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ENVIRONMENTAL SUPPORT AND EIA

AQUATIC BASELINE AND IMPACT ASSESSMENT REPORT

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EXECUTIVE SUMMARY

Haib is a porphyry copper exploration Project located in the //Karas Region of southern Namibia, approximately six (6) kilometres (km) north of the border with South Africa and between 12 km and 15 km east of the tarred B1 highway that connects Namibia with South Africa.

The Project is currently in the exploration and studies phase, whereby the feasibility of the Project is being defined through ongoing investigations and analysis. Knight Piésold Consulting (Pty) Ltd (KP Namibia) was appointed by Haib Minerals (Pty) Ltd to support in the development of the environmental scoping and impact studies and ongoing regulatory compliance. This aquatic baseline and impact assessment report is required for the scoping phase of the Project. This report describes available information on aquatic areas that will potentially be impacted by the proposed Project and activities that will be associated with the construction and operational phases.

Towards advancing the copper mining activities at Haib, a comprehensive Environmental and Social Impact Assessment (ESIA) with associated Environmental and Social Management Plan (ESMP) and public consultations are currently being undertaken and developed in accordance with the Namibian national requirements and the International Finance Corporation (IFC) standards. The ESIA is being prepared to obtain an Environmental Clearance Certificate (ECC) for the proposed Project from Namibian authorities and to support the standards of disclosure required by the Canadian Securities Administrator in a technical report (NI 43-101) providing environmental, social compliance components.

The proposed Project comprises an open pit mine, a 28 Mtpa crushing, milling and flotation concentrator, a hydrometallurgical plant consisting of an 7 Mtpa heap leach, copper solvent extraction, impurity removal and copper electrowinning plant, as well as infrastructure on and off site necessary to support these operations (waste rock dumps, stockpiles, tailings storage facilities, pipelines and abstraction works, power infrastructure, roads, offices, etc.). The operation will achieve a combined throughput of 35 Mtpa.

This report presents the results of a comprehensive aquatic biomonitoring study conducted at multiple points along the Orange River, assessing seasonal (dry and wet) changes in biological and chemical water quality. Monitoring focused on a range of key indicators, including *in-situ* water quality parameters, habitat integrity, macroinvertebrate biodiversity, fish community composition, diatom-based water quality, microbiological analysis, and water chemical analyses to establish a baseline environmental condition and identify potential stressors impacting the river ecosystem.

Site Selection

The assessment aimed to determine the aquatic baseline conditions towards ensuring effective monitoring and management of potential impacts. As a result, sites were strategically selected based on potential impacts to aquatic ecosystems due to the project activities. To ensure comprehensive results, five (5) sites, namely I1, C1, D1, D2 and D3 were selected, and placement thereof were based on suitability to assess potential impacts, accessibility and representative features.

In-Situ Water Quality

In-situ measurements revealed that most water quality parameters across all sites were within South Africa's Department of Water and Sanitation (previously Department of Water Affairs (DWAF)) guidelines. However, elevated Temperature and Dissolved Oxygen saturation were observed at site D3, likely due to seasonal changes and low flow velocities in shallow sections. All other parameters remained within acceptable guideline limits.

Invertebrate Habitat Assessment System (IHAS)

Habitat quality was generally low across all sites, with IHAS scores reflecting poor habitat availability. Sites C1, D1, and D3 demonstrated limited macroinvertebrate-supporting habitats due to eroded riverbanks, invasive vegetation (predominantly *Prosopis grandulosa*), and altered flow regimes. Only one site (I1) showed a relatively better habitat quality, though still reflecting moderate modifications.

Aquatic Macroinvertebrate Assemblage (SASS5)

Macroinvertebrate responses indicated ecological degradation, with SASS5 scores and Average Score Per Taxon (ASPT) values reflecting Largely to Seriously Modified conditions across most sites. Only site D3 initially presented improved conditions; however, the analysis of the dominant pollution-tolerant categorised the site into Category E (Seriously Modified). Reduced biodiversity and sensitive taxa abundance suggest long-standing ecological stressors such as habitat degradation and poor water quality.

Ichthyofauna (Fish) Assessment

Fish surveys recorded variable species presence and abundances, with fish communities dominated by tolerant species. All sites recorded low scores based on the Fish Assemblage Integrity Index (FAII) assessment, with most sites falling into Ecological Category D or E, indicating Largely to Seriously Modified Ecological States. Site D3, the furthest downstream site, had the lowest species richness despite the presence of commercially and ecologically important species such as *Labeobarbus kimberleyensis*.

Diatom Assessment

Diatom indices indicated moderate to poor biological water quality at all sites, closely linked to increasing nutrient loads and salinity, particularly during the wet season. The most affected site was D2, with a poor SPI score (Category D). Sites C1, I1, D1, and D3 showed moderate deterioration in taxa composition, strongly associated with agricultural runoff and fluctuating hydrological conditions. No valve deformities were detected, minimising the concern for metal toxicity.

Microbiological Analysis

Elevated Total Coliform and *E. coli* counts were detected at all sites during the wet season, with considerably high counts observed downstream, particularly at sites D1 and D2. These readings highlight contamination most likely from agricultural runoff from the adjacent farms along the Noordoewer stretch and from further upstream faecal inputs.

Chemical Water Quality

The chemical analysis identified several parameters exceeding DWAF and IFC guideline values:

- Elevated Aluminium, Iron, Zinc, and Copper concentrations were noted across the various sites and seasons, with probable sources including natural geology, and agricultural activities.
- Mercury was detected and exceeded guideline limits at the downstream sites (I1 and D2) during the dry season.
- Nitrate and Total Suspended Solids (TSS) levels were elevated downstream of the proposed Project area, attributed primarily to fertiliser use and sediment input from agricultural drainage channels.
- Other concerns include increased salinity, nutrient enrichment (most likely due to Nitrogen), and potential long-term risks associated with metals like Arsenic and Chromium. While these did not exceed guideline limits in the water samples, sediment-bound concentrations in previous studies (Erasmus, et al., 2024) indicate future risks through sediment resuspension events, and bioaccumulation in benthic feeders that serve as a source of protein for various communities along the Orange-Senqu River basin.

Following the impact assessment of the proposed Project, the potential impacts to the aquatic ecosystems associated with the **pre-construction** and **construction phases** of the proposed Project include:

- **Increased Sedimentation and Habitat Alteration**: Due to the arid nature of the project area and implementation of erosion control measures, this is expected to be of LOW significance before and after mitigation.
- **Habitat Loss**: Given the lack of natural diversity at this river segment, the impact remains LOW in significance both pre- and post-mitigation.
- **Community Assemblage Changes**: Given the existing degraded baseline conditions, any changes are expected to be of LOW significance.
- **Loss of Sensitive Fauna**: Few sensitive taxa were observed during baseline surveys, potential impacts to sensitive macroinvertebrates and fish communities are considered LOW in significance.
- **Water Quality Deterioration**: Increased runoff risks carrying sediments and hydrocarbon pollutants into the Orange River. The implementation of standard best practice mitigation methods limits this to a LOW significance impact.

The potential impacts to the aquatic ecosystems associated with **operational phase** impacts include:

- **Water Quality Deterioration**: Infrastructure failures or routine discharges may introduce pollutants into the river. Initially rated MODERATE, this impact is reduced to LOW with effective mitigation, such as bunding, containment, and water treatment systems.
- **Contribution to Algal Blooms**: Operational discharges may add nutrients to a system already experiencing frequent algal blooms. Due to the existing eutrophic conditions, the incremental contribution is considered LOW significance.
- **Loss of Aquatic Habitat and Biodiversity (In case of catastrophic failure)**: In the event of a tailings dam breach or critical infrastructure failure, significant aquatic ecosystem damage

could occur, potentially reaching the Atlantic Ocean. This is a worst-case scenario and is rated HIGH significance, reduced to MODERATE with appropriate design, monitoring, and emergency containment plans.

- **Increased Sediment Runoff and Erosion**: Runoff from operational areas such as stockpiles and waste dumps could worsen local sedimentation. While inherently MODERATE, the arid climate, terrain, and separation from the river reduce the impact to LOW significance post-mitigation.

The potential impacts to the aquatic ecosystems associated with **decommissioning and closure phase** impacts include:

- **Physical Disturbance, Alteration of Natural Flows and Contamination**: Decommissioning activities may result in increased sediment mobilisation and potential spillages, as well as altered flow through removal of stormwater management infrastructure. This impact is considered to be of LOW significance.
- **Rehabilitation Of Footprint Area**: The rehabilitation of the decommissioned infrastructure footprint areas will promote the re-establishment of vegetation which may serve as barriers to erosion and increase habitat availability for aquatic fauna within the marginal and riparian zones. This is a positive impact of MODERATE significance.

The integrated assessment indicates ecological degradation across much of the study area, driven by altered habitats, nutrient-enriched waters, microbiological contamination, and heavy metal presence which is largely linked to past and ongoing agricultural, mining, and residential activities within and upstream of the Orange River catchment. Despite some spatial and temporal variability, the overall ecological state ranges from Moderately to Seriously Modified. These results serve as a valuable environmental baseline to guide future monitoring and management interventions.

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ABBREVIATION

Al ..... Aluminium
ALARP ..... As Low As Reasonably Practicable
ANALAB ..... Analytical Laboratory Services
As ..... Arsenic
ASPT ..... Average Score Per Taxon
Cd ..... Cadmium
Cr ..... Chromium
Cu ..... Copper
DAS ..... Dust-a-Side
DO ..... Dissolved Oxygen
DSM ..... Deep South Mining Company
DWAF ..... Department of Water Affairs and Forestry
EC ..... Ecological Category
ECC ..... Environmental Clearance Certificate
EPL ..... Exclusive Prospecting Licence
ESIA ..... Environmental and Social Impact Assessment
ESMP ..... Environmental and Social Management Plan
FAII ..... Fish Assemblage Integrity Index
Fe ..... Iron
GFM ..... Great Fitzroy Mines
GISTM ..... Global Industry Standard for Tailings Management
GPS ..... Global Positioning System
GSM ..... Gravel, Sand and Mud
GWh ..... Gigawatt hour
Hg ..... Mercury
HM ..... Haib Minerals
HPGR ..... High-pressure grinding rolls
I&APs ..... Interested and Affected Parties
IFC ..... International Finance Corporation
IHAS ..... Invertebrate Habitat Assessment System
IPP ..... Independent Power Producer
IUCN ..... International Union for Conservation of Nature
K ..... Potassium
KP ..... Knight Piésold Consulting
kv ..... kilovolt
LDV ..... Light delivery vehicles
LOM ..... Life of Mine
m ..... metre
m^3/day ..... cubic metres per day
MEFT ..... Ministry of Environment, Forestry and Tourism
Mg ..... Magnesium
MIME ..... Ministry of Industries, Mines and Energy
ML ..... Mining Licence
mm^3/yr ..... cubic metres per year

Mn .... Manganese
MSB..................... Modified Single Buyer
Mtpa .... Million tonnes per annum
MWh .... Megawatt-hour
MWp .... Megawatt-peak
NASS..................... Namibian Scoring System
NCJV .... Namibian Copper Joint Venture
Ni .... Nickel
Pb .... Lead
PEA .... Preliminary Economic Assessment
PES .... Present Ecological State
PTV .... Pollution Tolerant diatom Valves
PV..................... Photovoltaic
QV .... Quality Value
ROM .... Run of Mine
RQO .... Required Quality Objective
RTZ .... Rio Tinto Zinc
SASS5..................... South African Scoring System version 5
SPI..................... Specific Pollution Sensitivity Index
SWAD..................... Storm Water Attenuation Dam
TDS .... Total Dissolved Solids
TOS .... Trade-Off Study
TSF..................... Tailings Storage Facility
TSS .... Total Suspended Solids
US EPA .... United States Environmental Protection Agency
WMA..................... Water Management Area
WRD..................... Waste Rock Dump
Zn .... Zinc

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

The Haib Copper Project is located in the south of the //Karas region of Namibia, close to the border with South Africa as defined by the Orange River (Figure 1-1). The Project is located at a latitude of approximately 28°41’48” and a longitude of approximately 17°52’59” (Figure 1-1). The Project is situated between 12 km and 15 km east of the main highway connecting South Africa to Namibia (B1). The Orange River runs immediately to the south of the EPL, and a number of farms surround the EPL. The biggest portion of EPL 3140 lies on state land. The eastern part of the EPL is located on Farm Tsams and the Farm Withoek is located within and on the north-eastern boundary of the EPL.

The Haib deposit straddles the Volstruis River, which is a tributary of the Haib River. Both are ephemeral tributaries of the Orange River, which lies south of Haib. The Haib deposit has a distinct surface expression with abundant copper staining on fractures and joint planes, particularly in and around the dry riverbed of the Volstruis River.

Towards advancing the copper mining activities at Haib, a comprehensive Environmental and Social Impact Assessment (ESIA) with associated Environmental and Social Management Plan (ESMP) and public consultations are currently being undertaken and developed in accordance with the Namibian national requirements and the International Finance Corporation (IFC) standards. The ESIA is being prepared to obtain an Environmental Clearance Certificate (ECC) for the proposed Project from Namibian authorities and to support the standards of disclosure required by the Canadian Securities Administrator in a technical report (NI 43-101) providing environmental, social compliance components.

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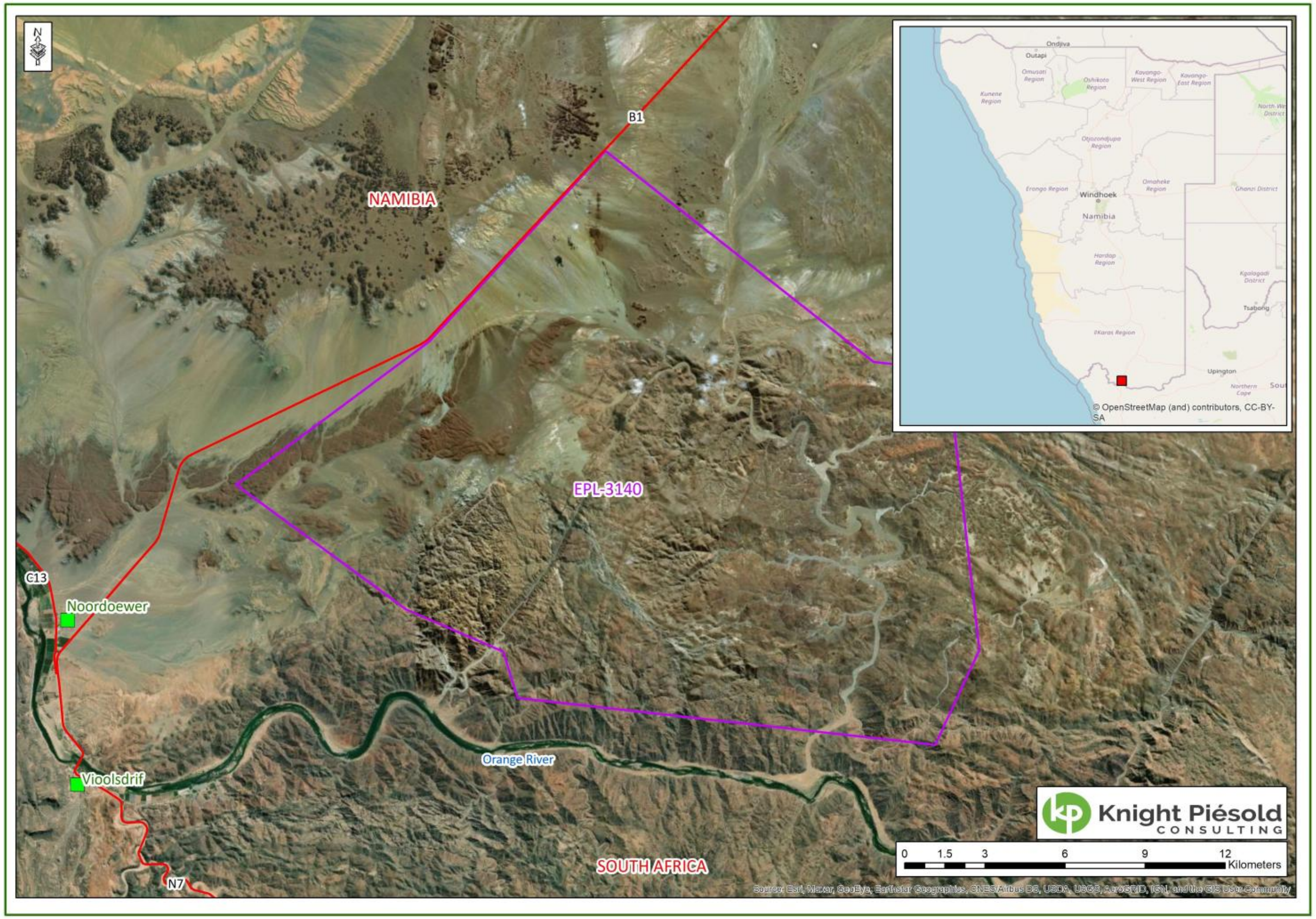

Figure 1-1: Location of EPL 3140

1.2 PROJECT DESCRIPTION

The proposed Project comprises an open pit mine, a 28 Mtpa crushing, milling and flotation concentrator, a hydrometallurgical plant consisting of an 7 Mtpa heap leach, copper solvent extraction, impurity removal and copper electrowinning plant, as well as infrastructure on and off site necessary to support these operations (waste rock dumps, stockpiles, tailings storage facilities, pipelines and abstraction works, power infrastructure, roads, offices, etc.). The operation will achieve a combined throughput of 35 Mtpa. The mining schedule indicates a total material movement of approximately 87.5 Mtpa, providing approximately 23 years' supply of mineralised material. This equates to a total of 1.58 billion tonnes of material to be mined.

1.2.1 SITE LAYOUT

The Haib deposit lies at elevations from a floor elevation of just under 375 meters above mean sea level (mamsl) to over 600 mamsl. The surrounding area is up to about 650 mamsl at the highest point. The area is rugged with steep-sided valleys and rugged local relief. Flatter topography is present in the west and north-west portions of the EPL footprint, but these areas are far away from the Haib deposit.

The site layout has been designed around critical landform features such as topography, sensitive biodiversity areas, and heritage features. The optimisation has additionally considered the efficiencies required for the mining operation. The proposed site layout is provided in Figure 1-2.

Although the mine development is at an advanced conceptual phase, the key components and potential options to be further assessed include the following:

- A single large open pit
- A concentrator processing plant (crushing, milling and flotation circuit with a capacity of 28 Mtpa)
- A heap leach, solvent extraction and electrowinning plant (capacity of 7 Mtpa with two alternative sites provided)
- A tailings storage facility (TSF) (three alternatives provided)
- Two Waste Rock Dumps (WRDs) (0.273Mt and 1.017 Mt)
- A solar photovoltaic (PV) plant (150 MWp)
- Storm water attenuation dams (SWADs) upstream of the open pit
- Off-channel water storage
- Water abstraction works, pipeline and associated infrastructure (Two alternatives provided)
- Ancillary infrastructure (access roads, transmission lines, labour accommodation camp, offices, etc.)

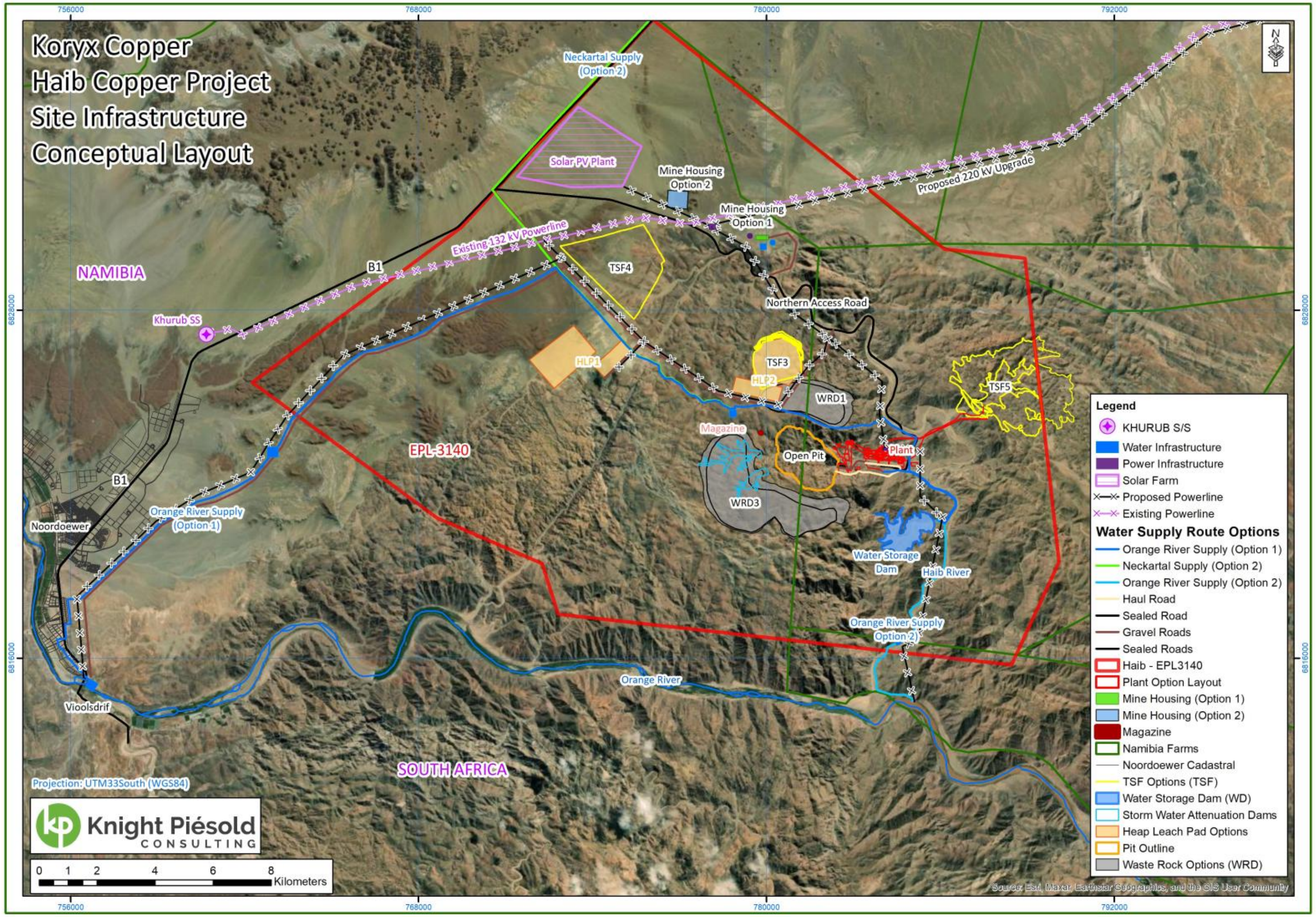

Figure 1-2: Haib Copper Site Layout (inclusive of alternatives)

1.2.2 MINING INFRASTRUCTURE AND SERVICES

1.2.2.1 MINERALISATION

The Haib mineralisation is hosted within two different structural domains (the Northwest (NW) and Southeast (SE) zones) separated by an approximately N-S striking, 60° E-dipping fault, termed "Quartz Vein". The mineralisation of the Northwest zone effectively terminates against an E-W striking shear zone in the northern part of the Project area.

The total strike length of the modelled portion of the deposit is approximately 2,100 m, with the across-strike and down-dip portions typically being 900 m to 1,000 m and 1,000 m, respectively.

1.2.2.2 MINING METHOD AND EQUIPMENT

The Haib Project will make use of conventional shovel and truck operations, with bulk open pit mining methods augmented by more selective mining in areas with narrow mineralised zones. The proposed mining practice for the Project involves an open-pit mining method, with drilling and blasting operations occurring on mineralised benches.

Mineralised material and waste will be loaded with hydraulic excavators and hauled by 240-tonne rigid dump trucks. Mineralised material will be directly tipped into the crusher bin to be routed to the primary crusher, Run of Mine (ROM) pad stockpile, low-grade stockpile, or waste dump.

Mined mineralised material will be stockpiled in paired stockpiles on the ROM pads and at other destinations at the milling and flotation stations, and the heap leach processing plants, depending on the grade and oxidation state. Mineralised material is then re-handled to the different processing plant routes per the feed schedule. In-pit blending will minimise the extent of the re-handling of mineralised material from the stockpile to the primary crusher to cater for short-term grade variations over the Life of Mine (LOM).

It is planned that the mine will operate 361 days per annum on a 24-hour basis. An approved localisation plan will be established to train and equip the Namibian workforce sufficiently, enabling a seamless transition of responsibilities over time. The bulk of the equipment operators are expected to be unskilled (approximately 80%) and will require basic-level training. The start-up strategy for the contract mining operations takes this requirement into account.

1.2.2.3 BLAST OPERATIONS

Rock fragmentation will be undertaken by drilling and blasting, and the Project assumes that all the material to be mined at the Project would require blasting.

1.2.2.4 DRILLING

Drilling is the first operation performed at most open-pit mining operations. For this Project, a diesel crawler down the hole (DTH) drill rig has been selected for the production holes for the mineralised material, waste benches, and the wall control blasting holes.

1.2.2.5 LOAD AND HAUL OPERATIONS

The overall scale of mining envisaged at the Haib Copper Project is a large-sized mine with total material movements of approximately 87.5 Mtpa. In order to manage mineralised material dilution and losses at the Project, selective mining practices have been incorporated into the ore mining methodology.

For the waste and mineralised material mining operation, it is envisaged that large-sized hydraulic face shovels will be operated in the 400-tonne class for selective mining combined with a fleet of 240-tonne rigid dump trucks.

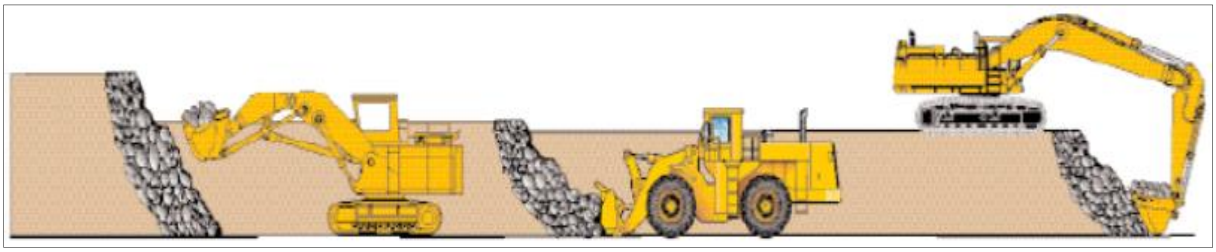

Figure 1-3: Possible loading methods

The hydraulic face shovel, wheel loader and hydraulic excavator will function as the primary loading equipment (Figure 1-3). Rigid frame and articulated diesel trucks have been used in the mining of small to large open pits for many years, and their mechanical capabilities are well respected. It was for this reason that diesel-powered rigid haul trucks were selected for the proposed Project.

During the mining operations, mineralised material would be excavated, and the mineralised material and waste be loaded as per the marked mineralised material and waste boundaries to ensure minimum contamination and maximum recovery of mineralised material.

1.2.2.6 SECONDARY AND TERTIARY (SUPPORT) EQUIPMENT

Secondary and tertiary equipment are mining equipment that falls outside that of the primary production equipment's scope, but which the mine would not function without. This support equipment is the lifeline of reliable and cost-effective mining production by supporting the primary production equipment with the following activities:

- Keeping loading, tipping and haul road areas clean, thus prolonging tyre life and making the operation safe
- Maintaining haul road conditions, thus prolonging tyre life and making the operation safe
- Suppressing dust emissions from a health, safety, environmental and financial perspective
- Supporting the complete equipment maintenance and diesel requirements for remote track-propelled equipment and breakdowns
- Bench preparation and levelling
- Fuelling of track-mounted equipment and dump trucks
- Rehabilitation – Track Dozers.

The tertiary (support) equipment fleet consists of units that assist in tasks that are required to make primary and secondary fleets work easier and safer. Other functions they complete are not production-related and have no direct impact on production, known as support tasks. The fleet consists of:

- Small trucks used for maintenance activities.
- Light delivery vehicles (LDVs) used to transport management, technical services and maintenance personnel around the mine.
- Busses used to transport operators from the change houses to the equipment in the field and back.
- Lighting plant to increase visibility around the excavators during nighttime.
- Pumping equipment for pit dewatering.

1.2.2.7 OTHER MINING ACTIVITIES AND INFRASTRUCTURE

The majority of surface haul roads, dumps, and stockpiles required for the LOM will be constructed during the first year of mining.

The waste dump will progress by the haul truck tipping on the top elevation of the dump with the dozer pushing the waste down. These actions will cause the waste dump to progress horizontally over time. Waste dumps will be progressively rehabilitated with topsoil, where possible. Rehabilitation will be performed as soon as possible on the external faces of the waste dump. Mineralised material stockpile dumps will be constructed in close vicinity to the primary crusher tipping point to minimise the reclamation costs.

Waste rock will also be required for the construction of mine infrastructure, such as ROM pad and tailings storage dam walls.

Mineralised material mined will be stockpiled in paired stockpiles on the ROM pads and at other destinations at the milling and flotation, and the heap leach processing plants, depending on the grade and oxidation state. Mineralised material will then be re-handled to the different processing plant routes per the feed schedule. In-pit blending will minimise the extent of the re-handling of mineralised material from the stockpile to the primary crusher to cater for short-term grade variations over the LOM.

In-pit water management will mainly consist of run-off control around the pit perimeter and temporary sumps at the lowest elevation in the pit. A mobile, trailer-mounted, pit-dewatering pump will pump excess water to the mine pond to be used for dust suppression, and the overflow will be pumped to the mine return water dam close to the plant to be used as processing water and for dust suppression purposes.

Haul road dust suppression is a key requirement considered for the Project. It will be handled through a comprehensive dust management system provided and managed by Dust-a-Side (DAS), an industry leader in this regard, or a similar product. DAS is a bitumen-based product which is applied during haul road construction and maintained on a customised maintenance programme.

1.2.3 PIT AND HAULAGE DESIGN

The objective of the pit design process is to transform the optimal pit shell into a practical pit with ramps, bench and berm configurations, taking into consideration design criteria and geotechnical constraints. The following methodology was followed during the design process:

- Use the selected optimal pit shells derived from the pit optimisation as the design limit.
- Use the latest block model to show the mineralised material distribution.
- Apply the pit design criteria and geotechnical parameters.

The width criterion for a haul segment is based on the widest vehicle in use (likely a Caterpillar 793 240-tonne rigid dump truck). The dimensions of the haul road are based on global standards of good practice.

The ultimate Haib pit design is illustrated in Figure 1-4 (isometric view with pit dimensions) and the pit in plan view illustrated in Figure 1-5.

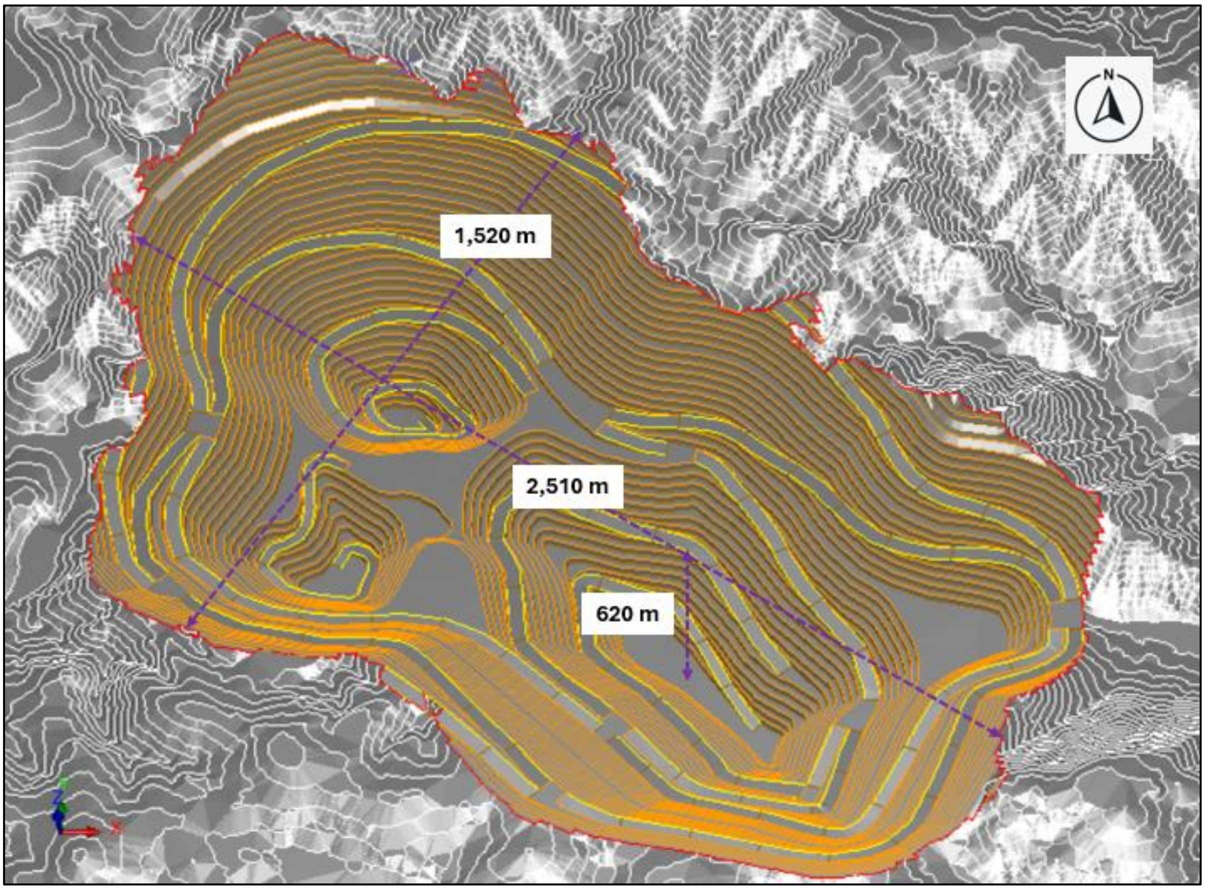

Figure 1-4: Haib ultimate pit design in isometric view

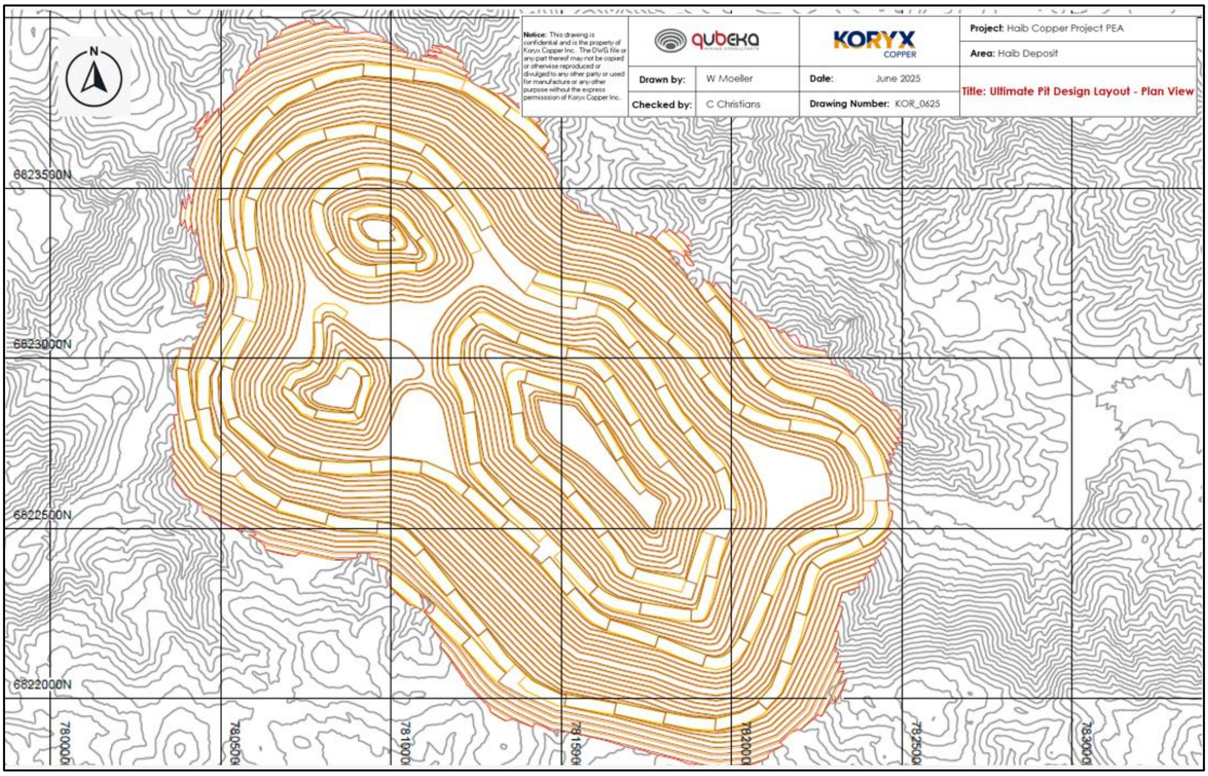

Figure 1-5: Haib ultimate AML pit design in plan view

1.2.4 METALLURGY AND PROCESSING

The mining and processing strategy builds upon the 1997 Feasibility Study, the 2021 Preliminary Economic Assessment (PEA), and the latest 2025 test work. This has resulted in a production plan that integrates a primary 28 Mtpa crushing, milling and flotation circuit in combination with a 7 Mtpa hydrometallurgical plant comprising heap leaching, copper solvent extraction and electrowinning to achieve a combined throughput of 35 Mtpa. The crushing, milling and flotation circuit will process the higher-grade primary sulphide material containing at least 0.275%. The lower-grade sulphide material containing 0.175% - 0.275% Cu will be processed in the hydrometallurgical circuit.

1.2.4.1 CONCENTRATOR PLANT PROCESS DESIGN

As described above, the concentrator processing plant has been laid out to the east of the pit. The ROM tip pads are located close to the pit edge and are at a similar elevation to the pit rim.

