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# Anglo American Platinum Rustenburg Process Division

## Annual Integrated Surface and Groundwater Quality, Biomonitoring and Toxicity Testing Assessment Report, Vol I

September 2018 to August 2019

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**Anglo American Platinum**
**Rustenburg Process Division**

# Annual Integrated Surface and Groundwater Quality, Biomonitoring and Toxicity Testing Assessment Report, Vol I

September 2018 to August 2019

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| **REPORTING SCOPE** | This is an extensive report and includes a full evaluation of all the results obtained during the annual monitoring period. The report includes a statistical summary (temporal & spatial) of all the chemical variables for all the monitoring localities, time-series graphs (for the entire database period), linear trend determinations, performance analyses and compliance assessments, water quality thematic maps indicating pollution sources and impacts on the receiving water body as well as a discussion and recommendation section. This report is composed of three volumes. |

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**APPENDIX A: Annual Report on Groundwater Monitoring**

**APPENDIX B: Biomonitoring Report**

**APPENDIX C: Toxicity Test Report**

# 1. INTRODUCTION

Globally, water is one of the prime environmental resources that are affected by anthropogenic activities. Activities associated with mining can pose a risk for adverse environmental impacts. Mining and mineral beneficiation can affect water quality; alter the hydrological and topographical characteristics on a local scale and subsequently surface runoff, soil moisture, evapo-transpiration and groundwater behaviour. Mining activities can pose a significant risk to South Africa's water resource security. Failure to manage the impacts on water resources in an acceptable manner throughout life-of-mine and post-closure will result in the mining industry finding it increasingly difficult to obtain community and government support for existing and future projects.

In South Africa, environmental impacts associated with mining are managed under the Minerals and Petroleum Resources Development Act, 2002 (MPRDA, Act 28 of 2002) which is administrated by the Department of Mineral Resources (DMR). The Department of Water and Sanitation (DWS) acts as primary agent for water related issues in the mining sector. As custodian of the natural water resources, it is an integral function of the Department of Water and Sanitation's (DWS) regulatory system to manage the effects of any anthropogenic activities on the country's water resources. The National Water Act provides the legal framework for the effective and sustainable management of our water resources. The protection of water resources is fundamentally related to their use, development, conservation, management and control.

The National Water Act, 1998 (Act 36 of 1998) (NWA) introduced the concept of Integrated Water Resource Management (IWRM), comprising all aspects of the water resource, including water quality, water quantity and the aquatic ecosystem quality (quality of the aquatic biota and in-stream and riparian habitat) (DWAF, 2007). The mentioned IWRM approach also calls for both resource and source directed measures. Resource directed actions include the formulation of resource quality objectives and catchment management strategies while source directed measures focus on impacts at source. The resource directed measures must also give effect to the Class, Reserve and Resource Quality Objectives of the water resources and associated protection measures (DWAF, 2008).

The promulgation of the NWA thus lead to a paradigm shift resulting in the natural environment being regarded as an integral part of the water resource itself, as well as one of the competing water users. Hence the biota, the physical and chemical in-stream habitats and the processes which link biota and habitat are all considered being inseparably part of the water resource itself.

Section 19 of Chapter 3 in the NWA deals with pollution prevention, and in particular the situation where pollution of a water resource occurs or might occur as a result of activities on land, such as mining, and states that: *"The person who owns, controls, occupies or uses the land in question is responsible for taking measures to prevent pollution of water resources. If these measures are not taken, the catchment management agency concerned may itself do whatever is necessary to prevent* *pollution or to remedy its effects, and to recover all reasonable costs from the persons responsible for the pollution."*

In Section 22 of Chapter 4 of the Act, the general principles for regulating the use of water are set out. Water use is defined broadly and includes the taking and storing of water, activities which reduce stream flow or alters a water course, waste discharges and disposal, removing water from underground and controlled activities which may impact detrimentally on a water resource. In general, a water use must be licensed under the Act.

Section 26 of the National Water Act, 1998 (Act 36 of 1998) also provides for the development of regulations to, amongst others:

- Require that the use of water from a water resource be monitored, measured and recorded.
- Regulate or prohibit any activity in order to protect a water resource or in-stream or riparian habitat.
- Prescribe the outcome or effect, which must be achieved through management practices for the treatment of waste, or any class of waste before it is discharged into or allowed to enter a water resource.
- Require that waste discharged or deposited into or allowed to enter a water resource be monitored and analysed, and prescribing methods for such monitoring and analysis.

Prior to issuing of the WUL the Rustenburg operations operated according to the expired Exemption Permit issued in terms of the now repealed Water Act, 1956 (Act 54 of 1956). Both the WUL and the expired Permit stipulated that a surface- and ground water quality, biomonitoring and toxicity testing program should be designed, implemented and maintained.

Rustenburg Platinum Mines: Rustenburg Section (RPM-RS) was issued with a Water Use License (WUL; License No 03/A22H/ACGIJ/926) in terms of Chapter 4 of the National Water Act, 1998 (Act No 36 of 1998) in March 2012. Due to several alsubstantial errors observed in the approved WUL and after consultation with DWA, an amendment WULA was submitted on 12 July 2012; A the new WUL (WUL; License No A22H/GIAC/6501) was issued in January 2018 and will henceforth be referenced as WUL, 2018.

The Anglo Platinum Environmental Department decided to take a pro-active approach towards auditing requirements, as well as the latest development in national water management policy. Aquatico Scientific was commissioned by Anglo Platinum to conduct the surface water and groundwater monitoring programme and to evaluate the physical, chemical and biological properties of the receiving water environment subject to potential impact.

This annual report presents the data from the Anglo Platinum monitoring programme while effectively indicating compliance with the applicable policy of regulating authorities, such as contained in ethe mentioned WUL. It is thus the intention of this annual monitoring report to indicate the implementation of a well-designed and maintained monitoring programme which is considered essential within any mine water management strategy on the basis that "one cannot manage what one cannot measure" (DWAF, 2008).

Additional information can be found in the comprehensive annual water management report "Anglo Platinum Process Division – Annual DWA Compliance Report" *No.* ***APPD/ACR1/2019/WR*** submitted to DWA and compiled by Aquatico Scientific. Additional information referenced in above-mentioned report includes:

- Operations and permit information;

- Production figures and water usage;
- Rainfall and evaporation data; and
- Flow data.

## 2. WATER USE LICENCE

**Note on compliance towards license conditions as set out in the WUL (2018)**

A new water use license in terms of Chapter 4 of the National Water Act, 1998 (Act No. 36 of 1998) (The Act) was issued by the Department of Water and Sanitation (DWS) in 2018: Licence no. A22H/GIAC/6501. The license was issued for water uses relating to the following:

i. Section 21(a) of the Act: Taking water from a water resource
ii. Section 21(g) of the Act: Disposing of waste in a manner which may detrimentally impact on a water resource

The uses applicable to the water monitoring programme and the current document are Section 21(g) of the Act relating to the disposing of waste which may detrimentally impact on a water resource.

As mentioned, the NWA introduced the concept of Integrated Water Resource Management (IWRM), comprising all aspects of the water resource, including water quality, water quantity and the aquatic ecosystem quality. The IWRM approach provides for both resources directed and source directed measures. Resource directed measures aim to protect and manage the receiving environment. Examples of resource directed actions are the formulation of resource quality objectives and the development of associated strategies to ensure on-going attainment of these objectives; catchment management strategies and the establishment of catchment management agencies (CMAs) to implement these strategies.

On the other hand, source directed measures aim to control the impacts at source through the identification and implementation of pollution prevention, water reuse and water treatment mechanisms.

The integration of resource and source directed measures forms the basis of the ***hierarchy of decision-taking*** aimed at protecting the resource from waste impacts (Figure 1). This hierarchy is based on a *precautionary approach* and the following order of priority for mine water and waste management decisions and/or actions is applicable:

**RESOURCE PROTECTION AND WASTE MANAGEMENT HIERARCHY**

**Step 1: Pollution Prevention**

↓

**Step 2: Minimisation of impacts**
Water reuse and reclamation
Water treatment

↓

**Step 3: Discharge or disposal of waste and/or waste water**
Site Specific risk-based approach
Polluter pays principle

**Figure 1: Resource Protection and Waste Management Hierarchy**

Appendix III of the WUL (2018) stipulates that the Licensee shall monitor the water resources at surface water monitoring points, groundwater monitoring points, biomonitoring points and toxicity monitoring points to determine the impact of the facilities and other activities on the water quality. The WUL has two main water quality objectives; (1) limits for the impact of the activities on groundwater (in Table 8 of the WUL), and (2) water quality limits stipulated for the impact of the activities on the surface water quality of the area (in Table 9 of the WUL), i.e. the resource water quality objectives.

Presented in Table 1 below are the guidelines which were issued by the DWA to serve as protection of the resource and to monitor the quality of of the source. Also shown are the SANS241:2015 Drinking water standard, the South African Water Quality Guidelines' Target water quality guideline ranges for Domestic Use (DWAF, 1996) and the quality typical of the wastewater dams (Return Water Dams) of the RPM-RS operations.

The table shows stringent WUL limits as oppose to the presented drinking water quality guidelines and also greater compared to typical upstream and wastewater quality for the RPM-RS lease area. It is therefore recommended that the WUL limits be revised which should be created using the background 'in-coming' quality as reference and not pristine groundwater quality of the region or catchment.

**Table 1: Quality limits for water monitoring programme**

| VARIABLE | Units | Groundwater Quality Limits (WUL 2018) | Surface Water Quality Limits (WUL 2018) | SANS 241-1:2015 Drinking water standards | General Limit [Section 21 (f) and (h)] | DWA SAWQG Ideal (Class 0) Domestic Water |
|---|---|---|---|---|---|---|
| pH | pH units | 6.0 - 9.5 | 6.0 - 9.0 | 5.0 - 9.7 | 5.5 - 9.5 | 6.0 - 9.0 |
| Electrical Conductivity (EC) | mS/m | 150 | 85.00 | 170 | 150 | 0 - 70 |
| Total Dissolved Solids (TDS) | mg/l | - | - | < 1200 | - | 0 - 450 |
| Dissolved Oxygen (DO) | mg/l | - | 43654.00 | - | - | - |
| Total Alkalinity ($CaCO_3$) | mg/l | - | - | - | - | - |
| Hardness (CaCO3) | mg/l | - | 50 | - | - | 0 - 200 |
| Calcium (Ca) | mg/l | 150 | - | - | - | 0 - 80 |
| Magnesium (Mg) | mg/l | 100 | - | - | - | 0 - 70 |
| Sodium (Na) | mg/l | 200 | - | 200 | - | <100 |
| Potassium (K) | mg/l | - | - | - | - | <25 |
| Chloride (Cl) | mg/l | 200 | - | 300 | - | < 100 |
| Sulphate ($SO_4$) | mg/l | 200 | - | 250 | - | 0 - 200 |
| Nitrate ($NO_3$) as N | mg/l | 10 | - | 11 - (Acute Health) | 15 | <6 |
| Ammonia ($NH_4$) as N | mg/l | - | 1.00 | 1.5 | 6 | 0 - 1.0 |
| Phosphate ($PO_4$) as P | mg/l | - | 0.125 | - | 10 | - |
| Fluoride (F) | mg/l | 1 | 0.75 | < 1.5 - (Chronic Health) | 1 | <0.7 |
| Aluminium (Al) | mg/l | - | 5 | 0.3 (Operational) | - | 0 - 0.15 |
| Iron (Fe) | mg/l | - | 0.5 | 0.3 - (Aesthetic)<br>2.0 - (Chronic Health) | 0.3 | 0 - 0.5 |
| Manganese (Mn) | mg/l | - | 0.18 | 0.1 - (Aesthetic)<br>0.4 - (Chronic Health) | 0.1 | 0 - 0.1 |
| Cadmium (Cd) | mg/l | - | - | 0.003 | 0.005 | <0.003 |
| Trivalent chromium ($Cr^{3+}$) | mg/l | - | - | 0.05 | - | - |
| Hexavalent chromium ($Cr^{6+}$) | mg/l | 0.0049 | 0.0049 | 0.1 | 0.05 | 0 - 0.05 |
| Copper (Cu) | mg/l | - | 0.3 | 2 | - | 0 - 1.0 |
| Nickel (Ni) | mg/l | - | - | 0.07 | - | - |
| Lead (Pb) | mg/l | - | - | 0.01 | 0.01 | 0 - 0.01 |
| Zinc (Zn) | mg/l | - | - | 5 | 0.1 | 0 - 20 |
| Arsenic (As) | mg/l | - | - | 0.01 | 0.02 | <0.01 |
| Cyanide (CN) | mg/l | - | - | 0.2 | 0.02 | - |
| Mercury (Hg) | mg/l | - | - | 0.006 | 0.005 | - |
| Seleniun (Se) | mg/l | - | - | 0.04 | 0.02 | - |
| Vanadium (V) | mg/l | - | - | - | - | - |
| Barium (Ba) | mg/l | - | - | 0.7 | - | - |
| Boron (B) | mg/l | - | - | 2.4 | 0.5 | - |
| SAR | mg/l | - | - | - | - | - |
| Free Chlorine (residual) $Cl_2$ | mg/l | - | - | 5 | 0.25 | 0.3-0.6 |
| E Coli counts / 100 ml | mg/l | - | - | 0 | 1000 | 0 |
| Total coliforms counts / 100 ml | mg/l | - | - | 10 | - | 0 |
| Het. Plate count / TVC | mg/l | - | - | 1000* | - | - |
| Faecal coliforms counts / 100 ml | mg/l | - | - | 0 | 1000 | 0 |
| Turbidity (NTU) | mg/l | - | - | 1 (Operational)<br>5 (Aesthetic) | - | < 0.1 |
| Total Suspended Solids | mg/l | - | - | - | 25 | - |
| Soap, Oil, Grease | mg/l | - | - | - | 2.5 | - |
| Chemical Oxygen Demand | mg/l | - | - | - | 75 | - |
| Hydrocarbons | mg/l | - | - | - | - | - |
| Polycyclic aromatics | mg/l | - | - | - | - | - |

## 3. LEGAL PERSPECTIVE AND MONITORING REQUIREMENTS

Mining operations are anticipated to pose a high risk for adverse environmental impacts. These impacts may occur slowly and unnoticed during the operational life cycle phase of the mine as mining activities progresses and/or during adverse weather conditions, or only emerge long after mining ceased. Possible impacts need to be prioritised in terms of a number of influencing factors such as the actual impact quantification, industry standards, applicable legislation, mitigation requirements, and mine management requirements (DWAF, 2006a).

The development of a site-specific efficient monitoring programme that complies with the requirements of mine management as well as regulatory requirements is of utmost importance. Water monitoring should be objective driven and purposefully utilised to achieve goals such as compliance auditing and reporting as summarised in the Figure 2.

Various environmentally related legislation require either directly or indirectly the monitoring of water resources, such as the Environment Conservation Act (Act 73 of 1989), the National Environmental Management Act (Act 107 of 1998), the Minerals and Petroleum Resources Development Act (Act 28 of 2002) (including Environmental Management Programme Reports (Section 39), Regulations relating to performance assessments (auditing) of EMPR's (Government Notice (GN) R801 of 25 June 1999) and Closure requirements (Section 12), as well as the National Water Act, 1998 (Act 36 of 1998).

Special emphasis should be placed on the National Water Act, 1998 regarding water resource monitoring. Subsequent to the implementation of the mentioned Act, the focus changed from concentrating on controlling pollution at source by means of regulatory standards, to a water resource management philosophy that concentrate also on resource management through maintaining the fitness for agreed or specified uses including the protection of aquatic ecosystems. The mentioned Act recognises that ecosystems form the resource base on which sustainable utilisation of water resources depend.

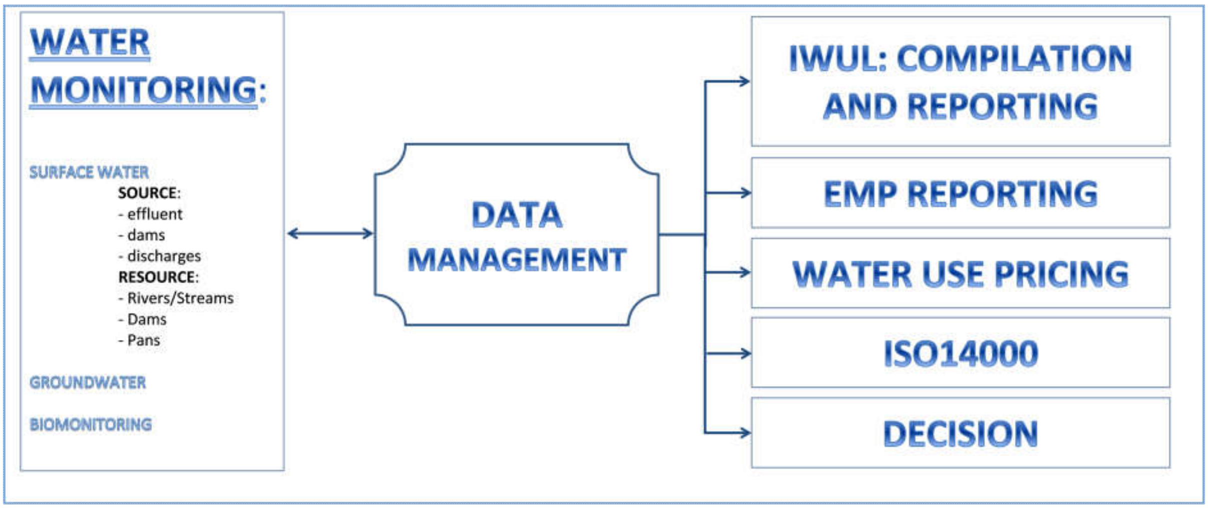



**Figure 2: Diagrammatic presentation of the importance of environmental monitoring in Integrated Environmental Management, as adopted from BPG G3**

Since the Department of Water Affairs (DWA) is the public trustee of South Africa's water resources it is the DWA's responsibility to ensure that water resources remain fit for use on a sustainable basis. DWA exercises the responsibility through the implementation of Regulations such as the regulations on use of water for mining and related activities aimed at the protection of water resources (GN 704 dated June 1999), the Water use licensing process, including the determination of the "reserve" for the various water resources. Verification of the mining operation's compliance with the applicable legislation (including the water use licences and requirements of the regulations) can only be illustrated through the implementation of a water resource monitoring plan.

The importance of a monitoring system can be emphasised through the following: "It is essential that any management system incorporate clearly defined monitoring systems to be implemented to measure the effectiveness of management strategies and mitigating actions and compliance with agreed targets and objectives. The responsibilities, reporting formats and frequencies must be defined, together with an auditing plan for both technical and compliance audits" (DWAF, 2008).

The DWA developed a series of Best Practice Guidelines (BPG's) for water quality management in the South African mining industry. This series of BPG's forms a component of the overall source directed water policy for mining and related activities implemented by the DWA. The following Best Practice Guideline are of importance to surface water monitoring; Integrated Mine Water Management (BPG G1; DWAF, 2006a), Water and salt balances (BPG G2; DWAF, 2006b) and Water Monitoring Systems (BPG G3; DWAF, 2007) make specific references to water monitoring requirements and was thus used as a guiding tool in this study and the subsequent development of a surface water monitoring programme for Anglo Platinum.

