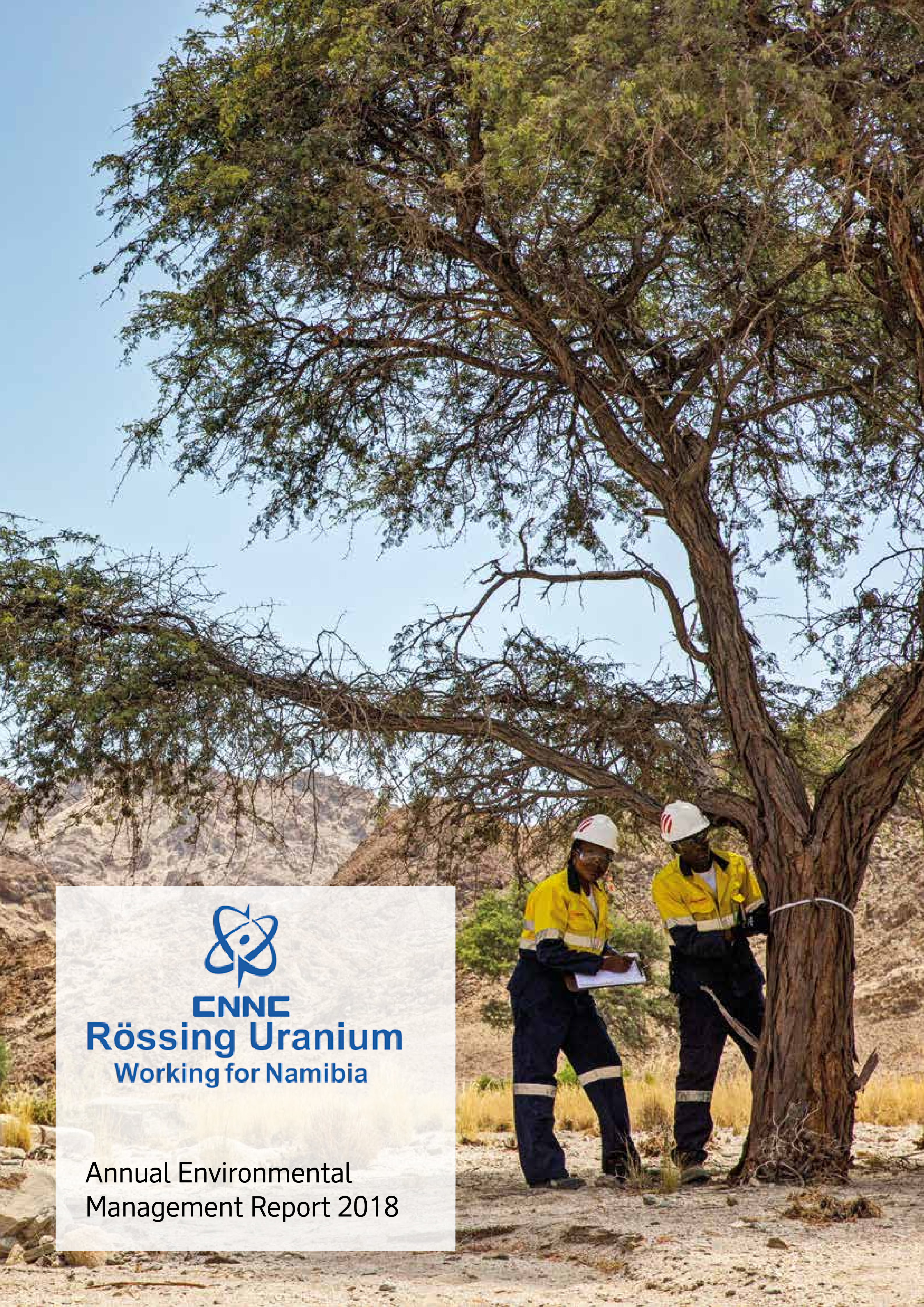

CNNC

Rössing Uranium

Working for Namibia

Annual Environmental Management Report 2018

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Acronyms and abbreviations

µm	micrometre, 10^{-6} m
dB	decibel
cm	centimetre
CO	carbon monoxide
CO_2-e	carbon dioxide equivalent
CSIR	Council for Scientific and Industrial Research
DWA	Department of Water Affairs
EMS	Environmental Management System
FPR	Final Product Recovery plant
GHG	greenhouse gas
GIS	Geographic Information Systems
GJ	gigajoule
GJ/kt	gigajoules per kilotonne
HSE	health, safety and environment
HSE MS	Health, safety and environment management system
IUCN	International Union for Conservation of Nature
km	kilometre
L	litre
m	metre
M	mega, one million
m^3	cubic metre
mamsl	metres above mean sea level
MAWF	Ministry of Agriculture, Water and Forestry
mg	milligram
mg/kg	milligram per kilogram
mg/L	milligrams per litre
mg/m^3	milligram per cubic metre
mg/m^2	milligram per square metre
ML 28	Rössing Uranium Limited's Mining Licence 28
m/s	metre per second
m^3/s	cubic metres per second
MSDS	material safety data sheets
m^3/t	cubic metre per tonne
NO_x	nitrogen oxide
PM_{10}	particulate matter smaller than 10 microns in diameter
ppm	parts per million
SANS	South African National Standards
SO_2	sulphur oxide
SOP	standard operation procedure
TPH	total petroleum hydrocarbon
TPM	total particulate monitors
TSF	Tailings Storage Facility
UN	United Nations
UNSCR	United Nations Security Council Resolution
U_3O_8	uranium oxide
yellowcake	ammonium diuranate

1. Introduction

1.1 Location

Rössing Uranium Limited mines a large-scale, low-grade uranium ore body in the Namib Desert, in the sparsely populated Erongo Region of Namibia (Figure 1).

The mine is located 12 km from the town of Arandis, which lies 70 km inland from the coastal town of Swakopmund. Walvis Bay, Namibia's only deep-water harbour, is located 30 km south of Swakopmund.

The mine site encompasses a mining licence and accessory works areas of about 180 km^2, of which 25 km^2 is used for mining, waste disposal and processing. Rössing mine is situated about 25 km upstream of the Khan/Swakop rivers confluence.

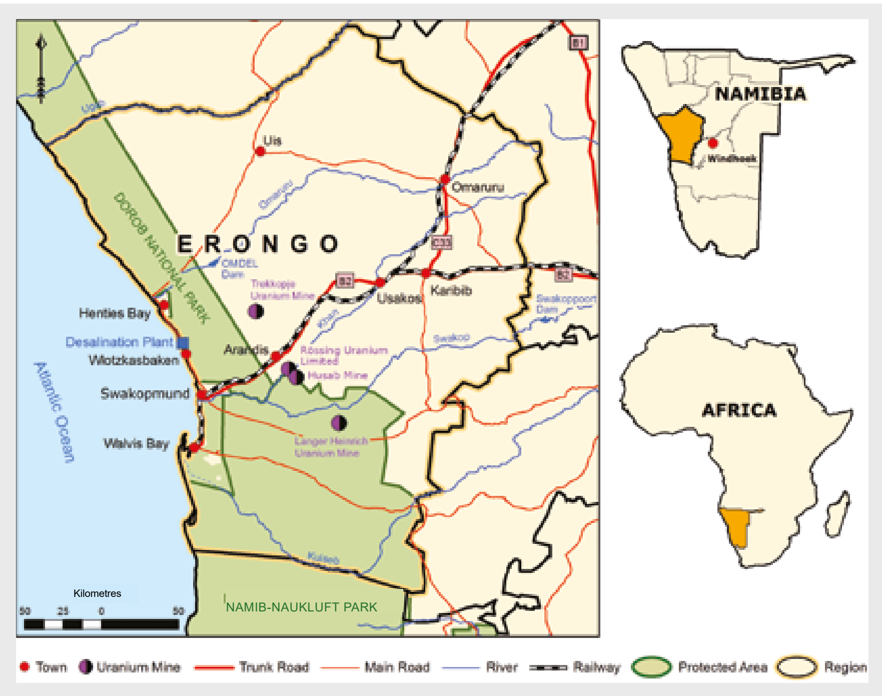


Figure 1: Location of Rössing mine.

1.2 Shareholding

On 16 July 2019, China National Uranium Corporation Limited (CNUC) became the new majority shareholder in Rössing Uranium Limited, following the sale of Rio Tinto's 68.62 per cent shareholding to CNUC.

The Namibian Government has a 3 per cent shareholding, with a majority (51 per cent) when it comes to voting on issues of national interest.

The Industrial Development Corporation of South Africa owns 10 per cent, while individual shareholders own a combined 3 per cent shareholding. The Iranian Foreign Investment Company owns 15 per cent, a stake that was acquired during the set-up of the company in the early 1970s.

1.3 Scale of operation

Rössing is the world's longest-running, open-pit uranium mine. It is a 24-hour, 365-days-a-year operation. Rössing is among the three Namibian uranium mines in operation which provides a considerable amount world uranium oxide mining output.

Rössing has a nameplate capacity of 4,500 metric tonnes (mt) of uranium per year and had produced 2,479 mt in 2018. This brings the total uranium oxide produced to 135,088 mt.

1.4 Current life-of-mine

The life-of-mine plan developed in 2011 foresaw the end of mining activities in 2023, and closure in 2025. In 2023, the final depth of the open pit will be reached at Bench 36, about 30 metres above mean sea level (mamsl). Processing of remaining ore stockpiles will continue for another two years, with the final uranium oxide production completed at the end of 2025. However, there is potential for an extension of the current life-of-mine after the sale of the Rio Tinto shares to CNUC.

2. Brief description of the environment

2.1 Geology

The Rössing uranium deposit lies within the central part of the late-Precambrian Damara orogenic belt that occupies an area of approximately 50 km wide and extends northeast for over 100 km in west-central Namibia. The Damara lithology consists mainly of folded, steeply dipping meta-sediments (gneiss, schist, quartzite and marble) arranged in a northeast-southwest striking belt.

The geology of the mining area at Rössing is associated with a dome structure and occurs in pegmatitic granite known as *alaskite*, which intruded into meta-sediments. The Rössing ore body is unique in that it is the largest known deposit of uranium occurring in granite. The nature and grade of uranium ore is extremely variable and can be present as large masses or narrow inter-bands within the barren meta-sediments.

All of the primary uranium mineralisation and the majority of the secondary uranium mineralisation occur within the alaskite. However, the alaskite is not uniformly uraniferous and much of it is un-mineralised or of sub-economic grade.

Uraninite is the dominant ore mineral (55 per cent); secondary uranium minerals constitute 40 per cent, while the refractory mineral betafite makes up the remaining 5 per cent. Ore grades at the mine are very low, averaging 0.035 per cent. The uranium ore consists of 70-90 per cent alaskite and is subdivided into four ore types according to the composition of the host rock.

2.2 Climate

Rössing is situated in an arid area and rainfall measurements are very low. In 2018, the total annual rainfall received on the mine was 29.6 mm, which is about 3 per cent deviation from the long-term average of 30.6 mm. The annual rainfall, and the long-term rainfall average, is displayed in Figure 2.

Rössing rainfall measurements indicate an average annual rainfall of about 30 mm over the years. The average has decreased since 2014 to 2017, before a sharp increase in 2018.

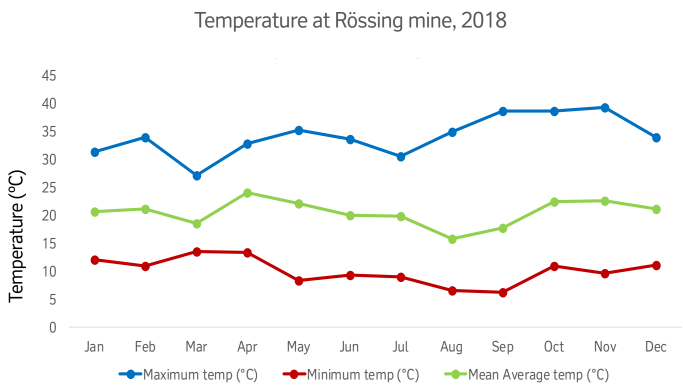


Figure 3. Temperatures measured at Rössing mine, 2018

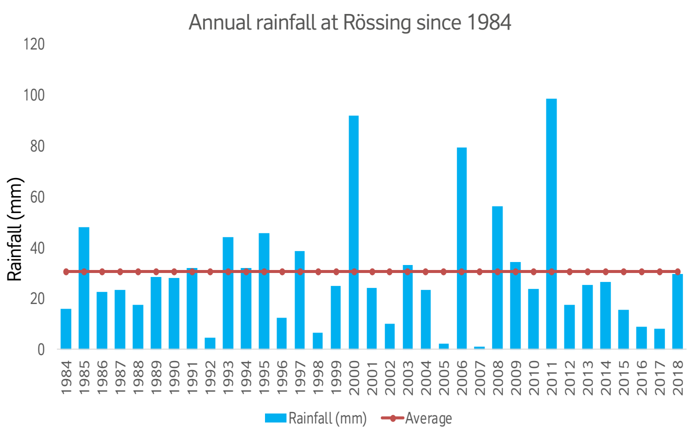


Figure 2. Variation in annual rainfall at Rössing, 1984-2018

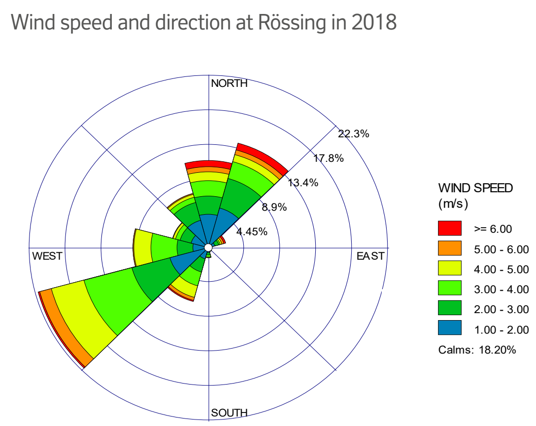


Figure 4. Wind speed and direction measured at Rössing, 2018

In terms of temperature, the variation between daily minimum and maximum temperatures are wide. The lowest temperatures are recorded during September and the highest temperatures are recorded in November, as shown in Figure 3. The coldest months usually begins in April and continues to July before temperatures start picking up again during summer.

