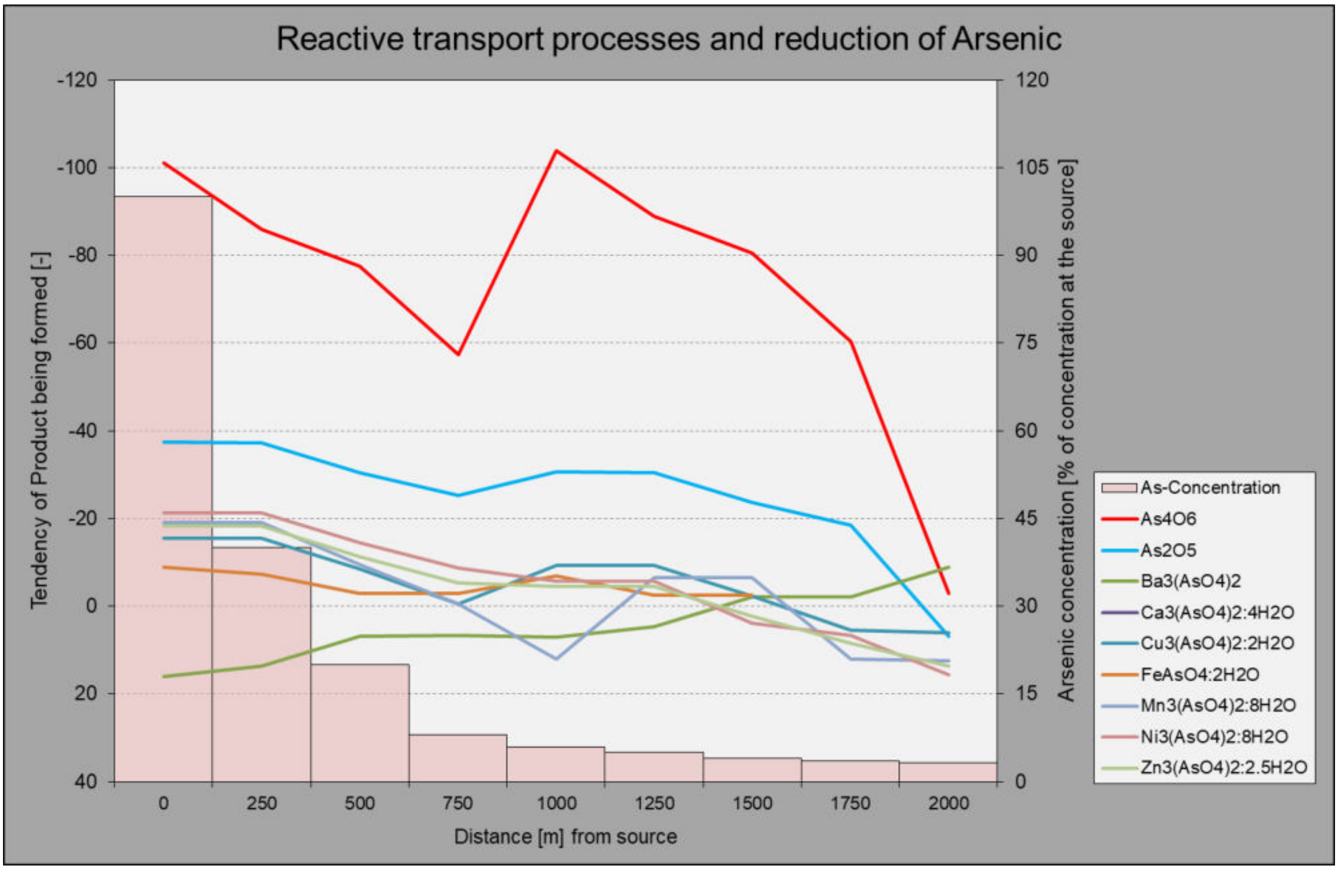

Figure 3-4: Reaction processes and reduction of Arsenic along average flow direction and velocities

3.3 CURRENT POLLUTION PLUME

Under the 2018 model update no specific source concentration was modelled and the plumes are illustrated in percentages of the relative source concentration. The following is summarised about the potential pollution plume from the SLR (2018) model report:

- After 10 years, the plume was predicted to spread mainly towards the general flow direction and concentrations decrease rapidly over a short distance.
- After 25 years, the plume was predicted to spread mainly in the general flow direction to the north of the Tsumeb Smelter site. After approximately 800 m, the contaminant concentrations drop to general background concentrations.
- After 100 years, at a maximum distance of around 3.2 km from the origin concentrations drop to below 5% of the initial concentration. Although, the plume is spreading further towards the northeast, concentrations do not change, in general (this scenario represents most likely the current situation).

For the actual behaviour of the pollution plume under the current conditions, which were rebuilt in the model, PhreeqC was coupled with FeFlow. Relevant transport processes were calculated with PhreeqC and were automatically transferred to FeFlow and vice versa. Appendix I shows the calculated contamination plume under current conditions. The calibration of the reactive transport model was based on real values, which have been detected and analysed in DPMT monitoring boreholes. This included the inclusion of information from additional monitoring boreholes that were recently drilled following a recommendation from SLR (2018). Since some monitoring boreholes do not show any signs of contamination, the potential pollution sources had to be adjusted and are thus not comparable to the previous model solution. The following are a summary of the status of the current pollution plume shown in Figure 3-5:

- Pollution sources have been outlined more accurate and precise with the plume stretching only 2 km to the northeast as opposed to the 3 km estimated in the 2018 model update. Thus, only parts of the active tailings dam, the evaporation ponds, the arsenic /calcine legacy site and parts of the smelter site are regarded as pollution sources at this stage.
- All others including the eastern tailings dam as well as the hazardous waste disposal site do not show any signs of pollution, hence they could not be regarded as source, unlike in the previous 2018 model update.
- Because arsenic was taken to be the most hazardous and mobile contaminant, only an *As*-plume has been depicted (see Appendix I). It should be noted that besides the fact that arsenic is amongst all contaminants the most mobile, it is reduced relatively fast. 1 km from the source (e.g. As 380 mg/l), there is only an arsenic concentration of below 4 mg/l detectable. Beyond this, As-concentrations are dropping then relatively fast to natural background concentrations.
- The calculated plume extent fits very well to observed arsenic concentrations and confines the current plume within the DPMT property (see Appendix I).

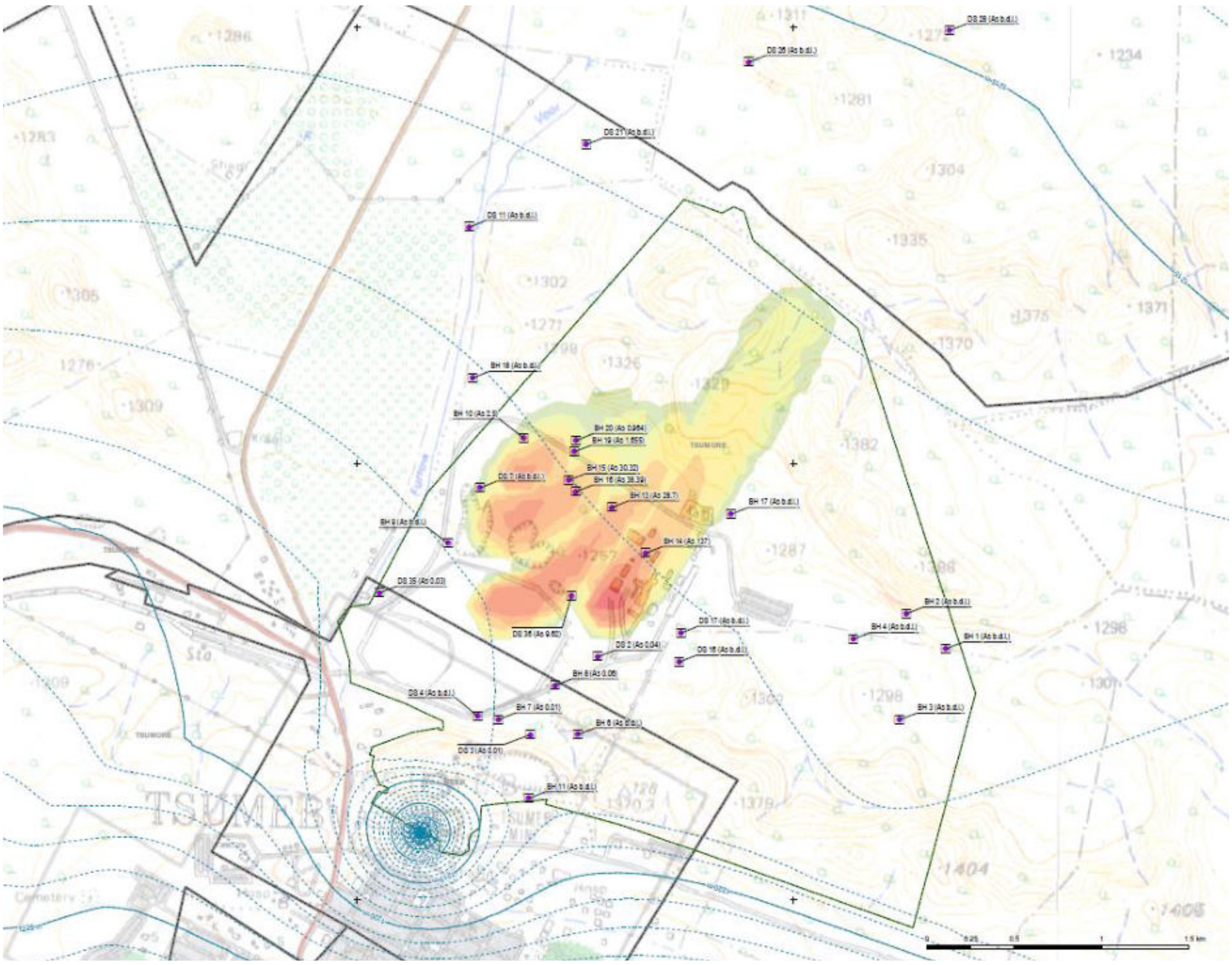

Figure 3-5: Contamination Plume current conditions

4. CONCLUSIONS

SLR Environmental Consulting (Namibia) (Pty) Limited (SLR) together with Beak Consultants GmbH (BEAK)was appointed by Dundee Precious Metals Tsumeb (Pty) Limited (DPMT) to firstly update the existing 3D groundwater flow model to simulate sustainable abstraction from Shaft No. 1 to support permitted groundwater abstraction, and secondly to extend the transport model solution to a reactive transport solution to estimate a more realistic plume extension around the DPMT operations.

As a result of the 2020 model update, the following is concluded in terms of simulating sustainable abstraction from Shaft No. 1:

- There is still an uncertainty with water volumes which are abstracted by farmers and other users.
- Drawdown and abstraction from the shaft and municipality wells can be observed in the model, but only has a local impact on groundwater levels.
- Groundwater abstraction does not have a significant impact on regional groundwater levels, due to the high potential of the aquifer.
- The maximum radius of influence from abstraction of 1.3 Mio m^3/annum is approximately 500 m. Thus, aimed abstraction (roughly 1.3 Mm^3/a) from the shaft is predicted to be sustainable.
- The hazardous waste disposal site is located close to the cone of depression from the shaft and thus could have impact on groundwater levels to the south west of the site where currently no monitoring boreholes exists to validate influence from pumping at the shaft.

As a result of the 2020 model update, the following is concluded in terms of extension of the 2018 transport model solution to a reactive transport solution to estimate a more realistic plume extension around the DPMT operations:

- Only parts of the active tailings dam, the evaporation ponds, the arsenic /calcine legacy site and parts of the smelter site are regarded as pollution sources at this stage.
- All others including the eastern tailings dam as well as the hazardous waste disposal site do not show any signs of pollution, hence they could not be regarded as source, unlike in the previous 2018 model update.
- Although there is currently no pollution detected in the shaft from the DPMT operations, there is a risk of contamination to the shaft from the hazardous waste site that is located close to the cone of depression induced by abstraction.
- Arsenic is amongst all contaminants the most mobile, it is reduced relatively fast; 1 km from the pollution source (e.g. As 380 mg/l) and there after only an arsenic concentration of below 4 mg/l detectable. Beyond this, arsenic concentrations are dropping then relatively fast to natural background concentrations.

5. RECOMMENDATIONS

The following recommendations are arising from the groundwater contamination potential investigations:

- Water abstraction is subject to variables and thus needs to be reviewed on an annual basis. Water levels monitoring should also include the Dewet Shaft for future correlation of any potential impact of abstraction from No.1 Shaft.
- The numerical groundwater flow and contaminant transport should be updated regularly to support the abstraction permit renewal.
- Although there are no signs of contamination in the shaft at this stage, the groundwater quality in the shaft should continue to be monitored on a Quarterly basis (especially after longer dry periods when simultaneously abstracting water from shaft).
- It is strongly recommended to have drill one (1) additional monitoring boreholes between the hazardous waste disposal site and the shaft (Figure 5-1).
- Additional three (3) monitoring boreholes, downstream the pollution sources are strongly recommended to further monitor the plume and validate the wider extent of the 2018 potential plume (Figure 5-1).
- Considering the extent of the current plume, groundwater level and quality monitoring should be revised and streamlined to allow for effective monitoring and analysis of groundwater samples. Further, a schedule for monitoring should be maintained in order to ensure a consistent record keeping that will set a standardised evaluation or interpretation of data especially in terms of external laboratories, analysis methods and detection limits.

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Markus Zingelmann (BEAK) & Winnie Kambinda (Report Author)	**Winnie Kambinda** (Project Manager)	**Arnold Bittner** (Reviewer)

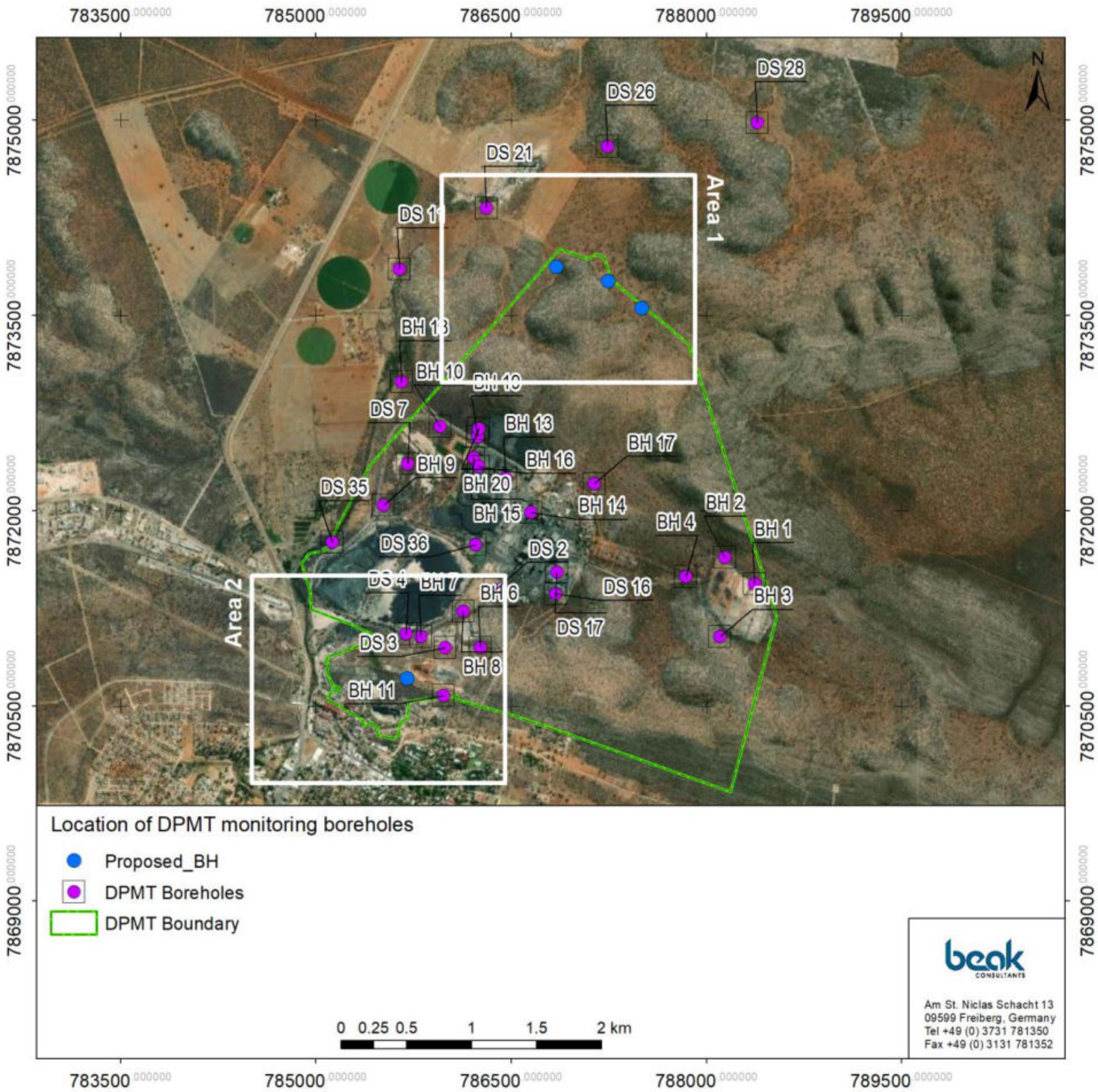

Figure 5-1: Recommended additional monitoring boreholes at DPMT

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Appendix A: Prediction after 5 years from today (Map Scale 1:25,000)

Appendix B: Prediction After 10 Years from Today (MAP SCALE 1:25,000)

Appendix C: Prediction After 25 Years from Today (MAP SCALE 1:25,000)

Appendix D: Prediction After 50 Years From Today (MAP SCALE 1:25,000)

Appendix E: Prediction After 100 Years from Today (MAP SCALE 1:25,000)

Appendix F: Prediction All Times High (MAP SCALE 1:25,000)

Appendix G: Prediction with no Recharge (MAP SCALE 1:25,000)

Appendix H: Well Catchments and Impact of Water Levels Due to Abstraction from Shaft No. 1

Appendix I: Current Contamination Plume

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SINOMINE TSUMEB SMELTER

BI-ANNUAL ENVIRONMENTAL PERFORMANCE REPORT, JANUARY – JUNE 2024

Based on:

Tsumeb Smelter Expansion Project -
Consolidated Environmental Management Plan of 2019

Report Number: RR012024

JULY 2024

Table of Contents

1 Introduction

The Tsumeb Smelter is owned and operated by Sinomine Tsumeb Smelter (herein referred to as STS). The Smelter is located on the outskirts of the Town of Tsumeb in the Oshikoto Region and approximately 2 km northeast from the town centre. The location and boundary of the Tsumeb Smelter is shown in Figure 1. The smelter produces blister copper and sulphuric acid as a by-product.

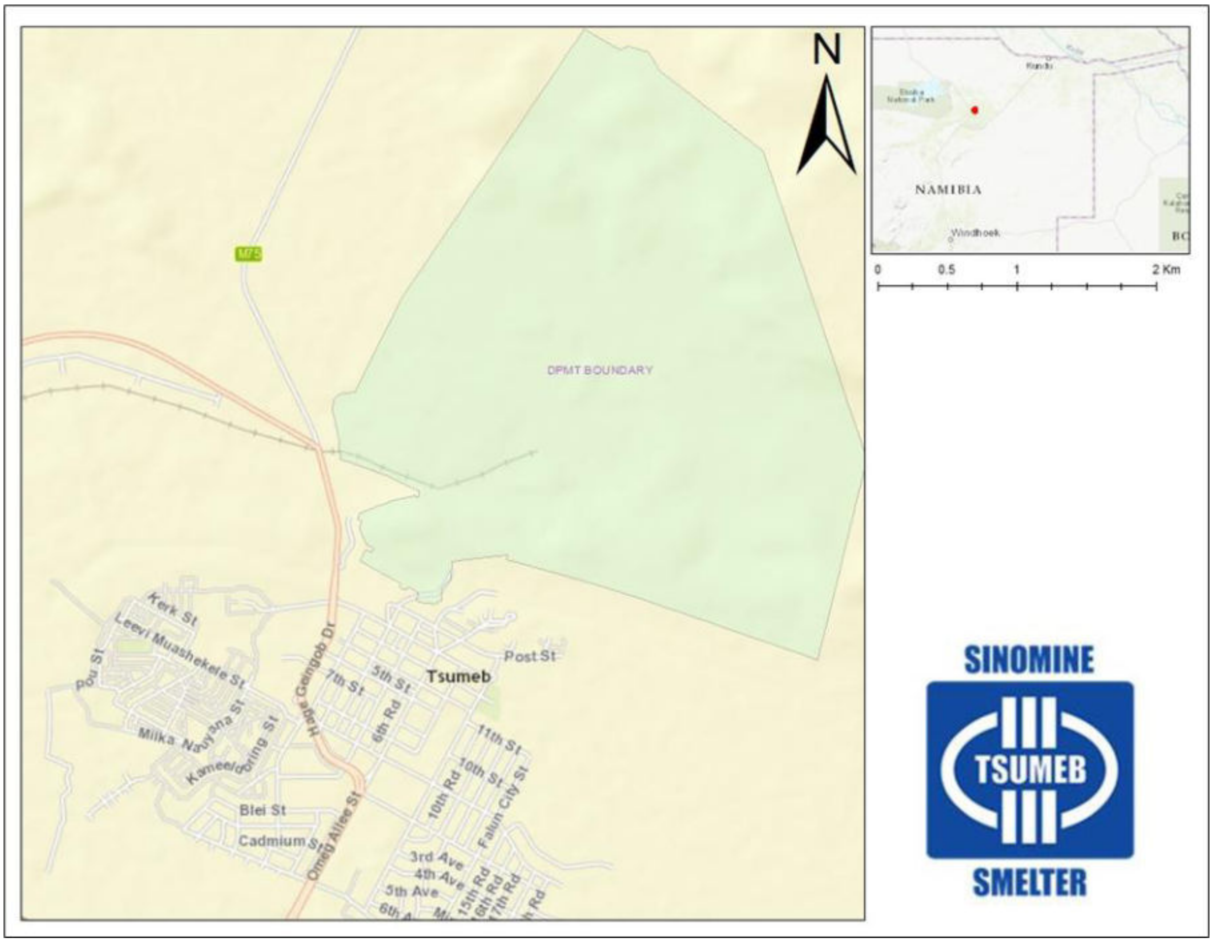

Figure 1: Location and Boundary of the Tsumeb

In 2016, The Tsumeb Smelter appointed SLR Namibia (Pty) Ltd to undertake an environmental and social impact assessment for the purpose of amending the then environmental clearance certificate to cover the smelter operations, consolidate separate clearance certificates of related activities and include the proposed smelter expansion and optimisation project.

The smelter expansion and optimisation project cover the current operational smelter infrastructure as well as proposed additional infrastructure to be implemented phase by phase with the overall goal to increase production throughput from 240,000 tpa to 370,000 tpa of copper concentrates. The proposed expansion is to be contained within the existing facility footprint and includes the following components:

- Upgrading of the existing ausmelt feed and furnace;
- Installation of a rotary holding furnace (RHF);
- Implementation of slow cooling of the RHF and converter slag;
- Upgrading of the slag mill to improve copper recovery and handle the increased tonnage from slow cooled slags;
- Molten slag granulation
- Installation of an additional Peirce-Smith (PS) converter; and
- Additional related infrastructure improvements (power supply, etc.).

The Environmental and Social Impact Assessment Report (including the Environmental Management Plan) was originally approved in December 2019 and has been renewed twice to date. The current environmental clearance certificate, as shown in Figure 2, was issued in January 2023 and is valid until 17 January 2026.

ECC – 2300075 Serial: 23eMWeK75

REPUBLIC OF NAMIBIA
MINISTRY OF ENVIRONMENT, FORESTRY AND TOURISM
OFFICE OF THE ENVIRONMENTAL COMMISSIONER

ENVIRONMENTAL CLEARANCE CERTIFICATE
ISSUED

In accordance with Section 37(2) of the Environmental Management Act (Act No. 7 of 2007)

TO

Dundee Precious Metals Tsumeb (Pty) Ltd
P . O. Box 936, Tsumeb

TO UNDERTAKE THE FOLLOWING LISTED ACTIVITY

Smelter Operation and Related Activities Including Proposed Smelter Expansion Project, Tsumeb, Oshikoto Region

Issued on the date: 2023-01-17
Expires on this date: 2026-01-17

ENVIRONMENTAL COMMISSIONER

(See conditions printed over leaf)

This certificate is printed without erasures or alterations

Recycle

Figure 2: Environmental Clearance Certificate for Smelter Operation and Related Activities including Proposed Smelter Expansion Project

This report provides an update on the overall environmental performance as well as providing implementation status and progress of the specific approved mitigation measures.

2 Environmental Performance Highlights

2.1 Construction Activities Management

As indicated in the introduction section, the construction and installation of new infrastructure as part of expansion component, are implemented in phases. To date, construction activities have not commenced yet, however mitigation measures are being incorporated into designs

2.2 Stakeholder Engagement

2.2.1 Stakeholder Engagement Plan

Tsumeb Smelter implemented a Stakeholder Engagement Plan (SEP) developed in line with the Stakeholder Engagement Framework. The plan assists the company to manage and facilitate current and future engagements through the various stages of the operations (including projects), and through to the closure.

The SEP adopts an inclusive life-of-operation perspective. This version of the SEP is an initial guide for engagements and will be revised when necessary and depending on the phase of the operation and when new information or studies (from Social Management Plan, Environmental Management Plan, etc.) become available, to inform ongoing stakeholder engagement through the various stages of the operation. The diagram below, illustrates the stakeholder engagement process flow.

2.2.2 Community Relations and Grievances

The Tsumeb Smelter engages community members through various platforms including the monthly meetings with the Tsumeb Municipality and local forums such as the Education clusters, Health and Security Forums. One such example is the Education clusters meeting held with principals and teachers to launch the Education Optimization project which culminated into the selection of various stakeholders to work groups, to drive the envisaged projects. The Executive Leadership townhall sessions were not resumed during the reporting period, however various engagements were held with community groups to discuss the future of Tsumeb Smelter as per the current sale processes, community development needs, community concerns and Smelter performance.

Community members, both within the town and farming communities, queried about various processes or aspects related to Tsumeb Smelter operations.

The queries received and addressed include:

- General Donations process
- Strategic transition of Dundee Precious Metals Tsumeb (DPM Tsumeb) to Sinomine Tsumeb Smelter
- Community Development Projects such as the Agri-Hub Project
- Job and internship opportunities
- Opportunities to partner on community projects
- Sulphur Dioxide (SO_2) emissions related complaints

2.2.3 Social Management Plan

One of the main outcomes of the social impact assessment was the preferential consideration of opportunities for Tsumeb community. As a result, this requirement was incorporated into on-going community investment activities. Engagements with local community groups have increased and relationships established. To continue with the social investment and subsequently maintain the social license to operate, the Tsumeb Agri-Hub project is significant in that various community members have been enlisted to work on the land earmarked for the project. This has created temporary employment opportunities for unemployed community members. Tsumeb Smelter continues to provide apprenticeship and internship opportunities to students to upskill and obtain industry experience needed for their professional development.

In addition to employment and industry skills development, Tsumeb Smelter supports efforts towards improving academic performance of Tsumeb schools through the Mathematics and Science Clinics for grade 12 learners, ICT infrastructure improvement, Reading Improvement Programme Pilot Project, Sports Facilities Upgrades and support to the National Science Fair, among others. This has been complemented by various donations of school uniforms, desks, chairs and stationery to various schools in and outside Tsumeb.

2.3 Air Quality Management

2.3.1 Ambient Air Quality – SO_2 Emissions

The operation of the Sulphuric Acid Plant and baghouse filtration systems, continue to have a positive impact on air quality to date; except for instances when the process experienced upset conditions, the trend in the SO_2 emissions continues to be downward as depicted in Figure 3. A similar downward trend is visible in the number of exceedances of the South African Ambient Air quality standard for SO_2.

In addition, community complaints related to SO_2 emissions, also continue to show a similar downward trend over the years. Overall, this is a good indicator that the installed Sulphuric Acid Plant continue to operate optimally to reduce emissions. Refer to section 4.1 for the monitoring results.

2.3.2 Ambient Air Quality – Arsenic Concentrations

In the absence of local standards for arsenic in ambient air, Tsumeb Smelter adopted a limit of 1/100th of the Occupational Exposure Limit (OEL) of 0.1 mg/m^3, which result in an adopted ambient air arsenic guideline of 1$\mu g/m^3$. Arsenic concentrations are measured in dust buckets and air filters on devices located in the community and on site. Arsenic concentration levels in the community and on the boundary of the site remain stable and sample levels are well below the adopted guideline levels. Spikes in arsenic levels are observed occasionally, mainly driven by wind patterns, during the windy season and attributed to the legacy tailings and dumps. Refer to section 4.1 for the monitoring results.

2.4 Soils And Land Management

2.4.1 Phytoremediation

Tsumeb Smelter obtained and maintains a nursery permit which is renewed on an annual basis for the operation and own use of the onsite nursery. The nursery propagates trees from cuttings and seeds of mainly the Tamarix usneoides (Tamarix) and Searsia lancea (karee) tree species. The southern African Tamarisk tree is indigenous to semi-arid and saline areas in the western regions of the sub-continent including Namibia. This species has the natural capability to uptake heavy metals from the soil, and thus gradually cleaning the contamination from the soil. It is for this reason that this species was selected as the main tree for use in the phytoremediation project. The term phytoremediation simply means using trees to clean up contamination.

For the reporting period, over 2000 trees were propagated from seeds of different species such as Camelthorn, Bird plum (*Berchemia discolor*), Karee (*Searcia lancea*), Weeping boer-bean (*Schotia brachypetala*), Sausage tree (*Kigelia africana*), Cape- Ebony (*Euclea pseudenebenus*), Tamboti (*Spirostachys africana*) and Combretum species. No trees were propagated from cuttings during reporting period. As part of the expansion of trial sites, thirty-one (31) trees were planted in the field along the smelter main access road in April 2024.

The phytoremediation project is ongoing with six (6) main sites established. To date (up to June 2024), there is a total inventory of 173 trees in the Nursery, awaiting field planting.

The Contaminated Land Assessment (CLA) study is in the final stage for completion and one of the key next steps is to communicate the findings to the relevant stakeholders. Some of the rm3ecommendations that are applicable to the site are already being implemented under the phytoremediation programme

2.5 Groundwater Quantity and Quality Management

Water for industrial and landscape use is abstracted from the mine shaft, under a valid water abstraction permit issued by Ministry of Agriculture, Water and Land Reform. The total water abstracted from the mine shaft for the period under review is 512,306 m^3 (i.e. 436,376 m^3 water to Smelter and 110,516m^3 water to Golf Course). This translates to a 21% water saving against the abstraction limit. Domestic water is purchased from and supplied by the Tsumeb Municipality and the consumption during the review period amounts to 75,930 m^3. Refer to section 4.2 for the monitoring results.

In terms of groundwater quality monitoring, Tsumeb Smelter has an extensive monitoring network comprising 31 own monitoring boreholes and 3 monitoring boreholes belonging to the farming community totaling 34 groundwater monitoring points. Of these 31 own boreholes, three (3) require rehabilitation and hence are not sampled, however, results from 21 boreholes indicates, including 6 of the 7 off-site boreholes, arsenic levels well within the ideal guideline of the new Namibian Drinking Water Guidelines. However, exception to this compliance is the remaining 13 boreholes which are located within the smelter premises and in proximity to historical waste dumps and one (1) farming community borehole. Refer to section 4.2 for the monitoring results.

A number of projects were commissioned to address groundwater-related issues. Those that are completed to date including the review period, are the construction of the Pollution Control Dam (PCD); the cleaning and decommissioning of the former unlined Dam 10; the upgrade of surface water trenches onsite including lining of the main water tunnel from Change House and installation of tailings return water silt trap station and piping to PCD. The implementation of the proposed insitu groundwater bioremediation treatment trial project has been deferred to 2025 due to a number of factors including potential contractual and intellectual property issues which still need to be understood between Tsumeb Smelter and the potential technology developer/service provider.

2.6 Surface Water Management

Surface water infrastructure (e.g. drainage canals, storage dams) needed upgrading. To this end, the surface water infrastructure upgrades have been completed, with some of the major water trenches being lined, as well as the construction of a lined Pollution

Control Dam (PCD) which has already been completed as part of the Surface Water Infrastructure Management (SWM) Project phase I. Further, lining the remaining surface water trenches was completed in September 2023. Hence this project is fully implemented.

2.7 Ecology Management

Tsumeb Smelter continues to raise awareness about indigenous trees, targeting employees and schools through competitions and commemorations. Various bird species continue to be observed around the smelter premises which can potentially be interpreted as an indicator that the air quality conditions in Tsumeb has and continue to improve. Tsumeb Smelter Nursery continues to operate and to date, over 16,000 plants have been produced and planted from "cuttings" of indigenous/local plant species, mainly the southern African Tamarix (Tamarix usneoides).

2.8 Community Health and Safety Management

A fence was installed to act as a buffer zone between the Tsumeb Smelter premises and the Ondundu Community. Although prone to the challenge of theft, the fence continues to act as a buffer zone to prevent the community from coming into proximity to the hazardous waste disposal facility. Safety signages written in local languages are installed in the field to educate and raise awareness with community members not to collect firewood and/or harvest wild fruits around the smelter premises. Some sections of the fence have been recently stollen by unknown community members and plans are in place to engage the community on the need to protect the fence, before re-installing the fence and other security mechanisms.

2.9 Occupational Health and Safety Management

2.9.1 Occupational Hygiene Exposures and Control – Noise

Noise is monitored in accordance with a formal monitoring programme and schedule. Most operational plant areas are classified as noise zones, with personal noise exposures and area noise levels more than 85 dBA.

All personnel working in identified noise zones are required to wear hearing protective devices (HPD's). Different types of ear protection are available and are selected as per the need of the wearer and noise levels in their work area. Issuing of HPD's is supported by fit testing. Most employees in noise zones and doing tasks with high risk of noise have been issued with custom molded hearing protectors. The hearing Conservation Program is in place and is continuously reviewed.

2.9.2 Occupational Health and Hygiene – Arsenic Fumes and Dust

In terms of occupational hygiene sampling, continued improvement can be seen across the site in general. On average, exposures comply with the Namibian exposure limit, and complies with the onsite standard of 0.04 mg/m3.

Engineering controls, under the arsenic exposure reduction plan, continue to be driven across areas of concern. Furthermore, facilities are currently being improved in most plant areas, to reduce incidental exposure and ingestion risks.

Domestic water is supplied by the Tsumeb Municipality to the Smelter. Tsumeb Smelter, during the reporting period still opted to supply the workforce with portable water sourced from a local supplier for drinking purposes. The practice of providing employees with portable water continues, while awaiting clearance from the municipality to commence consuming domestic water.

2.10 Socio-Economic Management

2.10.1 Social Investments

As part of the commitment to partner with communities, the Sinomine Tsumeb Smelter continues to invest in community development through various projects and initiatives, covering focus areas such as Agriculture, Education, Arts, Culture and Sports, SME development and Heritage preservation. For 2024 January to June, Sinomine Tsumeb Smelter has thus far invested N$ 2,554,291 in various initiatives.

Sinomine Tsumeb Smelter invested approximately 98 Million Namibian Dollars (N$) on community projects and initiatives between 2012 to 2024 year-to-date. The Community Investment for the reporting period is briefly outlined in the table 1 below:

Table 1: *Community Investments, January to June 2024*

<table>
<tr><th rowspan="2">Investment Themes</th><th colspan="2">Invested amount (N$)</th></tr>
<tr><th>Q1,2024</th><th>Q2,2024</th></tr>
<tr><td>• Tsumeb Agri-business development</td><td rowspan="3">1,260,706</td><td rowspan="3">1,293.586</td></tr>
<tr><td>• Empowering Comprehensive, Quality Educational systems across institutions;
• Institutional Capacity building
• Technical skills development for tertiary students;</td></tr>
<tr><td>• Access to healthcare facilities;
• Supporting community wellness and lifestyle changes;
• Support to local Health institutions.
• Emergency Health support</td></tr>
</table>

Investment Themes	Invested amount (N$)	
	Q1,2024	Q2,2024
• SME infrastructure development • Enterprise financing and capacity building for entrepreneurs;		
• Preserving cultural heritage; • Youth empowerment through arts education and sports development.		
• Environmental awareness in schools • Support to Waste Management efforts		
• Governance and administration; • Assist Vulnerable community members and Charitable organizations		
Total for Q1 & Q2	**N$ 2,554,292**	

2.11 Waste Management

2.11.1 Hazardous Waste Disposal Facility (HWDF)

The onsite Hazardous Waste facility and arsenic management in general, remains a key focus for Sinomine Tsumeb Smelter. Top management recognizes the critical need to operate and manage this facility competently and sustainably. Several management practices have been adopted to provide continuous assurance that the facility is safe to both the employees and the environment. External audits are conducted every second year, with the latest conducted in 2021 which indicates the facility is designed, operated, and managed in line with international acceptable standards. The 2023 audit was delayed due to lack of market response, however there is a procurement process in the final stage to obtain service of external audit during Q3, 2024.

Further, one of the deposition cells of the facility, referred to as cell 1 has reached capacity, and the installation of capping was successfully completed in Q1 of 2024. Currently, waste is deposited in what is referred to as cell 2.

In terms of the long-term options for the management of arsenic waste, Sinomine Tsumeb Smelter reached a decision on the alternative option for arsenic waste management. Following the completion of technical assessments and evaluation studies on various options which include an offsite disposal facility at a suitable and technically selected location, the offsite disposal facility is proven to be a feasible option at this stage. Hence the business has a plan to commence with engineering design and environmental impact assessment studies in 2024. Engagements with various relevant stakeholders including regulators and landowners has commenced in parallel.

2.11.2 General Waste Management Facility

The operation of General Waste Management Facility is progressing well after it was commissioned in September 2023 with the Environmental Commissioner Mr. Timoteus Mufeti gracing the official inauguration event as the keynote speaker. The facility comprises a waste deposition cell, a contaminated water pond, sorting and recycling facilities, remediation pad, interim storage facility for non-arsenic bearing hazardous waste as well as an office complex.

The facility supports the upstream activities of waste sorting at source and is therefore able to contribute to the full implementation of an integrated waste management plan and programme. To date 95 bales of recyclables have been produced from recovered recyclables which include cans, plastic, cartons, and paper. Other items that are recovered are pallets and other auction-worthy materials such as tables and chairs which are currently stored and awaiting to be disposed of through second-hand goods auction.

2.12 Environmental, Social Awareness and Training

A dedicated Training Department with training facilitators continues to provide training to all Sinomine Tsumeb Smelter and contractor employees related to health, safety and environmental management aspects through site-wide and specific area inductions. For further improvement initiatives, the Environment section is providing training on particularly integrated waste management, as well as permit condition awareness.

The purpose is to educate the Sinomine Tsumeb Smelter workforce on HSE related projects that the company is undertaking to ensure that there are controls in place to mitigate impacts associated with smelter operations are understood by the workforce. The Information Centre located in the centre of Tsumeb town is an accessible point for information about the Smelter's operations as well as in person feedback to and from the community.

2.13 Closure Phase

The Smelter's Closure Plan is continuously monitored through Asset Retirement Obligations tracking. The requirements for Tsumeb Smelter closure have been developed on the basis that the site be restored to functioning post-operational land use. Recommendations from the closure plan are currently being planned for implementation, whilst some of them, such as phytoremediation, are ongoing. The next update of the closure plan is scheduled for 2025.

The end-state vision for closure is to leave a rehabilitated site behind that is physically stable with limited residual contamination on land and in groundwater, to facilitate an industrial post-closure land use. This will be achieved largely via progressive rehabilitation during operations. If the above is not fully achieved and self-sustaining at closure, it will be on a well-established trajectory towards achieving a walkaway and/or positive legacy situation.

The site closure objectives for Tsumeb Smelter are outlined below:

Physical stability: To remove and/or stabilize surface infrastructure and unavoidable mining and mineral processing residue which are present on the Tsumeb Smelter site to facilitate the implementation of the planned post-closure land use.

Environmental quality: To ensure that local environmental quality is not adversely affected by possible physical effects and chemical contamination arising from the Tsumeb Smelter site during the tenure of Tsumeb Smelter, as well as to sustain catchment yield as far as possible after closure.

Health and safety: To limit the possible health and safety risks to humans and animals using the rehabilitated site.

Land use and land capability: To re-instate suitable land capabilities over the various portions of the site to facilitate the progressive implementation of the planned land use.

Aesthetic quality: To leave behind a rehabilitated Tsumeb Smelter site that, in general, is not only neat and tidy, giving an acceptable overall aesthetic appearance, but which in terms of this attribute is also aligned to the respective land uses.

Biodiversity: To encourage, where appropriate, the re-establishment of indigenous vegetation on the rehabilitated sites such that terrestrial biodiversity is largely re-instated over time; and

Socio-economic mitigation: To ensure that the infrastructure transfers, if applicable, measures and/or contributions made by the facility towards the long-term socio-economic benefit of the local communities are sustainable.

Ultimately Tsumeb Smelter recognizes the need and importance to demonstrate that closure of the facility is environmentally, socially, technically and economically feasible without incurring long-term liabilities for stakeholders.

3 Environmental Related Permits Obtained and/or Maintained

Tsumeb Smelter has maintained the following environmental related permits during the period under review:

- Water Abstraction Permit (Amendment) – valid till 31 July 2024. A renewal application was submitted in May 2024 to the Ministry of Agriculture, Water and Land Reform and approval should be received in the next reporting period.
- Nursery Permit – validity until 31 March 2025

- Wastewater and effluent disposal exemption permit – valid until 01 October 2024. Renewal application is submitted in June 2024 to the Ministry of Agriculture, Water and Land Reform and approval should be received in the next reporting period.

4 Environmental Monitoring Results

4.1 Air Quality

Tsumeb Smelter has adopted the South African National Ambient Air Quality Standard contained in the South African National Environmental Management: Air Quality Act, no. 39 of 2004. This standard stipulates exceedance limits for amongst other pollutants SO_2, with 10 minutes, 1 hour and 24 hours indicated concentrations as 500µg/m^3, 350µg/m^3 and 125µg/m^3 respectively and the number of times (frequency) these limits can be exceeded as 526, 88 and 4 respectively. Tsumeb Smelter operates six (6) real-time ambient air quality monitoring stations (AAQMS) of which four (4) are located within the community and two (2) on-site. These stations monitor amongst others Sulphur Dioxide (SO_2) and reports this via independent web hosting.

The same South African standard also stipulates acceptable dust fall rates for residential and non-residential areas at and beyond the boundary of the premises where dust is generated

4.1.1 Sulphur Dioxide (SO_2)

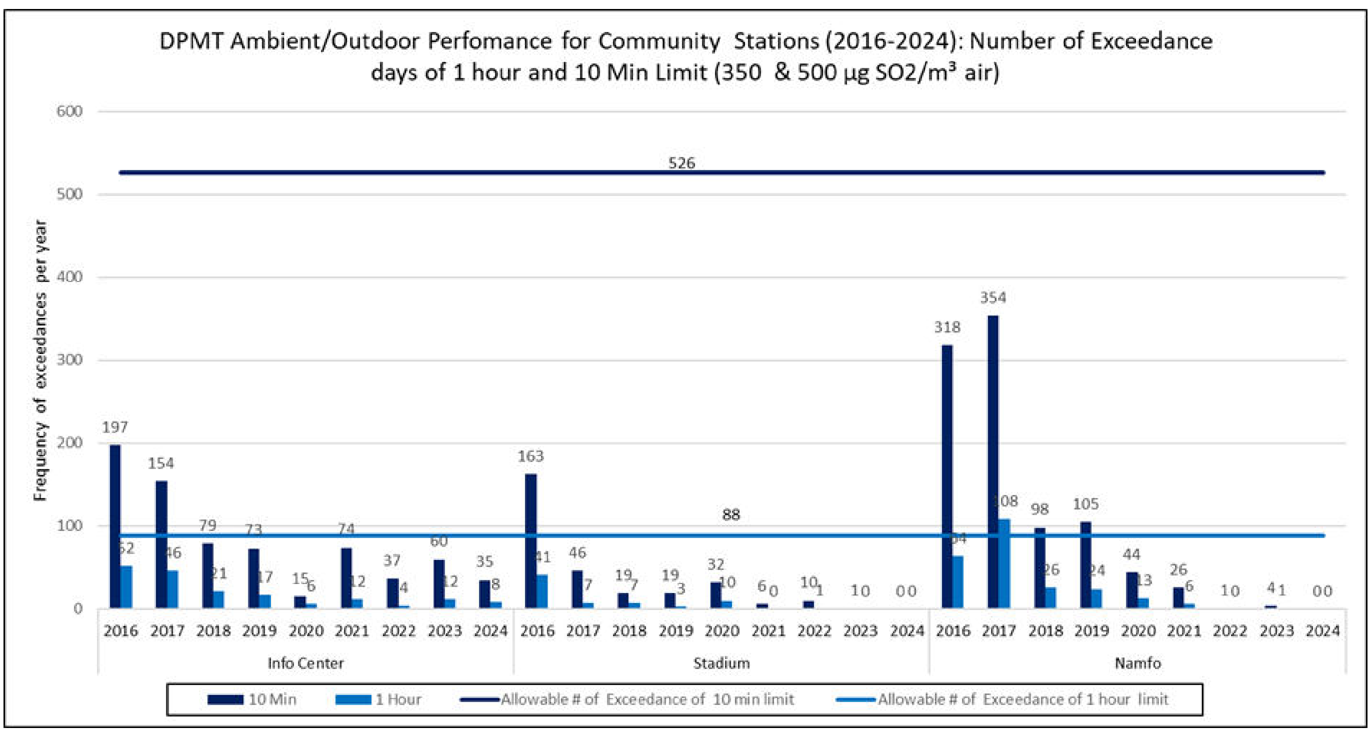

Figure 3: Community Stations (10-min and 1-hour) SO_2 Exceedance Performance 2016-2024t

Although the reporting period is January to June 2024, the results from monitoring stations cover the period from 2016 to date to include the sulphuric acid plant (SAP) commissioning period – this is to better visualize the impact of the SAP on the declining trends in air pollutant concentrations.

The exceedances in SO_2 of the 10 minute and 1-hour limits, which are 500mg/m^3 and 350mg/m^3 respectively, recorded in the community remains below the allowable limits and show a steady decline between 2020 – 2024 as indicated in Figure 3. This is attributable to stable plant operations which have resulted in increased efficiency in capturing SO_2 and converting this to sulphuric acid.