The BPG G3 guideline emphasise that the development and maintenance of a well-designed and effective monitoring programme is essential within any mine water management strategy. It deals with the following aspects of a monitoring strategy:

- Definition of the objectives of a monitoring strategy,
- Design of a monitoring strategy,
- Monitoring and sampling equipment and procedures,
- Procedures for implementation of monitoring programmes,
- Data management systems, and
- Audit and quality assurance of monitoring programmes.

It is stated in BPG G3, that accurate and reliable data forms a key component of many environmental management actions. Some of these actions may receive more focus from government officials, whilst others may be more important for the mine personnel or mine management. Water monitoring is a legal requirement and can be used in negotiations with authorities for licence applications. The most common environmental management actions that require data and thus the objectives of a water monitoring programme include, though not limited to the following (DWAF, 2007):

- Development of environmental and integrated mine water management plans based on impact and incident monitoring.
- Generation of baseline / background data before new project implementation.
- Identification of sources of pollution and extent of pollution.
- Monitoring of water usage by different users and thus maximising on water reuse.
- Calibration and verification of various prediction and assessment models.
- Identification and evaluation of appropriate water treatment technology.
- Control of unit processes such as water treatment plants or process plants.
- Evaluation and auditing of the success of implemented management actions (ISO14000, compliance monitoring).
- Assessment of compliance with set standards and legislation (EMPR's, water use licences).

- Assessment of impact on receiving water environment.

Without reliable measurement of water resource quality and quantity, the above functions cannot be undertaken and hence the saying that "one cannot manage that which one cannot measure".

A typical monitoring process is summarised in Figure 3 and was added in order to describe the process where it states that it “must be recognised and understood that the successful development and implementation of an appropriate, accurate and reliable monitoring programme requires that a defined structured procedure be followed. Furthermore, it is important that this is done by a suitably qualified person. The requirements for the use of suitably qualified persons during various activities undertaken in the monitoring process as well as the definition of a suitably qualified person are also prescribed in the above-mentioned guideline. A suitably qualified person is defined as a person having a level of training, experience and the recognised skills in the type of work to be done.

The detailed features of monitoring programmes are required to be very site-specific. No single uniform procedure that can be followed when defining and implementing a monitoring programme was thus provided in BPG G3. The following procedural requirements that should however be considered are also indicated in BPG G3:

- Interested and affected parties should be consulted at the appropriate time during the development, implementation and operation of the monitoring programme. The monitoring programme should be able to address their concerns and provide answers to their questions.
- The objectives of the management actions that drive the monitoring programme must be clearly defined, together with the data and information requirements that support these objectives.
- A detailed design of the monitoring programme must be undertaken. This should define the location of all monitoring points (indicated on a map), the type of data to be collected, as well as the data collection (protocol/procedure/methodology, frequency of monitoring and parameters determined, quality control and assurance), management (database and assessment) and reporting procedures. The implemented programme should be able to deliver the data and information that are required to achieve the objectives of the programme.
- Linked to the company SHE policies.
- The results from the monitoring programme should be representative of the actual situation. This requires that the monitoring programme should cover the relevant area in sufficient detail with a sufficient amount of appropriate monitoring points. It also requires that the sampling and monitoring should be undertaken according to procedures that will ensure representative samples and data.
- To ensure that the monitoring programme functions properly, an operating and maintenance programme should be developed and implemented.
- A well-defined data management system is required to ensure that data is secure, used optimally and is accessible to all the relevant users.
- The monitoring programme must include quality control (QC) measures and audits to ensure that the collected data are meeting the defined objectives (DWAF, 2007).

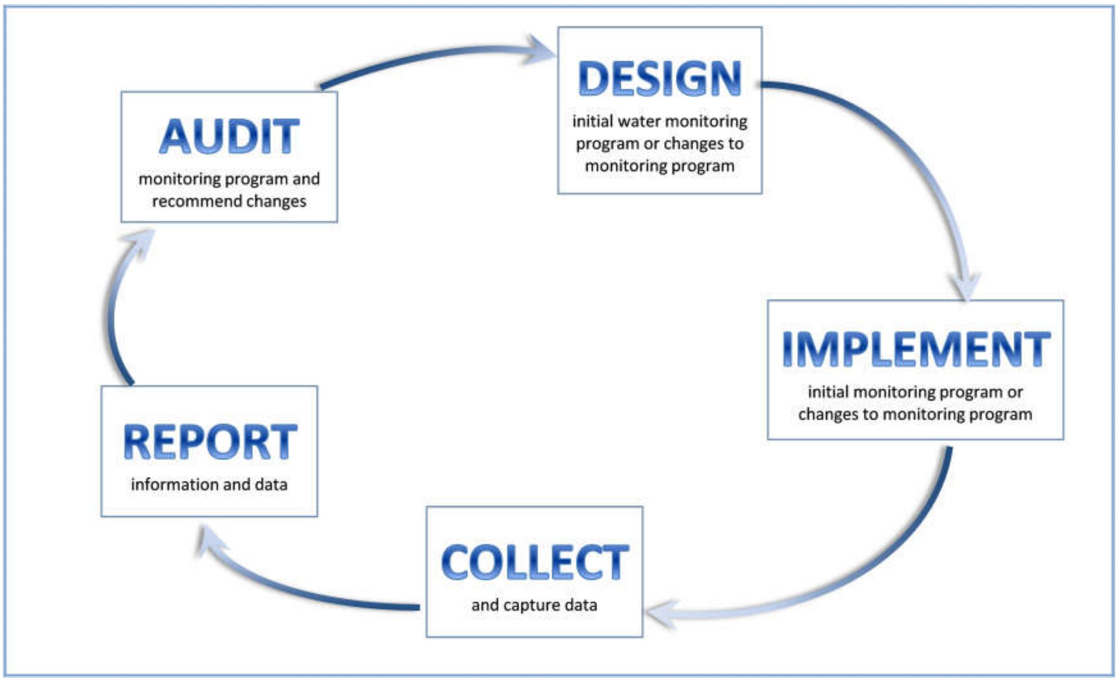



**Figure 3: Water monitoring process as adopted from BPG G3**

A water monitoring system on a mine should therefore consist of the following components:

- Surface and groundwater quality monitoring system.
- Surface and groundwater flow monitoring system.
- Bio-monitoring.
- Data and information management system.

Risk assessment needs to be built into any monitoring programme and it is important to determine the risk of water being polluted from different sources and its associated impact. The diversity of climates, ecosystems, land uses and topography are some Impacts that need to be considered in the design of a monitoring programme. Social factors have also become important elements in environmental management based on the Constitution of South Africa. The monitoring programme designed will thus be very site-specific and will need to consider regional physical and social factors.

The proposed procedure to develop a monitoring programme from the regulatory requirement point of view is described in detail in BPG G3 and summarised in Figure 4.

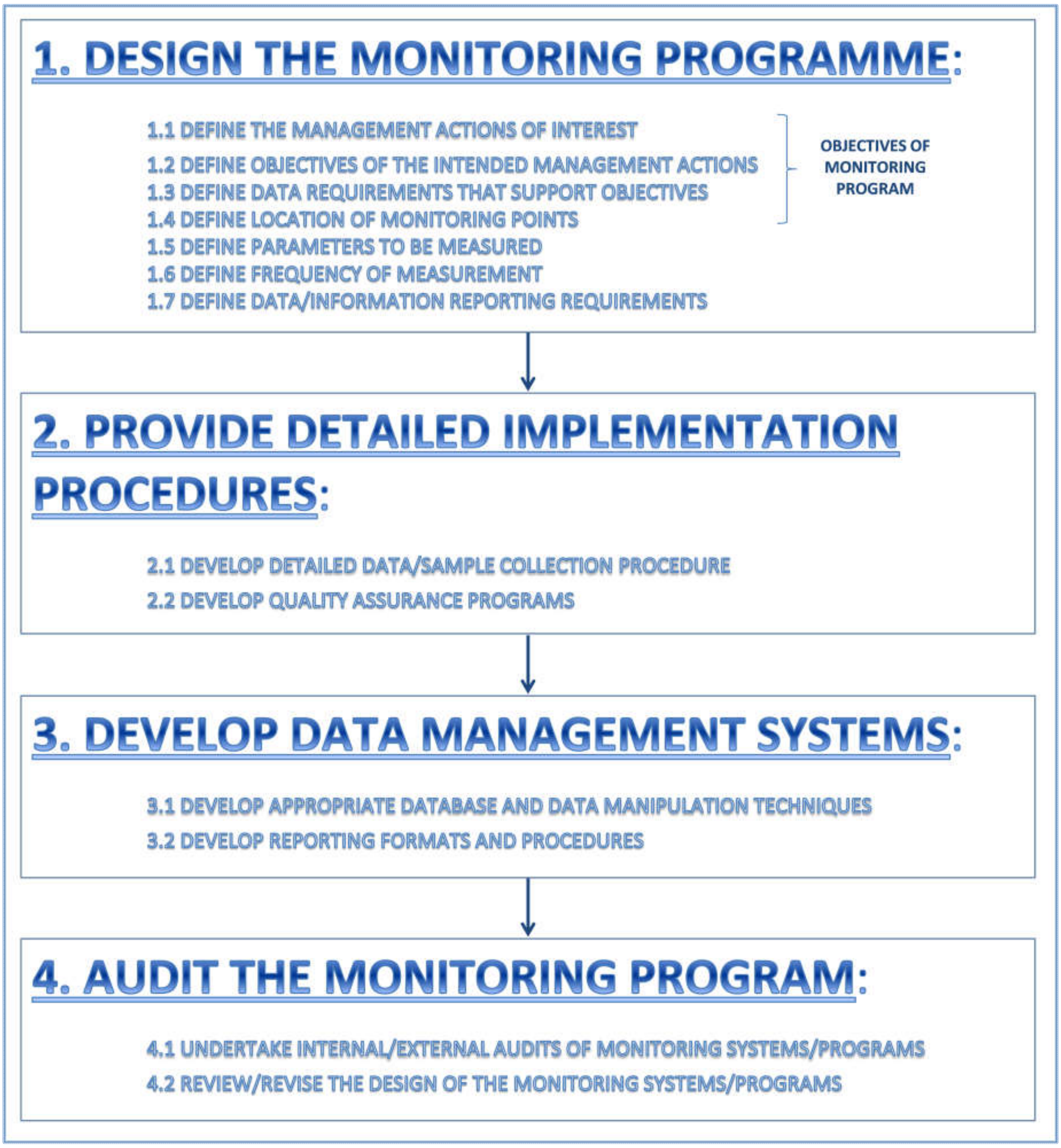



**Figure 4: Procedure to develop a monitoring programme as adopted from BPG G3**

The importance of data collection and implementation of a monitoring programme is also emphasised BPG G2. In the description and summary diagrams of the processes to develop water and salt balances, specific emphasis is given to “data collection and monitoring programme” as a specific and separate step in the development of such a water balance. This includes labelling of streams, collection and evaluation of existing data, identification of areas with insufficient data, development of a site-specific sufficient monitoring programme and the collection and assessment of new data.

It is stated in the above-mentioned guideline that to develop a water and salt balance, it is necessary to collect data of flow rates, dam volumes and water quality relevant to the identified water circuits. Existing data needs to be evaluated in order to determine where flow and quality data are not available, or where the data is out-dated, not reliable or insufficient. The areas in the water reticulation system where there are insufficient data must then be identified and a monitoring programme must be adapted or developed to collect sufficient data at these identified locations. The level of monitoring needs to take into consideration the significance of the point relative to the overall water and salt balance, and the accuracy required at the point. The monitoring programme should also take into consideration whether the water and salt balance are to assess missing flows or for compliance monitoring, which may have different requirements for location and accuracy. It must be noted at this stage that the current water monitoring program implemented at Anglo Platinum was not designed to cater sufficiently for the development of a water and salt balance.

# 4. SITE DESCRIPTION AND BACKGROUND INFORMATION

## 4.1. Background

Anglo American Platinum sold its Rustenburg mining operations to Sibanye Platinum, effective 1 November 2016. The mining operations were located north and east of the town Rustenburg in the Critical Zone of the western lobe of the Bushveld Complex. In the centre of these mining operations remained the Anglo American Platinum Process Division (henceforth referred to as the Rustenburg Process Division), including the Precious Metal Refiners, Rustenburg Base Metal Refiners, Waterval Smelter, Anglo Converting Process (ACP) and the Waterval East Tailings Storing Facility.

The Process Division is situated within the Hex River catchment just upstream from the Bospoort Dam (Quaternary catchment A22H). Various continuous, seasonal or event-linked discharges of affected process water takes place into seasonal tributaries of the Hex River, which drains the processing areas. The tributaries affected by the process division that drain into the Hex River are the Klipfonteinspruit and Klipgatspruit.

Activities in a catchment affect both the physical attributes and the chemical constituents of the water body and therefore also affect the biotic community. The Target Water Quality Guideline Ranges (TWQGR) as developed by the then Department of Water Affairs and Forestry and published in 1996, aim to ensure that water quality variables are maintained within the “no effect” range, i.e. such that the aquatic environment is not detrimentally affected by the additions of effluents.

## 4.2. Operational Overview

The Rustenburg Process Division is owned and operated by Anglo American Platinum Limited. Processing (smelting and refining) operations include mainly the Platinum and Platinum Group Metals (PGMs). Anglo American Platinum Limited is the world’s leading primary producer of Platinum and other PGMs including palladium, rhodium, ruthenium, iridium and osmium. Nickel, copper, other base metals and gold are also produced.

The process division is concerned with the beneficiation of ore into economical products and consists of the following operations:

*Waterval Smelter:*

The Smelter uses electric furnaces to smelt concentrate to produce a sulphur-rich matte with gangue impurities removed as slag. The slag is cleaned and converter slag is reduced in an electric furnace to recover PGMs and base metals for recycling back to the converter. Oxygen-enriched air is blown through a top-submerged lance converter to oxidise sulphur and iron contained in furnace matte to $SO_2$ gas and slag respectively.

*Anglo Converting Process (ACP) and Acid Plant:*

The ACP plant is designed to reduce sulphur dioxide emissions and increase converting capacity. The resulting converter matte is slow-cooled to concentrate PGMs into a metallic fraction. At the acid plant $SO_2$ gas is converted to $SO_3$ by passing it over catalytic beds and the subsequent addition of water produces 98% sulphuric acid which is sold to fertiliser manufacturers.

*Rustenburg Base Metal Refiners (RBMR):*

At the Magnetic Concentration Plant (MCP) crushed converter matte is milled and the PGM fraction is separated magnetically. This is pressure leached to yield a solid final concentrate that is sent to PMR. Base metal-rich non-magnetic solids and leach solution are processed further in the base metal refinery. The base metal-rich solids are leached in high pressure autoclaves and contacted with MCP leach solution to yield separate nickel and copper streams. The separate nickel and copper streams are purified. During this process cobalt sulphate is recovered. Nickel and copper metal cathodes are produced by passing an electrical current through the separate purified streams in a process called electro-winning. Excess sulphur in solution is neutralised with sodium hydroxide and crystallised to form a sodium sulphate product. The final economical products of the RBMR are cobalt sulphate, nickel, copper and sodium sulphate.

*Precious Metal Refiners (PMR):*

From the MCP Plant at the RBMR, final concentrate is dissolved using hydrochloric acid and chlorine gas. PGMs are sequentially separated and purified to yield platinum, palladium, iridium, ruthenium and gold. Osmium is precipitated as a salt.

## 5. WATER MONITORING PROGRAM

The Rustenburg Process DivisionRustenburg Process Division water monitoring program in its current format, barring the addition or decommissioning of certain localities over time as operations change, has been running consistently since 1995. The monitoring programme was developed to include the following objectives:

- To document the determination and assessment of the impacts of the Rustenburg platinum operations on the receiving river systems. This includes monitoring of process water, discharges and effluents and receiving water up- and downstream from potential impacts to ultimately quantify and highlight impacts caused by the Rustenburg Process Division business units as well as other non-mining related impacts.
- To determine the usefulness of water for potential downstream users.
- The implementation of a well-designed and maintained monitoring programme and database which is considered essential within any mine water management strategy.
- Measuring of compliance towards the Water User License (WUL, 2018) under Chapter 4 of the National Water Act, 1998 (Act 36 of 1998).
- Aligning with the programs and guidelines of the Department of Water Affairs.

It is indicated as part of this annual monitoring report that:

- A detailed design of the monitoring programme was undertaken and that monitoring was undertaken in accordance with the monitoring programme.
- The monitoring programme is site specific as reflected in this annual monitoring report.
- The implemented programme delivered the data and information required to achieve the objectives of the programme.
- The results of the monitoring programme represent the actual situation on site.
- The data management system was used to ensure that data is optimally utilised.
- The monitoring programme is a dynamic system that changes as the mine and the mine water management system change. Recommendations are made as part of this annual report pertaining to such changes.

The current Rustenburg Process Division monitoring program's locality names, coordinates, relevant catchment descriptions and sampling frequencies are illustrated in Table 2 and Table 3. A total of 47 surface water monitoring localities and 33 groundwater monitoring localities are currently active in the Rustenburg Process Division water monitoring programme.