In 2018, at Rössing the predominant winds experienced were blowing from west-southwest with over 17.8 per cent frequency of occurrence throughout the year (see Figure 4). Wind from the northeast is also experienced occasionally.

The combination of the low rainfall, high temperatures, the wide temperature ranges and prevalent winds result in evaporation rates that vary between 6 and 15 mm per day. The potential evaporation is thus around 3,000 mm per annum.

2.3 Topography and soils

At a mean altitude of 575 m above sea level, most of the Rössing tenement in the west, north and northeast consists of broad peneplains. The flat terrain is traversed by shallow drainage lines and stormwater gullies that drains into the Khan River. Close to the Khan River, the undulating plains change to an increasingly rugged terrain, which further increases towards the Swakop River.

Soils in the vicinity of Rössing could be described as shallow (<25 cm), with a large proportion of coarse fragments and occasional concretions, characterised by high soil pH-values. Hard surface and near-surface crusts are common. The crusts reduce rainfall infiltration rates and enhance run-off.

Sand deposits of varying depth are found in sheltered areas and are a mixture of dark- to light-brown grit, quartz and feldspar fragments. Coarse material is present on the slopes of some hills. Thickness varies, but may reach a depth of up to about 1.5 m.

The deepest soil is confined to the drainage lines, comprising of mainly infertile – almost sterile – alluvium, that vary in thickness. Moreover, topsoil is shallow, poorly developed, infertile and even absent over the largest part of the hill slopes and gravel plains of the mine tenement.

2.4 Biogeography

On the gravel plains at Rössing, vegetation is dominated by sparsely-scattered dwarf shrubs and ephemeral grasslands. This is also the case for the undulating hills and mountains with sparse grass cover. A total of 21 biotopes are discernible to identify landform boundaries in association with ecosystem functions and characteristic plant species. To date, a total of 241 plants species have been identified in the mine vicinity.

Sparse riparian vegetation marks the drainage lines, in particular the Khan River. In general, vegetation relates strongly to the frequency, intensity and duration of flooding events. A few species dominate: Anaboom (*Faidherbia albida*, previously *Acacia albida*), Camel thorn tree (*Vachellia erioloba*, still more commonly known as *Acacia erioloba*), Tamarisk (genus *Tamarix*) and thickets of the Mustard tree (*Salvadora persic*). The relative more dense riparian vegetation provides food and shelter to many animal species and sustains important migration and dispersal routes as a result.

A total of 272 species of ground-living insects are recorded at Rössing; this excludes flying groups such as moths and lacewings. The rocky hillsides, in particular those located along the Khan River, are regarded as the most important habitats of invertebrates.

The Namib Desert is known for its reptile diversity, particularly of lizards and geckos. At Rössing, 33 reptile species are expected to occur. Two species, *Merolis sp. Nov* and *Pedioplanis husabensis*, are of special concern. Three species of frogs are known to occur at Rössing. From a local perspective, the Khan River has the highest bird species diversity, indicating the importance of water availability and consequent-supported plant life, as well as the diversity of cliff habitats.

Mammal diversity at Rössing is not very high, as is typical in the central Namib. Climatic variation is closely coupled with marked changes in the abundance of animal species. Many of the animal species that occur around use a wide range of habitats, or may cross a wide range in the course of migrating from one habitat to another. Common animal species include klipspringer, oryx, springbok, ostrich, kudu, Hartmann's zebra, dassie (rock hyrax), black-backed jackal, baboon and rodents (particularly gerbils).

2.5 Surface and groundwater

Open-surface water in the Namib Desert is a rarity and may occur only ephemerally during the rainy season. Flowing surface water on the mining licence area only occurs after heavy rainfall. Run-off in the drainage lines is an episodic, brief event and peaks and periods of run-off vary widely.

Due to their alluvium beds, the tributaries of the Khan River contain subsurface water flow for most of the year. Permeability of the alluvium is high and the alluvium has also a high storage capacity with the water table being within 2 to 3 m of the surface.

Seasonal springs and small pools may occasionally form in the Khan River and in the gorges that drain into the Khan River. Only one natural perennial spring occurs in the Rössing area and is located in a side-arm of Panner Gorge.

Groundwater flows and rainfall seepage at Rössing is mainly along fractures and focus towards the gorges that drain into the Khan River.

Super-imposed on the natural groundwater system are sources and sinks created by mining. The open pit, more than 300 m deep, cross-cuts the hydrogeological connection between the existing Processing Plant and the Khan River receiving environment. It acts as a cut-off trench, and enables the interception and subsequent evaporation of potentially contaminated water moving downstream from the plant area.

The open pit also creates a cone of groundwater table depression that cuts off groundwater flow through bedrock and alluvial channels. Around the open pit, hydrogeological parameters of storage and permeability are very low.

The current elevation of the bottom of the open pit is substantially lower than the level of the Khan River (3 km to the south), and the regional water table (about 20 m below ground). The Khan River is also separated from the open pit by a low-permeability rock mass and the possibility of water from the Khan River entering the pit void is significantly reduced this way.

The natural groundwater quality in the vicinity of Rössing is very saline with total dissolved solids concentrations of 20 000-40 000 milligrams per litre (mg/L). The only groundwater potentially suitable for agricultural use near Rössing is found in the Khan River. This water is brackish and only suitable for livestock watering.

As a result of the high salinity of the water in the Khan River, the only beneficial uses of the water are for industrial purpose, such as dust suppression. Despite its salinity, the very hardy natural vegetation along the river depends on this water and abstraction is closely linked to monitoring of the water table.

2.6 Air quality

Atmospheric conditions at Rössing are prone to airborne dust and other impurities, a situation which is enhanced by air movements. Average daily wind speed measured at Rössing in 2018 was 1.2 metre per second (m/s) with the highest maximum wind speed over a one-hour period recorded at 18.8 m/s.

Though the recorded maximum speed was much lower in 2018, higher occurrences have been recorded before. These velocities usually occur during the winter and gusts of up to 34.90 m/s have been known to occur. The mean maximum gust is 26.17 m/s.

Potential for the transport of dust and other impurities via atmospheric pathways towards inhabited areas is dependent on the direction of receptor points relative to wind direction. Table 1 summarises localities relevant to wind direction at Rössing.

Generally-deposited dust is not considered a health hazard, but because it is visible, it could be the cause of public complaints. In suspension, dust particles with a diameter of less than 10 micrometre (μm) can be inhaled by humans. This kind of hazard is determined by concentrations of dust and the period of exposure.

It is not only human health that can be adversely affected by dust: the fall-out of heavy metals onto soil and the foliage of plants can also result in adverse environmental impacts. Combined with the concern about nuisance dust that may end up on the land neighbouring Rössing's mining licence area ML 28, potential environmental dust deposition is monitored at several stations around the mine site.

While most of the dust generated in the open pit at Rössing is of a fugitive nature, blasting activities can be considered as a point source of particulates, from where dust is dispersed into the surroundings of the mine. Large blasts occur approximately every week with smaller blasts twice or thrice a week.

The size of the blasting dust plume is unlikely to increase in size because as the pit deepens, the effects of blast dust become less. The dust plumes from the smaller blasts tend to disperse along the length of the pit and the dust settles on the benches and roads within the pit, from where it is remobilised by wind action and vehicles.

Of the eight common air impurities identified, five (SO_2, CO, NO_x, PM_{10} and dust deposition) are released at Rössing. However, only two are recognised as significant, i.e. particulate matter smaller than 10 microns in diameter (PM_{10}) and dust deposition, which are regularly monitored. Rössing conducts annual monitoring of SO_2, CO and NO_x that could be emitted as a result of the yellow cake roasting at the Final Product Recovery (FPR) plant.

In addition, greenhouse gas (GHG) emissions are estimated as carbon dioxide equivalent (CO_2-e) on a monthly basis, deduced from fuel consumption, electricity usage and explosives used for blasting.

Noise and vibration arise from exploration and operation activities, including mining, mineral processing, materials handling, infra-structure and on-site transport. Noise, ground vibrations and air blasts can have adverse impacts on the general living conditions of species and/or lifestyle of neighbours and are monitored to mitigate these impacts, in addition to spot-checks, specific surveys and investigations and regular risk assessments.

Air blast and ground vibration are monitored to provide information for geo-technical purposes as well, specifically to assess stability of man-made landforms.

2.7 Sites of archaeological and cultural interest

A total of 49 archaeological and historical sites are recorded at Rössing. Although there is some evidence of upper Pleistocene occupation, most of the archaeological sites date to within the last 5,000 years. A cluster of sites relates to grass-seed digging activities in well-drained soils derived from weathered granite, estimated to post-date AD 1000.

Table 1: Geographical position of localities relative to wind direction

Locality	Distance from mine	Direction	Relative to wind direction
Arandis Town	5 km	Northwest	Does not lie in the direction of E, NE, or SW winds
Arandis Airport	6 km	West	Lies in the direction of E wind
Swakopmund small holdings	50 km	Southwest	Lies in the direction of NE wind at a distance
Swakopmund Town	60 km	Southwest	Lies in the direction of NE wind at a distance
Walvis Bay	75 km	South-southwest	Lies in the direction of NE wind at a distance
Henties Bay	88 km	Northwest	Does not lie in the direction of E, NE, or SW winds

The seed-digging sites are concentrated around a number of low-lying granite outcrops associated with shallow depressions, which may contain water after rain, in between and relate to the seed-digging activities that still exist among Damara-speaking Namibians today. Historical sites relate to the narrow gauge railway that operated between Khan Mine and Arandis siding until about 1918.

The Rössing tenement is not an area of outstanding archaeological importance and does not have the dense site clusters which are characteristic of some parts of the escarpment and ephemeral river systems of the Namib Desert.

The areas of highest heritage value lie outside the main focus of mining activity and the mining area, and related high disturbance locations have a rather low heritage value. The sites also show a low vulnerability potential to disturbance. In general, the archaeological and historical sites are mainly of a low individual significance.

2.8 Land use

Apart from Arandis, there is no active land use in the proximity of Rössing's mining licence area. Water around Rössing is severely limited, meaning that agriculture is of marginal potential only, even along the ephemeral water sources of the Khan and Swakop rivers.

The closest commercial farmland is about 15 km to the east, and the border of communal land is about 15 km to the north. Along the lower Swakop River, close to the coast, commercial farming is undertaken on several smallholdings. Production aims to supply the needs of Swakopmund and Walvis Bay and includes asparagus, olive, mushroom and vegetable farming, as well as tourism- and leisure-oriented activities.

The Rössing mining license area is located within the #Gaingu Conservancy area. Not many people reside within the #Gaingu Conservancy area south of the main road.

About 720 ha of the mining licence area overlaps with the Namib-Naukluft Park on the southern bank of the Khan River.

The Dorob National Park is located about 10 km to the west of the mining licence area. Both parks fall within Category 2 of the International Union for Conservation of Nature (IUCN).

3. Environmental management at Rössing

3.1 The management system in effect

All operational activities at Rössing are managed to ensure that all impacts, on both the biophysical and socio-economic environment, are reduced to acceptable limits. Operations are governed through applicable national legislative and regulatory frameworks and managed through an integrated Health, Safety and Environment Management System (HSE MS). The HSE MS conforms to the international standards ISO 14001, OSHAS 18001 and ISO 9001, of which Rössing is certified to ISO 14001 since 2001.

Based on an understanding of potential health, safety and environment hazards/aspects, the HSE MS enables Rössing to identify key aspects and impacts, guide operating procedures and strive to continuous improvement in managing these. All potential impacts are listed on a business or site risk register, with related mitigating and operational controls.

The HSE MS is a tool designed to assist in achieving Rössing's goals, including its legal obligations. This systematic approach to management performance promotes the efficient use of resources and offers the prospect of financial gains to the company, generating a win-win outcome in terms of environmental and business performance.