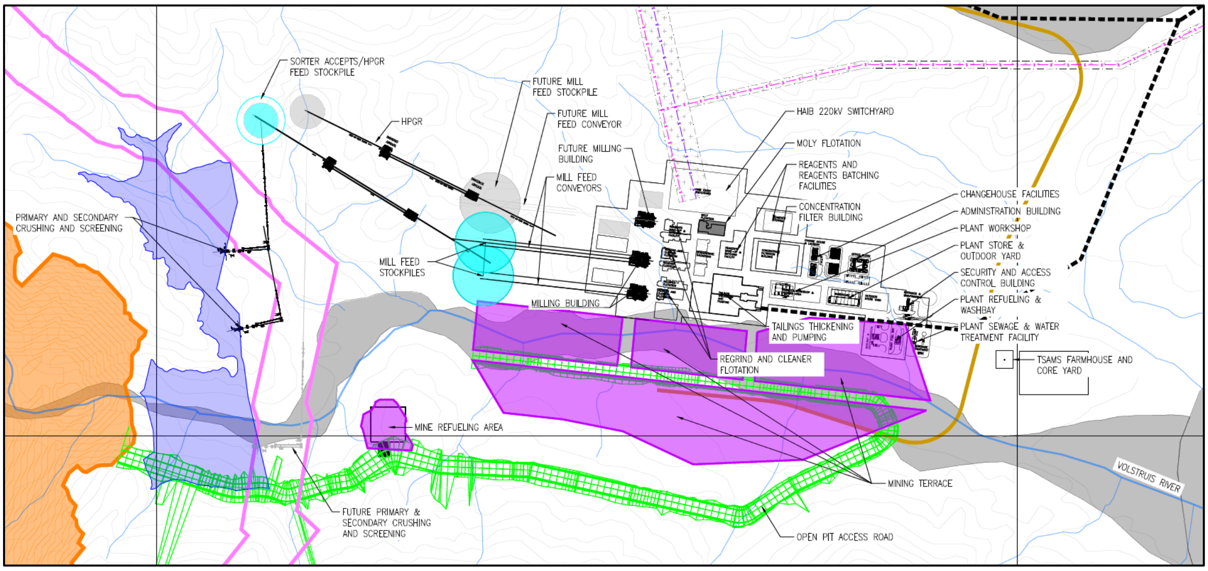

Figure 1-6: Comminution Circuit and Process Plant Infrastructure

Typical process plant supporting infrastructure has been indicated, comprising a change house, administration facility, workshop, stores, reagents stores, sewerage and water treatment facilities. Final copper and molybdenum concentrate will be dried in a filter press and exported by road.

The concentrator design is based on a 28 Mtpa facility, executed in a single phase and comprising two 14 Mtpa crushing, milling and flotation circuit modules. The flowsheet includes the following conventional size reduction and mineral beneficiation unit processes:

- Primary and Secondary Crushing and Screening
- Tertiary High-pressure grinding rolls (HPGR) and Screening.
- Milling and Classification, incorporating Coarse Particle Flotation and Coarse Gangue Rejection
- Copper Rougher Flotation
- Copper Rougher Flotation Concentrate Regrind
- Copper Cleaner and Cleaner Scavenger Flotation
- Copper Concentrate Thickening, Filtration and Dispatch
- Molybdenum Rougher Flotation
- Molybdenum Cleaner Flotation
- Molybdenum Final Cleaner Concentrate Leaching
- Molybdenum Concentrate Dewatering and Dispatch
- Tailings Dewatering and Pumping
- Reagent Delivery, Make-up, and Dosing Facilities
- Services: Air and Water Supply and Distribution.

A simplified summary flowsheet is presented in Figure 1-7.

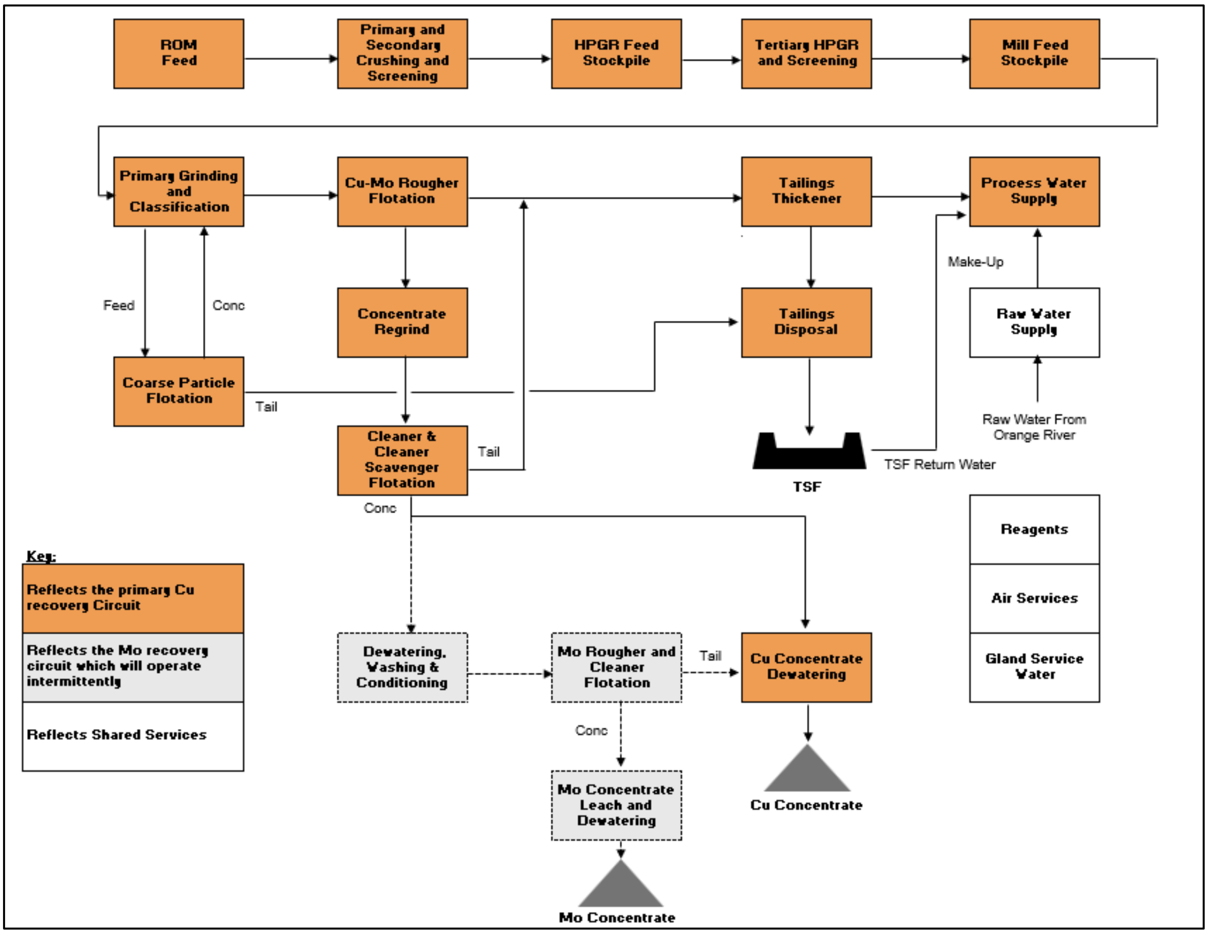

Figure 1-7: Concentrator Plant Simplified Summary Flowsheet

The process will produce separate copper and molybdenum flotation concentrates (dependent on market conditions and feed grade), which will be trucked and shipped to international customers.

1.2.4.2 HEAP LEACH PLANT PROCESS DESIGN

The area in the north-west of the EPL footprint on the flatter plain, as well as the area directly north of the pit have been identified as alternatives currently being assessed for the Heap Leach and Hydrometallurgical plant. Mineralised material will still be crushed at the ROM pads east of the pit and conveyed to the Agglomeration plant before being stacked on the Heap Leach pad.

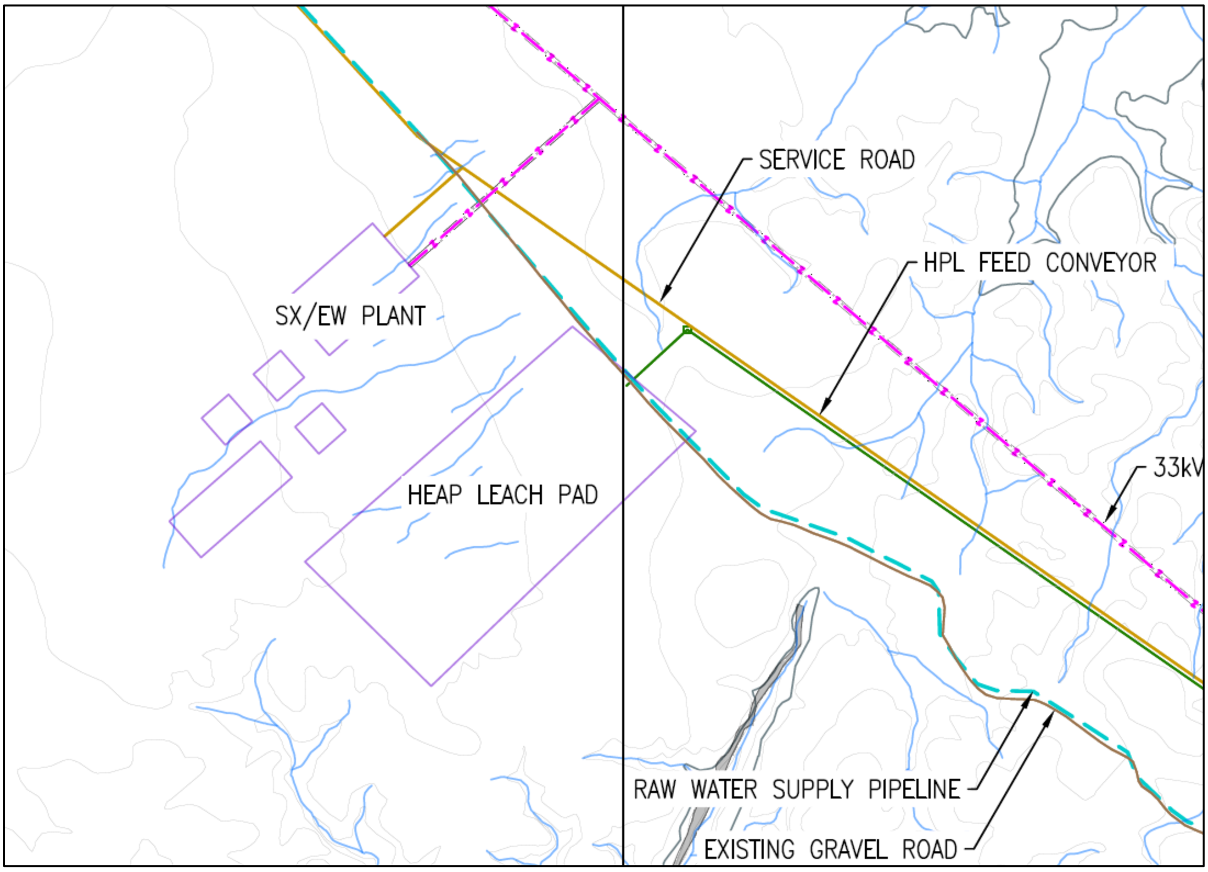

Figure 1-8: Heap Leach Pad and Plant Area (The alternative West of the pit)

The heap leach plant has been sized to process 7 Mtpa of ROM feed to match the steady-state mining production rate. This circuit will treat the lower grade sulphide material containing 0.175% - 0.275% Copper (Cu) and oxides to produce Grade A copper cathode product (99.995% Cu) that will be trucked, railed and shipped to international customers. The hydrometallurgical process uses crushing and screening, conveying, agglomeration, heap leach construction, bacterial heap leach processing, copper solvent extraction, iron removal and copper electrowinning steps that have all been applied on many other mineral projects worldwide. Metallurgical processes in this flowsheet are all based on international best practise. The low-grade mineralised material processing route is provided in Figure 1-9.

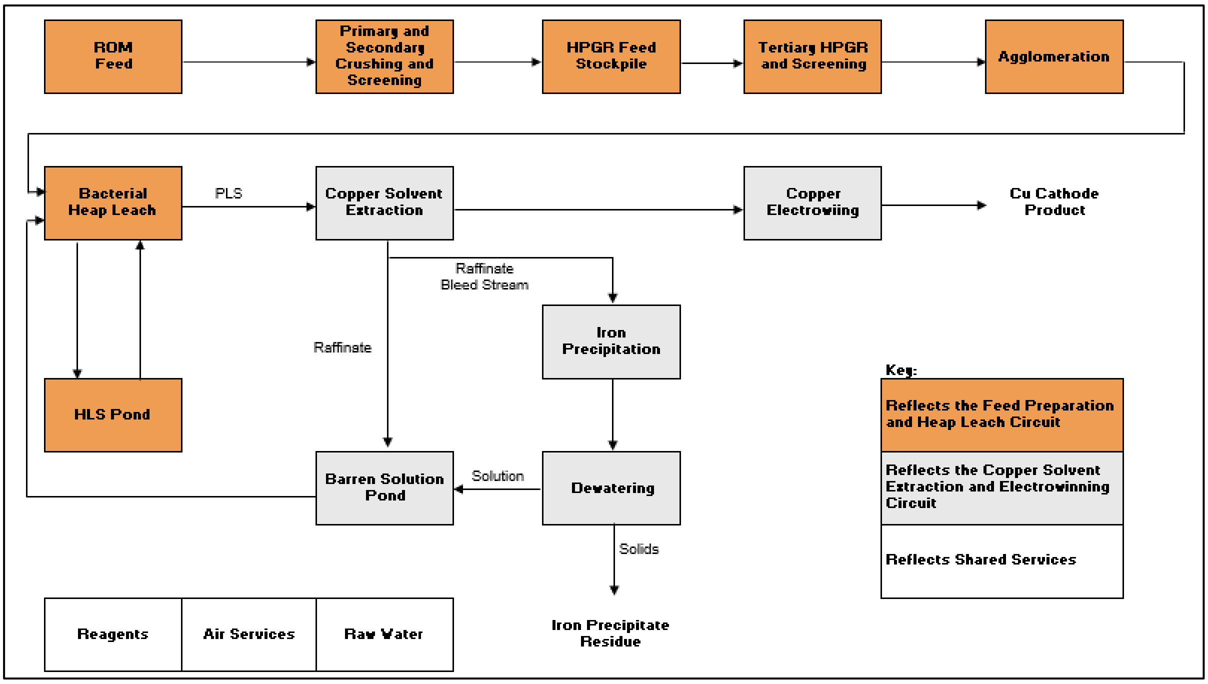

Figure 1-9: Hydrometallurgical Plant Simplified Summary Flowsheet

Three active heaps and possibly also a leach residue (“ripios”) dump will be developed. Mine haul trucks will be used to deliver mineralised material to the ROM tip located to the east of the pit. Low grade mineralised material will be crushed and conveyed over a ridge onto the plain or onto the plateau mentioned above, either from the primary and secondary crushers or after reclamation from low-grade mineralised material strategic stockpiles. Mineralised material will be delivered to a stockpile to feed the planned Heap Leach pad. Irrigation of the leach solution will be accomplished using drippers that are used primarily in arid environments to reduce evaporation compared to heap sprays.

The leach solution arrangements proposed are shown in Figure 1-10. “ILS” refers to intermediate leach solution, “BS” is barren liquor solution and “PROCESS” comprises copper solvent extraction and electrowinning.

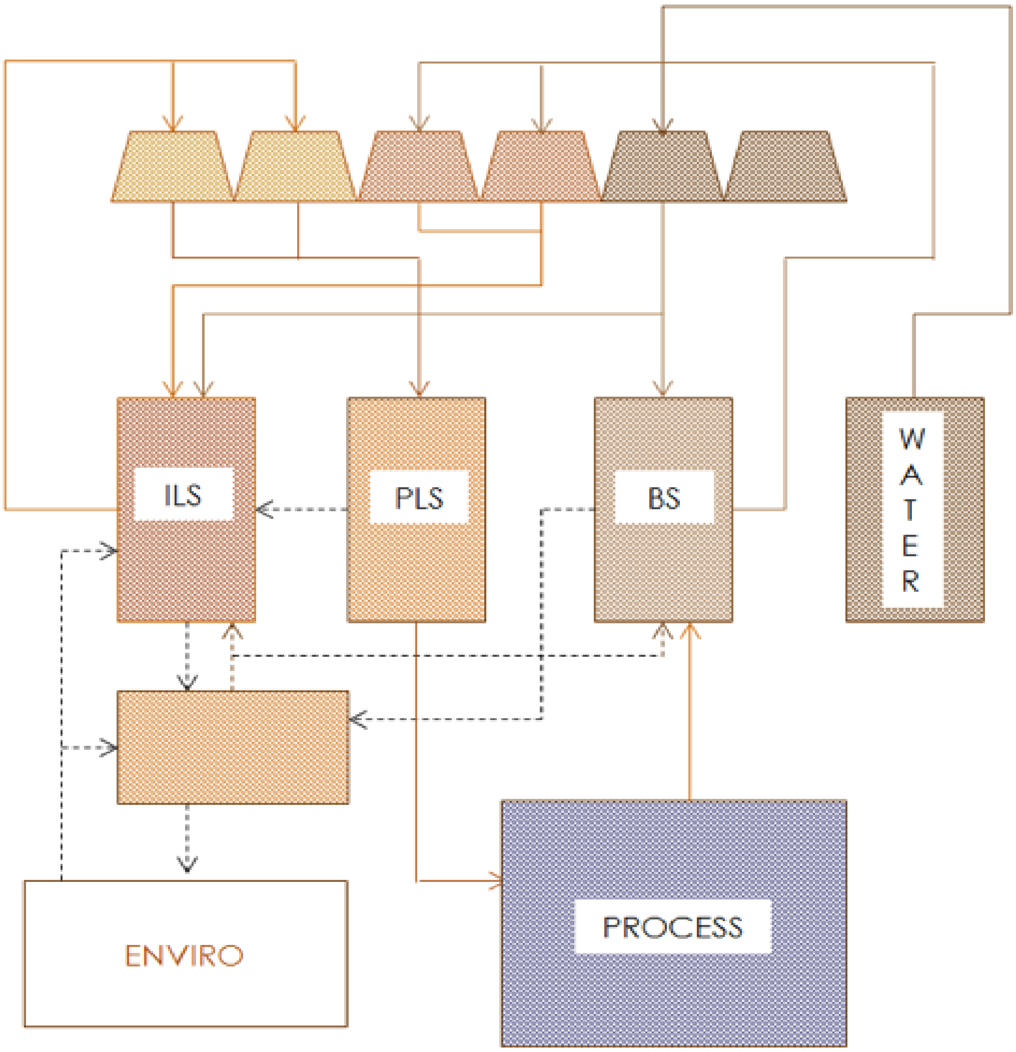

Figure 1-10: Leach Solution Ponds and Piping Interconnections

Electrowinning is an electrolytic technology using two electrodes – an anode and a cathode. In copper electrowinning, the cathode is a copper starter sheet made of copper electroplated onto titanium or stainless-steel blanks. Electrowinning involves applying an electrical potential to the electrodes in the copper electrolyte and then plating pure metallic copper onto the cathodes. The cathodes loaded with metallic copper will be washed in a cathode washing tank. The washed cathodes are then sent to a flexing station and a stripping station to release the metallic copper from the cathodes, while the wash water will be directed to the barren pond. The metallic copper sheets will be transferred to a strapping station and a weighing station, where they will be palletised and weighed prior to being transported to market.

1.2.5 INFRASTRUCTURE REQUIRED AT THE PLANT AND MINE LOCATIONS

1.2.5.1 TERRACING AND BULK EARTHWORKS

The current concentrator processing plant terrace consists of a single terrace.

1.2.5.2 STORMWATER MANAGEMENT

An allowance for contact and non-contact stormwater cut-off drainage and pollution control facilities has been made. The capacities of the facilities will be determined once the terracing and infrastructure requirements and design work commence. SWADs have been included in the facility to manage stormwater runoff into the pit.

1.2.5.3 BURIED SERVICES

The following bulk services were included for both the Plant and Mining terraces:

- Water reticulation
- Sewage reticulation
- Firewater reticulation
- Electrical sleeves.

1.2.5.4 HEAP LEACH FEED CONVEYOR

The option of transporting the low-grade mineralised material to the Heap Leach pad using a conveyor is included.

1.2.5.5 CONCENTRATE AND CATHODE COPPER TRANSPORTATION

A rail, rail and road, and road transportation trade-off study (TOS) was conducted to evaluate possible methods to transport product from the Haib site to market. The TOS investigated routes and methods to reach various harbours in Namibia and South Africa, as well as smelters located in Southern Africa. The transportation modes or options considered included the following:

- A combination of road transportation and a new rail siding on an existing rail line passing through Grunau or Karasburg, to transport mineralised material to the selected destination by rail.
- Road transportation only, from the site to the selected destination.

The following harbours were considered:

- Lüderitz - Namibia
- The harbour’s capacity needs to be confirmed.
- Walvis Bay - Namibia
- No restrictions.
- Gqeberha/PE - South Africa
- Can only handle containerised or bagged materials.

The following Smelters were considered:

- Dundee Smelter - Tsumeb (Namibia).
- Copper Belt Smelters - Lubumbashi (DRC) or Kitwe (Zambia).

The road-rail option has operational cost and flexibility benefits; however, it would require additional rail infrastructure and materials storage and handling facilities with a significant capital cost impact.

The final transportation route is to be determined as the Project progresses.

1.2.5.6 TAILING DELIVERY PIPELINES

There are three (3) tailing delivery pipelines servitudes allocated. The tailings delivery pipelines are from the concentrator processing plant to the following site alternatives:

- TSF Option 3
- TSF Option 4
- TSF Option 5

The TSF delivery line servitude includes a pipeline servitude and a service road. The access road and TSF Option 5 Pipeline cross the Haib River and requires a low-level river crossing that includes a pipeline servitude and roadway.

1.2.5.7 SUPPORT INFRASTRUCTURES AND SERVICES

The following mining infrastructure is required to support safe and efficient mining operations:

- Mining office blocks (office space for mining personnel)
- Geological core shed (storage of core and geological samples)
- Mining change house (ablutions and labour check in)
- Warehouse (storage of all critical and operational spares, as well as office and other consumables)
- Heavy mobile equipment workshop (main shop for maintenance and rebuilds of mining equipment)
- Light vehicle workshop (maintenance of all mine light vehicles, including those operating in the processing plant areas)
- Fuel facility (diesel for mine operations will be delivered by trucks to a designated area. A designed site fuel facility will be inclusive of a hard stand pad for minor maintenance and servicing of mining equipment outside the pit perimeter)
- Explosives magazine and bulk emulsion storage (siting is in conformance with the requirements of the Namibian Labour Act, Namibian Mining Legislation, Regional Explosives Standards or Regulations, and the Explosives Act 26 of 1956 (as amended and made applicable in Namibia; and the Explosives Regulations 1972 (and amendments))
- Communications infrastructure (infrastructure, including communication masts, will be installed, and provisions will be made with the relevant service provider).

1.2.6 OTHER INFRASTRUCTURE

1.2.6.1 SITE ACCESS ROAD

The Project area can be accessed from Windhoek or Noordoewer through the B1 National Highway and then sets of farm roads and tracks developed during the various exploration programmes. Two main access routes from the National Highway to the Mine Processing Infrastructure were investigated during the conceptual design stage, mainly a route going through the elevated plateau, and down very steep terrain, and an alternative route aligned on the side of the Haib Riverbank on more favourable geometrics, gradients, and cut and fill material balance.

The route along the Haib Riverbanks was selected for the conceptual design from a geometry perspective. The terrain makes it easier to achieve vertical and horizontal alignments within specification at lower costs and risks for the proposed Project. This route going through the Haib River basin will require further hydrological and engineering mitigation to manage extreme flood events, such as additional fill, river/flood plain crossing/drifts, and sidehill erosion protection/flood mitigation.

The bi-directional access route conceptual alignment (Figure 1-11) and a typical section on the conceptual level access road meanders along the side of the Haib River topography and creates intentional river course crossings to establish low-level crossings. Notably, the routing consists primarily of the LDV and Hauler type cross-section originating from the area of the process plant and terminating at an intersection with the B1 trunk road (Figure 1-12).

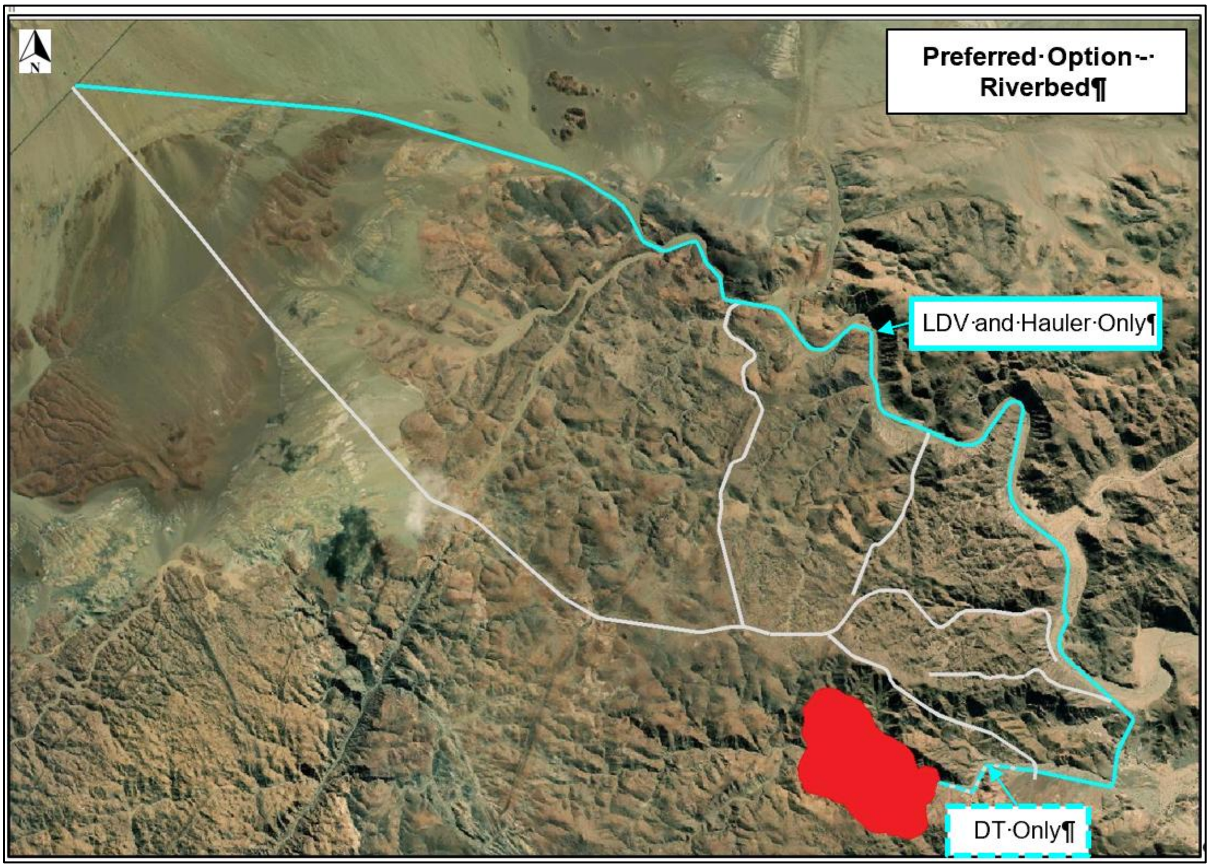

Figure 1-11: Main access route to the mining and processing area shown in blue

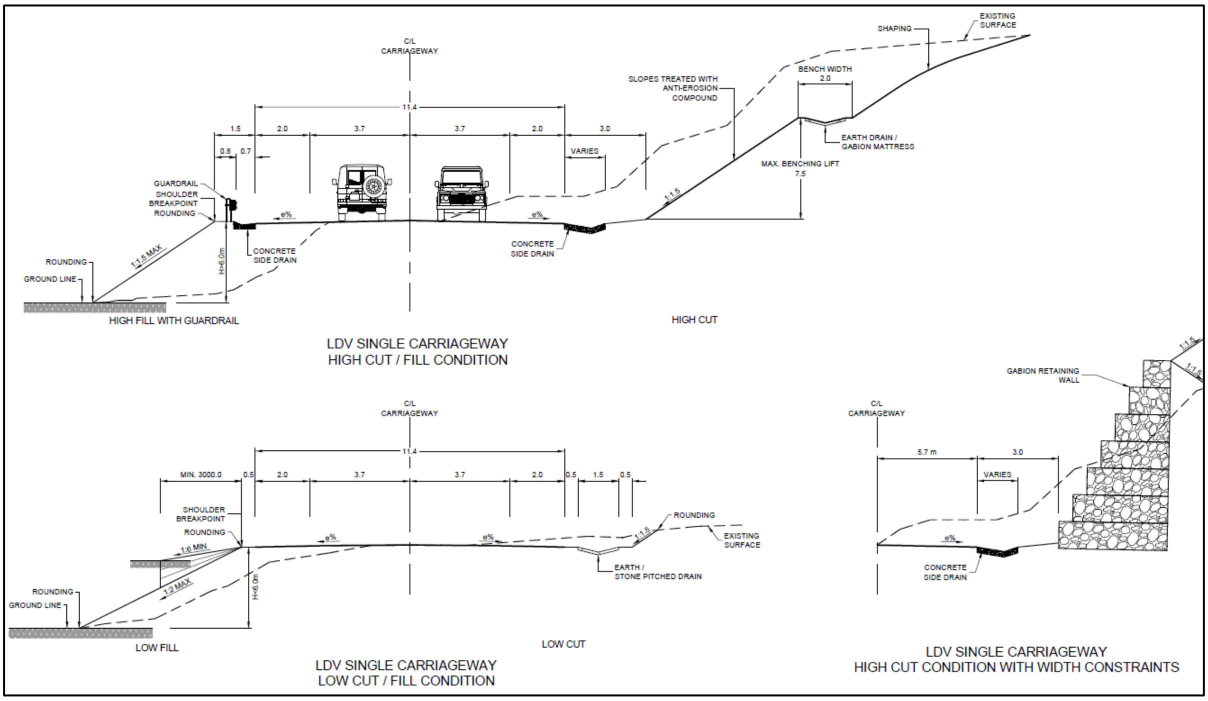

Figure 1-12: Typical section along the Project access route

The high-level geometric parameters comply with the design speed criteria of 60 kilometres per hour (km/h). The access road is to be sealed with an asphalt-based pavement at the start of the mine operation. The road upgrade also includes drainage improvement for long-term flood and erosion protection.

Other major internal roads include access to the TSF options, the Project utilities such as power and water supply and delivery routes, and the main mine camp and warehouses. A gravel wearing course has been specified for the internal roads, and adjusted to the anticipated traffic load, erosion, ease of maintenance, and cost optimisation for the internal roads and construction roads. In total, there is an allocation for 60 km of internal access roads for site utilities and infrastructure. Note gravel roads additionally accompany the pipeline and water abstraction alternatives from the Orange River to operational access routes.

1.2.6.2 MINE CAMP INFRASTRUCTURE

On-site accommodation will accommodate rotation-based personnel during construction and transitioned to the operations phase. It is assumed that all housing units and bulk infrastructure will be constructed from year zero, with no phasing allowed.

Two alternative locations for mine camp infrastructure have been identified (Figure 1-2). The mine camp alternatives are placed north of the main mining activities on flatter ground near the Project access road and solar PV power plant. The design includes workers' accommodation, multi-purpose warehouses, a gravity-fed water and sewer system, and associated infrastructure services to ensure functionality. The following additional services are also planned for the mine camp:

- Potable and fire water supply
- Gravity sewer reticulation and wastewater treatment

- Grey water storage
- Internal road infrastructure
- A designated solid waste management area
- Electrical supply and reticulation network, including both overhead and underground options.

Raw water will be sourced from the planned on-site reservoir via a gravity pipeline and treated at a containerised water treatment plant.

Effluent flows are estimated at 250 m³/day. Wastewater will be conveyed via a gravity network to a containerised treatment plant sized for an inflow of 275 m³/day. The treated effluent will be stored in a 420 m³ greywater reservoir for reuse. Access to the camp will be facilitated by a gravel road linked to the planned access road route, while internal traffic will be managed via a gravel road network.

Solid waste will be managed at a 0.5 ha security-fenced site, prepared through clearing and grubbing.

Electrical supply will be via a 33 kilovolt (kV) overhead line connected to the main substation, with a dedicated mini substation near the camp and internal overhead or underground distribution, including street lighting.

1.2.7 UTILITIES

1.2.7.1 POWER MANAGEMENT

The total electrical power demand for the proposed Haib Mine has been determined based on estimated plant operating loads, power required for water abstraction, and supporting infrastructure loads.

The estimated monthly energy consumption is 88 600 Megawatt-hour (MWh), of which approximately 30% is expected to be supplied by a photovoltaic farm. Consequently, the monthly energy requirement to be sourced from NamPower is projected to be up to 62,000 MWh. The conceptual grid connection infrastructure is sized to supply the full power demand with a double circuit overhead transmission line configuration, while the PV farm will provide a cost saving on the Project's long-term power consumption. The total annual energy consumption is estimated at a maximum of 1 124 Gigawatt-hour (GWh), including loads from support infrastructure, however, power optimisation studies are still ongoing and expected to provide improvements through introducing efficiencies.

1.2.7.2 BULK POWER SUPPLY (NAMPOWER)

The primary grid connection to the NamPower infrastructure consists of a 220 kilovolt (kV) overhead transmission line (OHTL) to link the proposed Haib Substation (site) to the existing Harib NamPower Substation. Engagement with NamPower was made early in the Project's conceptual studies to complete an in-depth grid integration study. Early findings confirm grid capacity, and the complete grid assessment is anticipated to be provided as part of NamPower's own network capacity analysis.

Deep connection works are to be determined by NamPower. These works will include all upgrades required on the NamPower network to the Harib Substation.

Shallow connection works will include the upgrades and expansion of the Harib Substation, the OHTL to the Project, a new NamPower Metering station near the Project access point, further OHTL into the Project site, and the main 220/33 kV Substation at the north side of the flotation processing plant.

Extensions to the Harib Substation will be constructed, owned and maintained by NamPower, while the 220 kV line to the Haib Substation will be constructed by the Mine and handed to NamPower for operation and maintenance. Note Transmission line upgrades and construction that do not fall within EPL 3140 will be assessed in an alternative ESIA.

1.2.7.3 SITE-WIDE ELECTRICAL RETICULATION

Electrical power reticulation from the Mine Switchyard will primarily take place at 33 kV. A 33 kV Consumer Substation will be established on the process plant terrace in close proximity to the Switchyard.

Four additional primary substations will support site-wide power distribution:

1. Comminution 33 kV Substation.
2. Flotation 33 kV Substation.
3. Raw Water Pump Station 33 kV Substation.
4. Plateau 33 kV Substation.

Reticulation to the Comminution and Flotation 33 kV Substations shall be undertaken via redundant cable feeders, whilst reticulation to the TSF Infrastructure, the Orange River raw water pumping station, the mine camp, and the Plateau 33 kV Substation shall be undertaken via overhead line circuit.

1.2.7.4 EMERGENCY POWER GENERATION

Emergency power will be supplied by high-speed diesel generator sets, appropriately sized to meet the proposed Mine's critical load requirements and emergency motor starting demands. These generator sets will be integrated with the 33 kV electrical network via the 33 kV Consumer Switchboard.

1.2.7.5 ALTERNATIVE AND SUPPLEMENTARY RENEWABLE POWER SUPPLY

The option selected for is a Solar PV farm through an Independent Power Producer (IPP) agreement to supply 30% of the total energy consumption as per NamPower's current limitation under the Modified Single Buyer (MSB) framework for IPP producers in Namibia. To account for the MSB 30% limitation, the phase 1 plant size is sized at 150 Megawatt-peak (MWp). An option to increase that contribution to 100% of the supply requirement was also investigated.

1.2.8 BULK WATER SUPPLY INFRASTRUCTURE

The proposed Project's water demand was estimated to be up to 20 million cubic metres per year (Mm^3/yr) of which supply is being investigated from two supply points, including the Orange River and Neckartal Dam, the latter of which will be further investigated during the ESIA process. Water use optimisation studies are still ongoing and expected to provide improvements through introducing efficiencies.

Raw water supply from the Orange River (included under this assessment) assumes seasonal reliability of supply. Off-channel storage facilities are thus proposed to offset the impacts of limited to nil water abstraction during the dry season or drought periods.

The water supply strategy proposes two water supply alternative locations within the Orange River. The first being directly downstream of the Vioolsdrift / Noordoever border post with a pipeline route following existing road corridors, reducing additional environmental impact, simplifying environmental permitting, and minimising land acquisition complexities. The second being directly upstream of the Haib / Orange River confluence with a pipeline route, much shorter than the first option, following up the Haib River.

Both alternatives comprise an abstraction weir, intake structure, a low-lift pumping station and two high-lift booster pumping stations, as well as a pipeline to a site reservoir. Reservoirs are included to allow for operational flexibility and short-term storage. Key engineering considerations in designing these options include energy efficiency, sediment control in the river intake structure, and potential flood protection.

Ownership and operation of the chosen alternative, and system once completed, will be transferred to NamWater, who will maintain and operate the scheme under an agreed volumetric tariff structure.

1.2.9 MINERAL AND NON-MINERALISED WASTE

1.2.9.1 WASTE ROCK

Dumps were designed as close to the pit exits as possible to optimise productivity and minimise waste mining costs or environmental impact. Rehabilitation requirements were considered in the dump location and design, and all dumping areas will undergo a mineralised material sterilisation campaign before waste dumping. The waste rock dumping strategy aims to reduce hauling distances and facilitate the progressive rehabilitation of waste dumps wherever possible. In-pit dumping will also be deployed where possible.