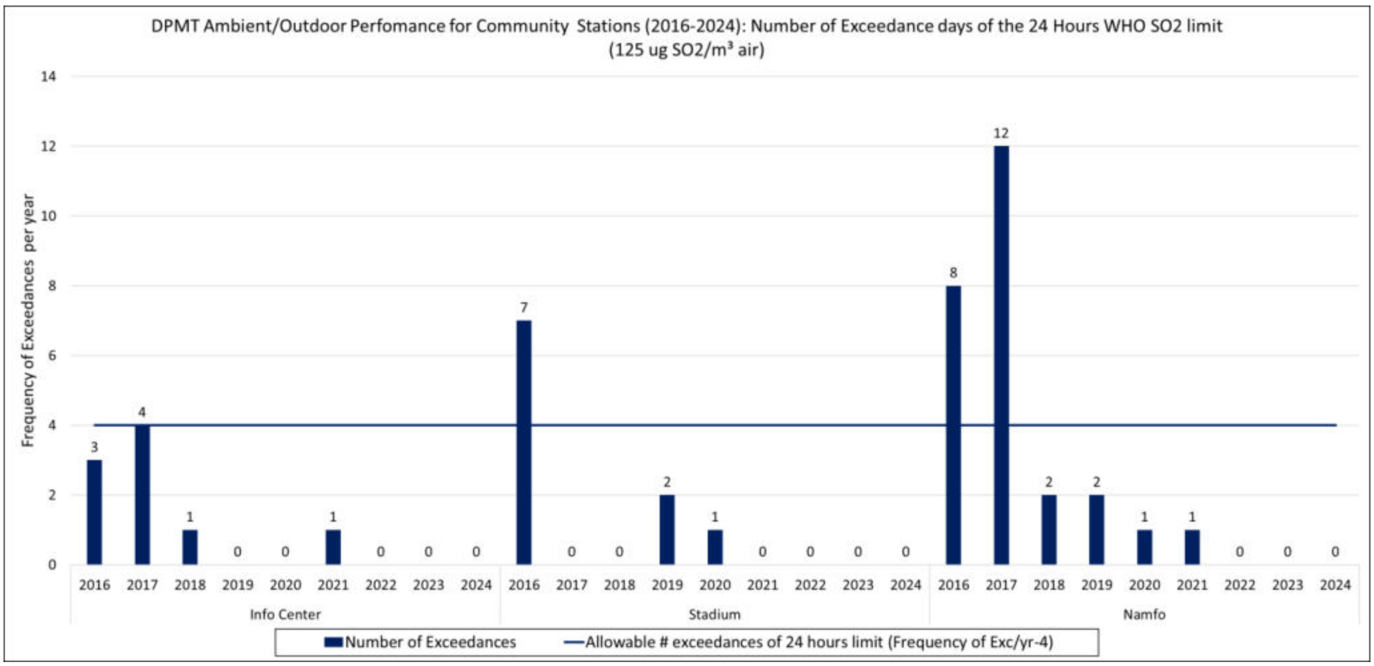

Figure 4: Community Station (24-hours) SO_2 Exceedance Performance 2016 – 2024

The exceedances in SO_2 of the 24 hours limit of 125mg/m^3 recorded in the community declines steadily and remain at zero for the last three (3) years as depicted in Figure 4. This is attributable to stable plant operations which have resulted in increased efficiency in capturing SO_2 and converting it to sulphuric acid.

The number of community complaints related to SO_2, are 13 for the reporting period of 2024 and this is attributed to unforeseen plant upset (see Figure 5).

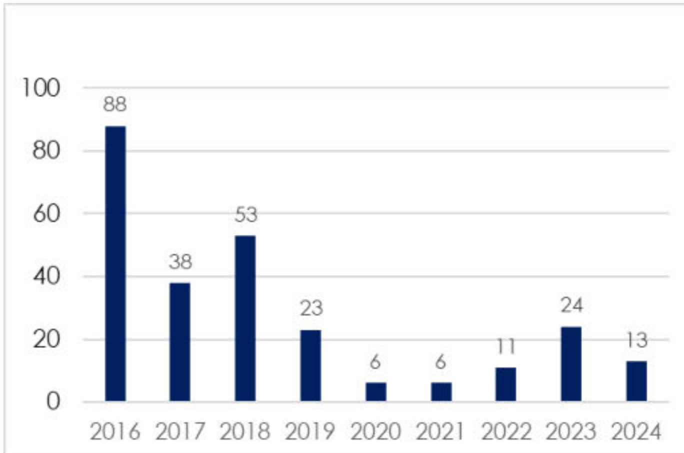

Figure 5: SO_2 Related Community Complaints

4.1.2 Arsenic in Ambient Air

Arsenic in ambient air is another parameter monitored at the six (6) Ambient Air Quality Monitoring Stations (AAQMS). Figure 6 and Figure 7 present trends of arsenic concentrations as retrieved from the stations.

Figure 6 depicts arsenic in air as measured at the AAQMS referred to as Hill and Sewerage AAQMS situated on-site, which indicates a performance well below the adopted limit for the past three years.

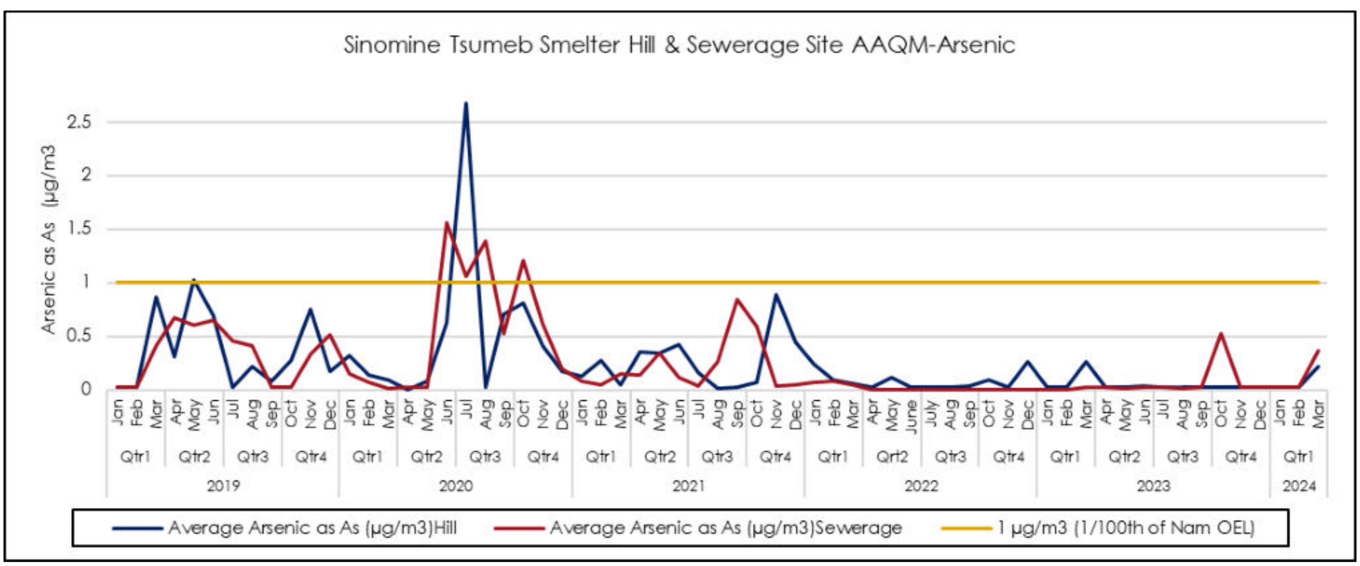

Figure 6: Arsenic in Ambient Air for Tsumeb Smelter Hill and Sewerage Site Stations

Figure 7 depicts arsenic in air as measured at the community stations which are located at Info Centre, Stadium and Namfo. The levels of arsenic in air at Info Centre and Stadium remain well below the adopted limit of 1 µg/m³. However, performance at Namfo occasionally exceeds the limit, especially during the windy period of July-Sept. Further, this may be attributable to windblown material or during ploughing season.

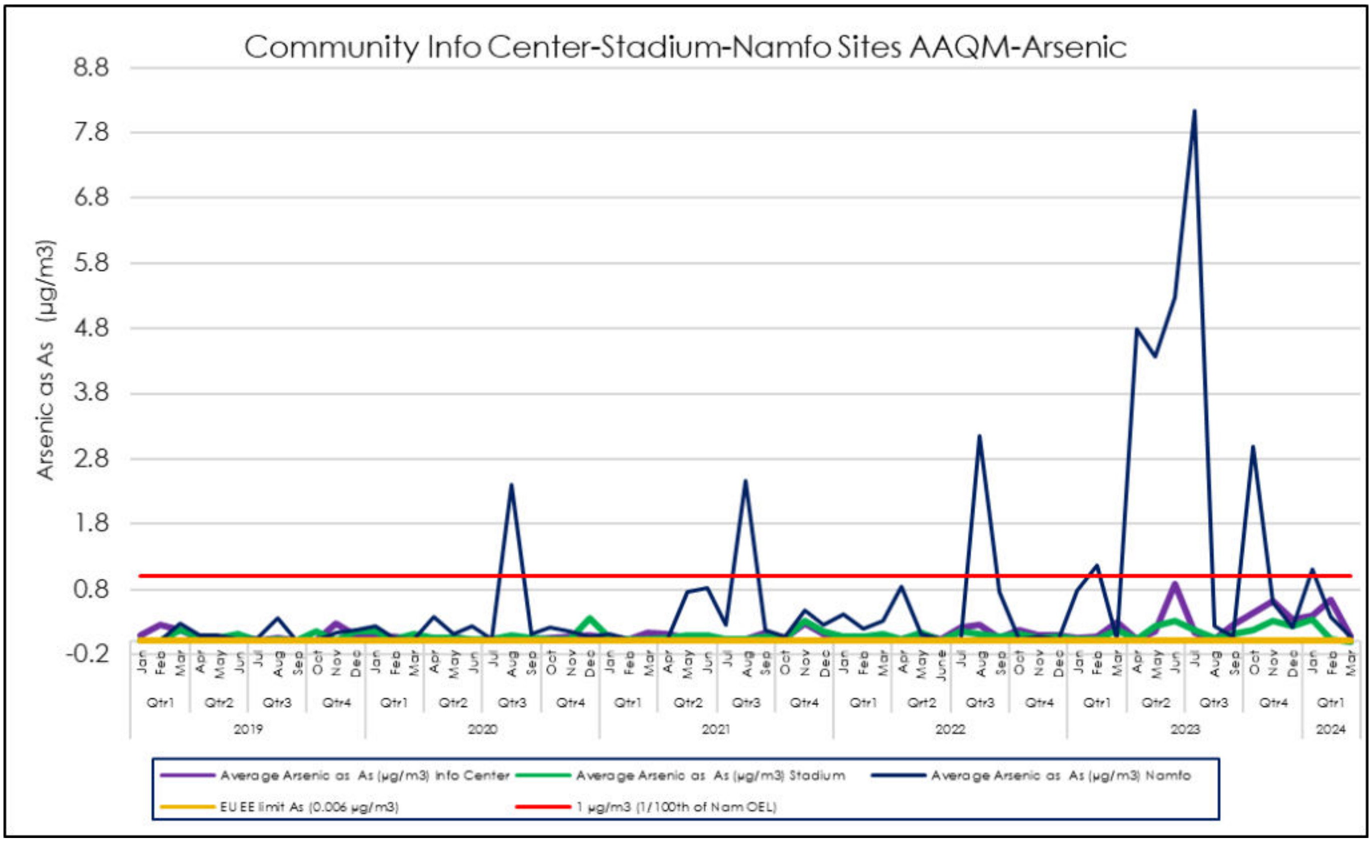

Figure 7: Arsenic in Ambient Air for Info Centre, Stadium, and Namfo Community Stations

In general, the windy season was a significant driver of arsenic in air at NAMFO [fallout zone] and the same had an opposite effect of reduced arsenic in air at two community stations. The precipitation also contributes to reduction in arsenic in air.

4.1.3 Dust fallout deposition

The monitoring program for dust fallout deposition in and around the smelter, comprises of 17 dust buckets of which 5 buckets are installed in the residential areas and the remaining 12 buckets in industrial areas including the smelter premises. In 2024, an additional 24 directional buckets were added to the monitoring network.

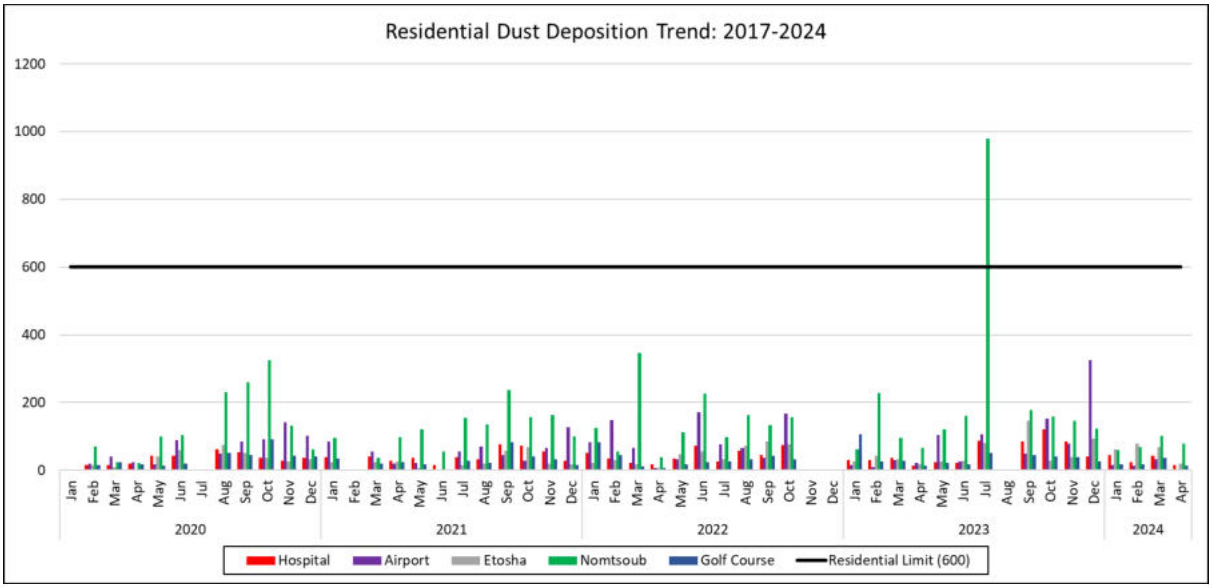

Figure 8: Dust fallout deposition trends in residential areas

Figure 8 presents the trends of dust fallout deposition in the residential areas covering 2020 to 2024. The trends behave well within the limit, apart from Nomtsoub which exceeded the limit in July 2023 due to road construction activities in the vicinity of the station. Overall, the graphs indicates that the community is not at danger of dust exposure. The attributes are related to the wind direction, wind speed as well as the proximity (distance) of these areas to the Smelter.

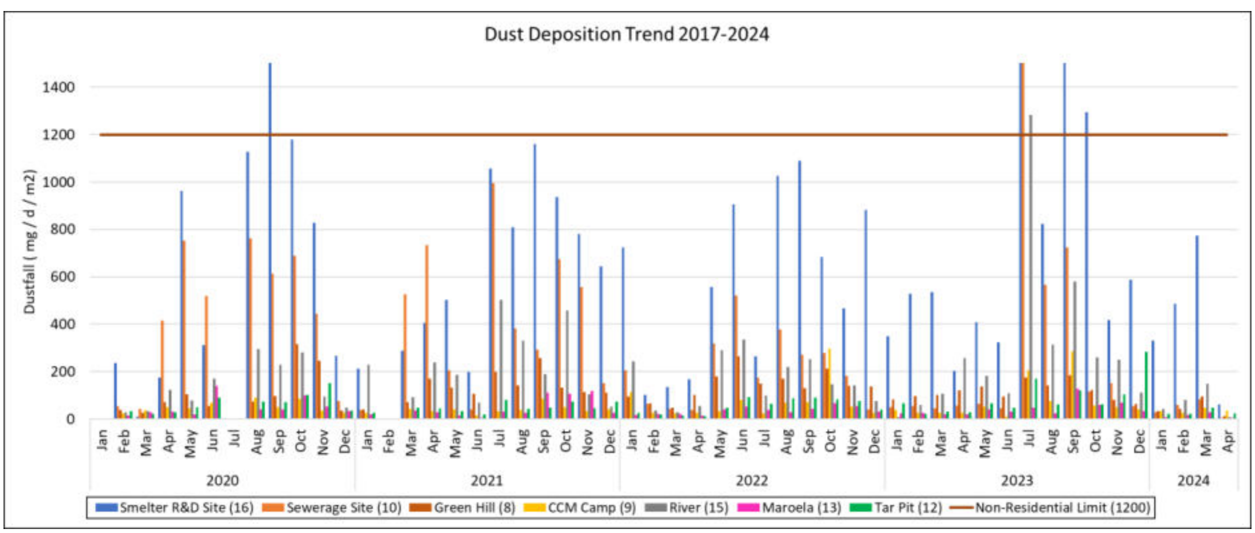

Figure 9: Dust fallout deposition trends in industrial area including Smelter site

Figure 9 presents the trends of dust fallout deposition in the industrial areas covering 2020 to 2024. The trends also behave well within the limit for most of the buckets, except for few observed exceedances particularly for Smelter, Sewerage and River dust buckets in the months of July, September and October. The observed exceedances associated with bucket in the Smelter premises, River and Sewerage, is attributed to the windy season as well as proximity to tailings. For the reporting period January to June 2024 there hasn't been any exceedances.

4.2 Water Quantity and Quality Monitoring

4.2.1 Domestic and Raw Water Consumption

Tsumeb Smelter operates under an abstraction permit for raw water with a limit of 1,3 million cubic meters per annum abstracted from the old Mine Shaft. The domestic water is supplied by Tsumeb Municipality and there is no limit however Tsumeb Smelter has adopted its own internal limit of 330 cubic meters per day in terms of consumption.

For the reporting period of January to June 2024, the domestic water consumption has been over the target, due to aged water infrastructure and maintenance works is ongoing. Whilst, raw water consumption has been relatively on target, hence overall compliance with the abstraction permits.

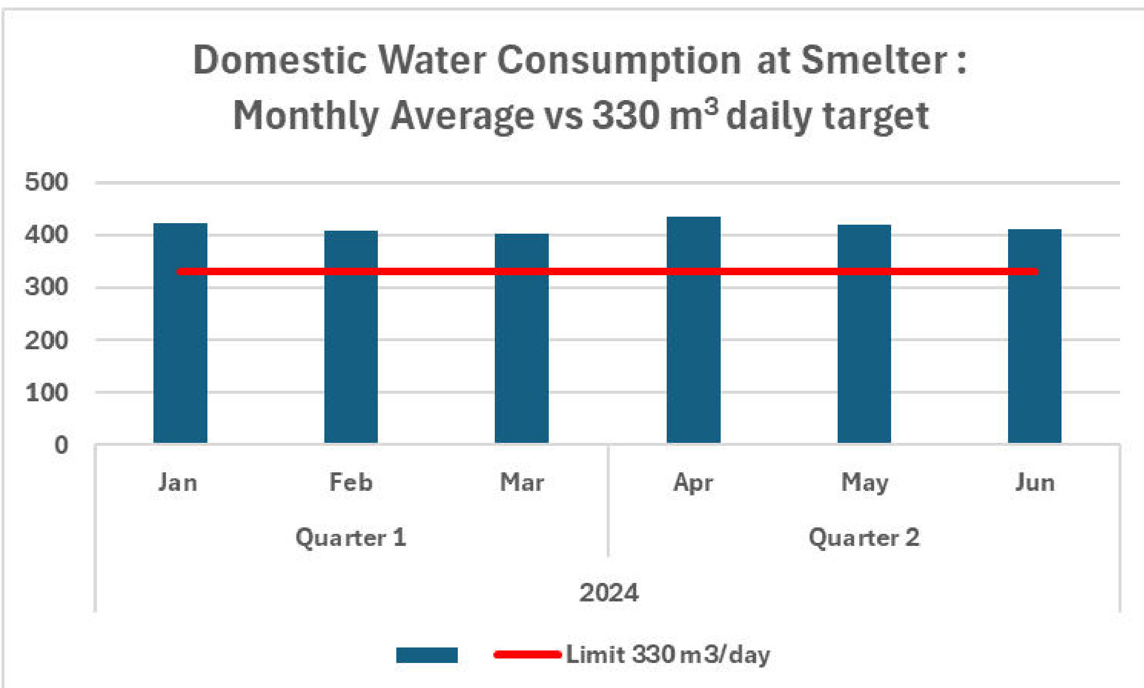

Figure 10: Domestic Water Consumption for January to June 2024

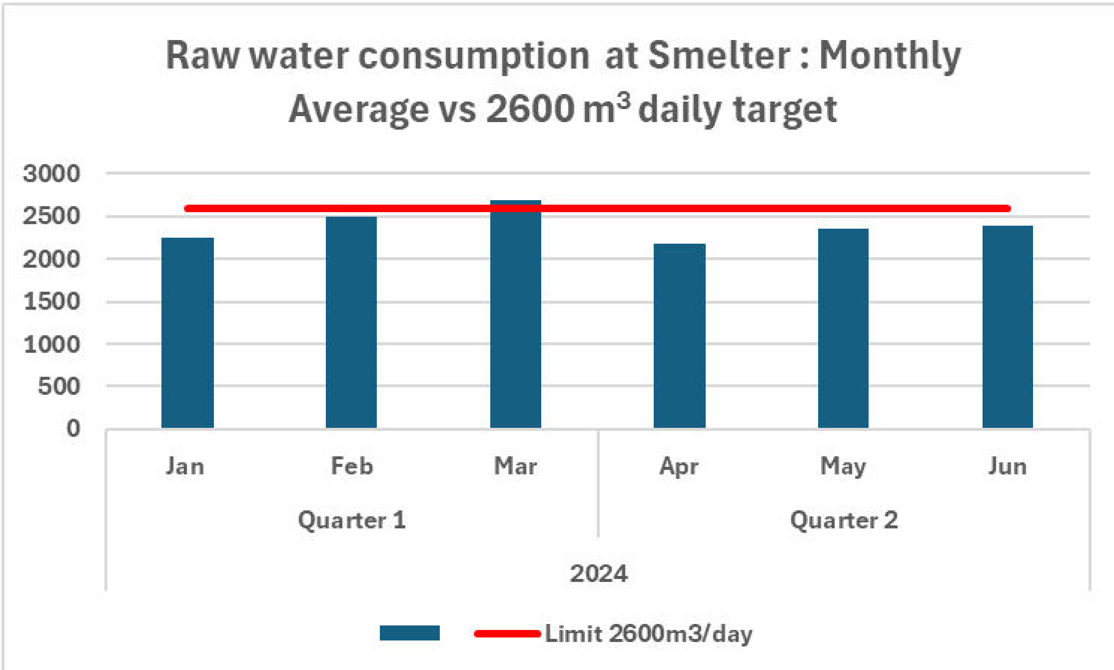

Figure 11: Water Consumption for January to June 2024

4.2.2 Groundwater Monitoring Network / Programme

Sinomine Tsumeb Smelter has a network of 31 groundwater monitoring boreholes and 3 private production boreholes. Six (6) boreholes are located outside the Tsumeb Smelter boundary, mainly on private agricultural lands. Three (3) of these monitoring boreholes requires rehabilitation, hence are not monitored (indicated in amber on Figure 12). Monitoring is conducted by means of the specific-depth sampling method (also called discreet sampling) and very good data is generated through this method. This method allows for the sampling of water at specific depths within the water column. Currently, sampling of physical and chemical analysis of samples are conducted on a monthly basis.

For the reporting period, the analysis of collected water samples was conducted at the Sinomine Tsumeb Smelter internal laboratory. However, previously and going forward these analyses will be conducted by an external laboratory. Results indicate 18 boreholes, including all 6 off-site boreholes, show arsenic levels well within the ideal guideline of Namibian Drinking Water Guidelines. However, exception to this compliance is the remaining 13 boreholes of which 12 are located within the smelter premises and in proximity to historical waste dumps and 1 located on a private farm. For the twelve (12) boreholes, high elevations of mostly arsenic concentrations have been observed since the onset of monitoring program by Tsumeb Smelter. Figure 12 below shows the locations of the boreholes as blue or red dots representing the status of the individual boreholes in terms of arsenic concentrations – low arsenic boreholes are indicated in blue and the elevated arsenic boreholes indicated are in red.

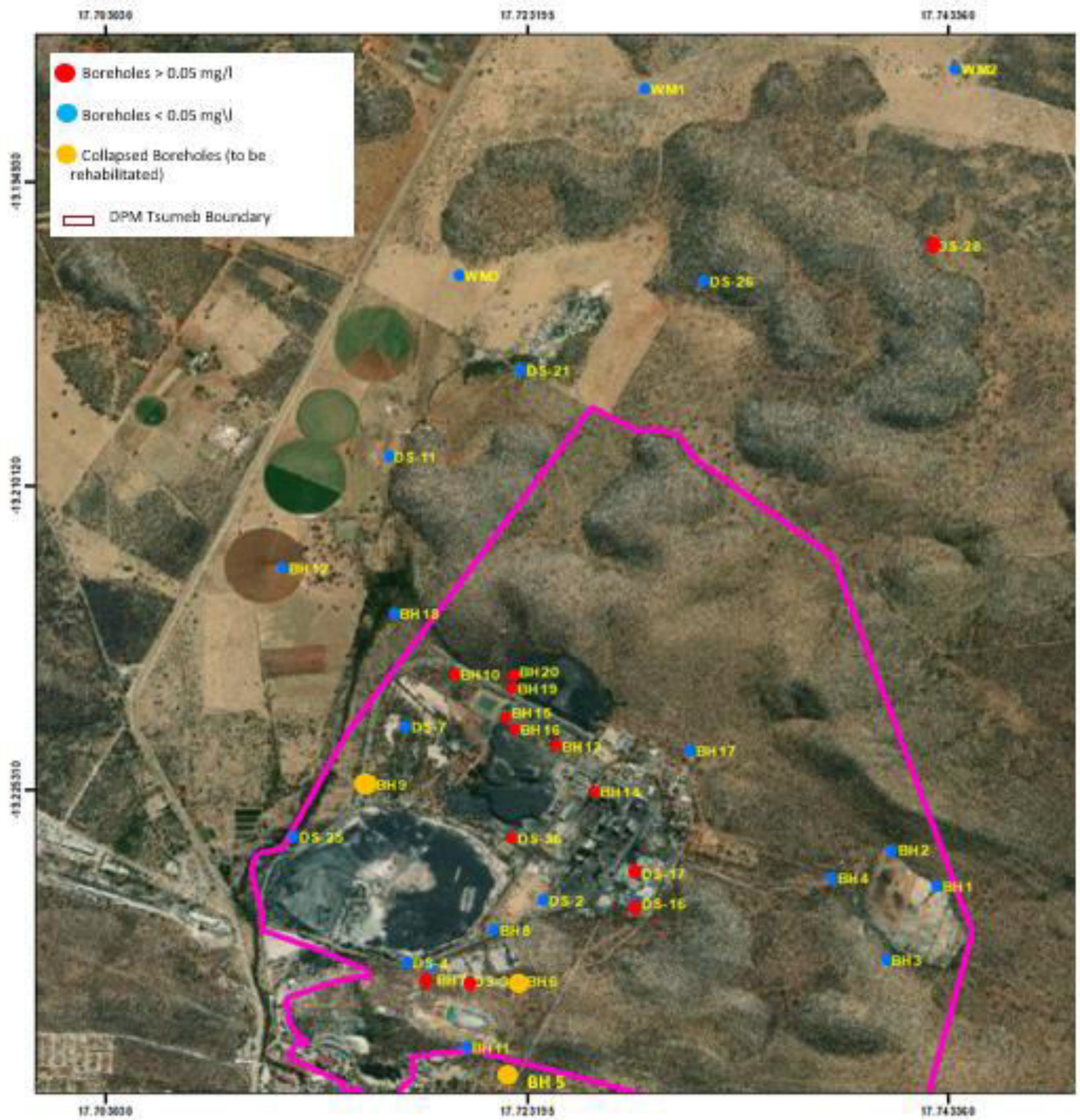

Figure 12:Groundwater monitoring network

It is important to indicate that, whilst we observe elevated concentrations in the boreholes on site, most of this contamination remains localised. However, to deal the current localised contamination, a plan is in place to install infrastructure and implement an Insitu groundwater bioremediation pilot project. On this project, Tsumeb Smelter has received a drilling permit (No. 11641) to drill 40 boreholes (schematically indicated in Figure 13, below) aimed to serve the purpose of groundwater treatment as well as monitoring of effectiveness of the treatment media (i.e. the before and after). Another borehole drilling application will be made in the next reporting period for the drilling of seven (7) additional boreholes.

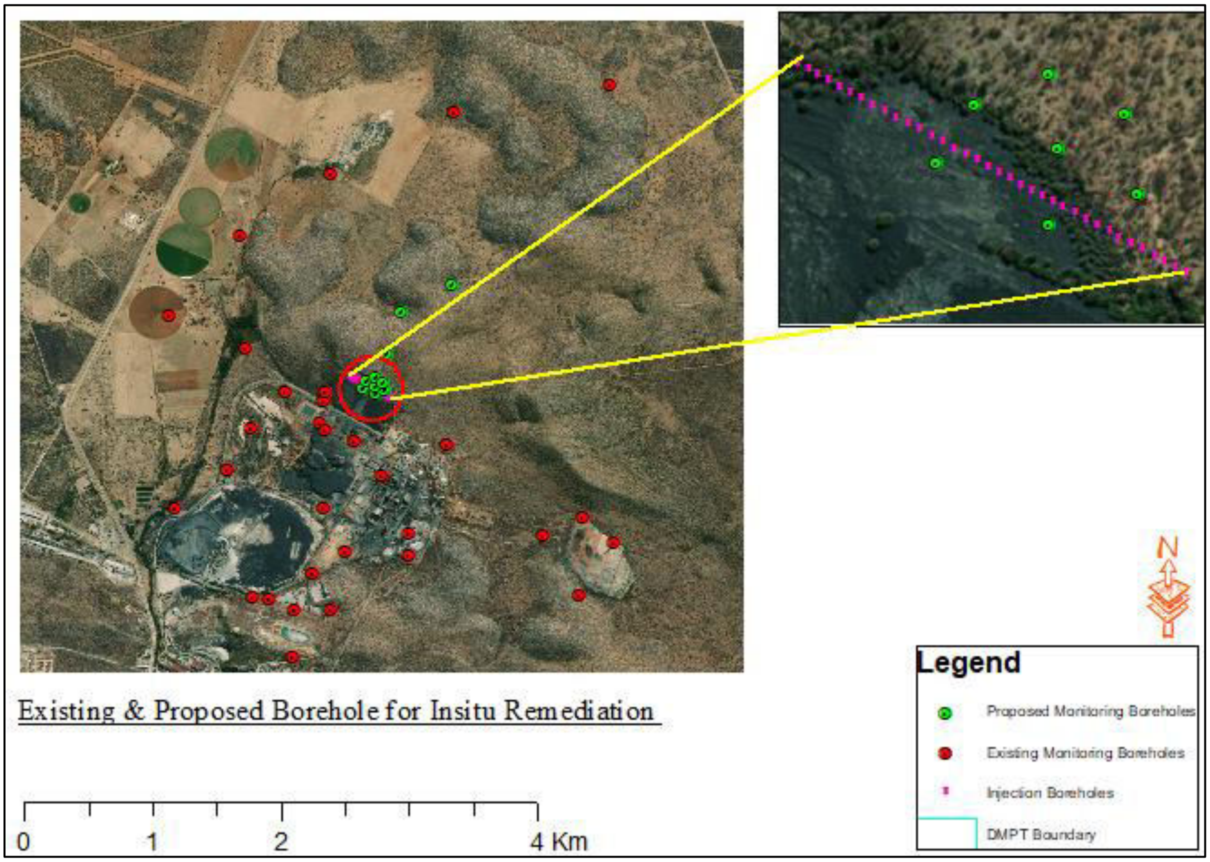

Figure 13: Proposed boreholes for the In-situ Groundwater Bioremediation Pilot Project

4.2.3 Surface Water Monitoring Network / Programme

A surface water monitoring programme is in place and currently, there are nineteen (19) monitoring points. These points are not necessarily natural water bodies but comprise of wastewater bodies and raw water reservoir. The purpose of the monitoring program is to keep track of the quality for potential compliance to discharge standards into the environment when it comes to wastewater.

Water sample analysis is conducted by an internal laboratory periodically also by an independent certified laboratory. Monitoring points are sampled on a quarterly basis, with additional sampling conducted on an ad hoc basis, for example, when rain water ponds during the rainy season.

Table 2 below presents the results from the surface water monitoring points. SW1, SW2, SW3, SW4 (samples collected from the Jordan River, and no samples were collected for this reporting period because the stream was dry most of the time) and SW8 are sampling points which depicts performance and behavior of potential sources of contamination for drinking water. SW10, SW12, SW15 and PCD represents sampling points on wastewater bodies which are a potential source for discharge into the environment. The quality of samples from the potential drinking water sources mostly meet the requirements of the Ideal Guideline of the Namibian Drinking Water quality guideline. The quality of samples from the potential discharge sources indicates high levels, however, these are not a cause for concern since the wastewater bodies are in lined facilities.

Table 2: Surface Water Quality Test Report based on Namibia Drinking Water Quality Guideline

Quarterly Averages - 2024															
Sample Name	Sample Description	pH	Conductivity	TDS	Total Alkalinity	Chloride	Sulfates	Arsenic	Iron	Manganese	Zinc	Sodium	Calcium	Magnesium	MoO_4
			m S/m	mg/l	mg/l as $CaCO_3$	mg/l Cl-	mg/l as SO_4	mg/l As	mg/l Fe	mg/l Mn	mg/l Zn	mg/l Na	mg/l Ca	mg/l Mg	mg/l
Namibian Drinking Water Guidelines															
Ideal Guideline		6.0 to 8.5	<80	< 500	NS	< 100	100	<0.01	<0.2	<0.05	1	<100	<80	<30	NS
Acceptable Guideline		6 to 9	<300	< 2 000	NS	< 300	< 300	<0.05	<0.3	<0.1	5	<300	<150	<70	NS
SW 1	Jordan River	No water flowing in the Jordan river during the reporting period													
SW 2															
SW 3															
SW 4															
SW 8	Shaft Water	7.1	131.55	785	262	72	282	<0.03	<0.01	<0.01	0.61	35.2	51.4	69.9	<0.01
General Discharge Standard															
		6,5% - 9,5%	<75 mS/m above the intake water quality	<500 above the intake water quality	N/S	<70 above the intake water quality	<40 above the intake water quality	<0.15	<1	<0.4	5	<90 above intake water quality	N/S	N/S	N/S
SW 10	TSF Return Water	6.67	280.00	3,255.33	153	1,256.00	1269	430	<0.01	0.11	250.3	61.1	152.2	<0.01	No results
SW 12	Reed Pond	7.75	76.10	320.00	179	112	70.8	9.12	0.02	<0.01	0.04	26.1	57.5	61.6	<0.01
SW 15	HWDF	3.7	1,700.00	8,925.00	<1.00	1,136.00	1,473.00	14,000.00	0.12	4.23	113	291	1,236.00	437	<0.01
PCD	Pollution Control Dam	6.51	276.00	3,276.00	181	72.6	1,209.00	556.00	0.14	0.12	2.64	50.1	563.4	90.5	<0.01

Legend:

- Compliant to Ideal Guidelines of the Namibian Drinking Water Guidelines
- Compliant with Acceptable Guideline of the Namibian Drinking Water Guidelines
- Those above the Acceptable Guideline of the Namibian Drinking Water Guidelines

The water monitoring program and networks are constantly being reviewed and evaluated, considering findings from studies, gap analyses and audits, data from historical monitoring and requirements from best practices. Actions are implemented on a regular basis (e.g., groundwater protocol, expansion of networks, surface water monitoring, etc.).

4.3 Waste Generation and Accounting

4.3.1 Hazardous Waste Disposal Facility

A total of 15,220.94 tons of arsenic-bearing waste was disposed to the facility from January to June 2024, against the previously reported period of July to December 2023, with a total of 11,736.23 tons deposited representing an increase in arsenic waste deposited. The variation between the two reporting periods is production driven.

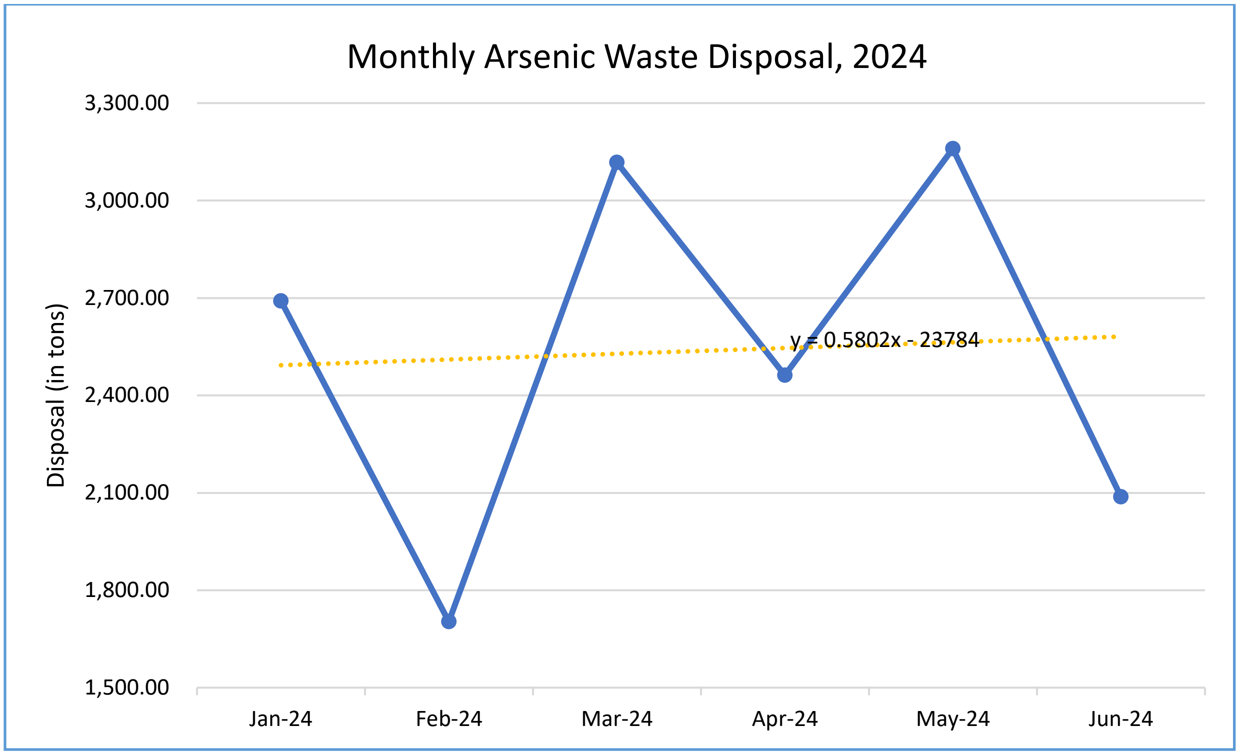

Figure 14: Hazardous waste (Arsenic Waste) disposed onsite HWDF

4.3.2 General Waste Facility

The General Waste Facility at Sinomine Tsumeb Smelter aims to promote recycling and contribute to sustainable waste management. As for January to June 2024, 252.82 tons of general waste were recorded, compared to 233.06 tons in July/December 2023, this total represents the overall waste generated onsite including the recycled volumes which currently stand at 95 bales of recyclable waste. Sinomine Tsumeb Smelter's recycling program is fully realised with the activities of collecting wastepaper, cans, plastics, and other recyclables which will be taken offsite for recycling purposes.

The scrap metals generated onsite amounted to 109.49 tons in January to June 2024, compare 101.61 tons observed during the previous reporting period – July to December 2023. Scrap metals are consolidated at the scrap yard, and to date, significant quantity of scrap is being stored onsite awaiting the completion of procurement process to get service of scrap dealer. No scrap went offsite for recycling during this reporting period.

The peak in scrap metal moved onsite for the month of May 2024 is potentially attributed to the ad-hoc plant maintenance work – mini shuts, and increased clean-up activities. Overall, the trends for January/June 2024 are closely like that of July/December 2023.

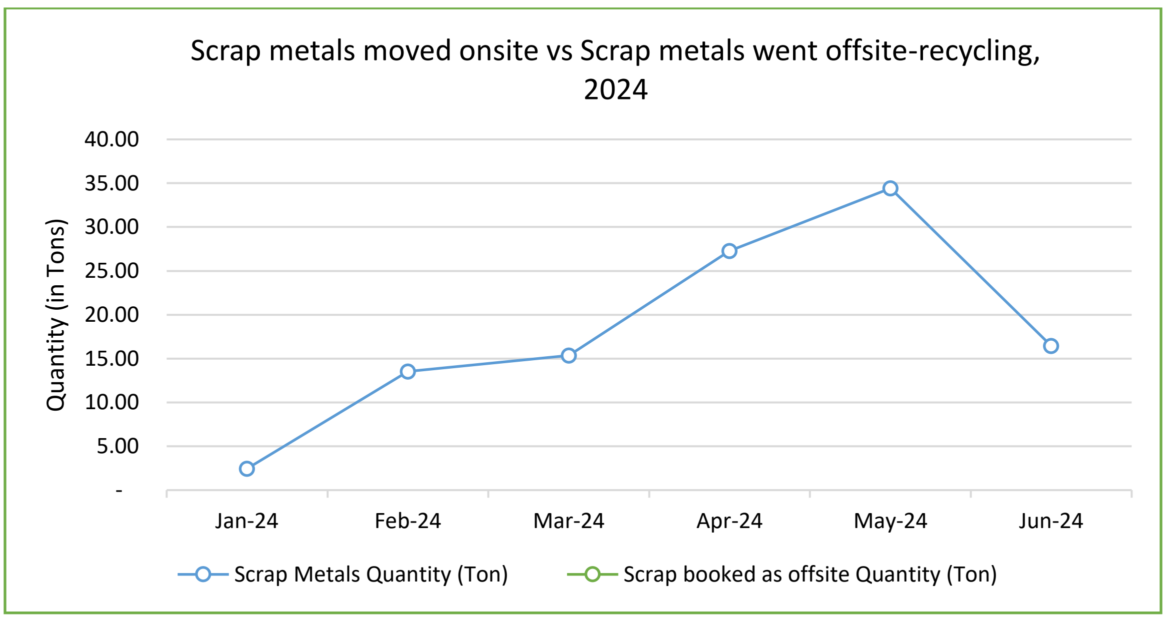

Figure 15: Non-hazardous waste moved onsite

4.3.3 Non-arsenic bearing hazardous waste

For January to June 2024, a total of 11,410.00 litres of used mineral oil but in most cases comprises of oily water, was taken offsite for recycling purposes by recyclers. This number is recorded through the disposal certificates received from the recyclers i.e. Wesco Engineering. Variations between months are a result of ad-hock collections by recyclers, compared to the previous reporting period the collected volume is 36,730 litres between July/ December 2023. The peak record is observed during March 2024.

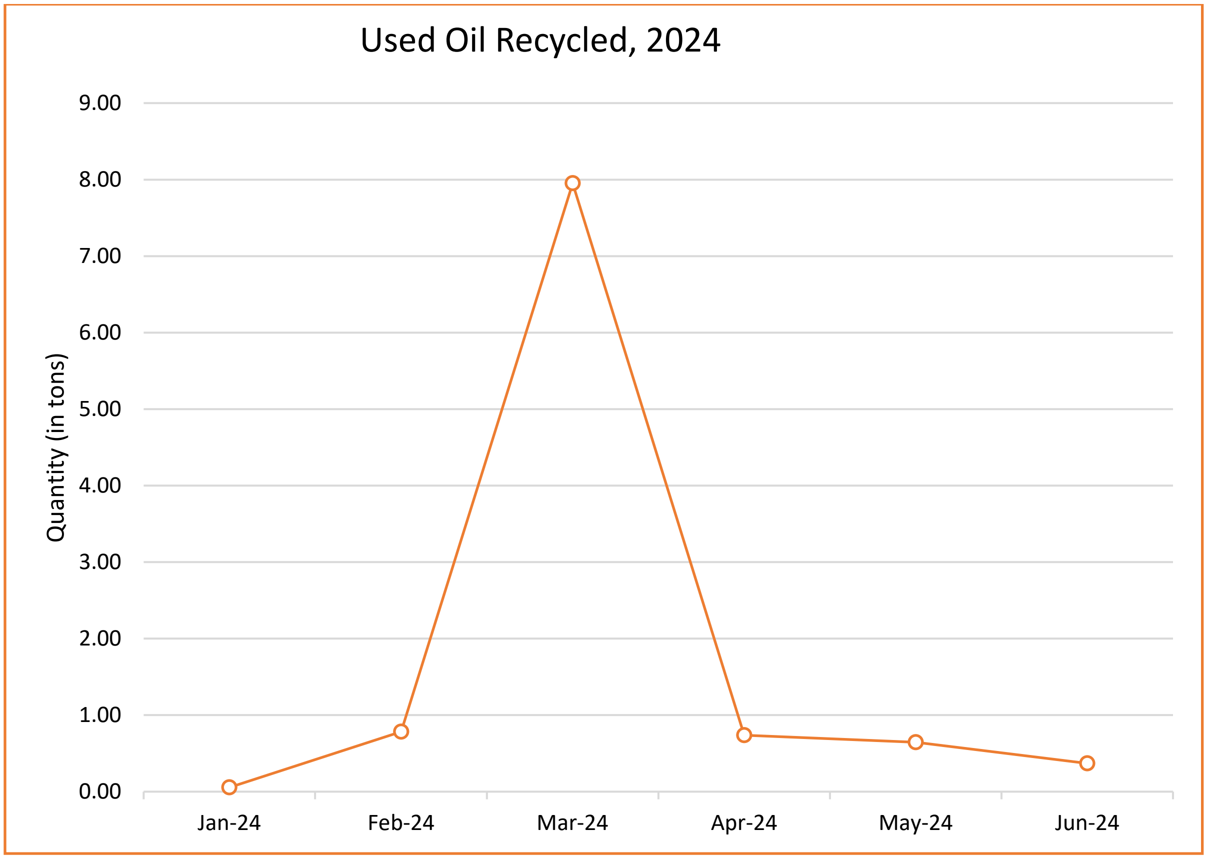

Figure 16: Used mineral oil removed from site for recycling

5 Conclusion

Sinomine Tsumeb Smelter has generally operated the smelter production infrastructure and processes in compliance with the requirements of the Amended Environmental Management Plan of 2019 on which the current Environmental Clearance Certificate is based. Sinomine Tsumeb Smelter is committed to maintain compliance to both national environmental management requirements and international good practices through current and planned improvement initiatives.