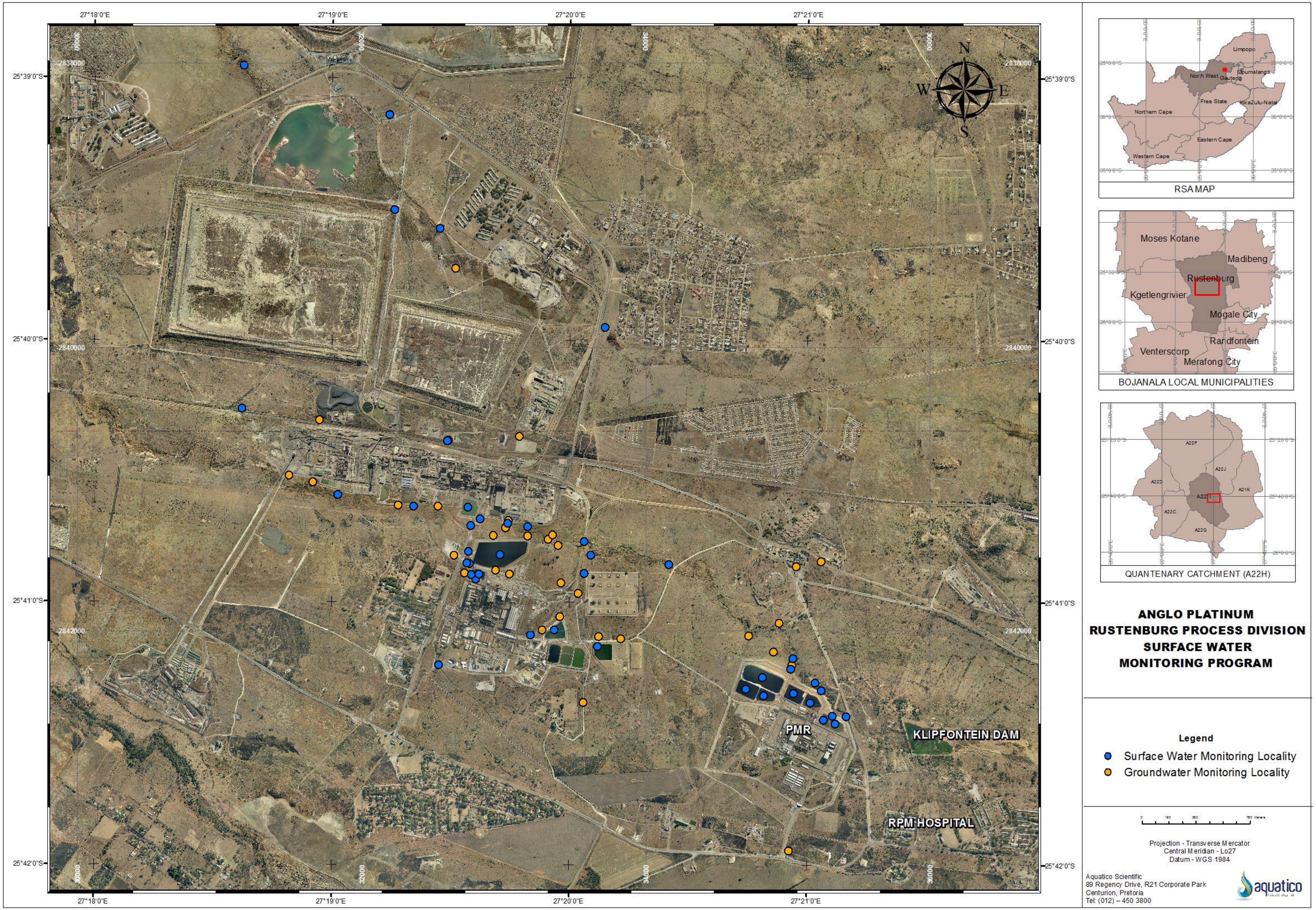



**Figure 5: Anglo Platinum monitoring area**

**Table 2: Rustenburg Process Division surface water monitoring locality names and descriptions**

| Site Name | Site description | Y-coordinates | X-coordinates | Monitoring Frequency |
|---|---|---|---|---|
| K008 | Klipfonteinspruit at PMR Bridge | -25.69061 | 27.35275 | M |
| K009 | PMR East rain water dam overflow | -25.68893 | 27.35098 | M |
| K010 | Klipfonteinspruit, downstream of K009 | -25.68844 | 27.35057 | M |
| K011 | Discharge at PMR culvert at PMR bridge | -25.69056 | 27.35177 | M |
| K012 | Klipfonteinspruit between PMR and RBMR on old road to magazine | -25.68096 | 27.34029 | M |
| K013 | Culvert ditch going to Klipfonteinspruit halfway between PMR bridge and Waterval bridge parallel to old railway | -25.68152 | 27.33435 | M |
| K014 | Intersection of Klipfonteinspruit and rail line bridge (south side) | -25.6795 | 27.33434 | M |
| K015 | 150 metres up from intersection of Klipfonteinspruit and rail line | -25.68036 | 27.33484 | M |
| K023 | Klipfonteinspruit at base of RBMR dump | -25.67855 | 27.33039 | M |
| K024 | Outflow of RBMR Dam 3 stormwater dam | -25.68091 | 27.32634 | M |
| K025 | Intersection between electric pylons & compressor air pipe between RBMR and lab. Storm water canal from ACP. | -25.67806 | 27.32706 | M |
| K028 | Klipfonteinspruit after confluence of RBMR west ditch system at Waterval smelter bridge | -25.67849 | 27.32638 | M |
| K032 | Klipfonteinspruit downstream of Waterval Smelter | -25.67655 | 27.31709 | M |
| K035 | Klipgat Return Water Dam of Waterval Tailings | -25.65237 | 27.32067 | M |
| K036 | Inflow into Klipgat return water dam from Waterval tailings dam 7-stream and Khomanani I Shaft sump canal | -25.65843 | 27.32103 | M |
| K044 | Trench to the west of the RBMR dam 3B | -25.68087 | 27.32612 | M |
| K059 | Culvert at railway entry to RBMR | -25.68543 | 27.3306 | Q |
| K062 | Spillway overflow RBMR stormwater dam 3B | -25.68015 | 27.32625 | M |
| K063 | Klipfonteinspruit at stormwater discharge from Waterval smelter and concentrator | -25.67728 | 27.3224 | M |
| K080 | Effluent and stormwater discharge west of PMR | -25.68759 | 27.34887 | M |
| K098 | ACP Pollution Control Dam | -25.677331 | 27.326189 | M |
| K099 | Klipfonteinspruit downstream of PMR | -25.68691 | 27.34901 | M |
| K136 | Klipgatspruit, downstream of Entabeni Hostel at Khomanani I Shaft (Frank I Shaft) | -25.65959 | 27.3242 | M |
| K158 | RBMR Dam1 | -25.68188 | 27.32676 | Q |
| K159 | RBMR Dam2 | -25.68163 | 27.32644 | Q |
| K160 | RBMR Dam3A | -25.68157 | 27.32700 | Q |
| K161 | RBMR Dam3B | -25.68034 | 27.32847 | Q |
| K162 | RBMR Triangular Dam | -25.68511 | 27.33229 | Q |
| K163 | RBMR SSSS Dam | -25.68618 | 27.33532 | Q |
| K167 | Cut-off trench north of Waterval concentrator just before discharge towards Klipfonteinspruit | -25.67106 | 27.31033 | Q |
| K168 | Cut off trench north of Waterval Smelter reverts area | -25.67312 | 27.32476 | M |
| K169 | Trench from PF Retief laboratory towards Klipfonteinspruit | -25.67835 | 27.32898 | M |
| K187 | Trench upstream of RBMR at culvert on access road to South gate | -25.68735 | 27.32416 | M |
| K188 | Klipgatspruit, downstream of Mfidikoe village, upstream of Khomanani I Shaft (Frank I Shaft), Frank Concentrator and Waterval Complex | -25.66587 | 27.33577 | M |
| K190 | Klipgatspruit, downstream of Klipgat Return Water Dam and Waterval Tailings | -25.64926 | 27.31044 | M |
| K208 | PMR Dam 1 | -25.68972 | 27.350228 | Q |
| K209 | PMR Dam 2 | -25.689142 | 27.349065 | Q |
| K210 | PMR Dam 3a | -25.690796 | 27.351136 | Q |
| K211 | PMR Dam 3b | -25.691052 | 27.35198 | Q |
| K212 | PMR Dam 4/5 | -25.6881 | 27.346858 | Q |
| K213 | PMR Dam 6E | -25.689256 | 27.346964 | Q |
| K214 | PMR Dam 6W | -25.688854 | 27.345702 | Q |
| K220 | RBMR Effluent dam 1 | -25.685799 | 27.331835 | Q |
| K221 | RBMR Effluent dam 2 | -25.685799 | 27.331835 | Q |
| K222 | RBMR Effluent dam 3 | -25.685799 | 27.331835 | Q |
| K223 | RBMR E&S feed dam 1 | -25.687804 | 27.330812 | Q |
| K224 | RBMR E&S feed dam 2 | -25.687661 | 27.330610 | Q |

***M – Monthly frequency**
**Q – Quarterly frequency**

**Table 3: Rustenburg Process Division groundwater monitoring locality names and descriptions**

| Site Name | Site description | Y-coordinates | X-coordinates | Monitoring Frequency |
|---|---|---|---|---|
| BMRWWTW | Downgradient of Waterval treatment works | -25.680378 | 27.325227 | Q |
| EM01 | UG2 complex downgradient south borehole | -25.675743 | 27.315343 | Q |
| EM11 | Central Deep borehole downgradient south-east of rock dump | -25.684665 | 27.348047 | Q |
| EM16 | Klipgatspruit borehole downgradient of Khomanani I Mine | -25.662122 | 27.325315 | Q |
| NB01 | UG2 complex upgradient north borehole | -25.671792 | 27.315785 | Q |
| NB02 | UG2 complex downgradient south-west borehole | -25.675300 | 27.313652 | Q |
| NB03 | Downstream South of ACP | -25.678150 | 27.329030 | Q |
| NB04 | PMR upgradient borehole | -25.699105 | 27.348748 | Q |
| NB48 | Waterval Tailings upgradient of Frank concentrator | -25.672808 | 27.329792 | Q |
| NB52 | BMR upgradient of SSS effluent dams | -25.689740 | 27.334303 | Q |
| NB56 | Central Deep borehole downgradient south of salvage yard | -25.680740 | 27.350972 | Q |
| NB57 | Central Deep borehole downgradient south of shaft | -25.681065 | 27.349220 | Q |
| NBH07 | Downgradient from PMR | -25.687347 | 27.348928 | Q |
| S011 | BMR downgradient west towards Klipfonteinspruit | -25.681508 | 27.325960 | Q |
| S051 | ACP downgradient south towards Klipfonteinspruit | -25.678628 | 27.328833 | Q |
| S102 | BMR downgradient north of north dump towards Klipfonteinspruit | -25.679347 | 27.331812 | Q |
| S104 | ACP downgradient south-east borehole | -25.679068 | 27.332142 | Q |
| S120 | BMR downgradient north of SSS effluent dams | -25.684282 | 27.332675 | Q |
| S140 | Downgradient south of Waterval Tailings - control towards WV Smelter | -25.673088 | 27.324837 | Q |
| S160 | BMR downgradient north-east of north dump towards Klipfonteinspruit | -25.679735 | 27.332518 | Q |
| S230 | BMR downgradient of SSS effluent dams | -25.685518 | 27.335377 | Q |
| S373 | PMR downgradient northwest borehole | -25.685472 | 27.345885 | Q |
| S374 | PMR downgradient north borehole | -25.686502 | 27.347647 | Q |
| S386 | BMR upgradient east of BMR rainwater dam | -25.681567 | 27.329112 | Q |
| S388 | Borehole west of BMR magazines | -25.682787 | 27.333922 | Q |
| S389 | BMR upgradient south of north dump | -25.682130 | 27.332737 | Q |
| S400 | Waterval Smelter downgradient borehole towards Klipfonteinspruit | -25.677258 | 27.324082 | Q |
| S403 | BMR downgradient east of SSS effluent dams | -25.685688 | 27.336937 | Q |
| S405 | BMR upgradient south of BMR rainwater dam | -25.681318 | 27.328167 | Q |
| S407 | Retrofit downgradient borehole towards Klipfonteinspruit | -25.677188 | 27.321320 | Q |
| S409 | BMR downgradient north towards Klipfonteinspruit | -25.679103 | 27.328003 | Q |
| S410 | BMR downgradient north-east towards Klipfonteinspruit | -25.679132 | 27.330390 | Q |
| S418 | BMR downgradient northwest of SSS effluent dams | -25.685108 | 27.331415 | Q |

***M – Monthly frequency**
**Q – Quarterly frequency**

# 6. SAMPLING AND MONITORING PROCEDURES

## 6.1. Fieldwork

The Aquatico Fieldwork Division uses acknowledged methods for sampling as per Rustenburg Process DivisionRustenburgProcess Division WUL conditions.

Sampling is conducted by qualified Aquatico Field Technicians in order to obtain a representative sample as well as the highest possible scientific integrity. Incorrect sampling procedures and methods will affect the accuracy. reliability and credibility of analytical results and can lead to misleading information and conclusions. A representative water sample can be described as:

"A sample taken in the correct manner at a point that truly represents the water body at the time, at the specific locality of concern"

All fieldwork conducted are based on the protocols and specifications, and code of practice contained in the SABS ISO 5667:1-15. These international standards address all aspects from the monitoring programme design, sampling methods as well as sample preservation and many other aspects. Applicable standards include:

- ISO 5667-1: 2006 Part 1: Guidance on the design of sampling programmes and sampling techniques
- ISO 5667-3: 2003 Part 3: Guidance on preservation and handling of samples
- ISO 5667-5: 2006 Part 5: Guidance on sampling of drinking water from treatment works and piped distribution systems
- ISO 5667-6: 2005 Part 6: Guidance on sampling of rivers and streams
- ISO 5667-11: 1993 Part 11: Guidance on sampling of groundwater
- DWAF Best Practice Guidelines Series G3: General Guidelines for Water Monitoring Systems

In certain cases, adhering to the norms as set out in the above SABS ISO standards is not possible due to certain practicalities. Two such cases, applicable to Anglo Platinum, are given below:

- Due to field conditions, no pH, EC, or temperature readings are taken *in situ*. As sampling takes place over different time periods in the field, temperature will vary from samples taken in the early morning to samples taken at midday, and late afternoon. These temperature variations will induce pH and EC fluctuations, and will ultimately make the data incomparable. Thus, pH and EC readings are taken under controlled laboratory conditions to ensure that data sets are more comparable and reliable. The Anglo Platinum water samples are delivered to the laboratory within a sufficient time period (less than 48 hours) to ensure freshness of the water samples for analysis.
- Boreholes at the Anglo Platinum are not purged before sampling. Purging is the practice of pumping a borehole up to a point of stable EC or when three volumes of water are removed from the borehole before collecting a sample for analysis. The ISO SABS 5667-11 guideline recommends that purging only be applied to boreholes being pumped, such as abstraction boreholes or water supply boreholes. The majority of the monitoring boreholes at Anglo Platinum are for observation/monitoring purposes. The ISO SABS 5667-11 stipulates "Depth sampling consists of lowering a sampling devise (bailer) into the borehole, allowing it to fill with water at a known depth, and retrieving the sample for transfer to an appropriate sampling container. This method of sampling is normally suitable for use in observation boreholes that are not being pumped". For observation boreholes that are equipped with pumps, which limit accessibility of the

sampling device, a sample is collected from a tap installed on the line (where available). A second reason for deviating from the practice of purging boreholes before sampling is the high cost involved at the level of monitoring employed at Anglo Platinum (i.e. purging 100+ boreholes on a quarterly frequency will have a dramatic effect on monitoring cost.

Aquatico developed a custom-made data input system in accordance with SABS ISO guidelines 5667-1 to 5667-3, to assist the field technician in recording the physical and environmental information of the sampling locality. This information is needed to interpret water quality especially if the water quality results obtained by the laboratory indicate sudden changes at a specific locality.

The field data typically include the following information:

- Location, name and details of the sample site
- Method of collection
- Name of collector
- Nature of pre-treatment, if any
- Preservative or stabilizer added, if any
- Flow status or dam level
- GPS Co-ordinates
- Photographic evidence
- Water level of boreholes
- Other data gathered at this point

All of the above information is recorded on a handheld PDA device deployed to the field complete with GPS, bar-code scanner, camera and database-linked MONLIMS software. The water quality database is electronically updated with this information when the field technician returns from the field trip.

*Sample collection and transport to the laboratory*

- Prior to going to the field, all project info required for the successful monitoring is downloaded onto an electronic handheld field unit (Figure 6A). The field technician thus works solely on the orders given by the field unit. As soon as he arrives at a certain sample point, he is prompted to complete a set of pre-set observations – these can be customised by the programme manager, for example, flow of stream, water-level of borehole, meter reading on flow meter, odour/colour of water etc. The software will not allow the technician to continue to a next step without successfully entering the required information.

- Prior to taking any sample, the software will also require that a photo of the sampling point be taken. The photo is automatically named and filed, together with a time and date of sample and GPS coordinate as reference to the sample taken. This acts as conclusive proof that the technician actually visited the correct sampling point, providing an audit trail for field work.

- The GPS coordinates are also verified against a pre-programmed XY coordinate for that specific sampling point. As soon as the technician is not within a 30m radius (customisable parameter) of the programmed position for the specific monitoring locality, the software immediately prompts a warning on the screen that it is not the correct location. This warning can be ignored by the technician but a new GPS coordinate will be taken in the background and stored with the site info to keep log of any deviation from the sampling set-up. A full audit report can be generated showing actual sampling localities, date and time of sampling and deviations from programme.

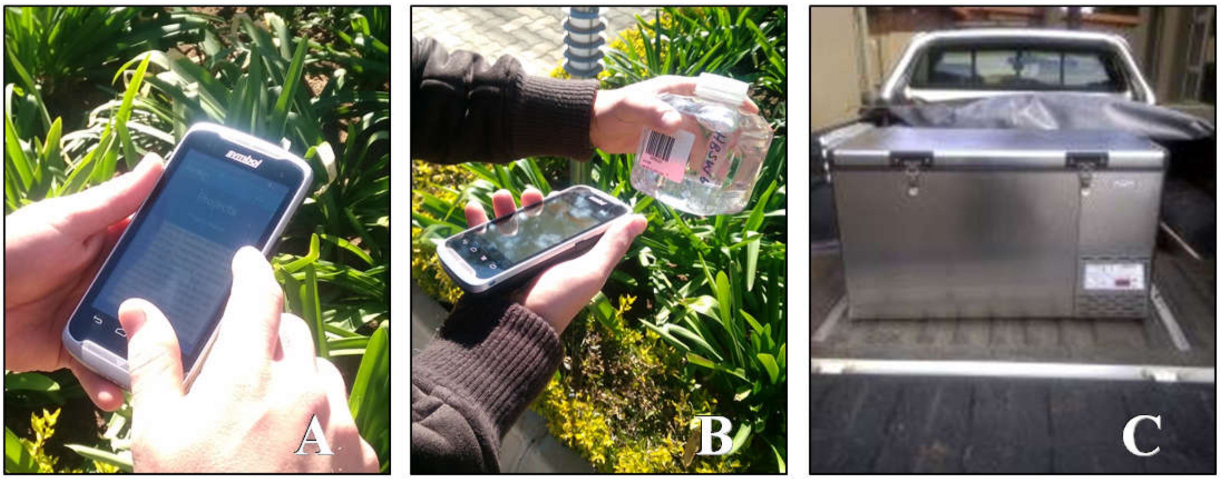



**Figure 6: A –The field PDA units that are being used during sampling. B – Field technician scanning a bar-coded sampling container after the sample has been taken. C – National Luna cooling units fitted on all field vehicles to ensure proper sample transport to the laboratory (at 4C)**

- At this point the technician will be prompted to take a specific sample type.

- All containers are pre-bar coded and the technician must scan the sampling container prior to taking the sample (Figure 6B); the reason for this step is twofold. Firstly, to ensure that it is the right sampling point and secondly to ensure that the correct sampling container type is used (i.e. organic samples in amber glass containers, microbiological samples in sterile containers etc.).

- Only at the point where all the requested tasks are completed will the software acknowledge that the function is completed and prompt the technician to proceed to the following locality.

- Once the field technician arrives back at the laboratory, all the samples are delivered to sample reception and the handheld unit is connected to the mainframe system via a docking station. All sampling info is downloaded into a SQL database.

- With the project set-up being completed and programmed at the start of the project (before fieldwork), all analytical requests are already in the database. As soon as the sample barcode is scanned at sample reception, the laboratory immediately knows what analyses need to be conducted on which samples.

- The fieldwork efficiency is also checked at this point to ensure that all samples taken in the field are actually being delivered to the laboratory; i.e. sample names and counts from field unit matches the laboratories submission worksheet or the system alarms should there be discrepancies in this regard. As example, a sample container may have been leaking in transit and although the sample container arrived at the laboratory, there is not sufficient volume of sample to be analysed, this will then be rectified immediately and the technician tasked for re-sampling.