External ISO audit evaluates the HSE MS periodically. In 2018, Rössing Uranium was successfully recertified for the ISO 14001:2004 and recommended for upgrade to ISO 14001:2015.

In addition to the HSE MS, Rössing implemented the Rio Tinto Health, Safety and Environmental Performance Standards since 2005. The intent of the standards is to gain commitment of employees on an annual basis to improvement in impact management performance. With the new shareholder, Rössing intends on retaining similar standards for managing the various HSE aspects /risks. Rössing will continue to uphold a high level of standards and retain its existing systems for managing HSE on all its facilities. Ultimately, environmental management at Rössing aims at achieving the following:

- Assess environmental impacts of mining activities throughout the design, planning, construction, operational and decommissioning phases
- Develop, implement and manage monitoring systems to ensure maximising of avoidance, mitigation and rehabilitation of adverse environmental impacts

- Comply with all environmental regulatory and legislative frameworks during all phases of the mine's operations through approved environmental management plans
- Investigate and exploit measures to reduce usage of non-renewable resources
- Maximise positive environmental impacts
- Avoid, mitigate and rehabilitate adverse impacts
- Limit contamination through prevention measures (escapes into aquatic and atmospheric pathways), appropriate containment, recycling and removal measures
- Protect, conserve and enhance cultural, heritage and archaeological resources
- Keep communities informed and involved in decision making about mining activities
- Monitor the health and safety of employees and contractors against agreed performance criteria, and
- Support and encourage awareness, training and responsibility of environmental management.

The use of a formalised, integrative HSE MS is essential in allowing Rössing to optimise, coordinate and manage the various operations, personnel, plant and equipment and their interactions in a manner that demonstrates consistent application of best practice in environmental management.

Matters of planning, implementation and operation, checking and corrective action, and management review, are embodied in the system. This approach assists in the identification of key environmental aspects and serves to guide Rössing in continued formulation of suitable standard operating procedures (SOPs) and in attaining continual improvement objectives.

Annual HSE management reviews are conducted at Rössing by leaders of the business. The annual review is a necessary part of the continual improvement process and helps senior management focus on the effectiveness of the management system and authorise actions and/or provide resources to improve HSE performance.

The aim of the HSE management review is to ensure that the HSE MS is efficient and effective in managing HSE performance and meeting legal and other requirements.

3.2 Environmental monitoring localities

The comprehensive environmental monitoring network at Rössing includes ambient dust fallout buckets, lithops monitoring, water quality monitoring boreholes, environmental noise and vibration and weather stations for meteorological parameters (see Appendix 5).

4. Environmental performance in 2018

Rössing's Environmental Management Plan contains a concise description of the management of environmental aspects and impacts at the mine, covering the various mine phases, from the designing to the decommissioning phase.

No significant environmental incidents occurred during 2018 and no deviation from the Environmental Management Plan was reportable to the respective authorities.

As a resource-intensive industry, Rössing's operations have the potential to impact on natural resources and the environment. For this reason, Rössing focuses continuously on improving environmental management programmes to maximise benefits and to minimise negative impacts. Key environmental management programmes include:

- Energy efficiency and greenhouse gas emissions
- Air quality control (including emissions of dust, other impurities, noise and vibration)
- Water management
- Waste management (both mineral and non-mineral waste)
- Chemical substance management, and
- Land-use management (including biodiversity, rehabilitation and closure).

As part of continuous improvement, there were notable improvements in the environmental monitoring space, as well as awareness on environmental aspects, such as waste management, air quality monitoring and water quality management. To mention a few:

- Rössing revived the weekly 'Wapaleka' cleaning campaign onsite, which encourages the entire workforce to voluntarily clean their working areas, and hence keeping the mine site clean on continuous basis.
- Ground water database base linked to Geographic Information Systems (GIS) for easy access and spatial display.
- Groundwater-quality monitoring schedule changed to an adaptive approach.
- Upgraded the seepage control systems for the trenches and rehabilitated monitoring boreholes.

- In terms of waste management, a training programme was tailor-made for each working area and introduced in addition to the annual HSEC training and inductions.
- The PM_{10} (inhalable dust) monitoring systems were installed with remote data loggers which now enables the high-peak events to be investigated immediately. The improvement also improved data availability significantly, as faulty equipment is noted and repaired/replaced immediately.
- Continuous total particulate monitors (TPM) was installed at the Final Product Recovery (FPR) to monitor dust emissions with the aim to improve scrubber efficiency and monitor effectiveness of improvements implemented by operations to keep air emissions minimal.

The performance in 2018 with regard to the environmental management programmes is discussed in the next sub-sections.

Environmental awareness and training are integral components of our environmental management system.

4.1 ENVIRONMENTAL AWARENESS AND TRAINING

4.1.1 Improved wildlife protection through 'SPOT the wild' competition

The 'SPOT the wild' competition is an initiative that was launched during the commemoration of World Environmental Day on 5 June 2018 to help the environmental section to map out hot spots and migration route areas where wildlife is mostly observed on the mine site.

The mapping of wild animal occurrence and understanding of the migration paths supported interventions such as road signs and rules, to ensure zero harm to our wildlife, enhance safety and promote living in harmony with the wildlife in and surrounding the mine's mining area.

4.1.2 Birdwatching event

The birdwatching event is hosted on an annual basis, involving the communities of Arandis, Swakopmund and Walvis Bay in promoting biodiversity conservation. In 2018, the event took place in September at Walvis Bay's Bird Paradise; 74 learners from 13 coastal schools, and five bird guides participated.

The birdwatching activities included identifying, counting and recording bird species found at the lagoon on the day. In total, 20 bird species were recorded and most observed birds were the greater and lesser flamingo, Cape gannet, common ringed plover, and the little stint. In addition to bird watching, the environmental section shared the environmental impacts at the mine and how they are managed.

In further support of the World Environmental Day, a member of the Albatros Task Force of Namibia was invited to speak to learners and teachers on the functions of the project and the impacts of plastic pollution on sea birds.

The leaners also participated in clean-up activities around the lagoon as part of awareness of plastic pollution in line with the theme 'Beat Plastic Pollution'. The leaners received re-usable shopping bags to promote banning of plastic bags in the local retail shops.

Learners from 13 coastal school participated in the annual birdwatching event that took place in September 2018 at Walvis Bay's Bird Paradise.

4.1.3 In-house waste management training and 'Wapaleka' cleaning initiative

The outcome of inspections at the mine areas shows that waste management is a challenge in most area and there is a lack of basic understanding in waste sorting and segregation. This was addressed through tailor-made training on waste management, in addition to the HSE trainings conducted among all employees. The training was well attended and achieved its objectives.

The 'Wapaleka' cleaning campaign was re-introduced and launched in 2018. ('Wapaleka' means 'clean up' in one of the local languages, Oshiwambo). The initiative promotes waste segregation, voluntarily cleaning and improving workplace conditions in and around the mine site. In 2018, over 6.2 tonnes of waste was collected voluntarily, in addition to the waste managed through the integrated waste management contractor.

4.1.4 Snake-handling training

Snakes, scorpions and other living creatures regularly inhabit the mine and the surrounding landscape. They occasionally cross and migrate into areas used by personnel and interaction is inevitable. The proximity of all working areas to the natural environment dictates that these animals could be found in any part of the mine site. The risk of possible encountering snakes or scorpions on mine site was assessed and it was rated as high.

To mitigate and manage this risk, a snake familiarisation and handling training was conducted in 2018. Seventeen employees from various sections on the mine were trained to handle snakes. The training was conducted by Stretch Combrink from The Living Desert Snake Park in Swakopmund.

The training aimed at equipping employees with skills and techniques to handle and relocate snakes at the mine. The training also provided an understanding of various snakes common to the Namib Desert and endemic to Namibia.

In 2018, seven snakes and eight scorpions were reported to have been rescued from the mine areas. Most scorpions were encountered at the IT building and the main gate.

Of the seven snakes, three were puff adders, three were western keel snakes and a black spitting cobra. Snakes were encountered at various mine areas: the main gate, Arandis services yard, engineering projects building, recovery maintenance workshop, laundry change house, the HSE building and the Processing Plant. The main gate area seems to be more susceptible to scorpions and snakes; this could be due to the garden shrubs around the area.

4.2 ENERGY EFFICIENCY AND GREENHOUSE GAS EMISSIONS

Rio Tinto regards efforts to stabilise global atmospheric concentrations of greenhouse gases (GHGs) at low levels is a priority. Therefore, we measure and manage energy intensity and emissions. The intensity of emissions is reported per unit of product target.

Sources of greenhouse gas emissions include electricity and fuel consumption, transport of reagents and uranium, blasting (explosives), waste (sewage, rubbish disposal and landfill) extraction and processing.

Greenhouse gas emissions and intensity per unit of product (actual), is reported to Rio Tinto monthly and annually against the projected targets (until 2020) as shown in Table 2.

Tier 2 targets are internal and calculate energy use per unit of 'work done'. 'Work done' targets are calculated for the energy used per unit and reported internally.

To calculate the greenhouse gas emissions equivalent of the amount of energy used, the total energy consumed is converted to CO_2 per tonne of U_3O_8 produced. The figures are used to drive energy efficiency and emission reductions on site, and are reported monthly and annually to Rio Tinto and going forward a similar process will be done with the new shareholder as per the existing standards.

To set targets, hauling and milling processes are measured to calculate the total amount of energy use per 'work done' at the mine's operations.

Measuring greenhouse gas emissions intensity per unit of product target and total amount of energy use per 'work done' gives an indication of energy used during the following two processes:

- Haul metric: GJ/kilotonne of material hauled, and
- Plant metric: GJ/kilotonne of ore milled.

4.2.1 Energy intensity

In 2018, production of 2,477.97 tonnes of uranium oxide was drummed, and the total energy consumption was 1,192,655.79 gigajoules (GJ). This converts to an annual energy consumption of

Table 2: Greenhouse gas emissions intensity targets

Year	Emissions (tonne CO_2-e)	Actual Emissions (tonne CO_2-e)	Product uranium emissions target (t CO_2-e/tonne of uranium oxide)	Actual Product uranium emissions target (t CO_2-e/tonne of uranium oxide)
2014	125935	148787	82	60
2015	124149	157440	82	74
2016	135654	150060	74	82
2017	146426	106870	62	86
2018	191524	118310	52	82
2019	171644		43	
2020	165515		39	

Table 3: Tier 2 - Haul and plant metrics		
Metrics	**Target: 2018**	**Actual: 2018**
Haul		
Haul metrics GJ/kt equivalent material hauled	17.68	21.42
Greenhouse gas haul metrics kg CO2-e/t material hauled	1.41	1.76
Plant		
Plant metrics GJ/kt equivalent ore milled	45.17	56.29
GHG Plant metrics kg CO2-e/t ore milled	6.5	8.02

481.30 GJ/t uranium oxide produced (see Figure 5).

4.2.2 Greenhouse gas emissions

The actual performance achieved in 2018 was 60.04 tonnes CO_2-e /t U_3O_8, which is 33 per cent below the target of 90 tonnes CO_2-e /t U_3O_8 (see Figure 6).

4.2.3 In-house metrics

Rössing's performance against Tier 2 targets is displayed in Table 3. These targets were not met during 2018, mainly due to the dependency on the ore grade and the mine-slowdown in May.

4.3 AIR QUALITY MANAGEMENT

The Air Quality Management Plan refers to a management plan that Rössing has put in place to help protect the environment from any harmful effects due to air pollution created during the mining activities. Therefore, air emissions are listed in an inventory and all air quality standards applied at Rössing are documented.

The air quality management practice at Rössing aims at understanding the dust footprint, in correlation to wind regime and characterising ambient air quality. This practice helps in reviewing the existing sources of air emissions from mining operations and creates a better understanding of the correlation between blasting and its impacts in the form of dust, noise and vibration.

Rössing's mining operation is susceptible to dust due to its location in high temperatures and low rainfall area. Dust monitoring is one aspect of air quality that is used to determine the amount of dust particles present in the environment over a given period of time.

There are two types of dust that we monitor, namely particulate matter 10 (PM_{10}) and respirable dust (dust fallout); the quantity and size of the particles are both measured.

4.3.1 Environmental Dust

PM_{10} monitoring focuses on measuring particles in the air that are equal to, or less than, 10 micrometres in diameter. MET-ONE e-samplers are used to monitor PM_{10} dust in and around the mine area.