It is anticipated that waste dumps will be situated to the north (0.273Mt) and south-west (1.017Mt) of the open pit.

1.2.9.2 TAILINGS DISPOSAL

The Project mining schedule shows that approximately 626 million tonnes of tailings will be generated through the life of mine. Three (3) TSF design option alternatives are currently being assessed, inclusive of TSF Option 3, TSF Option 4, and TSF Option 5 (Figure 1-2). TSF Options are defined as the following:

- TSF Option 3 (1.5 km north of the Open Pit, next to WRD 2)
- Zone embankment comprises an earth fill starter embankment with a filter zone, chimney drain, and upstream lined face tied into the foundation to reduce potential seepage ingress through the dam wall. The configuration also includes an underdrainage system and a downstream seepage cut-off trench to collect and reuse seepage water
- Final height: max height of 74 to 94 m (580 to 630 mamsl).
- Storage: 110 million tonnes
- TSF Option 3 is suited to a co-disposal of waste rock and filtered tailings disposal site or coarse sand separation facility

- TSF Option 4 (3.5 km east of the B1 Highway)
- Raised ring feed structure, sized to use a larger area to be self-raised with lower rate of rise, and with potential to be lined
- Final height: 80m
- Storage: 120 to 160 million tonnes

- TSF Option 5 (Remote – 5 km north-east of the Pit)
- Zone embankment comprises an earth fill starter embankment with a filter zone, chimney drain, and upstream lined face tied into the foundation to reduce potential seepage ingress through the dam wall. The configuration also includes an underdrainage system and a downstream seepage cut-off trench to collect and reuse seepage water

- Final height: max height of 232 m (340 to 557 mamsl)
- Storage: 515 million tonnes

The water management system comprises of a pumping station set on a floating barge linked to a decant causeway. Laboratory testing to determine additional tailing properties, including compaction characteristics (dry density and moisture content), permeability, consolidation behaviour, and shear strength, is still ongoing.

Early metallurgical test results show that the mineralised material composition isn't anticipated to contain sulphides or significant metal leaching contaminants. It is anticipated that the final facility will not require geomembrane lining systems for pollution control. Considering the arid environment and importance of water conservation, the conceptual design includes provision for a basin underdrainage collection system and seepage collection pond.

1.2.9.3 GENERAL WASTE

Waste will be separated at source, stored in a manner that there can be no discharge or contamination to the environment, and either recycled or reused where possible. On-site facilities will be provided at a dedicated waste storage facility for sorting and temporary storage before removal and disposal to appropriate recycling or disposal facilities off-site (Noordoewer for general waste).

Industrial waste will be sorted on-site and disposed of at appropriate facilities. Hazardous waste includes, but is not limited to, the following: fuels, chemicals, lubricating oils, hydraulic and brake fluid, paints, solvents, acids, detergents, resins, brine, solids from sewage, and sludge. A dedicated waste management and recycling facility will be built on-site that specifically manages these waste types, and this will likely include an incinerator.

1.2.9.4 EFFLUENT AND WASTEWATER

Sewage will be collected and transported to the treatment facility using gravity reticulation via buried sewer pipes. Sewage will be treated in a purpose-built sewage treatment plant. The plant will have the capacity to treat the sewage generated on-site per day. The water output from the plant will be suitable for use in dust suppression, vehicle washing, irrigation, firefighting, and process water.

The wastewater treatment plant will also produce a small quantity of sludge, which will be dried in a sludge-drying bed located at a point lower than the plant. Dried sludge can be used as fertiliser for rehabilitation of mining landforms.

1.3 OBJECTIVES / TERMS OF REFERENCE

The aquatic ecology report addresses the following:

- Provide feedback on the seasonal site surveys conducted
  - Dry Season: 19 – 20 June 2024
  - Wet Season: 26 – 27 March 2025
- Identify potential impacts on the system in relation to the proposed project
- Determine the baseline conditions for aquatic ecosystems related to potential impacts of the proposed project
- Conduct an impact assessment and recommend mitigation measures for identified impacts.

2.0 SITE DESCRIPTION

The proposed Haib Copper project is located in southern Namibia, approximately six kilometres (km) north of the border with South Africa. The project site itself straddles the Volstruis River, an ephemeral tributary of the Haib River, which then flows into the Orange River. The selected sites for an aquatic baseline study are located within the Orange River.

2.1 GENERAL SITE CHARACTERISTICS

2.1.1 CATCHMENT AREAS AND DEVELOPMENTS

The Haib project falls within the following South African water management area:

Table 2-1: Water Management Area (WMA)

Water Management Area	Vaal-Orange WMA (WMA04)
Quaternary catchments	D82A, D82E, D82F, D82G
Integrated Unit of Analysis (IUA)	Orange-Senqu River Basin
Total Catchment Area (km^2)	~1 000 000
Level 1 Ecoregion	Orange River Gorge
Rivers	Haib River and Orange River
Resource Quality Objective	Category C (Moderately Modified)

2.2 SURVEY SITE SELECTION

The assessment aimed to determine the baseline conditions towards ensuring effective monitoring and management of potential impacts. As a result, sites were strategically selected based on potential impacts to aquatic ecosystems due to the project activities. This is typically observed through upstream (control sites) and downstream (potential impact) sites. To ensure comprehensive results, five (5) sites were selected, and placement thereof were based on suitability to assess potential impacts, accessibility and representative features. Due to the lack of permanent aquatic habitats, the Orange River was the focus of the analysis.

2.2.1 ORANGE RIVER

The Orange River, one of Africa's longest rivers, originates in the Lesotho Highlands less than 200 km from the Indian Ocean and flows westward for approximately 2,092 km before reaching the Atlantic Ocean at Alexander Bay in South Africa and Oranjemund in Namibia. The river, together with its principal tributary, the Vaal River, drains a basin of about 855,000 square kilometers. It also serves as a natural boundary, forming the eastern border of South Africa’s Free State province and part of the international border between Namibia and South Africa.

2.2.2 AQUATIC SAMPLING SITES

The aquatic assessment sites are illustrated in the Figure 2-1 and Table 2-2 below.

Table 2-2: Proposed Aquatic Assessment

Site Code	Description	Coordinates (DMS)	Site Photo
U1	Site U1 is the furthest upstream point, serving as the upstream control site due its locality upstream of the proposed project area and activities. The site provides access to the river through an open water area used by the local farmers for water abstraction. The site is dominated by sandy riverbanks and riverbed, deep pools and limited marginal vegetation.	28°53'49.22"S 18°14'27.34"E	
C1	Site C1 is located approximately 34 km downstream of the upstream control site (U1). Based on the project concept layout, this site will be located in the vicinity of a pump station / abstraction works and would serve as the upstream impact site for activities in this location. The site provides access to open water, dominated by bedrock and sandy riverbanks used by the local fishermen.	28°45'57.16"S 17°55'16.45"E	

Site Code	Description	Coordinates (DMS)	Site Photo
I1	Located roughly 1 km downstream of site C1 and the proposed pump station, this site is located at the mouth of Haib River as it enters the Orange River and serves as the primary impact site. The site is dominated by boulders and fast flowing runs. Sampling is limited to shallow open water areas.	28°45'59.42"S 17°54'40.22"E	
D2	Located approximately 25 km downstream of the confluence between Haib and Orange River. This site serves as the first point of comparison to I1 for potential impacts arising from the Haib River in the Orange River. This site is dominated by eroding, sandy riverbanks with deep pools.	28°46'26.55"S 17°38'50.17"E	

Site Code	Description	Coordinates (DMS)	Site Photo
D1	Located approximately 2 km downstream of the Noordoewer border post and a proposed pump station. This point serves to identify and detect possible impacts from activities at the pump station. Similar to upstream sites, this site comprised of sandy riverbanks, deep pools and limited vegetation. Access is mainly limited to the riverbanks due to safety concerns.	28°45'16.31"S 17°36'44.06"E	
D3	The furthest downstream site is located approximately 40 km from the Haib-Orange River confluence, and approximately 12 km from site D1. This point serves to detect and identify potential impacts within the Orange River and for comparison with the upstream control site. The riverbed is dominated by boulders and stones, with vegetation limited to the margins. The site is also located adjacent to a farm and used by the locals for fishing.	28°41'45.98"S 17°30'24.53"E	

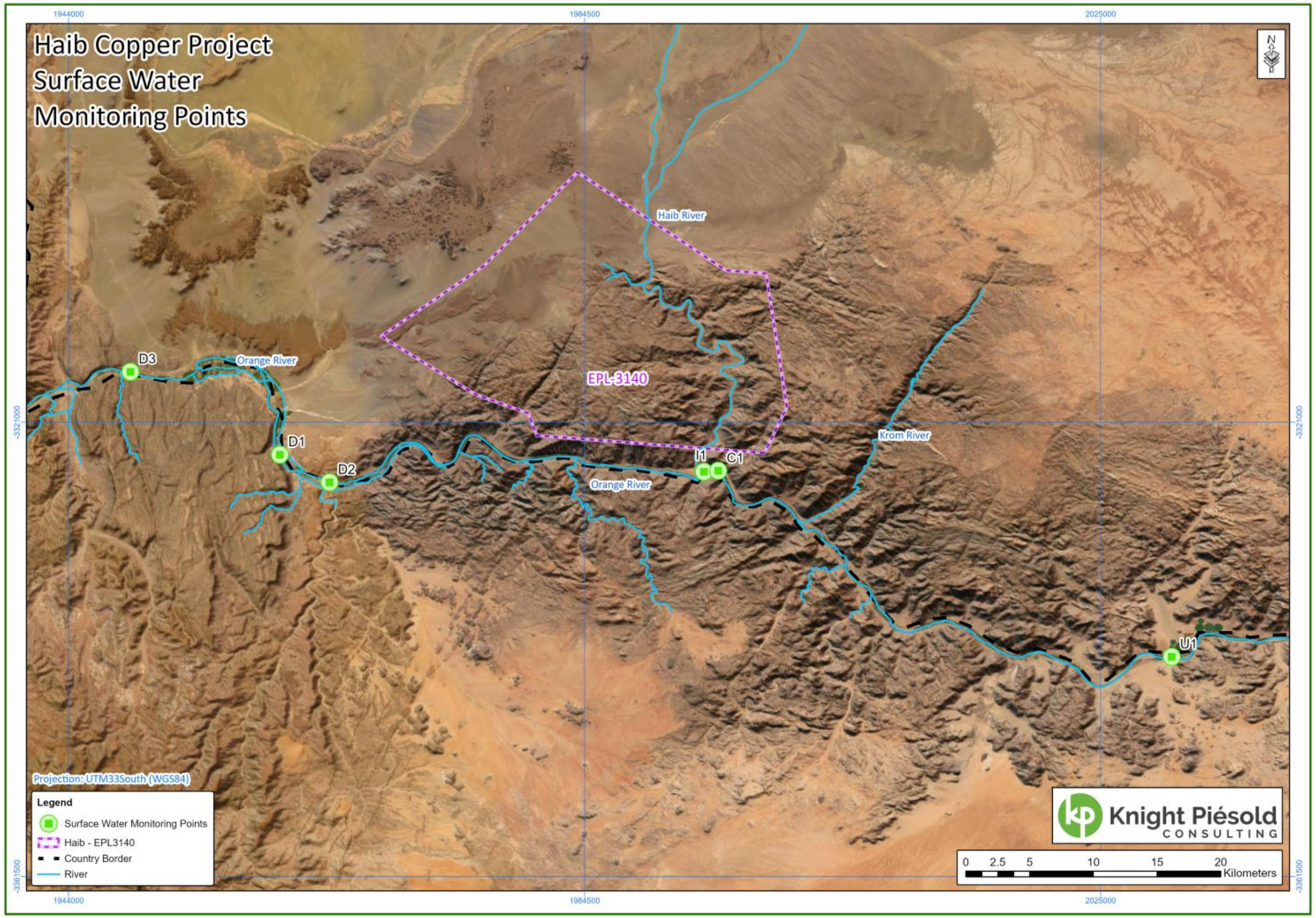

Figure 2-1: Aquatic Monitoring Sites

3.0 METHODOLOGY

3.1 DESKTOP ASSESSMENT

A comprehensive desktop assessment and literature review of all available information was conducted. Previous studies undertaken on the Orange River were used to provide baseline information, site visit preparation and reporting purposes.

3.2 AQUATIC ASSESSMENT

3.2.1 VISUAL ASSESSMENT

Each site was assessed against in-stream conditions such as morphology, hydrology and general site description. Photographic evidence was taken at each site as a representation of the conditions during the survey.

3.2.2 *IN-SITU* WATER QUALITY ASSESSMENT

The following water quality parameters was determined during the field survey using a Hanna 9811-5 multi-parameter field instrument:

- pH
- Total Dissolved Solids (mg/l)
- Electrical Conductivity (mS/m)
- Temperature (°C)
- Dissolved Oxygen (DO) (mg/l).

3.2.3 INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)

The habitat suitability for macroinvertebrates was assessed at each site making use of the IHAS methodology (McMillan, 1998). The habitat available for macro invertebrates assisted in the interpretation of survey results. Each site was assessed for stones in current, vegetation, other habitat / general and stream characteristics. The cumulative score of each of these sampling habitats will provide a score out of 100 given as percentage. The suitability was interpreted according to the guidelines of (McMillan, 1998) as follows:

- <55 % inadequate habitat
- 55-65 % adequate habitat
- >65 % good habitat.

3.2.4 AQUATIC MACRO INVERTEBRATES

Aquatic biomonitoring utilises the macro invertebrate index to detect the water quality of ecosystems. The index assigns each taxon with a sensitivity score that is used to indicate an overall Average Score Per Taxon (ASPT).

Benthic macro-invertebrates, in particular, are recognised as valuable organisms for bio-assessments, due largely to their visibility to the naked eye, ease of identification, rapid life cycle often based on the seasons and their largely sedentary habits (Dickens & Graham, 2002). Sampling was conducted using a standard size net with mesh <1 mm, dislodging macro invertebrates from their habitat substrates into the water column and catching the invertebrates in the net.

As the project is located along the Orange River, which serves as the border with South Africa, the South African Scoring System version 5 (SASS5) methodology was used in place of the Namibian Scoring System (NASS), as the latter is adapted for inclusion of northern Namibian taxa.

3.2.5 ICHTHYOFAUNA (FISH)

The Orange River has been well documented and studied in terms of fish species, especially the endemic species. The fish species documented and recorded during the surveys were used to determine the baseline conditions.

Fish data was collected through the following methods:

- Sampling by Electrofishing - Fish were sampled using a portable, battery-operated electro-fisher (SUM 1200V). This is a standard method of sampling fish and is less prone to biased sampling of certain species than other methods of sampling. Sampling effort at each site varied between 10 to 30 minutes, depending on the site conditions and the catch.
- Interviews and discussions with local fishermen and people along the project area. A photographic fish guide was used to discuss the expected fish species within the area.

The Present Ecological State of the fish assemblage was assessed using the species intolerance component of the Fish Assemblage Integrity Index (FAII) (Kleynhans, 1999) and (Kleynhans, 2003).

3.2.5.1 EXPECTED FISH SPECIES AND CONSERVATION STATUS

The conservation status of fish species expected to be present within the Lower Orange River was assessed in terms of the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2025). The information provided within Table 3-1 below was derived from (IUCN, 2025) with updated taxonomy.

Table 3-1: Fish species expected to occur within the Lower Orange River catchment area

Expected Species	Common Name	Conservation Status
Family: Anguillidae		
Anguilla mossambica	African Longfin Eel	NT
Family: Austroglanididae		
Austroglanis sclateri	Rock Catfish	LC

Expected Species	Common Name	Conservation Status
Family: Cichlidae		
Oreochromis mossambicus	Mozambique Tilapia	VU
Pseudocrenilabrus philander	Southern Mouthbrooder	LC
Tilapia sparrmanii	Banded Tilapia	LC
Family: Clariidae		
Clarias gariepinus	African Catfish	LC
Family: Cyprinidae		
Cyprinus carpio	Common Carp	LC
Enteromius paludinosus	Straightfin Barb	LC
Enteromius trimaculatus	Threespot Barb	LC
Labeo capensis	Orange River Mudfish	LC
Labeobarbus aeneus	Vaal-orange Smallmouth Yellowfish	LC
Labeobarbus kimberleyensis	Largemouth Yellowfish	NT
Enteromius hospes	Namaquab Barb	LC
Pseudobarbus quathlambae	Maloti Redfin	EN
Enteromius neefi	Sidespot Barb	LC
Enteromius lineomaculatus	Line-spotted Barb	LC
Family: Danionidae		
Engraulicypris brevianalis	River Sardine	LC
Family: Poeciliidae		
Gambusia affinis	Mosquitofish	LC

3.2.6 DIATOMS

Diatoms are photosynthetic unicellular organisms and are found in almost all aquatic and semi-aquatic habitats. They have been shown to be reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution (Tilman, et al., 1982) (Dixit, et al., 1992), as well as for general water quality. Benthic diatoms were sampled as indicators of biological water quality. Diatoms typically reflect water quality conditions over the past three days and are ecologically important because of their role as primary producers, which form the base of the aquatic food web. Diatoms typically account for the highest number of species among the primary producers in aquatic systems ((Leira & Sabater, 2005).

3.2.6.1 TERMINOLOGY

Several key ecological terms used in South African diatomology are summarised in Table 3-2 for the meaningful reading and understanding of the diatom results.

Table 3-2: Diatoms: Key ecological terms

Trophy	
Dystrophic	Rich in organic matter, usually in the form of suspended plant colloids, but of a low nutrient content.
Oligotrophic	Low levels or primary productivity, containing low levels of mineral nutrients required by plants.
Mesotrophic	Intermediate levels of primary productivity, with intermediate levels of mineral nutrients required by plants.
Eutrophic	High primary productivity, rich in mineral nutrients required by plants.
Hypereutrophic	Very high primary productivity, constantly elevated supply of mineral nutrients required by plants.
Mineral content	
Very electrolyte poor	< 50 µS/cm
Electrolyte-poor (low electrolyte content)	50 - 100 µS/cm
Moderate electrolyte content	100 - 500 µS/cm
Electrolyte-rich (high electrolyte content)	> 500 µS/cm
Brackish (very high electrolyte content)	> 1000 µS/cm
Saline	6000 µS/cm
Pollution (Saprobity)	
Unpolluted to slightly polluted	BOD <2, O_2 deficit <15% (oligosaprobic)
Moderately polluted	BOD <4, O_2 deficit <30% (β-mesosaprobic)
Critical level of pollution	BOD <7 (10), O_2 deficit <50% (β-ά-mesosaprobic)
Strongly polluted	BOD <13, O_2 deficit <75% (ά-mesosaprobic)
Very heavily polluted	BOD <22, O_2 deficit <90% (ά-meso-polysaprobic)
Extremely polluted	BOD >22, O_2 deficit >90% (polysaprobic)

3.2.6.2 SAMPLING AND ANALYSIS

The diatom analysis was conducted in South Africa by a diatom specialist, Shael Koekemoer of Koekemoer Environmental Aquatic Consultants. Epilithic and/or Epiphytic substrate was sampled as outlined in (Taylor, et al., 2007b). Preparation of diatom slides followed the hot HCl and $KMnO_4$ method as outlined in (Taylor, et al., 2007b). A Nikon Eclipse E100 microscope with phase contrast optics (1000x) was used to identify diatom valves on slides. The aim of the data analysis was to count 400 diatom valves to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor, et al., 2007b). Diatom index values are calculated in the database programme OMNIDIA (Lecointe, et al., 1993) for epilithon data in order to generate index scores to general water quality variables.

3.2.6.3 DIATOM BASED WATER QUALITY SCORE

Various indices housed within the OMNIDIA programme were used to characterise biological water quality of the sites. To assign biological water quality Ecological Categories (ECs) and associated water quality classes, the index scores of the Specific Pollution Sensitivity Index (SPI) (CEMAGREF, 1982): was used. SPI has the broadest species base and highest taxonomic resolution of all the indices and evaluates organic and inorganic pollution based on the sensitivity of each taxon, while taking into account the response of the whole diatom community (Almeida, 2001). This index was used to indicate general water quality from collected samples.

For the purposes of this study all efforts were made to identify species to species level. Where this was not possible, species were identified to genus level. Other indices used in the interpretation of diatom results included the ecological characterisation of diatom species based on (Van Dam, et al., 1994): This includes the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state.

Valve deformities were also observed as an indication of possible metal toxicity that may be present within the system. According to (Luis, et al., 2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The general threshold for the occurrence of valve deformities in a sample is usually considered between 1 - 2% and is regarded as potentially hazardous (Taylor, pers. comm.).

3.2.7 MICROBIOLOGICAL ANALYSIS

Water samples were collected at each site during the wet season and sent to Analytical Laboratory Services (ANALAB) in Namibia to be analysed for Total Faecal Coliforms and *Escherichia coli*. The inclusion of microbial analysis during the wet season survey (March 2025) was at the request of the regulatory body, therefore no data is available for the June 2024 dry season survey.

3.2.8 CHEMICAL ANALYSIS OF WATER

Water samples were taken at the various sites to establish the baseline water quality. Water samples were collected, chilled and couriered to South Africa to be analysed at Talbot Laboratories (Pty) Ltd for the parameters listed in Table 3-3 below. Post survey water samples were also collected in June and July 2025 and analysed at ANALAB. The results are included in this report as they represent the most recent data and supplemented by the ongoing routine monitoring.

Table 3-3: Chemical analysis of water samples

Parameters Analysed in the Chemical Analysis
Aluminium as Al
Arsenic as As
Biological Oxygen Demand as O_2

Parameters Analysed in the Chemical Analysis
Cadmium as Cd
Calcium as Ca
Chemical Oxygen Demand as O_2
Chloride as Cl^-
Chromium as Cr
Copper as Cu
Cyanide as CN^-
Electrical Conductivity
Fluoride as F^-
Iron as Fe
Lead as Pb
Magnesium as Mg
Manganese as Mn
Mercury as Hg
Nickel as Ni
Nitrate as N
Nitrite as N
pH
Potassium as K
Sodium as Na
Sulphate as SO_4^{2-}
Total Alkalinity as $CaCO_3$
Total Dissolved Solids
Total Hardness as $CaCO_3$
Total Suspended solids
Uranium as U
Zinc as Zn

3.3 LIMITATIONS AND ASSUMPTIONS

The following limitations and assumptions are declared:

- Not all sites identified during the desktop survey were confirmed and selected during the site visit due to accessibility limitations. Alternative suitable sites were selected in field.
- The Orange River is large perennial river that limited sampling due to high water levels and velocity within the system, even during the dry season. Monitoring site D2 could not be

surveyed for full aquatic biomonitoring due to the sheer steepness and depth at the site and thus put the surveyor in danger.

- Sampling points were recorded with the use of handheld Global Positioning System (GPS) equipment that has an accuracy of 10 to 30 meters.
- The results are based on two seasonal surveys during June 2024 and March 2025, and additional two (2) months routine monitoring water chemistry results
- The assessment is based on the available project description as of time of writing.
- The prescribed methods used for the study were based on methods developed for South African rivers and adapted for each sampling point based on the river conditions
- The inclusion of microbial analysis during the wet season survey (March 2025) was at the request of the regulatory body, therefore no data is available for the June 2024 dry season survey.

4.0 AQUATIC ASSESSMENT RESULTS

4.1 IN-SITU WATER QUALITY

In-situ water quality assessment serves as an early warning detection system for any possible water quality concerns within a river system. The *in-situ* water quality results were compared to the South African Department of Water Affairs and Forestry (DWAF) Ecosystem Guidelines. The guidelines were developed for aquatic ecosystems to provide a guideline for water quality applicable to organisms within these systems. The *in-situ* data results indicated that none of the sites recorded a deviation for any *in-situ* parameter, except for site D3 which recorded a deviation for Temperature and Dissolved Oxygen (DO) saturation (Table 4-1). The elevated temperature could be attributed to increased summer temperatures in the regions, coupled with assessing water sampled from a slow flowing shallow area.

Table 4-1: *In situ* Conditions for Both Dry and Wet Season Assessments

Sample Point	Date	pH	Temperature (° C)	TDS (mg/l)	Conductivity (mS/m)	DO (mg/l)	DO (%)
DWAF Ecosystem Guidelines		**6.5 – 9.0**	**5 – 30**	**<1100**	**<154**	**>5.0**	**80 - 120**
C1	06/2024	8.71	19.1	449	62.1	7.52	80.2
	03/2025	8.6	25.9	370	75	7.53	93.4
I1	06/2024	8.59	18.8	434	61.8	7.23	83.6
	03/2025	8.8	28.8	390	79	8.92	119.6
D1	06/2024	8.57	19.3	442	64.1	7.21	73.7
	03/2025	8.7	26.1	380	77	7.59	92.7
D2	06/2024	8.75	18.3	413	59.6	6.82	72.5
	03/2025	8.3	24.7	480	97	7.51	89.7
D3	03/2025	8.8	30.3	370	75	9.39	125.7

4.2 INVERTEBRATE HABITAT ASSESSMENT SYSTEM (IHAS)

The results for the assessment of the habitat availability and suitability for macroinvertebrates at each site and each season are summarised in Table 4-2 below:

Table 4-2: Habitat Availability and Quality Scores

Site	D3	C1		I1		D1	
Survey	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Stone in Current	16	15	11	19	20	0	0
Vegetation	10	8	9	6	9	8	7
Other Habitat / General	12	18	12	18	9	16	13
Stream Characteristics	16	12	17	21	17	13	14
IHAS Score	54	53	49	64	55	37	34
SASS Biotope Score	53%	57%	35%	35%	39%	24%	27%
SASS Biotope Category	C	C	E	E	E	F	F

4.2.1 C1

Site C1 serves as an upstream site and provided inadequate (poor) habitat availability during both the dry and wet season surveys with IHAS scores of 53 % and 49 %, respectively. The SASS biotope score deteriorated from 57 % (Category C – Moderately Modified) during the dry season survey to 35 % (Category E – Seriously Modified) during the wet season survey. The deterioration in habitat availability and quality could be attributed to limited vegetation as a result of eroded riverbanks and the sand dominated substrate which favours vegetation with certain adaptations. The site was dominated by deep, sandy pools and murky green water which provided limited visibility. The vegetation biotope was the most limited, with undercut tree roots and the invasive, sparsely scattered *Neltuma grandulosa* (Honey Mesquite) sampled as part of the vegetation biotope. The Gravel, Sand and Mud (GSM) biotope was widespread and comprised mainly of sand along the riverbanks and in sections with reduced flow. Sections with increased flow were mainly dominated by boulders and bedrock.

4.2.2 I1

Site I1 located at the mouth of the Haib River as it joins with the Orange River provided adequate habitat availability during both the dry and wet season surveys with IHAS scores of 64 % and 55 %, respectively. The reduced IHAS score during the wet season was a result of limited GSM availability due to increased water level and flow when compared to the dry season survey. The majority of sand and mud were washed further downstream, with the site being dominated by boulders and bedrock. The vegetation at the site was dominated by the invasive *N. grandulosa*, with erosion along the sandy riverbanks also limiting growth for a variety of vegetation types.

4.2.3 D1

Site D1 provided inadequate (poor) habitat availability during both the dry and wet season surveys with IHAS score of 37 % and 34 %, respectively. The habitat quality at this site is in a critically modified state due to absence of stones and limited vegetation. The sandy riverbanks were dominated by the invasive *N. grandulosa*, whereas the substrate on site was mainly sand and mud in the shallow and deep pools. Similar to further upstream sites, water at this site was murky green during both surveys due to algal blooms, with reduced flow in deep sections.

4.2.4 D3

Site D3 is the furthest downstream site. This site provided inadequate (poor) habitat availability with an IHAS score of 54 % and a moderately modified habitat quality with a SASS biotope score of 53 % during the wet season survey. No habitat assessment was carried out during the dry season due to challenges with access to the site. The poor habitat availability could be attributed to limited vegetation and GSM biotopes, a result of low water level and dominance of shallow, rocky pools. Water appeared murky green as a result of algal blooms, potentially from increased nutrient load into the system. The stones at the site were slippery as a result of algal growth.

4.3 AQUATIC MACROINVERTEBRATE ASSESSMENT

The Vioolsdrift region of the Orange River historically presented a high ecological state, rated as a Category B based on historical data prior to 2007 (Department of Water Affairs and Forestry, 2009). Further assessments within this region of the Orange River presented a Present Ecological State (PES) of Category C (Moderately Modified) for the Vioolsdrift area, downstream of the proposed project area (Department of Water and Sanitation, 2017). It should be noted that following these surveys, based on satellite maps, land use development has occurred upstream including increased agricultural development, residential development, and large- and small-scale industrial developments. These developments could potentially further modify the ecological state of the Orange River.

Table 4-3 presents all taxa observed during the wet and dry season surveys, as well as a summary of the survey data.

Table 4-3: Summarised SASS5 Results

Taxon	QV	C1		I1		D1		D3	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Baetidae > 2 sp	12		B						B
Leptophlebiidae (Prongills)	9								B
Atyidae (Freshwater Shrimps)	8	B	A	B		B	B		
Baetidae 2 sp	6	B		B					
Caenidae (Squaregills/Cainfles)	6	B	B	A	A				B
Gomphidae (Clubtails)	6	A		A		1			
Hydropsychidae 2 sp	6		B						
Veliidae/M...veliidae* (Ripple bugs)	5		1						
Ceratopogonidae (Biting midges)	5	B		A					
Corbiculidae (Clams)	5	B		B	1	A			A
Baetidae 1sp	4				A	A			
Coenagrionidae (Sprites and blues)	4		1	A			B		A
Hydropsychidae 1 sp	4								A

Taxon	QV	C1		I1		D1		D3	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
TURBELLARIA (Flatworms)	3			A					
Hirudinea (Leeches)	3	A					B		
Potamonautidae* (Crabs)	3	A		B		1			
Belostomatidae* (Giant water bugs)	3		A						
Corixidae* (Water boatmen)	3	B	B	B	B		B		A
Chironomidae (Midges)	2	B	A	B	A	A	B		
Oligochaeta (Earthworms)	1	A		A		A	B		
Culicidae* (Mosquitoes)	1	1				1			1
SASS5 Score		**49**	**49**	**52**	**20**	**30**	**21**		**44**
No. of Taxa		**12**	**9**	**12**	**5**	**8**	**6**		**8**
ASPT		**4.1**	**5.4**	**4.3**	**4.0**	**3.8**	**3.5**		**5.5**

	High	Moderate	Low	Very Low
Sensitivity Rating				

4.3.1 C1

During the dry season survey, a SASS5 score of 49 was recorded at site C1 from a total of 12 taxa, resulting in an Average Score Per Taxon (ASPT) of 4.1. During the wet season a SASS5 score of 49 from a total of nine (9) taxa were recorded, resulting in an ASPT of 5.4. During both seasons, site C1 was dominated by taxa with low to very low requirement for unmodified water quality. The most sensitive taxa were Atyidae (Freshwater Shrimps) during both surveys, with an additional sensitive taxon (Baetidae >2 sp.) recorded only during the wet season survey. Based on the SASS5 score and the ASPT, site C1 was placed into a PES of Category D (Largely Modified) during the dry season survey. A marginal improvement was observed during the wet season survey, placing this site into a PES of Category C (Moderately Modified). Poor habitat availability and quality, coupled with potentially impacted water quality could be attributed to the ongoing impacts within the Orange River.

4.3.2 I1

During the dry season, site I1 recorded a SASS5 score of 52 from a total of 12 taxa, resulting in an ASPT of 4.3 and categorising the site into a PES of Category D (Largely Modified). The only sensitive taxon during the dry season was Atyidae (Freshwater Shrimp) with the other taxa having a low to very low sensitivity rating. Conditions deteriorated further during the wet season when a SASS5 score of 20 was recorded from a total of five (5) taxa. This resulted in an ASPT of 4.0, placing the site into a PES of Category E (Seriously Modified). The recorded taxa during the wet season were all pollution tolerant taxa. The deteriorated habitat availability could be attributed to the reduction in macroinvertebrate diversity.

4.3.3 D1

During the dry season survey, a SASS5 score of 30 was recorded at site D1 from a total of eight (8) taxa, resulting in an Average Score Per Taxon (ASPT) of 3.8. During the wet season a SASS5 score of 21 from a total of six (6) taxa were recorded, resulting in an ASPT of 3.5. During both seasons, site D1 was dominated by taxa with low to very low requirement for unmodified water quality. The most sensitive taxon was Atyidae (Freshwater Shrimps) during both surveys. Based on the SASS5 scores and the ASPT, site D1 was placed into a PES of Category E (Seriously Modified) during both surveys. Site D1 provided inadequate (poor) habitat availability and critically modified habitat quality for macroinvertebrates during both surveys, resulting in the loss of sensitive taxa.

4.3.4 D3

The furthest downstream site, D3, recorded a SASS5 score of 44 from a total of eight (8) taxa, resulting in an ASPT of 5.5 during the wet season. This placed site D3 into a PES of Category B (Largely natural with few modifications). The most sensitive taxa recorded at this site during the wet season included Baetidae > 2 sp., and Leptophlebiidae (Prongills). However, the ecological category for this site was an outlier and not a true representation of conditions on site at the time of the survey. Due to the sample being dominated by pollution tolerant taxa, the adjusted PES would therefore categorise the site into Category E (Seriously Modified). The poor habitat quality, coupled with modified water quality from upstream activities could be attributed to the low macroinvertebrate diversity at the site.

4.4 ICHTHYOFAUNA ASSESSMENT

The summarised results of the observed fish species at each site are presented in Table 4-4.

Table 4-4: Summarised Fish Results

Expected Species	Sites - Observed Species						
	C1		I1		D1		D3
	Dry	Wet	Dry	Wet	Dry	Wet	Wet
Anguilla mossambica							
Austroglanis sclateri							
Clarias gariepinus			1				
Cyprinus carpio							
Engraulicypris brevianalis	2	10	4	6	24	20	1
Enteromius paludinosus	1						
Enteromius trimaculatus	1	1			1		
Gambusia affinis						2	
Labeo capensis	7	2		15	1	1	

Expected Species	Sites - Observed Species						
	C1		I1		D1		D3
	Dry	Wet	Dry	Wet	Dry	Wet	Wet
Labeobarbus aeneus	9	4	23	8	7		3
Labeobarbus kimberleyensis		10		4			20
Namaquacypris hospes							
Oreochromis mossambicus							
Pseudobarbus quathlambae							
Pseudocrenilabrus philander		1	6	20	2	12	
Tilapia sparrmanii	2	2	5	10	2	8	10
Additional Species							
Enteromius neefi			2				
Enteromius lineomaculatus			1				
Sample Size (n)	**22**	**30**	**52**	**63**	**37**	**43**	**34**
No. of Fish Species	**6**	**7**	**7**	**6**	**6**	**5**	**4**
FAII Score (%)	**44.9**	**55.4**	**54.4**	**48.0**	**43.2**	**34.1**	**32.8**
Ecological Category	**D**	**D**	**D**	**D**	**D**	**E**	**E**

4.4.1 C1

Site C1 recorded six (6) species during the dry season in comparison to the seven (7) recorded during the wet season. The wet season also presented a high abundance of fish (30) when compared to the dry season (22). The ecological category for both seasons was Category D (Largely Modified), with the FAII score increasing marginally during the wet season.

4.4.2 I1

Site I1 presented the highest fish abundance during the wet season, with *Pseudocrenilabrus philander* (Mouthbrooder) accounting for roughly 32 % of the sample size. However, more fish species were recorded during the dry season (7) in comparison to the wet season (6). During both surveys site I1 presented an ecological category D (Largely Modified), similar to the upstream site C1.

4.4.3 D1

Similar to site I1, site D1 presented the highest fish abundance during the wet season but the highest species diversity during the dry season. *Engraulicypris brevianalis* (River Sardine) accounted for the majority of the sample size during both seasons. The ecological category for the dry season was Category D, whereas conditions deteriorated during the wet season, presenting an Ecological Category E (Seriously Modified).

4.4.4 D3

Th furthest downstream site, D3, was only assessed during the wet season and presented the least species diversity in comparison to all sites. The FAII score of 32.8 % categorised site D3 into an EC of Category E (Seriously Modified). *Labeobarbus kimberleyensis* (Largemouth Yellowfish) accounted for more than 58 % of the sample size.

4.5 DIATOM ASSESSMENT

Moderate biological water quality prevailed at all sites except site D2 in March 2025. Slight deterioration was evident at sites C1, I1 and D1 from June 2024 due to increased salinity content and nutrient levels, which was attributed to agricultural activities and elevated flow. Biological water quality was poor at Site D2 in March 2025 due to increased nutrient levels and was the most impacted site in March 2025. Site D3 was sampled for the first time in March 2025 and the main impact on the site was elevated nutrient levels. Turbulence was elevated at most sites due to elevated flow, while the impact of sedimentation decreased at all sites except Site D1. The measure of impact remained stable between June 2024 and March 2025 and the bioavailability of toxins or metals at all sites was not a concern.

The sites are discussed in further detail below, with the results summarised within Table 4-5.

Table 4-5: Diatom Results Summary

Site	No species	SPI score	Water Quality Class	Category	PTV (%)	Valve deformities (%)
June 2024 – Dry Season						
C1	39	12.1	Moderate quality	C	7	0.3
I1	35	10.9	Moderate quality	C/D	13.8	0
D2	43	11.2	Moderate quality	C/D	16	0
D1	43	11.1	Moderate quality	C/D	10.5	0
March 2025 – Wet Season						
C1	34	11.9	Moderate quality	C/D	6.8	0
I1	33	10.6	Moderate quality	C/D	6.5	0
D2	34	9.7	Poor quality	D	8.5	0
D1	47	10.2	Moderate quality	C/D	20.3	0
D3	36	10.6	Moderate quality	C/D	9	0

4.5.1 C1

During the March 2025 biomonitoring assessment, Site C1 obtained a Specific Pollution sensitivity Index (SPI) score of 11.9, reflecting moderate biological water quality (Ecological Category C; Table 4-5). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score) was low March 2025. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate in March 2025, remaining stable from June 2024.