6 Reference

Dundee Precious Metals Tsumeb (Pty) Ltd, Proposed Tsumeb Expansion Project: Consolidated Environment and Social Management Plan - June 2019 (prepared by SLR Global)

7 Appendix

Appendix A Updates on Specific Performance Against Mitigation Measures

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
1. Construction activities					
Objective: • To ensure that all construction staff are aware of the objectives of the ESMP as well as the consequences of their individual actions • To limit construction-phase impacts relating to soil, noise, dust, visual and outside work force.					
▪ Contract Management	Lack of ESMP provisions	The requirements of the ESMP are to be included in all tender documentation for all contractors to allow service providers to make provision for environmental cost requirements and the ESMP is to form part of the contract agreement entered into with the service providers awarded contracts	Exco / Supply Chain	Prior to commencement of construction activities	IMPLEMENTED – HSE Criteria form part of tender process and evaluation
▪ Environmental Awareness and Training	Environmental Induction Training	Environmental induction training is to be undertaken by all persons undertaking new construction work at the smelter site. This is to be in line with Sinomine Tsumeb Smelter current site induction procedures.	Environment / Training	Immediate / Prior to commencement of any new construction related project	IMPLEMENTED – All contractors and new employees undergo General Induction and Site-Specific Induction

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
▪ Soil	Soil Impact	Where disturbed areas cannot be re-vegetated during the life of the operations, appropriate measures need to be taken to prevent further impacts on soil resources.	Environment / Projects	Prior to extension of sites	IMPLEMENTED – Topsoil stock pilled or to be stock pilled – Access control in place
	Footprint	Construction activities must be limited to the areas required for new project components.	Environment / Project	During Construction	IMPLEMENTED – Construction limited to the current footprint (Ongoing)
	Soil contamination during construction	Where construction of new components is undertaken on bare soil containing topsoil with vegetative material, the following measures are to be applied: • Consult the contaminated land assessment (CLA) and related soil survey information for suitability of re-use and appropriate handling of top soils within the smelter boundary. • If found to be suitable for re-use and handling in line with the above, strip and stockpile 'topsoil' from the footprints of new features before construction. Stockpiles to be no higher than 2 m. • Store 'topsoil' separate from other materials and subsoils. Demarcate stockpile areas and	Environment /Project	Ongoing during construction phases	IMPLEMENTED – Before deep excavation, topsoil is tripped and stock-pilled – Stock pilled topsoil is continuously used in nursery and rehabilitation project

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		erect appropriate durable signage. Draw up and maintain a soils register with estimates of soil type, quantities and quality. • Limit soil compaction, erosion, and contamination on 'topsoil' stockpiles/berms. • Design all new features to prevent soil pollution of surrounding undisturbed areas. • Design all new features to limit/prevent soil erosion. • Prevent soil contamination/pollution. • Infrastructure that will not be used in future is to be removed from site and footprint areas are to be remediated (cleared/ripped/levelled). • Areas showing residual contamination (oils, fuel) from construction activities are to be cleaned by lifting contaminated material for disposal in accordance with waste management requirements. • All construction waste material is to be removed from site and disposed of in accordance with waste management requirements.			
▪ Air Quality	Dust Emission	Wet suppression will be utilised in order to reduce fugitive dust emissions. Should wet suppression not	Environment	As required	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		be sufficient, environmental-friendly soil binding agents will be utilised.			– Permanent dust suppression contractor appointed – Dust suppression programme being implemented based on daily and seasonal schedule
		Durable and environmental-friendly dust suppression coatings to be in place on permanent haul and other internal roads	Environment	Immediate	IMPLEMENTED – Lignosulphonate is the product being used in dust suppression programme, which is environmental-friendly (biodegradable)
		Undertake air quality monitoring during construction in line with the following: • Use real-time dust monitors and other samplers, e.g. SO2 badges, in areas planned for construction to establish baseline (preconstruction) levels. • Ongoing monitoring during construction is to include environmental and occupational health metrics as used on site.	Environment	Ongoing	IMPLEMENTED – The existing Air Quality Monitoring Stations are in operation – Portable real-time monitors for dust and SO2 are in available onsite

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		• Pay special attention to arsenic levels in dust (PM10 and PM2.5) and where construction sites abut areas known to be historically contaminated (in line with CLA) or areas where old lead and cadmium plants operated, the air quality monitoring must take this into account and measure these compounds			
▪ Socio-Economic	Understanding of socio-economic environment and associated impacts	Sinomine Tsumeb Smelter will undertake further primary social and socio-economic data collection in order to update the current Social Impact Assessment (SIA) in order to be aligned with the European Bank for Reconstruction and impacts Development's (EBRD) Performance Requirements. The primary baseline data needs to be gender disaggregated. The SIA will be disclosed to key stakeholders and made available to the general public at the Sinomine Tsumeb Smelter information centre and public library. This ESMP will then be updated with any new mitigation and management measures that further data collection and analysis suggests are appropriate to address social and socio-economic impacts. The updated ESMP will be provided to MET and disclosed to stakeholders by Sinomine Tsumeb Smelter	Environment / Social Performance	Prior to construction	IMPLEMENTED Social impact assessment conducted Additional SIA was completed in 2022, and the SMP is being implemented in conjunction with this social and EMP

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
	Outside Construction Workers	• The appointed contractors should make the necessary arrangements for allowing workers from outside the area to return home on a regular basis and must transport workers back to their home towns within a day of their contracts ending in order to limit the impact of the presence of outside workers on the local communities. • All construction workers from outside Tsumeb should be transported back to their areas of origin within a day of their contract coming to an end	Contract Owners ısure	Ongoing	PARTIALLY IMPLEMENTED - Contractors are advised to take care of accommodation and transportation for their employees Procurement always encourage local contractors for skill enhancement
	Training and Skills Development	Where feasible, training and skills development programmes for locals should be initiated prior to the construction phase for new project components	Human Resources	Prior to constructio n	PARTIALLY IMPLEMENTED – Local service providers are encouraged to apply for tenders
	Heritage site	All sites of heritage importance within the smelter property should be protected from any construction-related activities. Should construction activities lead to the removal or damage of sites of heritage	Environment / Project	Prior to constructio n	IMPLEMENTED – Heritage sites identified

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		importance, approach the National Heritage Council for the appropriate permit(s) to be issued in terms of the National Heritage Act			– Ongoing identification is part of HSE Package for construction project commencement
	Chance heritage finds	Should any chance heritage finds be encountered in the form of archaeological artefacts or human remains during excavations, work should be ceased in the immediate vicinity and the finds confirmed by an archaeologist. Based on the nature of the find and archaeologist's advice, the National Heritage Council is to be advised and written permission requested to remove finds from the works area. In the event that human remains are discovered, advise and liaise with the National Heritage Council and Police and follow standard recovery procedures to the National Museum or National Forensic Laboratory, as directed	Environment / Project	Ongoing	IMPLEMENTED – Ongoing identification is part of HSE Package for construction project commencement
▪ Visual	Visual Impact	Wet suppression will be utilised in order to reduce fugitive dust emissions that could cause a visual intrusion. Should wet suppression not be sufficient, soil-binding agents will be utilised.	Environment / Project	As required	IMPLEMENTED – Dust suppression programme in place

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Chemical dust suppression to be in place on permanent haul and other roads at the Waste Landfill Site.	Environment / Project	Immediate	IMPLEMENTED – Dust suppression programme in place
		Vegetate inactive areas on site	Environment	Immediate and ongoing	PARTIALLY IMPLEMENTED – Nursery in place to propagate seedlings from cuttings and seeds – Planting in field (inactive areas) is ongoing
▪ Noise	Noise during construction	All vehicles and equipment (especially diesel-powered equipment) will be serviced regularly and be kept in good working order to limit vehicle noise	Health & Hygiene / Safety	Prior to construction and ongoing	PARTIALLY IMPLEMENTED – All mobile equipment to be fit for work before brought to site (road worthy certificates)
		Schedule high noise construction activities for daylight hour	Health & Hygiene / Safety	Construction phase	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Undertake construction noise monitoring in line with current on-site noise monitoring programme. Where noise becomes a nuisance, management measures will be investigated and implemented to address these.	Health & Hygiene / Safety	Ongoing	IMPLEMENTED – Noise monitoring programme in place
▪ Waste	Waste management	Provide sufficient capacity in the smelter waste management systems to accommodate additional waste from workers during the construction phase or specify that each contractor is responsible for their own waste management. If the latter, ensure that the contractor's actions comply with waste management legislation and best practice	Environment	Ongoing	PARTIALLY IMPLEMENTED – Waste Management Procedure in place to guide waste storage and disposal – The facility construction completed, for waste generated onsite
▪ Public Relations	Local employment	Preference to be given to local service providers and suppliers with capability to provide goods and services required for construction activities	Human Resources / Procurement	As required	IMPLEMENTED – Local suppliers encouraged to register as vendors to supply goods and services – Training will be conducted to increase participation

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Consult and update the Tsumeb Municipality's skills database for the area. Make this database available to appointed contractors for the construction phase.	Human resources /Procurement	As required	IMPLEMENTED
	Construction workers	Set up an Environmental Monitoring Committee (EMC) (or similar body including key stakeholders, community members, local authority, etc.) to monitor construction activities and the implementation of recommended mitigation measures. The EMC should be briefed on potential risks to the local community associated with outside construction workers, e.g. disruption of existing family structures and social networks linked to potential behaviour of male construction workers.	Social Performance	Construction Phase	PARTIALLY IMPLEMENTED – Stakeholder Engagement Plan and Strategy developed – Community forums established including MD Sessions with Community
▪ Workers/ Contractors' Accommodation	Accommodation	Accommodation for workers/contractors provided by Sinomine Tsumeb Smelter must be in line with the standards prescribed in the IGC and EBRD Guidance Note - Workers' Accommodation: Processes and Standards (A guidance note by IFC and the EBRD). This includes standards for: • General living facilities • Room/dormitory facilities • Sanitary and toilet facilities • Canteen, cooking and laundry facilities	Health and Hygiene	Construction Phase	PARTIALLY IMPLEMENTED – Sinomine Tsumeb Smelter Canteen supplies suitable and healthy food to employees including contractors. This has now been discontinued

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		• Nutrition and food safety • Medical facilities • Leisure, social and • Telecommunication facilities			– Note: Sinomine Tsumeb Smelter Contractor Camp has been discontinued and all contractors are to make necessary arrangement for accommodation of their employees
▪ Code of Conduct	Behaviour	Sinomine Tsumeb Smelter and the contractor(s) must, in consultation with representatives from the MF, develop a code of conduct applicable within both the workplace and the surrounding community for the construction phase. The code, which must be signed by all employees as part of their contract should identify which types of behaviour and activities are not acceptable. It should include a clear statement about zero-tolerance of gender-based violence and should be displayed on site and in the surrounding communities. Construction workers in breach of the code should be dismissed. All dismissals must comply with the Namibian labour legislation	Human Resources	Construction Phase	IMPLEMENTED – Sinomine Tsumeb Smelter Values – Disciplinary Code and Procedure

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
2. Stakeholder Engagement: In relation to general public and community relations					
Objective: • To promote transparency and facilitate communication with the affected public • To promote local employment and improve local economy • To minimise disturbance to neighbouring communities due to operational activities					
▪ Environmental Monitoring Committee		Establish in a transparent and independent manner an Environmental Monitoring Committee (EMC) to monitor environmental and health related issues associated with smelter operations. Details as set out below: • EMC to consist of representatives of Sinomine Tsumeb Smelter, local municipality, national government, local community, Non-Government Organisations and labour. • Include input from independent specialists (health and environmental), where required. • Establish EMC within 6 months of project approval. • EMC to initially meet on a quarterly basis. • All monitoring data to be provided to the EMC with measures put in place to prevent / reduce the risk of misinterpretation of data.	Community and Social Performance	Within 6 months of approval / ongoing	PARTIALLY IMPLEMENTED – Stakeholder Engagement Plan and Strategy developed – Community forums established including MD Sessions with Community

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		• All public complaints submitted to Sinomine Tsumeb Smelter to be provided to the EMC on a quarterly basis.			
▪ Information	Lack of information awareness	Appropriate and relevant monitoring information to be made available to the affected community.	Environment / Communication	Immediate and ongoing	IMPLEMENTED – Sinomine Tsumeb Smelter Information Centre in town continues to serve as primary point of contact with the community – Monitoring information provided to community during community sessions such as MD Sessions
▪ Information communication		Additional ad-hoc public feedback meetings to be held, when required, to communicate information on smelter operations and to provide opportunity for members of the public to ask questions and raise concerns.	Social performance	Whenever required	IMPLEMENTED – Monitoring information provided to community during community sessions such as MD Sessions

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					– Full time employees attending to community queries
▪ External grievances		Implement and monitor the "Receiving Suggestions, Opinions and Grievances Procedure". Ensure the procedure provides appropriate measures for handling of any Gender Based Violence (GBV) related complaints. Staff need to be trained to adequately handle GBV related complaints.	Social Performance	Ongoing	IMPLEMENTED
▪ Internal grievances		Implement and monitor the Sinomine Tsumeb Smelter Internal (Employee) Grievance Policy and Procedure (2017). Ensure the procedure provides appropriate measures for handling of any GBV related complaints. Staff need to be trained to adequately handle GBV related complaints.	Human resources	Ongoing	IMPLEMENTED
	Disturbance to neighbouring communities	Activities likely to cause a noise disturbance (e.g. blasting) are to be restricted to daylight hours and noise monitoring undertaken on-site in line with a noise monitoring programme in order to identify potential disturbances and avoid disturbance to neighbouring communities.	Plant /site managers	Ongoing	IMPLEMENTED – Blasting at quarry is scheduled and farmers are notified

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
▪ Municipal Planning		Actively engage with the Tsumeb Municipality and regional government regarding future landuse planning for residential areas in close proximity to the smelter property. Discussions should specifically focus on the closest residential area of Ondundu and farming activities immediately to the northwest of the smelter property.	Social performance	Ongoing	IMPLEMENTED – Tsumeb Municipality and Regional Council identified as key stakeholders – Buffer zone installed at Ondundu – Agricultural Assessment study commenced and farmers invited to participated as key stakeholders/affected parties
▪ Community perceptions		Community perceptions of high employment numbers for non-Tsumeb residents are to be addressed as part of a clear and transparent stakeholder engagement process. Collate employment information to address this concern. Ongoing communication is a key part of managing expectations, especially given the relatively small number of new job opportunities that the expansion of the smelter will create against the backdrop of higher expectations. Methodically develop a	Social performance	Ongoing	IMPLEMENTED – Stakeholder Engagement Plan developed

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Stakeholder Engagement Plan, including a matrix of different stakeholders and appropriate communication, to proactively address existing and potential concerns and perceptions			
▪ Stakeholder Engagement		Revise the Sinomine Tsumeb Smelter Stakeholder Relationship Management and Engagement Framework in line with EBRD PRs in order to ensure that particular attention is paid to how special interest groups are identified and approached (including vulnerable groups like the San, women and fence line communities), and to ensure appropriate handling of any Gender Based Violence (GBV) related complaints. Where appropriate methods of engagement and information sharing need to be tailored to special interest groups. Staff need to be trained to adequately handle GBV related complaints.	Social performance	Prior to construction	IMPLEMENTED – Stakeholder Engagement Plan developed
		Finalise and implement the Sinomine Tsumeb Smelter Stakeholder Relationship Management and Engagement Framework. Implementation of the Stakeholder Relationship Management and Engagement Framework should be reviewed at least every 6 months.	Social performance	Prior to construction	IMPLEMENTED – Stakeholder Engagement Plan and Strategy developed

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
3. Air quality: Dust and SO_2 emissions control					
Objective: • To reduce SO_2 and dust emissions from the smelter operations to ensure compliance with Sinomine Tsumeb Smelter's environmental emission and health exposure benchmark, reference and limit levels for SO_2 and other chemicals of concern. These levels are to be set as agreed with environmental authorities and must be defensible and relate to the smelter conditions and, where applicable, be in line with international standards • To reduce impacts of fugitive dust emissions • To monitor the effectiveness of dust management during operations and implement improvements as required					
Smelter Plant	SO_2 Emissions	Install and implement a daily (continuous) monitoring system for SO_2 emissions from stacks.	Environment	Within 6 months of approval	PARTIALLY IMPLEMENTED – Analysers have been procured – Installation planned.
		Regulate and benchmark SO_2 emission levels in line with SA NAAQS, WHO and EU standards. Any activities that lead to a sustained increase in SO_2 levels above the relevant standards will not be allowed. Production and process engineering or optimisation changes where sustained increases within the allowable SO_2 emissions window are a possibility, will be subjected to an environmental and	Operations / Environment	Ongoing	PARTIALLY IMPLEMENTED – Air quality standards being incorporated into design criteria for engineering controls

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		health risk assessment prior to initiation to inform the decision on whether the activity is to be allowed.			
		Continuous ambient monitoring of SO_2 to provide a warning system when SO_2 levels are above the South African National Ambient Air Quality Standards.	Operations / Environment	Ongoing	IMPLEMENTED – 6 Ambient Air Quality Monitoring Stations equipped with a mechanism to send out sms and email notifications to a select number of people when SO_2 exceeded
		Implement corrective management actions should SO_2 levels exceed guideline levels as per the South African National Ambient Air Quality Standards or EU standards, and in line with the accepted number of exceedances of the South African National Ambient Air Quality Standards or EU standards.	Operations / Environment	Ongoing	IMPLEMENTED – SO_2 Containment Procedure in place, detailing Sinomine Tsumeb Smelter responses to SO_2 exceedances
	Arsenic dust emissions	Converter furnace hood to be used to reduce fugitive emissions.	Operations / Technical	Ongoing	IMPLEMENTED – Fumes hoods in operation

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Long-term furnace fugitive sampling to be undertaken	Operations / Technical	Ongoing	PARTIALLY IMPLEMENTED – Fugitive emissions sampling incorporated into isokinetic sampling as interim measure
		Annual isokinetic sampling of particulates to be undertaken	Environment	Ongoing	IMPLEMENTED
		Complete testing of ladles of different geometry to understand what the required ladle dimension is to move from ditch cooling to slow cooling (pot cooling) of Ausmelt slag to provide information on the cooling rate.	Operations / Technical	Within 6 months	PARTIALLY IMPLEMENTED – Studies are in progress
		Complete mineralogical analysis on the slow cooled slag to fully understand the mechanism of fuming.	Operations	Within 6 months	PARTIALLY IMPLEMENTED – Studies are in progress
		Complete the study on the benefits of ditch cooling compared to quenching of slag	Operations	Within 6 months	PARTIALLY IMPLEMENTED – Studies are in progress
▪ Dust control		Rehabilitation of closed eastern tailings dam surface to reduce dust. In this regard, a rehabilitation plan	Environment	In line with rehabilitati	PARTIALLY IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		is to be drafted in line with specialist biodiversity and contaminated land input		on plan /within 2 years of approval	– Rehabilitation design completed
		Investigate options to avoid, reduce and contain fugitive emissions, including dust, associated with conveyors, material crushers, ladle cooling, slag cooling and slag crushing and loading. Based on the investigation, implement feasible measures and investments to avoid, reduce and contain fugitive emissions	Technical	Within 1 year of approval/ Ongoing	PARTIALLY IMPLEMENTED – Studies are in progress
		Machinery will be regularly monitored and maintained. Maintenance programmes will be established and implemented.	Operations	Ongoing	IMPLEMENTED
		Wetting the slag heaps with recycled water before and during moving of the material and/or enclosure, extraction and hooding with fabric filters, in order to limit fugitive dust during sizing and crushing operations at the slag plant.	Operations	Ongoing	IMPLEMENTED – Ladle cooling
		Vehicle speeds on unpaved roads will be limited to 40km/h to limit dust. Wet unpaved roads or consider the use of a durable suppressant coating.	Safety	Ongoing	IMPLEMENTED – Speed limit onsite is 20km/h

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					– Speed limit on onsite gravel road is 40km/h – Speed limit on access tarred road is 60 km/h
		Control dust on paved internal roads by considering the use of mechanical broom or vacuum sweepers. Metal rich dust may be bagged and redirected to the smelter for metal recovery or to the tailings for disposal, as appropriate.	Operations	Ongoing	IMPLEMENTED – Dust suppression programme in place – Vacuum trailer procured and in use
		Implement cattle-grids and vehicle brushes (or sprayers if recycled water is available) on the exit road from the smelter in order to minimise transport of polluted dust on car tyres into Tsumeb. De-sludge the water collection bays regularly and dispose of the sludge on the tailings facilities.	Operations	Ongoing	PARTIALLY IMPLEMENTED – Only service vehicles and machines are allowed in the operational areas
		Control dust sources by, where feasible, planting shelter belts of indigenous drought-tolerant evergreen trees along roads and around buildings to protect from fugitive dust and consume polluted runoff.	Environment	Ongoing	PARTIALLY IMPLEMENTED – Tamarisk trees are planted as part of phytoremediation and dust control programme

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
	RHF Emissions	Fume capture and extraction systems at the RHF must be maintained and operated to specifications, in order to ensure minimal fugitive emissions during charging, holding and pour cycles.	Operations	Ongoing	PARTIALLY IMPLEMENTED – Basic design criteria developed
		Investigate options to avoid, reduce and contain fugitive emissions generated during the smelting process. Based on the investigation, implement feasible measures and investments to avoid, reduce and contain fugitive emissions from the smelting process	Operations	Ongoing	PARTIAL IMPLEMENTED – Basic design criteria developed
		Movable and stationary hoods employed at the RHF must be positioned correctly during all cycles of the process in order to prevent fugitive emissions	Operations	Ongoing	PARTIALLY IMPLEMENTED – Basic design criteria developed
▪ Stack height	Inefficient / ineffective	The height of the new baghouse stack must be at least 70 m above ground level, to ensure that emissions released do not result in more than 25% of the ambient air quality limits at ground level	Technical / Projects	Design stages	PARTIALLY IMPLEMENTED – Study in progress
▪ Maintenance	Inadequate maintenance	Schedule adequate and regular maintenance activities across all smelter operations in order to	Technical / Projects	Ongoing	IMPLEMENTED – Maintenance scheduled on preventative maintenance basis

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		ensure stable operations of the plant and related emissions control of dust and gas.			
▪ General Waste Site	Dust Control	Wet suppression with recycled water will be utilised in order to reduce fugitive dust emissions. Should wet suppression not be sufficient, soil binding agents will be utilised.	Environment	Ongoing	IMPLEMENTED – Dust suppression programme
		Durable dust suppression coating to be in place on permanent haul and other roads at the general waste site.	Environment	Ongoing	IMPLEMENTED – Dust suppression programme
		Vegetate inactive areas on site.	Environment	Immediate and ongoing	PARTIALLY IMPLEMENTED – Rehabilitation design completed
▪ Hazardous Waste Facility	Dust control	Trucks transferring waste to site are not to be filled above the brim of the trailer.	Material Handling	Ongoing	IMPLEMENTED – Standard Operating Procedure in place
		Proper handling and disposal of arsenic containing dusts at the waste site must be implemented	Environment	Ongoing	IMPLEMENTED – Standard Operating Procedure in place

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					– Training material on waste management procedure
		Surface water from the return water dam is to be used for dust control on the hazardous waste site. If volumes of recycled water are insufficient for dust control, water is to be supplemented from another source. Overspray of water is to be prevented in order to contain contaminated water within the hazardous waste site footprint.	Environment	Ongoing	IMPLEMENTED – Return water being used in dust suppression as means of recycling and or harvesting water
		Consider the addition of an effective dust suppressant chemical to the water used for dust suppression. The choice of dust suppressant should be in line with the hazardous waste site operational manual, e.g. organic compositions are not allowed	Environment	When required	IMPLEMENTED – Dust suppression programme in place
▪ Sulphuric Acid Plant (SAP)	Integrity of railway lines for acid transportation	Problems with rail transportation would be minimised through consultation with TransNamib regarding the required modifications to the line, appropriate maintenance and effective emergency preparedness and response	Supply Chain Management / Logistics	Ongoing	IMPLEMENTED – Routine inspection and joint emergency drill exercise conducted
	SO_2 emissions	Ongoing management and maintenance of systems feeding off-gas to the sulphuric acid plant and the	Operations	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		acid plant itself, in order to maintain improvements in SO2 levels in the surrounding area			
		Ensure that the plant is optimised, and operations are stable in order to ensure an above 90% utilisation rate.	Operations	Ongoing	IMPLEMENTED
		Establish a procedure for ramping down / shutting down production, should operational problems be experienced at the sulphuric acid plant	Operations	Ongoing	IMPLEMENTED
		Undertake continuous monitoring of SO_2 emissions at the acid plant stack. Consider input of monitoring data into a real time atmospheric dispersion model	Environment	Ongoing	IMPLEMENTED
		Avoid start-up and interruptions of the acid plant operations between the hours of 11am and 4pm (the period of highest atmospheric instability)	Operations	Ongoing	IMPLEMENTED
	Acid rain	Monitor the potential for acid rain generation during the wet season in off-site vegetated and cultivated areas surrounding the smelter property.	Environment	Ongoing	IMPLEMENTED
▪ Kliplime Quarry	Dust emissions	Dust emitted from operations at the quarry and from transport vehicles on the access road must be	Quarry management	Ongoing	IMPLEMENTED – Quarry remain fenced area

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		managed as this may have an impact on the game and vegetation on the surrounding Tsumore Farm			– Trucks transporting lime rocks are covered – Safe/Standard Operating Procedure in place
▪ Emissions	Stack and fugitive emissions	Undertake stack emission testing for the full operational cycle of the RHF once the furnace is operational in order to validate theoretical emission estimates	Operations / Environment	Once RHF is operational	NOT IMPLEMENTED – RHF not yet operational however basic design criteria for RHF has been completed
		Undertake stack emissions testing on the outlet of the converter baghouse over the full converter cycle and at all other outlets to the atmosphere in order to monitor the efficiency of controls	Operations / Environment	Ongoing	IMPLEMENTED – Part of isokinetic sampling programme
		Measure building fugitive emissions once the RHF has been commissioned. These emissions need to be updated given the decommissioning of the reverberatory furnace as well as to determine the extent of fugitive emissions from the charging and pouring RHF. Determine arsenic (and other chemicals of concern) content in particulate emissions.	Operations / Health & Hygiene	Once RHF is operational	NOT IMPLEMENTED – RHF not yet installed and or operational

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Improve data availability on the PM10 and PM2.5 analysers installed at the Sinomine Tsumeb Smelter ambient monitoring stations. Also maintain data availability for SO2 and metal parameters by establishing a monitoring station maintenance programme and ensuring that critical spare equipment is kept in stock.	Environment	Within 1 year of approval	IMPLEMENTED – Maintenance and Calibrations is done on schedule
		Any anomalies or elevated levels in the ambient air quality monitoring station data should be immediately communicated to the site management team in order to ascertain the likely links of such anomalies with specific smelter operations/performance.	Environment	Ongoing	IMPLEMENTED – Exceedances notifications send out in a form of "SMS"
		Consider extending the ambient air quality monitoring network to include two additional monitoring stations, one at the airport and a second 1-2 km northwest of the smelter boundary	Environment	Within 1 year of approval	PARTIAL IMPLEMENTED – Budget provision made
		Expand the fall-out dust monitoring programme by installing monitoring equipment in strategic places around the smelter site and at ambient monitoring stations.	Environment	Within 1 year of approval	IMPLEMENTED – Dust buckets installed around the smelter

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
Standards	Internal Standards	Sinomine Tsumeb Smelter shall compare air monitoring results to the "Environmental Standards and Objectives for Pollutants in Air, Water and Soil" and implement corrective actions as required.	Environment	Ongoing	IMPLEMENTED
4. Soil and Land: Reducing the risk of soil contamination					
Objective: • To minimise contamination within the smelter footprint • To contain spillages of hazardous chemicals from equipment and vehicles and to prevent soil contamination from hydrocarbon spills. • To protect soils from becoming contaminated by runoff from the waste site and other contaminated areas					
Smelter Plant	Containment of hazardous material and risk of contamination of smelter footprint	In all areas where there is storage of hazardous substances (i.e. hydrocarbons), there will be containment of spillages on impermeable floors and bund walls that can contain 110% of the volume of the hazardous substances. All re-fuelling and any maintenance of vehicles will also take place on impermeable surfaces.	Supply chain management	Within 12 months of approval	PARTIALLY IMPLEMENTED – Bund integrity test planned – Outcome of integrity test to guide required upgrade
		Concrete or similar impervious surfaces are to be provided in all areas where concentrates and hazardous smelter wastes (e.g. baghouse dusts) are handled or stored.	Operations	Within 12 months of approval	PARTIALLY IMPLEMENTED – Bund integrity test planned

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					– Outcome of integrity test to guide required upgrade – Other containment issues being addressed by the surface water infrastructure upgrade project including diversion of clean run-off
		Regularly inspect concrete surfaces and undertake annual integrity tests in order to ensure that contaminants do not enter into underlying soils	Operations	Immediate and ongoing	PARTIALLY IMPLEMENTED – Bund integrity test planned/budgeted – Outcome of integrity test to guide required upgrade
		The handling and interim storage of hazardous workshop wastes is to take place on concrete and bunded surfaces.	Material handling / Asset Management	Ongoing	IMPLEMENTED – Servicing of mobile equipment take place only in the workshop or bunded service bays – The completed general waste facility has

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					provision for interim storage of hazardous waste including waste from workshops
		Existing stockpiles of arsenic calcines and baghouse dusts are to be disposed within the hazardous waste disposal site or another registered hazardous waste disposal facility.	Environment	Ongoing	PARTIALLY IMPLEMENTED – Volume survey conducted to quantify the amount of calcines – Calcines heaps being reduced by blending with concentrates on schedule basis
		Baghouse dusts and calcines that cannot be processed are to be disposed of at the hazardous waste site.	Operations	Ongoing	IMPLEMENTED
		Existing onsite contamination should be managed as part of the broader site contamination management	Site manager / Environment	Ongoing	PARTIALLY IMPLEMENTED – Full implementation to be realised by surface water infrastructure upgrade

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Appropriate protective clothing should be worn when in close contact with contaminated soil material to limit dermal and respiratory contact	Health and Hygiene	Ongoing	IMPLEMENTED – Minimum PPE requirement established and complied with
		Pollution will be prevented through basic infrastructure design and through maintenance of equipment.	Asset management	Ongoing	IMPLEMENTED – Design for surface water infrastructure upgrade in place
		Maintain and update the Hazardous Chemical Substances Emergency Response Plan in line with the increased throughput capacity of the smelter	Operations / Emergency Response	Ongoing	IMPLEMENTED - Chemical management plan developed - Emergency Preparedness and Response Plan/Procedure
		Any spills will be contained and cleaned up immediately. Spillages of chemicals during operations are to be reported and investigated through the site incident reporting and investigation procedure. Any contaminated soil must be contained	Operations / Environment	Ongoing	IMPLEMENTED - Root Cause Analysis and ICAM adopted as internal investigation methods

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		within appropriate containers until such a time that they can be disposed of at an appropriate facility			- Emergency Preparedness and Response Plan/Procedure - Hydrocarbon spill procedure in place - Spill kits procured as stock items
		Implement cattle-grids and vehicle brushes (or sprayers if dirty water is available) on the exit road from the smelter in order to minimise transport of polluted dust on car tyres into Tsumeb. Desludge the water collection bays regularly and dispose of the sludge on the tailings facilities.	Operations	Ongoing	PARTIALLY IMPLEMENTED – Only service vehicles and mobile equipment are allowed to enter the operational areas
		Develop a contamination containment plan for the smelter site in line with the CLA and incorporate the above measures.	Environment	Within 1 year of approval	IMPLEMENTED - Strategies have been developed for both soil and groundwater contamination. Implementation is ongoing in a phased approach.

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
	Soil contamination (Smelter Process Waste Management Facilities)	Slag Dumps, Non-Designated Dumping Areas, Tailings Storage Facilities, and Evaporation Ponds: • Construct and maintain optimum functioning of the 'clean' storm water runoff diversion canals/drains in order to divert 'clean' water around these potential pollution sources; • Canals must be lined with impermeable liners, e.g. HDPE or concrete; • Construct and maintain optimum functioning of 'dirty' water runoff intercept canals/drains to the pollution control dams; and • Remove non-designated waste and non-waste dumps to designated dumping areas. Tailings Pipelines: • Construct and maintain earth bund walls (vegetated) along entire length of pipelines; • Immediately repair pipelines where necessary; and • Immediately clean up spills.	Operations / Environment	Ongoing	PARTIALLY IMPLEMENTED – Construction for Clean water diversion channel commenced – Operational waste removal schedule in place
	Soil Contamination (Process Water Storage Facilities, and	Pollution Control Dams and 'Dirty' Water Canals/Drains: • Construct and maintain optimum functioning of these clad (HDPE or concrete) features by attending to leaks, clearing blockages,	Operations / Environment	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
	Clean StormWater Separation Facilities)	preventing siltation and purifying the 'dirty' water for re-use in the plant. 'Clean' Water Runoff Diversion Canals: • Maintain optimum functioning of these earth canals, in order to redirect 'clean' water around these potential pollution sources.			
	Soil Contamination (Topsoil' stockpiles/berms for rehabilitation 'topsoiling' purposes)	Sample/fertilize the 'topsoil' once every 3-4 years in order to maintain vegetative basal cover, thereby limiting soil erosion. No Grazing or burning of vegetation should be allowed.	Environment	Ongoing	PARTIALLY IMPLEMENTED – Topsoil stock piled and protected from disturbance
	Soil contamination via surface and stormwater runof	Control and minimise the ingress of stormwater within the plant footprint as part of a stormwater management plan.	Operations and Environment	Ongoing	PARTIALLY IMPLEMENTED – Construction for Clean water diversion channel commenced
		Undertake regular monitoring of groundwater and surface water within the smelter footprint and specifically surrounding the sulphuric acid plant.	Operations and Environment	Ongoing	PARTIALLY IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					– Groundwater monitoring programme in place
Ongoing contaminated soil remediation		The current Contaminated Land Assessment (CLA) must be completed. Once finalised the recommendations/mitigation and/or management measures of the CLA must be incorporated into the ESMP. The updated ESMP must then be provided to MET and disclosed to stakeholders by Sinomine Tsumeb Smelter. In line with the draft CLA findings, the following measures should be implemented on-site in the interim: • Control contamination sources by planting shelter-belts of indigenous drought-tolerant evergreen trees along roads and around buildings to protect against fugitive dust and to consume polluted run-off. • Remove spilled tailings and polluted sediments from the Jordan River in the dry season and dispose of it on the tailings facility. • Phytoremediation and stabilisation of the Jordan River stream banks with vegetation to prevent	HSE / ESG	Before July 2020	PARTIALLY IMPLEMENTED – CLA completed however findings yet to be communicated with all interested and affected parties – Nursery in place and currently continue with propagating of seedlings/trees for use in phytoremediation

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		erosion of polluted riparian soils. With minimal disturbance, plant riparian species indigenous to the general region. • Removal of the thin layer (<20cm) of surface spilled tailings to expose underlying wetland soils where the Jordan River discharges and planting of indigenous wetland species for phytoremediation. • Phytoremediation of patches of polluted soils using plants to extract sulphur and metals, where feasible, without further disturbance. • Undertake periodic harvesting of the metal-loaded leaves or branches and dispose on the tailings dam areas for dust suppression or mulch. Allow plants to resprout (perennials) or replant (annuals) after harvesting. • Excavation of the thin layer (<5cm to 30cm) of polluted soils across the smelter site and use for soil cladding on tailings facilities in preparation for vegetation. • Establish vegetation cover on the tailings facilities to control seepage to groundwater and prevent run-off of polluted stormwater. • Continue with nursery operation and trials for phytoremediation.			

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		• See the CLA study through to completion and review and add actions from the CLA for implementation as the studies are completed.			
General Waste Site	Soil Contamination	The waste site design provides for containment of contaminated water on the site	HSE / ESG	Prior to constructio n	IMPLEMENTED – The design for General Waste Facility provide for containment of contaminated water
		Should soils become contaminated; the contaminated soils will be contained and removed for appropriate disposal, either to landfill or to the hazardous waste disposal site, should the soil be contaminated with arsenic at the prerequisite levels for disposal.	Environment	Ongoing	IMPLEMENTED – The design for General Waste Facility provide for remediation of hazardous waste including contaminated soil – General waste facility design provides for interim storage of hazardous waste
		Soils contaminated with hydrocarbons are to be appropriately treated (e.g. bioremediated).	Environment	Ongoing	IMPLEMENTED – Portion of contaminated soil treated by blending

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					with concentrates and fluxes and feed into process – Remaining portion stored in drums and send offsite for disposal – The design for General Waste Facility provide for remediation of hazardous waste including contaminated soil
Standards	Internal standards	Sinomine Tsumeb Smelter shall compare soil quality monitoring results to the "Environmental Standards and Objectives for Pollutants in Air, Water and Soil" and implement corrective actions as required.			IMPLEMENTED

5. Groundwater: Reducing the risk of groundwater contamination

Objectives:
- To comply with the Namibian regulatory requirements
- To put measures in place to align the operations with the provisions of international best practices to protect water resources.
- To reduce the impact of the cone of depression caused by groundwater abstraction.
- To reduce the off-site spread of contaminated groundwater.
- To protect groundwater resources from seepage from potential contaminant sources

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
• To assess the effectiveness of pollution control measures.					
Smelter Plant	Contamination risk	East tailings dam is to be rehabilitated to prevent groundwater pollution as required in line with the revised Closure Plan.	Environment	Within 3 years of approval	PARTIALLY IMPLEMENTED – Design for ecological rehabilitation completed
		The use of standard erosion control measures, such as interception drains, contour planting, silt fences, establishment of groundcover species, optimal drainage construction, and silt ponds are applied where appropriate.	Environment	Within 2 years of approval	PARTIALLY IMPLEMENTED – Design for ecological rehabilitation completed
		Regular maintenance and proper safety procedures to prevent leaks and spills	Asset Management	Ongoing	IMPLEMENTED – Annual Maintenance Shutdown scheduled and implemented
		Implement and strengthen, where necessary, procedures to respond to emergency product spills in areas of Sinomine Tsumeb Smelter responsibility. This may extend beyond the immediate boundary of the Sinomine Tsumeb Smelter site.	Environment	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Dispose of waste material at a suitably contained disposal site	Environment	Ongoing	IMPLEMENTED
		Implement the phytoremediation trials in line with the revised Closure Plan	Environment	Ongoing after establishment of nursery	PARTIALLY IMPLEMENTED – Nursery in operation – Planting of trees on two sites commenced and ongoing
Groundwater monitoring		Maintain the current groundwater site wide sampling programme (i.e. timing, depth, efficiency of testing equipment, record keeping, etc.) in order for a database to be built up on water quality and enable rapid identification of any changes in quality.	Environment	Ongoing	IMPLEMENTED – Water Monthly monitoring programme in place
		Continued monitoring of groundwater quality and levels for the minimum period as specified by Namibian environmental regulations where applicable (e.g. S 31 EMA and the Water Act). All monitoring boreholes are to be properly surveyed in terms of position and height so that borehole levels can be expressed in meters above mean sea level, piezometric height can be derived and thereby the groundwater level profile.	Environment	Ongoing	IMPLEMENTED – Water Monthly monitoring programme in place

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Install one upgradient and two down gradient monitoring boreholes that can be monitored and sampled to determine the potential quality of unsaturated groundwater flow in the immediate vicinity of the sulphuric acid plant. Ensure that the newly drilled boreholes are properly logged and that proper pump tests are done and groundwater parameters derived. Ensure that the relevant borehole permits are obtained.	Environment	In line with budgetary allocation	IMPLEMENTED – Permits obtained for new boreholes drilling – Drilling Completion report and samples submitted to MAWLR
		Regular monitoring of the existing groundwater monitoring system shall occur at least quarterly and reported annually to authorities who regulate the management of the Tsumeb aquifers.	Environment	Ongoing	IMPLEMENTED – Monthly water monitoring programme in place
		Any complaints with respect to the management of groundwater quality will be directed to the site management. Complaints and any actions arising from a complaint will be recorded in a complaints register to be maintained by site management	Environment	Ongoing	IMPLEMENTED – Environmental Complaints register active and maintained
		Include regional groundwater monitoring from existing farm and municipal boreholes and produce a detailed groundwater monitoring schedule	Environment	Ongoing	PARTIALLY IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					– Water Monthly monitoring programme in place – Some of the new boreholes drilled are nearby farms
Identification of pollution sources		Finalising of the project for identifying major sources of groundwater pollution and implementing the clean-up and remediation of these sources over the Sinomine Tsumeb Smelter site.	Environment	Within 1 year of approval	PARTIALLY IMPLEMENTED – Groundwater contamination and treatment study completed – Insitu remediation proof of concept completed
	Arsenic plume migration	Additional boreholes should be drilled to the north of the site to better detect the arsenic pollution plume migration and further refine the updated 2018 groundwater model.	Environment	Within 2 year of approval / ongoing	IMPLEMENTED – 12 new boreholes drilled
		Investigate targeted solutions for groundwater treatment and pollution source elimination in order to reduce potential offsite pollution.	Environment	After refining groundwater model	PARTIALLY IMPLEMENTED – Groundwater model reviewed and updated

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
Groundwater model		Continue to refine the updated 2018 groundwater model by incorporating data from new monitoring boreholes to the north of the smelter boundary.	Environment	Within 1 year of approval	IMPLEMENTED – Groundwater model reviewed and updated
	Impact on groundwater quantity	Continue to monitor water levels in boreholes on site and off site (including Tsumeb Municipality and DWAF monitoring and production boreholes) to monitor possible cone of depression caused by pumping from Shaft 1.	Environment	Immediate	IMPLEMENTED – Groundwater model reviewed and updated
		Renew the groundwater abstraction permit with the Ministry of Agriculture, Water and Forestry, as required.	Environment	Prior to permit lapsing	IMPLEMENTED –
Handling and storage of hazardous substances		In all areas where there is storage of hazardous substances (i.e. hydrocarbons), there will be containment of spillages on impermeable floors and bund walls that can contain 110% of the volume of the hazardous substances.	Asset management / Environment	Ongoing	PARTIALLY IMPLEMENTED – Bund wall integrity test completed – Central facility (bulk used oil storage facility) planning
		All re-fuelling and any maintenance of vehicles will take place on impermeable surfaces.	Operations / Asset Management	Ongoing	IMPLEMENTED – Vehicle workshops upgraded

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					– Vehicles only serviced within a workshop or allocated service bays
		Pollution will be prevented through basic infrastructure design and through maintenance of equipment	Operations / Asset Management	Ongoing	PARTIALLY IMPLEMENTED – Surface water infrastructure upgrade being implemented in phases
		Environmental awareness for contractor and employees to be included during inductions	Environment / Operations	Ongoing	IMPLEMENTED – Site induction – Monthly Environmental themes
		Any spills will be contained and cleaned up immediately.	Environment / Operations	Ongoing	IMPLEMENTED – Emergency Response Plan/Procedure – Hydrocarbons spill response procedure
Stormwater management		Implement the surface water infrastructure upgrade project for the improved management of stormwater across the smelter site. Prioritised water infrastructure projects include the following:	Operations / Environment	In a phased manner in line with	PARTIALLY IMPLEMENTED – Pollution Control Dam in operation

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		• Pollution Control Dams; • Drainage channels to Pollution Control Dams; • Concrete lined channels to replace the existing damaged open channels; • Lining of the No 10 Dam; • Recovering and rerouting contaminated water sources using bunding and pumps; • Separation of process water and stormwater; • Clean water separation via an earth embankment and sump; and • Treatment of effluent for recycling.		stormwater management plan	– Surface-water infrastructure upgrade project being implemented in phases
General Waste site	Impact on Groundwater	Clean stormwater is to be diverted from all areas that may be contaminated	Environment	In a phased manner in line with the stormwater management plan	PARTIALLY IMPLEMENTED – Construction of General waste facility completed
		Water from the waste site is to be contained in a return water pond and re-used.	Environment	Ongoing	PARTIALLY IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					– Construction of General waste facility completed
		Monitor water quality near potential pollution sources and the surrounding community boreholes.	Environment	Continuation from the planning phase	IMPLEMENTED
Hazardous waste facility	Containment of contaminants onsite	Monitor and maintain leachate management systems to ensure liner efficiency in accordance with the Operational Manual.	Environment	As per requirements of operational manual	IMPLEMENTED
		Implement and maintain a leachate treatment and recycling system in accordance with the Operational Manual	Environment	As per requirements of operational manual	IMPLEMENTED
		Undertake regular leachate monitoring.	Environment	As per requirements of the leachate	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
				monitoring schedule	
		Continue to undertake regular groundwater monitoring.	Environment	As per requirements of the groundwater monitoring schedule	IMPLEMENTED
Sulphuric Acid Plant	Contamination risk	Appropriate collection of spillages of acid or contaminated solutions from leaking pipelines in areas that are not bunded, followed by remedial action if required (e.g. neutralization with lime).	Operations / Emergency Response	Ongoing	IMPLEMENTED
		Implement and strengthen, where necessary, emergency procedures for product spills in areas of Sinomine Tsumeb Smelter's responsibility. This may extend beyond the immediate boundary of the Sinomine Tsumeb Smelter site.	Operations / Emergency Response	As per requirements of operational manual	IMPLEMENTED
Closure phase	Rehabilitation	Decommissioning and closure procedures will be developed to avoid contamination of the groundwater resources as a result of activities such as the demolition, decontamination, and storage of	Operations / Environment	Ongoing	PARTIALLY IMPLEMENTED – Closure Plan revised

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		potentially contaminated plant infrastructure and waste.			– Progressive rehabilitation being implemented
		Rehabilitation of waste stockpiles and tailings facilities in line with the revised Closure Plan recommendations.	Environment	Ongoing / at closure	PARTIALLY IMPLEMENTED – Progressive rehabilitation being implemented
Water balance		Implement the actions recommended in the Surface Water Management: Site Water Balance Report (May 2019, Revision 3) compiled by Aurecon	Water Management	Ongoing	PARTIALLY IMPLEMENTED – Water Balance revised – Actions being progressively implemented
Standards	Internal standards	Sinomine Tsumeb Smelter shall compare water quality monitoring results to the "Environmental Standards and Objectives for Pollutants in Air, Water, and Soil" and implement corrective actions as required.	Environment	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
6. Surface-water: Reducing the risk of surface water contamination					
Objectives: • To minimize contamination risk to groundwater during construction and operation. • To ensure the continued diversion of clean water around the site and the containment of dirty water on the site. • To minimize additional contact runoff which could overload the stormwater system. • To upgrade areas where design capacity is reached, to prevent problems • To minimize health risks to surrounding communities, livestock, and natural faun,a and flora.					
Smelter Plant	Surface water contamination	The use of standard erosion control measures, such as interception drains, contour planting, silt fences, the establishment of groundcover species, optimal drainage construction, and silt ponds are to be applied where appropriate.	Environment	Within 1 year of approval	PARTIALLY IMPLEMENTED – Design for ecological rehabilitation completed
		Regular maintenance and proper safety procedures to prevent leaks and spills	Safety / Asset Management	Ongoing	IMPLEMENTED – Annual Maintenance Shutdown scheduled and implemented
		Measure the remaining extent of contaminated soil on the smelter property and plant a shelter belt of indigenous trees or shrubs along the edges of these areas to prevent erosion and transport of contaminated soil into the Jordan River.	Environment	Ongoing	PARTIALLY IMPLEMENTED – Design for ecological rehabilitation completed