The PM_{10} dust samplers are situated at four places around the mine, namely at the Arandis residential area, at the mine boundary on the south-westerly side of the mine, at the western tailings area

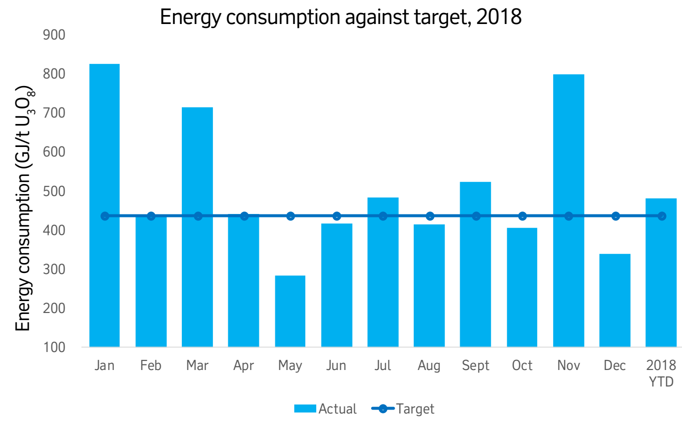


Figure 5. Total energy consumption intensity, 2018

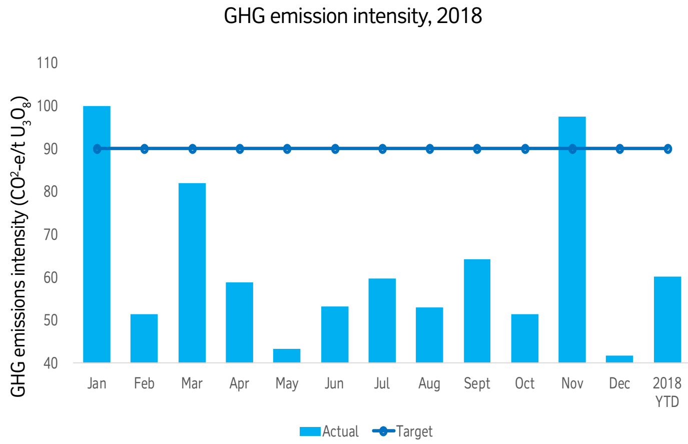


Figure 6. Total greenhouse gas emission intensity, 2018

and at the Contractor Management Centre (CMC).

The Arandis and boundary stations are two of the crucial PM_{10} stations, while the CMC and tailings stations are monitoring for operational purposes. The Arandis station monitors dust fallout to ensure that the dust from our operation does not disperse to the ambient environment.

The boundary station measures dust to verify that PM_{10} dust dispersal from potential sources in the operational areas is limited in distance and does not cross the boundary to the southwest of the mining license area.

In 2018, all PM_{10} dust levels recorded at all stations were below the World Health Organisation standard of 0.075 milligram per cubic metre (mg/m^3), as indicated in Figure 7. However, there were a high dust concentrations observed at the boundary station from January to May and at the CMC station from June to December. The CMC measurements could be associated to east winds.

The dust concentrations recorded at the Arandis and tailings stations were also below the WHO standard of 0.075 mg/m^3 even though the monitoring station was malfunctioning in some months,

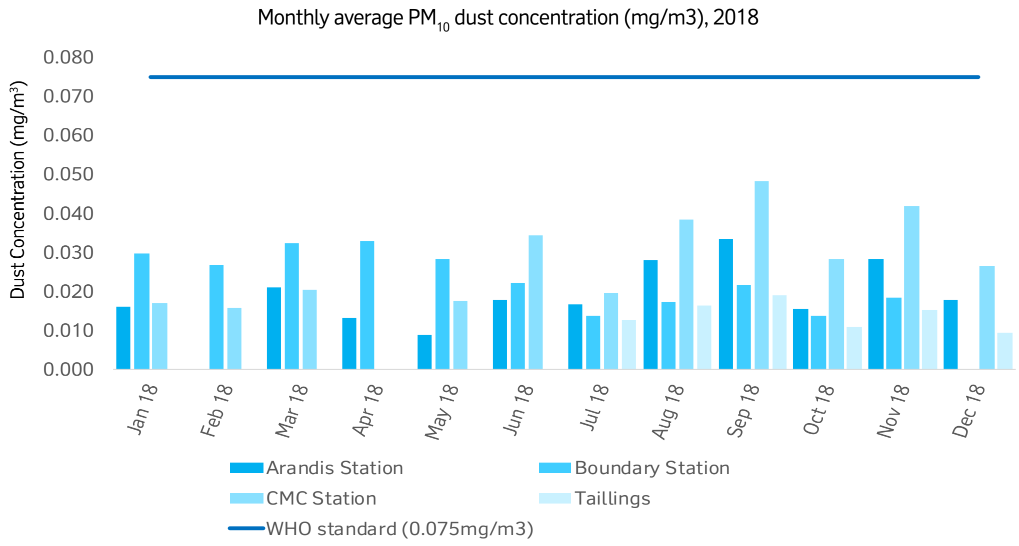


Figure 7. PM_{10} dust levels measured at all stations, 2018

as indicated in Figure 7.

4.3.2. Ambient dust fallout

Dust-fallout monitoring is an aspect of air quality management which involves the measurement of dust deposition in the ambient air, particularly as a result of our mining activity which may adversely affect the surrounding environment and residential inhabitants.

Total dust fallout is measured as the weight of dust deposited on one square metre of ground in a single day. Rössing has adopted to the South African National Dust-control Regulation (SA NDCR) which is 600 mg/m^2 per day for residential and 1,200 mg/m^2 per day for non-residential areas with an annual average target of 300 mg/m^2 per day.

The ambient network dust deposition rates for the period January to December 2018 were well below the SA NDCR dust-fallout limit for residential areas of 600 mg/m²/day.

The highest deposition rate of 113 mg/m²/day was recorded at BD7 in November, with the rest of the recordings ranging between 1 mg/m²/day and 105 mg/m²/day. Overall, the dust-fallout rates were slightly higher in October and November, but no significant

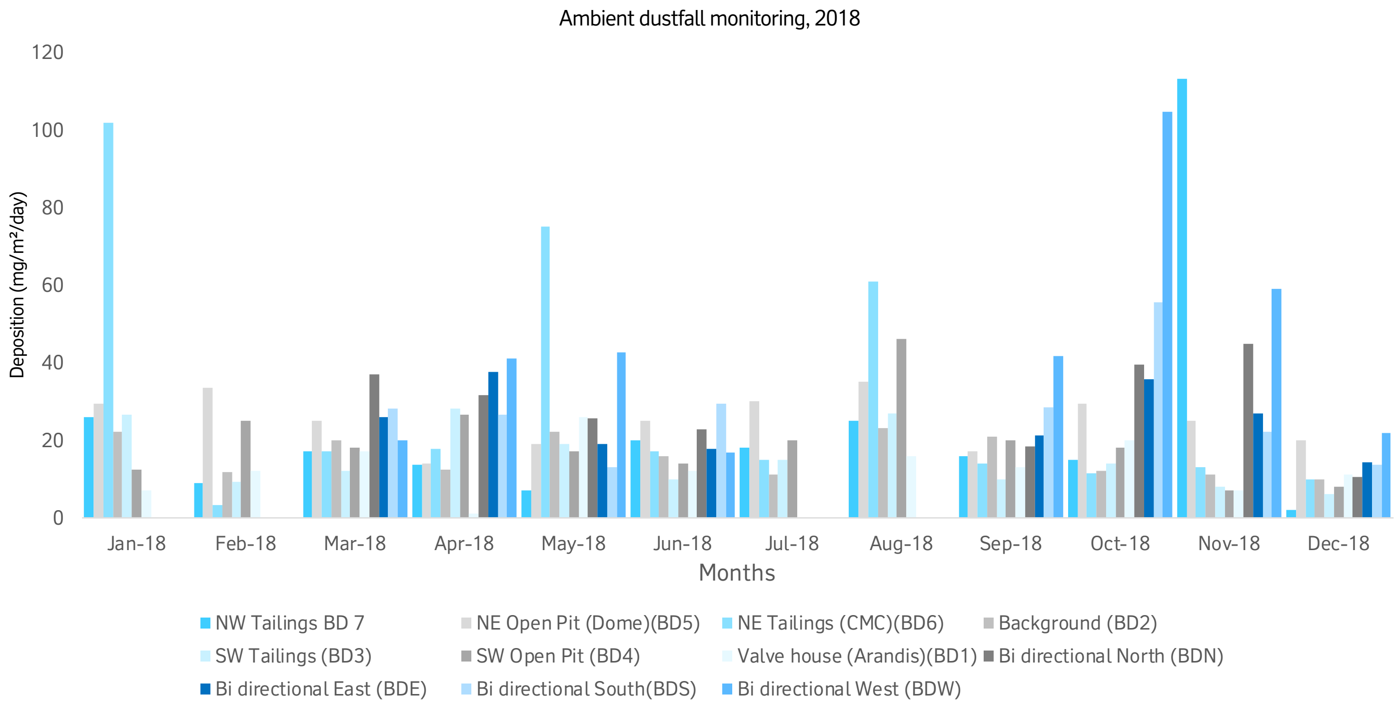


Figure 8. Ambient dust fall deposition network, 2018

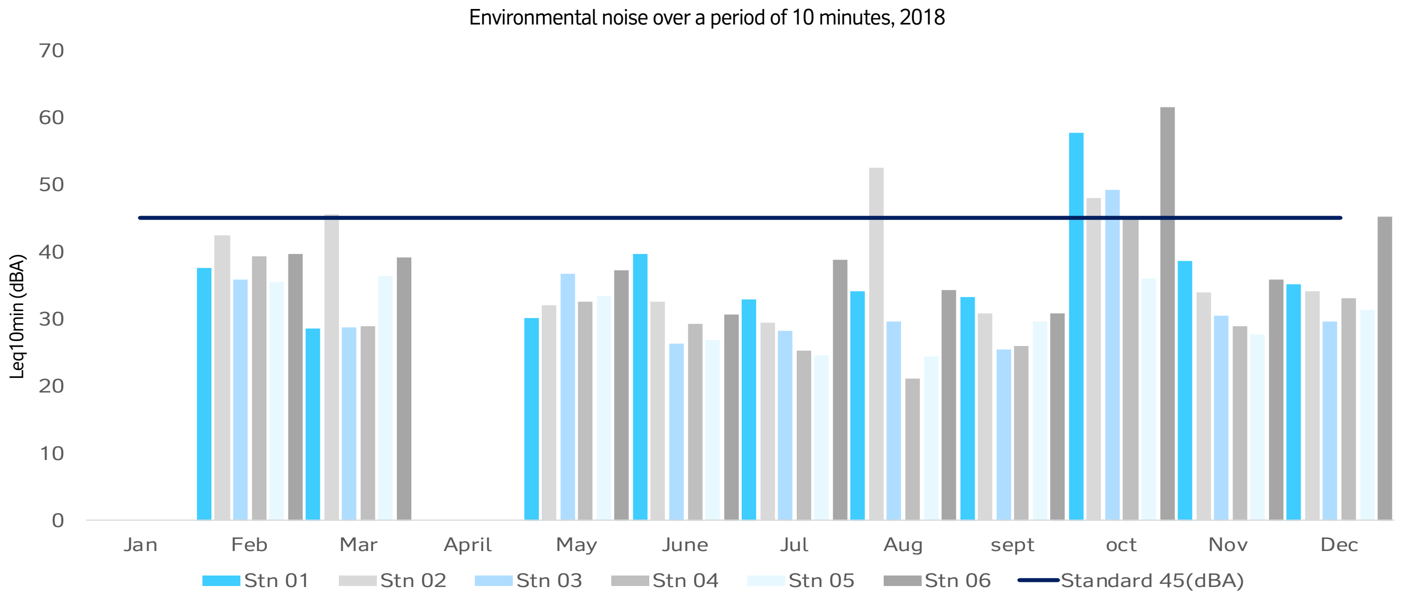


Figure 9. Environmental noise measured, 2018

trends were observed throughout the year (see Figure 8).

4.3.3 Environmental noise

In order to the monitor the noise impact the mining activities has on the environment, on a monthly basis environmental noise is measured at six stations. These stations are: Rössing main mine access road (Station 1), Arandis airport (Station 2), Khan River valley (Station 3); Khan River rock island (Station 4); Khan River bed (Station 5) and Khan River bed 2 (Station 6).

In the absence of national noise legislation or standards in Namibia, all operational noise measurements are carried out in accordance with the South African National Standards (SANS) 10103:2004 and compared to the SANS Code of Practice SANS 10103:2008 (SANS, 1992). Rössing has set internal noise level of 45 decibel (dB). Environmental noise is measured at 10 minute snapshots.

In 2018, there were seven occasions where the standard of 45 dB (A) was exceeded. Station 02, (at Arandis airport), exceeded three times, while the other stations (Station 1, 3, 4 and 5) has exceeded each once; this could be due to the natural sounds of wind rustling foliage, aeroplanes and cars moving in the vicinity.

The highest Leq10 recorded in 2018 was 61.6 dB (A) at Station 6 (Khan River bed) and the lowest Leq10 recorded was 22.1 dB (A), recorded at Station 4 (rock island) in the Khan River.

In conclusion, the events during which noise levels exceeded the standard could be attributed to other-than-mine activities and therefore were not due to the Rössing operational activities.

4.4 WATER MANAGEMENT

Water management at Rössing is guided by a formal water strategy and a water management plan, developed according to the Rio Tinto Performance Standard - Water quality protection and water management.