Slight deterioration in biological water quality was evident between June 2024 and March 2025 due to increased salinity content and nutrient levels resulting in the decreased abundance of sensitive species. Nutrient enrichment was reflected by the increased abundance of centric diatoms from the genera *Aulacoseira*, *Cyclostephanos*, *Stephanodiscus* and *Staurosira* (Bennion, et al., 2015). *Stephanodiscus minutulus* occurring at highest abundance and is found in strongly polluted water with a high electrolyte content along with the planktonic species, *Stephanodiscus agassizensis* which found in eutrophic rivers with an elevated electrolyte concentration and turbidity (Taylor, et al., 2007b). *Fragilaria geocollegarum*, a hardier species, also increased in abundance between June 2024 and March 2025 and seems to prefer more alkaline waters (pH 7.1 - 8.3), higher conductivity (458 - 1120 µS/cm), and more eutrophic conditions (early eutrophic to dystrophic) (Morales, 2002). While turbulence increased in March 2025, the overall impact of sedimentation, based on the abundance of motile species (Passy, 2007); (Tudesque, et al., 2012) decreased from June 2024. As observed in June 2024, key indicator species associated with anthropogenic impact occurred at low abundance indicating impact rates were low. No valve deformities were present, suggesting limited bioavailability of toxins or metals.

4.5.2 I1

During the March 2025 biomonitoring assessment, Site I1 obtained a SPI score of 10.6, reflecting moderate biological water quality (Ecological Category C/D; Table 4-5). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score) was low March 2025. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate in March 2025, remaining stable from June 2024.

Biological water quality deteriorated slightly in March 2025 due to increased salinity content and nutrient levels, with improvement in organic load evident. Compositional shifts in the diatom community at Site I1 was similar to Site C1 with nutrient enrichment reflected by the increased abundance of centric diatoms from the genera *Aulacoseira*, *Stephanodiscus* and *Staurosira* (Bennion, et al., 2015). *Staurosira elliptica* increased in abundance in March 2025, reflecting that the site was still exposed to harsh and frequently changing conditions (Fitchett, et al., 2016), which may be due to abstraction. *Stephanodiscus minutulus*, *Stephanodiscus agassizensis* and *Fragilaria geocollegarum* were dominant, reflecting the increase in nutrient levels and salinity content at the site ((Taylor, et al., 2007b); (Morales, 2002)). While turbulence increased in March 2025, the overall impact of sedimentation, based on the abundance of motile species (Passy, 2007; Tudesque, et al., 2012) decreased from June 2024. As observed in June 2024, key indicator species associated with anthropogenic impact occurred at low abundance indicating impact rates were low. No valve deformities were present, suggesting limited bioavailability of toxins or metals.

4.5.3 D1

During the March 2025 biomonitoring assessment, Site D1 obtained a SPI score of 10.2, reflecting moderate biological water quality (Ecological Category C/D; Table 4-5). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score) was moderate. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate in March 2025, remaining stable from June 2024.

Slight deterioration in biological water quality was evident in March 2025 due to increased organic load and nutrient levels. As observed at Site D2, water level fluctuation was more pronounced in March 2025 and reflected by the dominance of *Staurosira elliptica* (Fitchett, et al., 2016). The dominance of *Fragilaria geocollegarum* reflected the increase in nutrient levels and salinity content at the site ((Taylor, et al., 2007b); (Morales, 2002)) while *Aulacoseira ambigua* and *Nitzschia archibaldii* indicated elevated nutrient levels ((Dong, et al., 2015); (Lei, et al., 2021); (Hausmann, et al., 2016)). *Nitzschia* species increased in abundance between Site D2 and Site D1, but occurred at similar abundance than observed in June 2024, indicating that sedimentation was moderate with some impact on the taxonomic and the functional structure of the diatoms due to diminished suitable habitat and substrate (Tudesque, et al., 2012). As observed in June 2024, key indicator species associated with anthropogenic impact occurred at moderate abundance reflecting an increased gradient of impact at Site D1 mainly due agricultural activities and the town of Noordoewer, resulting in higher nutrient levels and salinity content. No valve deformities were present, suggesting limited bioavailability of toxins or metals.

4.5.4 D2

During the March 2025 biomonitoring assessment, Site D2 obtained a SPI score of 9.7, reflecting poor biological water quality (Ecological Category D; Table 4-5). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score) was low June 2024. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate in March 2025, remaining stable from June 2024.

Biological water quality deterioration between June 2024 and March 2025 was mainly associated with increased nutrient input. Increased nutrient levels were reflected by the increased abundance of the centrics *Aulacoseira ambigua* and *Aulacoseira granulate* (Urrutia, et al., 2000; Dong, et al., 2015; Lei, et al., 2021). *Staurosira elliptica* increased in abundance in March 2025, reflecting that the water level fluctuation was more pronounced in March 2025 (Fitchett, et al., 2016). The dominance of *Fragilaria geocollegarum* reflected the increase in nutrient levels and salinity content at the site (Taylor, et al., 2007b; Morales, 2002). Turbulence and sedimentation were not as pronounced at Site D2 in comparison to Site C1 and I1 in March 2025 (Passy, 2007; Tudesque, et al., 2012). As observed in June 2024, key indicator species associated with anthropogenic impact occurred at moderate abundance reflecting an increased gradient of impact at Site D2 due agricultural activities resulting in higher nutrient levels and salinity content. No valve deformities were present, suggesting limited bioavailability of toxins or metals.

4.5.5 D3

Site D3 was sampled for the first time in March 2025 and obtained a SPI score of 10.6, reflecting moderate biological water quality (Ecological Category C/D; Table 4-5). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score) was low. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate in March 2025.

The main impact on the site was elevated nutrient levels associated with agricultural activities. The species composition at Site D3 was similar to Site D2 and D1 with the centrics *Aulacoseira ambigua* and *Aulacoseira granulata* (Urrutia, et al., 2000; Dong, et al., 2015; Lei, et al., 2021) dominating along with *Staurosira elliptica* (Fitchett, et al., 2016) and *Fragilaria geocollegarum* (Taylor, et al., 2007b; Morales, 2002). While turbulence increased between Site D1 and D3, the overall impact of sedimentation, based on the abundance of motile species (Passy, 2007; Tudesque, et al., 2012) decreased. The measure of impact at Site D3 was moderate. No valve deformities were present, suggesting limited bioavailability of toxins or metals.

4.6 MICROBIOLOGICAL ANALYSIS

Microbiological samples collected during the wet season were analysed for Total coliforms and *E. coli*. The results are presented in Table 4-6 below.

The Total Coliforms count increases from up to downstream. The increase at the downstream sites could potentially be attributed to agricultural runoffs from the farms located along the Orange River on both the South Africa and Namibian sides, particularly within the Vioolsdrif area. *E. coli* count increases by tenfold at site D2 directly downstream of Vioolsdrift. This is potentially due to faecal pollution sources that intensify downstream. *E. coli* is a type of faecal coliform and can result in human health complications upon consumption of contaminated water.

Table 4-6: Microbiological Analysis Results

Sample Description	Total Coliforms (MPN/100ml)	*E. coli* (MPN/100ml)
C1	750	36
I1	1500	30
D2	4600	380
D1	11000	36

4.7 CHEMICAL ANALYSIS ASSESSMENT

Water samples were collected during the 2024 dry season (July 2024) and the 2025 wet season (March 2025) and analysed by Talbot Laboratory (Pty) Ltd. Subsequent monthly environmental monitoring at the project site had been implemented and results for June and July 2025 are included in this report to serve as representatives of recent conditions. The results from the chemical analysis of the sites have been compared to the International Finance Corporation (IFC) water quality guidelines and the South African DWAF guideline values for Aquatic Ecosystems (Table 4-7). These water quality reference values are summarised in Table 4-7.

4.7.1 PARAMETERS WITH ELEVATED CONCENTRATIONS

- **Aluminium** – Aluminium (Al) is the third most abundant element on Earth, and the concentration is often elevated in freshwater sources due to natural processes (e.g., rock weathering) and anthropogenic activities (e.g., industrial processes such as those involved in mining and other industries). Within the Orange River, Aluminium is generally above required guidelines limits throughout various seasons, potentially due to runoffs from irrigation practises at farms located adjacent to the stream as supported by (Sekwaila, et al., 2019). The Aluminium concentration exceeded the DWAF ecosystem guideline limits at all sites throughout the various surveys, with the highest concentrations recorded during the June 2025 survey.
- **Copper** – Copper (Cu) is a naturally occurring trace element in the Earth's crust and in freshwater sources. Natural sources include rock weathering and erosion, volcanic activities and geological deposits, whereas anthropogenic activities such as mining and agricultural activities can result in increased, toxic concentrations. Based on recent surveys, Copper concentrations were elevated during the dry months. Copper is an essential micronutrient for various aquatic life but can result in toxic effects such as adverse effects on growth, reproduction and even death (US EPA, 2025). The furthest upstream point (I1) exceeded both guidelines during the 2024 dry season.
- **Iron** – Iron (Fe) is the fourth most abundant element in the Earth's crust, with the majority of the iron combined with various other elements. As a naturally occurring element, Iron also tends to leach out from Sulphide and Silicate deposits, which can oxidise in aqueous solutions. A study by (Pitiya, et al., 2022), revealed that on average, Iron is the most abundant element in the sediment from the Lower Orange River. This could potentially be due to high concentrations in the water column, settling in the sediment at shallow sections. The results from this study revealed that on average, Iron was the most abundant, exceeding the IFC water quality guidelines during the June 2025 survey at all sites.
- **Mercury** – Mercury (Hg) is one of the rarest elements in the Earth's crust, occurring in its pure form (rarely) or in other minerals. It is often used by the manufacturing industry for chemicals and electronics, or in illegal mining activities to form an amalgam with gold deposits. This often leads to contamination of water sources as well as adverse health effects to humans and aquatic organisms (WHO, 2024). A recent study has revealed the presence of Hg at high concentrations within the Orange-Vaal River basin (Erasmus, et al., 2024). During the current study, Hg only exceeded both guidelines at site I1 and D2 during the June 2024 survey.
- **Nitrate** – Nitrate (NO_3^-) is one of the Nitrogen compounds essential for plant and animal growth, and occurs naturally in the environment (i.e., air, soil and water). On an industrial scale, Nitrate is used as a fertiliser, pharmaceutical products and explosives. Within the Orange River, sources of Nitrate would most likely be runoffs from nearby farms as a fertiliser. High concentrations of Nitrate in freshwater sources (e.g., rivers and lakes) have been documented to result in increased nutrient load, which promotes algal blooms (Fried, et al., 2012). Nitrate was below detection limits for most of the surveys, with the only exceedance recorded during the March 2025 survey at site C1.
- **Total Suspended Solids** – Total Suspended Solids (TSS) are particles found in the water column, larger than 2 microns and include gravel, sand, silt, clay, algae, etc., affecting water clarity and can be harmful to aquatic organisms. Particles can either be organic or inorganic, with the Orange River mainly impacted by organic particles (i.e., suspended algae) due to nutrient enrichment as a result of fertiliser runoffs, with the majority of the runoff into the Orange River occurring from the upper catchment area (Heath & Brown, 2007). The historical impact

of agricultural runoff on the Orange River remains evident, with the water appearing murky green and TSS exceeding guideline limits at various sites during the dry season.

- **Zinc** – Zinc (Zn) is found in the Earth's crust and is an essential trace element for most living organisms. The concentration of Zn within the Orange River system was found to be elevated by agricultural runoff, mining, and industrial activities (Erasmus, et al., 2024). Some of the mining and industrial activities are located in South Africa, the Northern Cape province. Some of these discharges and runoffs were traced to the Vaal River, which is a major tributary of the Orange River (Erasmus, et al., 2024). The current study supports previous studies, with the Zn concentration exceeding guideline limits at the various sites.

4.7.2 OTHER PARAMETERS OF CONCERN WITHIN THE ORANGE RIVER

The major water quality issues within the Orange River originate from the Vaal River, Modder Riet, the Orange River in the Upper Orange WMA and agricultural fields along the river (Department of Water Affairs and Forestry (DWAF), 2004). These include increased salinity, microbiological pollution and eutrophication due to increased nutrient load into the system. These often result in algal blooms which have been identified to be harmful to water users. Elements such as Magnesium (Mg), Nitrogen (N) and Phosphorus (P) contribute to increased algal blooms, with Manganese (Mn), Potassium (K) and Sulphates (SO_4^{2-}) serving complex roles to promote algal growth under certain conditions. The majority of the abovementioned elements are macro- and micro-nutrients necessary for growth and may be directly or indirectly involved in the processes that result in algal blooms.

Elements such as Arsenic and Chromium are considered heavy metals and can be elevated by intense mining activities. Both these heavy metals have recently been recorded to be settling in sediment at high concentrations (Erasmus, et al., 2024) within the Orange River. These elements may be recorded below detection limits in the water column but pose a health risk during resuspension of river sediment. Although the current study did not reveal any concerns within the water column, the potential impacts could result from the sediment.

Table 4-7: Chemical Analyses Results

Parameter	Units	DWAF Guideline Vol. 7	IFC Guideline	C1				D1				D2				I1				D3			U1	
				Jun-24	Mar-25	Jun-25	Jul-25	Jun-24	Mar-25	Jun-25	Jul-25	Jun-24	Mar-25	Jun-25	Jul-25	Jun-24	Mar-25	Jun-25	Jul-25	Mar-25	Jun-25	Jul-25	Jun-25	Jul-25
Aluminium as Al	µg/l	<5		349	140	1494	385	267	124	1 161	768	227	181	1 218	286	1 028	80	1 145	468	87	1 456	570	1 311	505
Arsenic as As	µg/l	<10	<100	1.7	B.D.L	2.5	1.1	1.6	B.D.L	1.9	1.4	1.6	B.D.L	1.8	1.2	2.4	B.D.L	1.6	1.2	B.D.L	2.5	1.2	1.6	1.3
Biological Oxygen Demand as O_2	mg/l		<50	2	NA	B.D.L	B.D.L	B.D.L	NA	B.D.L	B.D.L	B.D.L	NA	B.D.L	B.D.L	B.D.L	NA	B.D.L	B.D.L	NA	B.D.L	B.D.L	B.D.L	B.D.L
Cadmium as Cd	µg/l	<0.4	<50	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
Calcium as Ca	mg/l			50	NA	34	35	52	NA	35	35	51	NA	35	34	53	NA	34	35	NA	35	40	33	35
Chemical Oxygen Demand as O_2	mg/l		<150	27	NA	10	41	B.D.L	NA	10	3	27	NA	14	B.D.L	31	NA	11	B.D.L	NA	14	3	13	1.7
Chloride as Cl^-	mg/l			58	63	35	40	58	72	35	38	58	72	36	37	56	68	36	39	68	35	45	32	40
Chromium as Cr	µg/l			3.5	B.D.L	4.6	2.0	2.9	B.D.L	5.1	3.4	3	B.D.L	7.4	2.2	10.4	B.D.L	3.7	2.4	B.D.L	4.8	2.7	5.8	3.0
Copper as Cu	µg/l	<1.4	<300	20	B.D.L	7.2	2.5	7.3	B.D.L	4.9	11	17	B.D.L	5.6	B.D.L	943	B.D.L	5.1	B.D.L	B.D.L	6.1	2.7	5.3	4.2
Cyanide as CN^-	mg/l			B.D.L	B.D.L	0.01	NA	B.D.L	B.D.L	0.01	NA	11	B.D.L	0.01	NA	33	B.D.L	0.01	NA	B.D.L	0.01	NA	0.07	NA
Electrical Conductivity	mS/m	<154		64.2	70	45.8	49.4	62.6	74	47.1	49.0	64.5	72	46.7	47.8	66.5	73	46.4	49.5	72	47.0	56.4	45.1	49.0
Fluoride as F^-	mg/l	≤0.75		0.41	0.29	0.2	0.2	0.39	0.29	0.2	0.2	0.44	0.27	0.2	0.2	0.43	0.34	0.2	0.2	0.29	0.2	0.2	0.2	0.2
Iron as Fe	µg/l		<2 000	814	150	3 443	804	759	102	3 260	1 604	656	140	3 448	765	1 001	84	3 409	922	111	3 501	1 216	3 601	1 243
Lead as Pb	µg/l	<1.2	<200	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	2.2	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
Magnesium as Mg	mg/l			26	NA	17	17	26	NA	17	17	26	NA	17	16	27	NA	17	17	NA	17	19	16	17
Manganese as Mn	µg/l	≤180		49	91	96	50	45	54	90	64	44	77	96	46	66	50	88	63	75	106	109	111	54
Mercury as Hg	µg/l	≤0.04	<2	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	2	B.D.L	B.D.L	B.D.L	2.7	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
Nickel as Ni	µg/l		<500	1.7	B.D.L	B.D.L	B.D.L	1.6	B.D.L	B.D.L	B.D.L	3.3	B.D.L	B.D.L	B.D.L	3.7	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L
Nitrate as N	mg/l	<2.5		B.D.L	3.2	0.7	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	B.D.L	0.7	B.D.L	B.D.L	B.D.L	0.9	1.3	B.D.L	0.9	0.8	0.9	B.D.L
Nitrite as N	mg/l			B.D.L	B.D.L	0.02	0.01	B.D.L	0.07	0.01	B.D.L	B.D.L	0.28	B.D.L	0.01	B.D.L	B.D.L	0.01	0.01	B.D.L	0.01	0.01	0.01	0.03
pH	pH unit	6.5 - 9.0	6.0 - 9.0	7.8	7.7	8.5	8.2	7.9	7.9	8.4	8.4	7.9	7.7	8.4	8.3	7.8	7.8	8.4	8.2	7.8	8.5	8.2	8.5	8.0
Potassium as K	mg/l			2.62	NA	4.5	2.6	2.69	NA	4.6	2.5	2.66	NA	4.6	2.5	2.76	NA	4.5	2.6	NA	4.6	2.7	4.5	2.6
Sodium as Na	mg/l			57	72	31	34	59	75	32	33	57	75	32	32	58	73	32	34	73	31	35	30	34
Sulphate as SO_4^{2-}	mg/l			66.3	114	49	47	65.4	117	51	46	64.7	121	51	43	63.8	120	51	46	119	51	55	47	47
Total Alkalinity as $CaCO_3$	mg/l			216	NA	125	145	126	NA	135	150	156	NA	130	150	141	NA	125	150	NA	130	155	125	150
Total Dissolved Solids	mg/l	<1100		310	444	249	263	290	502	256	262	292	504	257	255	324	476	254	270	454	256	293	242	266
Total Hardness as $CaCO_3$	mg/l			230	NA	155	157	238	NA	157	157	235	NA	157	151	243	NA	155	157	NA	157	178	148	157
Total Suspended solids	mg/l		<50	30	NA	60	16	30	NA	48	40	32	NA	56	12	56	NA	48	8	NA	68	8	68	8
Uranium as U	µg/l			NA	B.D.L	5.4	3.3	NA	14.6	2.1	3.3	NA	19.8	4.8	3.3	NA	18.7	4.6	3.2	B.D.L	4.7	3.4	5.0	3.8
Zinc as Zn	µg/l	<2	<500	19.2	10.9	6.5	B.D.L	12.1	B.D.L	5.2	B.D.L	13.2	B.D.L	5.6	B.D.L	636	B.D.L	6.8	B.D.L	B.D.L	6.0	B.D.L	5.1	B.D.L

Exceedance of DWAF Guideline	Exceedance of IFC Guideline	Exceedance against both guidelines	Below Detection Limits	Not Analysed

5.0 IMPACT IDENTIFICATION AND ASSESSMENT

5.1 DEFINING THE NATURE OF THE IMPACT

An impact is essentially any change to a resource or receptor brought about by the presence of the proposed project component or by the execution of a proposed project related activity. The terminology used to define the nature of an impact is detailed in Table 5-1 below.

Table 5-1: Impact Nature

Term	Definition
Positive (+)	An impact that is considered to represent an improvement on the baseline or introduces a positive change.
Negative (-)	An impact that is considered to represent an adverse change from the baseline or introduces a new undesirable factor.
Direct impact (D)	Impacts that result from a direct interaction between a planned project activity and the receiving environment/receptors (e.g. between occupation of a site and the pre-existing habitats or between an effluent discharge and receiving water quality).
Indirect impact (I)	Impacts that result from other activities that are encouraged to happen as a consequence of the Project (e.g. in-migration for employment placing a demand on resources).
Cumulative impact (C)	Impacts that act together with other impacts (including those from concurrent or planned future third-party activities) to affect the same resources and/or receptors as the Project.

5.1.1 ASSESSING SIGNIFICANCE

The Knight Piésold impact significance rating system is based on the following equation:

Significance of Environmental / Social Impact = Consequence x Probability

The consequence of an impact can be derived from the following factors:

- **Severity / Magnitude** – the degree of change brought about in the environment
- **Reversibility** - the ability of the receptor to recover after an impact has occurred
- **Duration** - how long the impact may be prevalent
- **Spatial Extent** - the physical area which could be affected by an impact.

The **severity, reversibility, duration, and spatial extent** are ranked using the criteria indicated in Table 5-2 and then the overall consequence is determined by adding up the individual scores and multiplying it by the **overall probability** (the likelihood of such an impact occurring). Once a score has been determined, this is checked against the **significance** descriptions indicated in Table 5-3.

Table 5-2: Ranking Criteria

Severity / magnitude (M)	Reversibility (R)	Duration (D)	Spatial extent (S)	Probability (P)
5 – Very high – The impact causes the characteristics of the receiving environment/ social receptor to be altered by a factor of 80 – 100 %	**5 – Irreversible** – *Environmental* - where natural functions or ecological processes are altered to the extent that it will permanently cease. *Social* - Those affected will not be able to adapt to changes and continue to maintain-pre impact livelihoods.	**5 – Permanent** - Impacts that cause a permanent change in the affected receptor or resource (e.g. removal or destruction of ecological habitat) that endures substantially beyond the Project lifetime.	**5 – International** - Impacts that affect internationally important resources such as areas protected by international conventions, international waters etc.	**5 – Definite** - The impact will occur.
4 – High – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 60 – 80 %		**4 – Long term** - impacts that will continue for the life of the Project but ceases when the Project stops operating.	**4 – National** - Impacts that affect nationally important environmental resources or affect an area that is nationally important/ or have macro-economic consequences.	**4 – High probability** – 80% likelihood that the impact will occur
3 – Moderate – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 40 – 60 %	**3 – Recoverable** *Environmental* - where the affected environment is altered but natural functions and ecological processes may continue or recover with human input. *Social* - Able to adapt with some difficulty and maintain pre-impact livelihoods but only with a degree of support or intervention.	**3 – Medium term** - Impacts are predicted to be of medium duration (5 – 15 years)	**3 – Regional** - Impacts that affect regionally important environmental resources or are experienced at a regional scale as determined by administrative boundaries, habitat type/ecosystem.	**3 – Medium probability** – 60% likelihood that the impact will occur u

Severity / magnitude (M)	Reversibility (R)	Duration (D)	Spatial extent (S)	Probability (P)
2 – Low – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 20 – 40 %		**2 – Short term** - Impacts are predicted to be of short duration (0 – 5 years)	**2 – Local** - Impacts that affect an area in a radius of 2 km around the site.	**2 – Low probability** - 40% likelihood that the impact will occur
1 – Minor – The impact causes very little change to the characteristics of the receiving environment/ social receptor and the alteration is less than 20 %	**1 – Reversible** *Environmental* - The impact affects the environment in such a way that natural functions and ecological processes are able to regenerate naturally. *Social* - People/ communities are able to adapt with relative ease and maintain pre-impact livelihoods.	**1 – Temporary -** Impacts are predicted to intermittent/ occasional over a short period.	**1 – Site only** - Impacts that are limited to the site boundaries.	**1 – Improbable** - 20% likelihood that the impact will occur

Table 5-3: Significance Definitions

Score According to Impact Assessment Matrix	Significance Definitions	Colour Scale Ratings	
		Negative Ratings	Positive Ratings
Between 0 and 29 significance points indicate **Low Significance**	An impact of low significance is one where an effect will be experienced, but the impact magnitude is sufficiently small and well within accepted standards, and/or the receptor is of low sensitivity/value.	Low	Low
Between 30 and 59 significance points indicate **Moderate Significance**	An impact of moderate significance is one within accepted limits and standards. The impact on the receptor will be noticeable, and the normal functioning is altered, but the baseline condition prevails, albeit in a modified state. The emphasis for moderate impacts is on demonstrating that the impact has been reduced to a level that is As Low As Reasonably Practicable (ALARP). This does not necessarily mean that "moderate" impacts have to be reduced to "low" impacts, but that moderate impacts are being managed effectively and efficiently to not exceed accepted standards.	Moderate	Moderate
60 to 100 significance points indicate **High Significance**	An impact of high significance is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors. An impact with high significance will completely modify the baseline conditions. A goal of the ESIA process is to get to a position where the Project does not have any high negative residual impacts, certainly not ones that would endure into the long term or extend over a large area. However, for some aspects there may be high residual impacts after all practicable mitigation options have been exhausted (i.e. ALARP has been applied). It is then the function of regulators and stakeholders to weigh such negative factors against the positive factors, such as employment, in coming to a decision on the Project.	High	High

5.2 DESCRIPTION OF IMPACTS

5.2.1 PRE-CONSTRUCTION AND CONSTRUCTION PHASE

5.2.1.1 ALTERATION OF HABITAT DUE TO INCREASED SEDIMENTATION

The clearing of the area for the establishment of the construction activities, and the increased movement across the project site during the construction phase will result in increased sediment load availability and mobilisation by means of surface water runoff during rainy seasons, increasing the sediment load within the system and altering the habitat within the system. This impact is considered to be of LOW significance both before and after the implementation of mitigation measures due to the arid nature of the project area.

5.2.1.2 LOSS OF HABITAT

Construction related to the potential water offtake site within the Orange River will lead to loss of habitat within the immediate vicinity. Given the localised nature of this impact, along with the habitat heterogenicity of this stretch of the Orange River, this impact is considered to be of LOW significance both before and after the implementation of mitigation measures.

5.2.1.3 ALTERATION IN COMMUNITY ASSEMBLAGE

Alterations in community assemblages can be expected due to alterations in habitat availability, alterations in water quality and increased human activity within the immediate area interfering with breeding patterns, and the potential influence of alien invasive species migrating from further upstream. This impact is considered to be of LOW significance both before and after the implementation of mitigation measures.

5.2.1.4 LOSS OF SENSITIVE FAUNA

The potential spillages and habitat alterations associated with the construction phase activities may lead to the loss of sensitive fauna through habitat destruction, surface water contamination of hydrocarbons or through construction related disturbances. The impact is considered to be of LOW significance, as limited to no sensitive taxa were recorded for the project area.

5.2.1.5 ALTERED WATER QUALITY

Construction activities, such as hydrocarbon spills, run-off from construction material stockpiles and sediment mobilisation could alter the water quality of the Orange River, impacting both aquatic biodiversity as well as downstream users in Vioolsdrift and Noordoewer. This impact is considered to be of LOW significance due to already present heavy metals which are largely linked to past and ongoing agricultural, mining, and residential activities within and upstream of the Orange River catchment.

5.2.2 OPERATIONAL PHASE

5.2.2.1 ALTERED WATER QUALITY

During the operational phase, controlled discharges or spillages from site infrastructure may reach the Orange River, impacting on the water quality for aquatic biota and downstream users in Vioolsdrift and Noordoewer. This impact is considered to be MODERATE prior to the implementation of mitigation measures, after which it is considered to be of LOW significance.

5.2.2.2 INCREASED ALGAL BLOOMS

Algal blooms within the Orange River within the region of Vioolsdrift and Noordoewer are common occurrences due to the elevated nutrient load within the Orange River from upstream agricultural practices. The operational discharges from Haib's operations may further add to the frequency and density of algal blooms, but given the frequency and extent of existing blooms, this is considered an impact of LOW significance.

5.2.2.3 LOSS OF AQUATIC HABITAT AND BIODIVERSITY

Operational offtake from the Orange River may lead to reduced water levels, particularly during the drier months, which could reduce habitat availability for aquatic biota, reducing breeding habitat for species reliant on marginal vegetation or overhanging shelter. This impact is considered to be of LOW significance, given the low marginal habitat diversity present within this stretch of the Orange River.

In the unlikely event of a breach or dam break of any of the tailings facilities, or a critical failure of any chemical storage tanks, the operations will have significant detrimental impacts on the aquatic biodiversity and habitat within the Orange River and may potentially flow out to the Atlantic Ocean. This is considered to be an impact of HIGH significance, reduced to MODERATE significance through the implementation of mitigation measures.

5.2.2.4 INCREASED SEDIMENT RUNOFF & EROSION

During the operational phase, runoff from the TSFs, WRDs and stockpiles could lead to erosion and mobilisation of sediment further down gradient into the Haib River channel and ultimately the Orange River. This impact is considered MODERATE, however given the distance of the infrastructure from the Orange River, the topography within the project site, and the aridity of the area, this impact is reduced to LOW significance following the implementation of mitigation measures.

5.2.3 DECOMMISSIONING AND CLOSURE PHASE

5.2.3.1 PHYSICAL DISTURBANCE, ALTERATION OF NATURAL FLOWS AND CONTAMINATION

Decommissioning activities may result in increased sediment mobilisation and potential spillages, which may lead to contamination of the Orange River through runoff. Decommissioning activities may lead to alterations in natural flows through the removal of artificial stormwater management systems, resulting in additional potential for sediment mobilisation and erosion of ephemeral channels during high rainfall events. This impact is considered to be of LOW significance.

5.2.3.2 REHABILITATION OF FOOTPRINT AREA

The rehabilitation of the footprint area will promote natural vegetation to reestablish, which may lead to increased marginal vegetation along the Orange River, potentially increasing habitat availability for aquatic fauna. This is a positive impact that can be improved to MODERATE significance.

Table 5-4: Impact Ratings for the Haib Project

Project activity or issue	Potential impact	Nature of impact		Significance before mitigation							Significance after mitigation as per EMP						
		+/-	D/I/C	M	R	D	S	P	TOTAL	SP	M	R	D	S	P	TOTAL	SP
Pre-Construction and Construction Phase																	
Site clearance and construction	Alteration of habitat due to increased sedimentation	-	D	3	1	2	5	2	22	L	2	1	2	5	1	10	L
	Loss of habitat	-	D	2	3	2	5	2	24	L	2	3	2	5	1	12	L
	Alteration in community assemblage	-	I	1	3	2	5	2	22	L	1	3	2	5	1	11	L
	Loss of sensitive fauna	-	D	2	3	2	5	2	24	L	2	3	2	5	1	12	L
	Altered water quality	-	D	2	3	2	5	2	24	L	2	3	2	5	1	12	L
Operational Phase																	
Operational Discharges	Altered water quality	-	D	3	3	5	5	3	48	M	2	3	4	5	2	28	L
	Increased algal blooms	-	D	1	3	5	5	2	28	L	1	3	5	5	1	14	L
Operational offtake of the Orange River	Loss of aquatic habitat and biodiversity	-	D	2	3	4	5	2	28	L	2	3	4	5	1	14	L
Dam failure, spill or breach				5	5	5	5	3	60	H	5	5	5	5	2	40	M
Operation of the various TSFs	Increased sediment runoff & erosion	-	D	3	3	4	5	2	30	M	3	3	4	5	1	15	L
Decommissioning and Closure Phase																	
Decommissioning of infrastructure	Physical disturbance, alteration of natural flows and contamination	-	D	2	3	3	2	2	20	L	2	3	3	2	2	20	L
Rehabilitation of infrastructure footprints	Rehabilitation of footprint area	+	D	2	3	5	2	2	24	L	2	3	5	2	3	36	M

6.0 MITIGATION MEASURES

The mitigation measures provided below is recommended to minimise the impact of the proposed project activities on the aquatic ecosystem. The mitigation measures are split into construction and operational phase based on the associated impacts discussed in the previous chapter.

6.1 CONSTRUCTION PHASE

- Minimise construction activities in riparian zones and undertake all support operations outside the riparian zone. Demarcate buffer zone of 50 m from the edge of the riparian zone for all activities that are not needed within the riparian zone
- Rehabilitate disturbed areas and aim to recreate the same mix of habitats, including stream substrates that were present prior to disturbance
- Train contractors' staff on environmental awareness i.e., prohibit fishing, awareness of invasive species
- Direct stormwater runoff from access roads and all construction areas to buffer zones before reaching rivers and streams. Construct temporary silt fences downstream of disturbed areas, where appropriate
- Minimise the activities in the river channel to within the dry season and ensure that normal flow regime is allowed during construction of the impoundments, in order to mitigate the change in flow regime.
- Undertake concurrent rehabilitation of disturbed areas, where possible, to reduce soil erosion within the catchment
- Develop and implement a comprehensive plan to reduce soil erosion from disturbed areas, through the use of diversion channels and temporary silt traps.
- Construction materials should be stored in bunded areas to reduce the potential for surface runoff
- Hydrocarbon spill kits should be made readily available to reduce potential for hydrocarbon mobilisation into surface water courses.
- Ensure all vehicles are adequately maintained to reduce potential for hydrocarbon spills.

6.2 OPERATIONAL PHASE

- Clean surface water runoff should be diverted to settling ponds to allow the sediment to settle before releasing it into nature.
- Pipelines should be designed with secondary containment measures to hold any possible spillages as emergency measures.
- Manage surface water runoff during operational phase to minimise erosion.
- Undertake concurrent rehabilitation on the TSF embankments, especially the lowermost embankment, once it has reached its full horizontal extent.
- Water abstraction must be undertaken in accordance with abstraction guidelines, as not to impact on the environmental water requirements downstream.
- Implement stormwater measures around embankment material stockpile areas.

- Routine monitoring of pipelines should be conducted.
- Internal TSF inspections should be done quarterly to ensure safety and stability. Annual external inspections should be conducted by independent experts.
- Tailings embankments should be designed to resist erosion during high rainfall events.
- Hazardous products should be stored in hazardous material zone within a bunded area.
- The TSF facility, once constructed, should be managed and operated in accordance with the Global Industry Standard for Tailings Management (GISTM).
- Hazardous products should be stored in hazardous material zone within a bunded area.

6.3 DECOMMISSIONING AND CLOSURE PHASE

- Minimise decommissioning activities in riparian zones and undertake all support operations outside the riparian zone. Demarcate buffer zone of 50 m from the edge of the riparian zone for all activities that are not needed within the riparian zone
- Rehabilitate disturbed areas and aim to recreate the same mix of habitats, including stream substrates and riparian diversity that were present prior to disturbance
- Monitor rehabilitated areas for invasive alien species
- Train contractors' staff on environmental awareness i.e., prohibit fishing, awareness of invasive species
- Minimise the activities in the river channel and ensure that normal flow regime is allowed during construction of the impoundments, in order to mitigate the change in flow regime.
- Rehabilitate disturbed terrestrial areas, where possible, to reduce soil erosion within the catchment
- Decommissioned waste materials should be stored in bunded areas to reduce the potential for surface runoff
- Hydrocarbon spill kits should be made readily available to reduce potential for hydrocarbon mobilisation into surface water courses.
- Ensure all vehicles are adequately maintained to reduce potential for hydrocarbon spills.

7.0 MONITORING

The following monitoring systems need to be implemented:

- **Aquatic ecosystems**: Biomonitoring should be undertaken at least annually during construction and operation phases, although the frequency of biomonitoring should be reviewed after each monitoring run. Biomonitoring should be undertaken during the dry season (July/August). An annual report that details the biomonitoring results should be prepared. The report should recommend management actions needed, identify any additional studies that may be needed, and recommend changes to the biomonitoring plan (if any)
- **Water quality variables**: The *in-situ* water quality should be monitored weekly upstream and downstream of the construction areas. The *in-situ* variables include:
  - pH
  - Conductivity
  - Total Dissolved Solids
  - Dissolved Oxygen
- In addition, monthly water quality monitoring should be undertaken of water both upstream and downstream of the construction areas for the parameters listed below:
  - pH
  - Electrical Conductivity
  - Turbidity
  - Total Suspended Solids
  - Chemical Oxygen Demand as O_2
  - Total Alkalinity as $CaCO_3$
  - Chloride as Cl^-
  - Fluoride as F^-
  - Nitrate as N
  - Nitrite as N
  - Sodium as Na
  - Potassium as K
  - Magnesium as Mg
  - Calcium as Ca
  - Arsenic as As
  - Cadmium as Cd
  - Chromium as Cr
  - Copper as Cu
  - Iron as Fe
  - Mercury as Hg
  - Manganese as Mn
  - Nickel as Ni
  - Lead as Pb
  - Antimony as Sb
  - Selenium as Se
  - Tin as Sn
  - Strontinum as Sr

- Thallium as Tl
- Uranium as U
- Zinc as Zn
- The environmental manager on-site should monitor the following aspects weekly:
  - Sediment mobilisation and erosion
  - Flow monitoring
  - Visual assessment of the construction area
  - Implementation and compliance of the ESMP.

8.0 CONCLUSION

The aquatic study was undertaken as part of support in the development of environmental scoping and impact studies to provide updated baseline conditions of aquatic ecosystems associated with the proposed Haib Copper Project and assess the potential impact of the proposed project on the receiving aquatic environment. A survey was undertaken during June 2024 (dry season) and March 2025 (wet season). The sampling was limited to accessible areas within the Orange River. Additional inputs were received from the routine monitoring programme currently implemented on site.

8.1 HABITAT QUALITY AND AVAILABILITY

Habitat availability was mainly adequate to poor at all the sites. The quality of the available habitat ranged between Moderately to Critically Modified. The sites are mainly impacted by absence of certain biotopes (e.g., limited to no vegetation), limited variety for available biotopes (e.g., dominance of sand as a substrate) and fluctuating water levels that result in continuous modification of riverbanks.