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Implement phytoremediation to prevent the erosion and spread of polluted riparian soils.	Environment	Ongoing	PARTIALLY IMPLEMENTED – Design for ecological rehabilitation completed
Quality of railway lines for acid transportation		Implement and strengthen, where necessary, emergency procedures to respond to emergency product spills in areas of Sinomine Tsumeb Smelter's responsibility. This may extend beyond the immediate boundary of the Sinomine Tsumeb Smelter site.	Emergency Response	Ongoing	IMPLEMENTED – Emergency Preparedness and Response Plan/Procedure in place
Stormwater management		Implement the surface water infrastructure upgrade project for the improved management of stormwater across the smelter site. Prioritized water infrastructure projects include the following: • Pollution Control Dams; • Drainage channels to Pollution Control Dams; • Concrete lined channels to replace the existing damaged open channels; • Lining of the No 10 Dam; • Recovering and rerouting contaminated water sources using bunding and pumps; • Separation of process water and stormwater;	Operations / Asset Management	Implement in a phased manner, commencing within 1 year of approval	PARTIALLY IMPLEMENTED – Pollution Control Dam in operation – Surface-water infrastructure upgrade project being implemented in phases

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		• Clean water separation via an earth embankment and sump; and • Treatment of effluent for recycling.			
		Arsenic-laden	Operations / Asset Management		PARTIALLY IMPLEMENTED – Surface-water infrastructure upgrade project being implemented in phases including diversion of clean water
		Undertake regular monitoring of stormwater infrastructure to ensure there are no blockages or excessive siltation and contact water is efficiently stored.	Operations / Asset Management	Ongoing	IMPLEMENTED
		Undertake regular sampling of runoff water on the site and in the downstream Jordan River in order to monitor pollution levels of water leaving the site.	Environment	Ongoing	IMPLEMENTED
		A study investigating phytostabilisation measures to control dust is to be completed. Preliminary recommendations include revegetation of exposed areas and the planting of pollution control woodlands	Environment	Ongoing	PARTIALLY IMPLEMENTED - Design for ecological rehabilitation completed

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		at the base of tailings facilities to protect the Jordan River from runoff and sub-surface polluted seepage.			
	Additional surface water run-off	Review stormwater calculations with increased contact water from additional slag storage.	Water management	Within 1 year of approval	IMPLEMENTED – Water balance revised and ongoing
Emergency procedures		Ensure that emergency procedures are in place to deal with major flood events.	Emergency response	Within 1 year of approval	IMPLEMENTED – Emergency Preparedness and Response Plan/Procedure in place – Emergency procedure for floods events in place
Drinking water		Undertake regular monitoring of on-site drinking water sources to ensure quality complies with Namibian drinking water standards	Health and Hygiene	Ongoing	IMPLEMENTED
Sewage Treatment Plant	Monitoring	Monitor operations of the sewerage plant in accordance with the site water monitoring program.	Environment / Water Management	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Continuously monitor workshops, oil spillages, sewerage pipelines, and connections to prevent oil and other waste streams that could damage sewerage plant infrastructure from entering the system.	Environment / Water Management	Ongoing	IMPLEMENTED
	Permit	Ensure that a valid discharge permit for treated effluent is in place and renewed with the Ministry of Agriculture, Water, and Forestry, as required	Environment / Water Management	Prior to permit lapsing	IMPLEMENTED – Valid permit in place and renewal permit application will be submitted to MAWLR as part of maintaining license
General waste site	Stormwater management	Clean stormwater is to be diverted from all areas that may be contaminated.	HSE / ESG	In a phased manner in line with stormwater management plan	PARTIALLY IMPLEMENTED - Construction of General waste facility completed and provision for clean water diversion incorporated in the design
		Water from potentially contaminated areas to be contained in pollution control dams, recycled and re-	HSE / ESG	Ongoing	PARTIALLY IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		used. Implement a water quality monitoring programme at the general waste site area.			– Construction of General waste facility completed and provision for reusing contaminated water incorporated into operation manual
Hazardous waste facility	Diversion of clean water around the site and containment of dirty water	Monitoring and maintenance of surface water management measures in accordance with Operational Manual.	Environment	As per requirements of operational manual	IMPLEMENTED – Construction of clean water diversion channel completed as part of cell 2 construction project
		Implementation and maintenance of stormwater recycling system for run-off collected on site in accordance with Operational Manual.	Environment	As per requirement of operational manual	IMPLEMENTED
Water Balance		Implement the actions recommended in the Surface Water Management: Site Water Balance Report (May 2019, Revision 3) compiled by Aurecon	Water management	Ongoing	PARTIALLY IMPLEMENTED - Surface water infrastructure upgrade implemented in phases - Internal water consumption targets and

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					reduction initiatives implemented
7. Noise: The monitoring and management of noise impact					
Objectives: • To minimise noise disturbance to surrounding communities • To reduce impacts of noise from blasting and drilling on the surrounding areas and on the game on Tsumore Farm.					
Smelter Plant	Noise complaints	Monitor public complaints related to noise production from the smelter	Environment	Immediate	IMPLEMENTED
		If a complaint regarding noise emissions relating to the continuous audibility of the operations is received, short term (24-hour) ambient noise measurements should be conducted as part of investigating the complaint. The results of the measurements should be used to inform any follow-up interventions. Measurements should be conducted by trained persons	Environment	If required	IMPLEMENTED
	High noise activities	As far as is practicable, restrict start-up and major plant maintenance activities to daylight hours, should these activities be the source of high noise levels.	Asset Management	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
	Vehicle maintenance	All diesel-powered equipment and plant vehicles should undergo regular maintenance in order to prevent excessive noise levels. Undertake regular inspection of plant and, if necessary, replace intake and exhaust silencers.	Safety	Ongoing	IMPLEMENTED
	Plant equipment	Select equipment with lower sound power levels. Vendors should be required to guarantee optimised equipment design noise levels. Implement engineering controls (e.g. installation and maintenance of silencers) in order to limit noise levels.	Supply Chain Management / Procurement	Planning / Ongoing	IMPLEMENTED – Sinomine Tsumeb Smelter acquired new mobile equipment and noise requirements were part of the purchasing criteria
	Traffic noise	For management of noise from truck and vehicle traffic, the following should be implemented: • Minimise individual vehicle engine, transmission, and body noise/vibration. This is achieved through the implementation of an equipment maintenance program. • Maintain road surface regularly to avoid corrugations and potholes. • Avoid unnecessary idling times. • Minimise the need for trucks/equipment to reverse. This will reduce the frequency at	Safety	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		which disturbing but necessary reverse warnings will occur.			
Noise monitoring		Implement a noise monitoring programme to measure noise levels at sensitive noise receptors outside of the smelter footprint.	Environment / Health and Hygiene	Ongoing /on annual basis	IMPLEMENTED
Noise reduction	Excessive noise	Establish a noise reduction action plan in order to manage the impact of noise from current processes on the surrounding environment and employees. Include administrative measures and engineering controls	Environment / Health and Hygiene	Within 1 year of approval	IMPLEMENTED
Kliplime quarry	Blasting and drilling noise	Blasting and drilling operations must be limited to daylight hours during the week	Quarry management	Ongoing	IMPLEMENTED – Blasting scheduling include notifications to the neighbours and key stakeholders

8. Ecology: Minimising the damage and risks to natural ecology

Objectives:

- To prevent damage or risks to natural ecology
- To control encroachment and proliferation of invasive and weed species
- To minimise disturbance to biodiversity and to minimise pressure on natural resources
- To limit the spread of alien invasive vegetation.

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
Smelter Plant	Biodiversity action plan	Complete and execute a full Biodiversity Action Plan to address all issues relating to biodiversity management and rehabilitation, including all the below measures.	Environment	Within 2 years of approval	IMPLEMENTED – Biodiversity Action Plan in place – Annual action plan derived and implemented
	Damage or risks to natural ecology	Implement measures for the control of SO_2 emissions as set out in the Air Quality MMP to reduce risk of damage to vegetative material as a result of SO_2 emissions.	Operations	Ongoing	IMPLEMENTED
		Implement dust control measures as set out in the Air Quality MMP to reduce release of particulates which results in contamination of soils and vegetation.	Operations	Ongoing	IMPLEMENT
	Alien vegetation	• Problem alien invasive species on Sinomine Tsumeb Smelter property are to be controlled to prevent the spread of such species. Priority species for removal include the rubber vine (Cryptostegia grandiflora), wonderboom (Leucaena leucocephala), wild tobacco (Nicotiana glauca) and Prosopis species. • In the event that alien species provide a stability function, they are to be replaced with	Environment	Ongoing	IMPLEMENTED – Biodiversity Action Plan in place - Annual action plan derived and implemented

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		suitable indigenous species in a phased manner prior to removal. • Develop initiatives to contain invasive and alien species in the alien infested habitats along the eastern edge of the smelter property. • Remove cleared alien vegetation off-site so that it does not pose a fire risk.			
	Weeds	Weeds are to be mechanically removed and/or chemically controlled as appropriate. Disposal methods for cuttings will depend on the species (e.g. burning).	Environment	Ongoing	IMPLEMENTED
	No-go areas	Declare the dolomite hill habitat as a no-go area and avoid any further expansion into this habitat in line with the Biodiversity Action Plan.	Operations / Environment	Within 1 year of approval	IMPLEMENTED – Biodiversity Action Plan in place – Annual action plan derived and implemented
	Plant removal	Reduce access to the dolomite hill habitat and sandy plain habitat within the smelter boundary in order to prevent poaching of indigenous plants for firewood and medicinal purposes.	Environment	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
	Promotes species diversity	Diversify the range of dominant vegetation species across the smelter property through the following: • Collect seeds of preferred species identified in the Biodiversity Action Plan and reseed areas selected with the purpose to create new base areas from which they can spread naturally, e.g. drainage line banks. • Target the sandy plains and the old eastern tailings facility. • Use only indigenous species.	Environment	Ongoing	IMPLEMENTED
	Firewood harvesting	Prohibit wood harvesting on Sinomine Tsumeb Smelter property	Environment / Security	Ongoing	IMPLEMENTED - Access Restriction and Safety signages installed
	Animals	Sinomine Tsumeb Smelter will implement a zero tolerance policy with regard to the killing of any animals, including poaching. This applies to people directly employed by Sinomine Tsumeb Smelter as well as any contractors working on their behalf.	Environment / Security	Ongoing	IMPLEMENTED
		Prevent large animals (livestock and game) from entering the premises and drinking from contaminated open water sources.	Environment / Security	Ongoing	IMPLEMENTED - Perimeter fence maintained

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
	Road kills	Enforce speed limits on access and internal roads in order to prevent road kills.	Security	Ongoing	IMPLEMENTED
	Fire	No open fires will be permitted on site, except for fires in a controlled environment used for firefighting training.	Emergency response	Ongoing	IMPLEMENTED
Powerline	Bird strikes	Monitor for bird mortalities by undertaking the following steps: • Undertake quarterly monitoring surveys for bird mortalities along the entire length of powerline infrastructure and transformer structures, as well as on an around the tailings dam and near flood lights. • The identified "sensitive" sections should especially be closely checked, including the parts that cross drainage lines and other obvious flight corridors, and especially the section closest to the farm dam. • All mortalities should be recorded and reported to the Sinomine Tsumeb Smelter Environmental Section and the NamPower/NNF Strategic Partnership to follow up and obtain specific recommendations around management.	Environment	Ongoing	IMPLEMENTED – Powerline surveys planned and conducted and ongoing monitoring in place

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		• Should collisions start to occur repeatedly in any one area on the line that is not marked, the relevant section(s) should be retro-fitted with appropriate mitigation measures (flaps/markers). Should collisions still take place after mitigation, the marking methods would need to be reassessed.			
Kliplime quarry	Vegetation removal	Areas (quarry and project footprint area) from which vegetation may be removed are to be delineated prior to removal and vegetation is only to be removed from these areas.	Quarry management	During operations	IMPLEMENTED
		This material must be removed from the quarry site so that it does not pose a fire hazard	Quarry management	During operations	IMPLEMENTED
		Consider the utilisation of cleared material in the creation of windrows on old tailings facilities within the smelter boundary in order to promote plant growth by providing compost and acting as traps for seeds and plant material	Environment	Ongoing	IMPLEMENTED – Garden refuse disposed off at tailings
9. Community health and safety: Ensuring health and safety of the community					
Objectives: • To monitor the impact of smelter operations on community health and safety					

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
• To protect members of the community from dangers associated with access to the Kliplime Quarry.					
Smelter plant	Buffer zone	Initiate a process with Government to delineate and establish a buffer zone, taking into account findings of specialist studies in the current ESIA and other ancillary studies. This buffer zone is to exclude agricultural development, collection of plant material (such as marula fruit) and certain commercial activities that place people at risk as a result of historical and future fallout of chemicals of concern from the smelter. The buffer zone is to be maintained in consultation with the appropriate local authorities in order to exclude residences within areas that may result in the exposure of persons to air quality emissions and soils containing high levels of pollutants.	Environment	Within 6 months after CLA results become available	IMPLEMENTED
	Community health monitoring	Regular monitoring programme to be set up for voluntary community urine arsenic level testing. Schedule should be in line with a health specialist's recommendations. Monitoring should include tap water and drinking water source testing.	Health and Hygiene / Stakeholder	Ongoing and in line with health specialist recommendations	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Actions are to be identified to address issues of exposure identified by community health monitoring and to implement measures to reduce such exposure.	Health and Hygiene / Stakeholder	Ongoing and in line with health specialist recommendations	IMPLEMENTED
	SO_2 exposure	Better control fugitive SO_2 emissions at all points, particularly capturing emissions at the furnaces and the converters and from slow cooling of slag. Implement air quality management measures in the Air Quality MMP.	Operations	Ongoing	IMPLEMENTED – Additional studies in progress to explore options for control emissions associated with slow cooling processes
	Efficient hazardous waste site operation	Efficient operation and maintenance of the hazardous waste disposal site and closure and capping in line with the long term operational and revised Closure Plan when the approved capacity is reached	Environment	In accordance with deposition / Operation manual	IMPLEMENTED – Capping design also completed
	Emissions monitoring	Ensure all air quality monitoring stations are functional for SO_2	Environment	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Ensure that equipment at the monitoring stations is maintained and functional and undertake immediate repairs when necessary.	Environment	Ongoing	IMPLEMENTED
	Arsenic exposure investigation	Further arsenic exposure investigations to include the following: • Annual determination of arsenic levels in soil and grown vegetables/fruit in areas not covered by existing studies; • Hand to mouth behaviour as an arsenic exposure pathway; • Undertake more urine arsenic sampling in the most affected areas to the north of Tsumeb; • Undertake more urine arsenic sampling in under sampled areas within Tsumeb along with unexposed controls; and • Formalise a community arsenic management and monitoring programme to include the above investigations. Include community awareness component to address, e.g. personal hygiene and the related prevention of hand to mouth transmission of arsenic dust.	Health and Hygiene	Ongoing within 1 year of approval	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
	Harvesting of plant foods	No harvesting of wild plant foods or edible insects is to be allowed within the smelter boundary.	Environment / Security	Ongoing	IMPLEMENTED – Buffer zone – fenced installed between Sinomine Tsumeb Smelter and Ondundu community – Safety signages installed in the field in local languages
	Fencing and access	Fencing around the smelter site, tailings storage facilities and general waste site is to be maintained and access controlled.	Environment / Operations / Security	Ongoing	IMPLEMENTED
Kliplime quarry	Dangers associated with access to the Kliplime Quarry	The fencing around the Kliplime Quarry is to be maintained and access to the site is to be prohibited (gate is to be locked at all times).	Quarry management	Ongoing	IMPLEMENTED - Fence maintained and signages installed/maintained
		Warning signage is to be put in place.	Quarry management	Ongoing	IMPLEMENTED - Signages installed / maintained

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Provide site security during drilling and blasting.	Quarry management	During drilling and blasting	IMPLEMENTED – Signages installed / maintained
Hazardous waste facility	Access to site	Maintain the fence and gate at the access point to the hazardous waste site	Environment / Security	Ongoing	IMPLEMENTED – Fence maintained
		Maintain warning / access restriction signs at entrance to site	Environment / Security	Ongoing	IMPLEMENTED – Signages installed / maintained
		Access to site is to be controlled and no unauthorised entry is to be allowed.	Environment / Security	Ongoing	IMPLEMENTED – Signages installed / maintained
Further health impact assessments	Understanding of community health impacts	The recommendations/mitigation measures of the 2018/2019 Health Impact Assessment must be incorporated into this ESMP once finalised. The updated ESMP should then be provided to MET and disclosed to stakeholders by Sinomine Tsumeb Smelter.	Sinomine Tsumeb Smelter Exco	Prior to constructio n	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
Unplanned events related to project design and construction	Unplanned events	Ensure that HAZOP studies are carried out for the expansion project as well as part of the design phase for all future projects.	Sinomine Tsumeb Smelter Exco	Ongoing	IMPLEMENTED – All project designs undergo HAZOP
Arsenic exposure reduction	Arsenic exposure reduction plan	Conduct a review on at least a 6-monthly basis to assess the implementation of the Arsenic Exposure Reduction Plan.	Sinomine Tsumeb Smelter Exco	Ongoing	IMPLEMENTED
	Arsenic exposure	Conduct follow up community health surveillance to assess the level of arsenic exposure.	Health and Hygiene	Ongoing	IMPLEMENTED
		Construct a wash bay for trucks leaving the site.	Sinomine Tsumeb Smelter Exco	Ongoing	IMPLEMENTED
		Provide warning signs at legacy waste sites.	Sinomine Tsumeb Smelter Exco	Ongoing	IMPLEMENTED
		Measure airborne arsenic levels more widely in the community.	Environment / Health and Hygiene	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
HIV/AIDS Awareness	HIV/AIDS awareness	Implement an HIV/AIDS awareness programme for all construction workers at the outset of the construction phase	Health and Hygiene	Ongoing	IMPLEMENTED
10.Occupational health and safety: Ensuring health and safety of employees					
Objectives: • To monitor the impact of smelter operations and expansion on occupational health and safety • To improve the current occupational health and safety programmes to align with the increased smelter throughput capacity					
Smelter Plant	Arsenic exposure	Implement engineering controls for reducing arsenic exposure pathways rather than emphasising reliance on personal protective equipment (PPE).	Operations / Technical	Ongoing	IMPLEMENTED – Additional studies in progress to explore options for control emissions associated with slow cooling processes
		Continue to implement job rotations, but at lower arsenic cut-off values.	Operations / Health and Hygiene	Within 6 months of approval	IMPLEMENTED
		Investigate implementation of internationally recognised limits and standards for employee exposure to arsenic and complete arsenic exposure reduction action plan	Health and Hygiene	In progress compliance by end of	IMPLEMENTED – Arsenic reduction plan in place

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
				2021 if adopted	
		Conduct a review of control room facilities and upgrade where required in accordance with an arsenic exposure reduction action plan.	Health and Hygiene	Ongoing	IMPLEMENTED – Arsenic reduction plan in place – Construction/reverbing of new control rooms
	Contractors' health and safety risks	Ensure that provisions are in place to manage health and safety risks associated with contractors and suppliers, including contract clauses, audits and performance reviews.	Health and Hygiene	Ongoing	IMPLEMENTED – HSE Criteria part of tender process
	Emissions	Investigate options to avoid, reduce and contain fugitive emissions and dust associated with the various operational processes (i.e. materials handling, smelting and slag processing), especially with regards to the increased throughput capacity. Based on the options analysis, implement reasonable measures.	Operations / Health and Hygiene	Ongoing in line with planned maintenance and inspections	IMPLEMENTED – Arsenic reduction plan in place
		Ensure converter and Ausmelt bag filters and bag house maintenance is undertaken on a regular basis.	Operations / Health and Hygiene	End of 2019	IMPLEMENTED – Annual maintenance shutdowns

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Implement measures to reduce dust emissions from conveyors in line with arsenic exposure reduction action plan	Operations / Health and Hygiene	Ongoing	IMPLEMENTED
	Updates monitoring programmes	Review and update occupational hygiene and biological monitoring programmes to include considerations as a result of the increased throughput capacity. This should include dust, noise, heat and fume exposure, amongst others. Strengthen the industrial hygiene programme with more emphasis on industrial hygiene led exposure control rather than monitoring. Review the implementation of the Health & Hygiene Plan 2017 – 2021 on a 6-monthly basis	Health and Hygiene	Ongoing	IMPLEMENTED
	Efficient hazardous waste facility operation	Efficient operation and maintenance of the hazardous waste disposal site and closure and capping in line with the long term operational and revised Closure Plan when the approved capacity is reached	Environment	In accordance with deposition / operation manual	IMPLEMENTED
	Asbestos	Conduct a comprehensive asbestos survey, with an associated management plan.	Health and Hygiene	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
	Heat stress	Update heat stress monitoring programmes and implement engineering controls where feasible	Health and Hygiene	Ongoing	IMPLEMENTED
Unplanned events related to project design and construction	Unplanned events	Ensure that HAZOP studies are carried out for the expansion project as well as part of the design phase for all future projects	Sinomine Tsumeb Smelter Exco	Ongoing	IMPLEMENTED – All project designs undergo HAZOP
Standards	Internal Standards	Sinomine Tsumeb Smelter shall compare OHS monitoring results to the "Occupational Health Standard: Adopted Workplace Exposure Limits" and implement corrective actions as required.	Health and Hygiene	Ongoing	IMPLEMENTED
11.Socio-economic: Promoting local employment and improve local economy					
Objective: • To increase contribution to local and regional economy					
Smelter Plant	Local employment creation and improve local economy	Priority to be given to employment of local persons	Human resources	Ongoing	IMPLEMENTED
		Procurement to be given to local service providers within the district as far as practical.	Human resources	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Sinomine Tsumeb Smelter procurement procedures to address capacity building within the community skill sector to meet potential job opportunities available at the plant or any future Sinomine Tsumeb Smelter operations.	Human resources	Ongoing	IMPLEMENTED
	Gender equality	The recruitment selection process should continue to promote gender equality and the employment of women where possible	Human resources	Ongoing	IMPLEMENTED – Compliance with Affirmative Action requirements
	Local SMMEs	• In consultation with the Tsumeb Municipality, ensure that the database of local companies, specifically Small Medium and Micro Enterprises (SMME's) that qualify as potential service providers is kept up to date. These companies should be notified of the tender processes and invited to bid for project-related work. Where possible, assist local SMME's to complete and submit tenders. • Before the construction phase commences, Sinomine Tsumeb Smelter must meet with representatives from the Tsumeb Municipality and establish whether a skills database exists for the area the database must be made available to	Human resources	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		the contractors appointed for the construction phase. • Sinomine Tsumeb Smelter, in consultation with the Tsumeb Municipality, must assist local SMME companies to complete and submit the required tender forms and associated information.			
	Tsumeb Community Trust	• Continue to monitor the needs of the community in order to optimise the contribution of Sinomine Tsumeb Smelter (e.g. via the Tsumeb Community Trust) to benefit the local and regional economy. • Representatives from the local community and Tsumeb Municipality must be informed of the final decision regarding the project and the potential job opportunities for locals and the employment procedures that Sinomine Tsumeb Smelter intends following for the construction phase of the project	Sinomine Tsumeb Smelter Exco	Ongoing	IMPLEMENTED
Concentrate transport		Consider increasing the percentage of concentrate transported by rail from the Port of Walvis Bay in order to reduce safety risks posed by truck traffic to other road users.	Operations / Logistics	Investigate within 1 year of approval	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
Concentrate handling		Consider loading concentrate into bags or similar enclosed containers in order to limit dust emissions at the bulk handling facility in the Port of Walvis Bay	Operations / Logistics	Investigate within 1 year of approval	IMPLEMENTED – Pilot project to test feasibility completed and found not feasible
Sulphuric acid transport		The following measures shall be implemented when transporting sulphuric acid from the sulphuric acid plant: • The transporter must be provided with accurate information about the nature and properties of the load; • The load must be properly loaded and secured on site. • The transport operator must ensure that the Hazchem placards are properly fitted to the vehicle. • The responsible person must ensure that before the vehicle leaves the consignor's premises it is not overloaded or showing any obvious defect that would affect its safety. • Ensure that adequate steps are taken to minimise the effect an accident or incident may have on the public and on the environment; and	Logistics	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		• Initiate remedial action to clean up any spillage remaining on a site after an accident.			
Monitoring		Sinomine Tsumeb Smelter must establish a Monitoring Forum (MF) in order to monitor the construction phase and the implementation of the recommended mitigation measures. The MF should be established before the construction phase commences, and should include key stakeholders, including representatives from local communities and special interest groups (e.g. health and social welfare service providers, women's groups, any organisations dealing with GBV), local councillors, and the contractor(s). The MF should also be briefed on the potential risks to the local community associated with construction workers	Sinomine Tsumeb Smelter Exco	Ongoing	IMPLEMENTED
12. Waste Management: Effective waste management strategies					
Objective: • To minimise the impacts associated with waste generation and management on site					
Smelter Plant	Implementation of waste management plan	Implement the Sinomine Tsumeb Smelter Integrated Waste Management Plan in order to cover all aspects of waste production, reuse, recycling, treatment and disposal.	Environment	Ongoing	PARTIALLY IMPLEMENTED – Construction of general waste facility completed

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					– More skips and bins procured
	Unlined waste facilities	Ensure that all new waste-storage facilities are properly designed and constructed, as well as properly lined so as to prevent seepage into subsoil and the surrounding environment. These precautions will also restrict unwanted contact with humans and possible incompatible materials.	Environment	When designing new waste storage facilities	PARTIALLY IMPLEMENTED – More skips and bins procured – Integrity test planned
	Asbestos management	Review and upgrade the current asbestos management programme and drive actions in this plan for the appropriate management of asbestos waste products.	Health & Hygiene	Within 1 year of approval	PARTIALLY IMPLEMENTED – Asbestos removal programme in place – Ongoing till all asbestos is removed
	Impacts associated with waste generation	General requirements for storage and handling of waste: • General and hazardous wastes are to be separated at source across all smelter operations; • Formalise a general waste handling area(s) appropriate to the type and volume of wastes received and processed;	Environment	IMPLEMENTED	IMPLEMENTED – Construction of general waste facility completed – More skips and bins procured – Full segregation and recycling of waste to be realised upon

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		• The waste handling area should be equipped to manage specific hazardous waste streams, or a specific hazardous waste handling area(s) must be developed separately; • Ensure that waste storage containers, are intact and not corroded or in any other way rendered unfit for the safe storage of waste; • Clearly demarcate and provide signage on and around waste storage areas; • Implement adequate measures to prevent accidental spillage of waste products; • Ensure that waste storage areas are secured to prevent waste being blown offsite; • Ensure that nuisances such as odour, visual impacts and breeding of vectors do not arise; • Prevent pollution of the environment and harm to health • Management and operations of this general waste handling area need to be revised as a soon as possible and a waste disposal solution added • No hazardous wastes should be delivered to the general waste handling area, or the general waste site handling area could be upgraded to include a dedicated area and facilities (bunded			completion of general waste facility

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		and under roof) for the storage and handling of hazardous wastes. • The source practices which are resulting in hazardous wastes being included in the general waste stream are to be altered. • Recyclable materials should be collected and stored at one location for further sorting and or processing (only be relevant if a market can be established for recycling of such materials). • The residual portion of the waste stream requiring disposal should be subject to improved management. • Open air burning of such wastes must be avoided. An alternative, improved solution must be implemented for the disposal of residual waste. • If such burning were to continue in the short-term (for practical reasons) then the disposal of the resultant ash onto the ground at the general waste handling area must be prevented.			
General Waste Disposal site		Open air burning of general waste must not be allowed on site.	Environment	Ongoing	IMPLEMENTED – Burning of waste has ceased

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Establish a formal general waste landfill site in line with the approved landfill design or further investigate the feasibility of establishing a waste incinerator or disposing of general waste offsite in association with the Tsumeb Municipality.	HSE/ESG	Immediate	PARTIALLY IMPLEMENTED – Construction of general waste facility completed – More skips and bins procured in 2021
		No hazardous waste is to be disposed of at the general waste disposal site.	Environment	Ongoing	IMPLEMENTED – Non-arsenic hazardous waste send offsite for disposal - Remaining portion get treated onsite by incineration into converter blending in with process material
		Waste collection points have been established on site. Care will be taken to ensure that these have sufficient capacity and that they are serviced frequently. Different skips are provided for wood, scrap metal, hazardous waste and general waste.	Environment	Ongoing	IMPLEMENTED – Skip allocation register developed – More skips and bins procured

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
Contaminated runoff from waste storage sites		A well-designed drainage system around waste-generating and –storage sites will be required so as to intercept any spillage and contaminated run-off that might result from loading and transporting of waste on the Smelter's site. Waste water collected at a central drainage sump can be returned to the plant as process water or be tied-in with the feed to the Effluent Treatment Facility.	Operation/ Emergency Response	Ongoing	PARTIALLY IMPLEMENTED – SWIM project being implemented in phases
Emergencies		Emergency and safety protocols need to be in place in case of an incident which could lead to endangering the environment and human health. Emergency procedures are to consider events such as a potential tailings dam failure, pollution from erosion of the arsenic calcine dams, significant sulphuric acid spillage, etc. Existing emergency response plans should be maintained and updated, especially for the sulphuric acid plant where there would be an increase in acid production as a result of the increased throughput capacity of the smelter.	Operation/ Emergency Response	Ongoing	IMPLEMENTED
Dangerous goods/waste transport	Spills / leakage	Dangerous goods and waste-transporting pipelines must be constructed of compatible and durable material, and must be subject to periodical maintenance and inspection programmes	Logistic / Material Handling	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		The Road Traffic and Transport Regulations of 2001 specify duties of the operator, driver, consignor and consignee (Section 308), require the driver to undergo training (Section 311) and specify the documents to be held by the driver (Section 312). Compliance with these regulations will ensure proper handling of dangerous goods during transport.	Logistic / Material Handling	Ongoing	IMPLEMENTED
		Ensure chain of custody records/waste manifest documents are kept for all waste materials transported offsite by internal or external waste service providers.	Logistic / Material Handling	Ongoing	IMPLEMENTED – Disposal certificates issued and retained as reference of safe disposal
Hazardous waste management		Non-arsenic hazardous waste, not suitable for disposal at the on-site hazardous waste disposal site, will be collected by a contractor with the relevant permits and will be removed to a permitted hazardous waste disposal facility. Hazardous waste may only be stored on site, in a fenced off area with access control.	Environment	Ongoing	IMPLEMENTED – Hazardous waste temporally stored onsite and send offsite for disposal or recycling – Disposal certificate received and maintained – Arsenic waste disposed at onsite HWDF

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Management of hazardous wastes not disposed to the Sinomine Tsumeb Smelter hazardous waste disposal site must include the following: • Classify all wastes in terms of the Globally Harmonised System (SANS 10234); • Label containers and provide Safety Data Sheets for all hazardous wastes; • Ensure chain of custody records/waste manifest documents for each hazardous waste departing the Tsumeb Smelter is kept; • Audit all external waste service providers to ensure that waste management operations are legally compliant; • Implement the Minimum Requirements for waste Disposal to Landfill and Minimum Requirements for the handling, Classification and Disposal of Hazardous Waste (Second Edition 1998, South African Department of Water Affairs and Forestry) as provided in Table 2. These requirements are in line with IFC standards and are set out in the table below this MMP. Arsenic hazardous waste, including baghouse dusts and calcines that cannot be processed are to be disposed of at the Sinomine Tsumeb Smelter			

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		hazardous waste disposal site. Existing historic stockpiles of arsenic calcines and baghouse dusts are also to be disposed of at the hazardous waste disposal site or another registered hazardous waste disposal facility. A specific action plan and schedule must be established for disposal of old calcine dump material.			
Hazardous waste disposal facility expansion		The additional construction of Cell 2 of the hazardous waste disposal site as per the approved 201 500 m^3 site capacity will be undertaken in line with minimum best practices as per the original agreements for a H:H disposal site. In addition to the measures included in the Construction MMP, the following measures are to be implemented during the construction phase: • Areas designated for site development are to be clearly demarcated and no disturbance is to take place outside of demarcated areas. • No vegetation is to be removed or damaged outside of areas demarcated for the development of the waste site. • If borrow pit areas are to be utilised for construction materials the following measures should be implemented:	HSE / ESG	Once-off	IMPLEMENTED – Construction Of cell 2 of hazardous waste facility completed and operational

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		– Existing infrastructure is to be relocated in accordance with the landowner's requirements. – Access to site to be undertaken in accordance with landowner's requirements. – All infrastructure erected during borrowing activities to be removed from site at the end of operations unless agreed otherwise with the landowner. – Borrow pit areas to be fenced to restrict access of persons and cattle. – Faces of excavation are to be sloped to a maximum slope of 1:3. – Soil covering material is to be stripped and stockpiled prior to excavation. – Stockpiled soil is to be placed over excavated area as part of rehabilitation. – Rehabilitation of site to ensure free drainage of stormwater and to prevent water from collecting in excavated area.			
Hazardous waste disposal site operation		Ensure operation of the hazardous waste disposal site is in line with the long term operational and revised Closure Plan. Ensure that these plans are regularly reviewed and kept up to date	Environment	Ongoing	IMPLEMENTED – Site operated as guided by operation manual and SOPs.

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
Hazardous waste disposal alternatives		Further, investigate alternative options for the disposal of hazardous arsenic waste.	HSE / ESG	Ongoing	PARTIALLY IMPLEMENTED – 5 options being investigated – Vitrification pilot plant completed, and laboratory analysis completed – Identification and evaluation of the suitable Site for offsite disposal facility establishment completed – The offsite disposal facility is proven to be a feasible option at this stage
Recycling initiatives		Review feasibility of implementing a system for the reuse or recycling of certain waste items generated by smelter operations in collaboration with a local waste contractor.	Environment	Within 1 year of approval	PARTIALLY IMPLEMENTED – Scrap dealer onsite to remove scrap metals – Used oil collected by oil recyclers

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
					– Construction of general waste facility completed and will realise full implementation of waste management hierarchy
Sewage Treatment Plant		• Monitor operations of the sewerage plant in accordance with the site water monitoring programme. • Ensure that the new sewage plant is repaired as a matter of priority and fully commissioned, and the reed beds rehabilitated to remove sewage contaminant risks	Operations / Environment	Ongoing	IMPLEMENTED
Used oil management at workshops	Effect on operation	Continuously monitor workshops, oil spillages, sewerage pipelines and connections in order to identify and manage oil and other waste streams from entering the sewage system.	Operations / Environment	Ongoing	IMPLEMENTED – Used oil collected by oil recyclers
Standards		<u>Disposal site:</u> If waste is held at a storage site for a period exceeding three months, the site automatically qualifies as a Waste Disposal Site, and	Environment	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		must be registered as such and meet all the requirements of a disposal site.			
		Temporary storage area: A temporary storage area must have a firm, waterproof base and drainage system. It must be so designed and managed that there is no escape of contaminants into the environment.	Environment	Ongoing	IMPLEMENTED
		Identification of waste: The transporter must be provided with accurate information about the nature and properties of the load.	Environment	Ongoing	IMPLEMENTED
		Documentation: The transport operator must be provided with the relevant transportation documentation for the consignment.	Environment	Ongoing	IMPLEMENTED
		Security of load: The load must be properly loaded and secured on site.	Environment / Contractor / Material Handling	Ongoing	IMPLEMENTED
		Hazchem placard: The transport operator must be supplied with the appropriate Hazchem placards and must ensure that it is properly fitted to the vehicle.	Environment	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
		Vehicle roadworthiness: The responsible person must ensure that before the vehicle leaves the consignor's premises it is not overloaded or showing any obvious defect that would affect its safety.	Environment / Contractor	Ongoing	IMPLEMENTED
		Escape of hazardous spillage at site: The competent authority must be advised immediately would it prove impossible to contain spillage of a hazardous waste on the site.	ESG / HSE	Ongoing	IMPLEMENTED
		Protection against effect of accident: The waste generator – or his representative, i.e. transporter – must ensure that adequate steps are taken to minimise the effect an accident or incident may have on the public and on the environment.	Environment / Operations	Ongoing	IMPLEMENTED
		Spillage on site: The waste generator must initiate remedial action to clean up any spillage remaining on a site after an accident.	Operations	Ongoing	IMPLEMENTED
		Notification: All road accidents must be reported to the competent transport authority on the prescribed documentation.	Environment / Contractor	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
13.Environmental and Social Awareness and Training					
Objective: • To ensure that all persons working at the smelter are aware of the objectives of the ESMP as well as the consequences of their individual actions					
Smelter Plant		Environmental and social induction training is to be undertaken by all persons undertaking work at the smelter (to be incorporated into normal induction training) including permanent workers, contractors and consultants.	HSE / ESG and Human Resource	Ongoing	IMPLEMENTED
		Environmental and social aspects and controls are to be included in the area specific induction training.	HSE / ESG and Human Resource	Ongoing	IMPLEMENTED
		An environmental and social awareness and risk / job specific training programme to be implemented for smelter work force addressing pertinent topics as required, building on current awareness programmes	HSE / ESG and Human Resource	Ongoing	IMPLEMENTED

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
14.Closure					

Objectives:

In preparation for the closure phase of the Sinomine Tsumeb Smelter operations, a draft Closure Plan has been compiled that is continuously updated as changes are made to smelter operations and new specialist information and rehabilitation methodology becomes available. The Closure Plan review was finalised early 2021. The broad closure objectives as included in the draft Closure Plan are listed below:

- Physical stability: To remove and/or stabilise surface infrastructure and unavoidable mining and mineral processing residue which are present on the Sinomine Tsumeb Smelter site to facilitate the implementation of the planned end land use;
- Environmental quality: To ensure that local environmental quality is not adversely affected by possible physical effects and chemical contamination arising from the Sinomine Tsumeb Smelter site during the tenure of Sinomine Tsumeb Smelter, as well as to sustain catchment yield as far as possible after closure;
- Health and safety: To limit the possible health and safety threats to humans and animals using the rehabilitated site as it becomes available;
- Land use and land capability: To re-instate suitable land capabilities over the various portions of the site to facilitate the progressive implementation of the planned land use;
- Aesthetic quality: To leave behind a rehabilitated Sinomine Tsumeb Smelter site that, in general, is not only neat and tidy, giving an acceptable overall aesthetic appearance, but which in terms of this attribute is also aligned to the respective land uses;
- Biodiversity: To encourage, where appropriate, the re-establishment of indigenous vegetation on the rehabilitated sites such that terrestrial biodiversity is largely re-instated over time; and
- Socio-economic mitigation: To ensure that the infrastructure transfers, if applicable, measures and/or contributions made by the facility towards the long-term socio-economic benefit of the local communities are sustainable.

Impact Source/Issue	Potential Impact	Management & Mitigation Measures	Responsibility	Schedule	Implementation Update
Smelter Complex and associated infrastructures and processes - Draft Closure Plan		Revise the draft closure plan	HSE / ESG	Every 5 years depending on new information becoming available	IMPLEMENTED – Closure Plan reviewed – Progressive closure and rehabilitation being implemented on small scale – Next Closure Plan review scheduled for 2025

Prepared by:

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25/11/2024

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02/12/2024

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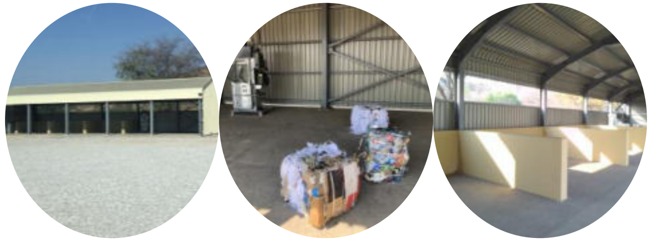
Process Flow

DPMT General Waste Facility

1. Waste Sorting at Source

2. Waste Collection & Transportation



3 (a). Processing of Recyclables into bales, storage before dispatched to external recyclers

4. Vehicle Wash bay & Water management

3(b). Disposal and further onsite sorting and collection of recyclables from mix waste

3(c). Hazardous waste interim storage area – before dispatched for onsite treatment and or offsite safe disposal

Background and Detail description of processes

Background

- Facility approved by Environmental Commissioner of Namibia
- Designed and constructed with reference to South African Standards
    - *Classified as Class B Landfill*
- Design and operation philosophy of the facility is in line with the principles of Integrated waste management/waste management hierarchy
    - *Encourage waste sorting at source and reduce waste to landfill*
- Facility comprises of:
    - Office complex/Administration office block
    - Recyclables processing facility installed with balling machine and storage compartment
    - Storage facility for hazardous waste destined for onsite treatment or offsite disposal
    - Bioremediation pad/Blending
    - Disposal cell
    - Water management system and vehicle wash bay
- Facility was constructed to the tune of 15.6 million Namibian Dollars

Onsite Waste Value Chain

- Waste collection and sorting at source
    - Various bins, skips, and cages are installed to collect different recyclables and waste at source
    - Waste Transportation to facility is by means of skip truck and tractor
- Recyclables processing facility (at facility)
    - *Various recyclables are received at the facility in separate bags – cans, papers, plastics, glass bottles etc*
    - *Each category of recyclables get balled/compressed using a baler machine*
    - *Glass bags and baled recyclable waste are stored in storage compartment until such a time, this is dispatched to identified external recyclers*
- Hazardous waste storage facility (at facility)
    - *Non-arsenic hazardous waste will be stored at this facility e.g. fluorescent tubes, contaminated soil, PPEs etc.*
    - *Interim storage until such a time this is dispatched for onsite treatment or offsite safe disposal*
- Disposal Cell (at facility)
    - Waste from mixed bins, skips are transported straight to the disposal cell
    - Further recovery of various recyclables is conducted onsite the disposal cell

Onsite Waste Value Chain Cont…

- Vehicle wash bay and general water management (at facility)
    - It is requirement that waste vehicle entering disposal cell will be washed at the wash bay
    - Water from wash bay, disposal cell as well as other facilities will report to contaminated water pond
    - From the pond, this water is left to evaporate and or pumped back to the disposal cell for dust suppression if necessary
- Other supporting infrastructures (at facility)
    - Access control gate
    - Office installed with IT services, lunch-room and ablution facility
    - Security cameras
    - Emergency equipment e.g. fire hydrant and extinguishers

Background and Detail description of processes

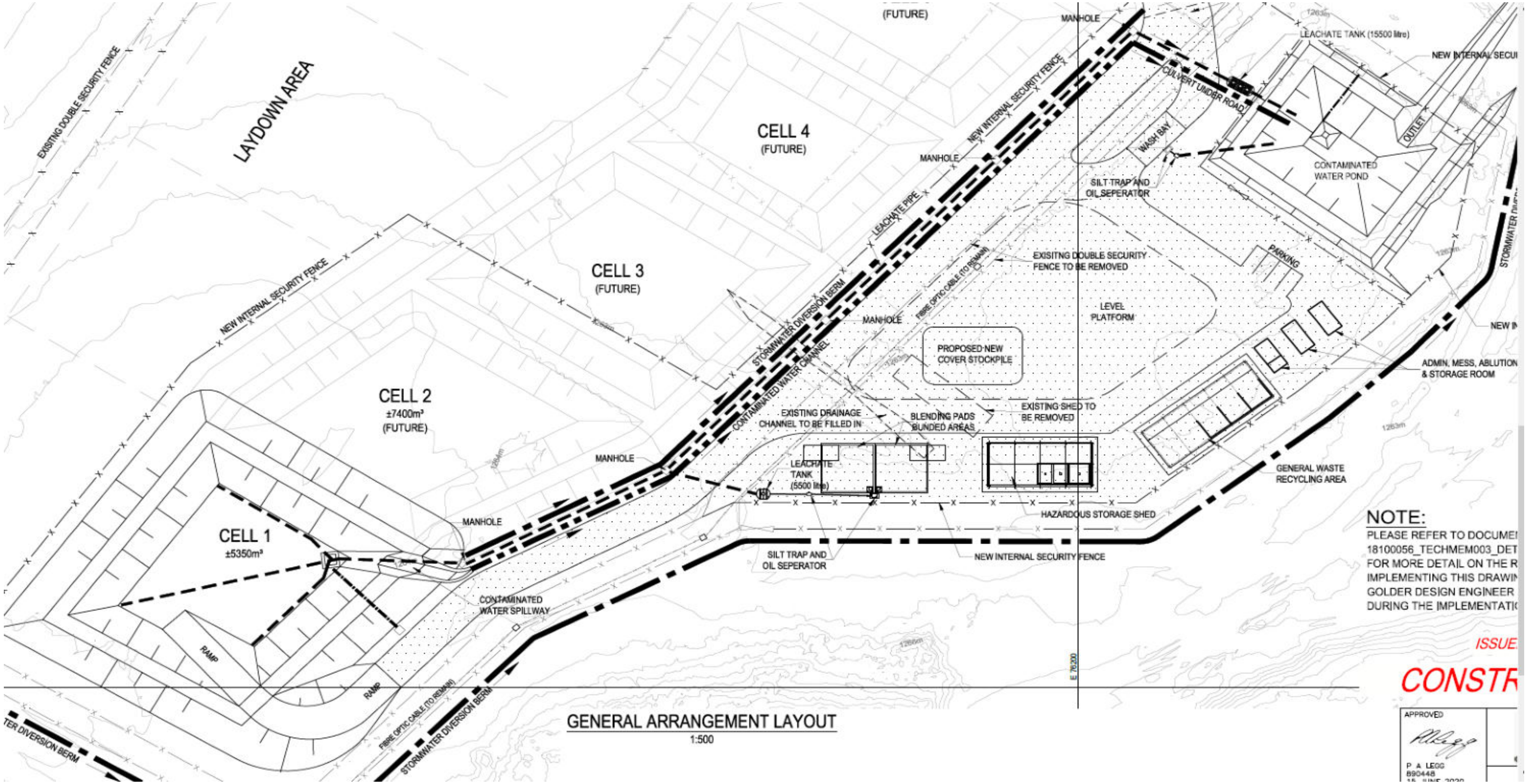
Waste tyres area

Disposal cell for general waste

Recyclable bales

Aerial View of General Waste Facility

General Layout of General Waste Facility



REPORT

Dundee Precious Metals Tsumeb

General Waste Landfill and Supporting Infrastructure: Operating and Maintenance Manual

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18100056-324750-7 _REV0

May 2019

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APPENDICES

1.0 INTRODUCTION

1.1 Project Background

In 2014, following due process of impact assessment as per the provisions of the Namibian Environmental Act No.7 of 2007, DPMT obtained approval for the establishment of its own General Waste Landfill. A detail design for the establishment of an **Integrated Waste Management Facility (IWMF)** that included a landfill was developed and this Operating and Maintenance Manual (O&MM) should be read in conjunction with the detail Design Report and Drawings for this facility. The drawings are attached in Appendix A of this manual.