Water management covers all activities connected to water abstraction, dewatering, transport, storage, usage (potable and process), and direct/indirect discharge, surface water (including run-off), impounded water and groundwater. The intent of the standard is to ensure efficient, safe and sustainable use and protection of water resources and ecosystems.

In accordance to Namibian legislation, specifically the Water Resources Management Act of 2014, the Ministry of Agriculture, Water and Forestry (MAWF) is the custodian of all water resources in the country. Under this mandate, MAWF issued Rössing with two permits:

- Industrial and Domestic Effluent Disposal Exemption Permit # 674 (valid until December 2020), and
- Khan River Water Abstraction Permit # 10 200 (valid until January 2021).

4.4.1 Total water usage

The monthly freshwater usage shown in Figure 10 was to 2,883,953 cubic metres (m^3) for 2018, which was 3.68 per cent below the planned 2,985,700 m^3 for the year. The planned fresh water annual volumes are based on planned tonnes to be milled for that year.

Freshwater consumed per tonne of ore milled was 0.326 m^3/t and the ratio of freshwater to total water consumed was 0.36 m^3/t. The steady increase in water used per tonne of ore milled from May onwards was associated with the high calcium carbonate (calc) content in the ore, which required additional water.

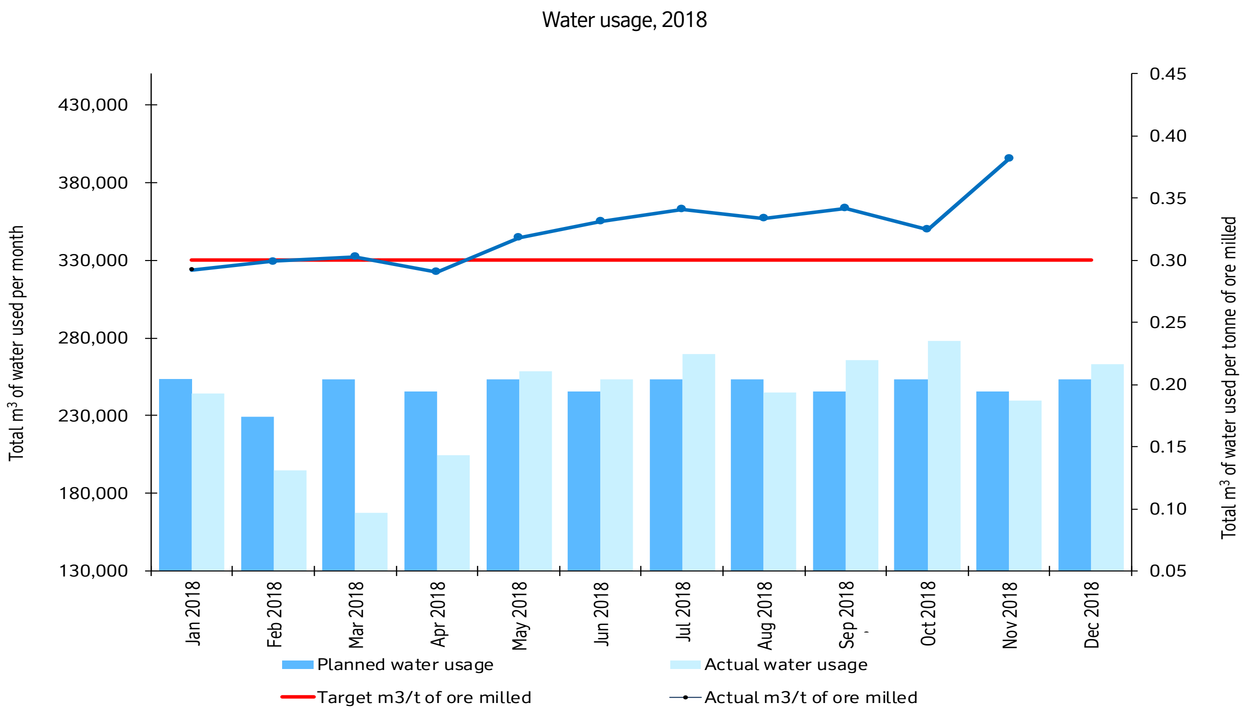


Figure 10. Water usage, 2018

4.4.2 Khan River water usage

Saline groundwater abstracted from the Khan River aquifer is used to spray on haul roads in the open pit to suppress dust. In 2018, a total of 129,210 m^3 was pumped; this is 15 per cent of the permitted 870,000 m^3. Abstraction is maintained below 600 m^3 a day as much as reasonably possible, which is established internally to be the sustainable yield of this portion of the Khan River.

In addition, the riparian vegetation and water levels in this compartment of the Khan River are monitored in order to identify potential impacts of the abstraction at an early stage. The Khan River riparian vegetation monitoring programme for the study area has been running for over 30 years; see the case study on the monitoring programme in sub-section 4.10 below.

Recent monitoring indicated that the trees in the study area are not affected by the abstraction from the aquifer. The river flooded for a few hours in November 2018, resulting in localised recharge spikes observed in monitoring bores.

4.4.3 Groundwater quality protection

Rössing's Tailings Storage Facility (TSF) is a source of potential groundwater contamination. Contaminated tailings seepage could potentially reach downstream water users in the Swakop River via the aquatic pathways of the alluvium and rock aquifers on site, and eventually the Khan River.

Therefore, the objective of the groundwater quality protection programme is to curb contaminated seepage from the TSF from entering the Khan River. To achieve this, a network of abstraction points, wells, sumps and trenches close to the source and in the wider environment are equipped to pump this seepage continuously. Abstracted seepage water is discharged into the overall recycle and reused in the Processing Plant.

In order to ensure the effectiveness of these control systems, a groundwater level and quality monitoring network is in place. Water-quality data is managed through a database and both water quality and water-level data can be displayed using a geographical information system (GIS).

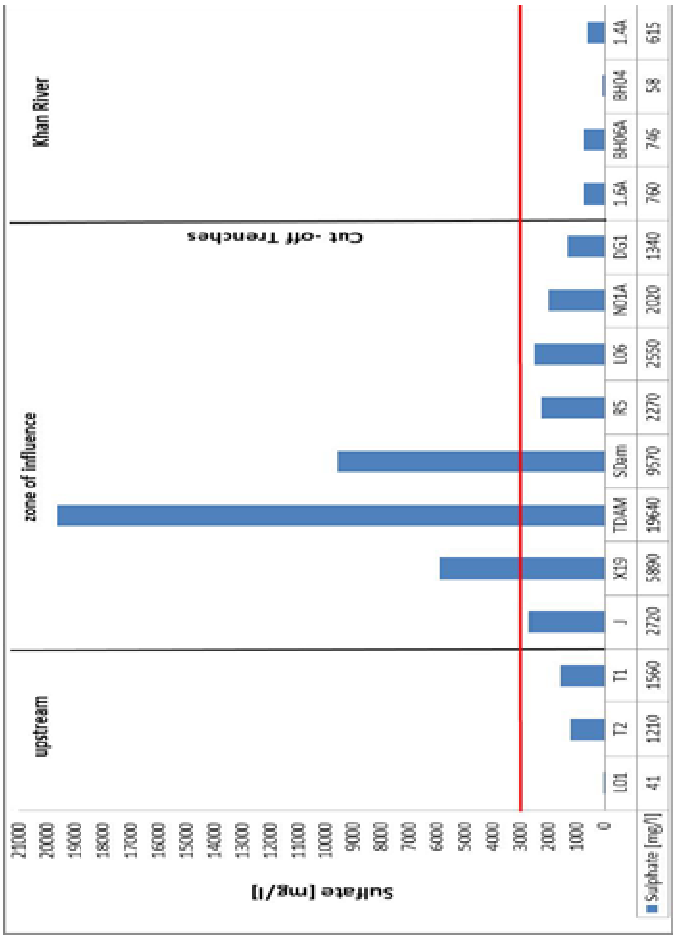
This function allows for quick and effective spatial display of data which improves data comparison and interpretation, as well as the management of the seepage control network.

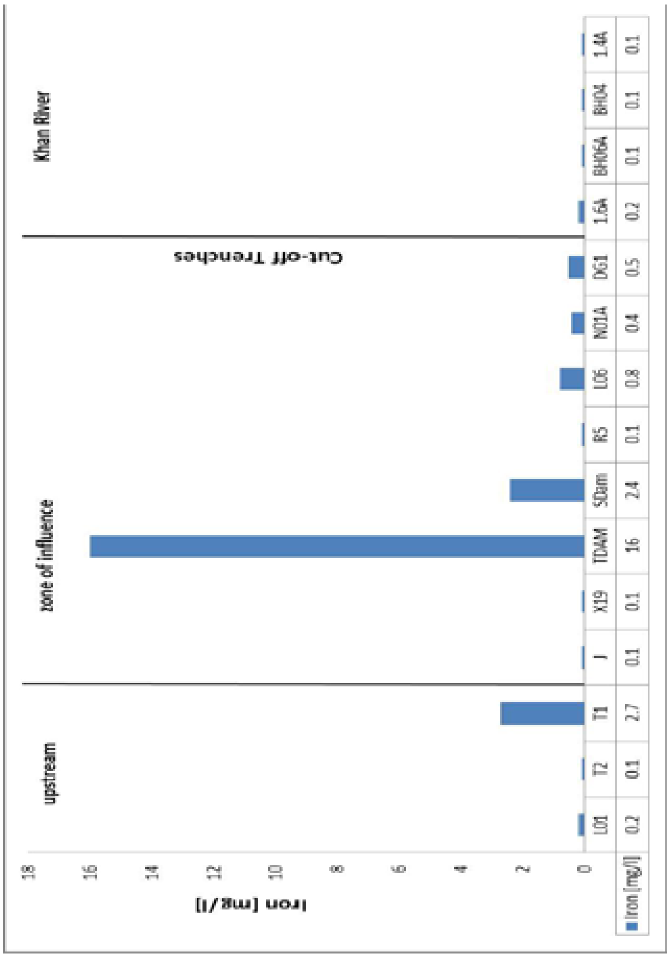
Rössing's water quality monitoring schedule is a listed item in the "Industrial and Domestic Effluent Disposal Exemption Permit" issued by the MAWF. Water samples are analysed by independent accredited laboratories, namely IAF Radioökologie GmbH (Germany) and DD Science Cc (Republic of South Africa).

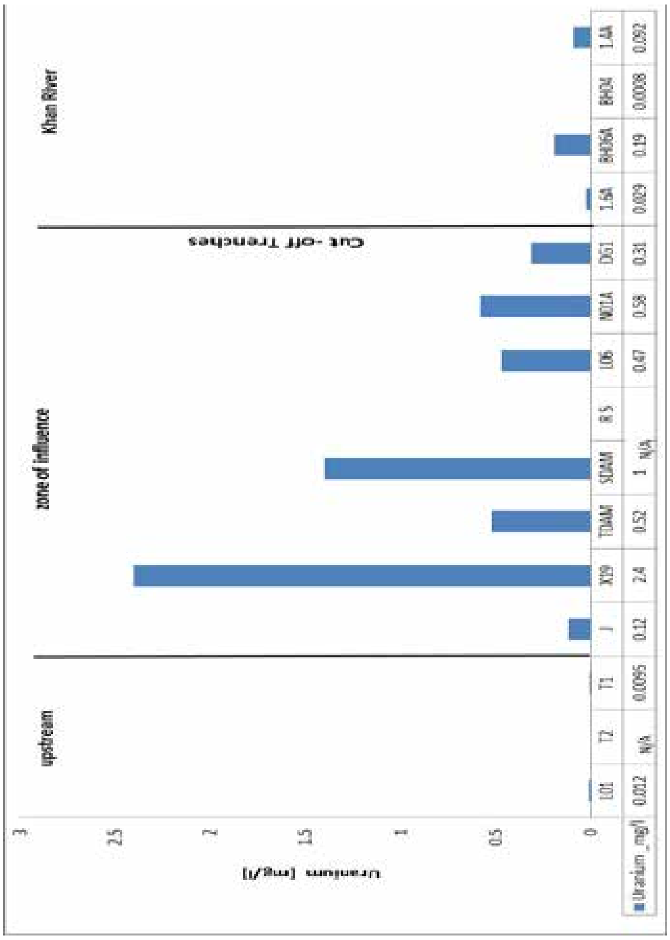
In the selection of graphs depicted in Figure 11, concentrations of ions from chemicals used in the Processing Plant are shown. Sampling locations are shown on the x-axis of the graphs and the graphs are grouped into three categories based on locations:

- Upstream background – this area is unlikely to be influenced by seepage due to local and regional groundwater flow.
- Zone of influence – defines the area upstream of the cut-off trenches which is either contaminated or has the potential to be contaminated by seepage.
- Khan River - receiving environment downstream of the cut-off trenches, which is mainly the Khan River.

The water-quality charts indicated bell-shape distribution of concentrations. All four charts indicate higher concentrations within the zone of influence, particularly in the areas where the seepage plume has been delineated.