8.2 AQUATIC MACROINVERTEBRATES

The Orange River was categorised between an ecological state of Largely natural with few modifications at the furthest downstream point to a Moderately / Seriously Modified upstream of the proposed project area. The ecological state at the sampling points in between was variable (i.e., Moderately to Seriously Modified) but could be attributed to the limited sampling habitat available as well as ongoing impacts within the Orange River over the years. Based on the current and previous data collected, conditions within the Orange River have to some degree negatively impacted on the macroinvertebrate assemblage.

8.3 ICHTHYOFAUNA

Fish were recorded at all the sites, but not in abundance. The ecological state at the various sites were between Largely and Seriously Modified. The downstream sites (D1 and D3) presented the lowest FAII scores and fish diversity. However, due to the nature of the sampling points, sampling was limited to certain sections of accessible area. Based on observations from the local fishermen, fish diversity and abundance tends to fluctuate with seasons within the Orange River.

8.4 DIATOMS

Moderate biological water quality prevailed at all sites except Site D2 during the 2025 wet season. Slight deterioration was evident at Sites C1, I1 and D1 from the 2024 dry season due to increased salinity content and nutrient levels, which was attributed to agricultural activities and elevated flow. Biological water quality was poor at Site D2 during the wet season due to increased nutrient levels and was the most impacted site. Site D3 was sampled for the first time in March 2025 and the main impact on the site was elevated nutrient levels. Turbulence was elevated at most sites due to elevated flow, while the impact of sedimentation decreased at all sites except Site D1.

8.5 CHEMICAL ANALYSES

- Elevated Aluminium, Iron, Zinc, and Copper concentrations were noted across the various sites and seasons, with probable sources including natural geology, and agricultural activities.
- Mercury was detected and exceeded guideline limits at the downstream sites (I1 and D2) during the dry season.
- Nitrate and Total Suspended Solids (TSS) levels were elevated downstream of the proposed Project area, attributed primarily to fertiliser use and sediment input from agricultural drainage channels.
- Other concerns include increased salinity, nutrient enrichment (most likely due to Nitrogen), and potential long-term risks associated with metals like Arsenic and Chromium (potentially from upstream mining activities). While these did not exceed guideline limits in the water samples, sediment-bound concentrations in previous studies (Erasmus, et al., 2024) indicate future risks through sediment resuspension events, and bioaccumulation in benthic feeders that serve as a source of protein for various communities along the Orange-Senqu River basin

8.6 IMPACT ASSESSMENT

The potential impacts to the aquatic ecosystems associated with the pre-construction and construction phases of the proposed Project include:

- **Increased Sedimentation and Habitat Alteration**: Due to the arid nature of the project area and implementation of erosion control measures, this is expected to be of LOW significance before and after mitigation.
- **Habitat Loss**: Given the lack of natural diversity at this river segment, the impact remains LOW in significance both pre- and post-mitigation.
- **Community Assemblage Changes**: Given the existing degraded baseline conditions, any changes are expected to be of LOW significance.
- **Loss of Sensitive Fauna**: Few sensitive taxa were observed during baseline surveys, potential impacts to sensitive macroinvertebrates and fish communities are considered LOW in significance.
- **Water Quality Deterioration**: Increased runoff risks carrying sediments and hydrocarbon pollutants into the Orange River. The implementation of standard best practice mitigation methods limits this to a LOW significance impact.

The potential impacts to the aquatic ecosystems associated with operational phase impacts include:

- **Water Quality Deterioration**: Infrastructure failures or routine discharges may introduce pollutants into the river. Initially rated MODERATE, this impact is reduced to LOW with effective mitigation, such as bunding, containment, and water treatment systems.
- **Contribution to Algal Blooms**: Operational discharges may add nutrients to a system already experiencing frequent algal blooms. Due to the existing eutrophic conditions, the incremental contribution is considered LOW significance.
- **Loss of Aquatic Habitat and Biodiversity (In case of catastrophic failure)**: In the event of a tailings dam breach or critical infrastructure failure, significant aquatic ecosystem damage could occur, potentially reaching the Atlantic Ocean. This is the most severe scenario and is rated HIGH significance, reduced to MODERATE with appropriate design, monitoring, and emergency containment plans.

- **Increased Sediment Runoff and Erosion**: Runoff from operational areas such as stockpiles and waste dumps could worsen local sedimentation. While inherently MODERATE, the arid climate, terrain, and separation from the river reduce the impact to LOW significance post-mitigation.

The potential impacts to the aquatic ecosystems associated with decommissioning and closure phase impacts include:

- **Physical Disturbance, Alteration of Natural Flows and Contamination**: Decommissioning activities may result in increased sediment mobilisation and potential spillages, as well as altered flow through removal of stormwater management infrastructure. This impact is considered to be of LOW significance.
- **Rehabilitation Of Footprint Area**: The rehabilitation of the decommissioned infrastructure footprint areas will promote the re-establishment of vegetation which may serve as barriers to erosion and increase habitat availability for aquatic fauna within the marginal and riparian zones. This is a positive impact of MODERATE significance.

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10.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

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APPENDIX A

Diatom Reports

HAIB – DIATOM RESULTS

JUNE 2024

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1. BACKGROUND

Diatoms have been shown to be reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution, as well as for general water quality. Diatoms are commonly employed in monitoring efforts as sensitive biological indicators to determine the anthropogenic impact on aquatic ecosystems, and have for a long time been used in bio-assessments (Kasperovičienė and Vaikutienė, 2007). As benthic diatom assemblages are sessile they are exposed to water quality at a site over a period antecedent to sampling. They therefore indicate recent as well as current water quality (Philibert *et al*., 2006). Diatoms (as a biological response variable) are included in biomonitoring as it provides additional information on the water quality assessment in terms of current pollution levels and possible trends in physical chemical variables. Diatoms also provide a general description of the water quality related habitat specifications linked to ecologically sensitive species requirements. Diatom-based water quality indices for riverine ecosystems have been implemented in South Africa since 2004 as there is a measurable relationship between water quality variables such as pH, electrical conductivity, phosphorus and nitrogen, and the structure of diatom communities as reflected by diatom index scores, allowing for inferences to be drawn about water quality (Taylor, 2004; De la Rey *et al*. (2004).

The specific water quality tolerances of diatoms have been resolved into different diatom-based water quality indices, used around the world. Most indices are based on a weighted average equation (Zelinka and Marvan, 1961). In general, each diatom species used in the calculation of the index is assigned two values; the first value (s value) reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value (v value) indicates how strong (or weak) the relationship is (Taylor, 2004). These values are then weighted by the abundance of the particular diatom species in the sample (Lavoie *et al*., 2006; Besse, 2007). The main difference between indices is in the indicator sets (number of indicators and list of taxa) used in calculations (Eloranta and Soininen, 2002). These indices form the foundation for developing computer software to estimate biological water quality. OMNIDIA (Lecointe *et al*., 1993) is one such software package; it has been approved by the European Union and is used with increasing frequency in Europe and will be used for this study.

1.1 AIMS AND OBJECTIVES

The aim of the diatom sampling and analysis is to provide biological water quality information for conditions on the day of biological component sampling regarding the aquatic health and functioning of the aquatic system, and providing additional input to the physico-chemical component of the study as a response variable. The overall objective of this report is to assess the impacts of anthropogenic activities on the Present Ecological State of the receiving aquatic ecosystem

1.2 TERMINOLOGY

Several key ecological terms used in South African diatomology are summarised in Table 1.1 for the meaningful reading and understanding of the diatom results.

Table 1.1 Diatoms: Key ecological terms Taylor *et al*. (2007a)

Trophy	
Dystrophic	Rich in organic matter, usually in the form of suspended plant colloids, but of a low nutrient content.
Oligotrophic	Low levels or primary productivity, containing low levels of mineral nutrients required by plants.
Mesotrophic	Intermediate levels of primary productivity, with intermediate levels of mineral nutrients required by plants.
Eutrophic	High primary productivity, rich in mineral nutrients required by plants.
Hypereutrophic	Very high primary productivity, constantly elevated supply of mineral nutrients required by plants.
Mineral content	
Very electrolyte poor	< 50 µS/cm
Electrolyte-poor (low electrolyte content)	50 - 100 µS/cm
Moderate electrolyte content	100 - 500 µS/cm
Electrolyte-rich (high electrolyte content)	> 500 µS/cm
Brackish (very high electrolyte content)	> 1000 µS/cm
Saline	6000 µS/cm
Pollution (Saprobity)	
Unpolluted to slightly polluted	BOD <2, O_2 deficit <15% (oligosaprobic)
Moderately polluted	BOD <4, O_2 deficit <30% (β-mesosaprobic)
Critical level of pollution	BOD <7 (10), O_2 deficit <50% (β-ά-mesosaprobic)
Strongly polluted	BOD <13, O_2 deficit <75% (ά-mesosaprobic)
Very heavily polluted	BOD <22, O_2 deficit <90% (ά-meso-polysaprobic)
Extremely polluted	BOD >22, O_2 deficit >90% (polysaprobic)

2. METHODS

2.1 SAMPLING AND ANALYSIS

Epilithic[1] and/or Epiphytic[2] substrate was sampled as outlined in Taylor *et al*. (2007a). Diatom samples were taken at the site by scrubbing the substrate with a small brush and rinsing both the brush and the substrate with distilled water.

Preparation of diatom slides followed the Hot HCl and $KMnO_4$ method as outlined in Taylor *et al.* (2007a). A Nikon Eclipse E100 microscope with phase contrast optics (1000x) was used to identify diatom valves on slides. The aim of the data analysis was to count 400 diatom valves to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor *et al*., 2007a). This range is supported by Prygiel *et al.* (2002), Schoeman (1973) and Battarbee (1986) as satisfactory for the calculation of relative abundance of diatom species. Nomenclature followed Krammer and Lange-Bertalot (1986-91). Diatom index values were calculated in the database programme OMNIDIA (Lecointe *et al.*, 1993) for epilithon data in order to generate index scores to general water quality variables.

2.2 DIATOM BASED WATER QUALITY SCORE

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to assign biological water quality Ecological Categories (ECs) and associated water quality classes. Classes based on the class limits provided in Table 2.1. Other indices housed within the OMNIDIA programme used to characterise biological water quality included:

- Biological Diatom Index (BDI): Primarily a practical index, as it treats morphologically related taxa as one group and composes so-called associated taxa eliminating species that are difficult to identify.
- The ecological characterisation of diatom species based on Van Dam *et al.* (1994): Includes the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state.
- Trophic Diatom Index (TDI) (Kelly and Whitton, 1995): This index provides the percentage pollution tolerant diatom valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.
- Valve deformities were also noted as it is an indication of possible metal toxicity that may be present within the system. According to Luís *et al*. (2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The general threshold for the occurrence of valve deformities in a sample is usually considered between 1 - 2% and is regarded as potentially hazardous (Taylor, *pers. comm*.).

[1] Diatoms growing on rock or stone surfaces.
[2] Diatoms growing on macrophytic surfaces.

Table 2.1 Class limit boundaries for the SPI index applied in this study

Interpretation of index scores		
Ecological Category (EC)	**Class**	**Index Score (SPI Score)**
A	High quality	18 - 20
A/B		17 - 18
B	Good quality	15 - 17
B/C		14 - 15
C	Moderate quality	12 - 14
C/D		10 - 12
D	Poor quality	8 - 10
D/E		6 - 8
E	Bad quality	5 - 6
E/F		4 - 5
F		<4

3. RESULTS AND DISCUSSION

Table 3.1 provides a summary of the results obtained following a detailed assessment of the diatom assemblage at each of the selected sites during the June 2024 biomonitoring assessment. Appendix A provides a list of diatom species sampled during the June 2024 biomonitoring assessment.

Table 3.1 Diatom results obtained for sites assessed during the June 2024 biomonitoring assessment

Site	No species	SPI score	Water Quality Class	Category	PTV (%)	Valve deformities (%)
C1	39	12.1	Moderate quality	C	7	0.3
I1	35	10.9	Moderate quality	C/D	13.8	0
D2	43	11.2	Moderate quality	C/D	16	0
D1	43	11.1	Moderate quality	C/D	10.5	0

3.1 SITE C1

During the January 2024 biomonitoring assessment, Site C1 obtained a Specific Pollution sensitivity Index (SPI) score of 12.1, reflecting moderate biological water quality (Ecological Category C; Table 3.1). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score – Table 3.1) was low June 2024. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate (Table 1.1).

In June 2024, *Fragilaria crotonensis* and *Nupela* species occurred in highest abundance. *Fragilaria crotonensis* occurs in oligotrophic to weakly eutrophic, slightly alkaline freshwater with moderate electrolyte content (Taylor *et al*., 2007b). *Nupela* species are usually sensitive species with a preference for low conductivity (Taylor and Cocquyt, 2016). The diatom assemblage indicated that nutrient levels and sedimentation was elevated and reflected by the dominance of *Aulacoseira granulata* and motile species from the genera *Nitzschia* and *Navicula*. *Aulacoseira granulata* indicates eutrophication and therefore increased total phosphorous (Urrutia *et al.,* 2000). Dong *et al*. (2016) linked *Aulacoseira granulata* to medium nutrients levels (mesotrophic) and turbulent conditions. *Nitzschia* and *Navicula* species are motile species and are superior competitors for nutrients in nutrient-rich environments and can physically avoid stress within the benthic mat by moving to resource-rich microhabitats (Passy *et al*., 2007). According to Tudesque *et al*. (2012), motile diatoms are able to tolerate the high load of suspended solids and highly motile species, *Nitzschia* species and moderately motile species i.e. *Navicula* species were prolific and indicated moderate sedimentation, which would impact the taxonomic and the functional structure of the diatoms due to diminished suitable habitat and substrate. Key indicator species associated with anthropogenic impact occurred at low abundance indicating impact rates were low. Valve deformities occurred at an abundance of 0.3%, falling within general threshold limits, suggesting limited bio-availability of toxins or metals.

3.2 SITE I1

During the June 2024 biomonitoring assessment, Site I1 obtained a SPI score of 10.9, reflecting moderate biological water quality (Ecological Category C/D; Table 3.1). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score – Table 3.1) was low June 2024. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate (Table 1.1).

Biological water quality deteriorated from Site C1, due to increased organic load and salinity content. The abundance of *Fragilaria crotonensis* decreased while the abundance of *Fragilaria geocollegarum*, a hardier species, increased and seems to prefer more alkaline waters (pH 7.1 - 8.3), higher conductivity (458 - 1120 µS/cm), and more eutrophic conditions (early eutrophic to dystrophic) (Morales, 2002). *Staurosira elliptica* was also dominant and is a benthic, facultative planktonic species; r-strategist species (fast reproducing), able to tolerate harsh and frequently changing conditions (Fitchett *et al*., 2015), suggesting that the site was regularly exposed to fluctuation in flow which may be due to abstraction. The planktonic species, *Stephanodiscus agassizensis* was also dominant and is a planktonic species found in eutrophic rivers with an elevated electrolyte concentration and turbidity (Taylor *et al*., 2007b). Motile species decreased in abundance, indicating a decrease in sedimentation and an increase in suitable habitat, which resulted in an improvement of taxonomic and functional structure of the diatoms. Key indicator species associated with anthropogenic impact occurred at low abundance indicating impact rates were low but increased from Site C1. No valve deformities were present, suggesting limited bio-availability of toxins or metals.

3.3 SITE D2

During the June 2024 biomonitoring assessment, Site D2 obtained a SPI score of 11.2, reflecting moderate biological water quality (Ecological Category C/D; Table 3.1). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score – Table 3.1) was low June 2024. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate (Table 1.1).

Biological water quality remained relatively stable between Site I1 and Site D2 in June 2024, although an increase in nutrient levels, organic load and salinity content was evident. *Achnanthidium minutissimum* was dominant and is an adnate pioneer species that achieves high numbers in response to natural physical stress (high current velocity and substrate scour) (Teply and Bahls, 2006), reflecting that flow increased at Site D2. *Fragilaria crotonensis* (Taylor *et al*., 2007b) was still dominant along with *Aulacoseira granulata* and *Stephanodiscus agassizensis* which reflected elevated nutrient levels and salinity content (Urrutia *et al.,* 2000; Taylor *et al*., 2007b) which increased between Site I1 and Site D2 due to agricultural activities. *Nitzschia frustulum* was also dominant and is a nitrogen heterotroph, extremely tolerant of salinity and high alkalinity and becomes abundant in brackish waters because competition from other diatom species is reduced. It is tolerant of critical levels of pollution, preferring elevated SO_4 waters (Cholnoky, 1968; Hecky and Kilham, 1973; Stenger-Kovács *et al*., 2014; Lengyel *et al*., 2015). *Nitzschia* species increased notably in abundance at Site D2, reflecting increased sedimentation which would impact the taxonomic and the functional structure of the diatoms due to diminished suitable habitat and substrate. Key indicator species associated with anthropogenic impact occurred at moderate abundance reflecting an increased gradient of impact at Site D2 due agricultural activities resulting in higher nutrient levels and salinity content. No valve deformities were present, suggesting limited bio-availability of toxins or metals.

3.4 SITE D1

During the June 2024 biomonitoring assessment, Site D2 obtained a SPI score of 11.1, reflecting moderate biological water quality (Ecological Category C/D; Table 3.1). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score – Table 3.1) was low June 2024. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate (Table 1.1).

Biological water quality remained relatively stable between Site D2 and Site D1 in June 2024. *Achnanthidium minutissimum* was dominant, reflecting that flow was elevated at Site D1 (Teply and Bahls, 2006). *Fragilaria crotonensis* (Taylor *et al*., 2007b) and *Fragilaria geocollegarum* was dominant along with *Aulacoseira granulata* and *Stephanodiscus agassizensis* which reflected elevated nutrient levels and salinity content (Urrutia *et al.,* 2000; Taylor *et al*., 2007b). The dominance of *Nitzschia frustulum* indicated that salinity content and nutrient levels were still elevated (Cholnoky, 1968; Hecky and Kilham, 1973; Stenger-Kovács *et al*., 2014; Lengyel *et al*., 2015). *Nitzschia* species increased in abundance between Site D2 and Site D1, reflecting increased sedimentation which would impact the taxonomic and the functional structure of the diatoms due to diminished suitable habitat and substrate. Key indicator species associated with anthropogenic impact occurred at moderate abundance reflecting an increased gradient of impact at Site D2 mainly due agricultural activities and the town of Noordoewer, resulting in higher nutrient levels and salinity content. No valve deformities were present, suggesting limited bio-availability of toxins or metals.

4. CONCLUSIONS

A summary of the June 2024 diatom results are provided in Figure 4.1.

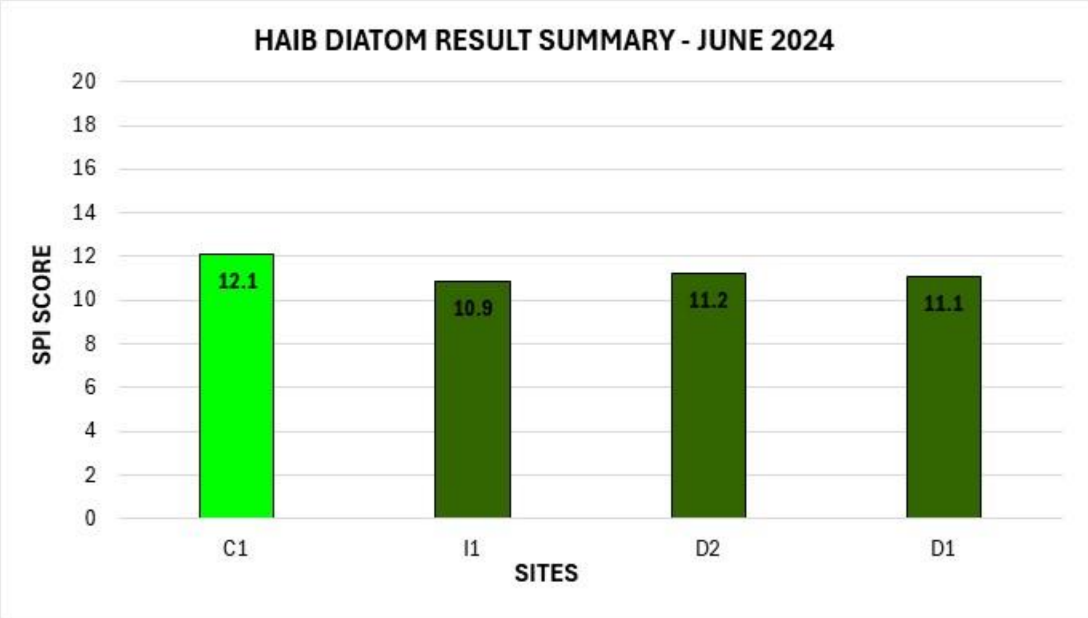

Figure 4.1 Haib: Diatom result summary – June 2024

Moderate biological water quality prevailed at Site C1 and nutrient levels and salinity content were moderate. Diatom data indicated that moderate sedimentation was present, which would impact the taxonomic and the functional structure of the diatoms due to diminished suitable habitat and substrate. Key indicator species associated with anthropogenic impact occurred at low abundance indicating impact rates were low. Biological water quality was moderate at Site I1 and deteriorated from Site C1, due to increased organic load and salinity content. Diatom data indicated that flow fluctuated, most probably due to abstraction, but that sedimentation decreased. Key indicator species associated with anthropogenic impact occurred at low abundance indicating impact rates were low but increased from Site C1.

Site D2 was characterised by moderate biological water with moderate nutrient levels and salinity content. Biological water quality remained relatively stable between Site I1 and Site D2 in June 2024, although an increase in nutrient levels, organic load and salinity content was evident, most probably due to agricultural activities. Diatom data indicated that that flow and sedimentation increased at Site D2. Key indicator species associated with anthropogenic impact occurred at moderate abundance, reflecting an increased gradient of impact at Site D2 due agricultural activities resulting in higher nutrient levels and salinity content. Biological water quality remained relatively stable between Site D2 and Site D1 in June 2024 with elevated nutrient levels and salinity content characterising the water. Diatom data indicated increased sedimentation between these sites while key indicator species reflected an increased gradient of impact at Site D2 mainly due agricultural activities and the town of Noordoewer, resulting in higher nutrient levels and salinity content.

Diatom data indicated that the bio-availability of toxins or metals at all sites was limited.

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6. APPENDIX A: DIATOM SPECIES LIST

A list of diatom species recorded in July 2024 at the biomonitoring sites, expressed as the number recorded out of a total count of 400 is provided below.

Species	C1	I1	D2	D1
Abnormal diatom valve (unidentified) or sum of deformities abundances	1			
Achnanthidium eutrophilum (Lange-Bertalot) Lange-Bertalot	3			
Achnanthidium exiguum (Grunow) Czarnecki		1		1
Achnanthidium minutissima Kützing (Czarnecki)	7	17	25	20
Amphora pediculus (Kützing) Grunow	2			
Aulacoseira granulata (Ehrenberg) Simonsen	21	11	26	17
Aulacoseira granulata var. *angustissima* (O Müller) Simonsen	7	16	3	5
Aulacoseira muzzanensis (Meister) Krammer	4			
Caloneis bacillum (Grunow) Cleve				1
Cocconeis pediculus Ehrenberg			1	
Cocconeis placentula Ehrenberg			1	
Cyclostephanos dubius (Fricke) Round	2	4	12	2
Cyclotella medunae Germain	1		1	1
Cyclotella meneghiniana Kützing	1	5	7	1
Cyclotella ocellata Pantocsek		2	1	2
Discostella stelligera (Hustedt) Houk & Klee	6	10	9	5
Encyonopsis microcephala (Grunow) Krammer	1	1	2	
Eolimna minima (Grunow) Lange-Bertalot		2		
Epithemia sorex Kützing	2	9	48	21
Fragilaria capucina Desmazières				3
Fragilaria crotonensis Kitton	179	117	87	129
Fragilaria geocollegarum Witkowski	11	42	7	23
Gomphonema parvulum (Kützing) Kützing	2		5	3
Gyrosigma acuminatum (Kützing) Rabenhorst				4
Gyrosigma rautenbachiae Cholnoky				1
Hantzschia amphioxys (Ehrenberg) Grunow		1		
Hippodonta capitata (Ehrenberg) Lange-Bertalot Metzeltin & Witkowski	1			
NAVICULA J.B.M. Bory de St. Vincent	1			5
Navicula cryptocephala Kützing	2		1	
Navicula cryptotenella Lange-Bertalot	3	11	15	11
Navicula recens (Lange-Bertalot) Lange-Bertalot	3	1		1
Navicula rostellata Kützing	19	4	11	1
Navicula tenelloides Hustedt			1	3
Navicula tripunctata (OF Müller) Bory				1
Navicula veneta Kützing	2	2	3	13
NITZSCHIA A.H. Hassall	19	15	11	27
Nitzschia angustata Grunow		4	1	1
Nitzschia archibaldii Lange-Bertalot			5	8
Nitzschia frustulum (Kützing) Grunow	6	7	26	20
Nitzschia gracilis Hantzsch				3
Nitzschia heufleriana Grunow	1		3	
Nitzschia linearis (Agardh) W Smith		22	2	
Nitzschia microcephala Grunow		3	2	1
Nitzschia palea (Kützing) W. Smith	6	13	18	6
Nitzschia pura Hustedt			1	
Nitzschia recta Hantzsch	8	3		
NUPELA W. Vyverman & P. Compere	31			
PINNULARIA C.G. Ehrenberg	1			

Species	C1	I1	D2	D1
Placoneis elginensis (Greg) Cox	1		3	1
Placoneis placentula (Ehrenberg) Heinzerling			1	
Planothidium rostrata (Øestrup) Round & Bukhityarova				2
Pleurosigma salinarum (Grunow)	4	3	6	
Pseudostaurosira brevistriata (Grun.in Van Heurck) Williams & Round				1
Rhoicosphenia curvata (Kützing) Grunow			1	
Rhopalodia gibba (Ehrenberg) O Müller		2	2	3
Sellaphora pupula (Kützing) Mereschkowksy				2
Sellaphora seminulum (Grunow) DG Mann	5		1	
Staurosira elliptica (Schumann) Williams & Round	13	20	6	11
Staurosira pinnata Ehrenberg		12	2	
Stephanodiscus agassizensis Håkansson & Kling	14	25	25	19
Stephanodiscus hantzschii Grunow	5	5	7	10
Stephanodiscus minutulus (Kützing) Cleve and Möller	3	3	6	3
Synedra nana Meister				2
Tryblionella calida DG Mann		1		
Tryblionella coarctata (Grunow) D.G. Mann	1			
Tryblionella levidensis WM Smith	1	5	1	3
Ulnaria biceps (Kützing) Compére			2	
Ulnaria ulna Sippe *angustissima* (Grunow) Lange-Bertalot		1	2	3
Total count	**400**	**400**	**400**	**400**

HAIB – DIATOM RESULTS

MARCH 2025

Authored by: Shael Koekemoer

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AQUATIC CONSULTANTS

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1. BACKGROUND

Diatoms have been shown to be reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution, as well as for general water quality. Diatoms are commonly employed in monitoring efforts as sensitive biological indicators to determine the anthropogenic impact on aquatic ecosystems, and have for a long time been used in bio-assessments (Kasperovičienė and Vaikutienė, 2007). As benthic diatom assemblages are sessile they are exposed to water quality at a site over a period antecedent to sampling. They therefore indicate recent as well as current water quality (Philibert *et al*., 2006). Diatoms (as a biological response variable) are included in biomonitoring as it provides additional information on the water quality assessment in terms of current pollution levels and possible trends in physical chemical variables. Diatoms also provide a general description of the water quality related habitat specifications linked to ecologically sensitive species requirements. Diatom-based water quality indices for riverine ecosystems have been implemented in South Africa since 2004 as there is a measurable relationship between water quality variables such as pH, electrical conductivity, phosphorus and nitrogen, and the structure of diatom communities as reflected by diatom index scores, allowing for inferences to be drawn about water quality (Taylor, 2004; De la Rey *et al*. (2004).

The specific water quality tolerances of diatoms have been resolved into different diatom-based water quality indices, used around the world. Most indices are based on a weighted average equation (Zelinka and Marvan, 1961). In general, each diatom species used in the calculation of the index is assigned two values; the first value (s value) reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value (v value) indicates how strong (or weak) the relationship is (Taylor, 2004). These values are then weighted by the abundance of the particular diatom species in the sample (Lavoie *et al*., 2006; Besse, 2007). The main difference between indices is in the indicator sets (number of indicators and list of taxa) used in calculations (Eloranta and Soininen, 2002). These indices form the foundation for developing computer software to estimate biological water quality. OMNIDIA (Lecointe *et al*., 1993) is one such software package; it has been approved by the European Union and is used with increasing frequency in Europe and will be used for this study.

1.1 AIMS AND OBJECTIVES

The aim of the diatom sampling and analysis is to provide biological water quality information for conditions on the day of biological component sampling regarding the aquatic health and functioning of the aquatic system, and providing additional input to the physico-chemical component of the study as a response variable. The overall objective of this report is to assess the impacts of anthropogenic activities on the Present Ecological State of the receiving aquatic ecosystem

1.2 TERMINOLOGY

Several key ecological terms used in South African diatomology are summarised in Table 1.1 for the meaningful reading and understanding of the diatom results.

Table 1.1 Diatoms: Key ecological terms Taylor *et al*. (2007a)

Trophy	
Dystrophic	Rich in organic matter, usually in the form of suspended plant colloids, but of a low nutrient content.
Oligotrophic	Low levels or primary productivity, containing low levels of mineral nutrients required by plants.
Mesotrophic	Intermediate levels of primary productivity, with intermediate levels of mineral nutrients required by plants.
Eutrophic	High primary productivity, rich in mineral nutrients required by plants.
Hypereutrophic	Very high primary productivity, constantly elevated supply of mineral nutrients required by plants.
Mineral content	
Very electrolyte poor	< 50 µS/cm
Electrolyte-poor (low electrolyte content)	50 - 100 µS/cm
Moderate electrolyte content	100 - 500 µS/cm
Electrolyte-rich (high electrolyte content)	> 500 µS/cm
Brackish (very high electrolyte content)	> 1000 µS/cm
Saline	6000 µS/cm
Pollution (Saprobity)	
Unpolluted to slightly polluted	BOD <2, O_2 deficit <15% (oligosaprobic)
Moderately polluted	BOD <4, O_2 deficit <30% (β-mesosaprobic)
Critical level of pollution	BOD <7 (10), O_2 deficit <50% (β-ά-mesosaprobic)
Strongly polluted	BOD <13, O_2 deficit <75% (ά-mesosaprobic)
Very heavily polluted	BOD <22, O_2 deficit <90% (ά-meso-polysaprobic)
Extremely polluted	BOD >22, O_2 deficit >90% (polysaprobic)

2. METHODS

2.1 SAMPLING AND ANALYSIS

Epilithic[1] and/or Epiphytic[2] substrate was sampled as outlined in Taylor *et al*. (2007a). Diatom samples were taken at the site by scrubbing the substrate with a small brush and rinsing both the brush and the substrate with distilled water.

Preparation of diatom slides followed the Hot HCl and $KMnO_4$ method as outlined in Taylor *et al.* (2007a). A Nikon Eclipse E100 microscope with phase contrast optics (1000x) was used to identify diatom valves on slides. The aim of the data analysis was to count 400 diatom valves to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor *et al*., 2007a). This range is supported by Prygiel *et al.* (2002), Schoeman (1973) and Battarbee (1986) as satisfactory for the calculation of relative abundance of diatom species. Nomenclature followed Krammer and Lange-Bertalot (1986-91). Diatom index values were calculated in the database programme OMNIDIA (Lecointe *et al.*, 1993) for epilithon data in order to generate index scores to general water quality variables.

2.2 DIATOM BASED WATER QUALITY SCORE

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to assign biological water quality Ecological Categories (ECs) and associated water quality classes. Classes based on the class limits provided in Table 2.1. Other indices housed within the OMNIDIA programme used to characterise biological water quality included:

- Biological Diatom Index (BDI): Primarily a practical index, as it treats morphologically related taxa as one group and composes so-called associated taxa eliminating species that are difficult to identify.
- The ecological characterisation of diatom species based on Van Dam *et al.* (1994): Includes the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state.
- Trophic Diatom Index (TDI) (Kelly and Whitton, 1995): This index provides the percentage pollution tolerant diatom valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.
- Valve deformities were also noted as it is an indication of possible metal toxicity that may be present within the system. According to Luís *et al*. (2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The general threshold for the occurrence of valve deformities in a sample is usually considered between 1 - 2% and is regarded as potentially hazardous (Taylor, *pers. comm*.).

[1] Diatoms growing on rock or stone surfaces.
[2] Diatoms growing on macrophytic surfaces.

Table 2.1 Class limit boundaries for the SPI index applied in this study

Interpretation of index scores		
Ecological Category (EC)	**Class**	**Index Score (SPI Score)**
A	High quality	18 - 20
A/B		17 - 18
B	Good quality	15 - 17
B/C		14 - 15
C	Moderate quality	12 - 14
C/D		10 - 12
D	Poor quality	8 - 10
D/E		6 - 8
E	Bad quality	5 - 6
E/F		4 - 5
F		<4

3. RESULTS AND DISCUSSION

Table 3.1 provides a summary of the results obtained following a detailed assessment of the diatom assemblage at each of the selected sites during the June 2024 and March 2025 biomonitoring assessment. Appendix A provides a list of diatom species sampled during the June 2024 biomonitoring assessment.

Table 3.1 Diatom results obtained for sites assessed during the June 2024 and March 2025 biomonitoring assessment

Site	No species	SPI score	Water Quality Class	Category	PTV (%)	Valve deformities (%)
June 2024						
C1	39	12.1	Moderate quality	C	7	0.3
I1	35	10.9	Moderate quality	C/D	13.8	0
D2	43	11.2	Moderate quality	C/D	16	0
D1	43	11.1	Moderate quality	C/D	10.5	0
March 2025						
C1	34	11.9	Moderate quality	C/D	6.8	0
I1	33	10.6	Moderate quality	C/D	6.5	0
D2	34	9.7	Poor quality	D	8.5	0
D1	47	10.2	Moderate quality	C/D	20.3	0
D3	36	10.6	Moderate quality	C/D	9	0

3.1 SITE C1

During the March 2025 biomonitoring assessment, Site C1 obtained a Specific Pollution sensitivity Index (SPI) score of 11.9, reflecting moderate biological water quality (Ecological Category C; Table 3.1). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score – Table 3.1) was low March 2025. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate (Table 1.1) in March 2025, remaining stable from June 2024.

Slight deterioration in biological water quality was evident between June 2024 and March 2025 due to increased salinity content and nutrient levels resulting in the decreased abundance of sensitive species observed in June 2025. Nutrient enrichment was reflected by the increased abundance of centric diatoms from the genera *Aulacoseira*, *Cyclostephanos*, *Stephanodiscus* and *Staurosira* (Bennion *et al*., 2015). *Stephanodiscus minutulus* occurring at highest abundance and is found in strongly polluted water with a high electrolyte content along with the planktonic species, *Stephanodiscus agassizensis* which found in eutrophic rivers with an elevated electrolyte concentration and turbidity (Taylor *et al*., 2007b). *Fragilaria geocollegarum*, a hardier species, also increased in abundance between June 2024 and March 2025 and seems to prefer more alkaline waters (pH 7.1 - 8.3), higher conductivity (458 - 1120 µS/cm), and more eutrophic conditions (early eutrophic to dystrophic) (Morales, 2002). While turbulence increased in March 2025, the overall impact of sedimentation, based on the abundance of motile species (Passy *et al*., 2007; Tudesque *et al*., 2012) decreased from June 2024. As observed in June 2024, key indicator species associated with anthropogenic impact occurred at low abundance indicating impact rates were low. No valve deformities were present, suggesting limited bio-availability of toxins or metals.

3.2 SITE I1

During the March 2025 biomonitoring assessment, Site I1 obtained a SPI score of 10.6, reflecting moderate biological water quality (Ecological Category C/D; Table 3.1). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score – Table 3.1) was low March 2025. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate (Table 1.1) in March 2025, remaining stable from June 2024.

Biological water quality deteriorated slightly in March 2025 due to increased salinity content and nutrient levels, with improvement in organic load evident. Compositional shifts in the diatom community at Site I1 was similar to Site C1 with nutrient enrichment reflected by the increased abundance of centric diatoms from the genera *Aulacoseira*, *Stephanodiscus* and *Staurosira* (Bennion *et al*., 2015). *Staurosira elliptica* increased in abundance in March 2025, reflecting that the site was still exposed to harsh and frequently changing conditions (Fitchett *et al*., 2015), which may be due to abstraction. *Stephanodiscus minutulus*, *Stephanodiscus agassizensis* and *Fragilaria geocollegarum* were dominant, reflecting the increase in nutrient levels and salinity content at the site (Taylor *et al*., 2007b; Morales, 2002). While turbulence increased in March 2025, the overall impact of sedimentation, based on the abundance of motile species (Passy *et al*., 2007; Tudesque *et al*., 2012) decreased from June 2024. As observed in June 2024, key indicator species associated with anthropogenic impact occurred at low abundance indicating impact rates were low. No valve deformities were present, suggesting limited bio-availability of toxins or metals.

3.3 SITE D2

During the March 2025 biomonitoring assessment, Site D2 obtained a SPI score of 9.7, reflecting poor biological water quality (Ecological Category D; Table 3.1). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score – Table 3.1) was low June 2024. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate (Table 1.1) in March 2025, remaining stable from June 2024.

Biological water quality deterioration between June 2024 and March 2025 was mainly associated with increased nutrient input. Increased nutrient levels were reflected by the increased abundance of the centrics *Aulacoseira ambigua* and *Aulacoseira granulata* (Urrutia *et al*., 2000; Dong *et al*., 2016; Lei *et al*., 2021). *Staurosira elliptica* increased in abundance in March 2025, reflecting that the water level fluctuation was more pronounced in March 2025 (Fitchett *et al*., 2015). The dominance of *Fragilaria geocollegarum* reflected the increase in nutrient levels and salinity content at the site (Taylor *et al*., 2007b; Morales, 2002). Turbulence and sedimentation was not as pronounced at Site D2 in comparison to Site C1 and I1 in March 2025 (Passy *et al*., 2007; Tudesque *et al*., 2012). As observed in June 2024, key indicator species associated with anthropogenic impact occurred at moderate abundance reflecting an increased gradient of impact at Site D2 due agricultural activities resulting in higher nutrient levels and salinity content. No valve deformities were present, suggesting limited bio-availability of toxins or metals.