The landfill component was originally designed based on DPMT generating 25 to 42 tonnes of general waste per month which translates into an average maximum total of 500 tonnes per annum, excluding scrap metal, building rubble and garden refuse.

This O&MM should be updated on a regular basis as the landfill develops and operational procedures are finetuned or amended. It is therefore a live document and any changes should be relayed to the relevant personnel or contractor operating the facility and if required training should be provided in line with any updates.

1.2 Objectives of the O&MM

The general objectives of the O&MM is to provide a practical guide to the operator to assist with the day to day operations of the facility. This should be done by developing and implementing “standard operating procedures” for the various operational areas of the facility listed below.

- General waste landfill;
  - General waste cell operation and maintenance;
  - Leachate collection system;
  - Leakage detection system;
  - Contaminated water system
  - Contaminated water pond;
  - Storm water diversion system; and
  - Progressive rehabilitation.
- General Waste Recyclable Storage Facility;
- Hazardous Waste Storage Facility;
- Blending / bioremediation pads;
- Wash Bay facility;
- On site buildings;
- Access road; and
- Auditing and monitoring.

2.0 EMERGENCY PREPAREDNESS AND RESPONSE

The actions and precautions outlined in this manual attempt to limit the occurrence of incidents at the Integrated Waste Management Facility.

The Waste Contractor is responsible for preventing any spillages of waste due to the transport of the waste material. Any spillages are to be cleaned immediately and the contractor has to ensure that any windblown litter is also collected. Any hazardous wastes are to be handled according to the appropriate SOP.

The Contractor shall have an emergency procedure, training and the necessary equipment in place to address the actions to be carried out in the event of an incident. The procedure must make provision for containment of hazardous waste, prevention of further spillage or contamination, PPE, cleaning activities, disposal of spilled material and contaminated soil, warning to bystanders and notification to the Supervisor of the incident.

Cover material is to be stockpiled close to the general waste landfill cell to cover the waste in the event of a fire. The Operations Manager must ensure that enough quantity is available to cover the waste body with a layer at least 150mm thick.

The Supervisor should check the weather forecast on a daily basis during the rainy season in order to take the necessary precautions in the event of a major rainfall event prediction.

The water level in the pond is to be kept at a minimum to allow for the collection of water during a storm event. As a precautionary measure, the level should not rise above 1.5 m, as measured from the spillways down. All efforts must be taken to drain the pond when the water level increases.

In the event of failure of the pump, or if there is a possibility of a serious power failure, a mobile pump from the plant must be collected to assist with pumping contaminated water and leachate back over the site if the pond is more than two thirds full.

If damage is caused to the HDPE liner, a specialist contractor will need to carry out the repairs as soon as possible. Material from the original supplies in the form of welding rod and sheeting should be available to carry out the repairs.

3.0 SAFETY

3.1 Waste Types and Classification of Site

The waste is produced in various sections of the operational plant, offices and kitchens and includes the following:

- General office waste;
- Organic waste from kitchen;
- Recyclable waste;
- Builders rubble; and
- Hazardous waste (types unknown at this stage (to be expanded once the facility is operational).

3.2 Health and Safety

3.2.1 Site Facilities

An office building, ablution facilities and a kitchen / tea room have been provided. Potable water is available at the facility for drinking and washing. Shower facilities are available, if a person is accidentally exposed to hazardous waste. An eyewash bottle is available, should any waste type affect the eyes of a person on site.

A first-aid box is available, and the keys are available from the office. The booklet needs to be completed whenever materials are removed from the box. The Supervisor carries out a monthly inspection to ensure that the box is in good condition and that the contents is still available.

Material Safety Data Sheets are to be available for all hazardous substances stored at the waste site. The volume of flammable substances needs to be limited as far as possible.

The Waste Contractor personnel shall be responsible for cleaning the ablutions, kitchen and dining areas on a regular basis.

The Contractor personnel must keep the site, general waste recyclable storage facility, hazardous waste storage facility and the on-site buildings in a clean condition to ensure good housekeeping.

3.2.2 Tripping/Slipping Hazards

There are several walkways, channels, berms and pipe work where a person may slip or trip. Care needs to be exercised when walking along the walls of the waste cells, the storm water diversion berms and the area around the contaminated water pond. The bunded areas at the storage facilities are also considered areas where extra care needs to be taken. Slipping is a higher risk after rain, particularly on the concrete lined floors of the storage facilities which may become slippery after rain.

3.2.3 Confined Spaces

The leachate collection sump, contaminated water sumps and the two leachate tanks are to be regarded as confined spaces and the necessary testing must be carried out when work needs to be carried out, in accordance with the confined space permit requirements. No one may enter the sumps while being alone. The buddy-system should be followed.

When entering the monitoring sumps, care needs to be exercised when going down as the step-irons are awkward. No loose items should be carried, as it will be difficult to retrieve an item, should it accidentally fall and holding on to the step-irons will also be more difficult. Personnel entering the sumps need to wear approved safety harnesses, which have been clipped to supports. Personnel should wear gum boots in order to stand in the contaminated water.

3.2.4 Fire

Fire extinguishers are available at the on-site buildings shelter in the event of a fire occurring at the buildings. The fire extinguishers should be checked on a regular basis. The storage facilities are equipped with sprinkler system.

During the winter months, the dry grass on the perimeter of the IWMF needs to be cut short, to prevent the risk of damaging the liners and other infrastructure.

3.2.5 Irrigation Water

It must be noted that the water in the irrigation system may be leachate or contaminated water from the waste body and the irrigation water may not be used for the washing of hands or for drinking purposes. Care needs to be exercised when being exposed to the irrigation system water: that is when attending to a leak, moving the sprayers around, hand spraying of an area or washing the vehicles at the wash bay.

Water in the ponds, leachate collection sump and tanks and the pump stations are contaminated and exposure to this water must be avoided. Care must be exercised when taking samples of water. Signage must indicate what precautionary measures should be adhered to regarding water when entering the site.

3.2.6 Waste Material

The hazardous waste stored in the hazardous waste storage facility needs to be handled with care and as per the stipulations of the materials safety data sheets (MSDS) and SOPs. The wearing of respirators and full protective PPE may be required for certain types of waste whenever the waste is handled, loaded, unloaded or processed. Hands must be carefully washed before any eating or drinking takes place and when personnel leave the storage facility. Eating and drinking may only take place at the kitchen / dining facility and no smoking is allowed at the landfill cell, general waste recyclable storage facility or hazardous waste storage facility.

3.2.7 Heat Exposure

Care must be exercised during the warmer parts of the day in the hot summer months to ensure that employees drink enough water to prevent dehydration. Refer to DPMT's policy on heat exposure for more information on the prevention of heat exposure and dehydration, the symptoms and actions to be taken.

3.2.8 Lightning

Lightning is considered a risk due to the open areas. The undercover areas provide safe refuge during thunder storms.

Operators must either head for the buildings or get into vehicles when lightning is present in the area.

3.2.9 Personal Protective Equipment (PPE)

Operators and their supervisors must wear safety boots, overalls, disposable coveralls, safety glasses, gloves and respiratory protection (when and where required) when handling, transporting or processing waste or washing vehicles.

Visitors to the IWMF need to wear safety shoes when entering the fenced area. A visitor entering the operational zone inside the landfill cell while waste is handled, transported or processed needs to wear safety shoes, overalls/ jackets, safety glasses and if required, respiratory protection.

3.2.10 Medical Surveillance

There is a possibility that personnel may be exposed to dust, organic compounds at the blending pads or hazardous substances. Therefore, all personnel visiting the IWMF on a regular basis and all operators at the IWMF need to undergo medical surveillance, as per DPMT medical surveillance procedures, including biological monitoring for arsenic.

3.2.11 Emergency Situations

The emergency assembly point is situated on the eastern side of the IWMF, close to the on-site buildings. The security officer has a radio, which may be used to contact the emergency services on site in the event of an emergency.

3.2.12 Incident Reporting

The Waste Contractor Supervisor reports any incidents/ accidents to the Supervisor who in turn will report such to the Superintendent. This includes any environmental, health or safety incidents. Incidents must be noted on the incident report form. The incident needs to be investigated and corrective actions defined and implemented to prevent recurrence.

4.0 GENERAL WASTE LANDFILL

This section relates to the operation and maintenance of the General Waste landfill and associated infrastructure.

The main component of the general waste landfill is the general waste cell used for disposing general waste. This cell has several components that require regular inspection and maintenance as listed below:

- General facility procedures:
  - General cell operations;
  - General cell maintenance;
- Leachate collection system;
- Leakage detection system;
- Contaminated water system;
- Contaminated water pond;
- Surface water diversion system; and
- Progressive rehabilitation.

4.1 General Waste landfill

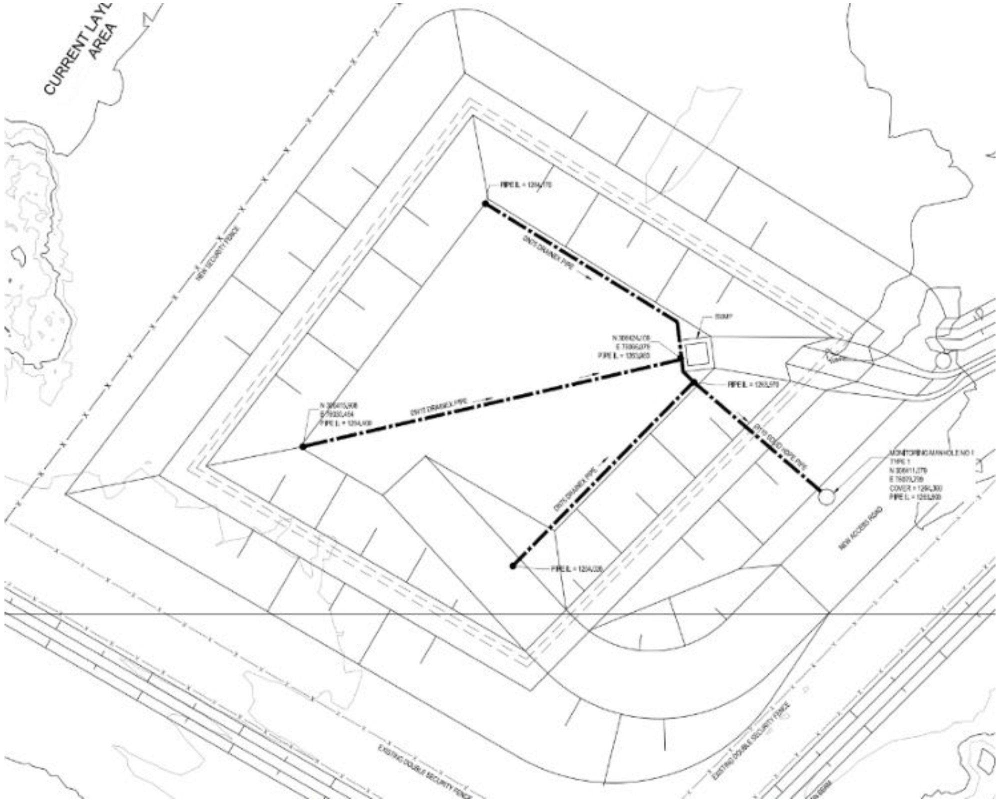
4.1.1 General Facility procedures

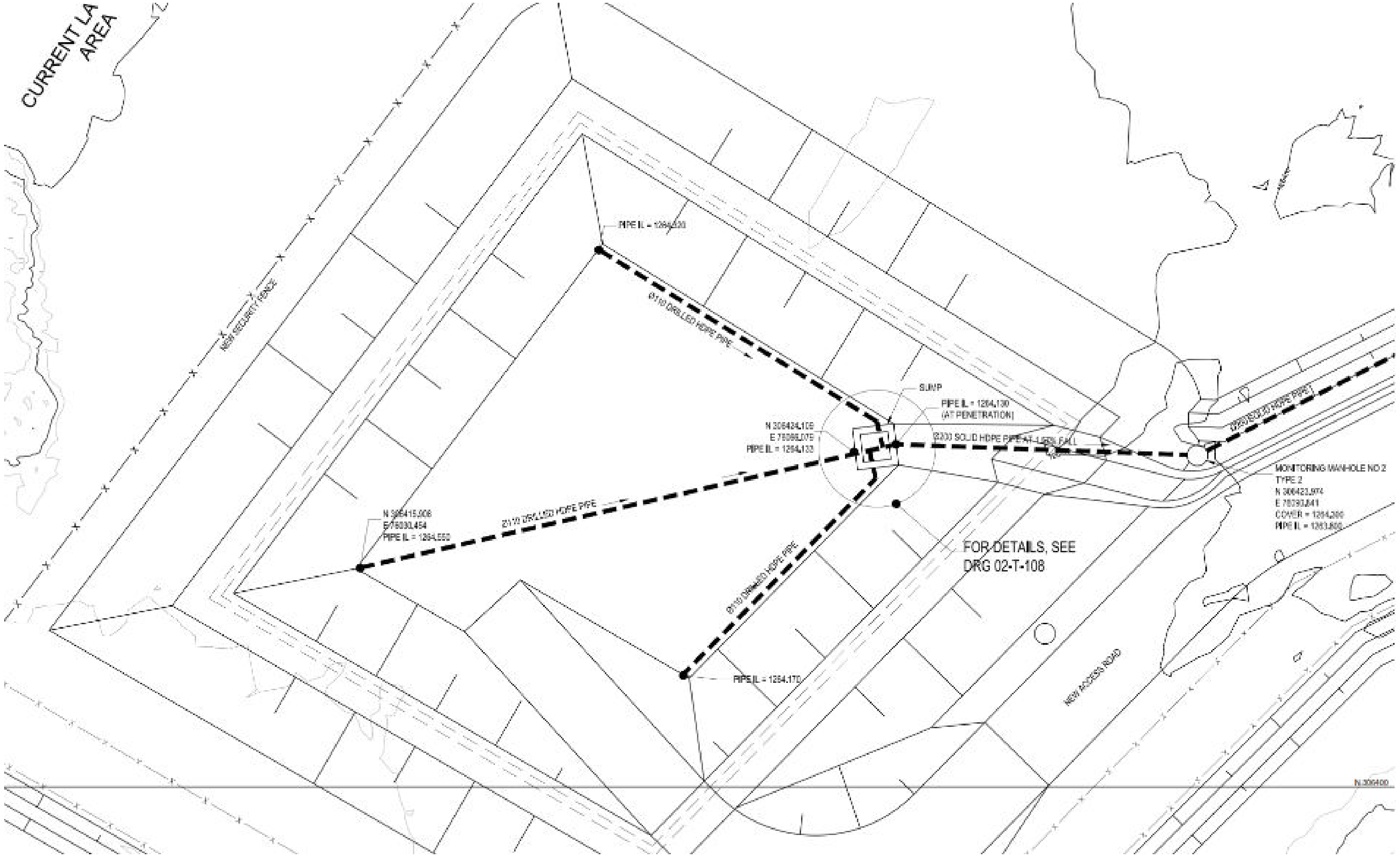
The table below highlights general procedures for the operation of the facility.

Description	Action required
General facility operation	
Access Control	The waste contractor's vehicles will be equipped with an electronic tag or the driver will have an access code which will allow entry into the facility. Before entering the facility, the vehicles need to be weighed and again upon exiting the facility to record the tonnages of the various waste types. The vehicle will be proceeded to the appropriate facility depending on the type of material i.e. general waste, recyclables or hazardous waste. Records should be kept of the material entering the site at each of the three facilities. Each waste load shall be inspected before being offloaded to ensure that the correct load is delivered at the correct location on site. After the load has been offloaded a further inspection of the waste will be conducted to ensure that it is not contaminated with waste types not allowed at the specific facility. The waste contractor and site personnel shall agree a specific offloading procedure at each of the facilities i.e. general waste recyclable storage facility, hazardous waste storage facility, landfill and blending pads.

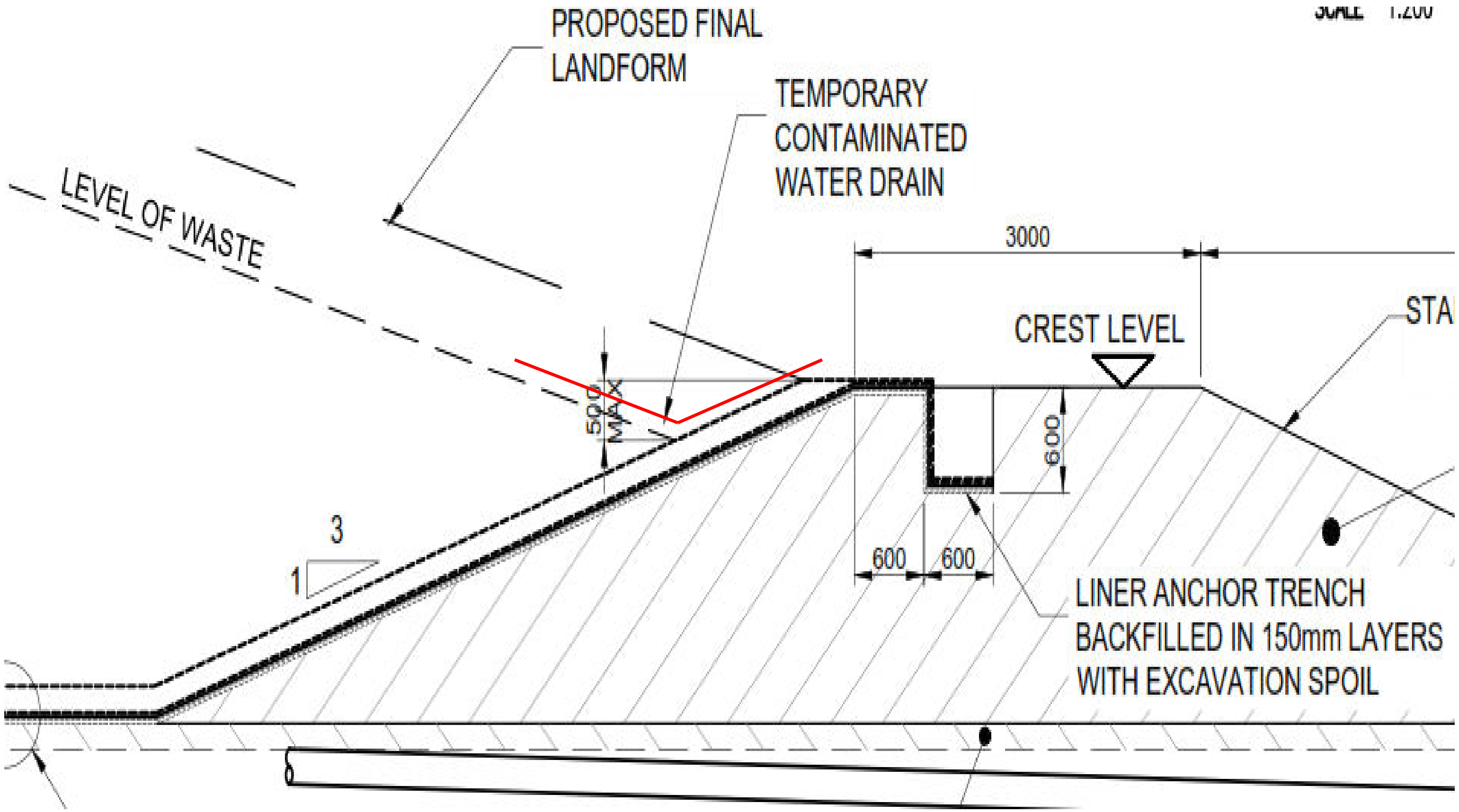
4.1.2 General Waste Cell Operation and Maintenance

The table below highlights the key aspects/components of the waste cell operation and maintenance.

Description	Action required
General cell operation	
Graphic of contaminated water / monitoring system	The landfill cell consists of four retaining berms forming the landfill cell, a subsoil/leakage detection system (shown below) in the base of the landfill cell, a geocomposite lining system, a leachate collection system (shown on the next page) and a contaminated water collection system. 

Description	Action required
Graphic of leachate collection system	

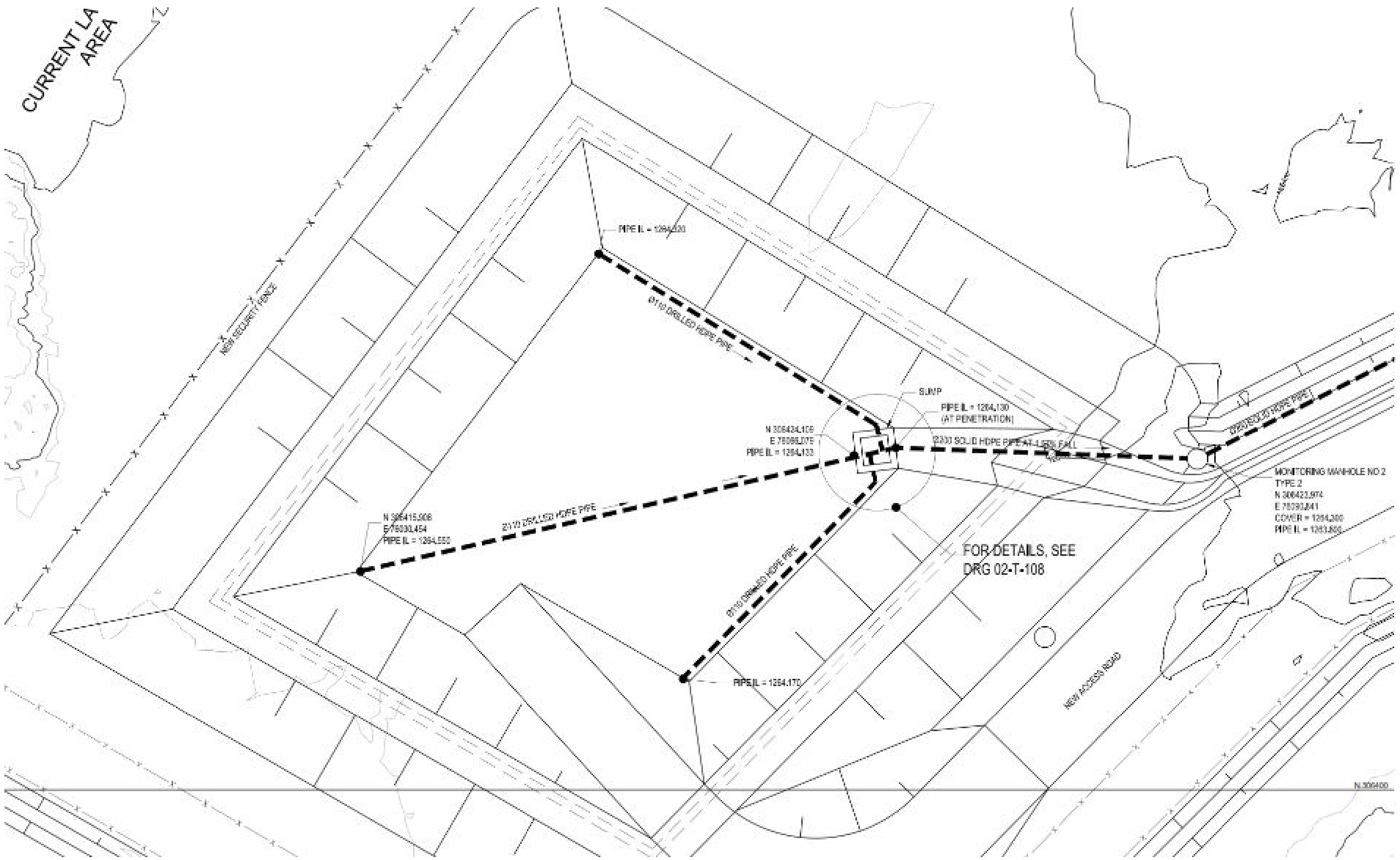
Description	Action required
Pioneering waste layer	To prevent damage to the constructed liner and the leachate collector drains, a pioneering layer of waste is to be deposited over the entire cell floor beginning from the access point to the cell. For this layer the area method of waste disposal is to be used, i.e., waste will be tipped at the entrance and then pushed over the liner with the TLB in a layer not less than 0.5m thick, and then systematically compacted by the TLB driving over the waste.
Cell operation	Small operational cells need to be developed inside the landfill cell to ensure effective operation of the landfill. This should be done by creating small berms to ensure an effective operational area of approximately 3 m x 4 m. The waste should be disposed of and compacted inside the small cell by spreading the waste in approximately 200 mm thick layers and driving over the waste several times with the TLB. Before the small cell in use is completely full a new small cell should be developed adjacent by placing another berm and then filling the void area with waste. This process continues in a chronological order until a "lift" is completed i.e. the entire operational area has been covered by a layer of waste of approximately 0.5 thick. The process then continues in the same fashion for the next layer. The general slope of the operations should be towards the sump/overflow on the eastern corner of the cell. A soil cover layer of minimum 50 mm thick should be placed on the waste disposed of every day to unsure that windblown litter and smells are contained. The area around the sump in the eastern corner should be left open until the waste level reaches the top of the berm after which the sump area should be filled with waste.

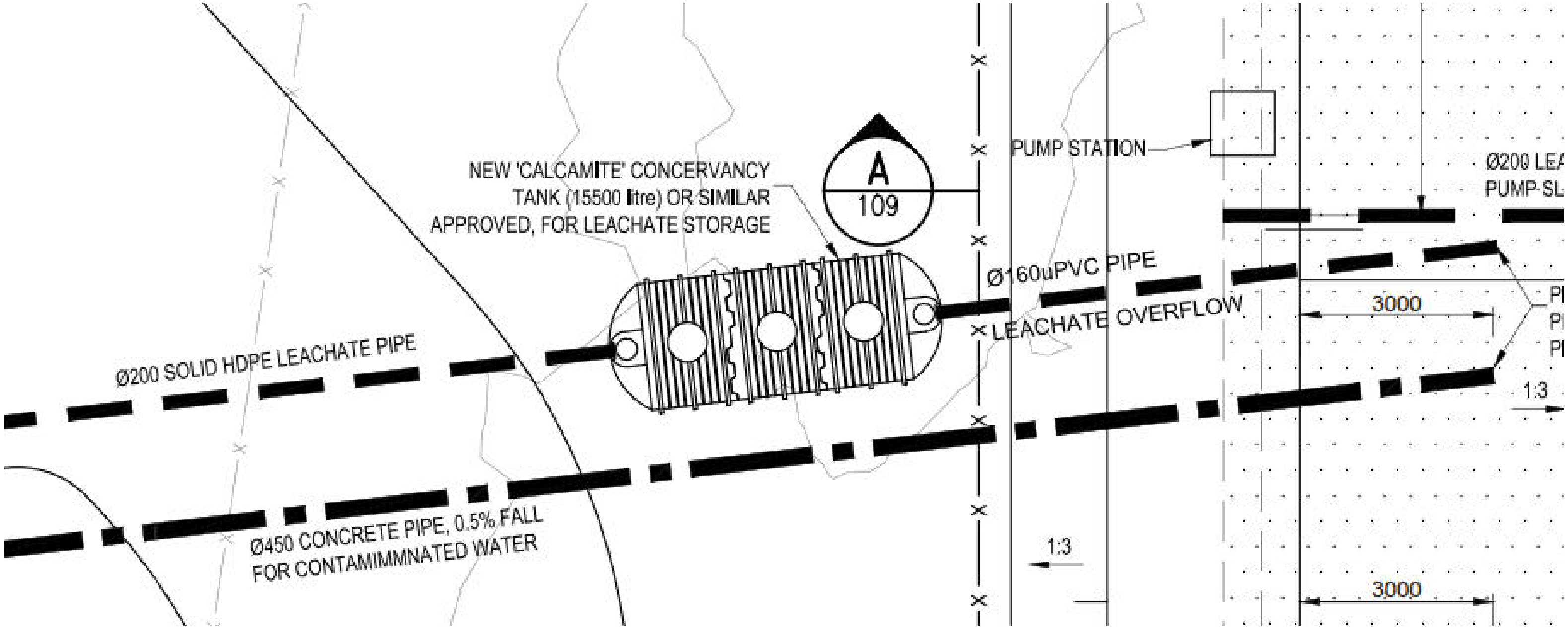
Description	Action required
Graphic of contaminated water channel between the outside berm and the waste body	An area should be left open between the toe of the waste body and the containment berm that will act as a water diversion channel draining toward the cell overflow. A sheet of HDPE (shown in red below) will be placed inside the waste body through the depression to create a contaminated water channel around the waste body.  This channel should be inspected daily to ensure that it is clean.

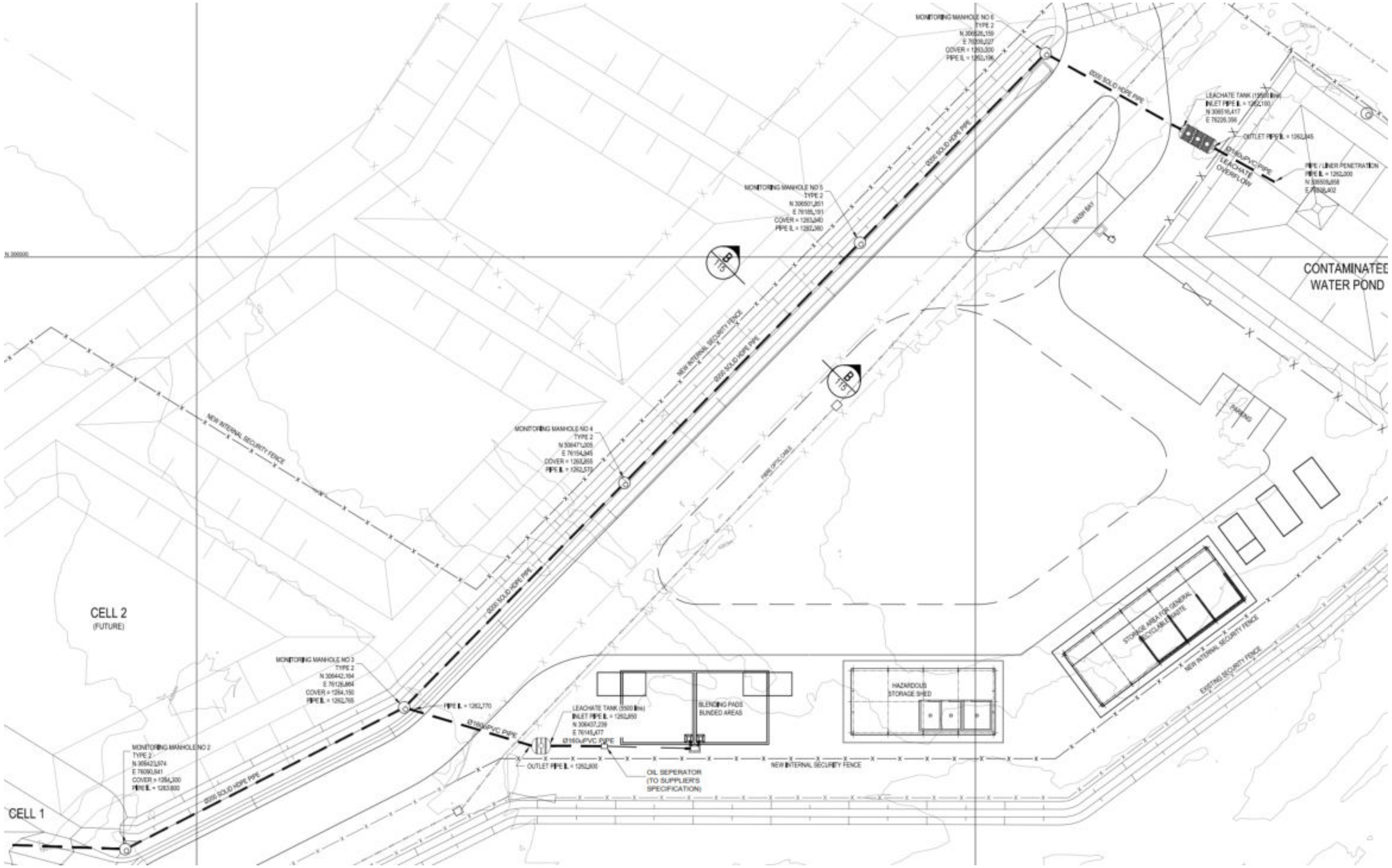
Description	Action required
Landfill shaping	Once the waste body is above the perimeter berm, the side slopes should be maintained at 1:3 (V:H) to assist with final rehabilitation. Batters (1:3) should be installed to guide the shaping of the side slopes. The side slopes can also be surveyed once the height of the cell has increased to approximately 2 m above the crest of the outside berm after which the side slopes can be trimmed to the correct slopes if required. The same will apply once the final height of approximately 4 m above the crest of the berm is reached.
General Cell Maintenance	
Landfill cell sump	During the initial fill process, the cell sumps should be kept open to ensure effective drainage of contaminated water. Once the level of the waste has reached the level of the containment berm, the sump should be filled with waste to ensure that leachate from beneath the waste is diverted to the leachate tank and contaminated surface water to the surface drain. At the same time the contaminated water should be pumped from the leachate tank into the pond to ensure that only leachate drains into the leachate tank once the cell operation is level and above the containment berm.
Dust suppression	A sprinkler system is linked to the contaminated water pond to use the water from the pond as a dust suppression measure. Care should be taken over where the sprinkler is placed to ensure that vehicles do not damage the sprinkler or pipe. The arc that the sprinkler sprays should be set every time the sprinkler is moved to ensure that the water is sprayed within the confinement of the cell.
Inspection of liner	During the fill operation the liner should be inspected once a week for obvious damage, especially where the liner crests the containment berm. The anchor trench should also be inspected at the same time.
Side slopes of containment berm	The side slopes should be inspected after every rain event to ensure that any erosion is repaired.
Down chute for contaminated water	The down chute should be inspected after every rain event and any damages should be repaired immediately.
Side slopes of landfill	Areas where interim capping (nominal soil layer) has been placed should be inspected after every rain event and any erosion damage repaired immediately.

4.1.3 Leachate collection system

The table below provides a short summary of the operation and maintenance requirements for the leachate collection system.

Description	Action required
General	The leachate collection system consists of a leachate collection sump, monitoring manhole, leachate manholes and leachate storage tank. The graphics below show the leachate collection system in the cell.
Graphic of the leachate collection system in the landfill cell	

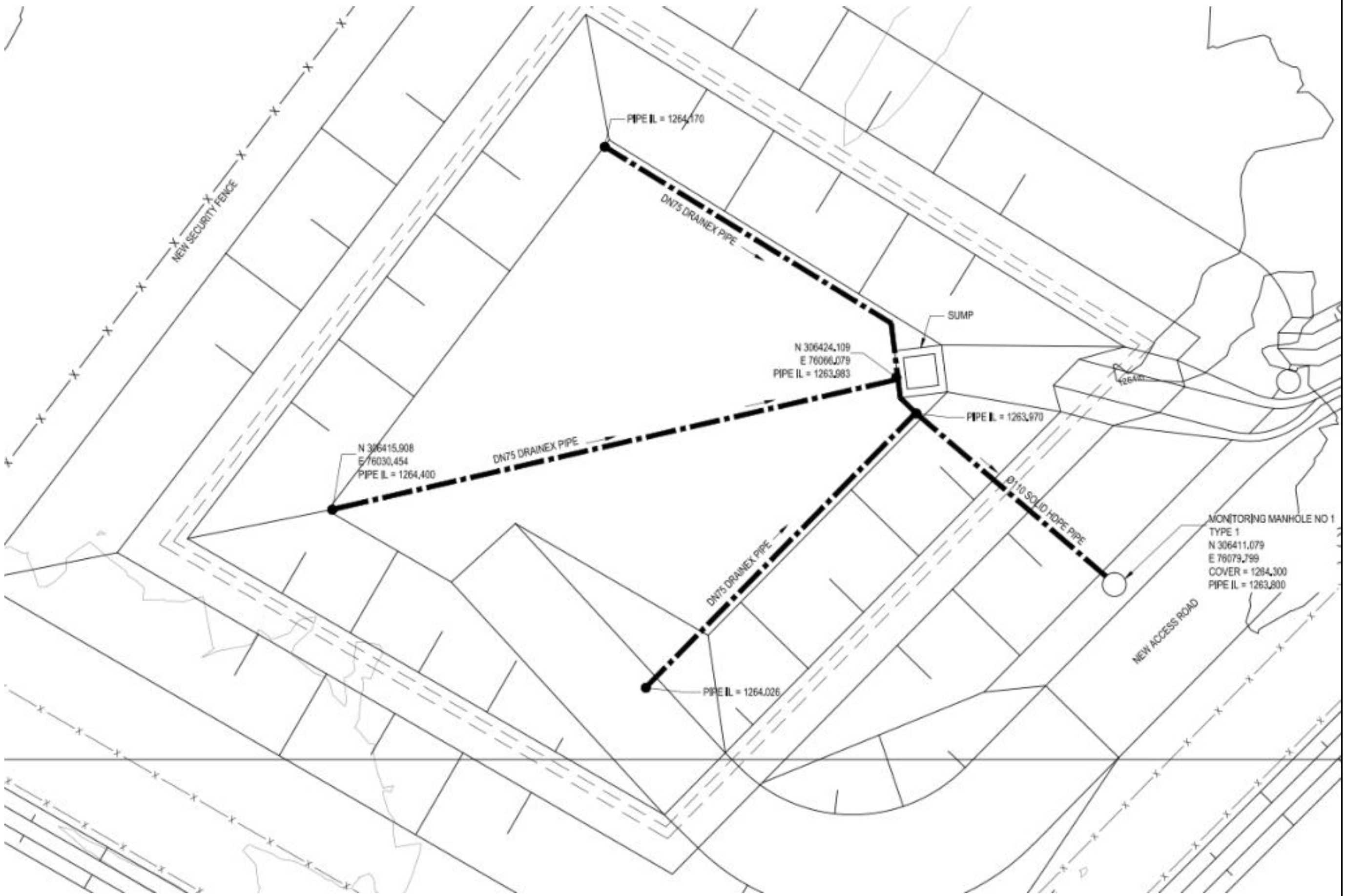
Description	Action required
Graphic of the main leachate storage tank adjacent to the contaminated water pond	The graphic below shows the leachate tank situated adjacent to the contaminated water pond. The next page shows the pipe layout from the landfill cell. 

<table>
<tr><th>Description</th><th>Action required</th></tr>
<tr><td>Graphic of the pipe layout for the leachate collection system</td><td>
</td></tr>
</table>

Description	Action required
Sump	The leachate sump should be kept clean and open until the waste body reaches the same height as the retaining berms after which it should be backfilled with waste. As far as possible fines should not be allowed to accumulate in the sump as this may clog the sump.
Monitoring manhole	The monitoring manhole should be checked once a week to ensure that it is functioning (draining), checked visually from surface. **Note that methane levels need to be monitored before the manhole is accessed. If methane is detected the manhole should be flushed by blowing fresh air into the manhole until no methane is detected before the manhole is accessed. The flushing should continue during the time the manhole is being accessed and personnel should wear respirators as a safety precaution. Ropes should also be tied around the person/s entering the manhole to assist with evacuation should the person faint. Adopt "Confined Space SOP".**
Leachate manholes	The manholes should be inspected once a week to ensure that they drain adequately. Note that methane levels need to be monitored before any manhole is accessed. **Note that methane levels need to be monitored before the manhole is accessed. If methane is detected the manhole should be flushed by blowing fresh air into the manhole until no methane is detected before the manhole is accessed. The flushing should continue during the time the manhole is being accessed and personnel should wear respirators as a safety precaution. Ropes should also be tied around the person/s entering the manhole to assist with evacuation should the person faint. Adopt "Confined Space SOP".**
Leachate storage tank	The leachate tank should be monitored on a weekly basis and leachate pumped to the cell as soon as an accumulation of leachate occurs. **Note that methane levels need to be monitored before the tank is accessed. If methane is detected the tank should be flushed by blowing fresh air into the tank until no methane is detected before the tank is accessed. The flushing should continue during the time the tank is being accessed and personnel should wear respirators as a safety precaution. Ropes should also be tied around the person/s entering the tank to assist with evacuation should the person faint. Adopt "Confined Space SOP".** The pumps should be tested on a monthly based to ensure that they are operational always.
Leachate pipes	Leachate pipes should be cleaned once a year and the same safety precautions as described above should apply. The pipes can be cleaned by a plumber using a "soft end", no cutting tools should be used in the pipes since this may cause damage to the inside of the pipes (plant should not be able to penetrate the pipes). Alternatively, a "jetting system" can be used.

4.1.4 Leakage detection system

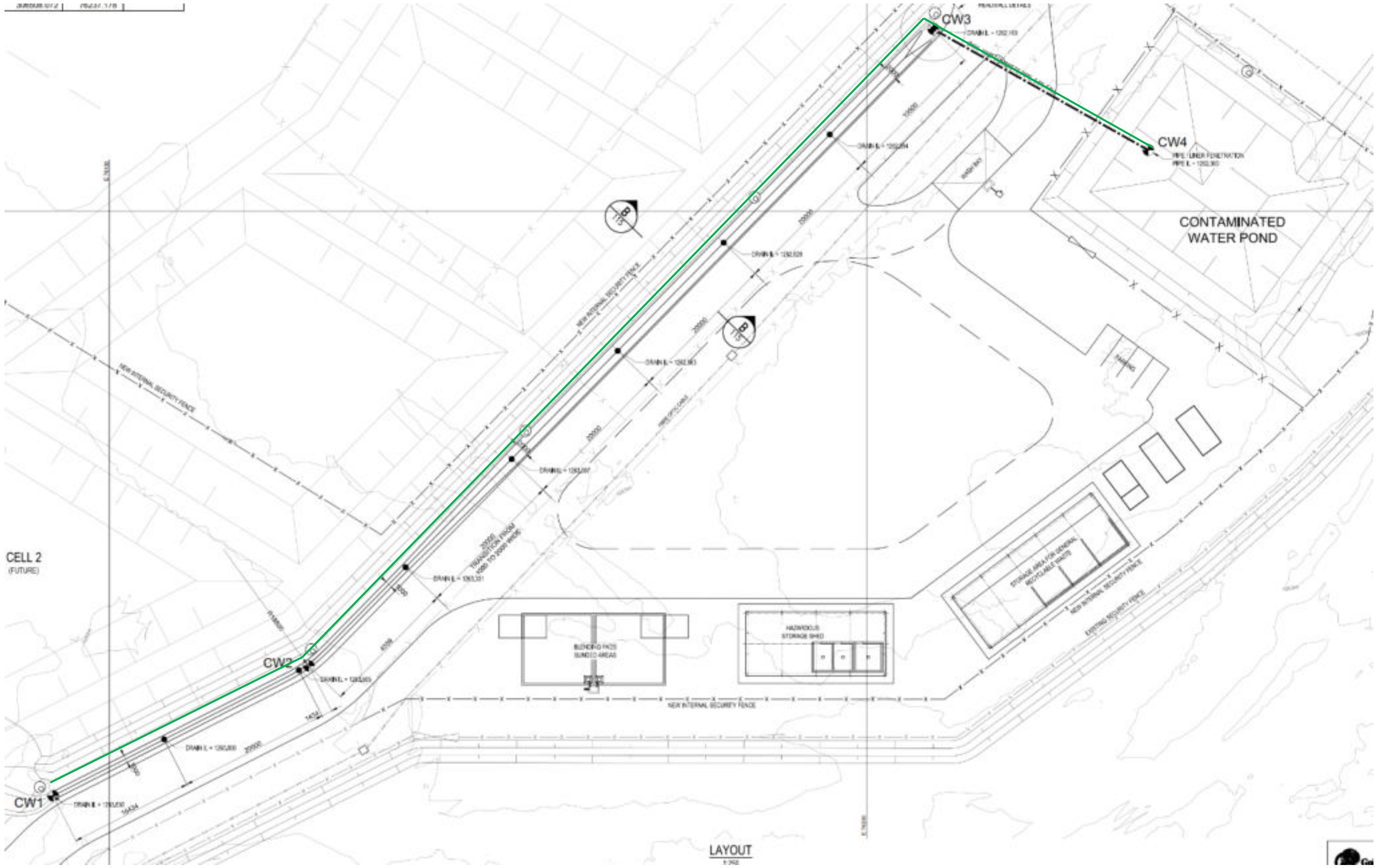
The table below provides a short summary of the operation and maintenance requirements for the leakage detection system.

Description	Action required
General	The leakage detection system consists of a 75 mm drainex pipe system below the cell liner system. The leachate collection pipes are placed directly above the leakage detection pipes.
Graphic of the pipe layout for the leakage detection system	

Description	Action required
Monitoring manhole	The monitoring manhole should be inspected once a week for any leakage. Any liquid in the manhole should be analysed to determine of it ground water or leachate emanating from the cell. **Note that methane levels need to be monitored before the manhole is accessed. If methane is detected the manhole should be flushed by blowing fresh air into the manhole until methane is not detected before the manhole is accessed. The flushing should continue during the time the manhole is being accessed and personnel should wear respirators as a safety precaution. Ropes should also be tied around the person/s entering the manhole to assist with evacuation should the faint. Adopt "Confined Space SOP".** Any leachate present in the manhole is an indication that the cell liner is leaking and should be investigated immediately by a competent person if portions of the liner is still exposed. Alternatively, the cell should be closed and capped as soon as an new cell has been developed. The contaminated water should be pumped to the contaminated water pond on an continuous basis. The monitoring manhole should be kept clear of weeds which should be removed on a continuous basis**.** The manhole cover should be replaced after every inspection.