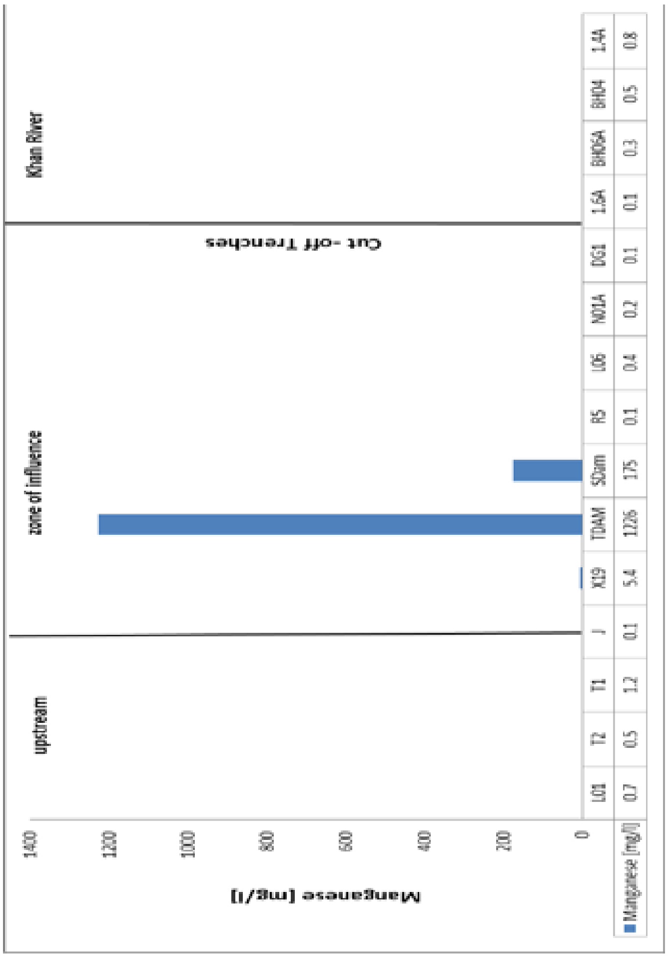


Figure 11. Water quality overview for August 2018

It has been suggested through various geochemical models that the decrease in concentrations of certain ions away from the source of contamination may be due to chemical precipitation of mineral phases within the tailings profile and the natural environment.

A report titled “Geochemistry and seepage of Rössing tailings water” by Dr Paul Brown explains the involved chemical processes.

The water-quality data in Figure 12 indicated that the seepage plume at Rössing remains confined within the zone of influence (in and around TSF).

The approximate extend of the seepage plume for 2018 is delineated in Figure 12; the outline remains unchanged as was observed in 2017, with no new monitoring locations contaminated.

4.4.4 Improvements in water management aspects

As part of Rio Tinto assurance programme, business conformance audits (BCA) and independent technical reviews are conducted across all operations on regular basis, including at Rössing. Reviews were conducted and as result, the following improvements were suggested and implemented:

a) Increase the control performance of the critical seepage recovery systems

In 2018, Rössing completed the structural upgrade on the cut-off trenches. The cut-off trenches are important seepage control features and prevent potentially contaminated water entering the Khan River.

The continuous operation of the cut-off trenches is imperative towards groundwater-quality protection for the Khan River alluvium aquifer.

The upgrade project involved installation of a fully automated state-of-the-art water abstraction and water level monitoring system. The project also involved the structural refurbishment of the aging water-quality monitoring borehole network, in which selected boreholes were successfully rehabilitated.

b) Review the water quality monitoring programme with regulatory involvement (MAWF)

The mine received regulatory approval from the MAWF, with amendments in permit # 674, to implement a revised water-quality monitoring programme. The programme does not rely on fixed sampling points anymore, but adapts sampling locations to changing circumstances with the aim to have areas of contamination accurately delineated all the time. The programme was implemented after MAWF approval was received in September 2018.

The adaptive programme is based on the use of sulphate concentrations of 3,000 parts per million (ppm) to delineate and to follow changes to the seepage plume extent. The 3,000 ppm is obtained through statistical analysis by adding three standard deviations to the mean sulphate concentration of upstream boreholes for baseline sulphate concentration.

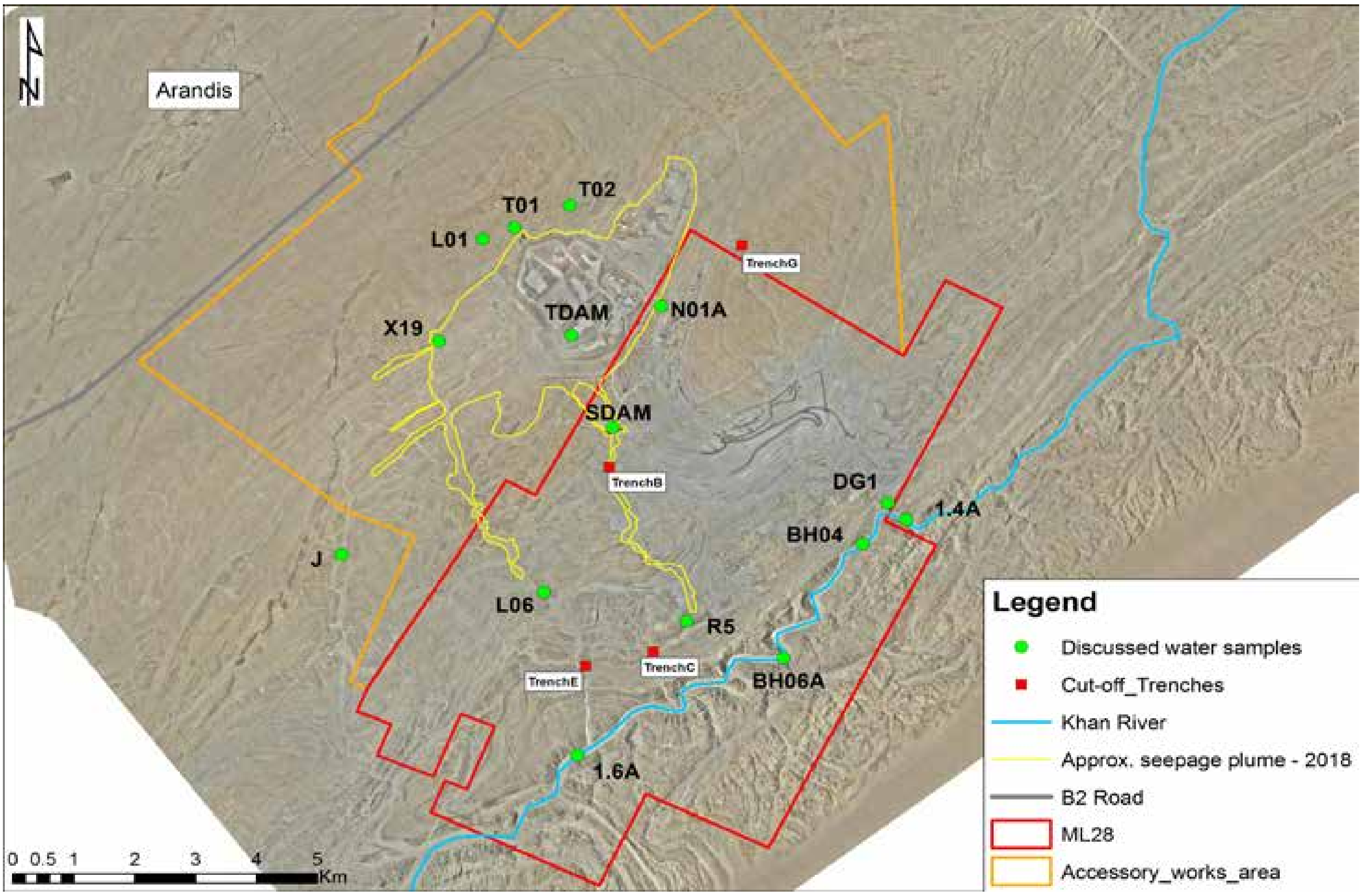


Figure 12. Map of water seepage plume at Rössing mine, 2018

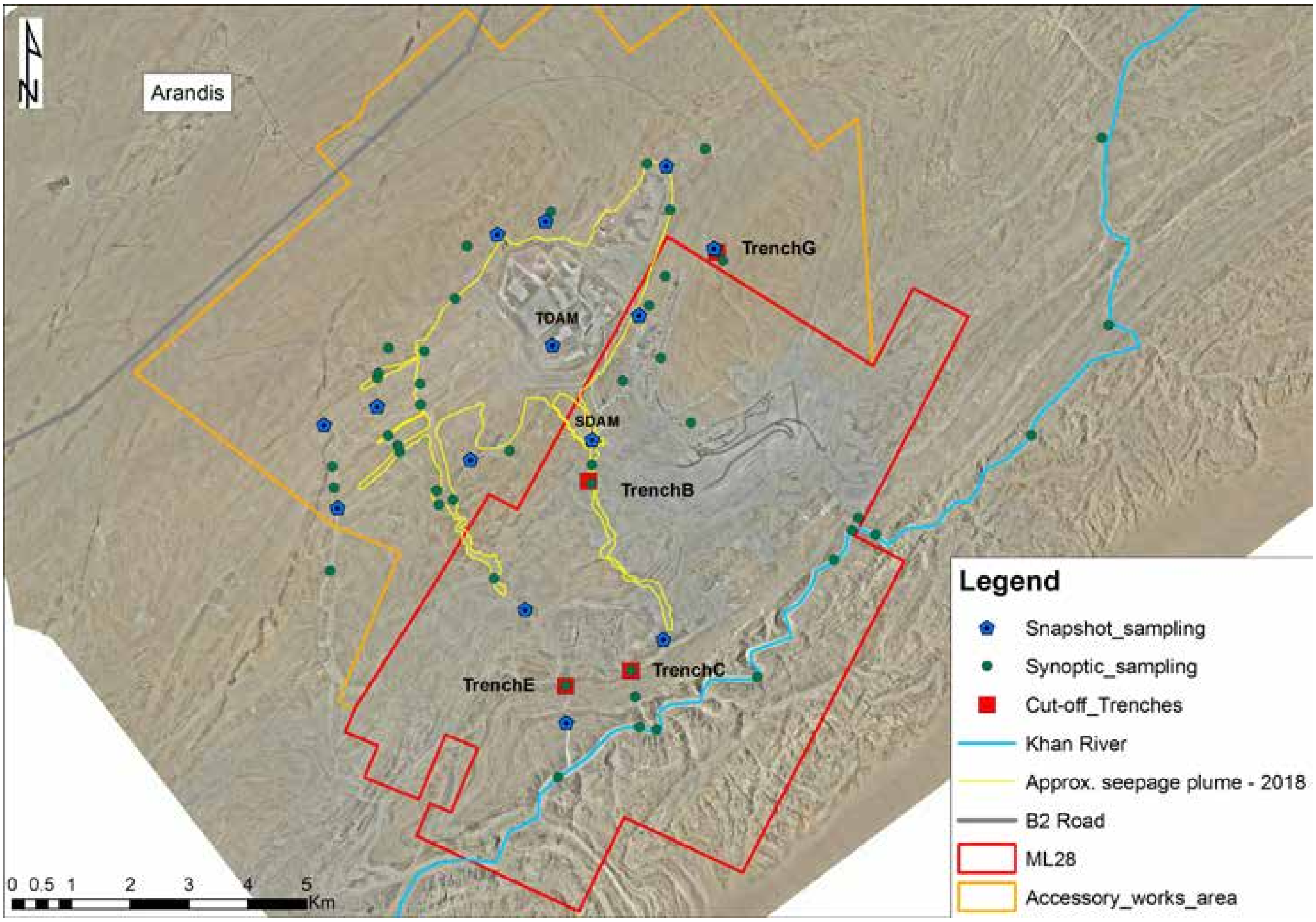


Figure 13. Water-quality monitoring boreholes

A number of sampling events carried out throughout the year are part of the adaptive programme. Firstly, 'snapshot' sampling is done twice yearly, using sulphate analysis only with the objective to detect potential change of the extent of the plume. A limited number of sampling locations, situated in the known direction of groundwater movement, are used.

Secondly, 'synoptic' sampling is done once a year and covers all boreholes, applying a wide range of chemical analysis. These include radionuclide, trace elements, as well as oil and grease analyses for selected boreholes. The objective of synoptic sampling is to maintain a continuous record of water-quality changes throughout the years and present a holistic picture of groundwater quality in the area.

The water-quality sampling boreholes discussed above are illustrated in Figure 13. Predominant groundwater flow directions in the catchment are south-south-westerly, with 500 metres per year flow velocities estimated in the steepest sloping segments of the primary alluvial aquifers and 100 metres per year in the secondary fracture systems.

4.5 WASTE MANAGEMENT

In addition to the legislative framework for waste management in Namibia, Rössing also manages its waste in accordance with the international standards such as the ISO 14001:2004, as well as the Rio Tinto Environmental Performance Standard E15 (Hazardous material and non-mineral waste control and minimisation) for conformances and compliance.