3.4 SITE D1

During the March 2025 biomonitoring assessment, Site D1 obtained a SPI score of 10.2, reflecting moderate biological water quality (Ecological Category C/D; Table 3.1). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score – Table 3.1) was moderate. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate (Table 1.1) in March 2025, remaining stable from June 2024.

Slight deterioration in biological water quality was evident in March 2025 due to increased organic load and nutrient levels. As observed at Site D2, water level fluctuation was more pronounced in March 2025 and reflected by the dominance of *Staurosira elliptica* (Fitchett *et al*., 2015). The dominance of *Fragilaria geocollegarum* reflected the increase in nutrient levels and salinity content at the site (Taylor *et al*., 2007b; Morales, 2002) while *Aulacoseira ambigua* and *Nitzschia archibaldii* indicated elevated nutrient levels (Dong *et al*., 2016; Lei *et al*., 2021; Hausmann *et al*., 2016). *Nitzschia* species increased in abundance between Site D2 and Site D1, but occurred at similar abundance than observed in June 2024, indicating that sedimentation was moderate with some impact on the taxonomic and the functional structure of the diatoms due to diminished suitable habitat and substrate (Tudesque *et al*., 2012). As observed in June 2024, key indicator species associated with anthropogenic impact occurred at moderate abundance reflecting an increased gradient of impact at Site D1 mainly due agricultural activities and the town of Noordoewer, resulting in higher nutrient levels and salinity content. No valve deformities were present, suggesting limited bio-availability of toxins or metals.

3.5 SITE D3

Site D3 was sampled for the first time in March 2025 and obtained a SPI score of 10.6, reflecting moderate biological water quality (Ecological Category C/D; Table 3.1). Nutrient levels and salinity content were moderate, based on the diatom assemblage collected, while organic load (as reflected by the PTV score – Table 3.1) was low. Further analysis of the various indices within OMNIDIA suggested general pollution levels were moderate (Table 1.1) in March 2025.

The main impact on the site was elevated nutrient levels associated with agricultural activities. The species composition at Site D3 was similar to Site D2 and D1 with the centrics *Aulacoseira ambigua* and *Aulacoseira granulata* (Urrutia *et al*., 2000; Dong *et al*., 2016; Lei *et al*., 2021) dominating along with *Staurosira elliptica* (Fitchett *et al*., 2015) and *Fragilaria geocollegarum* (Taylor *et al*., 2007b; Morales, 2002). While turbulence increased between Site D1 and D3, the overall impact of sedimentation, based on the abundance of motile species (Passy *et al*., 2007; Tudesque *et al*., 2012) decreased. The measure of impact at Site D3 was moderate. No valve deformities were present, suggesting limited bio-availability of toxins or metals.

4. CONCLUSIONS

A summary of the June 2024 and March 2025 diatom results are provided in Figure 4.1.

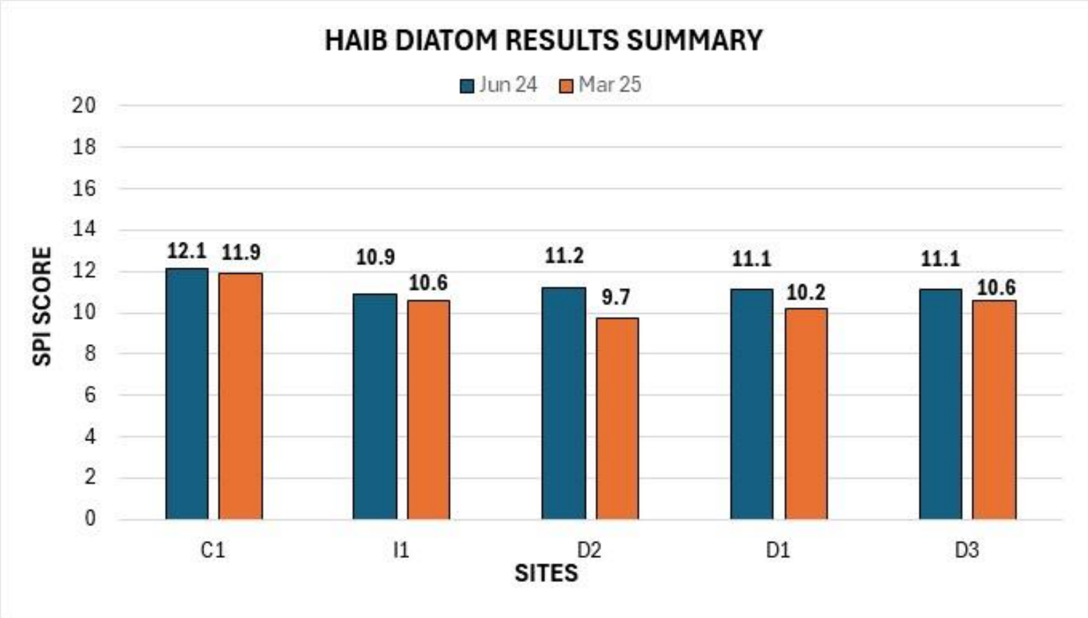

Figure 4.1 Haib: Diatom result summary for June 2024 and March 2025

Moderate biological water quality prevailed at all sites except Site D2 in March 2025. Slight deterioration was evident at Sites C1, I1 and D1 from June 2024 due to increased salinity content and nutrient levels, which was attributed to agricultural activities and elevated flow. Biological water quality was poor at Site D2 in March 2025 due to increased nutrient levels and was the most impacted site in March 2025. Site D3 was sampled for the first time in March 2025 and the main impact on the site was elevated nutrient levels. Turbulence was elevated at most sites due to elevated flow, while the impact of sedimentation decreased at all sites except Site D1. The measure of impact remained stable between June 2024 and March 2025 and the bio-availability of toxins or metals at all sites was not a concern.

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6. APPENDIX A: DIATOM SPECIES LIST

A list of diatom species recorded in March 2025 at the biomonitoring sites, expressed as the number recorded out of a total count of 400 is provided below.

Species	C1	I1	D2	D1	D3
Achnanthidium exiguum (Grunow) Czarnecki	1		3	1	
Achnanthidium minutissima Kützing (Czarnecki)	5	2		9	1
Amphora pediculus (Kützing) Grunow	1	1	3	3	2
Amphora veneta Kützing					1
Aulacoseira ambigua (Grunow) Simonsen	18	64	71	30	30
Aulacoseira granulata (Ehrenberg) Simonsen	7	30	40	18	25
Aulacoseira granulata var. *angustissima* (O Müller) Simonsen	12	18	14	3	1
Aulacoseira muzzanensis (Meister) Krammer				1	
Caloneis bacillum (Grunow) Cleve				1	
Cocconeis pediculus Ehrenberg					1
Cocconeis placentula Ehrenberg			1		2
Cyclostephanos dubius (Fricke) Round	12	3	2	2	
Cyclotella atomus Hustedt	15				1
Cyclotella meneghiniana Kützing	4	12	7		6
Cyclotella ocellata Pantocsek					3
Diatoma vulgaris Bory		1			
Discostella pseudostelligera (Hustedt) Houk et Klee	3	1		3	
Encyonopsis microcephala (Grunow) Krammer				7	
Eolimna minima (Grunow) Lange-Bertalot	2	1			1
Eolimna subminuscula (Manguin) Moser Lange-Bertalot & Metzeltin		3		1	
Epithemia sorex Kützing		1	1	3	
Fragilaria capucina Desmazières			2		
Fragilaria crotonensis Kitton	8	28	28	41	47
Fragilaria geocollegarum Witkowski	39	69	84	64	115
Geissleria ignota (Krasske) Lange-Bertalot & Metzeltin		1	1	2	3
Gomphonema gracile Ehrenberg				4	
Gomphonema parvulum (Kützing) Kützing	1		3	4	1
Gyrosigma acuminatum (Kützing) Rabenhorst		2		1	
Hantzschia amphioxys (Ehrenberg) Grunow	1	2		2	3
Hippodonta capitata (Ehrenberg) Lange-Bertalot Metzeltin & Witkowski		2			
Luticola mutica (Kützing) DG Mann		1			
Mastogloia smithii Thwaites				1	
Melosira varians Agardh			2	1	
NAVICULA J.B.M. Bory de St. Vincent				1	
Navicula cryptotenella Lange-Bertalot	2	1	2	4	1
Navicula gregaria Donkin					2
Navicula rhynchocephala Kützing	2	4	3	6	5
Navicula rostellata Kützing	1		1	1	1
Navicula veneta Kützing	1			3	
NITZSCHIA A.H. Hassall	9	10	20	25	11
Nitzschia acicularis (Kützing) WM Smith	2	1		7	
Nitzschia agnewii Cholnoky	1				
Nitzschia agnita Hustedt	4				
Nitzschia angustatula Lange-Bertalot				2	2
Nitzschia archibaldii Lange-Bertalot	1	12	19	49	17
Nitzschia frustulum (Kützing) Grunow	5	4	1	4	5

Species	C1	I1	D2	D1	D3
Nitzschia gracilis Hantzsch	6		1	6	1
Nitzschia intermedia Hantzsch			2		
Nitzschia linearis (Agardh) W Smith	5				2
Nitzschia linearis var. *subtilis* (Grunow)			5		
Nitzschia microcephala Grunow				1	
Nitzschia palea (Kützing) W. Smith		4	6	12	3
Nitzschia prolongata Hustedt					2
Nitzschia pumila Hustedt				1	
Nitzschia pura Hustedt			1		
PLACONEIS C. Mereschkowsky	2	2	3	2	5
Placoneis dicephala (W. Smith) Mereschkowsky			3		
Pleurosigma salinarum (Grunow) Cleve & Grunow			2	4	
Reimeria uniseriata Sala Guerrero & Ferrario				2	
Rhoicosphenia curvata (Kützing) Grunow	2			1	
Rhopalodia gibba (Ehrenberg) O Müller		1			
Sellaphora seminulum (Grunow) DG Mann	3				
Staurosira elliptica (Schumann) Williams & Round	17	59	35	36	73
Staurosira pinnata Ehrenberg				2	6
Stephanodiscus agassizensis Håkansson & Kling	35	26	11	3	8
Stephanodiscus hantzschii Grunow	16	11	13	12	11
Stephanodiscus minutulus (Kützing) Cleve and Möller	157	21	9	11	
Synedra nana Meister				2	1
THALASSIOCYCLUS Håkansson					1
Tryblionella debilis Arnott ex O'Meara		2	1	1	
Total count	**400**	**400**	**400**	**400**	**400**

APPENDIX B

Chemical Analysis

Certificate of Analysis

Project details

Customer Details

Invoice Category	400.001 - KPC
Customer reference:	HAIB COPPER (301-00906/05)
Quotation number:	Q2307-075_2
Order number:	162165
Company name:	KNIGHT PIESOLD CONSULTING
Contact address:	P O BOX 221, RIVONIA, 2128
Contact person:	LLOYD LYNCH

Sampling Details

Sampled by:	CUSTOMER
Sampled date:	2024/06/19
Additional customer information:	021199/24,021200/24,021201/24,021202/24 - SAMPLED BY: LLOYD LYNCH

Sample Details

Sample type(s):	SURFACE WATER SAMPLES
Date received:	2024/07/05
Delivered by:	COURIER SERVICE
Temperature at sample receipt (°C):	17.6

Report Details

Testing commenced:	2024/07/05
Testing completed:	2024/08/08
Report date:	2024/08/12
Our reference:	005824/24

Analytical Results

Methods	Determinands	Units	021199/24	021200/24
			HAIB: U1 19.06.2024	HAIB: I1 19.06.2024
Chemical				
85	Dissolved Calcium	mg Ca/ℓ	50	53
85	Potassium	mg K/ℓ	2.62	2.76
85	Dissolved Magnesium	mg Mg/ℓ	26	27
84	Sodium	mg Na/ℓ	57	58
83A	Dissolved Aluminium	µg Al/ℓ	22	18.4
83A	Dissolved Arsenic	µg As/ℓ	1.0	1.2
83A	Dissolved Cadmium	µg Cd/ℓ	<1	<1
83A	Dissolved Cobalt	µg Co/ℓ	<1	<1
83A	Dissolved Chromium	µg Cr/ℓ	1.1	1.1
83A	Dissolved Copper	µg Cu/ℓ	7.0	5.0
83A	Dissolved Iron	µg Fe/ℓ	21	15.5
83A	Dissolved Mercury	µg Hg/ℓ	<1	<1
83A	Dissolved Manganese	µg Mn/ℓ	<1	<1
83A	Dissolved Molybdenum	µg Mo/ℓ	1.3	<1
83A	Dissolved Nickel	µg Ni/ℓ	<1	<1
83A	Dissolved Lead	µg Pb/ℓ	<1	<1
91	Dissolved Silica	mg SiO_2/ℓ	8.59	11.0
83A	Dissolved Zinc	µg Zn/ℓ	24	9.9
83A	Total Aluminium	µg Al/ℓ	349	1028
83A	Total Arsenic	µg As/ℓ	1.7	2.4
83A	Total Cadmium	µg Cd/ℓ	<1	<1
83A	Total Cobalt	µg Co/ℓ	<1	<1
83A	Total Chromium	µg Cr/ℓ	3.5	10.4
83A	Total Copper	µg Cu/ℓ	20	943
83A	Total Iron	µg Fe/ℓ	814	1001
83A	Total Mercury	µg Hg/ℓ	<1	2.7
83A	Total Manganese	µg Mn/ℓ	49	66
83A	Total Molybdenum	µg Mo/ℓ	2.1	1.7
83A	Total Nickel	µg Ni/ℓ	1.7	3.7
83A	Total Lead	µg Pb/ℓ	<1	2.2
91	Total Silica	mg SiO_2/ℓ	5.11	11.1

Methods	Determinands	Units	021199/24	021200/24
			HAIB: U1 19.06.2024	HAIB: I1 19.06.2024
Chemical				
83A	Total Zinc	µg Zn/ℓ	19.2	636
10G	Total Alkalinity	mg $CaCO_3$/ℓ	216	141
16G	Chloride	mg Cl/ℓ	58	56
206	Cyanide (Total)*	µg CN/ℓ	<10	33
3	Chemical Oxygen Demand (Total)	mg O_2/ℓ	27	31
156	Biochemical Oxygen Demand (5-Day BOD)*	mg O_2/ℓ	2	<2
2A	Electrical Conductivity at 25°C	mS/m	64.2	66.5
18G	Fluoride	mg F/ℓ	0.41	0.43
Calc.	Free Ammonia	mg N/ℓ	<1.5	<1.5
Calc.	Saline Ammonia	mg N/ℓ	<1.5	<1.5
65Gc	Nitrate	mg N/ℓ	<0.25	<0.25
65Gb	Nitrite	mg N/ℓ	<0.05	<0.05
132	Total Oil & Grease*	mg/ℓ	<3	3
1	pH at 25°C	pH units	7.8	7.8
133	Total Phenols*	µg/ℓ	2	<2
127	Sulphide*	mg S^{2-}/ℓ	<0.04	<0.04
67G	Sulphate	mg SO_4/ℓ	66.3	63.8
5	Suspended Solids at 105°C	mg/ℓ	30	56
41	Total Dissolved Solids at 180°C	mg/ℓ	310	324
219	Total kjeldahl nitrogen, as N*	mg/ℓ	6.32	4.92
Calc.	Total Hardness	mg $CaCO_3$/ℓ	230	243
Organics				
101	TPH Diesel Range Organics (DRO), C10-C28	µg/ℓ	<680	<680

Methods	Determinands	Units	021201/24	021202/24
			HAIB: D1 20.06.2024	HAIB: D2 20.06.2024
Chemical				
85	Dissolved Calcium	mg Ca/ℓ	52	51
85	Potassium	mg K/ℓ	2.69	2.66
85	Dissolved Magnesium	mg Mg/ℓ	26	26
84	Sodium	mg Na/ℓ	59	57
83A	Dissolved Aluminium	µg Al/ℓ	6.5	18.2
83A	Dissolved Arsenic	µg As/ℓ	1.1	1.2
83A	Dissolved Cadmium	µg Cd/ℓ	<1	<1
83A	Dissolved Cobalt	µg Co/ℓ	<1	<1
83A	Dissolved Chromium	µg Cr/ℓ	<1	<1
83A	Dissolved Copper	µg Cu/ℓ	2.4	4.0
83A	Dissolved Iron	µg Fe/ℓ	6.5	8.0
83A	Dissolved Mercury	µg Hg/ℓ	<1	<1
83A	Dissolved Manganese	µg Mn/ℓ	<1	<1
83A	Dissolved Molybdenum	µg Mo/ℓ	<1	<1
83A	Dissolved Nickel	µg Ni/ℓ	<1	<1
83A	Dissolved Lead	µg Pb/ℓ	<1	<1
91	Dissolved Silica	mg SiO_2/ℓ	10.6	NR
83A	Dissolved Zinc	µg Zn/ℓ	12.4	6.7
83A	Total Aluminium	µg Al/ℓ	267	227
83A	Total Arsenic	µg As/ℓ	1.6	1.6
83A	Total Cadmium	µg Cd/ℓ	<1	<1
83A	Total Cobalt	µg Co/ℓ	<1	<1
83A	Total Chromium	µg Cr/ℓ	2.9	3.0
83A	Total Copper	µg Cu/ℓ	7.3	17.0
83A	Total Iron	µg Fe/ℓ	759	656
83A	Total Mercury	µg Hg/ℓ	<1	2.0
83A	Total Manganese	µg Mn/ℓ	45	44
83A	Total Molybdenum	µg Mo/ℓ	2.0	1.9
83A	Total Nickel	µg Ni/ℓ	1.6	3.3
83A	Total Lead	µg Pb/ℓ	<1	<1
83A	Total Zinc	µg Zn/ℓ	12.1	13.2

Methods	Determinands	Units	021201/24	021202/24
			HAIB: D1 20.06.2024	HAIB: D2 20.06.2024
Chemical				
10G	Total Alkalinity	mg $CaCO_3$/ℓ	126	156
16G	Chloride	mg Cl/ℓ	58	58
206	Cyanide (Total)*	µg CN/ℓ	<10	11
3	Chemical Oxygen Demand (Total)	mg O_2/ℓ	<25	27
156	Biochemical Oxygen Demand (5-Day BOD)*	mg O_2/ℓ	<2	<2
2A	Electrical Conductivity at 25°C	mS/m	62.6	64.5
18G	Fluoride	mg F/ℓ	0.39	0.44
Calc.	Free Ammonia	mg N/ℓ	<1.5	<1.5
Calc.	Saline Ammonia	mg N/ℓ	<1.5	<1.5
65Gc	Nitrate	mg N/ℓ	<0.25	<0.25
65Gb	Nitrite	mg N/ℓ	<0.05	<0.05
132	Total Oil & Grease*	mg/ℓ	<3	<3
1	pH at 25°C	pH units	7.9	7.9
133	Total Phenols*	µg/ℓ	<2	<2
127	Sulphide*	mg S^{2-}/ℓ	<0.04	<0.04
67G	Sulphate	mg SO_4/ℓ	65.4	64.7
5	Suspended Solids at 105°C	mg/ℓ	30	32
41	Total Dissolved Solids at 180°C	mg/ℓ	290	292
219	Total kjeldahl nitrogen, as N*	mg/ℓ	4.92	4.22
Calc.	Total Hardness	mg $CaCO_3$/ℓ	238	235
231	Total Silica*	mg SiO_2/ℓ	11.2	11.4
231	Dissolved Silica*	mg SiO_2/ℓ	NR	12.8
Organics				
101	TPH Diesel Range Organics (DRO), C10-C28	µg/ℓ	<680	<680

Refer to the “Notes” section at the end of this report for further explanations.

Specific Observations

The lab is aware that there are some non-correlations presenting itself for samples 021199/24 and 021201/24 in terms of the dissolved Zinc being higher than the total Zinc content.

The lab has repeated the testing for these non-correlations and the results have been confirmed as noncorrelating. The lab attributes this to sample matrix interferences.

The lab is aware that there are some non-correlations presenting itself for the sample 021199/24 and 021202/24 in terms of Dissolved Silica being higher than the Total Silica content.

The lab has repeated the testing for these non-correlations and the results have been confirmed as non-correlating. The lab attributes this to sample matrix interferences.

Quality Assurance

Technical signatories

Inorganic Chemistry: Sipho Mgabhi

Organic Chemistry: Sumayya Chohan

Notes to this report

Limitations

This report shall not be reproduced except in full without prior written approval of the laboratory.
Results in this report relate only to the samples as taken, and the condition received by the laboratory.
Any opinions and interpretations expressed herein are outside the scope of SANAS accreditation.
The decision rule applicable to this laboratory is available on request.
Sample preparation may require filtration, dilution, digestion or similar. Final results are reported accordingly.
Where the laboratory has undertaken the sampling, the location of sampling and sampling plan are available on request. Talbot is guided by the National Standards SANS 5667-1:2008 Part 1 Guidance on the Design of Sampling Programmes and Sampling Techniques and SANS 5667-3:2008 Part 3 Guidance on the Preservation and Handling of Water Samples.

Customers to contact Talbot Laboratories for further information.

Uncertainty of measurement

Talbot Laboratories' Uncertainty of Measurement (UoM) values are:

- Identified for relevant tests.
- Calculated as a percentage of the respective results.
- Applicable to total, dissolved and acid soluble metals for ICP element analyses.
- Available upon request.

Analysis explanatory notes

Tests may be marked as follows:

^	Tests conducted at our Pretoria satellite laboratory (1 Sydney Brenner St, Lynwood, Pretoria, 0087).
*	Tests not included in our Schedule of Accreditation and therefore that are not SANAS accredited.
#	Tests that have been sub-contracted to a peer laboratory.
NR	Not required -shown, for example, where the schedule of analysis varied between samples.
σ	ISO 9001 Certified testing.
a	Testing has deviated from Method.

End of Report

Certificate of Analysis

Project details

Customer Details

Invoice Category	400.001
Quotation number:	Q2307-075_1
Order number:	162165
Company name:	KNIGHT PIESOLD CONSULTING
Contact address:	P O BOX 221, RIVONIA, 2128
Contact person:	LLOYD LYNCH

Sampling Details

Sampled by:	CUSTOMER
Sampled date:	2025/03/27
Environmental conditions:	010033/25,010034/25,010035/25,010031/25,010032/25 - SUN
Additional customer information:	010033/25,010034/25,010035/25,010031/25,010032/25 - SAMPLED BY: MADISE MOTEBEJANA

Sample Details

Sample type(s):	SURFACE WATER SAMPLES
Date received:	2025/04/09
Delivered by:	COURIER SERVICE
Temperature at sample receipt (°C):	20.2

Report Details

Testing commenced:	2025/04/09
Testing completed:	2025/04/24
Report date:	2025/04/24
Our reference:	003401/25

Analytical Results

Methods	Determinands	Units	010031/25	010032/25
			HAIB: C1 27.03.2025	HAIB: D1 26.03.2025
Chemical				
233	Sodium	mg Na/ℓ	72	75
94	Acid Soluble Aluminium	µg Al/ℓ	140	124
92	Acid Soluble Arsenic	µg As/ℓ	<20	<20
94	Acid Soluble Boron	µg B/ℓ	101	110
94	Acid Soluble Barium	µg Ba/ℓ	104	107
94	Acid Soluble Cadmium	µg Cd/ℓ	<2	<2
94	Acid Soluble Copper	µg Cu/ℓ	<10	<10
94	Acid Soluble Iron	µg Fe/ℓ	150	102
92	Acid Soluble Mercury	µg Hg/ℓ	<20	<20
94	Acid Soluble Manganese	µg Mn/ℓ	91	54
94	Acid Soluble Nickel	µg Ni/ℓ	<10	<10
94	Acid Soluble Lead	µg Pb/ℓ	<10	<10
92	Acid Soluble Antimony	µg Sb/ℓ	<20	<20
92	Acid Soluble Selenium	µg Se/ℓ	<20	<20
94	Acid Soluble Uranium	µg U/ℓ	<10	14.6
94	Acid Soluble Vanadium	µg V/ℓ	<10	12.0
94	Acid Soluble Zinc	µg Zn/ℓ	10.9	<10
94	Total Chromium	µg Cr/ℓ	<10	<10
16G	Chloride	mg Cl/ℓ	63	72
123	Free Chlorine*	mg Cl_2/ℓ	<0.1	<0.1
135	Cyanide*	µg CN/ℓ	<10	<10
40A	Colour (True)	mg Pt-Co/ℓ	13	11
2B	Electrical Conductivity at 25°C	mS/m	70	74
18G	Fluoride	mg F/ℓ	0.29	0.29
64G	Total Ammonia	mg N/ℓ	<1.5	<1.5
65Gc	Nitrate	mg N/ℓ	3.2	<0.25
65Gb	Nitrite	mg N/ℓ	<0.05	0.07
Calc.	Combined Nitrate + Nitrite (sum of Ratios)*	-	0.35	<0.12
4	Turbidity	NTU	**14**	4.6
1B	pH at 25°C	pH units	7.7	7.9
133	Total Phenols*	µg/ℓ	<1	<1
67G	Sulphate	mg SO_4/ℓ	114	117
41	Total Dissolved Solids at 180°C	mg/ℓ	444	502
Organics				
100	Trihalomethanes*	Calc.	<8	<8

Methods	Determinands	Units	010031/25	010032/25
			HAIB: C1 27.03.2025	HAIB: D1 26.03.2025
100	Bromodichloromethane	µg/ℓ	<2	<2
100	Bromoform	µg/ℓ	<2	<2
100	Chloroform	µg/ℓ	<2	<2
100	Dibromochloromethane	µg/ℓ	<2	<2
100	Trihalomethanes Ratio*	Calc.	<0.08	<0.08
104	Total Organic Carbon	mg C/ℓ	7.8	8.3

Methods	Determinands	Units	010033/25	010034/25
			HAIB: D2 26.03.2025	HAIB: D3 27.03.2025
Chemical				
233	Sodium	mg Na/ℓ	75	73
94	Acid Soluble Aluminium	µg Al/ℓ	181	87
92	Acid Soluble Arsenic	µg As/ℓ	<20	<20
94	Acid Soluble Boron	µg B/ℓ	110	103
94	Acid Soluble Barium	µg Ba/ℓ	111	103
94	Acid Soluble Cadmium	µg Cd/ℓ	<2	<2
94	Acid Soluble Copper	µg Cu/ℓ	<10	<10
94	Acid Soluble Iron	µg Fe/ℓ	140	111
92	Acid Soluble Mercury	µg Hg/ℓ	<20	<20
94	Acid Soluble Manganese	µg Mn/ℓ	77	75
94	Acid Soluble Nickel	µg Ni/ℓ	<10	<10
94	Acid Soluble Lead	µg Pb/ℓ	<10	<10
92	Acid Soluble Antimony	µg Sb/ℓ	<20	<20
92	Acid Soluble Selenium	µg Se/ℓ	<20	<20
94	Acid Soluble Uranium	µg U/ℓ	19.8	<10
94	Acid Soluble Vanadium	µg V/ℓ	12.7	11.7
94	Acid Soluble Zinc	µg Zn/ℓ	<10	<10
94	Total Chromium	µg Cr/ℓ	<10	<10
16G	Chloride	mg Cl/ℓ	72	68
123	Free Chlorine*	mg Cl_2/ℓ	<0.1	<0.1
135	Cyanide*	µg CN/ℓ	<10	<10
40A	Colour (True)	mg Pt-Co/ℓ	10	<10
2B	Electrical Conductivity at 25°C	mS/m	72	72
18G	Fluoride	mg F/ℓ	0.27	0.29
64G	Total Ammonia	mg N/ℓ	<1.5	<1.5
65Gc	Nitrate	mg N/ℓ	<0.25	<0.25
65Gb	Nitrite	mg N/ℓ	0.28	<0.05
Calc.	Combined Nitrate + Nitrite (sum of Ratios)*	-	0.33	<0.12
4	Turbidity	NTU	**6.4**	2.2

Methods	Determinands	Units	010033/25	010034/25
			HAIB: D2 26.03.2025	HAIB: D3 27.03.2025
1B	pH at 25°C	pH units	7.7	7.8
133	Total Phenols*	µg/ℓ	1	<1
67G	Sulphate	mg SO_4/ℓ	121	119
41	Total Dissolved Solids at 180°C	mg/ℓ	504	454
Organics				
100	Trihalomethanes*	Calc.	<8	<8
100	Bromodichloromethane	µg/ℓ	<2	<2
100	Bromoform	µg/ℓ	<2	<2
100	Chloroform	µg/ℓ	<2	<2
100	Dibromochloromethane	µg/ℓ	<2	<2
100	Trihalomethanes Ratio*	Calc.	<0.08	<0.08
104	Total Organic Carbon	mg C/ℓ	8.8	8.0

Methods	Determinands	Units	010035/25
			HAIB: I1 26.03.2025
Chemical			
233	Sodium	mg Na/ℓ	73
94	Acid Soluble Aluminium	µg Al/ℓ	80
92	Acid Soluble Arsenic	µg As/ℓ	<20
94	Acid Soluble Boron	µg B/ℓ	103
94	Acid Soluble Barium	µg Ba/ℓ	101
94	Acid Soluble Cadmium	µg Cd/ℓ	<2
94	Acid Soluble Copper	µg Cu/ℓ	<10
94	Acid Soluble Iron	µg Fe/ℓ	84
92	Acid Soluble Mercury	µg Hg/ℓ	<20
94	Acid Soluble Manganese	µg Mn/ℓ	50
94	Acid Soluble Nickel	µg Ni/ℓ	<10
94	Acid Soluble Lead	µg Pb/ℓ	<10
92	Acid Soluble Antimony	µg Sb/ℓ	<20
92	Acid Soluble Selenium	µg Se/ℓ	<20
94	Acid Soluble Uranium	µg U/ℓ	18.7
94	Acid Soluble Vanadium	µg V/ℓ	11.4
94	Acid Soluble Zinc	µg Zn/ℓ	<10
94	Total Chromium	µg Cr/ℓ	<10
16G	Chloride	mg Cl/ℓ	68
123	Free Chlorine*	mg Cl_2/ℓ	<0.1
135	Cyanide*	µg CN/ℓ	<10
40A	Colour (True)	mg Pt-Co/ℓ	13
2B	Electrical Conductivity at 25°C	mS/m	73

Methods	Determinands	Units	010035/25
			HAIB: I1 26.03.2025
18G	Fluoride	mg F/ℓ	0.34
64G	Total Ammonia	mg N/ℓ	<1.5
65Gc	Nitrate	mg N/ℓ	<0.25
65Gb	Nitrite	mg N/ℓ	<0.05
Calc.	Combined Nitrate + Nitrite (sum of Ratios)*	-	<0.12
4	Turbidity	NTU	4.9
1B	pH at 25°C	pH units	7.8
133	Total Phenols*	µg/ℓ	<1
67G	Sulphate	mg SO_4/ℓ	120
41	Total Dissolved Solids at 180°C	mg/ℓ	476
Organics			
100	Trihalomethanes*	Calc.	<8
100	Bromodichloromethane	µg/ℓ	<2
100	Bromoform	µg/ℓ	<2
100	Chloroform	µg/ℓ	<2
100	Dibromochloromethane	µg/ℓ	<2
100	Trihalomethanes Ratio*	Calc.	<0.08
104	Total Organic Carbon	mg C/ℓ	7.8

Refer to the “Notes” section at the end of this report for further explanations.

Where the laboratory reporting limit for a test is higher than the required specification limit, the raw data is reviewed and the detection limit highlighted in bold font if outside of specification.

Specific Observations

1. The parameters tested on the sample submitted (lab number 010031/25) conform to the SANS 241:2015 requirements for drinking water, with the exception of Turbidity.

-The turbidity of the water exceeds the SANS limit of <1 NTU but is lower than 10 NTU where one would expect to start seeing aesthetic effects like a cloudy appearance to the water. Turbidity is also one of the indirect indicators of microbiological water quality and of inefficient water treatment. The presence of turbidity in water results in a cloudy or muddy appearance and may also affect taste and colour of the water.

2. The parameters tested on the sample submitted (lab number 010032/25, 010034/25 and 010035/25) conform to the SANS 241:2015 requirements for drinking water.

3. The parameters tested on the sample submitted (lab number 010033/25) conform to the SANS 241:2015 requirements for drinking water, with the exception of Turbidity.

-The turbidity of the water exceeds the SANS limit of <5 NTU and is one of the indirect indicators of microbiological water quality and of inefficient water treatment. The presence of turbidity in water results in a cloudy or muddy appearance and may also affect taste and colour of the water.

Quality Assurance

Technical signatories

Notes to this report

Limitations

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Where the laboratory has undertaken the sampling, the location of sampling and sampling plan are available on request. Talbot is guided by the National Standards SANS 5667-1:2008 Part 1 Guidance on the Design of Sampling Programmes and Sampling Techniques and SANS 5667-3:2008 Part 3 Guidance on the Preservation and Handling of Water Samples.

Customers to contact Talbot Laboratories for further information.

Uncertainty of measurement

The reported uncertainty of measurement is based on a standard uncertainty multiplied by a coverage factor of
=2, which, unless otherwise specifically stated, provides a level of confidence of approximately 95%.
Uncertainty of measurement is available here.

Decision Rule

Talbot Laboratories (Pty) Ltd shall apply the following decision rule in assessing the conformity of test results to the specification on the test report:

- A binary rule (pass / fail) based on a guard band as referenced in ILAC G8_09_2019; shall apply to results. This has a global false acceptance risk of 2%.
- Statements of conformity are reported as:
  Passed - The measured values were observed within tolerance at the points tested.
  Failed - The measured values were either observed out of tolerance at the points tested.
- Based on the laboratory's decision rule, all results in bold font are deemed non-compliant to the defined specification per determinand, where applicable.
- The decision rule will only be applied to accredited method results.
- In instances when a statement of conformity is not required, test results are reported as an absolute value.

Analysis explanatory notes

Tests may be marked as follows:

^	Tests conducted at our Pretoria satellite laboratory (1 Sydney Brenner St, Lynwood, Pretoria, 0087).
*	Tests not included in our Schedule of Accreditation and therefore that are not SANAS accredited.
#	Tests that have been sub-contracted to a peer laboratory.
NR	Not required -shown, for example, where the schedule of analysis varied between samples.
σ	ISO 9001 Certified testing.
a	Testing has deviated from Method.