*Samples and sampling containers applicable to Anglo Platinum*

Water samples for hydro-chemical or inorganic analysis are collected in new clean polyethylene bottles and stored in dust free thermo-isolated container. Samples for bacteriological analyses are sampled in sterile containers and kept cool (at around 4°C) in on-board fridge units (Figure 6C). Samples for hydrocarbon or organic analysis are sampled in clean, amber glass containers. Samples are not being preserved after sampling. As new and clean sampling bottles are used, cross-contamination is minimal. Water samples, which are not properly filtered, should never be preserved (acidified). This would lead to the re-suspension and remobilization of substances and could lead to “false–positive” results.

*Water-level measurements of boreholes at Anglo Platinum*

Accurate water-level measurements are critical in geo-hydrological studies and standard procedure when sampling a borehole/well. Depth to water measurements is conducted using the manual OTT KL010 Contact Gauge depth meter.

## 6.2. Laboratory Analysis

Approved laboratory analysing techniques are followed. Aquatico performs the hydro-chemical analyses as well as the bacteriological analyses.

Aquatico Laboratories is a state-of-the-art water testing laboratory in Irene, Centurion. This analytical laboratory is operational since July 2006. Aquatico Laboratories take part in the SANAS accredited SABS Proficiency Testing Scheme (PTS0003) for hydro-chemical analyses as well as the National Laboratory Association - South Africa Water Microbiology Proficiency Test Scheme. The Laboratory also took part in the non-accredited Anglo American Laboratory Proficiency Testing Programme (administrated by Thistle) and achieved an overall third place out of nine competing laboratories, based on z-score statistical results across the analytical suites. Further, Aquatico is an SANAS Accredited Testing Laboratory, No T0685. The SANAS accreditation certificate and schedule is provided in the Appendices.

Wherever current, analyses are carried out in accordance with methods prescribed by and obtainable from the South African Bureau of Standards, in terms of the Standards Act, Act 30 of 1982 as prescribed in the WUL. The routine laboratory analyses conducted on the Anglo Platinum samples is presented in Table 4 below.

**Table 4: Analytical packages associated with the Anglo Platinum water monitoring localities**

| Anglo suite | Suite description | Analysis description |
|---|---|---|
| Anglo Salts and Nutrients (Suite A) | Chemical salts and nutrients | pH, EC, Alk, TDS, Hardness, Ca, Na, Mg, K, Cl, $SO_4$, F, $NO_3$, $NH_4$, $PO_4$ , $PO_4$ as $PO_4$, TIN, DO, $Cr^{6+}$ |
| Anglo Comprehensive metals (Suite B) | Selected comprehensive metals | Al, Fe, Mn, Cr, Cu, Ni |
| Anglo env. bacteriological suite (Suite C) | Bacteriological variables | *E. coli*, Total coliforms |
| Anglo metal scan (suite D) | Selected broad metal scan | Ag, B, Ba, Be, Bi, Cd, Co, Ga, Li, Mo, Pb, Rb, Sr, Te, Tl, V, Zn |
| Anglo SOG (Suite E) | Total oil and grease (SOG) | SOG |
| Anglo Resource (Additional WUL Suite) | Anglo additional WUL requirements | DO, Pb, Zn, B, Phenol, Cr6+, As, Cd, Hg, Se, PO4 Calculated, TIN |
| Toxicity analysis | Toxicity analysis | Trophic level toxicity test |

Different analytical suites are applied to different water monitoring locality types at different frequencies. Table 5 below presents an overview of the suites applied to the locality types.

**Table 5: Analytical suites applied to the different types of surface water monitoring localities**

| Description | Anglo Salts and Nutrients (Suite A) | Anglo Comprehensive metals (Suite B) | Anglo env. bacteriological suite (Suite C) | Anglo metal scan (suite D) | Anglo SOG (Suite E) | Anglo Resource (WUL Suite) | Toxicity analysis |
|---|---|---|---|---|---|---|---|
| Applicable Bio-icon |  |  |  |  |  |  |  |
| Rivers/streams | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Stormwater dams | ✓ | ✓ | | ✓ | | ✓ | |
| Pollution Control Dams | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| Effluents, discharges | ✓ | ✓ | | ✓ | ✓ | ✓ | |
| Groundwater boreholes | ✓ | ✓ | | ✓ | | ✓ | |

*Laboratory set-up and workflow*

The sample enters the laboratory in a stream-lined workflow with various elements enhancing the analyses process as well as turn-around time. After being logged on the Laboratory information management system, the samples are firstly being filtered through a 0.45µm membrane filter as prescribed by ISO17025. The filtrate is transferred to new clean bar-coded sampling tubes and now ready for chemical analysis. pH and EC is determined on unfiltered samples and fed into the management software to act as an initial QC process in providing information to the other instrumentation in the Laboratory in terms of the expected quality of water (clean/dirty), the necessity for dilutions, etc. A further QC measure is minimising sample transfer between tubes to a single bar-coded sample tube that is introduced to the various instruments for analyses. The bar-coding system drastically minimises the possibility of sample-swop and result mis-feed into the information management system.

All results from the automated analytical instruments are automatically populated into the database minimising human error with data capturing. In terms of QC procedures, being an ISO17025 laboratory, quality is one of the main drivers in the laboratory. With each sample batch various Certified Reference Materials (CRMs) and quality standards and/or duplicate samples are analysed. Should one of the QC values fail the pre-set criteria, the entire batch of samples are automatically rejected and re-run. All QC samples are tabled and graphically plotted on a daily basis to ensure continuous monitoring and improvement.

When all requested variables are analysed, the data is ready for verification. During this step a technical signatory (Analyst) will evaluate the results provided by the software interface. All analytical checks and balances are calculated by the system and must comply with strict pre-set criteria and conditions. Samples/Variables that fail this step are prompted for re-analyses. As a further QC point, whenever possible, a historical water quality profile for that specific sampling locality is presented onscreen to enable the Analyst to evaluate temporal variance. Should the new results not comply with the history profile of the sample the technical signatory is notified and prompted to investigate further to assess the possibility of environmental factor or spill event.

As soon as all the results for the batch are available and verified by the technical signatories, the results are released and made available on the SQL software database for reporting purposes by the Scientific Reporting Division.

*Audit trail*

All actions or samples can be tracked on the software platform indicating the precise stage of completion for each task or sample. Various reports are generated providing valuable management information, for example.

- Number samples collected for project or field trip.
- All samples not collected in project or field trip.
- Reasons why samples not collected.
- Deviation distance from sampling point (by GPS).
- Days in holding.
- Turnaround days in Laboratory.
- Distance travelled.
- Number of samples per variable.

The software application was designed in such a way that all the info is stored within the SQL database. Any report or query could thus be executed to provide the desired management report. The software is also compatible with Microsoft Excel and can therefore interact with any other database system (such as Pivot).

## 6.3. Water Quality Reporting

Water Quality Reporting is conducted by the Aquatico Scientific Reporting Division consisting of qualified scientists and water quality specialists. All final evaluations are conducted by experienced and SACNASP registered (*Pri.Sci.Nat*) scientists.

The fieldwork information and water quality data, following laboratory analysis and verification, are entered into the Aquatico water quality management programme from where various custom-made reports are produced.

*Monthly Reporting:*

On a monthly basis, the Anglo Platinum Environmental Department is provided with the monitoring field data and water quality results in a PDF report as well as a Microsoft Excel format (WDAT) that is fully compatible with the Anglo American Platinum Integrated Data Display System (IDDS).

*Quarterly Reporting:*

On a quarterly basis, a concise quarterly report is produced that includes time-series graphs and maps of the most relevant information. The report also highlights water quality results that may require urgent management actions from the mine. This report is considered to be a short information report and will include a brief evaluation of the monthly surface water results over the quarterly period. This report can also be submitted to the Department of Water Affairs in-line with the WUL requirements for quarterly reporting of water results to the Chief Director.

*Annual Reporting:*

The Annual Integrated Surface and Groundwater Quality, Biomonitoring and Toxicity report (this report) is extensive and includes a full evaluation of all the results obtained during the annual monitoring period. The report includes a statistical summary (temporal & spatial) of all the chemical variables for all the monitoring localities, time-series graphs (for the entire database period), linear trend determinations, performance analyses and compliance assessments, water quality thematic maps indicating pollution sources and impacts on the receiving water body as well as a discussion and recommendation section. This report is composed of three volumes as discussed in further details in the next section.

Additional information can be found in the Comprehensive Annual Water Management Report “Anglo Platinum Rustenburg Process Division: Annual DWA Compliance Report” submitted to DWA and compiled by Aquatico Scientific. Additional information referenced in this report includes:

- Operations and permit information;
- Production figures and water usage;
- Rainfall and evaporation data; and
- Flow data.

## 6.4. Data Presentation

### 6.4.1. Volume 1

Anglo American Platinum Water Quality Assessment Report

The main report of the Anglo Platinum water quality assessment (Volume 1, “Annual Integrated Surface and Groundwater Quality, Biomonitoring and Toxicity Testing Assessment Report”, No. ***APPD/AR1.1/2018/WR***) is a detailed and descriptive report with an introduction outlining the purpose of water quality monitoring, a locality map with names and descriptions (surface water), a background and objectives section including interpretation of the results obtained for the specific annual period, which will include:

- Surface Water Quality Discussion;
- Anglo Platinum impact quantifications on the main catchment area of the Hex River;
  - Impact quantification (mg/l) = Average downstream value from an Anglo Platinum business unit (mg/l) – Average upstream value from an Anglo Platinum business unit (mg/l)
- Surface water quality risk assessment;

- Appendix A – Detailed Biomonitoring Report;
- Appendix B – Detailed Toxicity Report;

Appendix C – Detailed Groundwater Report6.4.2. Volume 2

Volume 2 contains data collected for review purposes (Report Number: *APPD/AR1.2/2018/WR).*

This will include:

*Locality Assessment Reports*

The Locality Assessment Report aims to give the reader a short water quality evaluation and interpretation of a specific Anglo Platinum monitoring locality during a specific period and also provide relevant information regarding a given monitoring locality. A locality assessment report consists of the following:

- Locality
  - Reference ID, type, locality photograph and coordinates
- Locality description
  - Type of monitoring locality and description
  - Applicable Target Water Quality Guideline Ranges (TWQGR) and or Permit Conditions (DWAF)
- Locality status
- Scheduled sampled month, sampling status (yes/no), observations
  - Average Water Quality Description
    - Average quarterly/yearly water quality description
    - Exceedance of applicable TWQGR/Permit Conditions (DWAF)
    - Additional notes
- Additional Analyses
  - Additional scheduled analyses which may include – bacteriological, soap, oil and grease, chemical oxygen demand (COD), chromium (VI) ($Cr^{6+}$), and/or full metal analysis.

*Site Reports*

A comprehensive format (Site Report) has been designed for data evaluation at Anglo Platinum surface water monitoring localities. The Site Report aids in the interpretation process of data, as well as giving more relevant information regarding a given monitoring locality during a specific period and are arranged according to catchment. A site report consists of the following:

- General description
  - (Site name, description, and type)
- Data table
  - Variables
  - Guideline/Permit Condition value
  - Results
  - Statistical presentation: (average, previous average and graph average)
- Time–series graphs & long-term trends
- Selected variables plot on the graph to give an indication of the range and linear movement for the variable over the database period. Also indicated are long-term trends for a specific variable at a monitoring locality.
- STIFF diagram

- The STIFF diagram exhibits a quick visual indication of the major anions / cations recorded (based on the meq/l and does not indicate mg/l concentration of a variable). This diagram plots the equivalent concentrations of the major anions and cations on a horizontal scale on opposite sides of a vertical axis. The plot point on each parameter is linked to the adjacent one until a polygon is created around the y-axis. The result is a small figure of which the geometry typifies the water composition at that point. Water with similar major ion ratios will show the same geometry.

*Locality Tables*

Time-series data and statistical analysis for the monitoring period are presented in tabular format according to catchment. Statistical evaluation of monitoring results and recommendations regarding the suitability for the identified uses are based only on variables being analysed. The summary tables include the following statistics for each monitoring locality:

- number of records in database period (September 2017 to August 2018);
- average value and standard deviation for database period;
- minimum, maximum and median values;
- $5^{th}$, $50^{th}$ and $95^{th}$ percentile for the entire database period;

A percentile is the value of a variable below which a certain percentage of observations fall, so for example, the $50^{th}$ percentile is the value below which 50 percent of the observations may be found.

6.4.3. Volume 3

Anglo Platinum Water Quality Executive Summary

The Executive Summary (Refer to Volume 3, “Annual Integrated Surface and Groundwater Quality, Biomonitoring and Toxicity Executive Summary”, No. ***APPD/AR1.3/2018/WR***) aims to give the reader a short and basic summarization of the current status of water quality at the respective business units, to highlight environmental and human risks associated thereof and to raise awareness specifically developed for department heads (HOD’s).

## 6.5. Data evaluation

### 6.5.1. Water quality evaluation against applicable guidelines

The South African Water Quality Guidelines are used by the Department of Water Affairs as its primary source of information and decision-support to judge the fitness of water for use and for other water quality management purposes. Five broad categories of water use are recognised in the South African Water Act, namely the use of water for **domestic purposes, industrial purposes, agricultural purposes, aquatic ecosystems** and **recreational purposes**. Added to that is the DWA’s mandate to protect the health and integrity of the aquatic ecosystem, which is therefore also seen as a major water user. Given its regional setting and for the purposes of the Rustenburg Process Division water monitoring programme, focus is placed on three of the above water users, namely Aquatic Ecosystems, Domestic Use and Agricultural Use, specifically, water used as livestock watering. The target water quality guideline range (TWQGR) is defined as those values or concentrations where no impact is expected on the specific user group, i.e. it is the ‘No Effect Range’. These values and concentrations are used within the water quality database evaluation and are presented in Table 5

Another guideline that will be used in these discussions is the General Limit (Table 7). The General Limit Guideline refers to the wastewater limit values as contained in Schedule 3 of the General Authorisations (General Authorisations in terms of Section 39 of the National Water Act, as documented in the Government Gazette No 26187, Notice No 399, dated 26 March 2004) and applies to the discharge of waste or water containing waste into a water resource through a pipe, canal, sewer or other conduit and the disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process. It should however be noted that the General Authorisation is not applied to any category A mine (defined as any gold or coal mine, any mine with an extractive metallurgical process, or any mine where sulphate producing or acid generating material occurs) and it is thus used with caution. The General Limit is only applied as a comparative guideline and should not be interpreted for compliance purposes.

**Table 6: SAWQG Target water quality guidelines**

| Variable | South African Water Quality Guidelines (DWAF, 1996) | | |
|---|---|---|---|
| | Dom[1] | Aqua[2] | Live[3] |
| pH | 6.0 –9.0 | <5% variation | - |
| Electrical Conductivity (mS/m) | 70 | - | 500 |
| Sulphate (mg/l $SO_4$) | <200 | - | <1 000 |
| Nitrate (mg/l $NO_3$) | <6 | - | <22 |
| Chloride (mg/l Cl) | <100 | - | <3 000 |
| Fluoride (mg/l F) | <0.7 | <0.75 | <2 |
| Ammonia (mg/l $NH_3$) | <1 | <0.007 | - |
| Calcium (mg/l Ca) | <80 | - | <1 000 |
| Magnesium (mg/l Mg) | <70 | - | <500 |
| Sodium (mg/l Na) | <100 | - | <2000 |
| Aluminium (mg/l Al) | <0.15 | <0.005 | <5 |
| Iron (mg/l Fe) | <0.5 | - | <10 |
| Manganese (mg/l Mn) | <0.1 | <0.18 | <10 |

[1] *DWAF SAWQG TWQGR for Domestic use*

[2] *DWAF SAWQG TWQGR for Aquatic Ecosystems*

[3] *DWAF SAWQG TWQGR for Agricultural Use - Livestock watering*

**Table 7: DWAF General Limit Guideline**

| Variable / Parameter | Unit | DWAF General Limit |
|---|---|---|
| pH | - | 5.5 - 9.5 |
| EC | mS/m | 150 |
| TDS | mg/l | (1000)* |
| TH | mg/l | - |
| M_Alk | mg/l | - |
| Cl | mg/l | - |
| $SO_4$ | mg/l | - |
| F | mg/l | 1 |
| $NO_3$_N | mg/l | 15 |
| $NH_4$_N | mg/l | 6 |
| $PO_4$ | mg/l | 10 |
| Ca | mg/l | - |
| Mg | mg/l | - |
| Na | mg/l | - |
| K | mg/l | - |
| Fe | mg/l | 0.3 |
| Al | mg/l | - |
| Mn | mg/l | 0.1 |
| SAR | - | - |
| SOG | mg/l | 2.5 |

As mentioned previously in this report, Anglo American Platinum is also a registered water user in terms of Chapter 4 of the National Water Act, 1998 (Act No. 36 of 1998) with a Water Use Licence issued to the mining operation in January 2018. In terms of this WUL the water quality limits presented in Table 8 should be adhered to; but do refer to Section 2 above for a detailed discussion on the WUL limits.

**Table 8: WUL Resource and Groundwater Quality Limits**

| VARIABLE | Units | Groundwater Quality Limits (WUL 2018) | Surface Water Quality Limits (WUL 2018) |
|---|---|---|---|
| pH | pH units | 6.0 - 9.5 | 6.0 - 9.0 |
| Electrical Conductivity (EC) | mS/m | 150 | 85.00 |
| Hardness (CaCO3) | mg/l | - | 50 |
| Calcium (Ca) | mg/l | 150 | - |
| Magnesium (Mg) | mg/l | 100 | - |
| Sodium (Na) | mg/l | 200 | - |
| Chloride (Cl) | mg/l | 200 | - |
| Sulphate ($SO_4$) | mg/l | 200 | - |
| Nitrate ($NO_3$) as N | mg/l | 10 | - |
| Ammonia ($NH_4$) as N | mg/l | - | 1.00 |
| Phosphate ($PO_4$) as P | mg/l | - | 0.125 |
| Fluoride (F) | mg/l | 1 | 0.75 |
| Aluminium (Al) | mg/l | - | 5 |
| Iron (Fe) | mg/l | - | 0.5 |
| Manganese (Mn) | mg/l | - | 0.18 |
| Hexavalent chromium ($Cr^{6+}$) | mg/l | 0.0049 | 0.0049 |
| Copper (Cu) | mg/l | - | 0.3 |
| Dissolved oxygen | mg/l | - | 7-8 |

*6.5.2. Water quality classification*

In 1998, the Department of Water Affairs and Forestry (DWAF), in association with the Water Research Commission (WRC) and the Department of Health (DOH) published a useful colour coding system for evaluating the prevailing water quality of water used for domestic use. The system is based on the principle of assigning a colour to a specific concentration range of variables commonly found in water and that has a major effect on the suitability of water for domestic use.