4.5.1 Management of non-mineral waste

Non-mineral waste at Rössing is characterised into two classes, namely general and hazardous waste, in accordance with the risk it poses. The type of non-mineral waste generated onsite are, for example, scrap metal, redundant conveyor belts, used oil, domestic waste, as well as lubricants from maintenance activities.

Rössing has a waste management plan in place that addresses all non-mineral wastes generated due to operational activities to ensure sound management through the minimisation of waste generation and safe handling, treatment and disposal of waste.

Since 2016, an integrated waste management contract was awarded to an external service provider, Karee Investment, to handle and remove recyclable materials and packaging materials onsite. Waste is weighed and an inventory for waste generated, stored onsite and offsite disposal is documented and maintained.

The onsite landfill site is dormant; only building rubble and garden refuse was disposed at the landfill during 2018.

Radio-active and contaminated waste is disposed in trenches at a designated site on the TSF where the quantity and the disposal location are recorded. Disposal at the contaminated waste site is restricted to one day in the week (Wednesday) only and access is controlled.

Hydrocarbon contaminated soil and sludge is disposed at the bioremediation facility for further treatment before final disposal at the TSF. Two batches of treated samples from Sluge farm cell 1 and 2 were send away for analysis and results were below the acceptable disposal target; treatment is ongoing. The total petroleum hydrocarbons (TPH) target is <10,000 mg/kg.

The oil-contaminated rags are packed in the 210 litre drums and stored at the temporally oil yard for further disposal at hazardous landfill site in Walvis Bay. Rössing has entered into an agreement with an offsite oil recycler to perform a trial to recover the residual oil from filters and scrap metal for recycling. This practise is favourable as it reduces waste to the landfill. The outcome from this experiment will determine the final decision for disposal.

As indicated in Table 4, a total of 1,312 tonnes of recyclable waste material (mainly used oil and scrap metal) were recycled offsite; 1,272 tonnes of contaminated solid wastes were disposed on the contaminated site on the TSF, while 231.3 tonnes of oil contaminated sludge and soil was disposed at the bioremediation facility for further treatment.

No chemical waste was disposed during 2018, as the closest licenced facility, namely the Walvis Bay hazardous landfill site, has been under renovation in 2018.

The measureable target for the reduction of non-mineral waste for recycling offsite was set at 80 per cent since 2016. This target was not achieved in 2018; offsite waste recycled disposal was only 47 per cent (see Table 4). The poor performance was due to the management of the integrated waste management contract by the external service provider. The challenges were discussed extensively and improvements are planned to be implemented by mid 2019.

Hydrocarbon used oil and grease generated from the wet part of the Processing Plant are regarded as potentially radioactive contaminated and cannot be recycled offsite without due diligence. The oil is stored onsite as per permit conditions of the oil storage permit which permits a total of 100,000 litres per annum. The potentially radioactive contaminated used oil is currently stored onsite awaiting the outcome of the oil dilution project.

The oil dilution project aims at eliminating any potential radioactivity in the used oil by mixing the potentially radioactive contaminated oil with clean used oil. The initial work completed includes oil drums scanning for radiation clearance. The cleared drums are further sampled for radionuclides and sent for high energy gamma analysis at South African Nuclear Energy Corporation (NECSA).

Preliminary results of U^{238} activity concentration showed that the oil samples are not classified as nuclear material and most samples showed activity concentrations below detectable limit. Once verified that there is no potential risk, a procedure will be developed to continuously assess the oil before recycled.

4.5.2 Management of mineral waste

At Rössing, mineral wastes are identified as waste rock and tailings. The Rössing Mineral waste management plan (JE20MMP009) has been developed and prepared in accordance with the Rio Tinto Mineral waste management guidance notes and the Rio Tinto Performance standard, Chemically active mineral waste control (E13), as well as Namibian regulatory requirements.

The intent of the plan is to ensure sound and effective mineral waste

Table 4: Non-mineral waste volumes (tonnes)

Year	Steel	Cardboard & paper	Wood	Plastic	e-waste	Conve-yors	Land filled	Total recycled	Total waste	% of total waste recycled
2002	1,597	10	17	-	-	-	433	1,624	2,057	78.9%
2003	1,897	23	43	-	-	-	504	1,963	2,467	79.6%
2004	1,734	36	57	-	-	-	785	1,874	2,659	70.5%
2005	1,700	39	60	-	-	-	1,016	1,885	2,901	65.0%
2006	1,411	37	42	-	-	-	548	1,500	2,048	73.2%
2007	2,290	31	45	-	-	-	445	2,374	2,819	84.2%
2008	2,254	21	39	-	-	24	410	2,339	2,750	85.1%
2009	1,715	19	29	-	4	12	679	1,779	2,458	72.4%
2010	3,128	13	45	6	3	85	672	3,380	4,052	83.4%
2011	2,314	30	91	15	-	-	746	2,517	3,254	77.1%
2012	2,930	8	45	7	-	63	415	3,055	3,470	88%
2013	908	26	115	9	-	21	165	1,182	1,347	88%
2016	315	9	49	6	-	2	0	421	916	46 %
2017	1734	11	34	23	-	2	0	1953	1804	>100 %
2018	1 188	9	73	2	-	34	1478	1321	2784	47 %

management by ensuring the safe handling, treatment and disposal of these wastes. The plan provides a documented record of the characteristics of the mineral waste, the disposal sites used, historical and future placement, environmental impacts and projected chemical behaviour in future. Waste storage facilities are placed within permitted areas only. Considerations in the placement are:

- Preferably, place waste within inactive portions of open pits or within existing disturbed areas
- Tie waste repositories into the surrounding topography to maintain regional drainage patterns and reduce visual impacts
- Avoid placement on land with high biodiversity or ecosystem services values
- Avoid placement in or near perennial surface water bodies or in large ephemeral drainage lines
- Avoid placement of chemically reactive waste over important groundwater aquifers or recharge zones
- Avoid placement in areas with significant archaeological or social value
- Avoid placement in close proximity to local communities
- Preferably, place chemically reactive wastes in drainage basins that already contain reactive waste (thereby avoid placement in pristine drainages)
- Avoid placement in areas with poor foundation conditions due to topography, underlying geology or hydrology, and
- Balance economic considerations, such as haul profiles, potential resource sterilisation, and pumping costs with environmental, social and closure considerations.

Waste rock consists of typically coarse, angular fragments of strong rock material that is resistant to mechanical disintegration and chemical decomposition, with the exception of the rock type's amphibole schist and biotite schist. Both of these rock types are occurring in minor quantities in the open pit and are generally associated with uranium grade, mostly processed as ore. Typically therefore, the Rössing dumps are of pervious, frictional material placed on competent, but steeply-sloping foundations of barren country rock.

An inventory of disposed mineral waste is kept at Rössing. It reflects the tonnage per year, the cumulative tonnage, surface area, volume and the location of the waste disposal site. Site maps are maintained by the mine's survey department. The spatial footprint of mineral waste and any changes during a specific year are reported annually.

Reshaping of the new mining and processing landforms represented by the waste rock dumps and the TSF need to be minimised at closure and to achieve this aim, dumping should progressively meet the final landform requirements. Additional work following closure (monitoring and maintenance) should be limited.

With this in mind, Rössing follows a waste rock disposal planning and design strategy. In the case of the TSF, an operating manual sets out the procedures to be followed in accordance with the engineering design. The following management objectives are set:

- Maintenance of geotechnical stability and access control
- Control of radiation and radon emanation
- Prevent contamination through management of surface drainage and rainwater leaching
- Meet long-term objectives through rehabilitation and restoration, and
- Ensure visual appearance and aesthetics fits into the surrounding landscape.

Operational manuals regulate the management of the waste rock dumps and comply with the Rio Tinto Management of pit slopes, stockpiles, spoils and waste dumps standard (Rio Tinto Major Hazard Standard, D3). A similar standard regulates the management of the tailings facility (Rio Tinto Major Hazard Standard, D5).

The likelihood of injury to humans and wildlife is minimized through the design, construction and access control and through ensuring geotechnical stable conditions. In addition the facilities are made inaccessible for temporary and long-term use or habitation.

Inspections of the tailings facility are carried out regularly by the engineer of record who is responsible for the design and implementation of changes to the facility. An independent external technical review team inspects the facility and its design every two years and reports on the findings and recommendations for improvement.

The combined surface area of the waste rock dumps and the TSF is currently calculated at 1377.12 ha. There was no expansion in the surface area of the storage facilities during 2018.

The waste rock dumps and the tailings facility will remain as mining landforms at mine closure. Visual impacts of the final landforms are minimized in order to maintain the characteristics and attractiveness of the surrounding landscape.

Deposition of mineral waste is thus scheduled in such a way that it complements the contours of the surrounding landscape. Rehabilitation actions that allow passive revegetation and integration into functioning ecosystems are the preferred option.

4.5.3 Chemical substance management

Table 5: Mineral waste disposed in 2010-2018 (volumes in tonnes)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Waste rock dumps	40,022,450	39,608,654	33,749,173	25,332,432	15,954,100	12,522,652	16,467,097	15,109,738	11,459,319
Tailings storage facility	11,594,430	10,370,362	12,152,173	11,261,619	7,040,277	6,875,719	9,194,439	8,962,923	8,851,288

Rössing uses existing Namibian legislation, international standards such as ISO 14001:2015, as well as the Rio Tinto Environmental performance standard E15 (Hazard materials and non-mineral waste control and minimisation) for conformances and compliance in terms of chemical substance management.

The aim of Rio Tinto standard is to ensure that the all hazardous materials are handled safely and controlled responsibly, and all risks to the environment are mitigated. For this reason, monitoring programmes are in place to prevent spillages and environmental contamination from the transport, use, storage and disposal of hazardous materials.

A Hazardous material and contamination control management plan (JE20/MMP/002), is in place at Rössing. The plan guides:

- safety and responsibility of usage and control of hazardous material handled by Rössing
- control measures to minimise the risks and the environmental impacts due to spill or other escapes, and
- properly characterise and manage cases of contamination on site.

The Rio Tinto standard requires an inventory of all hazardous substances and locations onsite to be maintained and valid material safety data sheet (MSDS) to accompany the hazardous material during storage, handling and transportation.

The plan also entails controls to prevent or minimise spillages during the handling and storage of chemical substances, conducting of routine inspections, monitoring procedures for leaks, integrity testing for deterioration of storage tanks and pipelines, spill and leakage detection equipment and emergency response plans. Regular internal and external audits, inspections and monitoring take place.

All employees who handle hazardous material are required to attend a compulsory training on hazardous material substances on an annual basis. Stakeholders (suppliers, service providers and end-users) are engaged to provide support in purchasing of chemicals and to ensure continuous improvement.

Furthermore, the plan identifies the needs for engineering controls to prevent spillages (for example, by means of secondary bunds).

4.6 LAND-USE MANAGEMENT

Rössing's footprint is characterised by artificial landforms, which include its waste rock dumps, open pit and TSF. Together with the Processing Plant, offices and linear infrastructures (power lines, pipelines and roads), the total footprint of Rössing is 2549.011 ha (see Table 6).

Sustainable land management is an important tool to promote environmental management and sustainable development. Rössing has developed a land-use plan to manage the process required for the use of any piece of land within the Rössing mining license.

In 2018, the total footprint at Rössing has not increased because there were no new projects on pristine land.

4.7 BIODIVERSITY MANAGEMENT

Biodiversity management aim to minimise the business impact on biodiversity and aspires to contribute to the conservation of biodiversity. Biodiversity is managed through the Biodiversity action plan (BAP) that has been developed based on the mitigation hierarchy of avoiding, minimising and rehabilitation impacts.

Rössing has made a commitment as part of its health, safety and environment policy to enhance biodiversity protection by assessing and considering ecological values and land-use aspects in investments, operational and closure activities.

In 2018, Rössing was involved in various biodiversity awareness capacity-building projects aimed at understanding and protecting biodiversity.

4.7.1 Powerline survey

Table 6: Rössing Uranium's footprint, 2013-2018		Total in 2013*	Total prior to 2014*	Total in 2015*	Total in 2016*	Total in 2017*	Total in 2018*
Infrastructure	Plant	195.44	195.44	195.44	195.44	195.44	195.44
	Roads	24.22	24.22	24.22	24.22	24.3	24.3
	Water	6.45	6.45	6.45	6.45	6.45	6.45
	Infrastructure rehabilitated	39.91	39.91	39.91	39.91	39.91	39.91
Non-infrastructure	Open Pit	457.5	457.5	457.5	457.5	457.5	457.5
	Waste rock dumps	745.25	747.30	747.35	747.45	747.45	747.45
	Tailings storage facility	734.14	737.05	737.24	741.70	742.22	742.22
	Explorations	7.34	7.34	7.34	7.34	7.34	7.34
	Other	275.54	275.54	275.54	275.54	275.54	275.54
	Non-infrastructure rehabilitated	52.86	52.86	52.86	52.86	52.86	52.86
Total		2538.65	2543.61	2543.85	2548.40	2549.01	2549.01

Direct avian mortality from collisions with power transmission lines is one of the impacts on birds that need to be monitored. Three power lines have been monitored on a quarterly basis since 2015. No bird mortality was observed during 2018.