Appendix 1: Specifications - SANS 241-1:2015 RECOMMENDED LIMITS

Reported Determinands	Limits	Reported Determinands	Limits
E.coli	0 Count/100mℓ (0 MPN/100mℓ)	Zinc	≤5000 µg/l (≤5 mg/ℓ)
Faecal Coliforms	0 Count/100mℓ (0 MPN/100mℓ)	Antimony	≤20 µg/ℓ (≤0.02 mg/ℓ)
Cryptosporidium species	Not Detected	Arsenic	≤10 µg/ℓ (≤0.01 mg/ℓ)
Giardia species	Not Detected	Barium	≤700 µg/ℓ (≤0.7 mg/ℓ)
Total Coliforms	≤10 Count/100mℓ (10 MPN/100mℓ)	Boron	≤2400 µg/ℓ (≤2.4 mg/ℓ)
Standard Plate Count	≤1000 Count/1mℓ	Cadmium	≤3 µg/ℓ (≤0.003 mg/ℓ)
Somatic Coliphages	Not Detected	Total Chromium	≤50 µg/ℓ (≤0.05 mg/ℓ)
Cytopathogenic viruses	Not detected	Copper	≤2000 µg/ℓ (≤2 mg/ℓ)
Enteric Virus (Sub#)	Not Detected	Cyanide	≤200 µg/ℓ (≤0.2 mg/ℓ)
Colour	≤15 mg/ℓ Pt-Co	Iron	Chronic: ≤ 2000 µg/ℓ (≤2 mg/ℓ)
Electrical Conductivity	≤170 mS/m	Iron	Aesthetic: ≤ 300 µg/ℓ (≤0.3 mg/ℓ)
Total Dissolved Solids at 180°C	≤1200 mg/ℓ	Lead	≤10 µg/ℓ (≤0.01 mg/ℓ)
Turbidity	Operational ≤1 NTU	Manganese	Chronic: ≤ 400 µg/ℓ (≤0.4 mg/ℓ)
Turbidity	Aesthetic ≤5 NTU	Manganese	Aesthetic: ≤100 µg/ℓ (≤0.1 mg/ℓ)
pH	≥ 5 to ≤ 9.7	Mercury	≤6 µg/ℓ (≤0.006 mg/ℓ)
Odour	Inoffensive	Nickel	≤70 µg/ℓ (≤0.07 mg/ℓ)
Free Chlorine	≤5 mg/ℓ	Selenium	≤40 µg/ℓ (≤0.04 mg/ℓ)
Monochloramine	≤3000 µg/ℓ (≤3 mg/ℓ)	Uranium	≤30 µg/ℓ (≤0.03 mg/ℓ)
Nitrate	≤11 mg/ℓ	Aluminium	≤300 µg/ℓ (≤0.3 mg/ℓ)
Nitrite	≤0.9 mg/ℓ	Total Organic Carbon	≤10 mg/ℓ
Combined Nitrate plus Nitrite (sum of Ratios)	≤1	Chloroform	≤300 µg/ℓ (≤0.3 mg/ℓ)
Sulphate	Acute: ≤ 500 mg/ℓ	Bromoform	≤100 µg/ℓ (≤0.1 mg/ℓ)
Sulphate	Aesthetic: ≤ 250 mg/ℓ	Dibromochloromethane	≤100 µg/ℓ (≤0.1 mg/ℓ)
Fluoride	≤1500 µg/ℓ (≤1.5 mg/ℓ)	Bromodichloromethane	≤60 µg/ℓ (≤0.06 mg/ℓ)
Ammonia	≤1.5 mg/ℓ	Trihalomethanes Ratio	≤1
Chloride	≤ 300 mg/ℓ	Microcystins	≤1 µg/ℓ
Sodium	≤200 mg/ℓ	Phenols	≤10 µg/ℓ (≤0.01 mg/ℓ)

End of Report

Analytical Laboratory Services
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P. O. Box 86782, Windhoek, Namibia

TEST REPORT I251303/1

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	04/Jul/25
	Eros	Date analysed:	15 July - 28 August 2025
	Windhoek	Date reported:	28/Aug/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303

Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	C1
Date of sampling	2025/06/26; 13h 54
Test item number	I251303/1

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**	**Livestock watering**
p H	**8.5**		6-9	
Electrical Conductivity	**45.8**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.2**	**mg/l**	-	
Temperature	**22.7**	**°C**	-	
Turbidity	**68**	**NTU**	<0.5	
Total Dissolved Solids	**249**	**mg/l**	<2000	6000
Total Suspended solids	**60**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**125**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**10**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**155**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**85**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**70**	**mg/l**	-	2057
Chloride as Cl^-	**35**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**49**	**mg/l**	<300	1000
Nitrate as N	**0.7**	**mg/l**	<11	100
Nitrite as N	**0.02**	**mg/l**	<0.15	10
Ammonia nitrogen as N	**<0.02**	**mg/l**	<0.50	
Hexavalent chromium as Cr^{6+}	**0.01**	**mg/l**	-	
Cyanide as CN^-	**0.01**	**mg/l**	<0.05	
Bromide as Br^-	**0.8**	**mg/l**	<1.0	
Iodine as I^-	**0.93**	**mg/l**	-	
Sodium as Na	**31**	**mg/l**	<300	2000
Potassium as K	**4.5**	**mg/l**	<100	
Magnesium as Mg	**17**	**mg/l**	<70	500
Calcium as Ca	**34**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.8**			
Langelier Index	**0.7**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.1**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.8**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen; ratios <0.2 no corrosive properties; ratios >0.2 increasing corrosive tendency	

Approved Technical Signatory
Ms. Helena Daniel

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P. O. Box 86782, Windhoek, Namibia

TEST REPORT I251303/1

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	04/Jul/25
	Eros	Date analysed:	15 July - 28 August 2025
	Windhoek	Date reported:	28/Aug/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303

Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	C1
Date of sampling	2025/06/26; 13h 54
Test item number	I251303/1

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**
Aluminium as Al	**1494**	µg/l	<100
Arsenic as As	**2.5**	µg/l	<50
Boron as B	**26**	µg/l	<500
Cadmium as Cd	**<1.0**	µg/l	<10
Chromium as Cr	**4.6**	µg/l	<100
Copper as Cu	**7.2**	µg/l	<2000
Iron as Fe	**3443**	µg/l	<300
Mercury as Hg	**<1.0**	µg/l	<2
Manganese as Mn	**96**	µg/l	<100
Nickel as Ni	**<1.0**	µg/l	<150
Lead as Pb	**<1.0**	µg/l	<50
Antimony as Sb	**<1.0**	µg/l	<50
Selenium as Se	**3.6**	µg/l	<50
Tin as Sn	**<1.0**	µg/l	<200
Strontinum as Sr	**171**	µg/l	
Titanium as Ti	**25**	µg/l	<300
Thallium as Tl	**<1.0**	µg/l	<10
Uranium as U	**5.4**	µg/l	<15
Zinc as Zn	**6.5**	µg/l	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
South African Water Quality Guidelines Volume 5: Agricultural water use: Livestock watering, Second Edition, 1996

Sample acceptance: Sample was collected in bottles provided by the laboratory.
Sample was suitable for testing

Approved Technical Signatory
Ms. Helena Daniel

TEST REPORT I251303/1

Assessment of water quality for human consumption

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Naturally occurring chemicals that are of health significance in drinking water
Fluoride: Exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.
0-1.0 mg/l fluoride: no adverse health effects or tooth damage occurs

Chemicals from agricultural activities that are of health significance in drinking water
Nitrate and nitrite: In water it has been associated with methaemoglobinaemia, especially in bottle-fed infants
0-6 mg/l nitrate as N: no adverse health effects

Some of the naturally occurring chemicals which occur in drinking water at concentrations below those at which toxic effects may occur.
Chloride: high concentrations of chloride give a salty taste to water. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste.
Hardness: Depending on the interaction of other factors, such as, pH and alkalinity, water with a hardness above approximately 200 mg/l may cause scale deposition in the pipe work and tanks. On heating, hard waters form deposits of calcium carbonate scale.
pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

Turbidity is a measure of the light-scattering ability of water and is indicative of the concentration of suspended matter in water.
Microorganisms are often associated with turbidity, hence low turbidity minimises the potential for transmission of infectious diseases. Turbidity also affects the aesthetic quality of water.
Turbidity in water is caused by the presence of suspended matter which usually consists of a mixture of inorganic matter, such as clay and soil particles and organic matter.
Turbidity may also be associated with the presence of inorganic ions such as manganese(II) and iron(II).
The consumption of turbid water *per se* does not have any direct health effects, but associated effects due to microbial contamination or the ingestion of substances bound to particulate matter, do.
Aesthetic effects (appearance, taste, odour) of turbidity can be mitigated or removed by decantation or by filtration (or by both), accelerated, if necessary, by previous aeration

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TEST REPORT I251303/2

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	04/Jul/25
	Eros	Date analysed:	15 July - 28 August 2025
	Windhoek	Date reported:	28/Aug/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303
		Enquiries:	Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D1
Date of sampling	2025/06/26; 16h 30
Test item number	I251303/2

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**	**Livestock watering**
p H	**8.4**		6-9	
Electrical Conductivity	**47.1**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.0**	**mg/l**	-	
Temperature	**22.5**	**°C**	-	
Turbidity	**65**	**NTU**	<0.5	
Total Dissolved Solids	**256**	**mg/l**	<2000	6000
Total Suspended solids	**48**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**135**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**10**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**157**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**87**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**70**	**mg/l**	-	2057
Chloride as Cl^-	**35**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**51**	**mg/l**	<300	1000
Nitrate as N	**<0.5**	**mg/l**	<11	100
Nitrite as N	**0.01**	**mg/l**	<0.15	10
Ammonia nitrogen as N	**<0.02**	**mg/l**	<0.50	
Hexavalent chromium as Cr^{6+}	**0.01**	**mg/l**	-	
Cyanide as CN^-	**0.01**	**mg/l**	<0.05	
Bromide as Br^-	**<0.05**	**mg/l**	<1.0	
Iodine as I^-	**0.93**	**mg/l**	-	
Sodium as Na	**32**	**mg/l**	<300	2000
Potassium as K	**4.6**	**mg/l**	<100	
Magnesium as Mg	**17**	**mg/l**	<70	500
Calcium as Ca	**35**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.8**			
Langelier Index	**0.6**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.1**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.8**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency	

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TEST REPORT I251303/2

To: **Knight Piesold Consulting (Pty) Ltd**
P.O.Box 86062
Eros
Windhoek
Namibia
Attn: Lloyd Lynch
e-mail: llynch@knightpiesold.com
Tel: 083-296 1131

Date received: 04/Jul/25
Date analysed: 15 July - 28 August 2025
Date reported: 28/Aug/25

Client Reference no.: Verbal
Quotation no.: QUA-81934
Lab Reference: I251303
Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D1
Date of sampling	2025/06/26; 16h 30
Test item number	I251303/2

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**
Aluminium as Al	**1161**	µg/l	<100
Arsenic as As	**1.9**	µg/l	<50
Boron as B	**26**	µg/l	<500
Cadmium as Cd	**<1.0**	µg/l	<10
Chromium as Cr	**5.1**	µg/l	<100
Copper as Cu	**4.9**	µg/l	<2000
Iron as Fe	**3260**	µg/l	<300
Mercury as Hg	**<1.0**	µg/l	<2
Manganese as Mn	**90**	µg/l	<100
Nickel as Ni	**<1.0**	µg/l	<150
Lead as Pb	**<1.0**	µg/l	<50
Antimony as Sb	**<1.0**	µg/l	<50
Selenium as Se	**4.0**	µg/l	<50
Tin as Sn	**<1.0**	µg/l	<200
Strontinum as Sr	**174**	µg/l	
Titanium as Ti	**20**	µg/l	<300
Thallium as Tl	**<1.0**	µg/l	<10
Uranium as U	**2.1**	µg/l	<15
Zinc as Zn	**5.2**	µg/l	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
South African Water Quality Guidelines Volume 5: Agricultural water use: Livestock watering, Second Edition, 1996

Sample acceptance: Sample was collected in bottles provided by the laboratory.
Sample was suitable for testing

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TEST REPORT I251303/2

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0-1.0 mg/l fluoride: no adverse health effects or tooth damage occurs

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Nitrate and nitrite: In water it has been associated with methaemoglobinaemia, especially in bottle-fed infants
0-6 mg/l nitrate as N: no adverse health effects

Some of the naturally occurring chemicals which occur in drinking water at concentrations below those at which toxic effects may occur.
Chloride: high concentrations of chloride give a salty taste to water. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste.
Hardness: Depending on the interaction of other factors, such as, pH and alkalinity, water with a hardness above approximately 200 mg/l may cause scale deposition in the pipe work and tanks. On heating, hard waters form deposits of calcium carbonate scale.
pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

Turbidity is a measure of the light-scattering ability of water and is indicative of the concentration of suspended matter in water.
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Turbidity may also be associated with the presence of inorganic ions such as manganese(II) and iron(II).
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Aesthetic effects (appearance, taste, odour) of turbidity can be mitigated or removed by decantation or by filtration (or by both), accelerated, if necessary, by previous aeration

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TEST REPORT I251303/3

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	04/Jul/25
	Eros	Date analysed:	15 July - 28 August 2025
	Windhoek	Date reported:	28/Aug/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303
		Enquiries: Ms Helena P. Daniel	

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D2
Date of sampling	2025/06/26; 15h45
Test item number	I251303/3

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**	**Livestock watering**
p H	**8.4**		6-9	
Electrical Conductivity	**46.7**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.2**	**mg/l**	-	
Temperature	**22.6**	**°C**	-	
Turbidity	**66**	**NTU**	<0.5	
Total Dissolved Solids	**257**	**mg/l**	<2000	6000
Total Suspended solids	**56**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**130**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**14**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**157**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**87**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**70**	**mg/l**	-	2057
Chloride as Cl^-	**36**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**51**	**mg/l**	<300	1000
Nitrate as N	**0.7**	**mg/l**	<11	100
Nitrite as N	**<0.01**	**mg/l**	<0.15	10
Ammonia nitrogen as N	**<0.02**	**mg/l**	<0.50	
Hexavalent chromium as Cr^{6+}	**0.01**	**mg/l**	-	
Cyanide as CN^-	**0.01**	**mg/l**	<0.05	
Bromide as Br^-	**0.36**	**mg/l**	<1.0	
Iodine as I^-	**1.0**	**mg/l**	-	
Sodium as Na	**32**	**mg/l**	<300	2000
Potassium as K	**4.6**	**mg/l**	<100	
Magnesium as Mg	**17**	**mg/l**	<70	500
Calcium as Ca	**35**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.8**			
Langelier Index	**0.6**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.2**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.8**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency	

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	P.O.Box 86062	Date received:	04/Jul/25
	Eros	Date analysed:	15 July - 28 August 2025
	Windhoek	Date reported:	28/Aug/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303

Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D2
Date of sampling	2025/06/26; 15h45
Test item number	I251303/3

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**
Aluminium as Al	**1218**	µg/l	<100
Arsenic as As	**1.8**	µg/l	<50
Boron as B	**28**	µg/l	<500
Cadmium as Cd	**<1.0**	µg/l	<10
Chromium as Cr	**7.4**	µg/l	<100
Copper as Cu	**5.6**	µg/l	<2000
Iron as Fe	**3448**	µg/l	<300
Mercury as Hg	**<1.0**	µg/l	<2
Manganese as Mn	**96**	µg/l	<100
Nickel as Ni	**<1.0**	µg/l	<150
Lead as Pb	**<1.0**	µg/l	<50
Antimony as Sb	**<1.0**	µg/l	<50
Selenium as Se	**4.2**	µg/l	<50
Tin as Sn	**<1.0**	µg/l	<200
Strontinum as Sr	**176**	µg/l	
Titanium as Ti	**22**	µg/l	<300
Thallium as Tl	**<1.0**	µg/l	<10
Uranium as U	**4.8**	µg/l	<15
Zinc as Zn	**5.6**	µg/l	

Remark: Overall classification of water, considering only constituents that have been tested for:
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Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
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Sample acceptance: Sample was collected in bottles provided by the laboratory.
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TEST REPORT I251303/3

Assessment of water quality for human consumption

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pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

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TEST REPORT I251303/4

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	04/Jul/25
	Eros	Date analysed:	15 July - 28 August 2025
	Windhoek	Date reported:	28/Aug/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303
		Enquiries:	Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D3
Date of sampling	2025/06/27; 08h10
Test item number	I251303/4

Parameter	Value	Units	Acceptable Standard limits Human consumption	Livestock watering
p H	**8.5**		6-9	
Electrical Conductivity	**47.0**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.0**	**mg/l**	-	
Temperature	**22.7**	**°C**	-	
Turbidity	**67**	**NTU**	<0.5	
Total Dissolved Solids	**256**	**mg/l**	<2000	6000
Total Suspended solids	**68**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**130**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**14**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**157**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**87**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**70**	**mg/l**	-	2057
Chloride as Cl^-	**35**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**51**	**mg/l**	<300	1000
Nitrate as N	**0.9**	**mg/l**	<11	100
Nitrite as N	**0.01**	**mg/l**	<0.15	10
Ammonia nitrogen as N	**<0.02**	**mg/l**	<0.50	
Hexavalent chromium as Cr^{6+}	**0.01**	**mg/l**	-	
Cyanide as CN^-	**0.01**	**mg/l**	<0.05	
Bromide as Br^-	**0.36**	**mg/l**	<1.0	
Iodine as I^-	**0.81**	**mg/l**	-	
Sodium as Na	**31**	**mg/l**	<300	2000
Potassium as K	**4.6**	**mg/l**	<100	
Magnesium as Mg	**17**	**mg/l**	<70	500
Calcium as Ca	**35**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.8**			
Langelier Index	**0.7**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.1**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.8**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency	

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TEST REPORT I251303/4

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	04/Jul/25
	Eros	Date analysed:	15 July - 28 August 2025
	Windhoek	Date reported:	28/Aug/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303
		Enquiries:	Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D3
Date of sampling	2025/06/27; 08h10
Test item number	I251303/4

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**
Aluminium as Al	**1456**	**µg/l**	<100
Arsenic as As	**2.5**	**µg/l**	<50
Boron as B	**28**	**µg/l**	<500
Cadmium as Cd	**<1.0**	**µg/l**	<10
Chromium as Cr	**4.8**	**µg/l**	<100
Copper as Cu	**6.1**	**µg/l**	<2000
Iron as Fe	**3501**	**µg/l**	<300
Mercury as Hg	**<1.0**	**µg/l**	<2
Manganese as Mn	**106**	**µg/l**	<100
Nickel as Ni	**<1.0**	**µg/l**	<150
Lead as Pb	**<1.0**	**µg/l**	<50
Antimony as Sb	**<1.0**	**µg/l**	<50
Selenium as Se	**3.7**	**µg/l**	<50
Tin as Sn	**<1.0**	**µg/l**	<200
Strontinum as Sr	**176**	**µg/l**	
Titanium as Ti	**32**	**µg/l**	<300
Thallium as Tl	**<1.0**	**µg/l**	<10
Uranium as U	**4.7**	**µg/l**	<15
Zinc as Zn	**6.0**	**µg/l**	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
South African Water Quality Guidelines Volume 5: Agricultural water use: Livestock watering, Second Edition, 1996

Sample acceptance: Sample was collected in bottles provided by the laboratory.
Sample was suitable for testing

Approved Technical Signatory
Ms. Helena Daniel

TEST REPORT I251303/4

Assessment of water quality for human consumption

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P. O. Box 86782, Windhoek, Namibia

Naturally occurring chemicals that are of health significance in drinking water
Fluoride: Exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.
0-1.0 mg/l fluoride: no adverse health effects or tooth damage occurs

Chemicals from agricultural activities that are of health significance in drinking water
Nitrate and nitrite: In water it has been associated with methaemoglobinaemia, especially in bottle-fed infants
0-6 mg/l nitrate as N: no adverse health effects

Some of the naturally occurring chemicals which occur in drinking water at concentrations below those at which toxic effects may occur.
Chloride: high concentrations of chloride give a salty taste to water. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste.
Hardness: Depending on the interaction of other factors, such as, pH and alkalinity, water with a hardness above approximately 200 mg/l may cause scale deposition in the pipe work and tanks. On heating, hard waters form deposits of calcium carbonate scale.
pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

Turbidity is a measure of the light-scattering ability of water and is indicative of the concentration of suspended matter in water.
Microorganisms are often associated with turbidity, hence low turbidity minimises the potential for transmission of infectious diseases. Turbidity also affects the aesthetic quality of water.
Turbidity in water is caused by the presence of suspended matter which usually consists of a mixture of inorganic matter, such as clay and soil particles and organic matter.
Turbidity may also be associated with the presence of inorganic ions such as manganese(II) and iron(II).
The consumption of turbid water *per se* does not have any direct health effects, but associated effects due to microbial contamination or the ingestion of substances bound to particulate matter, do.
Aesthetic effects (appearance, taste, odour) of turbidity can be mitigated or removed by decantation or by filtration (or by both), accelerated, if necessary, by previous aeration

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TEST REPORT I251303/5

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	04/Jul/25
	Eros	Date analysed:	15 July - 28 August 2025
	Windhoek	Date reported:	28/Aug/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303
		Enquiries:	Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	I1
Date of sampling	2025/06/26; 14h27
Test item number	I251303/5

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**	**Livestock watering**
p H	**8.4**		6-9	
Electrical Conductivity	**46.4**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.2**	**mg/l**	-	
Temperature	**22.7**	**°C**	-	
Turbidity	**66**	**NTU**	<0.5	
Total Dissolved Solids	**254**	**mg/l**	<2000	6000
Total Suspended solids	**48**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**125**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**11**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**155**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**85**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**70**	**mg/l**	-	2057
Chloride as Cl^-	**36**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**51**	**mg/l**	<300	1000
Nitrate as N	**0.9**	**mg/l**	<11	100
Nitrite as N	**0.01**	**mg/l**	<0.15	10
Ammonia nitrogen as N	**<0.02**	**mg/l**	<0.50	
Hexavalent chromium as Cr^{6+}	**0.01**	**mg/l**	-	
Cyanide as CN^-	**0.01**	**mg/l**	<0.05	
Bromide as Br^-	**0.51**	**mg/l**	<1.0	
Iodine as I^-	**0.46**	**mg/l**	-	
Sodium as Na	**32**	**mg/l**	<300	2000
Potassium as K	**4.5**	**mg/l**	<100	
Magnesium as Mg	**17**	**mg/l**	<70	500
Calcium as Ca	**34**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.8**			
Langelier Index	**0.6**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.2**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.8**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency	

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TEST REPORT I251303/5

To: **Knight Piesold Consulting (Pty) Ltd**
P.O.Box 86062
Eros
Windhoek
Namibia
Attn: Lloyd Lynch
e-mail: llynch@knightpiesold.com
Tel: 083-296 1131

Date received: 04/Jul/25
Date analysed: 15 July - 28 August 2025
Date reported: 28/Aug/25

Client Reference no.: Verbal
Quotation no.: QUA-81934
Lab Reference: I251303
Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	I1
Date of sampling	2025/06/26; 14h27
Test item number	I251303/5

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**
Aluminium as Al	**1145**	**µg/l**	<100
Arsenic as As	**1.6**	**µg/l**	<50
Boron as B	**27**	**µg/l**	<500
Cadmium as Cd	**<1.0**	**µg/l**	<10
Chromium as Cr	**3.7**	**µg/l**	<100
Copper as Cu	**5.1**	**µg/l**	<2000
Iron as Fe	**3409**	**µg/l**	<300
Mercury as Hg	**<1.0**	**µg/l**	<2
Manganese as Mn	**88**	**µg/l**	<100
Nickel as Ni	**<1.0**	**µg/l**	<150
Lead as Pb	**<1.0**	**µg/l**	<50
Antimony as Sb	**<1.0**	**µg/l**	<50
Selenium as Se	**3.6**	**µg/l**	<50
Tin as Sn	**<1.0**	**µg/l**	<200
Strontinum as Sr	**184**	**µg/l**	
Titanium as Ti	**18**	**µg/l**	<300
Thallium as Tl	**<1.0**	**µg/l**	<10
Uranium as U	**4.6**	**µg/l**	<15
Zinc as Zn	**6.8**	**µg/l**	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
South African Water Quality Guidelines Volume 5: Agricultural water use: Livestock watering, Second Edition, 1996

Sample acceptance: Sample was collected in bottles provided by the laboratory.
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TEST REPORT I251303/5

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pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

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TEST REPORT I251303/6

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	04/Jul/25
	Eros	Date analysed:	15 July - 28 August 2025
	Windhoek	Date reported:	28/Aug/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303
		Enquiries:	Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	U1
Date of sampling	2025/06/26; 11h12
Test item number	I251303/6

			Acceptable Standard limits	
Parameter	**Value**	**Units**	**Human consumption**	**Livestock watering**
p H	**8.5**		6-9	
Electrical Conductivity	**45.1**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.2**	**mg/l**	-	
Temperature	**22.9**	**°C**	-	
Turbidity	**70**	**NTU**	<0.5	
Total Dissolved Solids	**242**	**mg/l**	<2000	6000
Total Suspended solids	**68**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**125**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**13**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**148**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**82**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**66**	**mg/l**	-	2057
Chloride as Cl^-	**32**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**47**	**mg/l**	<300	1000
Nitrate as N	**0.9**	**mg/l**	<11	100
Nitrite as N	**0.01**	**mg/l**	<0.15	10
Ammonia nitrogen as N	**<0.02**	**mg/l**	<0.50	
Hexavalent chromium as Cr^{6+}	**0.01**	**mg/l**	-	
Cyanide as CN^-	**0.07**	**mg/l**	<0.05	
Bromide as Br^-	**0.66**	**mg/l**	<1.0	
Iodine as I^-	**0.69**	**mg/l**	-	
Sodium as Na	**30**	**mg/l**	<300	2000
Potassium as K	**4.5**	**mg/l**	<100	
Magnesium as Mg	**16**	**mg/l**	<70	500
Calcium as Ca	**33**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.8**			
Langelier Index	**0.7**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.2**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.8**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency	

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	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303
		Enquiries: Ms Helena P. Daniel	

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	U1
Date of sampling	2025/06/26; 11h12
Test item number	I251303/6

Parameter	Value	Units	Acceptable Standard limits Human consumption
Aluminium as Al	**1311**	µg/l	<100
Arsenic as As	**1.6**	µg/l	<50
Boron as B	**28**	µg/l	<500
Cadmium as Cd	**<1.0**	µg/l	<10
Chromium as Cr	**5.8**	µg/l	<100
Copper as Cu	**5.3**	µg/l	<2000
Iron as Fe	**3601**	µg/l	<300
Mercury as Hg	**<1.0**	µg/l	<2
Manganese as Mn	**111**	µg/l	<100
Nickel as Ni	**<1.0**	µg/l	<150
Lead as Pb	**<1.0**	µg/l	<50
Antimony as Sb	**<1.0**	µg/l	<50
Selenium as Se	**3.8**	µg/l	<50
Tin as Sn	**<1.0**	µg/l	<200
Strontinum as Sr	**167**	µg/l	
Titanium as Ti	**20**	µg/l	<300
Thallium as Tl	**<1.0**	µg/l	<10
Uranium as U	**5.0**	µg/l	<15
Zinc as Zn	**5.1**	µg/l	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
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TEST REPORT I251303/6

Assessment of water quality for human consumption

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pH: Optimum pH 6.5-8.
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Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
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TEST REPORT I251303

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	04/Jul/25
	Eros	Date analysed:	15 July - 28 August 2025
	Windhoek	Date reported:	28/Aug/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251303
		Enquiries: Ms Helena P. Daniel	

Quality control samples analysed included certified and external reference samples to monitor accuracy

Test	QC reading	Assigned value	Unit	Acceptance criteria	Range
p H	6.98	7.05	-	± 3 SD	6.91 - 7.18
Electrical Conductivity	142.6	142.5	mS/m	± 3 SD	139.2 - 145.8
Turbidity	18.4	17.8	NTU	± 3 SD	16.8 - 18.8
Total Alkalinity as $CaCO_3$	965	988	mg/L	± 3 SD	926 - 1050
Chloride as Cl^-	470	479	mg/L	± 3 SD	463 - 496
Fluoride as F^-	0.42	0.48	mg/L	± 3 SD	0.37 - 0.59
Nitrate as N	10.15	9.85	mg/L	± 3 SD	8.91 - 10.79
Nitrite as N	0.122	0.123	mg/L	± 3 SD	0.100 - 0.146
Sodium as Na	19.37	20.0	mg/L	± 10%	18.0 - 22.0
Potassium as K	20.02	20.0	mg/L	± 10%	18.0 - 22.0
Magnesium as Mg	20.28	20.0	mg/L	± 10%	18.0 - 22.0
Calcium as Ca	21.10	20.0	mg/L	± 10%	18.0 - 22.0
Manganese as Mn	1.023	1.0	mg/L	± 10%	0.90-1.10
Iron as Fe	1.028	1.0	mg/L	± 10%	0.90-1.10

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Summary of test methods - Water Quality

Determinant	Unit	DL	Technique	Method reference
Absorbed oxygen	mg/l O_2	2	titrimetric	SANS 5220:2005
Acidity	mg/l $CaCO_3$	10	titrimetric	AWWA 2310 B
Alkalinity	mg/l $CaCO_3$	10	titrimetric	AWWA 2320 B
Ammonium	mg/l N	0.02	colorimetric	AWWA 4500-NH_3 F / modified Berthelot
Bicarbonate & Carbonate	mg/l $CaCO_3$	1	by calculation	
Biological oxygen demand, 5-day	mg/l O_2	2	electrometric	AWWA 5210 B
Biological oxygen demand, carbonacious	mg/l O_2	2	electrometric	AWWA 5210 B
Bromide & Iodide	mg/l Br^-	0.05	iodometric	P. Höfer
Chloride	mg/l Cl^-	1	argentometric	AWWA 4500-Cl^- B
Chlorine, free and total	mg/l Cl_2	0.05	colorimetric	AWWA 4500-Cl G
Chlorophyll a	µg/L	0.01	spectrophotometric	ISO 10260:1992 E
Chemical oxygen demand	mg/l O_2	1	colorimetric	AWWA 5220 D
Colour	Pt	10	colorimetric	AWWA Pt-Co-2120 B
Cyanide	mg/l CN	0.02	colorimetric	AWWA 4500-CN E
Density	mg/l g/ml	-	gravimetric	METH W 016
Dissolved oxygen	mg/l O_2	0.1	electrometric	AWWA 4550-O G
Electrical conductivity	mS/m	0.1	electrometric	AWWA 2510 B
Fat, oil & grease	mg/l	2	extraction/gavimetric	AWWA 5520 B
Fixed and volatile solids, ignited at 550°C	mg/l	1	gravimetric	AWWA 2540 E
Fluoride	mg/l F^-	0.1	electrometric	AWWA 4500-F C
Hardness	mg/l $CaCO_3$	1	by calculation	AWWA 2340 B
Hexavalent chromium	mg/l Cr	0.01	colorimetric	AWWA 3500-Cr B
Hydrolysable phosphates	mg/l P	0.01	digestion, PO4	AWWA 4500-P B.2 + E
Kjeldahl nitrogen	mg/l N	0.5	by calculation	
Molybdosilicate	mg/l SiO_2	0.4	colorimetric	AWWA 4500-Si C
Nitrate	mg/l N	0.5	colorimetric	Spectroquant / AWWA 4500-NO_3 E
Nitrite	mg/l N	0.01	colorimetric	AWWA 4500-NO2 B
Oxidation reduction potential (Redox)	mV	-	electrometric	AWWA 2580 B
pH		-	electrometric	AWWA 4500-H^+ B
Phenols	mg/l Phenol	0.05	colorimetric	ASTM D1783-01, B
Reactive phosphorous	mg/l PO_4	0.03	colorimetric	AWWA 4500-P E
Settable solids	mg/l	1	gravimetric	AWWA 2540 F
Sulfide	mg/l S^{2-}	0.05	colorimetric	AWWA 4500-S^{2-} D
Sulfite	mg/l SO_3^{2-}	2	iodometric	AWWA 4500-SO_3^{2-} B
Sulphate	mg/l SO_4	1	nephelometric / colorimetric	AWWA 4500-SO4 E / F
Total dissolved solids	mg/l	1	gravimetric	AWWA 2540 C
Total nitrogen	mg/l N	0.5	digestion, NO3	EN ISO 11905-1:1997
Total phosphorous	mg/l P	0.01	digestion, PO4	AWWA 4500-P B.5 + E
Total solids	mg/l	1	gravimetric	AWWA 2540 B
Total suspended solids	mg/l	1	gravimetric	AWWA 2540 D
Turbidity	NTU	0.05	nephelometric	AWWA 2130 B
UV absorbing organic constituents at 254nm	cm^{-1}	-	colorimetric	AWWA 5910 B

Aluminium	mg/l Al	0.01	ICP-OES	AWWA ICP-3500-Al C
Antimony	mg/l Sb	0.01	ICP-OES	AWWA ICP-3500-Sb C
Arsenic	mg/l As	0.01	ICP-OES	AWWA ICP-3500-As D
Barium	mg/l Ba	0.01	ICP-OES	AWWA ICP-3500-Ba C
Beryllium	mg/l B	0.01	ICP-OES	AWWA ICP-3500-Be
Bismuth	mg/l Bi	0.01	ICP-OES	AWWA ICP-3500-Bi
Boron	mg/l B	0.01	ICP-OES	AWWA ICP-3500-B D
Cadmium	mg/l Cd	0.01	ICP-OES	AWWA ICP-3500-Cd C

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Calcium	mg/l Ca	0.1	ICP-OES	AWWA ICP-3500-Ca C
Chromium (total)	mg/l Cr	0.01	ICP-OES	AWWA ICP-3500-Cr C
Cobalt	mg/l Co	0.01	ICP-OES	AWWA ICP-3500-Co C
Copper	mg/l Cu	0.01	ICP-OES	AWWA ICP-3500-Cu C
Gold	mg/l Au	0.01	ICP-OES	AWWA ICP-3500-Au
Iron	mg/l Fe	0.01	ICP-OES	AWWA ICP-3500-Fe C
Lead	mg/l Pb	0.01	ICP-OES	AWWA ICP-3500-Pb C
Lithium	mg/l Li	0.01	ICP-OES	AWWA ICP-3500-Li C
Magnesium	mg/l Mg	0.1	ICP-OES	AWWA ICP-3500-Mg C
Manganese	mg/l Mn	0.01	ICP-OES	AWWA ICP-3500-Mn C
Mercury	mg/l Hg	0.01	ICP-OES	AWWA ICP-3500-Hg
Molybdenum	mg/l Mo	0.01	ICP-OES	AWWA ICP-3500-Mo C
Nickel	mg/l Ni	0.01	ICP-OES	AWWA ICP-3500-Ni C
Potassium	mg/l K	0.1	ICP-OES	AWWA ICP-3500-K C
Rubidium	mg/l Rb	0.01	ICP-OES	ICP-OES
Selenium	mg/l Se	0.01	ICP-OES	AWWA ICP-3500-Se I
Silica	mg/l Si	0.01	ICP-OES	ICP-OES
Silver	mg/l Ag	0.01	ICP-OES	AWWA ICP-3500-Ag
Sodium	mg/l Na	0.1	ICP-OES	AWWA ICP-3500-Na C
Strontium	mg/l Sr	0.01	ICP-OES	AWWA ICP-3500-Sr C
Thallium	mg/l Th	0.01	ICP-OES	AWWA ICP-3500-Tl C
Tellurium	mg/l Te	0.01	ICP-OES	AWWA ICP-3500-Te
Tin	mg/l Sn	0.01	ICP-OES	AWWA ICP-3500-Sn
Titanium	mg/l Ti	0.01	ICP-OES	AWWA ICP-3500-Ti
Uranium	mg/l U	0.01	ICP-OES	AWWA ICP-3500-U
Vanadium	mg/l V	0.01	ICP-OES	AWWA ICP-3500-V C
Zinc	mg/l Zn	0.01	ICP-OES	AWWA ICP-3500-Zn C

Lower reporting limit

These are estimated values only; accurate lower levels of detection (LLDs) (measurement as part of a method) and method detection levels (MDLs) (measurement for the whole method) still have to be established

Given the varied matrices submitted to the laboratory and divers quality needs method and/or reagent blanks, performance evaluation samples and duplicate results may be included to assist in appropriate use of laboratory data.

All submitted samples are initially run undiluted unless sample dilutions are required in order to reduce or eliminate known matrix / interference effects. When an analyte concentration exceeds the calibration or linear range, the sample is re-analysed after appropriate dilution. The analyst will use the least dilution necessary to bring the analyte within the range. In both cases, a loss of sensitivity is experienced. All sample dilutions result in an increase in the lower reporting limit by a factor equal to the dilution. The less than symbol "<" is used for qualified data below the lower reporting limit.