4.1.5 Contaminated water system

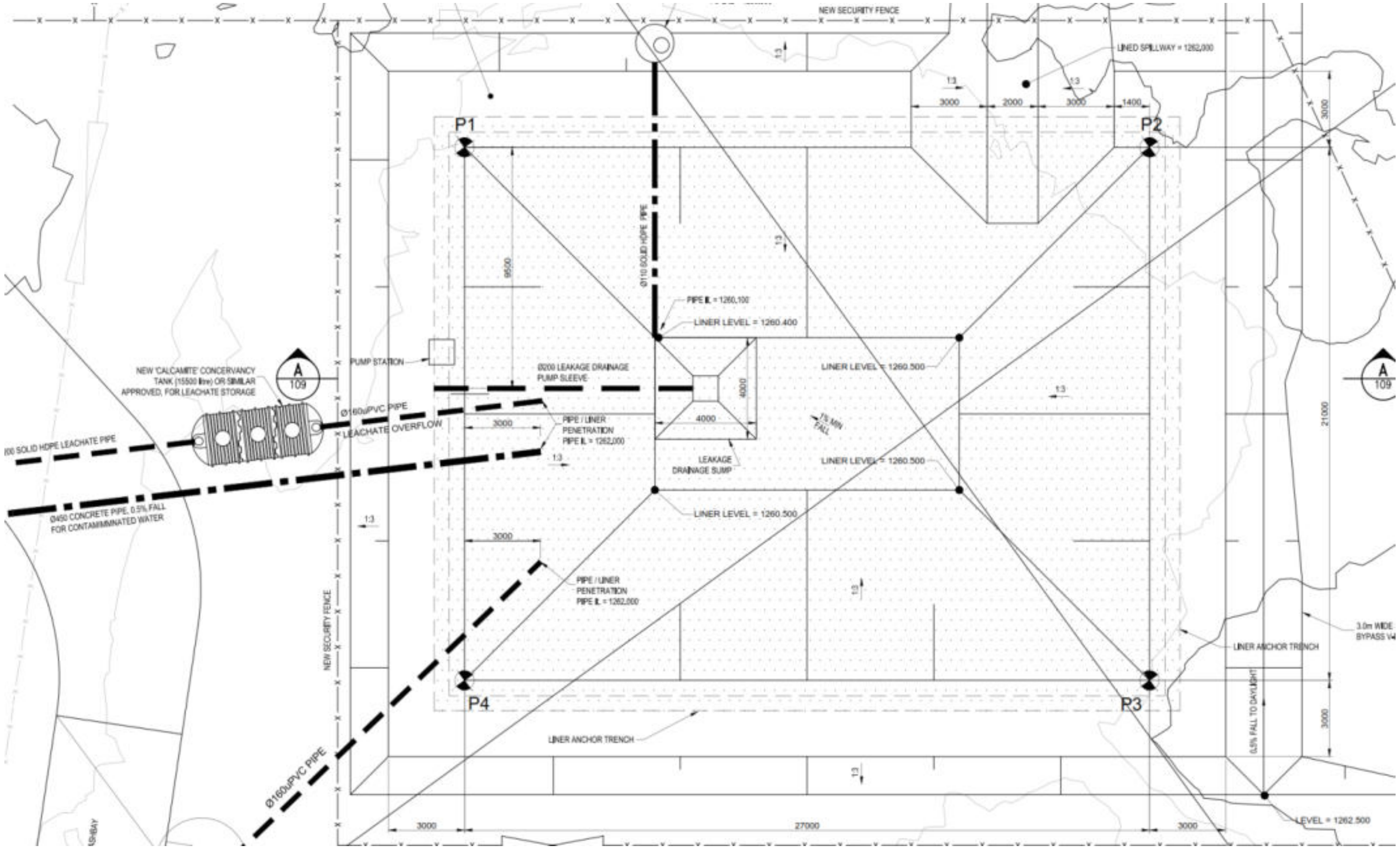
The table below provides a short summary of the operation and maintenance requirements for the contaminated water system.

Description	Action required
General	The contaminated water system (adjacent to the green line) consists of a spillway leading into a concrete lined surface drain discharging into a 450dia concrete pipe leading into the contaminated water pond (discussed separately).
Graphic of the contaminated water channel from the landfill cell to the contaminated water pond	

Description	Action required
Contaminated water channel	The main channel and spillway should be inspected on a weekly basis to ensure that the channel is free from any obstructions. After every rain event any silt build-up should be removed from the channel and the pipe leading to the channel should be cleaned. Any damage to the channel should be repaired immediately to ensure that contaminated water does not spill into the environment. The spillway should be inspected on a weekly and after every rain event for any damage. Damage to the spillway should be repaired immediately.
Discharge pipe	The discharge pipe should be inspected on a weekly basis during the rainy season and any silt should be removed as soon as possible to ensure continuous flow of contaminated water.

4.1.6 Contaminated water pond

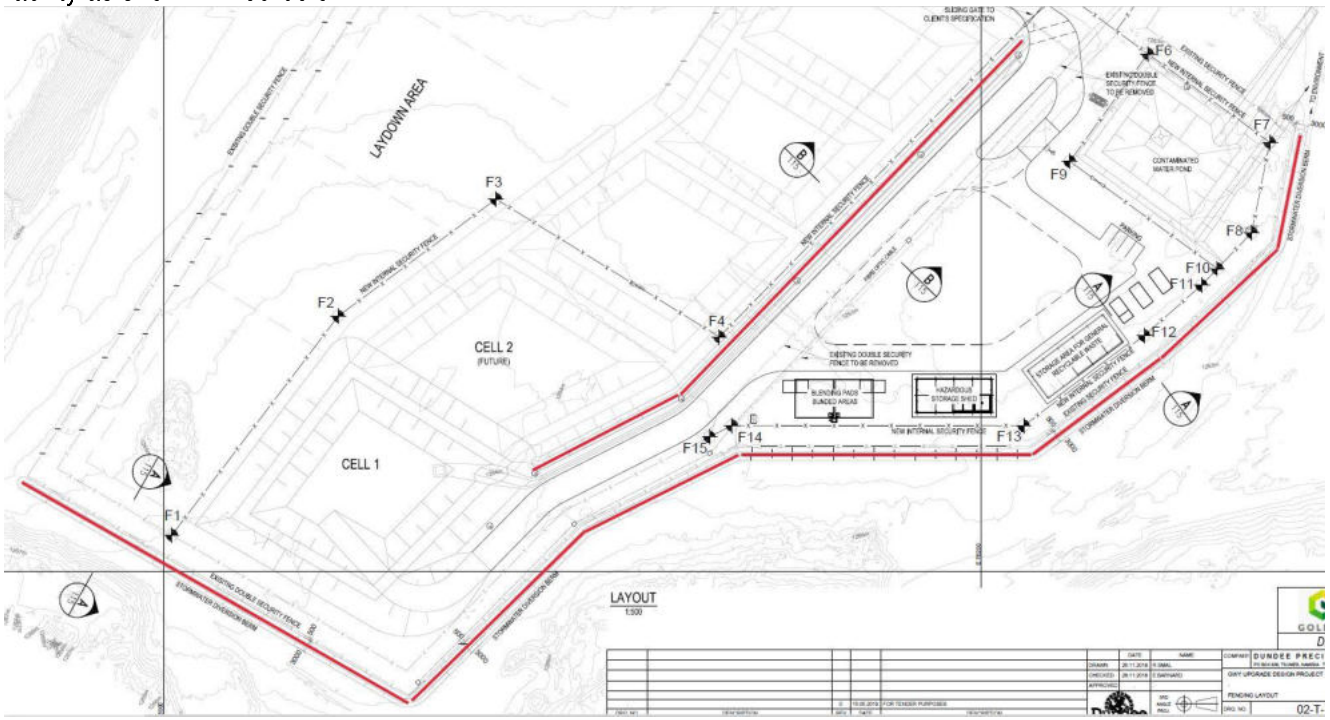
The table below provides a short summary of the operation and maintenance requirements for the contaminated water pond.

Description	Action required
Contaminated water pond	The contaminated water pond consists of four retaining berms forming the pond, a subsoil/leakage detection system in the base of the pond, a geocomposite lining system, a pump system and a spillway.
Graphic of the contaminated water pond	

Description	Action required
	The most critical component of the contaminated water pond is the liner system. The pond is equipped with a double geomembrane lining with a leakage detection/drainage system. A secondary leakage detection/subsoil drainage system is at the base of the pond. The leakage detection pipe on the corner slope of the pond should be monitored for water on weekly basis. Should water be detected inside the monitoring pipe, the water should be pumped back into the pond immediately on a continues basis while the pond is being emptied. Once the pond is emptied a visual inspection of the pond should be done to identify any obvious damage. A reputable company should be contracted to repair the pond lining and at the same time conduct a proper leak detection survey. Should any water be detected in the leakage detection manhole, the same procedure as described above should be followed. The monitoring manhole should be inspected once a week for any leakage. Any liquid in the manhole should be analysed to determine of it ground water or water emanating from the pond. **Note that methane levels need to be monitored before the manhole is accessed. If methane is detected the manhole should be flushed by blowing fresh air into the manhole until methane is not detected before the manhole is accessed. The flushing should continue during the time the manhole is being accessed and personnel should wear respirators as a safety precaution. Ropes should also be tied around the person/s entering the manhole to assist with evacuation should they faint. Adopt “Confined Space SOP”.**
Contaminated water / leachate pump and irrigation system	The pump installed on the wall of the contaminated water pond is used to pump contaminated water from the pond and/or leachate from the leachate tank for irrigation and dust control over the surface of the waste in the landfill. The pump is to be fitted with a floating suction with strainer and footvalve. This pump is to be operated manually as required for dust control or to lower the level of the water in the pond by evaporation throug the irrigation sprinkler(s) on the landfill. The pump is to be on a planned maintenance schedule. The pump and valves must be checked for intergity, wear, cleanliness and functionality. The floating suction must be checked regularly for debris that could cause blockage of the suction. The irrigation pipeline to the landfill cell is buried and should not require routine maintenance apart from inspection for leaks along the route. The sprayers and nozzles of the iirigation sprinkler(s) must be checked regularly before irrigation to ensure effective watering of the landfill. The water flow and pressure must be monitored visually to ensure that the sprinkler(s) work properly.

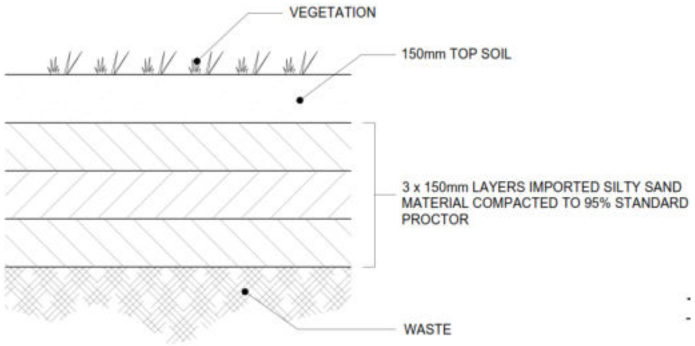
4.1.7 Storm water diversion system

The table below provides a short summary of the operation and maintenance requirements for the storm water diversion system.

Description	Action required
Storm water diversion Graphic of the storm water diversion berms	The storm water diversion system consists of several compacted soil diversion berms placed at strategic locations adjacent to the facility as shown in red below.  These berms should be inspected monthly and / or directly after any rain event and any damage should be repaired immediately.
Storm water outlet adjacent to contaminated water dam	The storm water outlet adjacent to the contaminated water dam should be inspected after every rain event and any silt should be removed.

4.1.8 Progressive rehabilitation

The table below provides a short summary of the progressive rehabilitation of the landfill.

Description	Action required
Landfill cell	Progressive rehabilitation of the landfill requires that each cell be rehabilitated and capped after fully used. Progressive capping should be applied as soon as a cell has been filled and the next cell is commissioned. The top and three sides of the cell should receive a final capping layer with the side directly adjacent to the new cell receiving an interim capping layer since waste will be placed against this side as the adjacent cell is landfilled. The closure capping system for the landfill comprises 3 x 150 mm layers of silty soil with a 150 mm layer of topsoil to provide a growth medium. **Only local grass species should be planted on top of the landfill cover with scrubs and trees not being allowed since roots of scrubs and trees will penetrate the capping layers and compromise the cover system.** Vegetation on rehabilitated areas should be maintained during operation of the landfill. This will ensure that there is no need for later rehabilitation of previously completed areas. The capped areas should be inspected after every rain event for possible erosion and any erosion should be repaired immediately. After closure of the landfill, ongoing maintenance of the landfill cover and vegetation will be required. Any erosion should be repaired as soon as possible to avoid major repairs should consecutive storm events cause erosion. The contaminated water drain adjacent to the rehabilitated cell will be diverted to the environment since surface run-off from capped areas of the landfill will be considered as clean water. 

5.0 GENERAL WASTE RECYCLABLE STORAGE FACILITY

5.1 General Facility Operation and Maintenance

The table below highlights the key aspects/component of the general waste recyclable storage facility's operation and maintenance.

<table>
<tr><th>Description</th><th>Action required</th></tr>
<tr><td colspan="2">General facility operation</td></tr>
<tr><td>Processing and storage of material</td><td>The facility consists of a rectangular cladded shed with a receiving area as well as storage bunkers where material is stored. The anticipated operations are as follows:
■ Recyclables collected from plant areas are either stored in their respective wheelie bins or dumped in the receiving area;
■ Materials are sorted into various recyclable components such as paper, glass, plastic, etc.;
■ The material is bagged or baled;
■ The material is placed in designated containers or storage bunkers;
■ The bales, bags or containers are collected or loaded for transport to recycling companies or organisations. Materials unsuitable for recycling must be taken to the landfill cell for disposal.</td></tr>
<tr><td>Maintenance</td><td>■ The floor of the facility should be kept neat and clean to ensure a safe operating environment;
■ At the end of each shift, loose material on the sorting floor should be kept to a minimum;
■ The storage bunkers should be kept neat and free of any loose material;
■ The storage bunkers should be cleaned out regularly to prevent vermin for breeding in the waste;
■ The baler should be maintained and serviced as required by the manufacturer;
■ The fire suppression system should be tested by the ER unit as required;
■ The structural steel building and cladding should be inspected once a year by a competent person for corrosion and or structural damage.
■ Floor and bunded areas should be inspected on a weekly basis;
■ Any damage to the floors, bunded areas or structural steelwork should be repaired timeously.</td></tr>
</table>

6.0 HAZARDOUS WASTE STORAGE FACILITY

6.1 General Facility Operation and Maintenance

The table below highlights the key aspects/component of the hazardous storage facility's operation and maintenance.

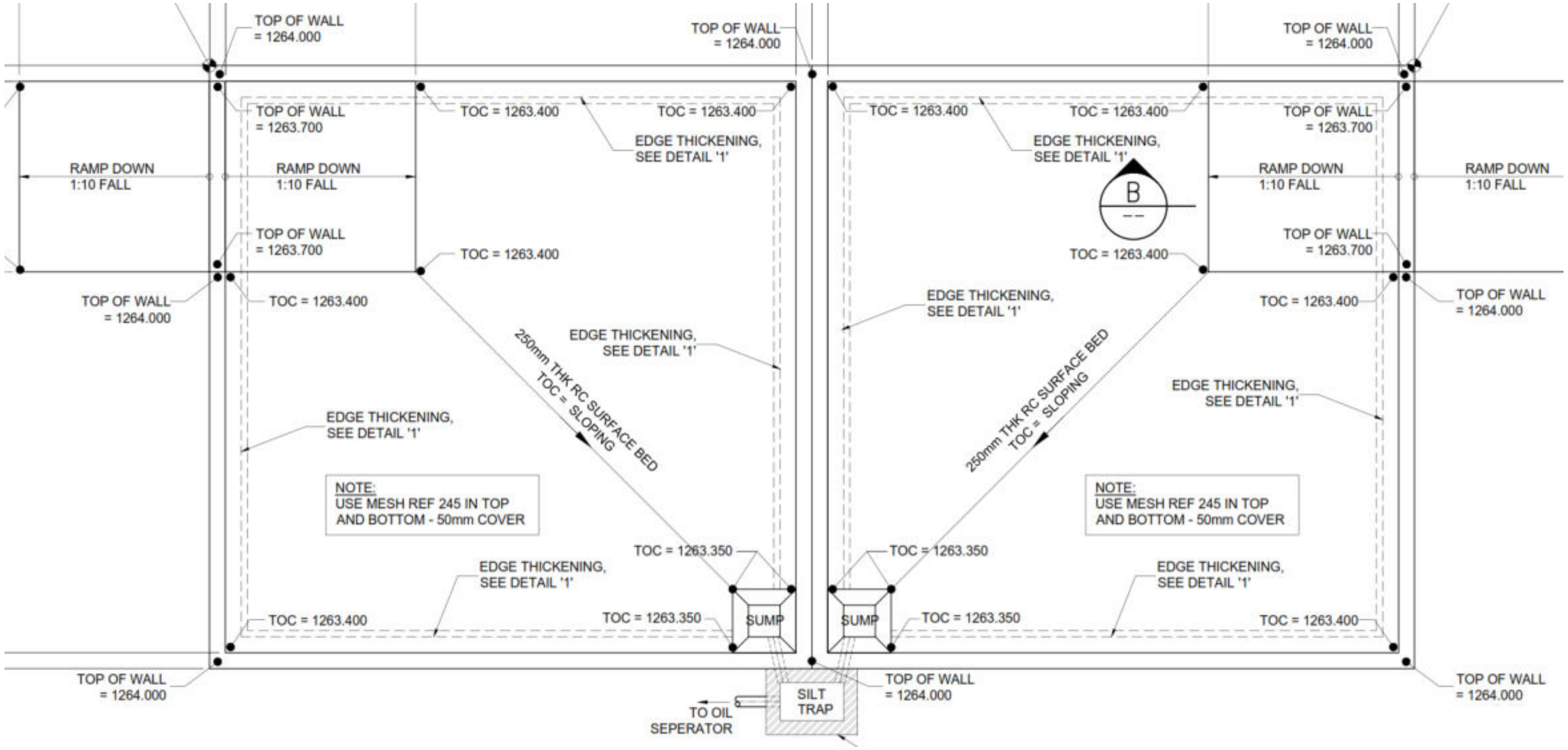
Description	Action required
General facility operation	
Processing and storage of material	The facility consists of a rectangular cladded shed with a receiving area where small quantities of hazardous waste material is received, sorted and packaged. There are three storage bunkers for the temporary storage of packaged hazardous waste materials. Personnel working at this facility should receive the necessary training to identify and handle the various hazardous waste types expected to be stored at the facility. Any unknown material should be stored in a container close to the entrance / offloading area until proper identification is done. Material received should be sorted into various hazardous waste types and placed in containers if not already received into containers. The material should then be stored in the dedicated storage bunkers for each group of hazardous waste types.
Maintenance	Safe operating procedures (SOPs) should be developed and updated on a regular basis to ensure safe working procedures are followed. DPMT HSSE required should be included: ■ The floor of the facility should be kept neat and clean always to ensure a safe operating environment; ■ Containers should be checked daily for leaks; ■ Any leaks should be reported immediately; ■ Depending on the material that leaked, appropriate removal and cleaning of the floor and sump areas will be required the same day as the leak occurred; ■ The storage bunkers should be kept neat and free of any loose material; ■ The fire suppression system should be tested by the ER unit as required; ■ The structural steel building and cladding should be inspected once a year by a competent person for corrosion and or structural damage; ■ Floor and bunded areas should be inspected on a weekly basis; and ■ Any damage to the floors, bunded areas or structural steel should be repaired timeously.

7.0 BLENDING / BIOREMEDIATION PADS

7.1 General Facility Operation and Maintenance

The table below highlights the key aspects/component of the blending / bioremediation pads operation and maintenance.

Description	Action required
General facility operation	
Processing of material	The facility consists of two rectangular bunded concrete pads where material is dumped and mixed based on specific requirements. Each pad is equipped with a silt trap leading to an oil separator that is linked to a leachate tank. It is recommended that a skid steer loader or TLB is used to blend and load materials at the facility. The operators should always be aware not to bump against the sides (bunds) of the facility as this may cause the bunds to crack or break. Material should not be mixed / blended too close to the back edge of the pads near the sumps so as to minimise material spillage into the sump. The sumps should be cleaned directly after blending has occurred before the material is removed to ensure that the material removed from the sump is placed on the stockpile on the slab for removal. The pads should be cleaned as soon as material has been removed. When mixing of oil and soil is done, personnel should take extreme care not to slip when cleaning the pads. The oil separator should be checked and cleaned after every time blending / mixing of material occurred as well as after rain events. Accumulated oil should be disposed with the following contaminated soil blending operation.

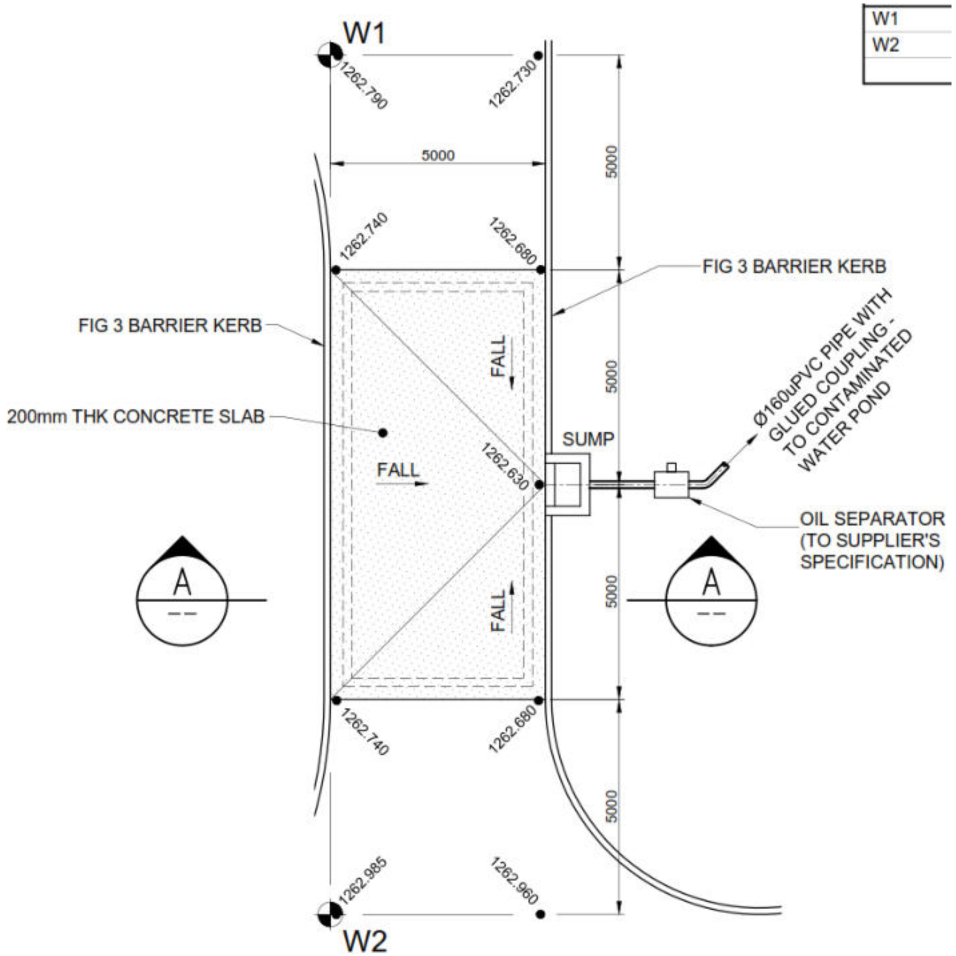
Description	Action required
Graphic of blending / bio – remediation pads	

8.0 WASH BAY FACILITY

8.1 General Facility Operation and Maintenance

The table below highlights the key aspects/component of the wash bay facility's operation and maintenance.

Description	Action required
General facility operation	
General	The wash bay consists a rectangular concrete slab with a sump where vehicles leaving the site can be washed out and the wheels washed. Runoff from the wash bay flows into a sump / silt trap and from there through and then into the contaminated water pond. The sump should be cleaned on a weekly basis or more frequently as required by sediment and trash build-up. The oil separator should be inspected and if required cleaned on a weekly basis. The pipeline from the oil separator should be cleaned on an annual basis, if necessary by "jet cleaning". The concrete slab and curbing should be inspected on an annual basis or more regularly if necessary and repaired if and where required.

Description	Action required
Graphic of the wash bay	

9.0 SITE BUILDINGS

9.1 General Facility Operation and Maintenance

The table below highlights the key aspects/component of the -site buildings operation and maintenance.

Description	Action required
General facility operation	
General	The following inspections should be done on a monthly basis and repairs made where required: ■ Lights; ■ Air-conditioners; ■ Geysers; ■ Taps; ■ Toilets; ■ General plumbing; and ■ Electrical fittings. The following should be inspected on an annual basis and repaired where required; ■ Base of buildings; ■ Roof and ceilings; ■ Paint; ■ Doors and locks; and ■ Windows.

10.0 ACCESS ROAD

10.1 General Facility Operation and Maintenance

The table below highlights the key aspects/component of access road maintenance.

Description	Action required
General facility operation	
General	The access road from the site entrance to the landfill cell, storage areas and on-site buildings should be maintained on a regular basis to ensure effective and efficient runoff from the road ways to allow for access during all weather conditions. During the rainy season roadways should be inspected and repaired if necessary to ensure access to the facility at all times. Roadways should not be graded but instead material similar to that used for the construction of the road ways should be used to fill depressions, potholes and other damaged areas. The material should be compacted properly to ensure effective repairs.

11.0 AUDITING AND MONITORING

11.1 General Facility Auditing and Monitoring

The table below highlights the key aspects of environmental auditing and monitoring of the IWMF.

Description	Action required
General facility operation	
General	The objectives of auditing and monitoring are to: ■ Ensure that the approved facility design is properly implemented; ■ Function as a control measure to ensure that the operation conforms to the required standards and legislative requirements; ■ Quantify any effect that the operation has on the environment, and in particular, any impact on the receiving water regime; ■ Serve as an early warning system, so that any problems that do arise can be timeously identified and rectified; ■ Monitoring performance, and hence is a management tool for DPMT; and ■ Any problems identified during monitoring and auditing must be listed on an action list and then rectified as soon as possible.
Internal Facilities Audit	The internal audit will focus on overall operational aspects. This is to ensure that the site is operated in compliance with this operating and maintenance manual and any other Health and Safety requirements and general plant requirements influencing the facility. It is proposed that a check list be developed over time to assist with internal audits.
Annual Audit	An annual audit of the entire facility should be conducted by a suitably qualified Professional Person with the appropriate waste management experience. This audit will focus on both operational and environmental aspects. Copies of the internal audits should also be made available to the external auditor, as well as the chemical analysis of the ground water monitoring network, leachate and polluted water.
Monitoring	Once finalised the “Pollution Control Rationale and Groundwater Monitoring Protocol” should be implemented for ground water monitoring at the facility.

12.0 CONCLUSIONS

This document needs to be updated directly after construction. Photos of the facility showing details of various components should be included in the document. This document should be reviewed and updated as required once per annum.

Signature Page

Golder Associates Africa (Pty) Ltd.

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HB/FM/mfb

https://golderassociates.sharepoint.com/sites/34541g/deliverables/reports/18100056-324750-7_o&m/18100056-324750-7_rep_dpmt-o&m_rev0_20190514.docx

APPENDIX A

List of Drawings

AS-BUILT DRAWINGS

This list needs to be updated after construction is completed

Dwg No.	Drawing Name
02-T-101	Existing Site Layout - Survey November 2018
02-T-102	General Arrangement
02-T-103	Cell 1 - Bulk Earthworks and Liner Layout
02-T-104	Cell 1 - Subsoil Drainage Layout
02-T-105	Cell 1 - Leachate Drainage Layout
02-T-106	Cell 1 - Sections and Details Sheet 1
02-T-107	Cell 1 - Sections and Details Sheet 2
02-T-108	Contaminated Water Pond - Layout
02-T-109	Contaminated Water Pond - Sections and Details
02-T-110	Contaminated Water Pond - Leakage Drainage Sump Details
02-T-111	Fencing Layout
02-T-112	General Site Works - Layout
02-T-113	Contaminated Water Drainage System - Layout
02-T-114	Leachate Collection System - Layout
02-T-115	General Site Works - Sections and Details Sheet 1
02-T-117	Leachate Storage Tank at Blending Pads - 5500 Litres - Layout and Details
02-T-118	Leachate Storage Tank at Cont. Water Pond - 15500 Litres - Layout and Details
02-T-119	Washbay Facility - Layout, Sections and Details
02-T-120	Process Flow Diagram
02-T-201	General Waste Recyclable Storage Area - Architectural Details - Layout
02-T-202	General Waste Recyclable Storage Area - Architectural Details - Elevations
02-T-203	General Waste Recyclable Storage Area - Architectural Details - Sections
02-T-204	General Waste Recyclable Storage Area - Surface Bed - Concrete Layout & Details
02-T-205	General Waste Recyclable Storage Area - Surface Bed - Reinforcement Layout & Details
02-T-206	General Waste Recyclable Storage Area - Structural Steel - Plan on Base Plates
02-T-207	General Waste Recyclable Storage Area - Structural Steel - Plan on Roof

Dwg No.	Drawing Name
02-T-208	General Waste Recyclable Storage Area - Structural Steel - Elevations
02-T-211	Hazardous Storage Shed - Architectural Details - Layout
02-T-212	Hazardous Storage Shed - Architectural Details - Elevations
02-T-213	Hazardous Storage Shed - Architectural Details - Sections
02-T-214	Hazardous Storage Shed - Surface Bed - Concrete Layout & Details
02-T-215	Hazardous Storage Shed - Surface Bed - Reinforcement Layout & Details
02-T-217	Hazardous Storage Shed - Structural Steel - Plan on Roof
02-T-218	Hazardous Storage Shed - Structural Steel - Elevations
02-T-221	Blending Pads - Surface Bed - Concrete Layout & Details
02-T-222	Blending Pads - Surface Bed - Concrete Layout & Details
02-T-223	Bending Pads – Surface Bend – Reinforcement Layout & Details

APPENDIX B

Document Limitations

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DUNDEE PRECIOUS METALS TSUMEB

HAZARDOUS WASTE DISPOSAL FACILITY
CELL 1 CAPPING
DETAILED DESIGN REPORT

Report No.: JW218/20/I279 - Rev 0

July 2020

Jones & Wagener
Engineering & Environmental Consultants
Internet presence: www.jaws.co.za

DOCUMENT APPROVAL RECORD

Report No.: JW218/20/I279 - Rev 0

ACTION	FUNCTION	NAME	DATE	SIGNATURE
Prepared	Engineer	Tondani Nevhutalu	June 2020	
Reviewed	Associate	Riva Nortje	July 2020	
Approved	Director	Jabulile Msiza	July 2020	

LOCATION: Lat: -19.23706667
(Decimal Degrees) Long: 17.71948333

RECORD OF REVISIONS AND ISSUES REGISTER

Date	Revision	Description	Issued to	Issue Format	No. Copies
23/7/2020	0	Detailed Design Report	DPMT	Electronic	N/A

SYNOPSIS

Jones & Wagener were appointed to undertake the Basic and Detailed Engineering for the capping of Cell 1 of the Dundee Precious Metals Tsumeb (DPMT) Hazardous Waste Disposal Facility (HWDF) in February 2020. The purpose of the overall project is to undertake the engineering necessary, as well as provide the technical documentation and drawings required for the capping of Cell 1 of the DPMT HWDF, excluding the western slope. This report covers the Detailed Engineering Phase of the project.

This report includes an introduction, the scope of work specified, a site description, the design criteria determined for the project, the design standards used, the functional specifications determined for the final cover and for the interim landform, a discussion on end-use, design of the final capping layers, design of the final and interim landforms, stormwater management, the above liner drainage system, erosion control measures, stability consideration, monitoring and maintenance of the cap. Compliance of the design with the function specifications is tabled in the summary. The Detailed Engineering drawings developed are included in Appendix A.

The functional specification for the Final Cover for Cell 1 of the DPMT HWDF included a number of requirements. These requirements are listed below, with a summary of how these functional specification requirements are met in the Detailed Engineering Design.

Functional Specification for Final Cover	Detailed Design measures to meet Final Cover Functional Specification
The final cover must separate the waste body being capped from the general environment.	The 800mm thick final cover separates the waste body from the general environment, particularly as it includes a geomembrane liner and four soil layers.
The final cover must minimise the generation of contaminated stormwater by Cell 1.	Contaminated stormwater will not be generated on the portion of Cell 1 once final cover has been applied. Contaminated stormwater will be generated on the uncapped western portion.
The final cover must increase the release of clean runoff to the natural environment from the HWDF.	The final cover facilitates the release of clean runoff from the portion capped to the natural environment.
The final cover must minimise infiltration of precipitation into the waste body, to reduce and taper off leachate generation from the portion of Cell 1 being capped.	The final cover has been designed with a composite barrier system comprising a compacted cohesive soil layers overlain by a 2mm HDPE geomembrane which will minimise infiltration.
The final cover must minimize the generation of hazardous dust from the portion of Cell 1 to be capped.	Placement of a 200mm calcrete foundation layer over the waste body will minimise the generation of hazardous dust during construction. No hazardous dust will be generated from the cover itself once installed.

Functional Specification for Final Cover	Detailed Design measures to meet Final Cover Functional Specification
The final cover must provide a barrier to burrowing animals.	Both the gravel erosion protection layer and the geomembrane provide a good level of protection against burrowing animals.
The final cover should minimize erosion by wind.	By installing a gravel layer over the cover, wind erosion will be minimised.
The final cover should minimize erosion by water.	Erosion by water should be kept in check by the gravel layer over the final capping, and by the stone pitching installed in the drains.
The final cover should minimize visual intrusion of the waste site on the landscape by limiting the maximum height to 1332m amsl.	The final cover has been designed to have a maximum elevation of 1332m amsl. Visual intrusion could be further reduced by planting trees strategically around to the south-east-east and to the north-west-west of the site.
The permeability of the cap should have a permeability less than or equal to the permeability of the bottom liner system present.	The final cover has been designed so that its permeability is equivalent to the bottom liner system constructed for Cell 1.
A “non-infiltration cap” is indicated per the South African Technical Advisory Practice Note (2019), with a maximum infiltration rate of 15 litres per hectare per day.	The composite barrier system included in the final cover design for Cell 1 has a maximum infiltration rate of 15 litres per hectare per day, provided that material and construction specifications are met, site supervision and construction quality assurance are undertaken, and regular maintenance takes place.

The following functional specification requirements are relevant to the Interim Final Landform. These requirements are listed below, with a summary of how these functional specification requirements are met in the Detailed Engineering Design.

Functional Specification for Interim Final Landform	Detailed Design measures to meet Interim Final Landform Functional Specification
The interim landform must allow for continued drainage of contaminated stormwater from the surface of Cell 1 to Pond 1, noting that the existing lined toe drains may not have sufficient capacity to carry all contaminated water from Cell 1.	The interim landform includes two vee drains on the plateau draining west towards Pond 1, to limit contaminated stormwater entering the existing lined toe drains.

Functional Specification for Interim Final Landform	Detailed Design measures to meet Interim Final Landform Functional Specification
The interim landform should allow for the disposal of as much arsenic dust as possible within the confines of the final landform, while still allowing runoff of contaminated runoff from Cell 1 to Pond 1.	The interim landform has been optimised, so that the maximum elevation reached is 1331.2m amsl, cut to fill is minimised on the areas exceeding that level, and so that the minimum gradient on the plateau is 1V:50H.
The interim landform should provide a smooth compacted surface for the construction of the final cover.	The interim landform has been designed to provide a smooth compacted surface for the construction of the final cover.

DUNDEE PRECIOUS METALS TSUMEB

HAZARDOUS WASTE DISPOSAL FACILITY
CELL 1 CAPPING
DETAILED DESIGN REPORT REPORT NO: JW218/20/I279 - Rev 0

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APPENDICES

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LIST OF FIGURES

LIST OF DRAWINGS

DRAWING NO	DRAWING TITLE	REVISION
02-T-1223	FINAL LANDFORM - GENERAL ARRANGEMENT	E
02-T-1224	CURRENT LANDFORM AS AT 5 FEBRUARY 2020: LAYOUT	C
02-T-1225	INTERIM CAPPING LANDFORM: LAYOUT AND TYPICAL SECTIONS	E
02-T-1226	FINAL CAPPING LANDFORM: LAYOUT AND SETTING OUT POINTS	B
02-T-1227	FINAL CAPPING: SECTIONS AND DETAILS	D
02-T-1228	ABOVE BARRIER DRAINAGE SYSTEM: LAYOUT, SECTIONS AND DETAILS	D
02-T-1229	SURFACE WATER DRAINAGE SYSTEM: LAYOUT, SECTIONS AND DETAILS	D
02-T-1230	BARRIER CONNECTIONS: LAYOUT AND DETAILS	C
02-T-1307	DOWN CHUTES: SECTION AND DETAILS	D
02-T-1308	STORMWATER TOE DRAIN 1 AND 2: LAYOUT AND LONGITUDINAL SECTION	A
02-T-1309	STORM WATER TOE DRAIN 3, 4 AND 5: LAYOUT AND LONGITUDINAL SECTION	A

DRAWING NO	DRAWING TITLE	REVISION
02-T-1310	DROP INLET BOX 1: LAYOUT AND SECTIONS	A
02-T-1311	STORM WATER LAYOUT	A
02-T-1312	DROP INLET BOX 2: LAYOUT AND SECTIONS	A
02-T-1313	DROP INLET BOX 3: LAYOUT AND SECTIONS	A
02-T-1314	DROP INLET BOX 4: LAYOUT AND SECTIONS	A

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DUNDEE PRECIOUS METALS TSUMEB

HAZARDOUS WASTE DISPOSAL FACILITY
CELL 1 CAPPING
DETAILED DESIGN REPORT REPORT NO: JW218/20/I279 - Rev 0

1. INTRODUCTION

1.1 Background

Tsumeb mine is a copper mine in northern Namibia, approximately 65 km east of the Etosha National Park and 430 km north of Windhoek. Tsumeb Corporation Limited (TCL) commissioned the Tsumeb smelter plant in 1963 under American mining company, Newmont Mining Corporation. It featured an integrated copper and lead section (with refinery), and smaller plants that produced cadmium and arsenic trioxide as by-products. Production officially started in March 1964. By 1986 the smelter was also producing sodium antimonite for export. In 1988, TCL was taken over by Gold Fields South Africa and administered by Gold Fields Namibia ("GFN"). Approximately six years later, the Lead Smelter was closed permanently. In 1996, TCL's mining and smelting operations came to a standstill following a prolonged labour strike. This ultimately led to the closure and liquidation of GFN in 1998. In March 2000, Namibia's High Court accepted an offer by Ongopolo Mining and Processing Limited ("OMPL") to take over GFN's mines, as well as the smelter plant in Tsumeb (Dundee Precious Metals, 2017).

In June 2004 Jones & Wagener (Pty) Ltd (J&W) were appointed for the design of a hazardous waste disposal facility (HWDF) at the Tsumeb smelter by Ongopolo Mining and Processing Limited, who owned and operated the smelter at the time. The project was put on hold when the smelter was sold to Weatherly PLC in July 2006, and all mining operations were suspended in December 2008 due to a major decline in the world copper price, although the smelter remained operational. Golder Associates Africa (Pty) Ltd (Golder) reviewed the HWDS design by J&W in 2009. Weatherly PLC sold the smelter to Dundee Precious Metals, a Canadian-based international mining company with operations in Namibia and Bulgaria, and exploration in Armenia, Bulgaria and Serbia, in March 2010 (Dundee Precious Metals, 2017).

Dundee Precious Metals report that the smelter is one of only a few in the world which can treat complex copper concentrates that contain arsenic. Blister copper, sulphuric acid and arsenic trioxide are produced by the smelter. Less than half of the concentrate smelted by DPMT is reported to come from Dundee Precious Metals' mine in Chelopech, Bulgaria, while additional business is solicited from Peru, Chile and Namibia (Dundee Precious Metals, 2017).

It is noted that there have been considerable changes to the smelter since the initial work was carried out for the HWDS. The Top-Submerged Lance Ausmelt furnace was converted from a lead to a copper smelting vessel in 2010 and is the only primary smelting vessel after the decommissioning of the Reverberatory furnace in 2013. A new Oxygen Plant, commissioned in February 2014 to increase the efficiency of the furnace, delivers up to 405 tonnes of oxygen per day. A sulphuric acid plant was commissioned in 2015. Two new Peirce Smith copper converters were commissioned in the first quarter of 2016. Both the off gas from the Ausmelt furnace and the Peirce Smith converters are to be treated in the sulphuric acid plant to remove sulphur dioxide from the off gas before the cleaned gas is vented to atmosphere (Dundee Precious Metals, 2017).

The HWDS project was resurrected in early 2010 and J&W completed the design of Phase 1. The construction contract was negotiated with Prodev Plant Hire who commenced with construction in April 2010. In December 2010 it was decided to extend Phase 1 and J&W completed the design for the extension as a variation to the original contract. Construction was completed in March of 2012. Phase 1's construction included Cell 1, Pond 1 and associated works.

Golder were subsequently appointed by Dundee Precious Metals Tsumeb (Pty) Limited (DPMT) for the design of future development of the HWDS, including for the conceptual design of Cell 2 to Cell 6 and a detailed design of Cell 2 in January 2017. J&W undertook an engineering peer review of the designs undertaken by Golder in late 2017, following which changes to the design were made. Construction of Cell 2, Pond 2 and Pond 3 was undertaken in 2018 and 2019 and is complete. J&W reviewed the draft Operating Manual developed for the HWDS by Golder.

Jones & Wagener (J&W) was requested to submit a proposal for the capping design of the DPMT HWDS on 28 August 2019. The Request for Quotation (RFQ) was for the Basic and Detailed Engineering for the capping of Cell 1 of the DPMT HWDS. Optional services included in the RFQ were for Provision of Construction Quality Assurance and Control services and technical assistance during construction.

1.2 Purpose

The purpose of the overall project is to undertake the basic and detailed engineering necessary, as well as provide the technical documentation and drawings required for the capping of Cell 1 of the DPMT HWDS, excluding the western slope. This report covers the Detailed Engineering Phase of the project.

The capping system needs to provide a long-term, cost-effective and environmentally sustainable solution to isolating the hazardous waste body from the environment.

1.3 Terms of Reference

Jones & Wagener were appointed to undertake this project per contract DT20-000 signed by DPMT on 12 February 2020.

2. SCOPE OF WORK

2.1 Scope of Services

The Scope of Work (SoW) for the project is chiefly contained in two documents received from DPMT, namely:

- Dundee Precious Metals Tsumeb, 20 August 2019, Capping of Hazardous Waste Disposal Facility, Project Design Criteria, Document # 03_08-1249-DCR-001, Revision # 0.
- Dundee Precious Metals Tsumeb, 20 August 2019, Scope of Work, Design of Closure System for Hazardous Waste Disposal Facility, Document # 03_08-1249-SOW-GEN-708, Revision # 0.

The DPMT SoW lists the following Scope for Specific Design:

“1. Provision of design personnel (with all equipment and software required to perform the work) to attend site to perform preliminary layouts in consultation with DPMT representatives. Inclusive of mobilisation, demobilisation, medicals, inductions, accommodation, transport and messing.

2. Review the conceptual closure design and advise proposed amendments/improvements.

3. Detail Engineering closure design (up to Issued for Construction (IFC) level, AACEI Class 1) for Cell 1 and stormwater system design:

   a. Final shaping

   b. Final cover barrier design

   c. Protective cover design

   d. Side slopes veneer stability design

   e. Stormwater drainage systems

4. Specifications and bills of quantities/materials (up to Issue for Tender (IFT) level, AACEI Class 1) for Cell 1 and the associated stormwater system design.

5. Construction timeline for closure of Cell 1.

6. 15% Accurate cost estimate for implementation of all capping and stormwater construction/implementation.

7. Detailed Construction Plan for construction/implementation of Cell 1 closure, including method statements and risk assessments for critical and high-risk activities.

8. Construction Quality Assurance and Quality Control Plan, including quality control check sheets and draft certificates.”

The DPMT SoW gives the Engineering Design requirements as follows:

“1. The design shall include all necessary calculations, drafting, specifications and supporting documentation required to execute the project. All design drawings and documentation shall be in a completely auditable format such that it can be reviewed by the Company or 3rd Party at request.

2. The Consultant shall review, check and progress the Company’s preliminary design included in this scope and confirm that such design is suitable, appropriate, fit for purpose and satisfies the Company’s project intent.

3. The Consultant shall be responsible for all required engineering design disciplines.

4. The Consultant shall establish or develop specifications for engineering standards where existing Company or referenced standards do not exist.

5. The Consultant shall perform all drafting services, drawing production and issue of drawings. Drawings shall be handed over to the Company in an approved native (*.dwg) file format as well as PDF. Drawing numbering to be to the approved Company standard.
6. The Consultant shall provide technical advice to DPMT on technical issues.
7. Preparation, checking and issuing of all computations, calculations and design sketches.
8. Reporting of progress on the status and issue of engineering deliverables."

2.2 Deliverables

The deliverables for the Detailed Engineering phase of the project are listed in the DPMT SoW as follows:

1. Updated engineering calculations
2. Site Layout Drawings
3. Detailed Earthworks and Civil Drawings
4. Work Package Specifications
5. Construction Timeline
6. Cost Estimate
7. Construction Plan
8. Construction QA and QC Plan with QC check sheets

2.3 Information Provided

The following technical information was provided by DPMT for RFQ# 03_08-RFQ-1249:

- Aerial photos of HWDF (Hazardous Waste Disposal Facility) during construction of Cell 2, Pond 2 and Pond 3.
- Dundee Precious Metals Tsumeb, 20 August 2019, Capping of Hazardous Waste Disposal Facility, Project Design Criteria, Document # 03_08-1249-DCR-001, Revision # 0.
- Dundee Precious Metals Tsumeb, 20 August 2019, Scope of Work, Design of Closure System for Hazardous Waste Disposal Facility, Document # 03_08-1249-SOW-GEN-708, Revision # 0.
- Dundee Precious Metals Tsumeb, 29 August 2019, Health, Safety & Environmental Criteria for Design, Purchasing, Installation, Refurbishment and Upgrading, Doc #8-01-MS-PR-04.
- Dundee Precious Metals Tsumeb, 4 September 2019, Capping of HWDF – Tender Meeting Minutes.
- Dundee Precious Metals, 5 September 2019, Capping of Hazardous Waste Disposal Site, Tender Clarification Queries, Doc #03_08-1249-TCQ001.
- Dundee Precious Metals, Request for Quotation, Reference No: 03_08-RFQ-1249 Rev.0, Regarding Capping of Hazardous Waste Disposal Site, received 21 August 2019.