The outcome of the monitoring of avian mortality feeds in the national plan of monitoring and managing power-line/bird interactions and is incorporated into the planning of future power-line networks the through NamPower/Namibia Nature Foundation (NNF) strategic partnership.

4.7.2 Invertebrate survey

In 2018, invertebrate monitoring in the rocky areas continued, as was recommended in 2016 that Rössing do least three monitoring exercises in this area; 2018 was the third sampling year.

About sixty sampling points were prepared where 2.5 litre pit trap buckets were set up at the Dome and Rocky Hills sites in April. The buckets were removed after ten weeks. Sorting and identification of concentrated trap contents was done by Biodata Consultancy. The processed specimens were donated to the National Museum of Namibia for safekeeping. Consistently, more specimens have been recorded at the Dome site compared to the Rocky Hills site.

Over the three years, invertebrate numbers at the Dome site have increased each successive year, while the numbers at the Rocky Hills have decreased each year. At least 48 of previously unrecorded taxa were recorded. The trap-door spider *(Moggridgea eremicola)* has still not been found, the species that the intensive sampling intended to record. This species is listed as Critically Endangered, and it is not known whether it still persists in this area.

The study recommended three more years of sampling; however, this recommendation will need to be discussed in light of all indications that *Moggridgea eremicola* is a rare species and the sampling should align with the business environmental objectives for the future. The 2015 report, which evaluated the 5-year monitoring effort, indicated that the mine's operation has no impact on the abundance of invertebrate species, and this should be sufficient to discontinue sampling in the Dome and Rocky Hills sites. The envisioned plan for the invertebrate will be to focus monitoring efforts on rehabilitated areas that will give input into the mine's restoration efforts.

4.8 Management of rehabilitation

Rehabilitation is a general term referring to all measures taken to repair damaged environments, including removal of infrastructures, cleaning up pollution and revegetating (Burke, 2007:5). Rehabilitation is part of the mitigation hierarchy of biodiversity management.

4.8.1 Progressive rehabilitation

The Rio Tinto Environmental standard, E14 – Land disturbance control and rehabilitation, requires business units to undertake rehabilitation as soon as practicable on land that is no longer needed for current or future operational requirements. About 10 per cent of Rössing's total operational footprint is available for progressive rehabilitation before closure. Therefore, 90 per cent of Rössing total operational footprint is still in operational use. Rehabilitation plans of these areas are addressed in the closure plan.

Progressive rehabilitation refers to the demolition of facilities, clean-up of waste and soil pollution, reshaping and re-vegetation works undertaken during the life of a project as soon as practical, following the cessation of use of an area. About 100 ha of the Upper Dome Gorge area was earmarked for progressive rehabilitation in 2018.

The Upper Dome Gorge area has been disturbed substantially during the construction phase of the mine. In addition to quarrying sand from the river bed and gravel from hard rock outcrops, flood retention structures, pipelines leading to the contractor camp, power lines and exploration tracks were established in the early 1970s.

The first part of rehabilitation exercise was carried out by a local contractor. The planned work involved demolishing redundant infrastructure and facilities, clean-up activities of waste and litter, removal of buried waste, landscaping (slope stability and erosion protection) and ecological restoration. Over 350 tonnes of waste from dismantled facilities, litter and buried rubble were removed in this exercise and disposed on the mine's landfill.

A successfully survey of ground penetrating radar was conducted to map buried historical waste in the area to confirm the depth and thickness of buried waste. The buried waste characterisation is planned for 2019.

Undertaking progressive rehabilitation facilitates the development of the knowledge and capability to meet the rehabilitation targets and restoration criteria. It also aids in the best techniques and options for rehabilitation, especially in the hyper-arid area the mine operates. It furthermore leads to timely adjusted operating cost and budgeting for future work, such as landscaping and ecological restoration, which is planned to be completed in the next few years.

4.9 CLOSURE PLANNING

Mine closure is an integral part of Rössing's mine planning cycle, from exploration via mine development and production to decommissioning and after care. Therefore, closure planning has been a continuous process at Rössing since 1992.

Changes in operational circumstances, environmental conditions, legislative and regulatory frameworks, and stakeholder expectations were considered every time plans were updated over the past 26 years. Current life-of-mine plans foresee cessation of mining and processing in 2025.

Rössing's closure plan is guided by an aspirational vision for a post closure situation that is translated into objectives and targets. The vision considers mitigating the socio-economic impact closure would have on the employees, the neighbouring towns of the Erongo Region, as well as on the environment around the site.

Principally, the open pit will not be backfilled; it will remain a mining void into the future. The TSF will be covered with waste rock to prevent dust emissions and rainwater erosion.

Rössing will continue recovering tailings seepage, but instead of reusing it for mining processes, it will be allowed to evaporate. The Processing Plant and the mine's infrastructure will be demolished. Recyclable materials will be decontaminated before selling. Materials not leaving the mine site will be disposed of safely and sufficiently covered so that they cannot cause harm.

To achieve these objectives and targets, Rössing has developed implementation plans for mitigation measures and calculated the associated closure costs. The development of a detailed closure plan at pre-feasibility level, containing more technical detail and higher cost-estimation accuracy than the current plan, has started in 2018.

Rainfall statistics have been confirmed by incorporating paleo flood events into the analysis. A start has been made to confirm that the planned rock cover for the TSF will not cause slope instability due to rainwater infiltration.

Detailed engineering designs for various alternatives to transfer long-term tailings seepage to an open pit lake for evaporative disposal have been completed, allowing an informed choice to be made. A preliminary execution plan for the rest of the prefeasibility study has been completed.

The establishment of the Rössing Environmental Rehabilitation Fund, which provides for expenditures associated with the mine's closure, complies with statutory obligations and stipulated requirements of both the Ministry of Mines and Energy and the Ministry of Environment and Tourism. Accordingly, the fund agreement states that each year Rössing will make a contribution to the fund to provide for the eventual closure of the mine.

At the end of December 2018, the fund had a cash balance of N$845 million. In 2018, the total cost of closure, excluding retrenchment costs, was estimated at N$1.66 billion. The mine will make additional payments to the fund each year to provide for the eventual total cost of closure by 2025.

4.10 CASE STUDY - 30 years of Khan River vegetation monitoring

Since Rössing operation started in 1976, the mine has extracted brackish water from the Khan River for industrial purposes. In 2018, Rössing reached a milestone of 30 years of commitment of monitoring the riparian vegetation along the mine frontage of the Khan River.

Early research indicated that the abstraction could impact the dependent vegetation and associated biodiversity of the Rössing compartment of the Khan River. Rössing hence requested the Council for Scientific and Industrial Research (CSIR) of South Africa to develop a monitoring programme that would assess the impacts of water abstraction from the Khan River on the vegetation in the river bed.

The water abstraction was permitted by the Department of Water Affairs (DWA) by granting an abstraction permit with the condition that the Khan River vegetation is regularly monitored. Accordingly, Rössing implemented the recommended monitoring programme in 1988, which is still in place.

The first objective of the programme is to ensure that changes in the vitality of the trees due to ground water abstraction are noticed early enough to adjust the pumping rate and to prevent irreversible damage to the vegetation, as well as to ensure compliance to the Khan River abstraction permit conditions.

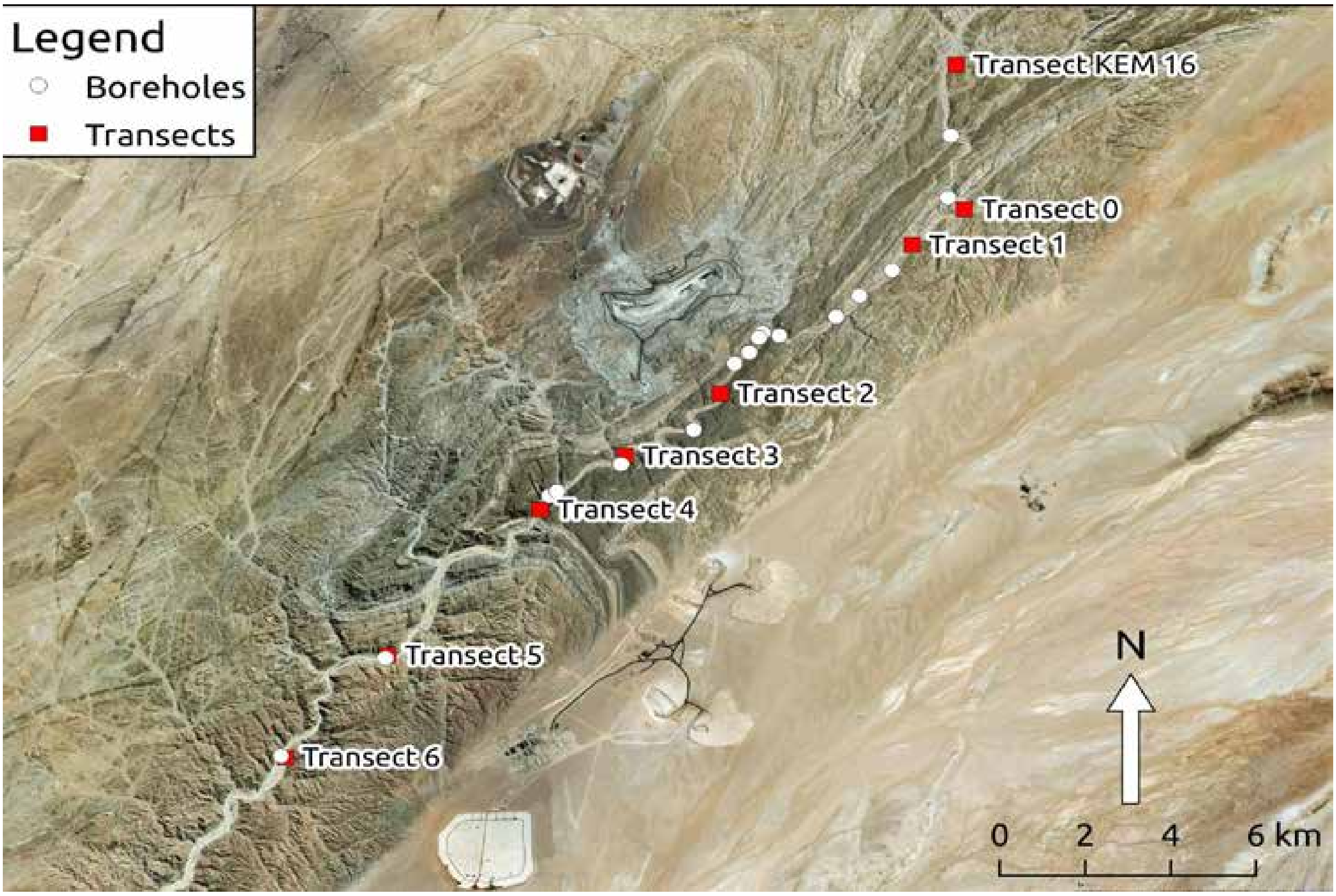


Figure 14. Location of transects and production boreholes (Drawing: Sokolic, 2018)

The programme consists of monitoring eight sites of which six (transect 1-6) were chosen in 1988 whilst transect 0 and KEM16 were chosen in 1993 and 1996 respectively when new production holes were introduced. Each transect has about eight trees that are identified and tagged. The monitoring is carried out twice a year, in March and September respectively. The transects are positioned over a total distance of 22 kilometres along the banks of the Khan River (see Figure 14).

The trees' general conditions are assessed during the survey by recording the presence of flowers, production of pods, as well as assessing the leaves' conditions and estimating the proportion of dead branches. Fixed-point photography is also employed during each survey. Each tree's trunk circumference and height are measured. The results are reported annually to the DWA. Over the years, the monitoring programme has informed management decisions to reduce the number of production boreholes from ten to two.

In 2018, a qualitative research approach was used to evaluate the Khan River riparian vegetation monitoring programme in respect of its effectiveness as a case study for a master thesis. The research assessed to what extent the monitoring programme has been effective to satisfy Rössing's management requirements. The programme was reviewed against set criteria by gathering information through semi-structured interviews with key informants and review of records.

Previous research on evaluation criteria has shown that there is no one-size-fits-all approach that will satisfy all monitoring programmes, but certain key characteristics have been proven to be instrumental in the effectiveness of a monitoring programme.

The findings of the present review revealed that the Khan River riparian vegetation monitoring programme's effectiveness can be attributed to continuous funding, committed leadership, the sharing of data with research institutes and regular review ensuring legal compliance over the years.

Long-term monitoring programmes are a valuable part of environmental management. They provide evidence-based information that informs policy, environmental management decisions and contribute to new knowledge. Long-term monitoring provides insight into changes in the ecosystem that cannot be determined from short-term research.

The Khan River vegetation monitoring programme will continue for the years to come, at least as long as Rössing abstracts water from the Khan River.

5. APPENDIX

Environmental monitoring network at Rössing