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TEST REPORT I251597/1

To:	**Knight Piesold Consulting (Pty) Ltd**			
	P.O.Box 86062		Date received:	14/Aug/25
	Eros		Date analysed:	21 - 29 August 2025
	Windhoek		Date reported:	05/Sep/25
	Namibia			
Attn:	Lloyd Lynch		Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com		Quotation no.:	QUA-81934
Tel:	083-296 1131		Lab Reference:	I251597

Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	U1
Date of sampling	2025/08/04
Test item number	I251597/1

Parameter	Value	Units	Acceptable Standard limits Human consumption	Livestock watering
p H	**8.0**		6-9	
Electrical Conductivity	**49.0**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.2**	**mg/l**	-	
Temperature	**21.7**	**°C**	-	
Turbidity	**8.6**	**NTU**	<0.5	
Total Dissolved Solids	**266**	**mg/l**	<2000	6000
Total Suspended solids	**8**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**150**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**1.7**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**157**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**87**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**70**	**mg/l**	-	2057
Chloride as Cl^-	**40**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**47**	**mg/l**	<300	1000
Nitrate as N	**<0.5**	**mg/l**	<11	100
Nitrite as N	**0.03**	**mg/l**	<0.15	10
Hexavalent chromium as Cr^{6+}	**<0.01**	**mg/l**	-	
Sodium as Na	**34**	**mg/l**	<300	2000
Potassium as K	**2.6**	**mg/l**	<100	
Magnesium as Mg	**17**	**mg/l**	<70	500
Calcium as Ca	**35**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.7**			
Langelier Index	**0.3**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.4**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.7**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency	

Approved Technical Signatory
Ms. Helena Daniel

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TEST REPORT I251597/1

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	14/Aug/25
	Eros	Date analysed:	21 - 29 August 2025
	Windhoek	Date reported:	05/Sep/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251597
		Enquiries:	Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	U1
Date of sampling	2025/08/04
Test item number	I251597/1

Parameter	Value	Units	Acceptable Standard limits Human consumption
Aluminium as Al	**505**	µg/l	<100
Arsenic as As	**1.3**	µg/l	<50
Boron as B	**51**	µg/l	<500
Cadmium as Cd	**<1.0**	µg/l	<10
Chromium as Cr	**3.0**	µg/l	<100
Copper as Cu	**4.2**	µg/l	<2000
Iron as Fe	**1243**	µg/l	<300
Mercury as Hg	**<1.0**	µg/l	<2
Manganese as Mn	**54**	µg/l	<100
Nickel as Ni	**<1.0**	µg/l	<150
Lead as Pb	**<1.0**	µg/l	<50
Antimony as Sb	**<1.0**	µg/l	<50
Selenium as Se	**1.9**	µg/l	<50
Tin as Sn	**<1.0**	µg/l	<200
Strontinum as Sr	**184**	µg/l	
Titanium as Ti	**22**	µg/l	<300
Thallium as Tl	**<1.0**	µg/l	<10
Uranium as U	**3.8**	µg/l	<15
Zinc as Zn	**<1.0**	µg/l	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
South African Water Quality Guidelines Volume 5: Agricultural water use: Livestock watering, Second Edition, 1996

Sample acceptance: Sample was collected in bottles provided by the laboratory.
Sample was suitable for testing

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TEST REPORT I251597/1

Assessment of water quality for human consumption

Naturally occurring chemicals that are of health significance in drinking water
Fluoride: Exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.
0-1.0 mg/l fluoride: no adverse health effects or tooth damage occurs

Chemicals from agricultural activities that are of health significance in drinking water
Nitrate and nitrite: In water it has been associated with methaemoglobinaemia, especially in bottle-fed infants
0-6 mg/l nitrate as N: no adverse health effects

Some of the naturally occurring chemicals which occur in drinking water at concentrations below those at which toxic effects may occur.
Chloride: high concentrations of chloride give a salty taste to water. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste.
Hardness: Depending on the interaction of other factors, such as, pH and alkalinity, water with a hardness above approximately 200 mg/l may cause scale deposition in the pipe work and tanks. On heating, hard waters form deposits of calcium carbonate scale.
pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

Turbidity is a measure of the light-scattering ability of water and is indicative of the concentration of suspended matter in water.
Microorganisms are often associated with turbidity, hence low turbidity minimises the potential for transmission of infectious diseases. Turbidity also affects the aesthetic quality of water.
Turbidity in water is caused by the presence of suspended matter which usually consists of a mixture of inorganic matter, such as clay and soil particles and organic matter.
Turbidity may also be associated with the presence of inorganic ions such as manganese(II) and iron(II).
The consumption of turbid water *per se* does not have any direct health effects, but associated effects due to microbial contamination or the ingestion of substances bound to particulate matter, do.
Aesthetic effects (appearance, taste, odour) of turbidity can be mitigated or removed by decantation or by filtration (or by both), accelerated, if necessary, by previous aeration

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TEST REPORT I251597/2

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	14/Aug/25
	Eros	Date analysed:	21 - 29 August 2025
	Windhoek	Date reported:	05/Sep/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251597
		Enquiries:	Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	C1
Date of sampling	2025/08/04
Test item number	I251597/2

			Acceptable Standard limits	
Parameter	**Value**	**Units**	**Human consumption**	**Livestock watering**
p H	**8.2**		6-9	
Electrical Conductivity	**49.4**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.2**	**mg/l**	-	
Temperature	**21.3**	**°C**	-	
Turbidity	**8.8**	**NTU**	<0.5	
Total Dissolved Solids	**263**	**mg/l**	<2000	6000
Total Suspended solids	**16**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**145**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**41**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**157**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**87**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**70**	**mg/l**	-	2057
Chloride as Cl^-	**40**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**47**	**mg/l**	<300	1000
Nitrate as N	**<0.5**	**mg/l**	<11	100
Nitrite as N	**0.01**	**mg/l**	<0.15	10
Hexavalent chromium as Cr^{6+}	**<0.01**	**mg/l**	-	
Sodium as Na	**34**	**mg/l**	<300	2000
Potassium as K	**2.6**	**mg/l**	<100	
Magnesium as Mg	**17**	**mg/l**	<70	500
Calcium as Ca	**35**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.7**			
Langelier Index	**0.5**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.3**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.7**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency	

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TEST REPORT I251597/2

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	14/Aug/25
	Eros	Date analysed:	21 - 29 August 2025
	Windhoek	Date reported:	05/Sep/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251597

Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	C1
Date of sampling	2025/08/04
Test item number	I251597/2

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**
Aluminium as Al	**385**	µg/l	<100
Arsenic as As	**1.1**	µg/l	<50
Boron as B	**55**	µg/l	<500
Cadmium as Cd	**<1.0**	µg/l	<10
Chromium as Cr	**2.0**	µg/l	<100
Copper as Cu	**2.5**	µg/l	<2000
Iron as Fe	**804**	µg/l	<300
Mercury as Hg	**<1.0**	µg/l	<2
Manganese as Mn	**50**	µg/l	<100
Nickel as Ni	**<1.0**	µg/l	<150
Lead as Pb	**<1.0**	µg/l	<50
Antimony as Sb	**<1.0**	µg/l	<50
Selenium as Se	**2.1**	µg/l	<50
Tin as Sn	**<1.0**	µg/l	<200
Strontinum as Sr	**193**	µg/l	
Titanium as Ti	**14**	µg/l	<300
Thallium as Tl	**<1.0**	µg/l	<10
Uranium as U	**3.3**	µg/l	<15
Zinc as Zn	**<1.0**	µg/l	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
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Sample acceptance: Sample was collected in bottles provided by the laboratory.
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TEST REPORT I251597/2

Assessment of water quality for human consumption

Naturally occurring chemicals that are of health significance in drinking water
Fluoride: Exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.
0-1.0 mg/l fluoride: no adverse health effects or tooth damage occurs

Chemicals from agricultural activities that are of health significance in drinking water
Nitrate and nitrite: In water it has been associated with methaemoglobinaemia, especially in bottle-fed infants
0-6 mg/l nitrate as N: no adverse health effects

Some of the naturally occurring chemicals which occur in drinking water at concentrations below those at which toxic effects may occur.
Chloride: high concentrations of chloride give a salty taste to water. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste.
Hardness: Depending on the interaction of other factors, such as, pH and alkalinity, water with a hardness above approximately 200 mg/l may cause scale deposition in the pipe work and tanks. On heating, hard waters form deposits of calcium carbonate scale.
pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

Turbidity is a measure of the light-scattering ability of water and is indicative of the concentration of suspended matter in water.
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Turbidity may also be associated with the presence of inorganic ions such as manganese(II) and iron(II).
The consumption of turbid water *per se* does not have any direct health effects, but associated effects due to microbial contamination or the ingestion of substances bound to particulate matter, do.
Aesthetic effects (appearance, taste, odour) of turbidity can be mitigated or removed by decantation or by filtration (or by both), accelerated, if necessary, by previous aeration

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TEST REPORT I251597/3

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	14/Aug/25
	Eros	Date analysed:	21 - 29 August 2025
	Windhoek	Date reported:	05/Sep/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251597

Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	I1
Date of sampling	2025/08/04
Test item number	I251597/3

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**	**Livestock watering**
p H	**8.2**		6-9	
Electrical Conductivity	**49.5**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.2**	**mg/l**	-	
Temperature	**22.1**	**°C**	-	
Turbidity	**10**	**NTU**	<0.5	
Total Dissolved Solids	**270**	**mg/l**	<2000	6000
Total Suspended solids	**8**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**150**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**<1**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**157**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**87**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**70**	**mg/l**	-	2057
Chloride as Cl^-	**39**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**46**	**mg/l**	<300	1000
Nitrate as N	**1.3**	**mg/l**	<11	100
Nitrite as N	**0.01**	**mg/l**	<0.15	10
Hexavalent chromium as Cr^{6+}	**<0.01**	**mg/l**	-	
Sodium as Na	**34**	**mg/l**	<300	2000
Potassium as K	**2.6**	**mg/l**	<100	
Magnesium as Mg	**17**	**mg/l**	<70	500
Calcium as Ca	**35**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.7**			
Langelier Index	**0.5**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.3**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.7**	increasing corrosive tendency	Applies to water in the pH range 7-8	
			which also contains dissolved oxygen	
			ratios <0.2 no corrosive properties	
			ratios >0.2 increasing corrosive tendency	

Approved Technical Signatory
Ms. Helena Daniel

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P. O. Box 86782, Windhoek, Namibia

TEST REPORT I251597/3

To: **Knight Piesold Consulting (Pty) Ltd**
P.O.Box 86062
Eros
Windhoek
Namibia
Attn: Lloyd Lynch
e-mail: llynch@knightpiesold.com
Tel: 083-296 1131

Date received: 14/Aug/25
Date analysed: 21 - 29 August 2025
Date reported: 05/Sep/25

Client Reference no.: Verbal
Quotation no.: QUA-81934
Lab Reference: I251597
Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	I1
Date of sampling	2025/08/04
Test item number	I251597/3

Parameter	Value	Units	Acceptable Standard limits Human consumption
Aluminium as Al	**468**	µg/l	<100
Arsenic as As	**1.2**	µg/l	<50
Boron as B	**50**	µg/l	<500
Cadmium as Cd	**<1.0**	µg/l	<10
Chromium as Cr	**2.4**	µg/l	<100
Copper as Cu	**<1.0**	µg/l	<2000
Iron as Fe	**922**	µg/l	<300
Mercury as Hg	**<1.0**	µg/l	<2
Manganese as Mn	**63**	µg/l	<100
Nickel as Ni	**<1.0**	µg/l	<150
Lead as Pb	**<1.0**	µg/l	<50
Antimony as Sb	**<1.0**	µg/l	<50
Selenium as Se	**2.0**	µg/l	<50
Tin as Sn	**<1.0**	µg/l	<200
Strontinum as Sr	**190**	µg/l	
Titanium as Ti	**15**	µg/l	<300
Thallium as Tl	**<1.0**	µg/l	<10
Uranium as U	**3.2**	µg/l	<15
Zinc as Zn	**<1.0**	µg/l	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
South African Water Quality Guidelines Volume 5: Agricultural water use: Livestock watering, Second Edition, 1996

Sample acceptance: Sample was collected in bottles provided by the laboratory.
Sample was suitable for testing

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Assessment of water quality for human consumption

Naturally occurring chemicals that are of health significance in drinking water
Fluoride: Exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.
0-1.0 mg/l fluoride: no adverse health effects or tooth damage occurs

Chemicals from agricultural activities that are of health significance in drinking water
Nitrate and nitrite: In water it has been associated with methaemoglobinaemia, especially in bottle-fed infants
0-6 mg/l nitrate as N: no adverse health effects

Some of the naturally occurring chemicals which occur in drinking water at concentrations below those at which toxic effects may occur.
Chloride: high concentrations of chloride give a salty taste to water. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste.
Hardness: Depending on the interaction of other factors, such as, pH and alkalinity, water with a hardness above approximately 200 mg/l may cause scale deposition in the pipe work and tanks. On heating, hard waters form deposits of calcium carbonate scale.
pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

Turbidity is a measure of the light-scattering ability of water and is indicative of the concentration of suspended matter in water.
Microorganisms are often associated with turbidity, hence low turbidity minimises the potential for transmission of infectious diseases. Turbidity also affects the aesthetic quality of water.
Turbidity in water is caused by the presence of suspended matter which usually consists of a mixture of inorganic matter, such as clay and soil particles and organic matter.
Turbidity may also be associated with the presence of inorganic ions such as manganese(II) and iron(II).
The consumption of turbid water *per se* does not have any direct health effects, but associated effects due to microbial contamination or the ingestion of substances bound to particulate matter, do.
Aesthetic effects (appearance, taste, odour) of turbidity can be mitigated or removed by decantation or by filtration (or by both), accelerated, if necessary, by previous aeration

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TEST REPORT I251597/4

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	14/Aug/25
	Eros	Date analysed:	21 - 29 August 2025
	Windhoek	Date reported:	05/Sep/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251597
		Enquiries:	Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D1
Date of sampling	2025/08/04
Test item number	I251597/4

Parameter	Value	Units	Acceptable Standard limits Human consumption	Livestock watering
p H	**8.4**		6-9	
Electrical Conductivity	**49.0**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.4**	**mg/l**	-	
Temperature	**20.1**	**°C**	-	
Turbidity	**14**	**NTU**	<0.5	
Total Dissolved Solids	**262**	**mg/l**	<2000	6000
Total Suspended solids	**40**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**150**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**3**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**157**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**87**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**70**	**mg/l**	-	2057
Chloride as Cl^-	**38**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**46**	**mg/l**	<300	1000
Nitrate as N	**<0.5**	**mg/l**	<11	100
Nitrite as N	**<0.01**	**mg/l**	<0.15	10
Hexavalent chromium as Cr^{6+}	**<0.01**	**mg/l**	-	
Sodium as Na	**33**	**mg/l**	<300	2000
Potassium as K	**2.5**	**mg/l**	<100	
Magnesium as Mg	**17**	**mg/l**	<70	500
Calcium as Ca	**35**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.7**			
Langelier Index	**0.7**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.0**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.7**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency	

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P. O. Box 86782, Windhoek, Namibia

TEST REPORT I251597/4

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	14/Aug/25
	Eros	Date analysed:	21 - 29 August 2025
	Windhoek	Date reported:	05/Sep/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251597
		Enquiries:	Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D1
Date of sampling	2025/08/04
Test item number	I251597/4

Parameter	Value	Units	Acceptable Standard limits Human consumption
Aluminium as Al	**768**	µg/l	<100
Arsenic as As	**1.4**	µg/l	<50
Boron as B	**52**	µg/l	<500
Cadmium as Cd	**<1.0**	µg/l	<10
Chromium as Cr	**3.4**	µg/l	<100
Copper as Cu	**11**	µg/l	<2000
Iron as Fe	**1604**	µg/l	<300
Mercury as Hg	**<1.0**	µg/l	<2
Manganese as Mn	**64**	µg/l	<100
Nickel as Ni	**<1.0**	µg/l	<150
Lead as Pb	**<1.0**	µg/l	<50
Antimony as Sb	**<1.0**	µg/l	<50
Selenium as Se	**1.6**	µg/l	<50
Tin as Sn	**<1.0**	µg/l	<200
Strontinum as Sr	**188**	µg/l	
Titanium as Ti	**34**	µg/l	<300
Thallium as Tl	**<1.0**	µg/l	<10
Uranium as U	**3.3**	µg/l	<15
Zinc as Zn	**<1.0**	µg/l	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
South African Water Quality Guidelines Volume 5: Agricultural water use: Livestock watering, Second Edition, 1996

Sample acceptance: Sample was collected in bottles provided by the laboratory.
Sample was suitable for testing

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Assessment of water quality for human consumption

Naturally occurring chemicals that are of health significance in drinking water
Fluoride: Exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.
0-1.0 mg/l fluoride: no adverse health effects or tooth damage occurs

Chemicals from agricultural activities that are of health significance in drinking water
Nitrate and nitrite: In water it has been associated with methaemoglobinaemia, especially in bottle-fed infants
0-6 mg/l nitrate as N: no adverse health effects

Some of the naturally occurring chemicals which occur in drinking water at concentrations below those at which toxic effects may occur.
Chloride: high concentrations of chloride give a salty taste to water. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste.
Hardness: Depending on the interaction of other factors, such as, pH and alkalinity, water with a hardness above approximately 200 mg/l may cause scale deposition in the pipe work and tanks. On heating, hard waters form deposits of calcium carbonate scale.
pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

Turbidity is a measure of the light-scattering ability of water and is indicative of the concentration of suspended matter in water.
Microorganisms are often associated with turbidity, hence low turbidity minimises the potential for transmission of infectious diseases. Turbidity also affects the aesthetic quality of water.
Turbidity in water is caused by the presence of suspended matter which usually consists of a mixture of inorganic matter, such as clay and soil particles and organic matter.
Turbidity may also be associated with the presence of inorganic ions such as manganese(II) and iron(II).
The consumption of turbid water *per se* does not have any direct health effects, but associated effects due to microbial contamination or the ingestion of substances bound to particulate matter, do.
Aesthetic effects (appearance, taste, odour) of turbidity can be mitigated or removed by decantation or by filtration (or by both), accelerated, if necessary, by previous aeration

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TEST REPORT I251597/5

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	14/Aug/25
	Eros	Date analysed:	21 - 29 August 2025
	Windhoek	Date reported:	05/Sep/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251597

Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D2
Date of sampling	2025/08/04
Test item number	I251597/5

Parameter	Value	Units	Acceptable Standard limits Human consumption	Livestock watering
p H	**8.3**		6-9	
Electrical Conductivity	**47.8**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.1**	**mg/l**	-	
Temperature	**21.6**	**°C**	-	
Turbidity	**10**	**NTU**	<0.5	
Total Dissolved Solids	**255**	**mg/l**	<2000	6000
Total Suspended solids	**12**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**150**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**<1**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**151**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**85**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**66**	**mg/l**	-	2057
Chloride as Cl^-	**37**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**43**	**mg/l**	<300	1000
Nitrate as N	**<0.5**	**mg/l**	<11	100
Nitrite as N	**0.01**	**mg/l**	<0.15	10
Hexavalent chromium as Cr^{6+}	**0.01**	**mg/l**	-	
Sodium as Na	**32**	**mg/l**	<300	2000
Potassium as K	**2.5**	**mg/l**	<100	
Magnesium as Mg	**16**	**mg/l**	<70	500
Calcium as Ca	**34**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.7**			
Langelier Index	**0.6**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.2**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.6**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency	

Approved Technical Signatory
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TEST REPORT I251597/5

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	14/Aug/25
	Eros	Date analysed:	21 - 29 August 2025
	Windhoek	Date reported:	05/Sep/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251597
		Enquiries: Ms Helena P. Daniel	

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D2
Date of sampling	2025/08/04
Test item number	I251597/5

Parameter	Value	Units	Acceptable Standard limits Human consumption
Aluminium as Al	**286**	µg/l	<100
Arsenic as As	**1.2**	µg/l	<50
Boron as B	**51**	µg/l	<500
Cadmium as Cd	**<1.0**	µg/l	<10
Chromium as Cr	**2.2**	µg/l	<100
Copper as Cu	**<1.0**	µg/l	<2000
Iron as Fe	**765**	µg/l	<300
Mercury as Hg	**<1.0**	µg/l	<2
Manganese as Mn	**46**	µg/l	<100
Nickel as Ni	**<1.0**	µg/l	<150
Lead as Pb	**<1.0**	µg/l	<50
Antimony as Sb	**<1.0**	µg/l	<50
Selenium as Se	**1.8**	µg/l	<50
Tin as Sn	**<1.0**	µg/l	<200
Strontinum as Sr	**177**	µg/l	
Titanium as Ti	**9.0**	µg/l	<300
Thallium as Tl	**<1.0**	µg/l	<10
Uranium as U	**3.3**	µg/l	<15
Zinc as Zn	**<1.0**	µg/l	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
South African Water Quality Guidelines Volume 5: Agricultural water use: Livestock watering, Second Edition, 1996

Sample acceptance: Sample was collected in bottles provided by the laboratory.
Sample was suitable for testing

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TEST REPORT I251597/5

Assessment of water quality for human consumption

Naturally occurring chemicals that are of health significance in drinking water
Fluoride: Exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.
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Chemicals from agricultural activities that are of health significance in drinking water
Nitrate and nitrite: In water it has been associated with methaemoglobinaemia, especially in bottle-fed infants
0-6 mg/l nitrate as N: no adverse health effects

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Hardness: Depending on the interaction of other factors, such as, pH and alkalinity, water with a hardness above approximately 200 mg/l may cause scale deposition in the pipe work and tanks. On heating, hard waters form deposits of calcium carbonate scale.
pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

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Aesthetic effects (appearance, taste, odour) of turbidity can be mitigated or removed by decantation or by filtration (or by both), accelerated, if necessary, by previous aeration

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P. O. Box 86782, Windhoek, Namibia

TEST REPORT I251597/6

To:	**Knight Piesold Consulting (Pty) Ltd**		
	P.O.Box 86062	Date received:	14/Aug/25
	Eros	Date analysed:	21 - 29 August 2025
	Windhoek	Date reported:	05/Sep/25
	Namibia		
Attn:	Lloyd Lynch	Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com	Quotation no.:	QUA-81934
Tel:	083-296 1131	Lab Reference:	I251597
		Enquiries:	Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D3
Date of sampling	2025/08/04
Test item number	I251597/6

Parameter	**Value**	**Units**	**Acceptable Standard limits Human consumption**	**Livestock watering**
p H	**8.2**		6-9	
Electrical Conductivity	**56.4**	**mS/m**	<300	
Dissolved Oxygen as O_2	**7.2**	**mg/l**	-	
Temperature	**21.6**	**°C**	-	
Turbidity	**9.5**	**NTU**	<0.5	
Total Dissolved Solids	**293**	**mg/l**	<2000	6000
Total Suspended solids	**8**	**mg/l**		
P-Alkalinity as $CaCO_3$	**<10**	**mg/l**	-	
Total Alkalinity as $CaCO_3$	**155**	**mg/l**	-	
Chemical Oxygen Demand as O_2	**3**	**mg/l**	-	
Biological Oxygen Demand as O_2	**<2**	**mg/l**	-	
Total Hardness as $CaCO_3$	**178**	**mg/l**	<1000	
Ca-Hardness as $CaCO_3$	**100**	**mg/l**	-	2500
Mg-Hardness as $CaCO_3$	**78**	**mg/l**	-	2057
Chloride as Cl^-	**45**	**mg/l**	<300	1500-3000
Fluoride as F^-	**0.2**	**mg/l**	<1.5	2.0-6.0
Sulphate as SO_4^{2-}	**55**	**mg/l**	<300	1000
Nitrate as N	**0.8**	**mg/l**	<11	100
Nitrite as N	**0.01**	**mg/l**	<0.15	10
Hexavalent chromium as Cr^{6+}	**<0.01**	**mg/l**	-	
Sodium as Na	**35**	**mg/l**	<300	2000
Potassium as K	**2.7**	**mg/l**	<100	
Magnesium as Mg	**19**	**mg/l**	<70	500
Calcium as Ca	**40**	**mg/l**	<150	1000
Stability pH, at 25°C	**7.7**			
Langelier Index	**0.5**	scaling	>0=scaling, <0=corrosive, 0=stable	
Ryznar Index	**7.1**	stable	<6.5=scaling, >7,5=corrosive, ≥6.5 and ≤7.5=stable	
Corrosivity ratio	**0.8**	increasing corrosive tendency	Applies to water in the pH range 7-8 which also contains dissolved oxygen ratios <0.2 no corrosive properties ratios >0.2 increasing corrosive tendency	

Approved Technical Signatory
Ms. Helena Daniel

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P. O. Box 86782, Windhoek, Namibia

TEST REPORT I251597/6

To:	**Knight Piesold Consulting (Pty) Ltd**			
	P.O.Box 86062		Date received:	14/Aug/25
	Eros		Date analysed:	21 - 29 August 2025
	Windhoek		Date reported:	05/Sep/25
	Namibia			
Attn:	Lloyd Lynch		Client Reference no.:	Verbal
e-mail:	llynch@knightpiesold.com		Quotation no.:	QUA-81934
Tel:	083-296 1131		Lab Reference:	I251597

Enquiries: Ms Helena P. Daniel

Sample details	Water
Location of sampling point	Orange River
Description of sampling point	D3
Date of sampling	2025/08/04
Test item number	I251597/6

Parameter	Value	Units	Acceptable Standard limits Human consumption
Aluminium as Al	**570**	µg/l	<100
Arsenic as As	**1.2**	µg/l	<50
Boron as B	**50**	µg/l	<500
Cadmium as Cd	**<1.0**	µg/l	<10
Chromium as Cr	**2.7**	µg/l	<100
Copper as Cu	**2.7**	µg/l	<2000
Iron as Fe	**1216**	µg/l	<300
Mercury as Hg	**<1.0**	µg/l	<2
Manganese as Mn	**109**	µg/l	<100
Nickel as Ni	**<1.0**	µg/l	<150
Lead as Pb	**<1.0**	µg/l	<50
Antimony as Sb	**<1.0**	µg/l	<50
Selenium as Se	**2.2**	µg/l	<50
Tin as Sn	**<1.0**	µg/l	<200
Strontinum as Sr	**239**	µg/l	
Titanium as Ti	**22**	µg/l	<300
Thallium as Tl	**<1.0**	µg/l	<10
Uranium as U	**3.4**	µg/l	<15
Zinc as Zn	**<1.0**	µg/l	

Remark: Overall classification of water, considering only constituents that have been tested for:
Not Acceptable

Interpretation based on Water Resources Management Regulations, Water Resources Management Act, 2013 (No 11)
South African Water Quality Guidelines Volume 5: Agricultural water use: Livestock watering, Second Edition, 1996

Sample acceptance: Sample was collected in bottles provided by the laboratory.
Sample was suitable for testing

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Assessment of water quality for human consumption

Naturally occurring chemicals that are of health significance in drinking water
Fluoride: Exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis.
0-1.0 mg/l fluoride: no adverse health effects or tooth damage occurs

Chemicals from agricultural activities that are of health significance in drinking water
Nitrate and nitrite: In water it has been associated with methaemoglobinaemia, especially in bottle-fed infants
0-6 mg/l nitrate as N: no adverse health effects

Some of the naturally occurring chemicals which occur in drinking water at concentrations below those at which toxic effects may occur.
Chloride: high concentrations of chloride give a salty taste to water. Concentrations in excess of 250 mg/l are increasingly likely to be detected by taste.
Hardness: Depending on the interaction of other factors, such as, pH and alkalinity, water with a hardness above approximately 200 mg/l may cause scale deposition in the pipe work and tanks. On heating, hard waters form deposits of calcium carbonate scale.
pH: Optimum pH 6.5-8.
pH does not exert direct health effects, but may exert indirect health effects via metal solubility.
Sodium: The average taste threshold for sodium is about 200 mg/l.
Sulphate: It is generally considered that the taste impairment is minimal at levels below 250 mg/l.
Magnesium: The average taste threshold for magnesium is about 70 mg/l
Total dissolved solids: The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

Turbidity is a measure of the light-scattering ability of water and is indicative of the concentration of suspended matter in water.
Microorganisms are often associated with turbidity, hence low turbidity minimises the potential for transmission of infectious diseases. Turbidity also affects the aesthetic quality of water.
Turbidity in water is caused by the presence of suspended matter which usually consists of a mixture of inorganic matter, such as clay and soil particles and organic matter.
Turbidity may also be associated with the presence of inorganic ions such as manganese(II) and iron(II).
The consumption of turbid water *per se* does not have any direct health effects, but associated effects due to microbial contamination or the ingestion of substances bound to particulate matter, do.
Aesthetic effects (appearance, taste, odour) of turbidity can be mitigated or removed by decantation or by filtration (or by both), accelerated, if necessary, by previous aeration

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TEST REPORT I251597

To: **Knight Piesold Consulting (Pty) Ltd**
P.O.Box 86062
Eros
Windhoek
Namibia
Attn: Lloyd Lynch
e-mail: llynch@knightpiesold.com
Tel: 083-296 1131

Date received: 14/Aug/25
Date analysed: 21 - 29 August 2025
Date reported: 05/Sep/25
Client Reference no.: Verbal
Quotation no.: QUA-81934
Lab Reference: I251597
Enquiries: Ms Helena P. Daniel

Quality control samples analysed included certified and external reference samples to monitor accuracy

Test	QC reading	Assigned value	Unit	Acceptance criteria	Range
p H	6.93	7.05	-	± 3 SD	6.91 - 7.18
Electrical Conductivity	142.7	142.5	mS/m	± 3 SD	139.2 - 145.8
Turbidity	18.3	17.8	NTU	± 3 SD	16.8 - 18.8
Total Suspended Solids	4.999	5.0	g	± 1%	4.95 - 5.05
Chemical Oxygen Demand as O_2	9.6	8.3	mg/L	± 3 SD	2.9 - 13.7
Total Alkalinity as $CaCO_3$	965	988	mg/L	± 3 SD	926 - 1050
Chloride as Cl^-	486	479	mg/L	± 3 SD	463 - 496
Fluoride as F^-	0.48	0.48	mg/L	± 3 SD	0.37 - 0.59
Nitrate as N	8.93	9.85	mg/L	± 3 SD	8.91 - 10.79
Nitrite as N	0.123	0.123	mg/L	± 3 SD	0.100 - 0.146
Sodium as Na	18.96	20.0	mg/L	± 10%	18.0 - 22.0
Potassium as K	19.19	20.0	mg/L	± 10%	18.0 - 22.0
Magnesium as Mg	20.14	20.0	mg/L	± 10%	18.0 - 22.0
Calcium as Ca	20.87	20.0	mg/L	± 10%	18.0 - 22.0
Arsenic as As	10.376	10.0	µg/l	± 20%	8.0 - 12.0
Cadmium as Cd	10.117	10.0	µg/l	± 20%	8.0 - 12.0
Chromium as Cr	11.821	10.0	µg/l	± 20%	8.0 - 12.0
Copper as Cu	10.947	10.0	µg/l	± 20%	8.0 - 12.0
Iron as Fe	8.225	10.0	µg/l	± 20%	8.0 - 12.0
Mercury as Hg	11.082	10.0	µg/l	± 20%	8.0 - 12.0
Manganese as Mn	11.205	10.0	µg/l	± 20%	8.0 - 12.0
Nickel as Ni	10.908	10.0	µg/l	± 20%	8.0 - 12.0
Lead as Pb	10.215	10.0	µg/l	± 20%	8.0 - 12.0
Antimony as Sb	10.408	10.0	µg/l	± 20%	8.0 - 12.0
Selenium as Se	10.280	10.0	µg/l	± 20%	8.0 - 12.0
Tin as Sn	10.089	10.0	µg/l	± 20%	8.0 - 12.0
Strontinum as Sr	10.208	10.0	µg/l	± 20%	8.0 - 12.0
Thallium as Tl	10.517	10.0	µg/l	± 20%	8.0 - 12.0
Uranium as U	10.759	10.0	µg/l	± 20%	8.0 - 12.0
Zinc as Zn	10.286	10.0	µg/l	± 20%	8.0 - 12.0

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Summary of test methods - Water Quality

Determinant	Unit	DL	Technique	Method reference
Absorbed oxygen	mg/l O_2	2	titrimetric	SANS 5220:2005
Acidity	mg/l $CaCO_3$	10	titrimetric	AWWA 2310 B
Alkalinity	mg/l $CaCO_3$	10	titrimetric	AWWA 2320 B
Ammonium	mg/l N	0.02	colorimetric	AWWA 4500-NH_3 F / modified Berthelot
Bicarbonate & Carbonate	mg/l $CaCO_3$	1	by calculation	
Biological oxygen demand, 5-day	mg/l O_2	2	electrometric	AWWA 5210 B
Biological oxygen demand, carbonacious	mg/l O_2	2	electrometric	AWWA 5210 B
Bromide & Iodide	mg/l Br^-	0.05	iodometric	P. Höfer
Chloride	mg/l Cl^-	1	argentometric	AWWA 4500-Cl^- B
Chlorine, free and total	mg/l Cl_2	0.05	colorimetric	AWWA 4500-Cl G
Chlorophyll a	µg/L	0.01	spectrophotometric	ISO 10260:1992 E
Chemical oxygen demand	mg/l O_2	1	colorimetric	AWWA 5220 D
Colour	Pt	10	colorimetric	AWWA Pt-Co-2120 B
Cyanide	mg/l CN	0.02	colorimetric	AWWA 4500-CN E
Density	mg/l g/ml	-	gravimetric	METH W 016
Dissolved oxygen	mg/l O_2	0.1	electrometric	AWWA 4550-O G
Electrical conductivity	mS/m	0.1	electrometric	AWWA 2510 B
Fat, oil & grease	mg/l	2	extraction/gavimetric	AWWA 5520 B
Fixed and volatile solids, ignited at 550°C	mg/l	1	gravimetric	AWWA 2540 E
Fluoride	mg/l F^-	0.1	electrometric	AWWA 4500-F C
Hardness	mg/l $CaCO_3$	1	by calculation	AWWA 2340 B
Hexavalent chromium	mg/l Cr	0.01	colorimetric	AWWA 3500-Cr B
Hydrolysable phosphates	mg/l P	0.01	digestion, PO4	AWWA 4500-P B.2 + E
Kjeldahl nitrogen	mg/l N	0.5	by calculation	
Molybdosilicate	mg/l SiO_2	0.4	colorimetric	AWWA 4500-Si C
Nitrate	mg/l N	0.5	colorimetric	Spectroquant / AWWA 4500-NO_3 E
Nitrite	mg/l N	0.01	colorimetric	AWWA 4500-NO2 B
Oxidation reduction potential (Redox)	mV	-	electrometric	AWWA 2580 B
pH		-	electrometric	AWWA 4500-H^+ B
Phenols	mg/l Phenol	0.05	colorimetric	ASTM D1783-01, B
Reactive phosphorous	mg/l PO_4	0.03	colorimetric	AWWA 4500-P E
Settable solids	mg/l	1	gravimetric	AWWA 2540 F
Sulfide	mg/l S^{2-}	0.05	colorimetric	AWWA 4500-S^{2-} D
Sulfite	mg/l SO_3^{2-}	2	iodometric	AWWA 4500-SO_3^{2-} B
Sulphate	mg/l SO_4	1	nephelometric / colorimetric	AWWA 4500-SO4 E / F
Total dissolved solids	mg/l	1	gravimetric	AWWA 2540 C
Total nitrogen	mg/l N	0.5	digestion, NO3	EN ISO 11905-1:1997
Total phosphorous	mg/l P	0.01	digestion, PO4	AWWA 4500-P B.5 + E
Total solids	mg/l	1	gravimetric	AWWA 2540 B
Total suspended solids	mg/l	1	gravimetric	AWWA 2540 D
Turbidity	NTU	0.05	nephelometric	AWWA 2130 B
UV absorbing organic constituents at 254nm	cm^{-1}	-	colorimetric	AWWA 5910 B

Aluminium	mg/l Al	0.01	ICP-OES	AWWA ICP-3500-Al C
Antimony	mg/l Sb	0.01	ICP-OES	AWWA ICP-3500-Sb C
Arsenic	mg/l As	0.01	ICP-OES	AWWA ICP-3500-As D
Barium	mg/l Ba	0.01	ICP-OES	AWWA ICP-3500-Ba C
Beryllium	mg/l B	0.01	ICP-OES	AWWA ICP-3500-Be
Bismuth	mg/l Bi	0.01	ICP-OES	AWWA ICP-3500-Bi
Boron	mg/l B	0.01	ICP-OES	AWWA ICP-3500-B D
Cadmium	mg/l Cd	0.01	ICP-OES	AWWA ICP-3500-Cd C

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Calcium	mg/l	Ca	0.1	ICP-OES	AWWA ICP-3500-Ca C
Chromium (total)	mg/l	Cr	0.01	ICP-OES	AWWA ICP-3500-Cr C
Cobalt	mg/l	Co	0.01	ICP-OES	AWWA ICP-3500-Co C
Copper	mg/l	Cu	0.01	ICP-OES	AWWA ICP-3500-Cu C
Gold	mg/l	Au	0.01	ICP-OES	AWWA ICP-3500-Au
Iron	mg/l	Fe	0.01	ICP-OES	AWWA ICP-3500-Fe C
Lead	mg/l	Pb	0.01	ICP-OES	AWWA ICP-3500-Pb C
Lithium	mg/l	Li	0.01	ICP-OES	AWWA ICP-3500-Li C
Magnesium	mg/l	Mg	0.1	ICP-OES	AWWA ICP-3500-Mg C
Manganese	mg/l	Mn	0.01	ICP-OES	AWWA ICP-3500-Mn C
Mercury	mg/l	Hg	0.01	ICP-OES	AWWA ICP-3500-Hg
Molybdenum	mg/l	Mo	0.01	ICP-OES	AWWA ICP-3500-Mo C
Nickel	mg/l	Ni	0.01	ICP-OES	AWWA ICP-3500-Ni C
Potassium	mg/l	K	0.1	ICP-OES	AWWA ICP-3500-K C
Rubidium	mg/l	Rb	0.01	ICP-OES	ICP-OES
Selenium	mg/l	Se	0.01	ICP-OES	AWWA ICP-3500-Se I
Silica	mg/l	Si	0.01	ICP-OES	ICP-OES
Silver	mg/l	Ag	0.01	ICP-OES	AWWA ICP-3500-Ag
Sodium	mg/l	Na	0.1	ICP-OES	AWWA ICP-3500-Na C
Strontium	mg/l	Sr	0.01	ICP-OES	AWWA ICP-3500-Sr C
Thallium	mg/l	Th	0.01	ICP-OES	AWWA ICP-3500-Tl C
Tellurium	mg/l	Te	0.01	ICP-OES	AWWA ICP-3500-Te
Tin	mg/l	Sn	0.01	ICP-OES	AWWA ICP-3500-Sn
Titanium	mg/l	Ti	0.01	ICP-OES	AWWA ICP-3500-Ti
Uranium	mg/l	U	0.01	ICP-OES	AWWA ICP-3500-U
Vanadium	mg/l	V	0.01	ICP-OES	AWWA ICP-3500-V C
Zinc	mg/l	Zn	0.01	ICP-OES	AWWA ICP-3500-Zn C

Lower reporting limit

These are estimated values only; accurate lower levels of detection (LLDs) (measurement as part of a method) and method detection levels (MDLs) (measurement for the whole method) still have to be established
Given the varied matrices submitted to the laboratory and divers quality needs method and/or reagent blanks, performance evaluation samples and duplicate results may be included to assist in appropriate use of laboratory data.

All submitted samples are initially run undiluted unless sample dilutions are required in order to reduce or eliminate known matrix / interference effects. When an analyte concentration exceeds the calibration or linear range, the sample is re-analysed after appropriate dilution. The analyst will use the least dilution necessary to bring the analyte within the range. In both cases, a loss of sensitivity is experienced. All sample dilutions result in an increase in the lower reporting limit by a factor equal to the dilution. The less than symbol "<" is used for qualified data below the lower reporting limit.

APPENDIX C

Microbial Analysis

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TEST REPORT: I250690

To: **Knight Piesold Consulting (Pty) Ltd**
P.O. Box 86062
Windhoek, Namibia

Att: Ms Bianca Eiases
E-mail: BEiases@knightpiesold.com
Tel: 061 307 297

Date sample(s) received**:** 28/03/2025
Date sample (s) analysed: 28/03 – 01/04/2025
Date reported: 04/04/2025

Client reference No.: Not applicable
Quotation No.: QUA81427
Lab reference: I250690/1-4
Enquiries: Ms Rosina Shangula | Windhoek Lab

1. **Temperature of cooler box at receipt:** Acceptable (9.9°C)
2. **Number and Type of samples received:** 4 x water samples
3. **Sampling date & time:** 27/03/2025, 16:00 – 17:30
4. **Sampling location:** Orange River
5. **Sampling done by:** Mr Madise Mobebegana (Customer)

6. **Remark: Sample acceptance**
- Sample(s) were suitable for testing

7. **Test(s) Requested**
- METH M 026: Total Colony Count (TCC), CFU/ml
- METH M 046: Total coliforms, MPN/100ml
- METH M 046: *E. coli*, MPN/100ml

8. **Results**

Sample Description	**Matrix**	**Lab Sample Number**	**TCC@35°C cfu/ml**	**Total coliforms** MPN/100ml	***E. coli*** MPN/100ml
C1	River water	I250690/1	9800	750	36
D1	River water	I250690/2	14 600	11 000	36
D2	River water	I250690/3	13 400	4 600	380
I1	River water	I250690/4	23 000	1 500	30

Comments:
- < = less than; > = more than
- cfu = colony forming units
- MPN/100ml = Most probable number per 100 ml; this number is based on probability formulas and is an estimate of the mean density of bacteria in the sample.
- External reference methods are listed on FM 7.1-1-5 Sample Submission Form: Microbiology Testing

Approved Technical Signatory
Ms. Rosina Shangula

The result(s) relate(s) only to the specific sample(s) tested and received (if sampling undertaken by the customer) and do not apply to any similar sample that has not been tested. This test report shall not be published or reproduced except in full, without written approval of the laboratory