- Golder Associates Africa, 2017, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-516, Cell 2 Liner System, Sections & Details Sheet 1, Rev 5.
- Golder Associates Africa, 2017, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-516, Cell 2 Liner System, Sections & Details Sheet 2, Rev 6.
- Golder Associates Africa, 2017, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-517, Pond 2 Liner System, Sections & Details Sheet 1, Rev 5.
- Golder Associates Africa, 2017, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-517, Pond 2 Liner System, Sections & Details Sheet 2, Rev 6.
- Golder Associates Africa, 2017, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-518, Pond 3 Liner System, Sections & Details Sheet 1, Rev 6.
- Golder Associates Africa, 2017, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-518, Pond 3 Liner System, Sections & Details Sheet 2, Rev 5.
- Golder Associates Africa, 2018, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-591, Waste Deposition Plan, Stage A - Cell 1 Landfilling to Final Height Liner System, Rev A.
- Golder Associates Africa, 2018, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-592, Waste Deposition Plan, Stage B - Cell 2 Active Landfilling, Rev A.
- Golder Associates Africa, 2018, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-593, Waste Deposition Plan, Stage C – Pond 1 Active Landfilling, Rev A.
- Golder Associates Africa, 2018, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-594, Waste Deposition Plan, Stage D – Pond 2 Active Landfilling, Rev A.
- Golder Associates Africa, 2018, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-595, Waste Deposition Plan, Stage E – Pond 2 Capping Applied, Rev A.
- Golder Associates Africa, 2018, Tsumeb Hazardous Waste Disposal Site – Detail Design, Drawing No 08-T-596, Waste Deposition Plan, Final Landfill Development – All Areas Rehabilitated, Rev A.
- Golder Associates Africa, 21 August 2019, Closure Design for the Hazardous Waste Disposal Site, Technical memorandum Reference No. 1670030A_TM_019 Rev 02.
- Jones & Wagener, 2003. Tsumeb Smelter Hazardous Waste Disposal Facility, Drawing 8624-00-003 Phase 1 Sections & Details, Sheet 1, Rev A.
- Jones & Wagener, 2010. Tsumeb Smelter Hazardous Waste Disposal Facility, Drawing 8624-00-004 Phase 1 Typical Sections & Details, Sheet 2 of 2, Rev 1.
- Schwarting Land Surveyors, 14 July 2019, Report on Volume Survey on Hazardous Waste Disposal Facility.
- SRK Consulting, DPM HWDF photos 2017 v 2019.

Additional information provided in response to Requests for Information (RFIs) comprised the following:

- Aquatico Laboratories, 08 January 2020, Dundee Precious Metals Tsumeb Test Report no. 79792, PDF
- Aquatico Laboratories, 08 January 2020, Dundee Precious Metals Tsumeb Test Report no. 79792, .xml
- Aquatico Laboratories, 15 January 2020, Dundee Precious Metals Tsumeb Test Report no. 80111, PDF
- Aquatico Laboratories, 15 January 2020, Dundee Precious Metals Tsumeb Test Report no. 80111, .xml
- Argos Scientific, December 2019, Ambient Air Quality Monitoring Report for Tsumeb
- Dundee Precious Metals, Cell 1 As-built 0.5m Grid, .xml
- Dundee Precious Metals, February, Surface Water Results, .xml
- Dundee Precious Metals, AutoCAD format title block (A0, A1 and A3), .dwg
- Dundee Precious Metals Tsumeb, 27 April 2016, Engineering Specification for Standard Colour Code of Plant, Equipment and Pipelines, Ref: 05_05_04_ES03 Colour Code Rev. 8
- Dundee Precious Metals Tsumeb, 15 August 2016, Engineering Drawing Standard, Ref: 05_05_01_STD 01 Engineering Drawing Standard Rev. 7
- Dundee Precious Metals, 12 December 2018, Document Numbering Procedure, Ref: 100-000-PRO-DNP-001 Rev. 0
- Dundee Precious Metals, 03 July 2019, Material stock take, .xml
- Dundee Precious Metals Tsumeb, 15 October 2019, Hazardous Waste Disposal Site Operations Manual.
- Golder Associates Africa, 5 September 2019, Final Landform Design for Cell 1 of the Hazardous Waste Disposal Site, Technical Memorandum, Ref: 1670030A_TM_020 Rev. 00
- Ministry of Environmental and Tourism, 13 August 2019, Environmental Clearance Certificate
- Namibia Technical Services, 22 July 2019, Aggregate Compliance - Summary of Aggregate Test Results
- Schwarting Land Surveyors, 29 November 2019, Report on Volume Survey on Hazardous Waste Disposal Facility.
- Schwarting Land Surveyors, 5 February 2020, Report on Volume Survey on Hazardous Waste Disposal Facility.
- Tulela Mining & Construction, 12 July 2018, Akkerman Bulk Fill Material Borrow Pit Sample Report
- Tulela Mining & Construction, 23 October 2018, Akkerman Clay Borrow Pit Sample Report

- WorleyParsons Resources & Energy, 18 April 2016, Tsumeb Smelter Expansion Feasibility Study Civil Design Criteria, Ref: 207040-00149-001-CI-CRT-1001

3. SITE DESCRIPTION

The hazardous waste disposal facility is located north of the town of Tsumeb, approximately 430km north of Windhoek in Namibia, at latitude 19°14'13.44"S and longitude 17°43'10.14"E.

The HWDF is located within an old rock quarry located south of the Smelter Complex on a ridge separating the Smelter from the town of Tsumeb and within the DPMT property boundaries.

Figure 3-1: DPMT HWDF location showing Cell 1 and Pond 1 on image dated 29 October 2018

3.1 Ground Conditions

From the "Report to Dundee Precious Metals Tsumeb on a Dolomite Stability Assessment for Phase 3 of the Hazardous Waste Facility at Tsumeb Smelter, Namibia" (GCS, 2016):

"Tsumeb is located in the Otavi Mountainland which is part of the former extensive Damara Mountain Chain. The predominant rock type beneath the site is dolomite which has undergone various degrees of karstification by a process of carbonic acid weathering as exemplified by Ghaub Cave, Otjikoto and Guinas Lakes.

The site is underlain by dolomite with chert bands and stromatolitic horizons that belong to the Huttenberg Formation, Tsumeb Group.

The subsoil conditions encountered over the site generally comprise a thin layer of stockpiled cover material, a dolomite gravel layer (possibly blast rock residue) overlying jointed and bedded dolomite bedrock at less than 0.5 m below surface. All three boreholes were drilled to a maximum depth of 10 m and were recorded as dry and this concurs with the hydrogeological information at the mine which shows the groundwater level to be greater than 50 m below surface."

3.2 Climatic Conditions

The climate of Tsumeb and surrounds is classified as "BSh" in terms of the Köppen-Geiger system. Type B climate is defined by little precipitation, S denotes a semi-arid or steppe climate, and h indicates that the average temperature in the winter months exceeds zero degrees Celsius. Type "BSh" therefore denotes hot semi-arid climates, which tend to be located in the 20s and 30s latitudes.

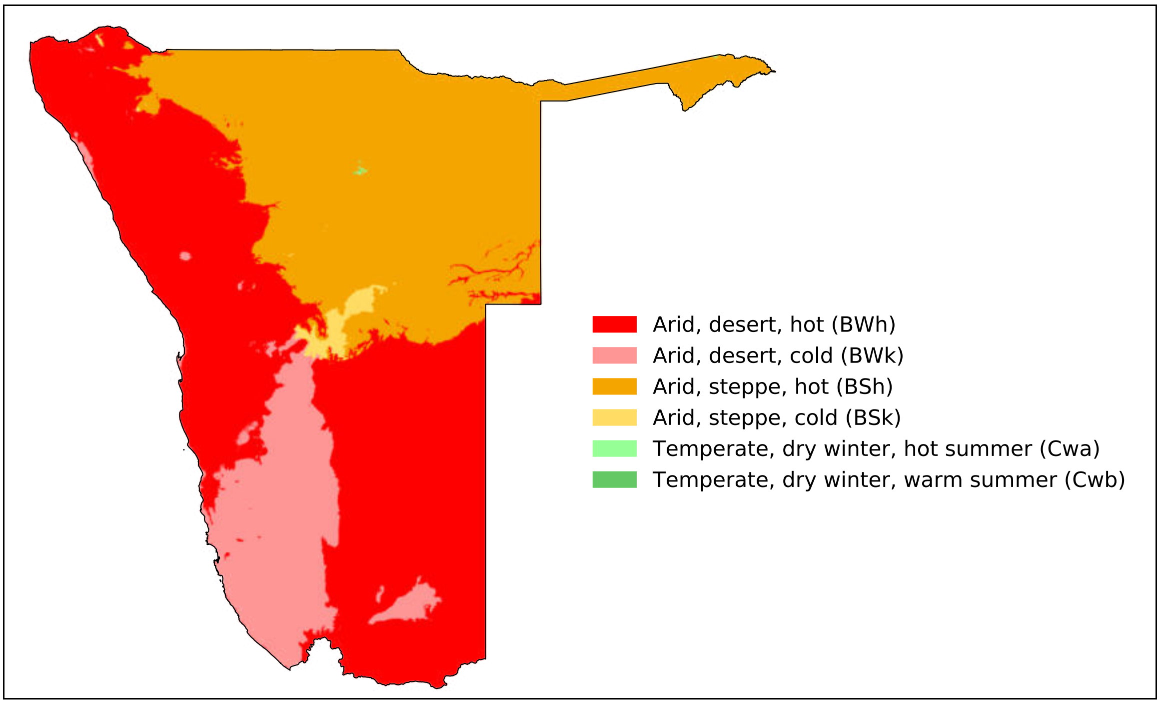

Figure 3-2: Köppen-Geiger climate classification map for Namibia (1980-2016)

Source: Beck et al.: Present and future Köppen-Geiger climate classification maps at 1-km resolution, Scientific Data 5:180214 (2018)

The average annual temperature is 22.0°C in Tsumeb, with average temperatures fluctuating between 16.2 °C in June and 25.9 °C in October. Mean annual precipitation is reported as 550 mm. The area experiences summer rainfall, with average precipitation of 131mm in January and 0mm in July.

Winds are predominantly from the east, with the winter months considered windy.

3.3 Facility Operations

Cell 1 of the HWDF remains in operation, with arsenic dust disposed of in one cubic metre bags, as well as bulk dust. Cell 1 will continue to be operated until the interim final landform is reached, following which operations will be shifted to Cell 2. A new access road to the south of Cell 1 will be used to access Cell 2. This will avoid potential traffic congestion at the current access gate and ramp to Cell 1 while capping of Cell 1 is undertaken, and site operation continues.

Dust control is critical for operations, and dust control is currently practised on site via a formal irrigation-type system on Cell 1. Formal infrastructure on Cell 1 for dust control will need to be removed prior to final application and shifted to Cell 2.

4. DESIGN CRITERIA

The design criteria define the functional requirements which must be achieved to fulfil the scope of works. These are categorised into the general criteria, factors affecting closure design, risks affecting the design, stormwater drainage, slope stability and site-specific considerations affecting the design.

4.1 General Criteria

The following general criteria were included by DPMT in the project design criteria (DPMT Document 03_08-1249-DCR-001):

"The designed capping system needs to:

- Provide long-term minimisation of liquids through the capped portion of the landfill
- Function with minimum maintenance
- Promote maximum runoff of precipitation and minimise erosion or abrasion of the cover
- Accommodate settling and subsidence so that the cover's integrity is maintained, and
- Ensure the stability of the cover soil."

4.2 Factors Affecting Closure Design

The following factors affecting closure design were included by DPMT in the project design criteria (DPMT Document 03_08-1249-DCR-001):

- "The closure design should be sufficiently robust to withstand the effects of the elements over a long-term period.
- There is a restriction on the final height of the landfill of 1 332 m amsl, the final layer of the capping should therefore not exceed this height.
- The capping should be sufficiently robust to minimise the risk of human intervention through the cover into the waste body.
- The cover system must not be adversely affected by the chemicals within the waste and possible leachate emanating from the landfill.
- The final cover system must be stable on the landfill slopes under all conditions and must be able to withstand long-term erosion; and prevent rainwater ingress.
- Clean stormwater runoff from the landfill cover needs to be managed to prevent erosion on the cover surface and the receiving area around the landfill.
- Possible health and safety risks to the eventual construction team will have to be considered when selecting the capping method.
- Constructability of the selected capping method needs to be considered, bearing in mind safe working procedures.

- Ensure the visual appearance is not detrimental to the amenity of the area."

It is noted that it is not possible to design for a stable cap in perpetuity, and that erosion is likely to occur as a natural process in time. The design period for the barrier would extend to 100 years, given CE certification of relevant manufactured products, but maintenance will be required on surface layers and drainage systems during that period. Maintenance is particularly critical immediately after the construction to determine whether systems are functioning as intended and issues arising are addressed.

4.3 Risks Affecting Closure Design

DPMT included the following risks in the project design criteria (DPMT Document 03_08-1249-DCR-001):

"Although the arsenic dust waste that is delivered to the site is spread and compacted, the bags of loose dust are not compacted to the same degree as the bulk waste, so that differential settlement of the final surface of the waste body is likely to occur. This will have to be taken into account when selecting material for the capping system."

Additional risks identified include:

During the construction period:

- Exposure to hazardous dust (arsenic)
- Dust from excavation, transport and construction of soil layers
- Accidents and injury from increased traffic
- Working at heights on edges of plateau
- Injury from mishandling of geosynthetic rolls
- Erosion by wind or precipitation during construction
- Exposure to low pH liquids on site
- Potential crushing of new concreted vee drain within lined edge of Cell 1
- Exceedance of the final height of 1332m amsl stated to the authorities if capping layers are thicker than designed
- Instability of capping layers if drainage layer capacity is exceeded by direct rainfall during construction
- Instability of capping layers if soil capping layers are constructed down slope rather than upslope and the geocomposite drainage layer is damaged

During the post-capping and maintenance period:

- Potential for animal burrows
- Risk of human intervention
- Areas of differential settlement
- Erosion
- Cracking of erosion protection measures
- Blockage of drains

- Performance of Cell 1 affected if backup of liquids into the Cell 1 leakage detection system occurs, as contaminated liquids would bypass the Cell 1 composite liner
- Instability of capping layers if drainage systems are not functional or overwhelmed
- Melting of geosynthetic layers if vegetation establishes on the cap, and is subsequently burnt.

4.4 Stormwater Drainage

DPMT included the following regarding stormwater drainage in the project design criteria (DPMT Document 03_08-1249-DCR-001):

"After capping has been completed, all rainwater falling onto Cell 1 will be considered clean. This water can then be channelled by conventional open stormwater systems and discharged to the environment."

The capping design will therefore consider the collection of and discharge points for this stormwater, while minimising erosion of the cap.

4.5 Slope Stability

DPMT included the following regarding slope stability in the project design criteria (DPMT Document 03_08-1249-DCR-001):

"Due to the steep nature of the final side slopes of the site, careful consideration will have to be given to the stability of the cover and any reinforcement that might be necessary to ensure the stability of the protective cover layer."

It is noted that lining of steep slopes increases strain in geosynthetic materials, which would reduce material durability. In addition, compaction of soil materials is difficult on steep slopes. For rehabilitation, slopes of 1 in 3 or flatter are generally preferable for these reasons.

4.6 Site Specific Considerations for Design

DPMT included the following regarding site specific considerations for design in the project design criteria (DPMT Document 03_08-1249-DCR-001):

"DPMT requires the Design Engineer to consider the following aspects in any design produced where applicable, for construction and during normal operations of new facilities:

- Arsenic exposure
- Asbestos exposure
- Sulphur dioxide exposure
- Noise exposure
- Lighting/illumination
- Chemical storage and management
- Hydrocarbon storage and management
- Risk management and assurance
- Water consumption

- Fire and explosion
- Falling from height
- Lifting operations
- Uncontrolled release of energy
- Contact with electricity"

5. DESIGN STANDARDS

DPMT states that "The order of priority for design standards shall be first General Legislature and DPMT Policies, followed by the site standards, followed by the general standards in the stated sequence".

5.1 General Legislature

The design should comply with the Namibian local, regional and national legislation including:

- Republic of Namibia, 1990. Namibian Constitution, Government Gazette 2, as amended in 1998 (Government Gazette 2014), 2010 (Government Gazette 4480) and 2014 (Government Gazette 5589).

- Namibia Minerals (Prospecting and Mining) Act, 33 of 1992 – Mine Health & Safety Regulations, 11th Draft

- Namibia Labour Act, 156 of 1992 – Regulations Relating to the Health and Safety of Employees at Work, 1997

- Namibia Water Corporation Ltd, 1998. Guidelines for the Evaluation of Drinking-Water for Human Consumption with regard to Chemical, Physical and Bacteriological Quality.

- Republic of Namibia Ministry of Environment and Tourism, 2007. Environmental Management Bill, Bill 8 of 2007.

- Republic of Namibia Ministry of Environment and Tourism, 2012a. Commencement of the Environmental Management Act, Government Notice No. 28, Government Gazette of the Republic of Namibia, No. 4878, 6 February 2012.

- Republic of Namibia Ministry of Environment and Tourism, 2012b. List of activities that may not be undertaken without Environmental Clearance Certificate: Environmental Management Act, 2007, Government Notice No. 29, Government Gazette of the Republic of Namibia, No. 4878, 6 February 2012.

- Republic of Namibia Ministry of Environment and Tourism, 2012c. Environmental Impact Assessment Regulations: Environmental Management Act, 2007, Government Notice No. 30, Government Gazette of the Republic of Namibia, No. 4878, 6 February 2012.

5.2 DPMT Policies

DPM Corporate Responsibility Policy, 2018

5.3 DPMT Standards

The following DPMT standards were issued for use in this project:

Document number	Document name	Revision
207040-00149-001-CI-1001-R0	Civil Design Criteria	0
05_05_01_STD_01	Engineering Drawing Standard	7
ES-P3	Color Coding Standard	7
100-000-PRO-DNP-001	Document Numbering Procedure DPMT	0

5.4 General Design Standards

- Technical Advisory Practice Note: Capping Closure of Waste Management Facilities and Pollution Point Sources, Department of Environmental Affairs of the Republic of South Africa, 2019. http://sawic.environment.gov.za/documents/9707.pdf
- The International Finance Corporation World Bank Group, 2007. Environmental, Health and Safety Guidelines for Waste Management Facilities.
- United States of America Environmental Protection Agency (USEPA) Resource Conservation and Recovery Act (RCRA) Subtitle D (requirements applicable to final covers for hazardous waste landfills).
- Koerner, R.M., 2012. Designing with Geosynthetics. In 6th Edition. Xlibris Corporation.
- Standards South Africa, 2005. South African National Standard 10409 SANS 10409: 2005. Design, selection and installation of geomembranes.

5.5 General Drawing Standards

- International Geosynthetics Society, 2009. Recommended Descriptions of Geosynthetic Functions, Geosynthetic Terminology, Mathematical and Graphical Symbols. Available to IGS members at http://www.geosyntheticssociety.org/wp-content/plugins/resources/documents/Recommended%20Mathematical%20and%20Graphical%20Symbolsv1.pdf

5.6 Material Standards

- Geosynthetic Institute, 2019. GRI Test Method GM13. Standard Specification for Test Methods, Test properties and Testing Frequency for High Density Polyethylene

(HDPE) Smooth and Textured Geomembranes. Available at http://www.geosynthetic-institute.org/grispecs/gm13.pdf

- Standards South Africa, 2015. South African National Standard 1526 SANS 1526: 2015. Thermoplastics polyolefin sheeting for use as a geomembrane.
- Geosynthetic Institute, 2016. GRI Test Method GT12(a). Standard Specification for Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials. Available at https://geosynthetic-institute.org/grispecs/gt12a.pdf
- Geosynthetic Institute, 2016. GRI Test Method GT13(a). Standard Specification for Test Methods and Properties for Geotextiles Used as Separation Between Subgrade Soil and Aggregate. Available at https://geosynthetic-institute.org/grispecs/gt13a.pdf
- Geosynthetic Institute, 2019. GRI-GCL3 Standard Specification. Standard Specification for Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs). Available at https://geosynthetic-institute.org/grispecs/gcl3.pdf
- Geosynthetic Institute, 2016. GRI Standard GS-15. Standard Specification for Test Methods, Test Properties and Testing Frequency for Geocells Made from High Density Polyethylene (HDPE) Strips. Available at https://geosynthetic-institute.org/grispecs/gs15.pdf

5.7 Construction Standards

- Republic of Namibia, 2010. Namibia Planning and Construction Council Bill, Bill 7 of 2010.
- Republic of South Africa Department of Labour, 2014. Construction Regulations in terms of the Occupational Health and Safety Act, 1993.
- South African National Standards (SANS)/ South African Bureau of Standards (SABS) construction standards.
- Geosynthetic Institute, 2013. GRI Test Method GM14. Standard Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes. Available at http://www.geosynthetic-institute.org/grispecs/gm14.pdf
- Geosynthetic Institute, 2017. GRI Test Method GM19a. Standard Specification for Seam Strength and Related Properties of Thermally Bonded Reinforced Polyolefin Geomembranes/Barriers. Available at http://www.geosynthetic-institute.org/grispecs/gm19a.pdf
- Standards South Africa, 2005. South African National Standard 10409 SANS 10409: 2005. Design, selection and installation of geomembranes.

6. FUNCTIONAL SPECIFICATION

6.1 Introduction

Systems engineering is an interdisciplinary field of engineering and engineering management that focuses on how to design, integrate, and manage complex systems over their life cycles. The systems engineering process encompasses activities necessary to define the system and which need to be carried out to convert a system definition to a sufficiently detailed system design specification for implementation.

A functional specification in systems engineering development is a document that specifies the functions that a system or a component of a system must perform.

In order to develop this preliminary functional specification, project design criteria and reference documents have been considered.

Technical Advisory Practice Note: Capping Closure of Waste Management Facilities and Pollution Point Sources, Department of Environmental Affairs of the Republic of South Africa, 2019 requires consideration of the following broad aspects to be considered:

- The nature of the waste body or pollutant to be capped
- Past, present and future impacts on water resources
- The cap as a function of baseliner performance

Based on these aspects, the decision to design a low infiltration or non-infiltration cap is made.

6.2 The Nature of the Waste Body or Pollutant to be Capped

Arsenic dust is hazardous, non-biodegradable, and presents an ongoing pollution risk if not contained. The Leachable Concentration Threshold Limit (LCTL) for arsenic is a maximum of 4mg/l for Type 1 waste in terms of the South African National Norms and Standards for the Assessment of Waste for Landfill Disposal, DEA 2013, No. R. 635. If arsenic concentrations of >4mg/l are leached from a waste, then the waste may not be disposed to landfill without treatment to meet threshold limits.

Arsenic concentrations in Pond 1 have been measured as 5 495mg/l in February 2020 Week 1, 8 971mg/l in February 2020 Week 3, and 1 034mg/l on 11 March 2020. These concentrations indicate that the arsenic dust classifies as highly hazardous.

The South African National Norms and Standards for Disposal of Waste to Landfill, DEA 2013, No. R. 636 prohibit the disposal of waste with a pH value of less than 6 or more than 12. The pH of Pond 1 liquids was measured as 4.96 in February 2020 Week 1, 4.16 in February 2020 Week 3 and 3.4 on 11 March 2020. The pH of the Pond 1 liquids would therefore preclude disposal of the arsenic dust from which the liquid drains in South Africa without pre-treatment.

The analysis confirms the hazardous state of the arsenic dust.

6.3 Past, Present and Future Impacts on Water Resources

Arsenic in the borehole downslope of the HWDF, BH6, has a maximum concentration of 0.01mg/l in the November and December 2019 analyses. The upslope borehole, BH11, has a maximum arsenic concentration of 0.023mg/l in the November and December 2019 analyses. The Guidelines for the Evaluation of Drinking-Water for Human Consumption with regard to Chemical, Physical and Bacteriological Quality by the Namibian Water

Corporation Ltd (Namwater) (1998) includes a limit for arsenic of 0.1mg/l for drinking water which is bacteriologically very safe (Group A).

The arsenic concentrations in the monitoring boreholes for the HWDF are therefore lower than the most stringent limits set in the Namibian drinking water standards. Typically, an assessment would include groundwater modelling using different seepage scenarios to determine potential impacts.

SLR undertook groundwater flow and transport model for DPMT as required by an environmental impact assessment for the proposed Dundee smelter expansion project (SLR, 2018). The HWDF was modelled as a “potentially unlined/ leaky facility”, and potential contamination from the facility was modelled at 10 years, 25 years, 100 years and 200 years. No specific contaminant source concentration was modelled, but rather plumes illustrate percentages of contaminant source concentration. A contaminant plume from the HWDF was modelled as developing towards the east and then then north-east towards the Eastern Tailings Dam. Groundwater impacts from the HWDF are shown as being contained within the DPMT property boundaries during the 200-year period, and SLR note that “after 200 years, there is no significant change of the plume length visible, although minor changes in the concentrations in the close vicinity of the source can be seen.”. SLR predict that plumes from other sources will exceed ten percent of contaminant source concentrations beyond DPMT property boundaries in 100 years.

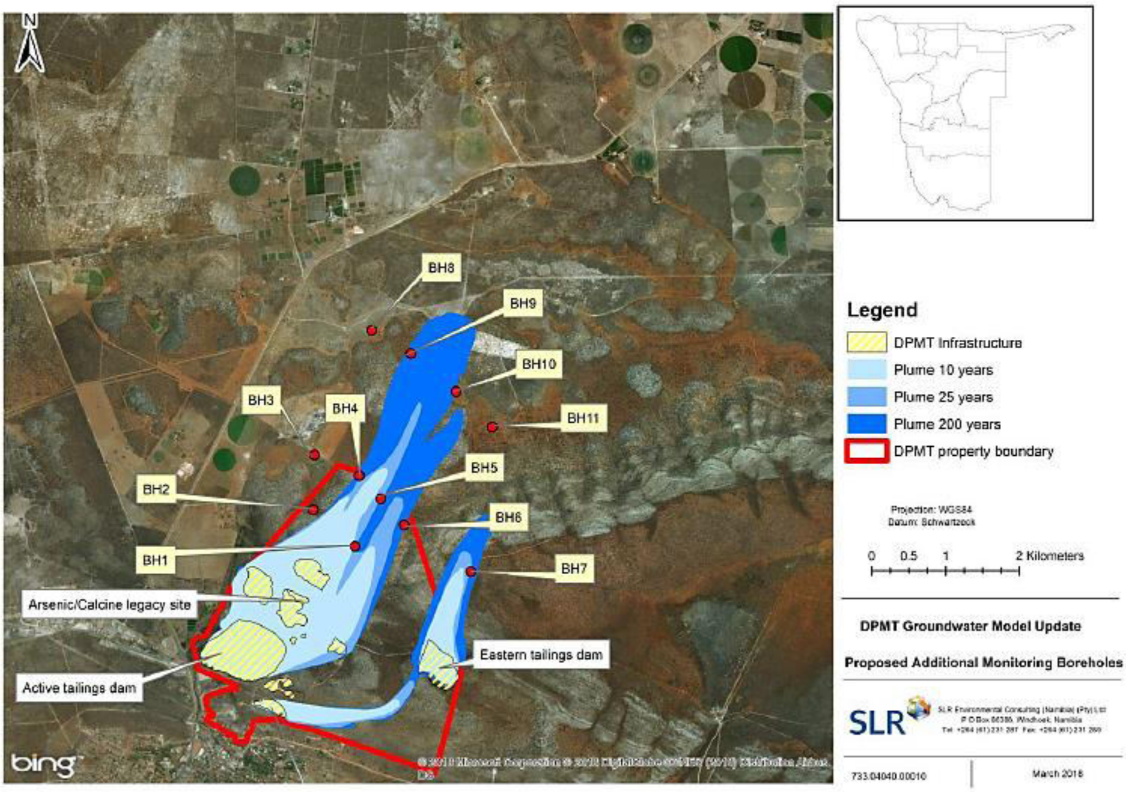

Figure 6-1: Contaminant plume extent from groundwater model (SLR, 2018)

Given the hazardous nature of the seepage from the DPMT HWDF, it would be preferable for the facility to contain as much contamination as possible.

6.4 The cap as a function of baseliner performance

No flow from the Cell 1 leakage detection outlet was visible during the site visit (March 2020), but the outlet is difficult to see as it is directly below the leachate collection outlet. A composite barrier system is in place for Cell 1, but not double composite barrier systems as required for newer hazardous waste disposal facilities. Based on the fact that the arsenic dust contained in Cell 1 is hazardous waste which is not biodegradable, and that the basal liner does not meet current hazardous waste liner specifications in neighbouring South Africa, a “non-infiltration cap” is indicated per the South African Technical Advisory Practice Note (2019), with a maximum infiltration rate of 15 litres per hectare per day.

6.5 Functional Specifications

These functional specifications were developed based on the project scope of work, two site visits held in March 2020 and discussions with DPMT.

The following functions are required to be performed by the interim landform of the majority of Cell1 of the DPMT HWDF:

- The interim landform must allow for continued drainage of contaminated stormwater from the surface of Cell 1 to Pond 1, noting that the existing lined toe drains may not have sufficient capacity to carry all contaminated water from Cell 1.
- The interim landform should allow for the disposal of as much arsenic dust as possible within the confines of the final landform, while still allowing runoff of contaminated runoff from Cell 1 to Pond 1.
- The interim landform should provide a smooth compacted surface for the construction of the final shape and cover.

The following functions are required to be performed by the final cover of the portion of Cell1 of the DPMT HWDF being capped:

- The final cover must separate the waste body being capped from the general environment.
- The final cover must minimise the generation of contaminated stormwater by Cell 1.
- The final cover must increase the release of clean runoff to the natural environment from the HWDF.
- The final cover must minimise infiltration of precipitation into the waste body, to reduce and taper off leachate generation from the portion of Cell 1 being capped.
- The final cover must minimize the generation of hazardous dust from the portion of Cell 1 to be capped.
- The final cover must provide a barrier to burrowing animals.
- The final cover should minimize erosion by wind.
- The final cover should minimize erosion by water.
- The final cover should minimize visual intrusion of the waste site on the landscape by limiting the maximum height to 1332mamsl.

From the design criteria documents referenced:

- The permeability of the cap should have a permeability less than or equal to the permeability of the bottom liner system present.
- Based on the fact that the arsenic dust contained in Cell 1 is hazardous waste which is not biodegradable, and that the basal liner does not meet current hazardous waste liner specifications in neighbouring South Africa, a "non-infiltration cap" is indicated per the South African Technical Advisory Practice Note (2019), with a maximum infiltration rate of 15 litres per hectare per day.

These preliminary functional specifications have been used in the design of the capping of Cell 1 of the DPMT HWDF.

7. END USE

Given the hazardous nature of the arsenic dust disposed of in the HWDF, designating an active end-use, such as a sports field, would not be advisable. In the Republic of South Africa, no active end-uses are permitted for hazardous waste disposal facilities in terms of the Minimum Requirements for Waste Disposal by Landfill (DWAF, 1998).

Given the location of the HWDF, its position on DPMT property, and limited accessibility, an active end-use for the HWDF would not be considered practical in any event.

Neither the design of the capping layers nor the final landform have therefore taken a specific end-use into account.

8. DESIGN OF FINAL CAPPING LAYERS

The design of the final cover for Phase 1 of the DPMT HWDF includes the design of the capping layers. The design thickness of the final cap is necessary to determine the interim final landform to be achieved by the waste disposal contractor on site before the final cover can be constructed.

The capping layers making up the final cover are shown in Figure 8-1.

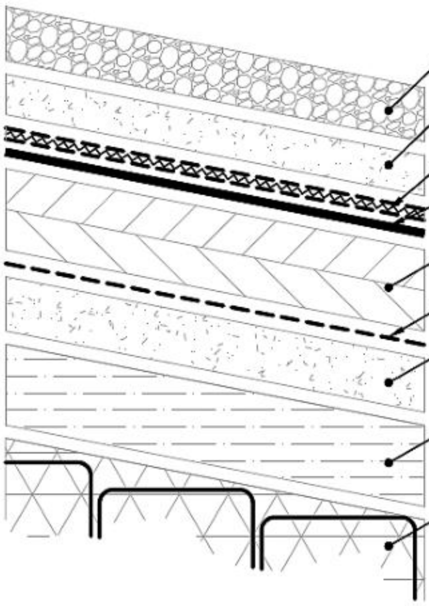

Figure 8-1: Final landform capping layers for Cell 1 Final Cover

8.1 Foundation Layers

In order to place the capping layers, foundation layers are required. Firstly, a smooth layer of wetted, compacted arsenic dust is to be constructed as the upper layer of the interim landform achieved by the waste disposal contractor operating the HWDF. Dust control will be required on this layer between completion by the waste disposal contractor, and commencement of final cover placement.

A 200mm compacted calcrete layer is required as a foundation and buffer layer between the waste and the cap itself. The calcrete layer placed directly above the arsenic dust will also provide a smooth surface which will allow the geosynthetics lining contractor to deploy and install the geomembrane without direct exposure to hazardous waste material while cutting, welding and testing.

On top of this calcrete layer, a separation geotextile will be installed, to form a filter between the cohesive soil to be placed above it, and potentially to form a capillary break layer between the different soils. Capillary break layers can be useful in limiting contaminated liquids from entering the clean soils above them. The geotextile has been specified as a Class 1 separation geotextile, as Class 1 is more robust during construction, and provides a slightly thicker capillary break than Classes 2 and 3. This geotextile must be manufactured from polypropylene or polyethylene, given the low pH environment.

8.2 Barrier layers

The preliminary functional specifications developed for this project include the following, which are relevant to the performance of the barrier layers of the cap:

- The permeability of the cap should have a permeability less than or equal to the permeability of the bottom liner system present.
- A “non-infiltration cap” is indicated with a maximum infiltration rate of 15 litres per hectare per day.

The barrier systems designed and constructed for Cell 1 differ between the floor of Cell 1 and the side slopes.

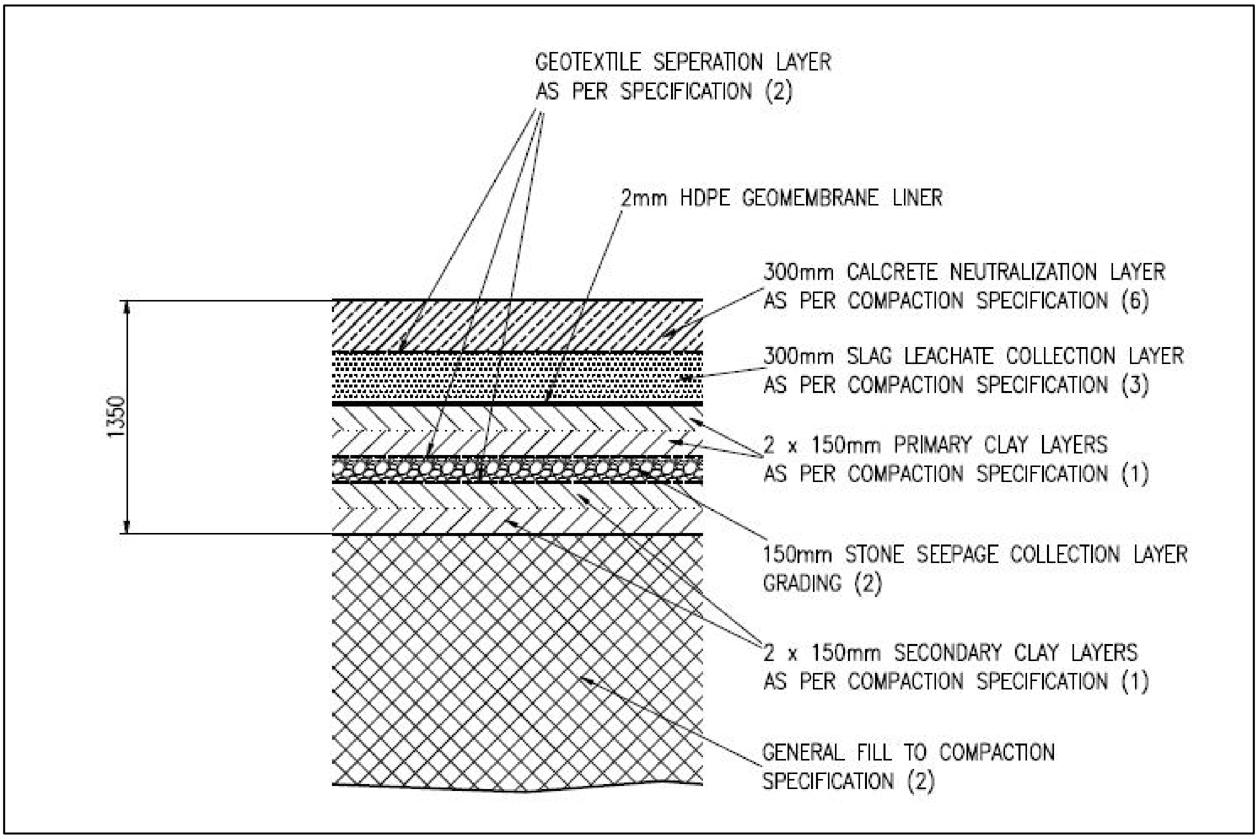

Figure 8-2: Basal layer works for Cell 1 (from JW Drawing 8624-04-016, 2011)

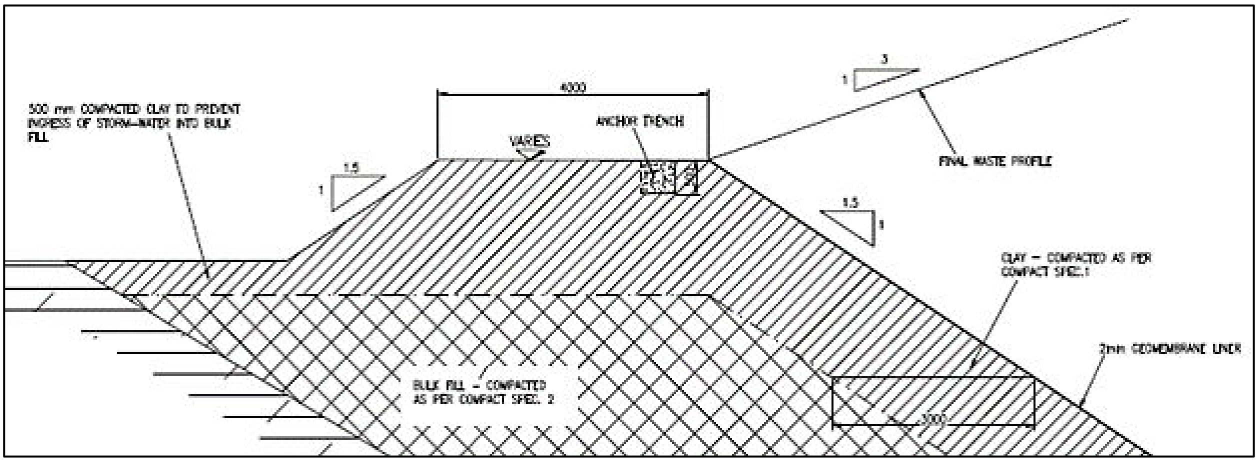

Figure 8-3: Side slope layer works for Cell 1 (from JW Drawing 8624-04-16, 2011)

The compaction specifications referred to in Figure 8-2 and Figure 8-3 are as follows as shown in Table , taken from JW Drawing 8624-04-16, dated 2011.

Table 8-1: Compaction specifications for Cell 1 basal liner construction

Compaction Specification	Density Specified	Moisture Content Range Specified
1	98% of standard Proctor maximum dry density	+1% to +3% of optimum moisture content
2	95% of standard Proctor maximum dry density	-2% to +2% of optimum moisture content
3	70% of relative maximum dry density	Not specified

Permeability testing of clayey soil termed "Ackerman Clay" in 2004 in a triaxial laboratory apparatus indicated an average permeability of 8 x 10^{-8} cm/s. This meets the maximum permeability specification of 1 x 10^{-7} cm/s for compacted clay layers for hazardous waste landfills included in the Minimum Requirements for Waste Disposal by Landfill (MRs) (DWAF, 1998). The Plasticity Index (PI) of the material is approximately 8%, while the Minimum Requirements set a maximum PI of 10 for soils used in capping layers, to limit desiccation cracking. Particle size grading undertaken of the Ackerman Clay classifies the material as a silty sand rather than a clay.

Additional testing was undertaken on samples from Ackerman's Farm in 2018, but unfortunately the results received do not include permeability testing, and it is not known how much of this material was used in the construction of Phase 2. The average PI of the cohesive soil samples tested in 2018 is 11.5, with PI values ranging from 7 to 19.

The particle size grading of the various samples tested is included in Figure 8-4. It is noted that Sample 4A is a mixture of calcrete gravel and cohesive soil, with only 54% of the mass of the sample passing through the 2mm sieve.

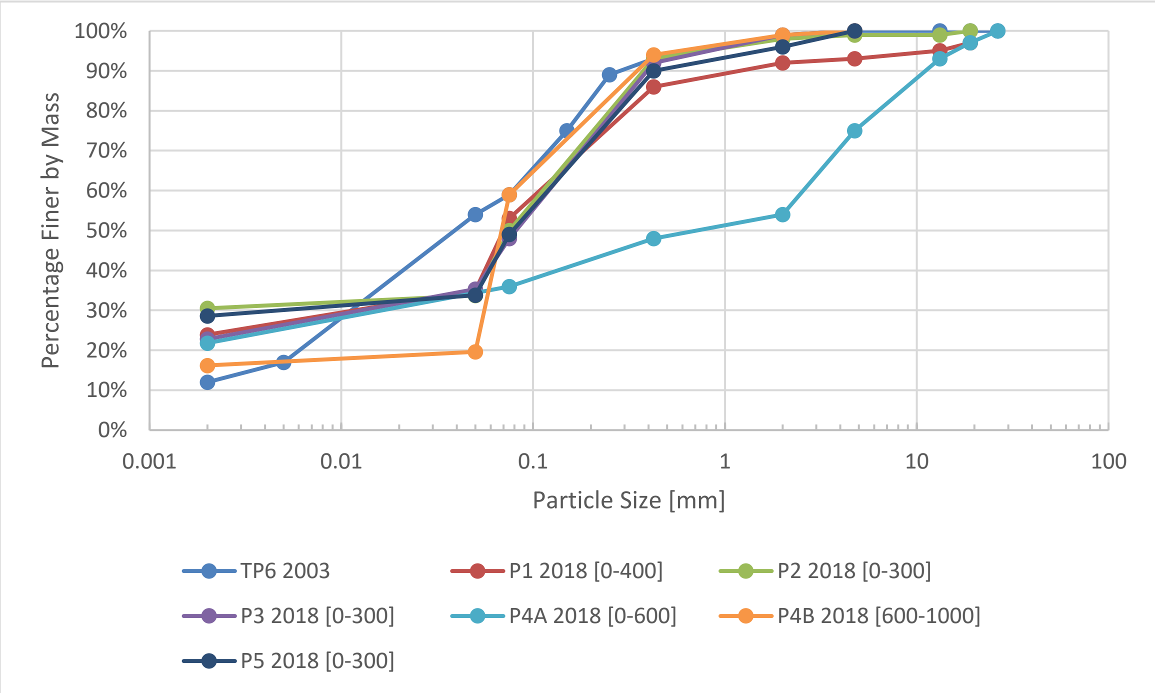

Figure 8-4: Particle Size Grading of Cohesive Soil Samples from Ackerman's Farm

From the co-ordinates on the 2018 test results, Ackerman's Farm is approximately 6kms from the HWDF as the crow flies, but using existing roads and access points, haul of up to 15.5kms is required (see Figure 8-5).

Figure 8-5: Location of Ackermans Clay relative to the DPMT HWDF

Compaction of the cohesive soil layers for the capping of Cell 1 have been specified as 98% Proctor compaction at a moisture content of optimum moisture content +1% to +3% to minimise permeability.A high density polyethylene (HDPE) geomembrane is specified rather than a linear low density polyethylene (LLDPE), due to HDPE's superior chemical resistance, and superior durability compared to LLDPE. While LLDPE has been specified for covers previously, recent formulations for flat die manufactured HDPEs have improved yield elongation and break elongation values, so that performance in the event of limited differential settlement is no longer a decider between HDPE and LLDPE geomembranes.

The barrier design for the DPMT HWDF final cover for Cell 1 includes two 150mm thick layers of "Ackerman Clay" compacted to Specification 1 included in Table , overlain by a double textured 2mm HDPE geomembrane. This composite barrier meets the requirement taken from the United States of America's Environmental Protection Agency that "the permeability of the cap should have a permeability less than or equal to the permeability of the bottom liner system present".

A composite barrier comprising two layers of compacted cohesive soil overlain by a 2mm thick HDPE geomembrane with low hydraulic head above it would be expected to allow leakage of less than 15 litres per hectare per day, provided that the cap is installed under strict supervision, with construction quality assurance measures in place, is protected from damage by external forces, and is maintained as required.

It is noted that a geosynthetic clay liner (GCL) could have been considered as an alternative to the 2 x 150mm compacted cohesive soil layers proposed. GCLs have been installed in the basal lining of Cell 2, Pond 2 and Pond 3 for the HWDF. GCLs are used with caution in final covers as they are prone to desiccation and may require up to a meter of cover to protect them. Ensuring ongoing hydration of a GCL is necessary for efficient performance, and GCLs are susceptible to cation exchange which increases their permeability. Unfortunately, the chemical analyses of the Pond 1 liquids received do not include potassium, which is required to calculate the ratio of monovalent to multivalent cations. The short project duration and nature of the Pond 1 liquid has not allowed for laboratory testing of the GCL with site-specific liquids. The use of a GCL in the capping has therefore not been considered further, as its potential performance within the final cover cannot be assessed. The GCL remaining on site following the construction of Phase 2 will be used under the geomembrane in the crest drains, so that this remaining material is used.

The Canadian Council of Ministers for the Environment, 2006 state that “The barrier layer of the cover system should be joined securely to the landfill liner system at the perimeter of the landfill cells.” Connecting the basal geomembrane to the capping geomembrane is considered good practice, and limits accidental access to the waste body in the long term. The capping design for Cell 1 of the HWDF therefore includes connecting the Cell 1 basal liner to the capping geomembrane.

While connection details are included on the drawings, the state of the original geomembrane under the ramp to the Cell 1 washbay will need to be inspected. The current ramp was not constructed as part of the original design, and protection measures for the original geomembrane are not known. The liner connection is this area will need to be developed on site once exposed.

8.3 Above Liner Drainage Layer

The drainage layer directly above the barrier layers serves a number of purposes, as follows:

- To drain water off the geomembrane in a controlled manner,
- To reduce the risk of veneer failure of the layers above the geomembrane, by not allowing them to saturate, and
- To provide some protection to the geomembrane while placing the layers above it.

The above liner drainage layer has been designed as a geocomposite drainage product, with non-woven geotextile bonded to both sides.

The bonds between the drainage core and the non-woven geotextiles bonded to the core are critical for stability of the cover. It is necessary to ensure that the geocomposite drainage layer is properly bonded per the project specifications.

8.4 Upper Calcrete Layer

The upper calcrete layer serves a number of purposes:

- It provides some pressure on the composite barrier beneath it, improving contact between the compacted cohesive layers and the geomembrane overlying those layers.
- It provides some storage for precipitation seeping through the overlying erosion protection layer.
- It reduces the flow rate of precipitation reaching the above liner drainage layer, so that the capacity of the above liner drainage layer is not overwhelmed.

The upper calcrete layer has been designed as a 150mm thick compacted layer.

Calcrete samples from Ackermans farm were tested, with the resulting particle size grading shown in Figure 8-6. Unfortunately, no permeability testing was carried out on the calcrete. From the sizing of the geocomposite drainage layer, the permeability of the upper calcrete layer should not be greater than 5 x 10^{-5}cm/s.