Due to significance of using water for domestic purposes and the importance of effective water quality evaluation for the use, efficient data for a wide variety of variables are available. The colour coding system will specifically be used to assess the water quality of the identified monitoring localities sampled. When comparing data with the guidelines for domestic use, the worst substance class will determine the overall class of the water supply. Data can be interpreted as in Table 9:

- Water testing within the Blue or Green colour class may be used without reservation and is considered safe for all users.
- Water testing within the Yellow colour class is generally regarded as safe, however sensitive users should be identified and warned to take personal consumption precautions.
- Water testing within the Red colour class can be used as a short-term emergency supply, approximately seven days only, when other sources are unavailable.
- When water tests within the Purple colour class the public must be warned not to use the water, or to use emergency home treatment where possible. If this is not possible, alternative water supplies must be considered and made available

**Table 9: Structure of the classification system describing the effects of the different classes of water on the various domestic uses of water (DWAF *et al*, 1998)**

| CLASS / COLOUR | DESCRIPTION | EFFECTS |
|---|---|---|
| **Class 0 (Blue)** | Ideal water quality | **Drinking health**: No effects, suitable for many generations |
| | | **Drinking aesthetic**: Water is pleasing |
| | | **Food preparation**: No effects |
| | | **Bathing**: No effects |
| | | **Laundry**: No effects |
| **Class 1 (Green)** | Good water quality | **Drinking health**: Suitable for lifetime use. Rare instances of sub-clinical effects |
| | | **Drinking aesthetic**: Some aesthetic effects may be present |
| | | **Food preparation**: Suitable for lifetime use |
| | | **Bathing**: Minor effects on bathing or on bath fixtures |
| | | **Laundry**: Minor effects on laundry or on fixtures |
| **Class 2 (Yellow)** | Marginal water quality | **Drinking health**: May be used without health effects by majority of individuals of all ages, but may cause effects in some individuals in sensitive groups. Some effects possible after lifetime use. |
| | | **Drinking aesthetic**: Poor taste and appearance are noticeable |
| | | **Food preparation**: May be used without health or aesthetic effects by the majority of individuals. |
| | | **Bathing**: Slight effects on bathing or on bath fixtures |
| | | **Laundry**: Slight effects on laundry or on fixtures |
| **Class 3 (Red)** | Poor water quality | **Drinking health**: Poses a risk of chronic health effects, especially in babies, children and the elderly |
| | | **Drinking aesthetic**: Bad taste and appearance may lead to rejection of water |
| | | **Food preparation**: Poses a risk of chronic health effects, especially in babies, children and the elderly |
| | | **Bathing**: Significant effects on bathing or on bath fixtures |
| | | **Laundry**: Significant effects on laundry or on fixtures |
| **Class 4 (Purple)** | Unacceptable water quality | **Drinking health**: Severe acute health effects, even with short-term use |
| | | **Drinking aesthetic**: Taste and appearance will lead to rejection of water |
| | | **Food preparation**: Severe acute health effects, even with short-term use |
| | | **Bathing**: Serious effects on bathing or on bath fixtures |
| | | **Laundry**: Serious effects on laundry or on fixtures |

### *6.5.3. Water quality parameters*

Physical Water Quality

This refers to the water quality properties such as temperature, electrical conductivity, pH and oxygen content that may be determined by physical methods. When referring to the physical quality of water at Anglo Platinum we refer to the three parameters namely pH, EC or TDS. The physical quality affects the aesthetic as well as chemical quality of the water.

**Table 10: Physical Quality of Water Parameters**

| Physical quality |
|---|

| Parameter | Relevance |
|---|---|
| pH | Affects the corrosivity and taste of water |
| EC / TDS | Serves as a general indicator of change in water quality and affects the “freshness” taste of the water. Indicates the salinity and quantity of dissolved substances. |

Chemical Water Quality

The chemical quality of the water refers to the nature and concentrations of dissolved substances such as organic or inorganic compounds, including metals, in the water body. Many chemicals in water are essential for the biotic community and may form an integral part of the nutritional requirements. However, elevated levels may be limiting for some of the downstream water users.

**Table 11: Chemical Quality of Water**

| Chemical quality | |
|---|---|
| Parameter | Relevance |
| Alkalinity | Indicative of intrinsic buffering capacity against acidification. |
| Major anions | Typically, chloride, sulphate, fluoride and the nitrogen compounds, Impacts the salinity levels |
| Hardness | Mainly affected by Calcium and Magnesium and affects the scaling and foaming quality of the water |
| Major cations | Typically, Calcium, Magnesium and Sodium - Elevated levels could affect the taste of water |
| Heavy metals | Toxic at low concentrations |

Bacteriological Water Quality

Generally, the microbiological quality of water refers to the presence of organisms that cannot be individually seen with the naked eye, such as protozoa, bacteria and viruses. Many of these microbes are associated with the transmission of infectious water-borne diseases such as gastro-enteritis and cholera. In order to determine the bacteriological status and safety of Anglo Platinum water, Aquatico specifically focuses on total coliforms and *E. coli* (indicator of faecal coliforms) bacteria.

**Table 12: Bacteriological Quality of Water**

| Bacteriological quality | |
|---|---|
| Parameter | Relevance |
| Faecal coliforms | Indicates recent faecal pollution and the potential risk of contracting infectious diseases |
| Total coliforms | Indicates the general hygienic quality of the water |

Parameters such as pH, hardness and salinity are used to describe the general quality of water. These are tabulated below (Table 13) and are based on the descriptions as proposed by DWA:

**Table 13: General water quality description parameters**

| Acidity | |
|---|---|
| pH: > 8.5 | Alkaline/Basic |
| pH: 6.0- 8.5 | Neutral |
| pH: < 6 | Acidic |
| Hardness | |
| Hardness < 50 mg/l | Soft |
| Hardness 50 - 100 mg/l | Moderately soft |
| Hardness 100 -150 mg/l | Slightly hard |
| Hardness 150 – 200 mg/l | Moderately hard |
| Hardness 200 – 300 mg/l | Hard |
| Hardness 300 – 600 mg/l | Very Hard |
| Salinity | |
| TDS < 450 mg/l | Non saline |
| TDS 450 – 1 000 mg/l | Saline |
| TDS 1 000 – 2 400 mg/l | Very saline |
| TDS 2 400 – 3 400 mg/l | Extremely saline |

## 7. SURFACE WATER MONITORING SUMMARY PER BUSINESS UNIT

The data summary aims to give the reader a short and basic summarisation of the current water quality status of the relevant process areas at Anglo American Platinum Rustenburg. Each business unit will be discussed separately focusing on qualities of process and pollution dams, effluents and up- and downstream qualities of adjacent streams and rivers. Each section will include a map illustrating the relative positions of monitoring localities situated in a specific catchment, and the general quality thereof (physical, chemical, bacteriological and organic where applicable). Localities discussed include:

- Process water (including return water dams and pollution control dams);
- Discharges, effluents and seepages of mining and non-mining sources;
- Receiving environment (including natural streams and rivers).

An impact evaluation is ultimately discussed using a simplified diagram for the river catchments showing the relative positions of possible pollutant contributors on a particular system. Only localities upstream and downstream from potential impacts are included in the diagrams. Averages for a specific period of selected variables are plotted on histograms while estimated impacts are presented in tabular format. The impacts are discussed broadly as combined impacts observed between upstream and downstream localities and calculated using the following:

*Impact quantification (mg/l) = annual average downstream value (mg/l) – annual average upstream value (mg/l)*

Where a specific business unit has impacted negatively on a specific river or spruit the impact quantified is in red font and where a positive impact has been quantified the impact is in green.

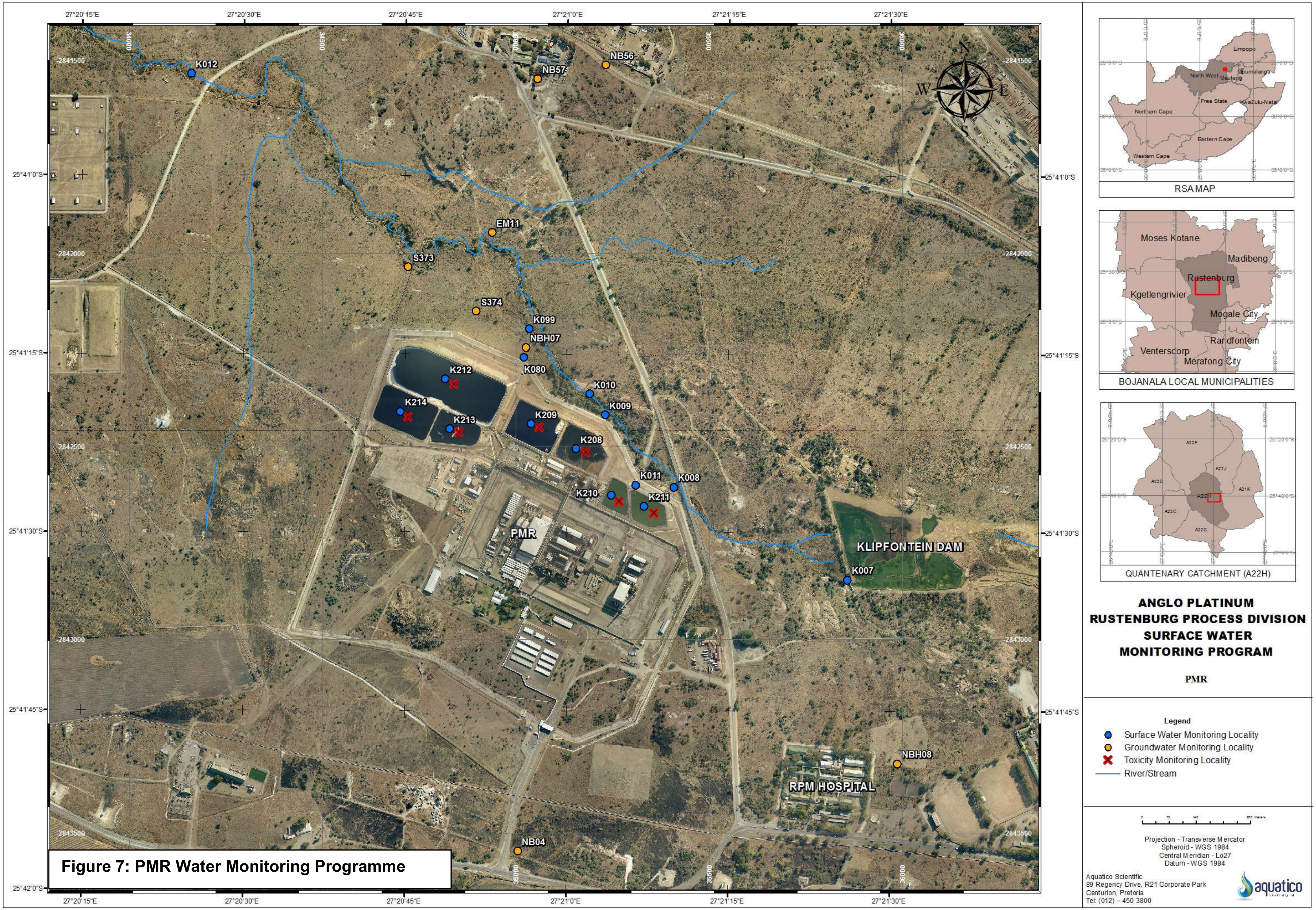



**Figure 7: PMR Water Monitoring Programme**

**Table 14: PMR sampling register of the surface water monitoring conducted during the annual period**

| Anglo Rustenburg Surface water monitoring | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Effluent | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K009 | PMR East rain water dam overflow | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| K011 | Discharge at PMR culvert at PMR bridge | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| K080 | Effluent and stormwater discharge west of PMR | Dry | Dry | Stagnant | Stagnant | Dry | Dry | Dry | Dry | Stagnant | Stagnant | ● | Dry |
| Pollution control dam | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K208 | PMR Dam 1 | - | NS | - | - | NS | - | - | NS | - | - | NS | - |
| K209 | PMR Dam 2 | - | ● | - | - | ● | - | - | ● | - | - | ● | - |
| K210 | PMR Dam 3A | - | NS | - | - | ● | - | - | ● | - | - | ● | - |
| K211 | PMR Dam 3B | - | ● | - | - | ● | - | - | ● | - | - | ● | - |
| K212 | PMR Dam 4+5 | - | ● | - | - | ● | - | - | ● | - | - | ● | - |
| K213 | PMR Dam 6 East | - | ● | - | - | ● | - | - | ● | - | - | ● | - |
| K214 | PMR Dam 6 West | - | ● | - | - | ● | - | - | ● | - | - | ● | - |
| River or stream | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K007 | Klipfontein Dam | - | - | - | - | - | - | - | ● | Dry | Dry | ● | ● |
| K008 | Klipfonteinspruit at PMR Bridge | Dry | Dry | Dry | Dry | ● | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| K010 | Klipfonteinspruit, downstream of K009 | ● | ● | ● | Stagnant | ● | ● | Dry | ● | ● | ● | ● | ● |
| K012 | Klipfonteinspruit between PMR and RBMR on old road to magazine | Dry | Dry | Dry | Dry | ● | ● | Dry | ● | Dry | Dry | Dry | Dry |
| K099 | Klipfonteinspruit downstream of PMR | Dry | Dry | ● | Dry | Dry | ● | Dry | ● | ● | Dry | ● | Dry |

*● – Sampled
NS – Not submitted
- – Not scheduled for sampling (quarterly sampling frequency in the case of pollution control dam localities)

## 7.1. PRECIOUS METAL REFINERS (PMR)

Presented in Table 14 is the frequency of sampling at each PMR monitoring locality during the annual period. Additionally, the average data tables are illustrated within Table 15 and Table 16, results are discussed separately according to the relevant sections below.

### 7.1.1. Process water

The PMR Pollution Control Dams (**K209**, **K211, K212**, **K213** and **K214**) were sampled on a quarterly basis throughout the annual period; **K210** was not submitted on one occasion. Locality **K208** was however not sampled and is currently under construction. Due to the high security area in PMR, these dams are sampled by PMR staff and samples are samples are submitted to Aquatico for analysis. pH levels fluctuated quarterly, with average TDS concentrations of all the localities being recorded as extremely saline (average TDS concentrations exceeding 60000 to 100000 mg/l). The average hardness concentration of the water also indicated very hard water with high concentrations of salts, nutrients and metals. Chloride and sodium concentrations are dominant in the PMR dams and may be used as indicator variables.

Water quality profiles (STIFF diagrams) for each dam remained stable throughout the annum. The major contributing cation was sodium. Chloride was the major contributing anion for all these localities (STIFF diagram, Figure 8). A hazard is posed towards the integrity of the Klipfonteinspruit in the event of uncontrolled discharges and effluents from the PMR complex. Furthermore, a high risk also remains towards groundwater contamination if seepages or dam-liner failure occurs.

Compared with the General Authorisation limit guidelines, analysed variables from all five dams exceeded in terms of average EC, fluoride, ammonium, iron, manganese and copper concentrations (amongst others). Water quality limits are not stipulated in the WUL for process water storage localities.

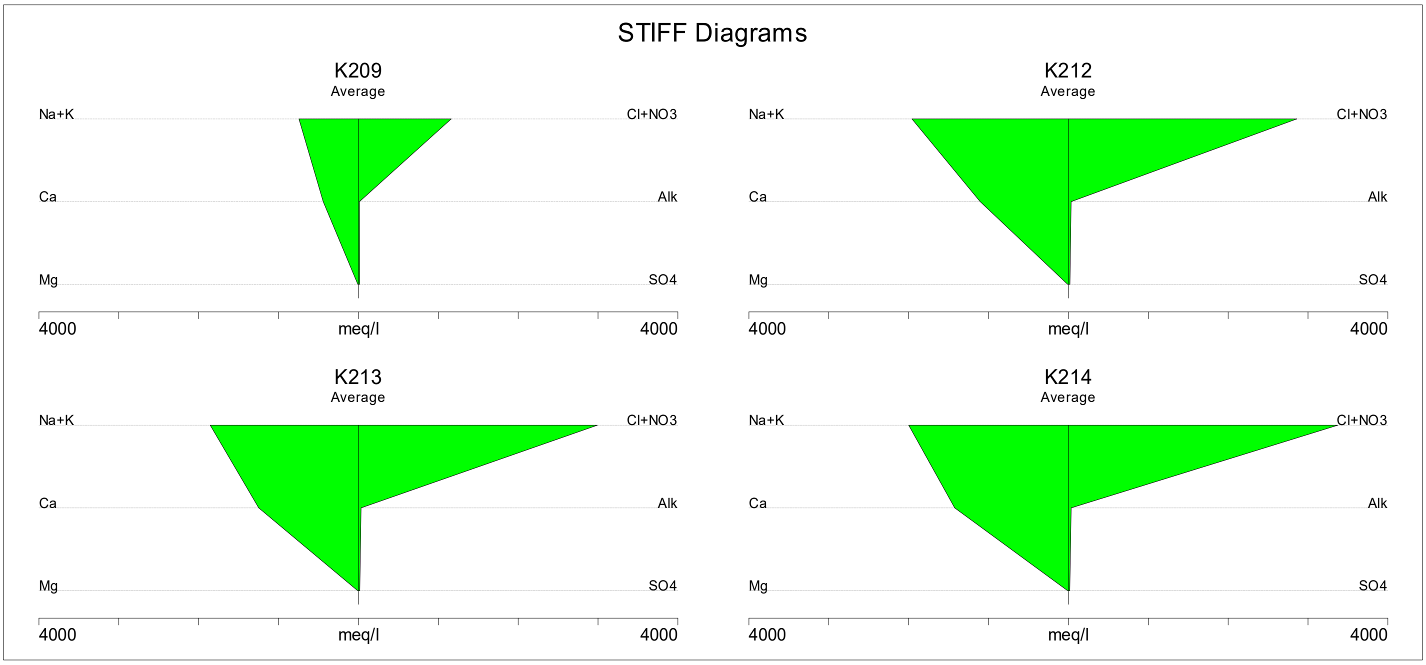



**Figure 8: STIFF diagrams representing the water quality profile of the PMR Pollution control dams (K209, K212, K213 and K214)**

Average water quality at the PMR stormwater dam localities **K210** and **K211** was alkaline, non-saline (average TDS concentrations of 320 mg/l and 357 mg/l respectively) and moderately soft with low salt concentrations and heavy metals mostly below detection limits. The major contributing cation for K210 and K211 was sodium while the major contributing anion was bicarbonate alkalinity ($HCO_3$) (STIFF diagram, Figure 9). Discharges from K210 and K211 in high rainfall situations should not cause significant deteriorating impacts on the Klipfonteinspruit.

K210 exceeded the General Authorisation limit guidelines in terms of average pH and copper concentrations while K211 exceeded in terms of average copper concentrations.

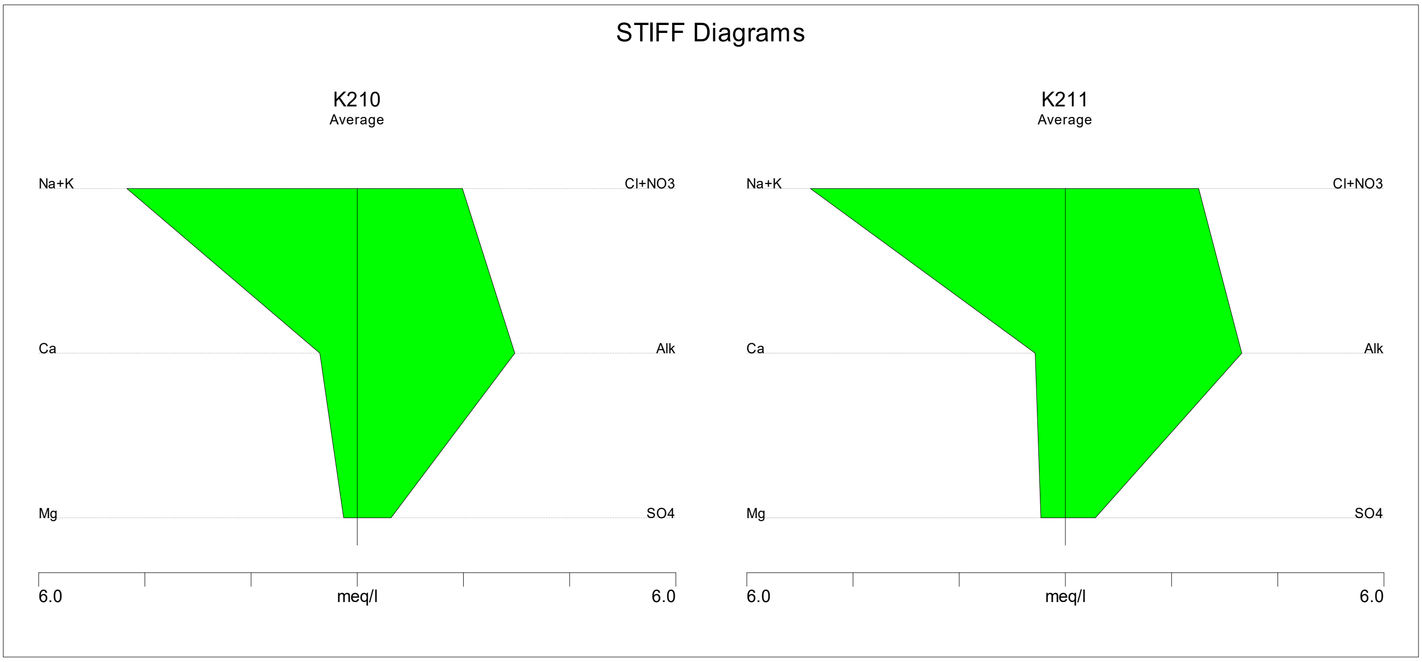
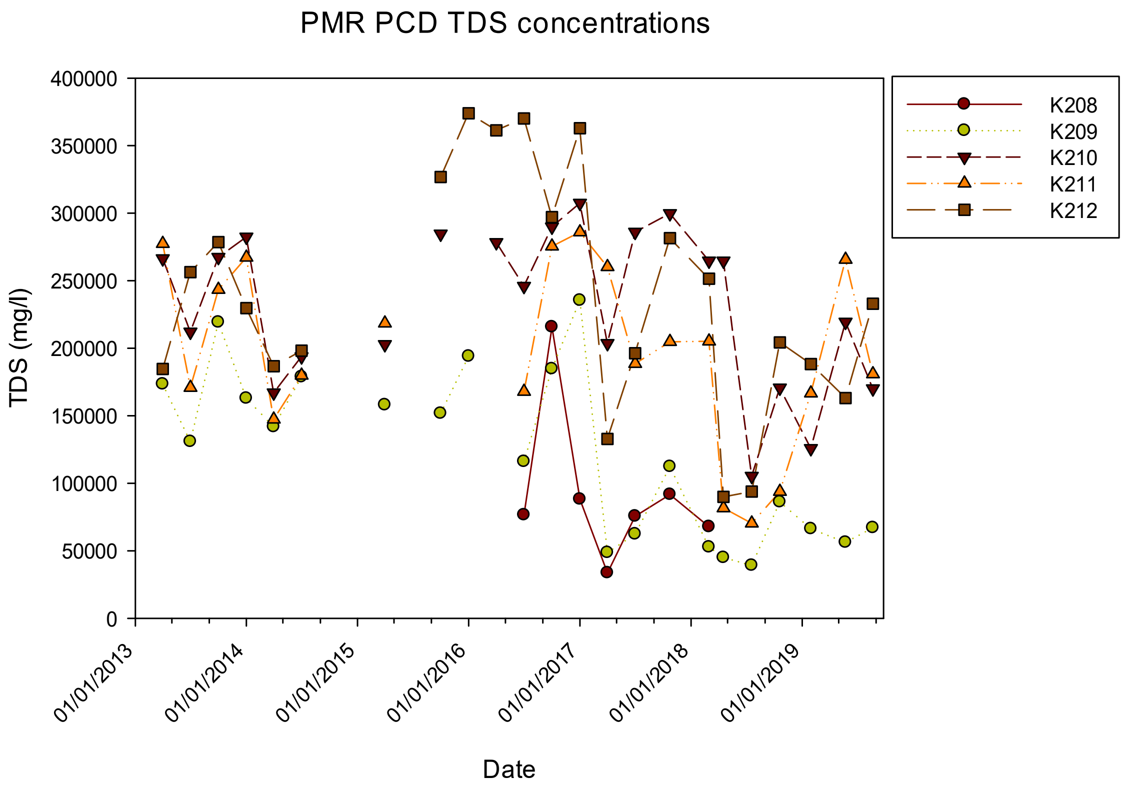



**Figure 9: STIFF diagrams representing the water quality profile of the PMR Pollution control dams (K210 and K211)**

The time-line graph Figure 10 indicates quarterly variances in terms of TDS (salinity) concentrations. A decrease over the indicated time period was noted at the pollution control dams and stormwater dams in relation to overall salinity concentrations. That being said, the average salinity of the pollution control dams remained high.



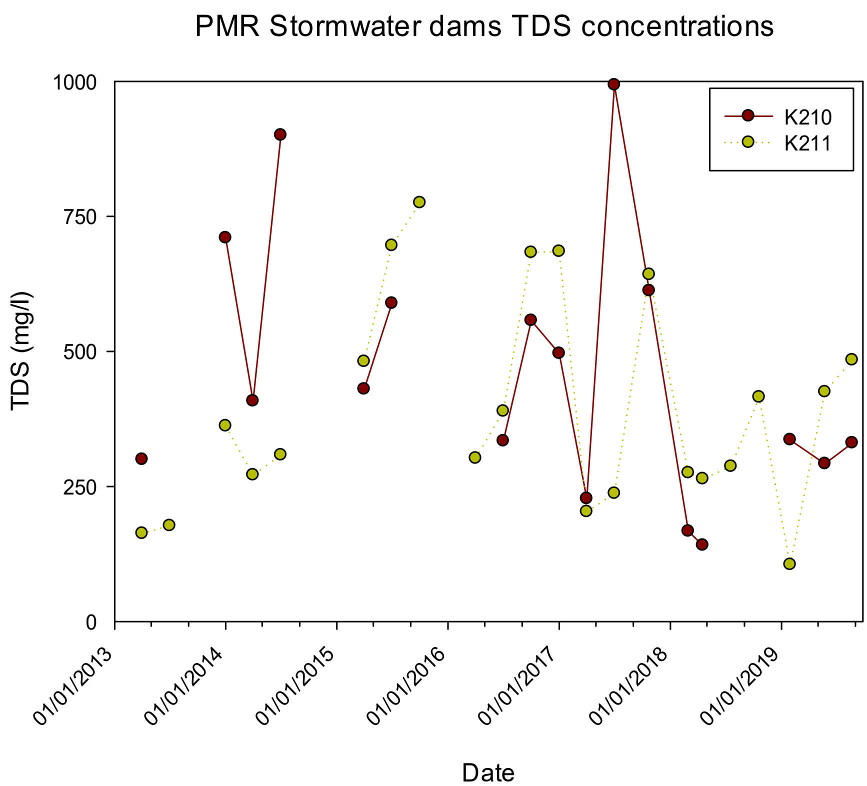




**Figure 10: PMR pollution control dams and stormwater dams timeline graph**

**Table 15: Average PMR process dams data table for the annual monitoring period**

| AVERAGE DATA TABLE: | |
|---|---|
| PROJECT NAME | Anglo Rustenburg Surface water monitoring |
| ASSESSMENT SET 1 | General Authorisation Limit, Section 21f and h, 2013 |
| ASSESSMENT SET 2 | AAP Rustenburg - Surface water WUL |

Value exceeds the assessment set 1

| VARIABLE | UNITS | ASSESSMENT 1 | ASSESSMENT 2 | MONITORING LOCALITIES | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | K208 | K209 | K210 | K211 | K212 | K213 | K214 |
| pH @ 25°C | pH | 5.5/9.5 | 6.0/9.0 | - | 3.75 | 9.86 | 9.5 | 6.06 | 6.07 | 5.59 |
| Electrical conductivity (EC) @ 25°C | mS/m | 150 | 85 | - | 10895 | 49.7 | 56.6 | 18888 | 18363 | 19470 |
| Total dissolved solids (TDS) | mg/l | - | - | - | 68868 | 320 | 357 | 171498 | 176689 | 197144 |
| Total hardness | mg CaCO3/l | - | 50 | - | 22449 | 48 | 51 | 55762 | 63046 | 71870 |
| Calcium (Ca) | mg/l | - | - | - | 8843 | 14.1 | 11.4 | 22142 | 25019 | 28542 |
| Magnesium (Mg) | mg/l | - | - | - | 89.5 | 3.13 | 5.61 | 115 | 139 | 146 |
| Sodium (Na) | mg/l | - | - | - | 16924 | 97.5 | 108 | 44375 | 41966 | 45211 |
| Potassium (K) | mg/l | - | - | - | 343 | 3.71 | 3.93 | 1138 | 1182 | 1296 |
| Total alkalinity | mg CaCO3/l | - | - | - | *668* | 148 | 166 | 1725 | 1688 | 1748 |
| Chloride (Cl) | mg/l | - | - | - | 41180 | 69.1 | 84.7 | 101324 | 106083 | 119582 |
| Sulphate ($SO_4$) | mg/l | - | - | - | 708 | 30.6 | 27.1 | 941 | 857 | 841 |
| Fluoride (F) | mg/l | 1 | 0.75 | - | *103* | 0.697 | *0.645* | 96.3 | 117 | 130 |
| Nitrate ($NO_3$) as N | mg/l | 15 | - | - | 8.98 | 0.334 | 1.66 | 19.2 | 14.2 | 18 |
| Ammonium ($NH_4$) as N | mg/l | 6 | 1 | - | *175* | 4.65 | 4.64 | *175* | 176 | 189 |
| Orthophosphate ($PO_4$) as P | mg/l | 10 | 0.125 | - | *0.797* | *0.033* | *0.003* | *1* | *2.63* | *2.82* |
| Aluminium (Al) | mg/l | - | 5 | - | *9.2* | *0.032* | *0.058* | *1.12* | *0.951* | *0.851* |
| Iron (Fe) | mg/l | 0.3 | 0.5 | - | 192 | *0.002* | *0.002* | 2.62 | 2.29 | 1.43 |
| Manganese (Mn) | mg/l | 0.1 | 0.18 | - | 40.3 | *0.001* | *0.001* | 23.9 | 25 | 30.1 |
| Chromium (Cr) | mg/l | - | - | - | *0.989* | *0.002* | *0.002* | *0.221* | *0.201* | *0.44* |
| Copper (Cu) | mg/l | 0.01 | 0.3 | - | 44 | *0.004* | *0.005* | 47.5 | 49.4 | 50.1 |
| Nickel (Ni) | mg/l | - | - | - | 188 | *0.059* | 0.121 | 160 | 169 | 183 |

### 7.1.2. Discharges, effluents and seepages

The Klipfontein dam (**K007**) was added to the monitoring programme to be used as an additional upstream locality. Three samples were collected between April and August 2019; average water quality depicted neutral, very saline and very hard water quality. Very high concentrations of nitrates were also detected.

**K009** (PMR East rain water dam overflow) and **K011** (Discharge at PMR culvert at PMR Bridge) were recorded as dry throughout the annual period.

**K080** (Effluent and stormwater discharge west of PMR) was sampled once during the annual period and was recorded as dry or stagnant throughout the rest of the annual period. Water quality was alkaline, very saline and moderately soft and may be indicative of stormwater run-off with moderate to high salinity.

### 7.1.3. Receiving environment

**K012** is used as the downstream locality of PMR in the Klipfonteinspruit with **K008** as the upstream locality. An increase, especially in TDS, chloride and sodium was observed downstream of PMR with a significant reduction in sulphate concentrations.

The Klipfonteinspruit is discussed in greater detail under section 8.1.

**Table 16: Average spatial assessment for PMR impacts on the Klipfonteinspruit**

| VARIABLE | UNIT | AAP Rustenburg - Surface water WUL | Locality | | CALCULATED CHANGE |
|---|---|---|---|---|---|
| | | | Upstream | Downstream | |
| | | | K008 | K012 | |
| pH @ 25°C | pH | 6.0/9.0 | 8.53 | 8.19 | -0.34 |
| Electrical conductivity (EC) @ 25°C | mS/m | 85 | 67.8 | 162 | 94.2 |
| Total dissolved solids (TDS) | mg/l | - | 525 | 1007 | 482 |
| Total hardness | mg CaCO3/l | 50 | 370 | 432 | 62 |
| Total alkalinity | mg CaCO3/l | - | 369 | 142 | -227 |
| Chloride (Cl) | mg/l | - | 25.2 | 523 | 498 |
| Sulphate ($SO_4$) | mg/l | - | 73.3 | 29.3 | -44 |
| Fluoride (F) | mg/l | 0.75 | *0.132* | *0.132* | 0 |
| Nitrate ($NO_3$) as N | mg/l | - | 0.253 | 0.244 | -0.009 |
| Ammonium ($NH_4$) as N | mg/l | 1 | 0.089 | 0.099 | 0.01 |
| Orthophosphate ($PO_4$) as P | mg/l | 0.125 | *0.003* | *0.007* | 0.004 |
| Calcium (Ca) | mg/l | - | 94.7 | 113 | 18.3 |
| Magnesium (Mg) | mg/l | - | 32.5 | 36 | 3.5 |
| Sodium (Na) | mg/l | - | 50 | 199 | 149 |
| Potassium (K) | mg/l | - | 12.8 | 6.43 | -6.37 |
| Aluminium (Al) | mg/l | 5 | *0.001* | *0.001* | 0 |
| Iron (Fe) | mg/l | 0.5 | *0.002* | *0.002* | 0 |
| Manganese (Mn) | mg/l | 0.18 | *0.001* | *0.001* | 0 |
| Chromium (Cr) | mg/l | - | *0.002* | *0.002* | 0 |
| Copper (Cu) | mg/l | 0.3 | *0.001* | 0.017 | 0.016 |

| | | | | | |
|---|---|---|---|---|---|
| Nickel (Ni) | mg/l | - | 0.012 | *0.013* | 0.001 |

**Table 17: Average PMR receiving environment data table for the annual monitoring period**

| AVERAGE DATA TABLE: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PROJECT NAME | | | Anglo Rustenburg Surface water monitoring | | | | | | |
| ASSESSMENT SET 1 | | | AAP Rustenburg - Surface water WUL | | | | | | |
| ASSESSMENT SET 2 | | | SANS 241-1:2015 Drinking Water Standard (SABS, 2015) | | | | | | |
| | | | | | | | | | Value exceeds the assessment set 1 |
| VARIABLE | UNITS | AAP Rustenburg - Surface water WUL | SANS 241-1:2015 Drinking Water Standard (SABS, 2015) | MONITORING LOCALITIES | | | | | |
| | | | | K007 | K008 | K010 | K012 | K099 | K080 |
| pH @ 25°C | pH | 6.0/9.0 | 5.0/9.7 | 8.02 | 8.53 | 7.89 | 8.19 | 9.31 | 9.61 |
| Electrical conductivity (EC) @ 25°C | mS/m | 85 | 170 | 199 | 67.8 | 2490 | 162 | 1072 | 286 |
| Total dissolved solids (TDS) | mg/l | - | 1200 | 1380 | 525 | 15548 | 1007 | 5341 | 1542 |
| Total hardness | mg CaCO3/l | 50 | - | 830 | 370 | 6857 | 432 | 426 | 82 |
| Calcium (Ca) | mg/l | - | - | 191 | 94.7 | 1752 | 113 | 111 | 26.1 |
| Magnesium (Mg) | mg/l | - | - | 85.7 | 32.5 | 603 | 36 | *36.4* | 4.1 |
| Sodium (Na) | mg/l | - | 200 | 73.8 | 50 | 3380 | 199 | 1755 | 551 |
| Potassium (K) | mg/l | - | - | 13.9 | 12.8 | 25.7 | 6.43 | 179 | 24.7 |
| Chloride (Cl) | mg/l | - | 300 | 185 | 25.2 | 9375 | 523 | 2702 | 544 |
| Sulphate ($SO_4$) | mg/l | - | 500 | 363 | 73.3 | 338 | 29.3 | 71.4 | 59 |
| Fluoride (F) | mg/l | 0.75 | 1.5 | *0.207* | *0.132* | *0.237* | *0.132* | 0.893 | 0.721 |
| Nitrate ($NO_3$) as N | mg/l | - | 11 | 95.7 | 0.253 | *0.311* | 0.244 | 9.34 | 7.48 |
| Ammonium ($NH_4$) as N | mg/l | 1 | 1.5 | 2.79 | 0.089 | 0.552 | 0.099 | 0.301 | 0.476 |
| Orthophosphate ($PO_4$) as P | mg/l | 0.125 | - | *0.069* | *0.003* | *0.064* | *0.007* | *0.385* | 0.444 |
| Ortophosphate as $PO_4$ | mg/l | 0.234 | - | *0.211* | *0.008* | *0.196* | *0.02* | *1.18* | 1.36 |
| Aluminium (Al) | mg/l | 5 | 0.3 | 0.028 | *0.001* | *0.338* | *0.001* | *0.387* | 0.139 |
| Iron (Fe) | mg/l | 0.5 | 0.3 | *0.002* | *0.002* | *0.499* | *0.002* | *0.079* | *0.002* |
| Manganese (Mn) | mg/l | 0.18 | 0.1 | *0.024* | *0.001* | *2.86* | *0.001* | *0.018* | *0.001* |
| Chromium (Cr) | mg/l | - | 0.05 | *0.002* | *0.002* | *0.012* | *0.002* | *0.019* | 0.011 |
| Copper (Cu) | mg/l | 0.3 | 2 | *0.005* | *0.001* | *0.068* | 0.017 | 0.173 | 0.3 |
| Nickel (Ni) | mg/l | - | 0.07 | *0.011* | 0.012 | *0.053* | *0.013* | 0.112 | 0.078 |
| Dissolved oxygen (DO) | mg/l | 7.0/8.0 | - | - | 1.31 | 3.59 | 2.4 | 3.29 | 2.91 |
| Lead (Pb) | mg/l | - | 0.01 | *0.002* | *0.002* | *0.042* | *0.002* | *0.01* | *0.002* |
| Zinc (Zn) | mg/l | - | 5 | 0.155 | *0.001* | *1.11* | *0.001* | *0.004* | *0.001* |
| Boron (B) | mg/l | - | 2.4 | - | 0.644 | *0.098* | 0.026 | 0.059 | 0.035 |
| Phenol | mg/l | - | 0.01 | - | *0.005* | *0.032* | *0.008* | *0.007* | *0.005* |
| Hexavalent chromium ($Cr^{6+}$) | mg/l | 0.0049 | - | *0.001* | *0.001* | *0.001* | *0.001* | *0.008* | 0.004 |
| Arsenic (As) | mg/l | - | 0.01 | - | *0.003* | *0.003* | *0.003* | *0.028* | 0.03 |
| Cadmium (Cd) | mg/l | - | 0.003 | *0.001* | *0.001* | *0.022* | *0.001* | *0.001* | *0.001* |
| Mercury (Hg) | mg/l | - | 0.006 | - | *0.002* | *0.002* | *0.002* | *0.002* | *0.002* |
| Selenium (Se) | mg/l | - | 0.04 | - | *0.001* | *0.001* | *0.001* | *0.014* | 0.029 |
| E.coli | CFU/100ml | - | 0 | 450 | 10 | - | - | - | - |
| Total coliform | CFU/100ml | - | 10 | 695 | 14 | - | - | - | - |