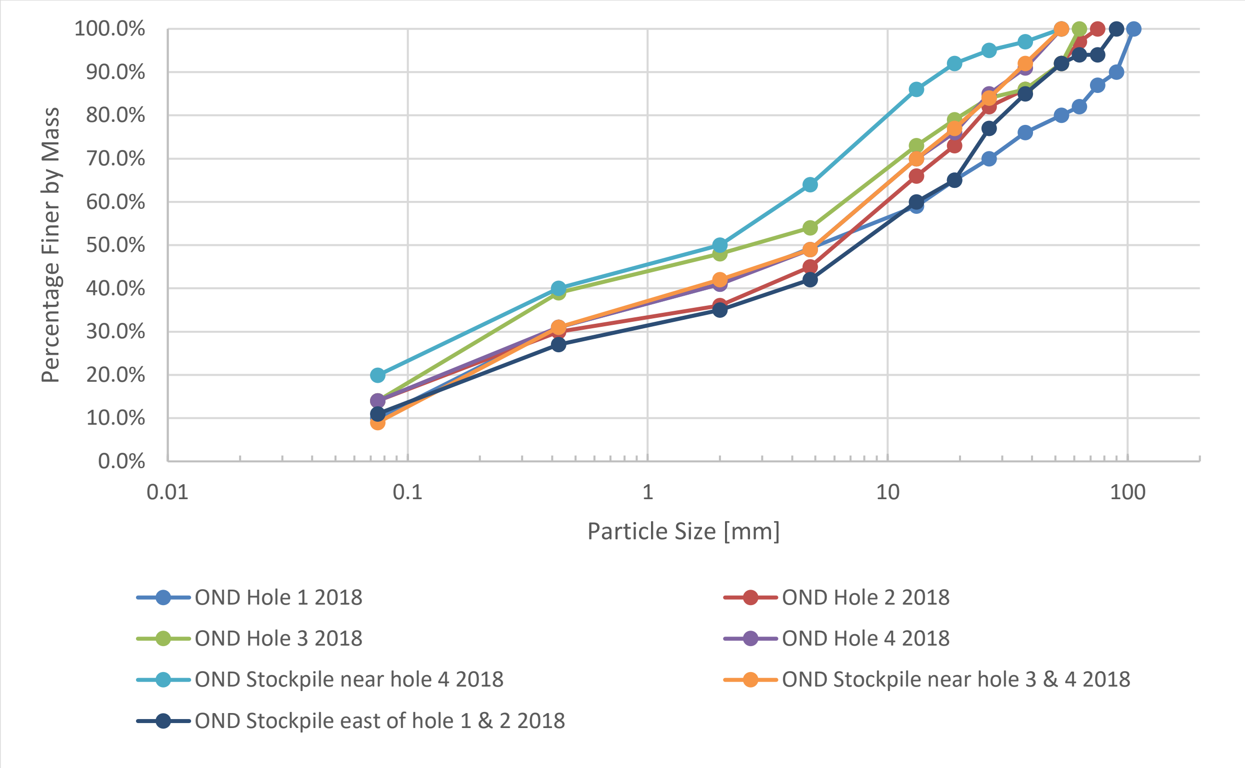

Figure 8-6: Particle Size Grading of Calcrete Samples from Ackermans Farm

8.5 Erosion Protection Layer

In a wetter climate than experienced by Tsumeb, a vegetation support layer is typically constructed as the top layer of the final cap. For the DPMT HWDF, the site is not easy to access, is not currently visible from Tsumeb (although it is visible from the smelter, and from the west of the site), and vegetation establishment would require ongoing maintenance. Placing a hard erosion protection layer is therefore seen as preferred. This would have the added benefit of providing erosion protection in the first wet season post construction, while vegetation takes a period to establish.

The erosion protection layer for the final cover of Cell 1 of the HWDF is proposed as a stone layer. A 150mm layer comprising graded stone is required. In the basic engineering design, graded stone sizing between 19mm to 53mm stone was proposed as these sizes appeared to be available from the quarry at the base of the hill on which the HWDF is situated. However, that quarry does not appear to be operational. Coarse aggregate for concrete (nominal 19mm) is available in the Tsumeb area, and testing undertaken in 2019 shows that this is suitably graded for the proposed erosion protection layer. In order to avoid stones rolling off the slope and entering the toe drains, a gabion sausage or sock is required at the toe, to contain the stone layer.

It is possible that seeds from adjacent vegetation will establish in the upper calcrete layer and grow through the stone layer. Given that the upper calcrete layer is 150mm thick and overlies two geosynthetic layers, such vegetation may not survive dry spells. While grasses on the cover would be acceptable, the roots of shrubs and/or trees could potentially damage the layers above the geomembrane, and should not be allowed to establish.

9. DESIGN OF FINAL AND INTERIM LANDFORMS

The final landform was designed taking into account the existing Cell 1 landform, the maximum height of the capped landform of 1332m amsl as well as gradient and drainage requirements. Once the final landform was designed, the interim landform was developed by allowing the final cover thickness of 800mm and taking interim contaminated water drainage requirements into consideration.

9.1 Final Landform Plateau

The plateau of the final landform has a ridge at the maximum elevation of 1332m amsl located at the centre running in the east-west direction. The plateau then slopes down towards the north and the south of the site at a slope of 1V:50H. This ensures that runoff due to a rainfall event does not pond on the plateau. The total area of the plateau to be capped is 12 055 m^2.

9.2 Final Landform Side Slopes

The survey conducted on the 5th February 2020, indicates that the side slopes are currently being raised at a slope of 1V:±1.8H. According to the Technical Advisory Practice Note: Capping Closure of Waste Management Facilities and Pollution Point Sources (DEA, 2019), in order to prevent erosion and promote stability of the landfill site, the slopes should not be capped at steeper than 1V:2.5H.

The design requires the reshaping of the side slopes from a 1V:±1.8H slope to 1V:3H. This is achieved by extending the toe line and filling the side slopes using Calcrete, compacted in 200mm horizontal layers. The total volume of Calcrete required to achieve the side slopes of 1V:3H is approximately 4 580 m^3. Once the side slopes are at the required slope of 1V:3H, the capping layers are applied as per capping on the plateau.

9.3 Interim Landform

The interim shaping of the landfill includes a cut and fill method on the plateau to ensure the final landform shape is achieved after constructing a final cover with thickness 800mm. Given that two areas of the plateau are less than 800mm from the final height cut to fill is necessary. Using the latest survey (5th February 2020) the total cut volume from the plateau is 1 280 m^3 and the total fill volume on the plateau is 18 000 m^3 so that the final landform does not exceed 1332m amsl at the highest point.

Two vee drains are located on the plateau of the interim landform. These drains reduce the capacity required by the existing toe drains and channel contaminated stormwater on the plateau of Cell 1 to Pond 1. The drains are sloped at 1V:100H to ensure adequate drainage with reduced siltation.

The survey conducted on the 5th February 2020, indicates that the side slopes are currently being raised at a slope of 1V:±1.8H. In order to achieve the interim landform, sections on the northern and southern plateau will need to be raised to the elevations indicated on Drawing 02-T-1225. Therefore, slopes on the northern and southern end of the landfill should be raised at a gradient of 1V:3H. In doing so, the extent of reshaping required on the slopes before final capping is applied is decreased.

10. STORMWATER MANAGEMENT

10.1 Introduction

The rainwater that falls onto Cell 1 after the landfill has been successfully capped is considered to be clean. A stormwater system is necessary to ensure management of the runoff away from contaminated environments such as the leachate pipe network and the ponds.

The stormwater management system considers collection and discharge of the runoff while minimising the risk of erosion. This is achieved by the design of crest perimeter berms, above barrier edge drains, downchutes, toe drains, dropboxes, outlet pipes and a drift.

10.2 Rational Method for Flood Calculations

The Rational Method is a deterministic method that uses the law of conservation of mass to create a simplified representation of the flood event. The rainfall intensity of the site is an important input in the calculations. The method then assumes aerial and time distributions as well as an empirical hydrograph. Runoff coefficients for the site are determined and using the Rational Method, flood peaks can be calculated for small catchments of less than 15km^2.

The Rational Method was used to estimate the peak flow for the surface water flowing from the plateau to the downchutes.

The plateau was divided into three catchments taking into consideration the slope of the plateau and the natural water flow path.

Catchment 1 has an area of 6 084 m^2 with the longest watercourse of 116.91 m, Catchment 2 has an area of 2 193 m^2 with a longest watercourse of 82.59 m and Catchment 3 has an area of 2 298 m^2 with the longest watercourse of 114.62 m. These are shown in **Error! Reference source not found.**.

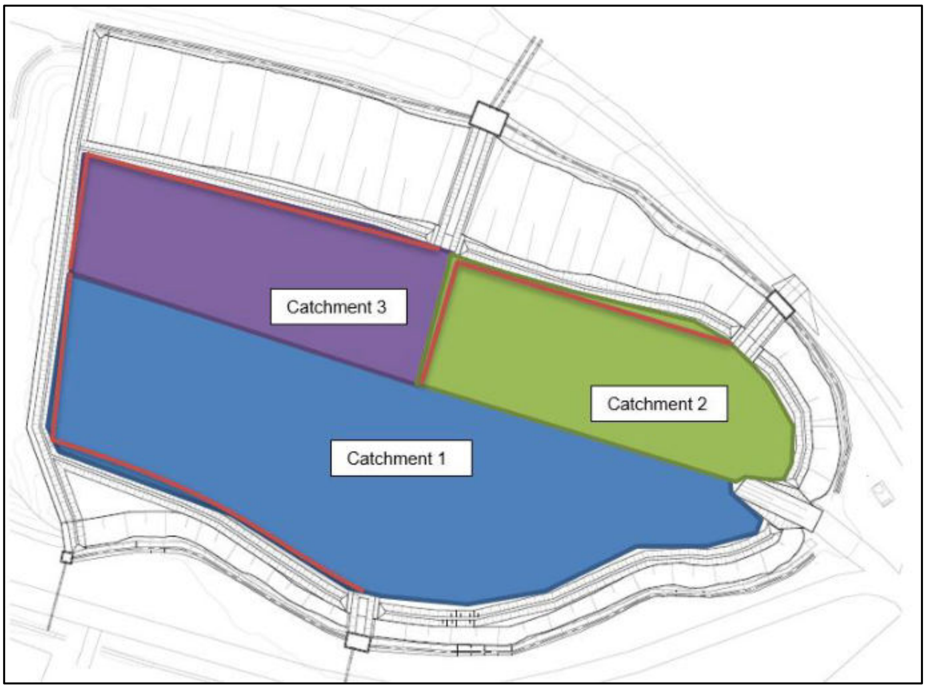

Figure 10-1: Catchment delineation of plateau for Rational Method

The following inputs were assumed for the site:

Maximum Annual Precipitation – 555 mm

2-year return interval day storm depth (TR102 – Adamson) – 50 mm

Lightning flash density per km^2 (CSIR, 1996) – 4.3

Average number of thunder days per year – 50 days

<u>1-day rain values</u>

1:100 – 150 mm

1:50 – 125 mm

1:20 – 100 mm

The calculated 100-year flood event peak flow for the catchments are listed in Table .

Table 10-1: Rational Method peak flows for a 100-year flood event

Catchment	Calculated Peak Flow [m^3/s]
1	0.325
2	0.121
3	0.124

Once the peak flow is determined, the channels can be sized in order to have sufficient capacity to contain the flood event. The Manning equation was used to calculate for the hydraulic capacity of the channels.

10.3 Crest Perimeter berms

The perimeter berms located at the edge of the plateau are to be constructed of compacted Calcrete at 98% Standard Proctor optimum moisture content +0% to +2%. They serve the purpose of intercepting the runoff stormwater from the plateau and directing this runoff to the nearest downchute. As a result, runoff from the top of the landfill is controlled and erosion of the plateau cap is minimised.

The total length of the perimeter berm is approximately 452 m including the berms to be constructed at the western edge of capping. With a trapezoidal cross-sectional shape, the top width of the berm is to be 500 mm wide with side slopes of 1V:2H. The minimum height from the top of the capping layers is 600 mm. A typical cross section is shown in Figure 10-2.

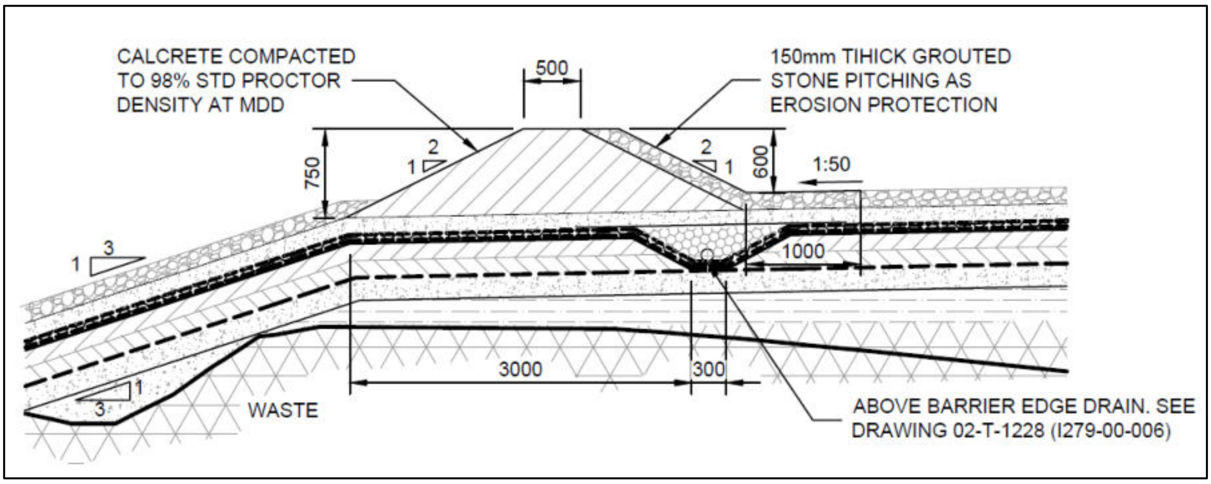

Figure 10-2: Cross sectional detail for the crest perimeter berm (Drawing 02-T-1229)

10.4 Downchutes

The downchutes are constructed from grouted stone pitching and they run on the side slopes from the plateau to the toe line. They channel the surface runoff from the plateau to the dropboxes and outlets which eventually drain to the environment.

Downchute 1 is located on the southern slope of the site, Downchute 2 is located on the north eastern slope and downchute 3 is located on the northern slope.

Downchutes 2 and 3 have similar dimensions with a trapezoidal cross section down the slope. The base of the downchute is 2 m and the side slopes are at 1V:2H. The depth of the downchutes is 750 mm from the top of the capping layers at a slope of 1V:3H downwards towards the dropbox. The length down the slope for Downchute 2 and Downchute 3 is approximately 8.86 m and 23.91 m, respectively.

Downchute 1 is to have a trapezoidal cross section with the base width of 3 m at a depth of 750 mm. The side slopes of the downchute are at 1V:2H with the longitudinal slope of 1V:3H towards the dropbox. The cross-sectional detail can be seen in Figure 10-3 below. The slope length for Downchute 3 is approximately 3.03 m at a slope of 1V:3H.

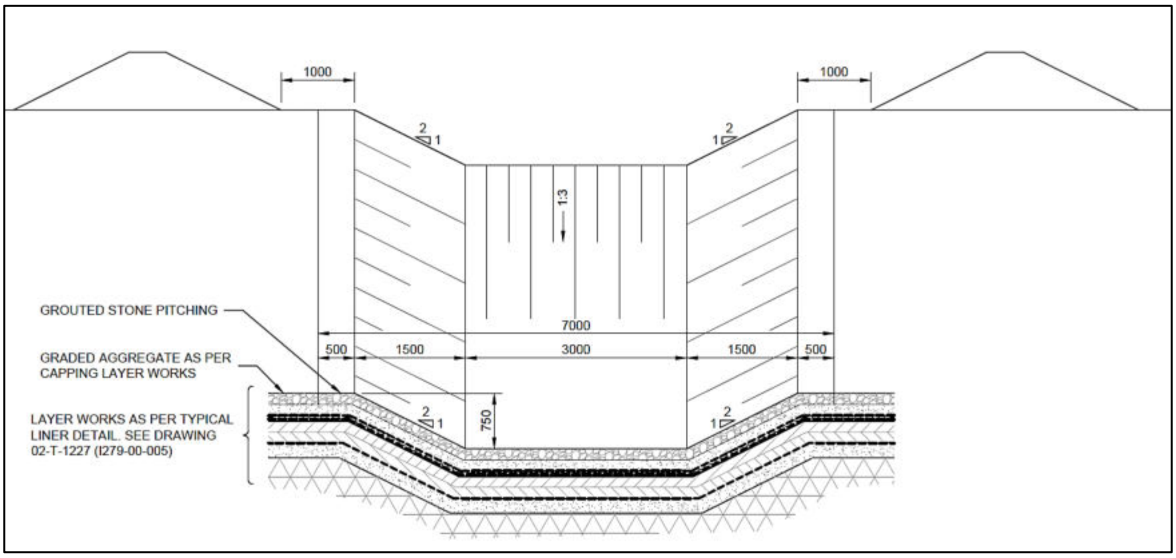

Figure 10-3: Cross Section of Downchute 1 (Drawing 02-T-1307)

10.5 Toe drains

Toe drains are located at the bottom of the landfill slopes, along the toe line. These drains collect clean surface runoff from the slopes of the final landform and channel this towards the dropboxes connected to an outlet draining to the environment.

According to Drainage Manual Namibia (2014), the minimum permissible downstream slope of lined channels is 1V:400H and the maximum cross-sectional side slope for a channel with Rock lining is between 1V:1H and vertical. Using the Drainage Manual Namibia (2014) as a guideline, the toe drain sizes were determined. This is shown in Table 10-2 below.

The toe drains are lined with a 150 mm layer of stone pitching, placed on separation geotextile, to prevent erosion along the drains and to provide stability of the side slopes. A typical cross-sectional detail is shown in Figure 10-4.

Table 10-2: Toe drain sizing detail

	Channel		
Toe Drain	**Length (m)**	**Downstream Slope (V:H)**	**Side slope (V:H)**
1	65.74	1:50	1:2
2	104.74	1:150	1:2
3	31.85	1:30	1:1
4	79.42	1:13	1:2
5	85.81	1:200	1:1

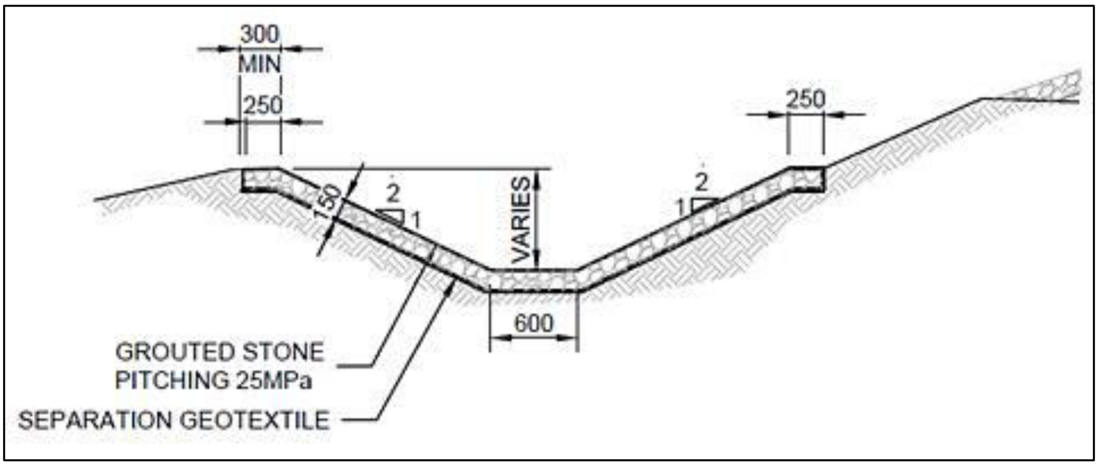

Figure 10-4: Typical cross section of the toe drains (Drawing 02-T-1229)

10.6 Dropboxes

A drop box can be described as a drop inlet structure open at the top and with an outlet point at the downstream end. The dropboxes located on the site serve the following purpose:

- Control the downstream outlet pipe flow by providing a temporary storage;
- Dissipating the energy of the water flowing from the downchute and preventing a flood event; and
- Redirecting the surface runoff from the toe drains towards a specific outlet point.

The dropboxes are to be constructed with 250 mm Engineering Face Brick resting on a 30Mpa Concrete slab with reinforcing mesh. A Rectagrid RS40 Grating is bolted to the top of the box to ensure minimisation of debris entering the dropbox and to ensure safety of persons and/or animals from falling in. A typical example of the Rectagrid RS40 Grating is shown in Figure 10-5.

Dropbox 1 is located at the western end of Toe Drain 1. The box intercepts water that would otherwise runoff to the uncapped area on the Western end of Cell 1. The dropbox is square with inner dimensions of 2m by 2m with an outlet pipe on its south facing wall that connects the dropbox to the southern existing stormwater drain.

Dropbox 2 is located at the end of Downchute 1 and it intercepts runoff from this downchute as well as Toe Drain 2. The dropbox is rectangular with inner dimensions of 3m by 5m. The outlet pipe connected at the south facing wall which ensures the water drains to the existing stormwater channel, south of the site.

Dropbox 3 is located at the bottom of Downchute 2 and the end of Toe Drain 3. This dropbox is rectangular with inner dimensions of 2.35m and 6m. An open channel outlet is located on the north-eastern facing wall and transports the surface runoff through a drift and into the environment outside of the site.

Dropbox 4 is located at the bottom of Downchute 3 with both Toe drain 4 and 5 draining into it. The rectangular shape has inner dimensions of 5m by 7m. Two pipes located on the north facing wall of the box form an outlet for the captured water. The dropbox has two grid support beams spanning across the 5m width. These serve as a support to the Rectagrid installed above them. This design is detailed in Drawing 02-T-1314.

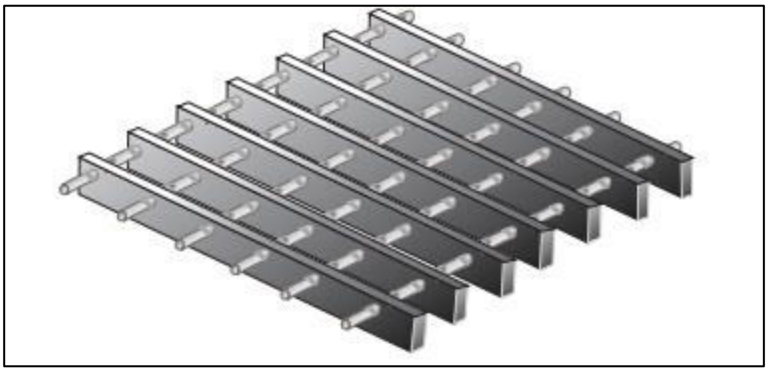

Figure 10-5: Typical Example of Rectagrid RS40 Grating

(https://mentis.co.za/wp-content/uploads/2020/03/Grating-Comp.pdf)

10.7 Outlet Pipes

The outlet pipe located at dropbox 1 has a diameter of 300 mm and a length of approximately 14.82 m. The longitudinal slope of this pipe is 1V:100H to ensure that the stormwater is discharged into the existing stormwater canal.

The outlet pipe channelling water from dropbox 2 to the existing stormwater canal has a diameter of 375 mm and an approximate length of 14 m. The longitudinal slope of this pipe is 1V:100H.

The outlet at dropbox 4 includes two pipes both at a diameter of 450 mm. These pipes channel the stormwater from the dropbox to discharge outside to the environment outside the site boundary on the northern slopes. The longitudinal slopes for these pipes is 1V:100H.

10.8 Drift

Drifts are sections on a road where a body of water is allowed to cross provided the flow depth is low enough for cars to drive over it safely. They are most appropriate for this landfill site as the surface runoff is only expected due to a rainfall event.

A drift is located on the north-eastern access road on the site. The drift channels surface runoff from the dropbox to discharge to the environment, north-east of the site.

The drift is constructed of 200 mm thick grouted stone pitching, overlaying a separation geotextile.

The drift approaches have a slope of 1V:10H and the width of the drift bed is 4m. An illustration of this drift is shown in Figure 10-6.

The typical drift detail is shown on Drawing 02-T-1229.

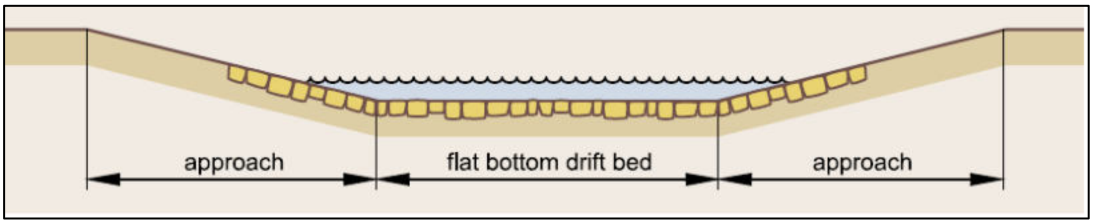

Figure 10-6: Illustration of a Drift (Johannesses B., 2008)

11. ABOVE LINER DRAINAGE SYSTEM

11.1 Introduction

The purpose of the above liner drainage system is to drain water off the geomembrane in a controlled manner, and to reduce the risk of veneer failure of the layers above the geomembrane, by not allowing them to saturate. The layer will also provide some protection to the geomembrane while placing the layers above it.

The above liner drainage system comprises a geocomposite drainage (GCD) layer, pipework to collect water from the GCD, and pipe outlets to the stormwater downchutes to empty the above liner drainage system. The above liner drainage system is shown on Drawing 02_T_1228.

11.2 Geocomposite Drainage Layer

The above line drainage layer has been designed as a geocomposite drainage product (GCD), with non-woven geotextile bonded to both sides to improve filtration into the layer from above, and to improve interface shear properties with the geomembrane below it. The GCD has been sized based assuming a permeability of the overlying layer of 5 x 10^{-5}cm/s, and it is imperative that this permeability is achieved. The flow required in the GCD under normal stress of 20kPa at a slope of 1 in 50 is 0.23l/m/s before reduction factors. Testing should be carried out between soft platens rather than hard platens to better simulate the conditions expected on site.

The internal shear properties of the GCD are critical to ensuring that the layer does not introduce a shear plane on the side slopes which could lead to veneer instability. The minimum peak shear angle required for the GCD is 24.4 degrees – see Section 13.

11.3 Pipe Network

The network of collection pipes set within the above liner drainage system are shown on Drawing 02_T_1228. One set of collection pipes will be installed in close proximity to the crest berms around the northern, eastern and southern edges of the plateau.

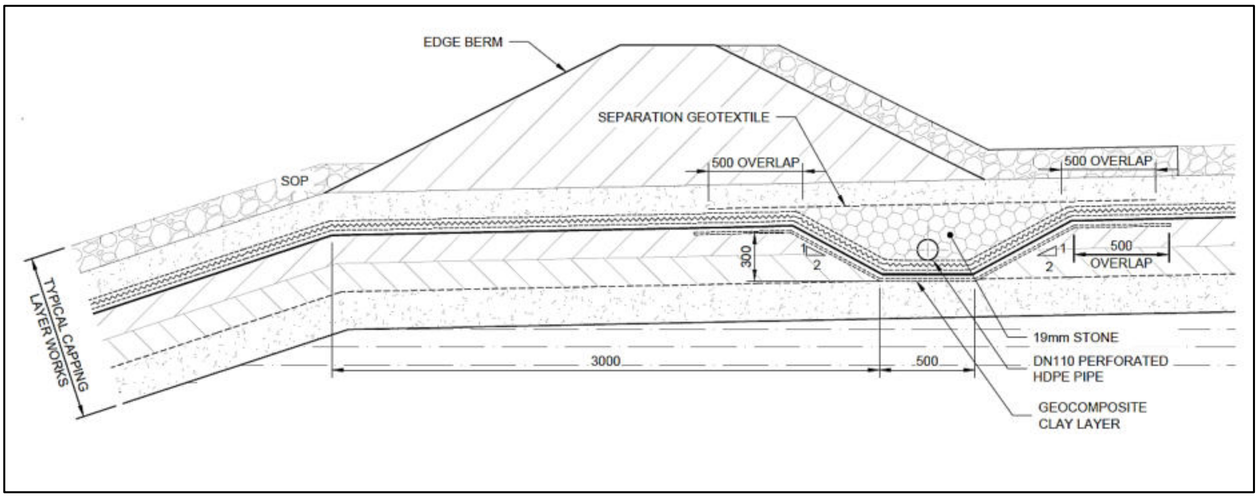

Figure 11-1: Crest Edge Drain (Drawing 02-T-1228)

The second set of collection pipes will be installed in a collection and outlet trench around the northern, eastern and southern toe of Cell 1. A typical cross section of this detail is shown in Figure 11-2

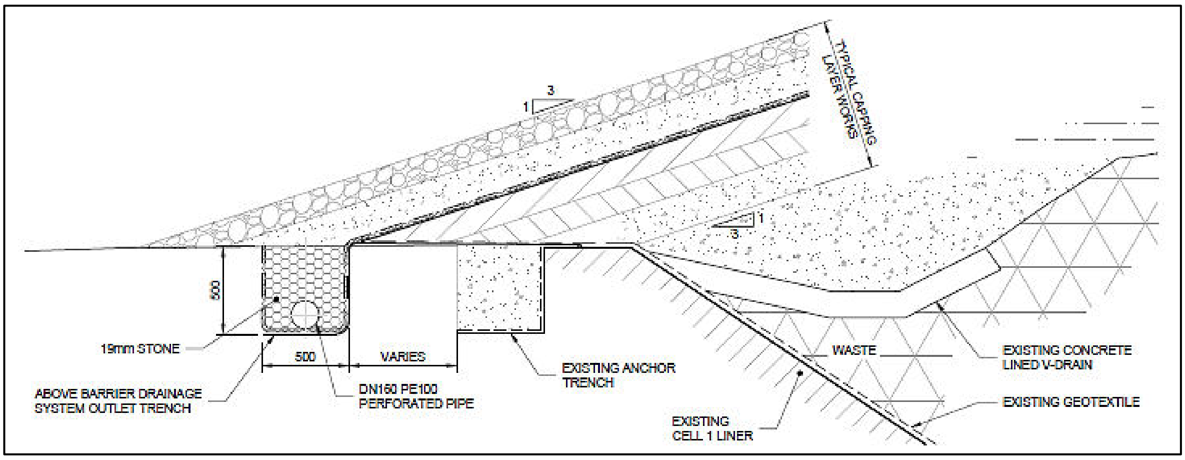

Figure 11-2: Above liner drainage system outlet trench (Drawing 02-T-1228)

11.4 Pipe Outlets to Downchutes

The above liner drainage system pipes will outlet into the downchutes, with outlets at both the crest and toe of each downchutes, as shown on Drawing 02-T-1228.

12. <u>EROSION CONTROL MEASURES</u>

The primary erosion control measure for the cap is the gravel layer which will be placed over the upper calcrete layer. This layer will comprise graded stone available in the area – see Section 8.5 for further information.

12.1 Crest berms

To protect against erosion along the inner side of the crest berm which diverts the surface runoff towards the downchute, grouted stone pitching with thickness of 150mm and extending 1m onto the stone aggregate capping layer, should be installed.

This detail is shown on Drawing 02-T-1229.

12.2 Downchutes

A 750mm drop inlet, constructed with grouted stone pitching, is located at the start of every downchute. The drop inlet allows for the dissipation of energy of the runoff entering the downchute, the grouted stone pitching further reduces the velocity by providing a frictional force against the movement of the water, thus protecting the channel against erosion.

The downchute detail design is shown in Drawing 02-T-1307.

12.3 Toe drains

Similar to the downchutes, the toe drains are constructed from a 150mm thick layer of grouted stone pitching. The stone aggregate provides side slope stability at slopes of 1V:1H and 1V:2H. Stone pitching reduces the velocity of the runoff and as a result, erosion of the channel is minimised. The lengths of the toe drains were also minimised by ensuring they discharge at several points along the toe line of the final landform, with the longest toe drain being approximately 105 mm.

The typical cross section of the toe drains is shown on Drawing 02-T-1229.

12.4 Outlet Pipes

The outlet pipes located at dropbox 1 and 2 both slope south to drain in the southern existing stormwater trench. To ensure that the existing stormwater drain is not eroded by the water exiting the pipe and having to change direction to the direction of the drain, the canal should be lined with grouted stone pitching 2m upwards from the pipe and 10m downwards from the pipe. This is shown in Figure 12-1.

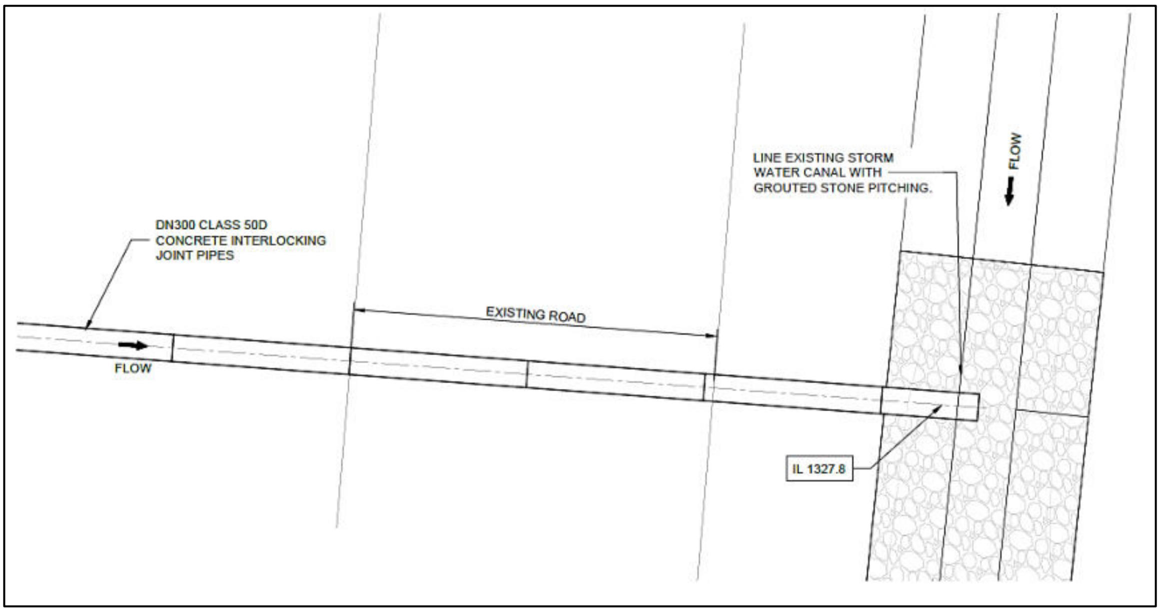

Figure 12-1: Outlet Pipe Discharging Into Existing Stormwater Drain (Drawing 02-T-1310)

12.5 Drift

The drift is constructed with stone pitching along its surface area. This assists in minimising erosion and protects against the load exerted by the traffic that will drive across the drift. Downstream the drift, the water is discharged into the environment outside the site boundary. The latest survey used to design for stormwater infrastructure did not cover the extent beyond the site boundary. It is advised that stone pitching is placed downstream of the drift discharge point to ensure the runoff does not erode the environment and vegetation.

13. STABILITY

The design for the capping of Cell 1 of the HWDF includes constructing the outer slopes of the Cell 1 with a gradient not steeper than one vertical unit to three horizontal units. The 1V:3H gradient allows for construction of the soil capping layers using conventional plant and improves veneer stability.

The veneer stability of the capping layers was assessed using shear interface values and internal shear values available from literature as well as J&W's shear database. No shear properties for the soils available for capping were available, nor has site specific shear interface testing been undertaken.

The relevant layers and interfaces are included in Table 13-1, considering the capping from the top down.

Table 13-1: Potential shear planes considered for capping veneer stability (top down)

	Internal Shear: Stone, Soil or Waste	Interface Shear	Internal Shear within Geocomposite Drainage Layer
1	Stone		
2	Calcrete		

	Internal Shear: Stone, Soil or Waste	Interface Shear	Internal Shear within Geocomposite Drainage Layer
3		Calcrete to geocomposite drainage layer	
4			Dimpled side of core to geotextile
5			Flat side of core to geotextile
6		Geocomposite Drainage Layer to textured geomembrane	
7		Textured geomembrane to cohesive soil	
8	Cohesive Soil		
9		Cohesive soil to geotextile	
10		Geotextile to calcrete	
11	Calcrete		
12		Calcrete to arsenic waste	

An assessment of shear properties indicated that the shear properties between the layers of the geocomposite drainage layer is likely critical with a peak shear angle of 24.4° and adhesion of 3.1kPa. It is noted that the peak interface shear between the cohesive soil used and the textured geomembrane is likely to be in a similar range.

Considering veneer stability for an infinite slope, the factor of safety is 1.34, provided that the above liner drainage system works efficiently. This increases to 1.36 for a maximum 34m long slope at 1 in 3, assuming that no saturation of the cover occurs and excludes pressure from construction vehicles.

So that stability is not jeopardised during construction, it is imperative that placing and compaction of capping layers on the side slopes take place up the slope, and not down the slope. In addition, the geocomposite drainage layer should be covered as soon as possible after installation, so that its capacity is not exceeded direct inflow. If the above liner drainage layer capacity is exceeded, for example if the top of the slope is not yet covered and rainfall occurs, soil placed on top of the drainage layer on the lower portion of the slope could become saturated and a slip could result.

14. MONITORING OF THE CELL 1 CAPPING

Monitoring of the capped portion of Cell 1 is required so that any issues can be addressed timeously. Monitoring of landfills typically includes visual monitoring as well as environmental monitoring.

14.1 Visual monitoring

Monthly inspections of the cap and associated drainage systems are recommended during the wet season, and three-monthly inspections during the dry season. Additional inspections following heavy rainfall events are recommended. Visual inspections should look out for:

- Uneven settlement of the cap
- Ponding of water on the cap
- Cracks in the stone pitching

- Cracks through cover running parallel to plateau edge
- Bulging of cover at toe
- Migration of stones off cover
- Erosion of soils
- Silting of drains
- Pipe blockages
- Undesirable vegetation
- Disturbance of cover by fauna
- Presence of firebreak around facility
- Condition of sandbags along the western edge of the Cell 1 cap.

Regarding vegetation, grasses would generally be acceptable, but the establishment of shrubs and trees on the cap would not be advisable.

14.2 Environmental monitoring

Environmental monitoring includes groundwater quality monitoring, surface water quality monitoring, air quality monitoring and so forth. Current environmental monitoring practices for the HWDF should continue.

Both Cell 1 and Pond 1 were constructed with a leachate collection system and a leakage detection system. The Pond 1 leachate collection system outlet pipe has a blank flange installed on the pipe outlet or it would drain the pond (see Figure 14-1). All four systems have outlets into an HDPE sump located near the south-east corner of Pond 1, with valves at the end of each outlet pipe (see Figure 14-1 and Figure 14-2).

Figure 14-1: Pond 1 pipe outlets into HDPE sump

Figure 14-2: Cell 1 outlet pipes into HDPE sump

Liquids collected in the HDPE sump are drained via pipes to a new HDPE sump, called the Leachate Pump Station, which also receives liquids from Cell 2 and Pond 2 as designed by Golder.

The current Operating Manual for the HWDF (dated July 2019) states that "Contaminated water/leachate from Cell 1, Pond 1, Cell 2 and Pond 2 will collect in the Leachate Pump Station from where it will be pumped into Pond 3. The two submersible pumps in the Leachate Pump Station are activated to pump leachate/contaminated water to Pond 3 such that the liquid level does not rise above the invert level of the Cell 1 leakage detection pipe that discharges into the existing Leachate Sump."

It is possible to flood the Cell 1 and Pond 1 leakage detection systems from the Leachate Pump Station if level controls are not operational. It is also possible to flood the leakage detection systems if there is flow from Pond 1 and drainage to the Leachate Pump Station is not possible, for example if the valve on the Cell 1 and Pond 1 outlet pipe into the Leachate Pump Station is closed. These situations would have the effect of short circuiting the primary composite liner in Cell 1 and Pond 1, which could have serious environmental consequences, as there is no secondary geomembrane liner for those facilities.

It would be of interest to monitor the rate of flow from Cell 1's leachate collection and leakage detection systems following capping to track reductions in flows, provided that the outlet pipes can be safely accessed in the HDPE sump. Monthly monitoring would likely be sufficient, provided that flows are low. During a site visit in March 2020, DPMT advised that it is currently not permitted to enter the HDPE sump for Cell 1 and Pond 1 since alterations were made to the wall constructed around the sump as part of the project for the construction of Cell 2, Pond 2 and Pond 3. The installation of a stepladder and handrails are likely required to access the top of the HDPE sump.

If the various leachate collection and leakage detection outflow rates are not monitored and recorded, and the risk of flooding of the leakage detection systems is apparent - for example when waste disposal commences in Pond 1 - it may well be preferable to close the leakage detection valves from Cell 1 and Pond 1, to avoid short-circuiting their lining systems.

15. MAINTENANCE OF THE CELL 1 CAPPING

Maintenance of the Cell 1 capping system will be required. This will or may include:

- Filling in of any low spots on the cover if necessary
- Reinstatement of gravel layer if washdowns occur
- Desilting of the stormwater drains
- Desilting of the drop boxes
- Emptying of water from the drop boxes before the dry season if necessary
- Unblocking of pipelines if necessary
- Patching of cracks in stone pitching if necessary
- Reinstatement of a firebreak around the site if necessary

Maintenance should be scheduled if issues are identified during the inspections carried out.

16. SUMMARY

The functional specification for the Final Cover for Cell 1 of the DPMT HWDF included a number of requirements. These requirements are listed below, with a summary of how these functional specification requirements are met in the Detailed Engineering Design.

Functional Specification for Final Cover	Detailed Design measures to meet Final Cover Functional Specification
The final cover must separate the waste body being capped from the general environment.	The 800mm thick final cover separates the waste body from the general environment, particularly as it includes a geomembrane liner and four soil layers.
The final cover must minimise the generation of contaminated stormwater by Cell 1.	Contaminated stormwater will not be generated on the portion of Cell 1 once final cover has been applied. Contaminated stormwater will be generated on the uncapped western portion.
The final cover must increase the release of clean runoff to the natural environment from the HWDF.	The final cover facilitates the release of clean runoff from the portion capped to the natural environment.

Functional Specification for Final Cover	Detailed Design measures to meet Final Cover Functional Specification
The final cover must minimise infiltration of precipitation into the waste body, to reduce and taper off leachate generation from the portion of Cell 1 being capped.	The final cover has been designed with a composite barrier system comprising a compacted cohesive soil layers overlain by a 2mm HDPE geomembrane which will minimise infiltration.
The final cover must minimize the generation of hazardous dust from the portion of Cell 1 to be capped.	Placement of a 200mm calcrete foundation layer over the waste body will minimise the generation of hazardous dust during construction. No hazardous dust will be generated from the cover itself once installed.
The final cover must provide a barrier to burrowing animals.	Both the gravel erosion protection layer and the geomembrane provide a good level of protection against burrowing animals.
The final cover should minimize erosion by wind.	By installing a gravel layer over the cover, wind erosion will be minimised.
The final cover should minimize erosion by water.	Erosion by water should be kept in check by the gravel layer over the final capping, and by the stone pitching installed in the drains.
The final cover should minimize visual intrusion of the waste site on the landscape by limiting the maximum height to 1332m amsl.	The final cover has been designed to have a maximum elevation of 1332m amsl. Visual intrusion could be further reduced by planting trees strategically around to the south-east-east and to the north-west-west of the site.
The permeability of the cap should have a permeability less than or equal to the permeability of the bottom liner system present.	The final cover has been designed so that its permeability is equivalent to the bottom liner system constructed for Cell 1.
A “non-infiltration cap” is indicated per the South African Technical Advisory Practice Note (2019), with a maximum infiltration rate of 15 litres per hectare per day.	The composite barrier system included in the final cover design for Cell 1 has a maximum infiltration rate of 15 litres per hectare per day, provided that material and construction specifications are met, site supervision and construction quality assurance are undertaken, and regular maintenance takes place.

The following functional specification requirements are relevant to the Interim Final Landform. These requirements are listed below, with a summary of how these functional specification requirements are met in the Detailed Engineering Design.

Functional Specification for Interim Final Landform	Detailed Design measures to meet Interim Final Landform Functional Specification
The interim landform must allow for continued drainage of contaminated stormwater from the surface of Cell 1 to Pond 1, noting that the existing lined toe drains may not have sufficient capacity to carry all contaminated water from Cell 1.	The interim landform includes two vee drains on the plateau draining west towards Pond 1, to limit contaminated stormwater entering the existing lined toe drains.
The interim landform should allow for the disposal of as much arsenic dust as possible within the confines of the final landform, while still allowing runoff of contaminated runoff from Cell 1 to Pond 1.	The interim landform has been optimised, so that the maximum elevation reached is 1331.2m amsl, cut to fill is minimised on the areas exceeding that level, and so that the minimum gradient on the plateau is 1V:50H.
The interim landform should provide a smooth compacted surface for the construction of the final cover.	The interim landform has been designed to provide a smooth compacted surface for the construction of the final cover.

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Jabulile Msiza PrEng
for Jones & Wagener

23 July 2020
File Name: I279-02_REP-02_Detailed_Design_Report

APPENDIX A

DETAILED DESIGN DRAWINGS

DRAWING NO	DRAWING TITLE	REVISION
02-T-1223	FINAL LANDFORM - GENERAL ARRANGEMENT	E
02-T-1224	CURRENT LANDFORM AS AT 5 FEBRUARY 2020: LAYOUT	C
02-T-1225	INTERIM CAPPING LANDFORM: LAYOUT AND TYPICAL SECTIONS	E
02-T-1226	FINAL CAPPING LANDFORM: LAYOUT AND SETTING OUT POINTS	B
02-T-1227	FINAL CAPPING: SECTIONS AND DETAILS	D
02-T-1228	ABOVE BARRIER DRAINAGE SYSTEM: LAYOUT, SECTIONS AND DETAILS	D
02-T-1229	SURFACE WATER DRAINAGE SYSTEM: LAYOUT, SECTIONS AND DETAILS	D
02-T-1230	BARRIER CONNECTIONS: LAYOUT AND DETAILS	C
02-T-1307	DOWN CHUTES: SECTION AND DETAILS	D
02-T-1308	STORMWATER TOE DRAIN 1 AND 2: LAYOUT AND LONGITUDINAL SECTION	A
02-T-1309	STORM WATER TOE DRAIN 3, 4 AND 5: LAYOUT AND LONGITUDINAL SECTION	A
02-T-1310	DROP INLET BOX 1: LAYOUT AND SECTIONS	A
02-T-1311	STORM WATER LAYOUT	A
02-T-1312	DROP INLET BOX 2: LAYOUT AND SECTIONS	A
02-T-1313	DROP INLET BOX 3: LAYOUT AND SECTIONS	A
02-T-1314	DROP INLET BOX 4: LAYOUT AND SECTIONS	A