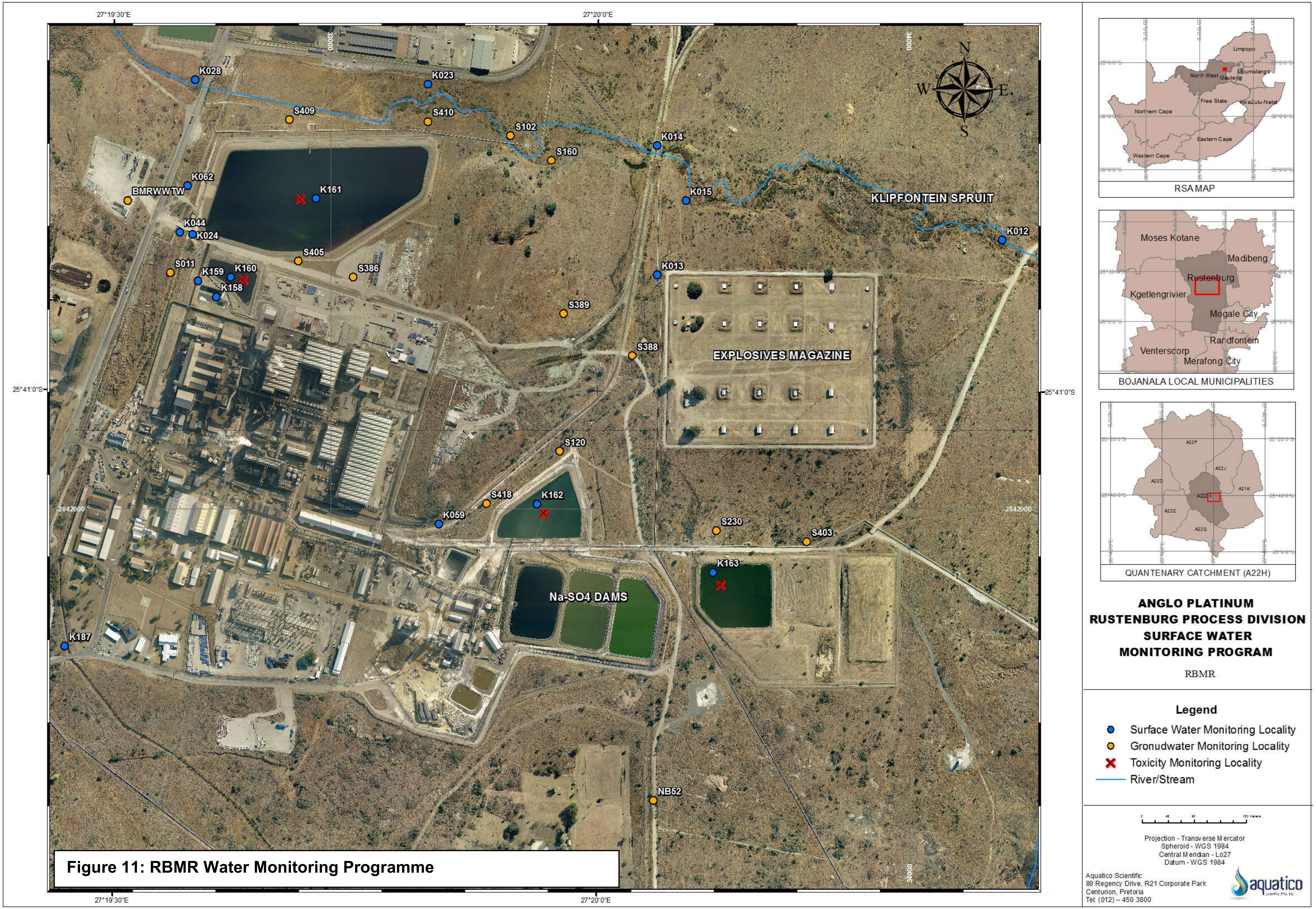



**Figure 11: RBMR Water Monitoring Programme**

**Table 18: RBMR sampling register of the surface water monitoring conducted during the annual period**

| Anglo Rustenburg Surface water monitoring | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Effluent** | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K013 | Culvert ditch going to Klipfonteinspruit halfway between PMR bridge and Waterval bridge parallel to old railway | Dry | Dry | Dry | Dry | Dry | Dry | Dry | ● | ● | Dry | Dry | Dry |
| K024 | Outflow of RBMR dam 3 rain catchment. RBMR rain water collection dam | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| K044 | Trench to the west of the RBMR dam 3B | Dry | Dry | Dry | Dry | Dry | Dry | Dry | ● | Dry | Dry | Dry | Dry |
| K062 | Spillway overflow RBMR stormwater dam 3B | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| K187 | Trench upstream of RBMR at culvert on access road to South gate | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| K059 | Culvert at railway entry to RBMR | - | Dry | - | - | ● | - | - | Dry | - | - | Dry | - |
| **Pollution Control Dam** | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K158 | RBMR Dam 1 | - | NS | - | - | - | NS | - | - | NS | - | - | NS |
| K159 | RBMR Dam 2 | - | NS | - | - | - | NS | - | - | NS | - | - | NS |
| K160 | RBMR Dam 3A | - | NS | - | - | - | ● | - | - | ● | - | - | NS |
| K161 | RBMR Dam 3B | - | ● | - | - | - | ● | - | - | ● | - | - | NS |
| K162 | RBMR Triangular Dam - West section | - | ● | - | - | - | ● | - | - | ● | - | - | ● |
| K162 Duplicate | RBMR Triangular Dam - East section | - | - | - | - | - | - | - | - | - | - | - | ● |
| K163 | RBMR SSSS dams | - | Stagnant | - | - | - | NS | - | - | NS | - | - | NS |
| K220 | RBMR Effluent dam 1 | - | ● | - | - | - | ● | - | - | ● | - | - | ● |
| K221 | RBMR Effluent dam 2 | - | ● | - | - | - | ● | - | - | ● | - | - | ● |
| K222 | RBMR Effluent dam 3 | - | ● | - | - | - | ● | - | - | ● | - | - | ● |
| K223 | RBMR E&S feed dam 1 | - | ● | - | - | - | ● | - | - | ● | - | - | ● |
| K224 | RBMR E&S feed dam 2 | - | ● | - | - | - | ● | - | - | ● | - | - | ● |
| **River or Stream** | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K012 | Klipfonteinspruit between PMR and RBMR on old road to magazine | Dry | Dry | Dry | Dry | ● | ● | Dry | ● | Dry | Dry | Dry | Dry |
| K014 | Intersection of Klipfonteinspruit and rail line bridge (south side) | Dry | Dry | ● | Dry | ● | ● | Dry | ● | ● | Too low | ● | Dry |
| K015 | 150 metres up from intersection of Klipfonteinspruit and rail line | Dry | Dry | Dry | Dry | ● | ● | Dry | ● | ● | ● | ● | Dry |
| K023 | Klipfonteinspruit at base of RBMR dump | Dry | Dry | Dry | Dry | ● | ● | ● | ● | ● | ● | ● | ● |
| K028 | Klipfonteinspruit after confluence of RBMR west ditch system at Waterval smelter bridge | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |

*● – Sampled

NS – Not submitted

\- – Not scheduled for sampling (quarterly sampling frequency in the case of pollution control dam localities)

## 7.2. RUSTENBURG BASE METAL REFINERS (RBMR)

Presented in Table 18 is the frequency of sampling at each RBMR monitoring locality during the annual period. Additionally, the average data tables are illustrated within Table 19 and Table 20 below, results are discussed separately according to the relevant sections below.

### 7.2.1. Process water

The Process water dams at RBMR are sampled by RBMR staff and samples are then submitted to Aquatico for analysis. Most RBMR pollution control dam samples were submitted throughout the annual period on a quarterly basis; RBMR dams 1 and 2 have been demolished and were thus not sampled for the annual period. RBMR dam 3A was submitted on two occasions while the RBMR SSSS dam was not sampled on any occasion during the annual period. The effluent dams (**K220**, **K221** and **K222**) and the E&S feed dams (**K223** and **K224**) were submitted throughout the annum.

Water quality profiles (STIFF diagrams) for most of the sampled dams at RBMR are similar with Na+K as the main contributing cation and sulphate as the main contributing anion. The meq/l concentrations were however noted to differed between the dams. On average, acidic water quality was found at K160 and K161, while most other analysed dam samples had alkaline water quality. RBMR dams 3A and 3B (K160 and K161) recorded significantly high metal concentrations (copper, nickel, etc.).

Fluctuating concentrations of TDS and metals were recorded in all samples; Figure 13 displays the TDS trends from 2013. Dam operation water levels should be maintained at these dams to prevent discharge which will cause deteriorating conditions to the receiving natural environment.

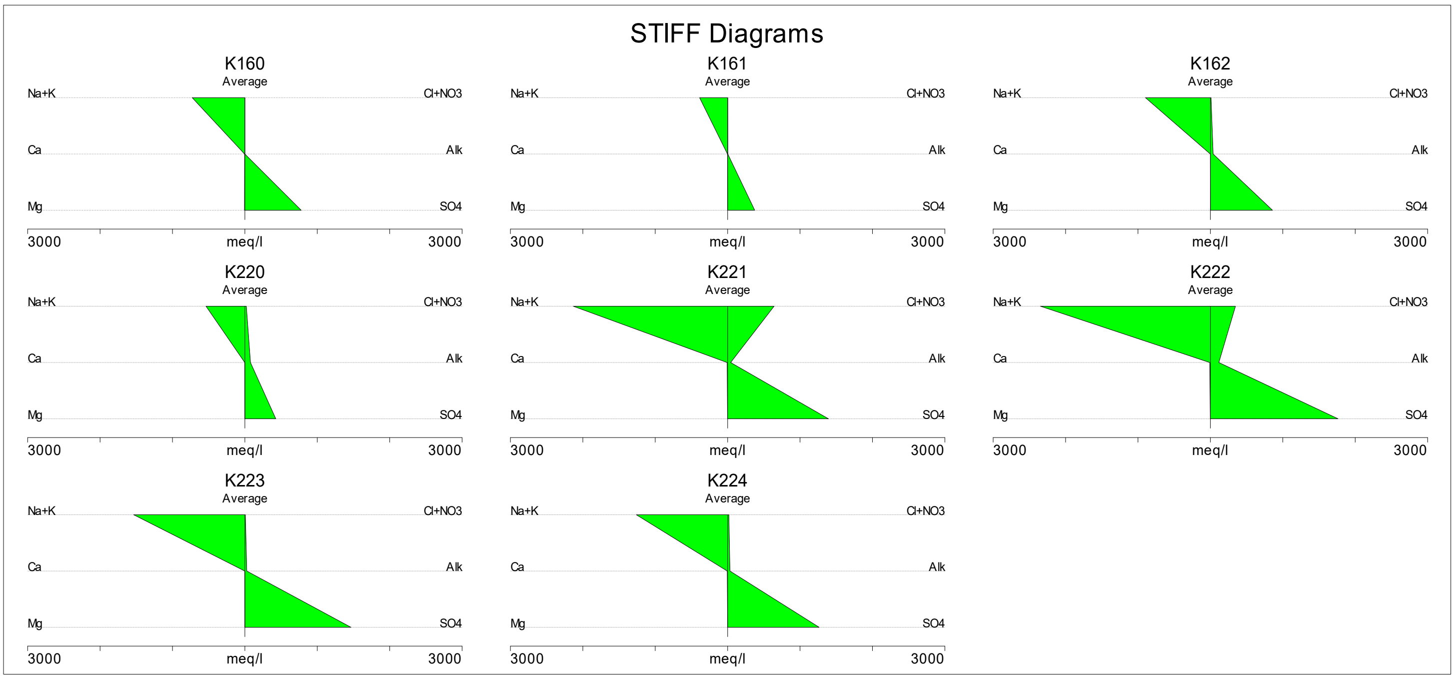



**Figure 12: STIFF diagrams showing the water quality profiles of the RBMR pollution control dams**

The new WUL (2018) does not include any guidelines for water to be stored in a process water dam. The general authorisation limit guidelines and the WUL limits for surface water are therefore used for comparative purposes; many of the analysed variables exceeded these guidelines due to the extreme salinity of these process water dams and concentrations of fluoride, base metals and heavy metals. A hazard is posed towards the integrity of the Klipfonteinspruit; a high risk also remains towards polluting groundwater if seepages and / or effluents are not controlled.

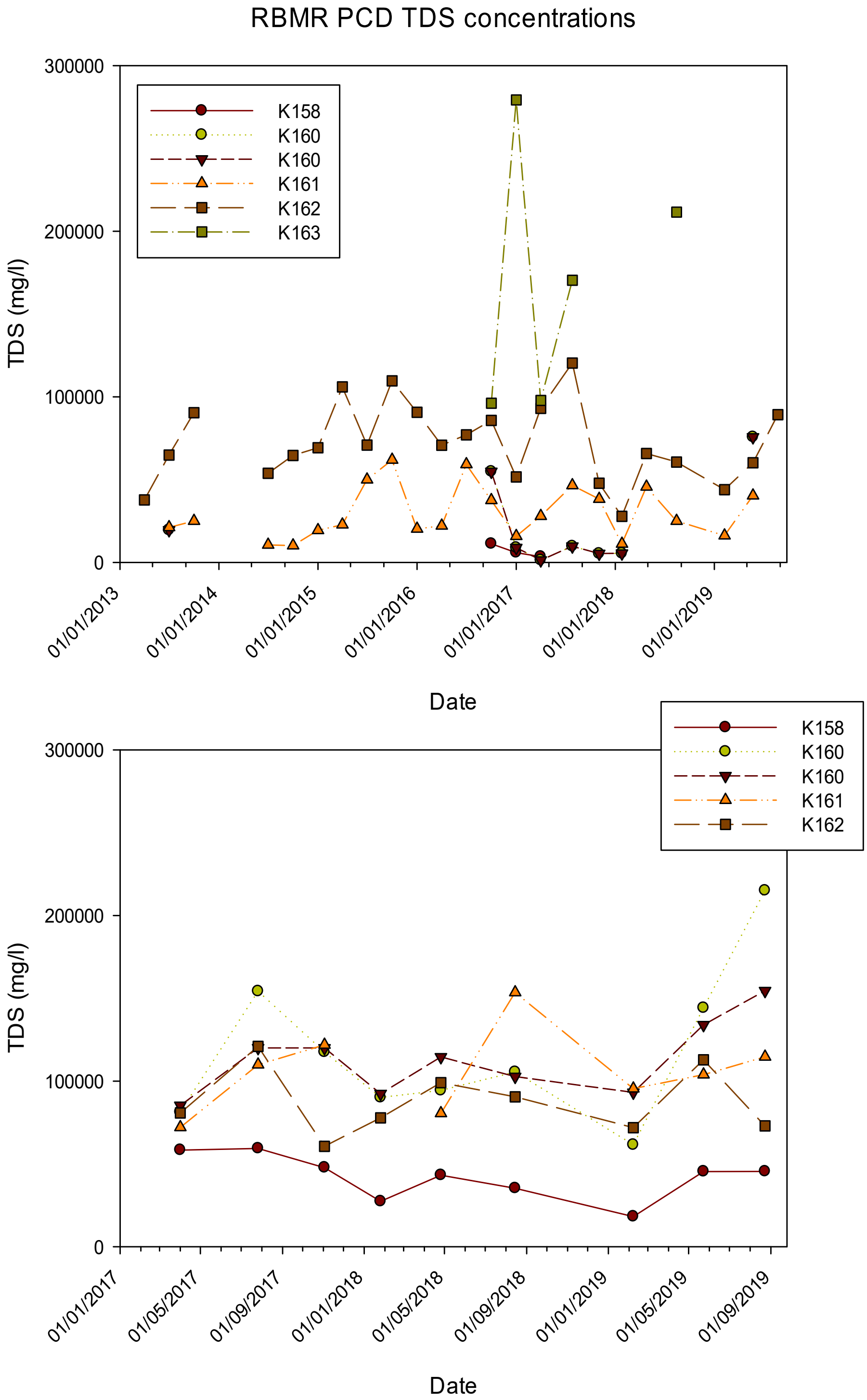



**Figure 13: RBMR PCD TDS concentration trend line graph**

**Table 19: Average RBMR process dams data table for the annual monitoring period**

| | |
|---|---|
| PROJECT NAME | Anglo Rustenburg Surface water monitoring |
| ASSESSMENT SET 1 | General Authorisation Limit, Section 21f and h, 2013 |
| ASSESSMENT SET 2 | AAP Rustenburg - Surface water WUL |

Value exceeds the assessment set 1

| VARIABLE | UNITS | ASSESSMENT 1 | ASSESSMENT 2 | MONITORING LOCALITIES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | K160 | K161 | K162 | K162 duplicate | K220 | K221 | K222 | K223 | K224 |
| pH @ 25°C | pH | 5.5/9.5 | 6.0/9.0 | 2.91 | 5.73 | 10.3 | 10.2 | 10.2 | 9.68 | 9.72 | 8.7 | 9.14 |
| Electrical conductivity (EC) @ 25°C | mS/m | 150 | 85 | 5280 | 2759 | 6503 | 8550 | 3428 | 10098 | 10163 | 8695 | 7143 |
| Total dissolved solids (TDS) | mg/l | - | - | 54355 | 27115 | 63452 | 102629 | 36059 | 141017 | 155586 | 107064 | 92011 |
| Total hardness | mg CaCO3/l | - | 50 | 548 | 167 | 105 | 111 | 113 | 434 | 555 | 123 | 325 |
| Calcium (Ca) | mg/l | - | - | 89.5 | 50.9 | 39.7 | 44.6 | 35.8 | 135 | 185 | 42.3 | 116 |
| Magnesium (Mg) | mg/l | - | - | 78.9 | 9.59 | *1.42* | *0.039* | *5.88* | 23.7 | 22.6 | *4.26* | *8.48* |
| Sodium (Na) | mg/l | - | - | 16715 | 8884 | 20552 | 35287 | 12322 | 47851 | 53000 | 35023 | 28346 |
| Potassium (K) | mg/l | - | - | 33.7 | 34.4 | 112 | 114 | 36.7 | 1999 | 1633 | 502 | 1125 |
| Total alkalinity | mg CaCO3/l | - | - | *0.995* | 126 | 1896 | 1669 | 3883 | 2088 | 5831 | 1326 | 1627 |
| Chloride (Cl) | mg/l | - | - | 8.27 | 69 | 320 | 88 | 723 | 22734 | 12287 | 234 | 600 |
| Sulphate ($SO_4$) | mg/l | - | - | 37378 | 17971 | 41214 | 66050 | 20516 | 66896 | 84701 | 70397 | 60735 |
| Fluoride (F) | mg/l | 1 | 0.75 | *0.653* | 3.96 | 36.2 | 22.8 | 35.9 | 97.7 | 188 | 11.2 | 29 |
| Nitrate ($NO_3$) as N | mg/l | 15 | - | 0.68 | 1.02 | 2.46 | 0.665 | 1.05 | *0.45* | *0.553* | 5.67 | 2.08 |
| Ammonium ($NH_4$) as N | mg/l | 6 | 1 | 1.1 | 3.21 | *0.957* | 0.718 | *2.61* | *0.066* | *0.027* | 1.03 | 0.175 |
| Orthophosphate ($PO_4$) as P | mg/l | 10 | 0.125 | 1.61 | 0.045 | 13 | 8.84 | 17.2 | 21.1 | 15.6 | 4.69 | 3.7 |
| Aluminium (Al) | mg/l | - | 5 | 17.2 | 1.77 | *0.62* | 0.061 | 0.35 | *0.017* | *0.018* | *0.013* | *0.03* |
| Iron (Fe) | mg/l | 0.3 | 0.5 | 176 | *2.86* | 0.456 | 2.86 | 0.194 | 0.894 | 0.854 | *0.52* | 0.407 |
| Manganese (Mn) | mg/l | 0.1 | 0.18 | 10.7 | 1 | *0.001* | *0.001* | *0.001* | *0.005* | *0.001* | *0.001* | *0.001* |
| Chromium (Cr) | mg/l | - | - | 8.36 | 1.27 | *0.021* | *0.002* | *0.004* | *0.032* | *0.095* | *0.061* | *0.101* |
| Copper (Cu) | mg/l | 0.01 | 0.3 | 3139 | 186 | 1.07 | 0.237 | *0.046* | *0.257* | *0.177* | *0.146* | *0.155* |
| Nickel (Ni) | mg/l | - | - | 12591 | 2150 | 6.76 | 0.492 | 0.388 | 0.77 | 0.87 | 0.195 | *0.175* |

In August 2019, two samples were taken from the RBMR triangular dam (K162 west section and K162 duplicate east section). Slight differences in water quality may be seen between the two samples.

### 7.2.2. Discharges, effluents and seepages

Dry conditions persisted at **K013** (Culvert ditch going to Klipfonteinspruit halfway between PMR bridge and Waterval bridge parallel to old railway), **K024** (Outflow of RBMR rain water collection dam), **K062** (Spillway overflow RBMR storm water dam 3B) and **K187** (Trench upstream of RBMR at culvert on access road to South gate) throughout the annual period.

**K044** (Trench to the west of the RBMR dam 3B) was sampled in April 2019. Water quality was neutral, saline and hard with moderate salts and nutrients. High concentrations of fluoride, copper and nickel were detected which would impact the Klipfonteinspruit.

**K059** (Culvert at railway entry to RBMR) was sampled in January 2019, recording water quality that was alkaline, extremely saline and very hard with high concentrations of sodium and sulphate as well as fluoride.

### 7.2.3. Receiving environment

The upstream locality of RBMR, **K012** (Klipfonteinspruit between PMR and RBMR on old road to magazine) was sampled in January, February and April 2019, recording dry conditions throughout the rest of the annual period. **K028** is used as the downstream locality of RBMR and was sampled throughout the annum. The average water quality revealed significant deteriorating conditions from the upstream to the downstream locality at RBMR. Sulphate, fluoride and nickel concentrations revealed the most significant increases and may be as a direct result of process water from the RBMR dams which are dominated by these constituents.

Figure 14 shows the average water quality profiles of localities upstream (K012), midstream (K014 and K023) and downstream (K028) of RBMR in the Klipfonteinspruit. These water quality profiles may be compared with those in Figure 12 for the RBMR process water dams.

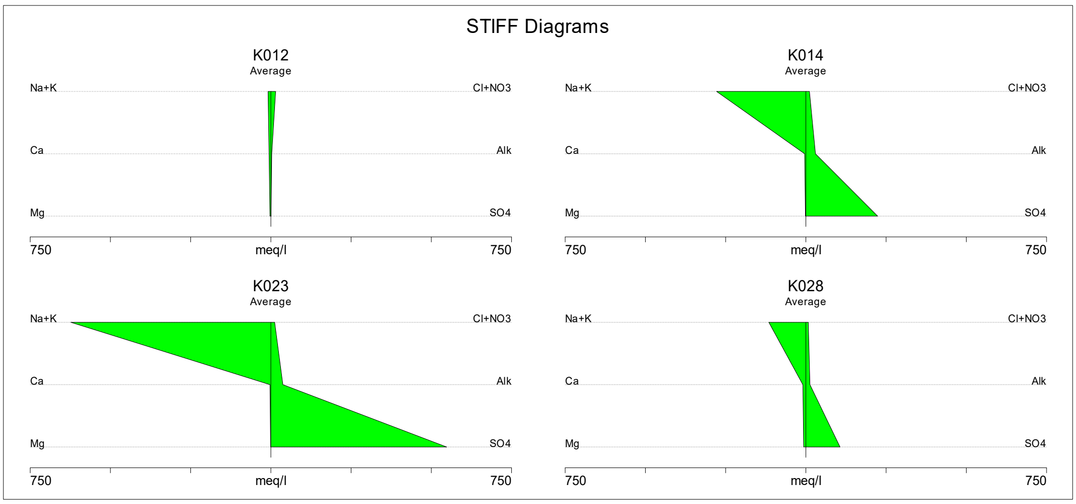



**Figure 14: STIFF diagrams showing the water quality profiles of the Klipfonteinspruit, up-, mid- and downstream of RBMR.**

The Klipfonteinspruit is discussed in greater detail under section 8.1.

**Table 20: Average spatial assessment for the BMR impacts on the Klipfonteinspruit**

| VARIABLE | UNIT | AAP Rustenburg - Surface water WUL | Locality | | CALCULATED CHANGE |
|---|---|---|---|---|---|
| | | | Upstream | Downstream | |
| | | | K012 | K028 | |
| pH @ 25°C | pH | 6.0/9.0 | 8.19 | 8.74 | 0.55 |
| Electrical conductivity (EC) @ 25°C | mS/m | 85 | 162 | 1318 | 1156 |
| Total dissolved solids (TDS) | mg/l | - | 1007 | 8749 | 7742 |
| Total hardness | mg CaCO3/l | 50 | 432 | 822 | 390 |
| Total alkalinity | mg CaCO3/l | - | 142 | 637 | 495 |
| Chloride (Cl) | mg/l | - | 523 | 267 | -256 |
| Sulphate ($SO_4$) | mg/l | - | 29.3 | 5113 | 5084 |
| Fluoride (F) | mg/l | 0.75 | *0.132* | 11.3 | 11.2 |
| Nitrate ($NO_3$) as N | mg/l | - | 0.244 | 0.692 | 0.448 |
| Ammonium ($NH_4$) as N | mg/l | 1 | 0.099 | 0.235 | 0.136 |
| Orthophosphate ($PO_4$) as P | mg/l | 0.125 | *0.007* | *1.95* | 1.94 |
| Calcium (Ca) | mg/l | - | 113 | 189 | 76 |
| Magnesium (Mg) | mg/l | - | 36 | 84.7 | 48.7 |
| Sodium (Na) | mg/l | - | 199 | 2631 | 2432 |
| Potassium (K) | mg/l | - | 6.43 | 41.3 | 34.9 |
| Aluminium (Al) | mg/l | 5 | *0.001* | *0.005* | 0.004 |
| Iron (Fe) | mg/l | 0.5 | *0.002* | *0.1* | 0.098 |
| Manganese (Mn) | mg/l | 0.18 | *0.001* | *0.48* | 0.479 |
| Chromium (Cr) | mg/l | - | *0.002* | *0.011* | 0.009 |
| Copper (Cu) | mg/l | 0.3 | 0.017 | 0.369 | 0.352 |
| Nickel (Ni) | mg/l | - | *0.013* | 11.4 | 11.4 |

## Table 21: Average RBMR receiving environment data table for the annual monitoring period

| AVERAGE DATA TABLE: | |
|---|---|
| PROJECT NAME | Anglo Rustenburg Surface w ater monitoring |
| ASSESSMENT SET 1 | AAP Rustenburg - Surface w ater WUL |
| ASSESSMENT SET 2 | SANS 241-1:2015 Drinking Water Standard (SABS, 2015) |
| | Value exceeds the assessment set 1 |

| VARIABLE | UNITS | ASSESSMENT 1 | ASSESSMENT 2 | MONITORING LOCALITIES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | K012 | K014 | K015 | K023 | K028 | K013 | K044 | K059 |
| pH @ 25°C | pH | 6.0/9.0 | 5.0/9.7 | 8.19 | 9.95 | 10.1 | 10.1 | 8.74 | 10.5 | 8.14 | 8.94 |
| Electrical conductivity (EC) @ 25°C | mS/m | 85 | 170 | 162 | 3421 | 4690 | 4840 | 1318 | 5025 | 225 | 509 |
| Total dissolved solids (TDS) | mg/l | - | 1200 | 1007 | 18619 | 33947 | 42350 | 8749 | 36903 | 1415 | 4358 |
| Total hardness | mg CaCO3/l | 50 | - | 432 | 267 | 229 | 187 | 822 | 109 | 281 | 381 |
| Calcium (Ca) | mg/l | - | - | 113 | 76.8 | 67.3 | 56.5 | 189 | 34 | 82.2 | 114 |
| Magnesium (Mg) | mg/l | - | - | 36 | 18.3 | 14.8 | 11.1 | 84.7 | 5.76 | 18.3 | 23.2 |
| Sodium (Na) | mg/l | - | 200 | 199 | 6350 | 11205 | 14267 | 2631 | 12104 | 372 | 1177 |
| Potassium (K) | mg/l | - | - | 6.43 | 79.4 | 123 | 105 | 41.3 | 145 | 12.9 | 13.3 |
| Chloride (Cl) | mg/l | - | 300 | 523 | 393 | 438 | 416 | 267 | 320 | 146 | 38.3 |
| Sulphate ($SO_4$) | mg/l | - | 500 | 29.3 | 10738 | 20877 | 26305 | 5113 | 22913 | 620 | 2807 |
| Fluoride (F) | mg/l | 0.75 | 1.5 | 0.132 | 23.1 | 36.4 | 31 | 11.3 | 25.5 | 15.3 | 1.32 |
| Nitrate ($NO_3$) as N | mg/l | - | 11 | 0.244 | 1.63 | 0.919 | 1.15 | 0.692 | 1.23 | 1.47 | 0.437 |
| Ammonium ($NH_4$) as N | mg/l | 1 | 1.5 | 0.099 | 0.378 | 0.185 | 0.099 | 0.235 | 0.066 | 1.74 | 0.223 |
| Orthophosphate ($PO_4$) as P | mg/l | 0.125 | - | 0.007 | 6.73 | 11.7 | 15 | 1.95 | 11 | 0.08 | 0.589 |
| Ortophosphate as $PO_4$ | mg/l | 0.234 | - | 0.02 | 20.6 | 35.9 | 46 | 5.97 | 33.8 | 0.245 | 1.81 |
| Aluminium (Al) | mg/l | 5 | 0.3 | 0.001 | 0.445 | 0.638 | 0.301 | 0.005 | 0.531 | 0.077 | 0.001 |
| Iron (Fe) | mg/l | 0.5 | 0.3 | 0.002 | 0.171 | 0.262 | 0.472 | 0.1 | 0.403 | 0.13 | 0.002 |
| Manganese (Mn) | mg/l | 0.18 | 0.1 | 0.001 | 0.539 | 0.113 | 0.061 | 0.48 | 0.001 | 0.183 | 0.023 |
| Chromium (Cr) | mg/l | - | 0.05 | 0.002 | 0.037 | 0.038 | 0.07 | 0.011 | 0.054 | 0.002 | 0.033 |
| Copper (Cu) | mg/l | 0.3 | 2 | 0.017 | 0.192 | 0.195 | 0.2 | 0.369 | 0.543 | 1.85 | 0.037 |
| Nickel (Ni) | mg/l | - | 0.07 | 0.013 | 0.082 | 0.057 | 0.063 | 11.4 | 0.002 | 32.2 | 0.074 |
| Dissolved oxygen (DO) | mg/l | 7.0/8.0 | - | 2.4 | 3.05 | 1.92 | 1.95 | 3.58 | 3.07 | 1.79 | - |
| Lead (Pb) | mg/l | - | 0.01 | 0.002 | 0.019 | 0.033 | 0.043 | 0.018 | 0.064 | 0.076 | 0.002 |
| Zinc (Zn) | mg/l | - | 5 | 0.001 | 0.028 | 0.061 | 0.081 | 0.108 | 0.091 | 0.217 | 0.031 |
| Boron (B) | mg/l | - | 2.4 | 0.026 | 23.2 | 39.8 | 29.7 | 10.3 | 42.7 | 3.12 | 4.8 |
| Phenol | mg/l | - | 0.01 | 0.008 | 0.005 | 0.005 | 0.005 | 0.006 | 0.005 | 0.005 | - |
| Hexavalent chromium ($Cr^{6+}$) | mg/l | 0.0049 | - | 0.001 | 0.011 | 0.009 | 0.009 | 0.001 | 0.001 | 0.001 | 0.001 |
| Arsenic (As) | mg/l | - | 0.01 | 0.003 | 0.03 | 0.043 | 0.042 | 0.009 | 0.037 | 0.003 | - |
| Cadmium (Cd) | mg/l | - | 0.003 | 0.001 | 0.007 | 0.007 | 0.004 | 0.004 | 0.001 | 0.001 | 0.001 |
| Mercury (Hg) | mg/l | - | 0.006 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | - |
| Selenium (Se) | mg/l | - | 0.04 | 0.001 | 0.021 | 0.027 | 0.024 | 0.013 | 0.032 | 0.001 | - |
| E.coli | CFU/100ml | - | 0 | - | - | - | - | 8.96 | - | - | - |
| Total coliform | CFU/100ml | - | 10 | - | - | - | - | 72.38 | - | - | - |

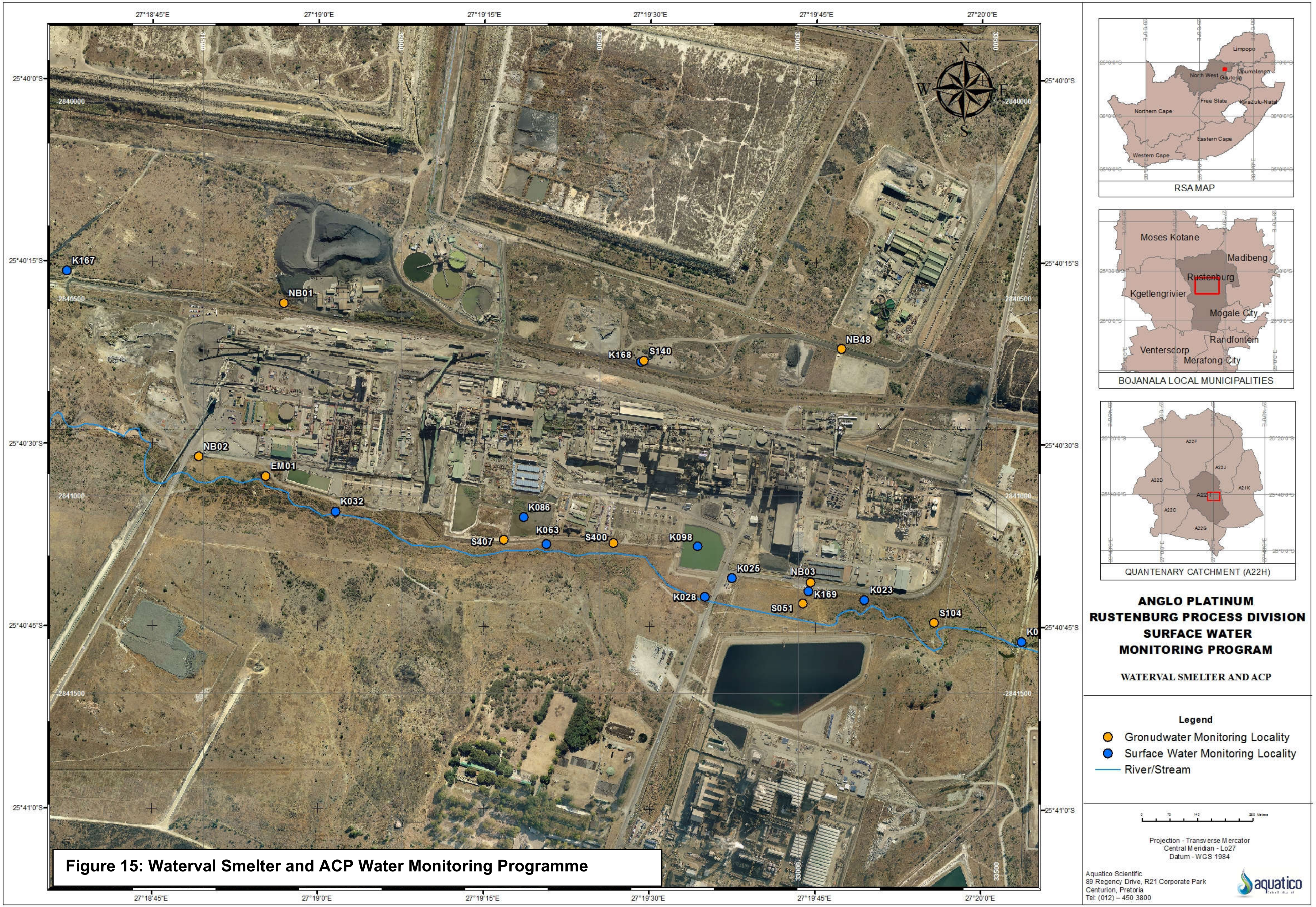



**Figure 15: Waterval Smelter and ACP Water Monitoring Programme**

**Table 22: Waterval Smelter and ACP sampling register of the surface water monitoring conducted during the annual period**

| Anglo Rustenburg Surface water monitoring | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canal or trench | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K025 | Intersection between electric pylons & compressor air pipe between RBMR and lab. Storm water canal from ACP | Dry | Dry | Dry | Dry | ● | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| K167 | Cut-off trench north of Waterval concentrator just before discharge towards Klipfonteinspruit | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | Dry | Dry |
| K168 | Cut off trench north of Waterval Smelter reverts area | Dry | Dry | Dry | Dry | ● | ● | ● | ● | ● | Dry | Dry | Dry |
| K169 | Trench from PF Retief laboratory towards Klipfonteinspruit | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | Not sampled | ● |
| Pollution control dam | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K098 | ACP Pollution Control Dam | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| River or stream | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K014 | Intersection of Klipfonteinspruit and rail line bridge (south side) | Dry | Dry | ● | Dry | ● | ● | Dry | ● | ● | Too low | ● | Dry |
| K023 | Klipfonteinspruit at base of RBMR dump | Dry | Dry | Dry | Dry | ● | ● | ● | ● | ● | ● | ● | ● |
| K028 | Klipfonteinspruit after confluence of RBMR west ditch system at Waterval smelter bridge | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| K063 | Klipfonteinspruit at stormwater discharge from Waterval smelter and concentrator | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |

*● – Sampled

## 7.3. WATERVAL SMELTER AND ACP

Presented in Table 22 is the frequency of sampling at each Waterval Smelter and ACP monitoring locality during the annual period. Additionally, the average data tables are illustrated in Table 23 and Table 25, which are discussed separately according to the relevant sections below.

### 7.3.1. Process water

The ACP Pollution Control Dam (**K098**) was sampled throughout the annual period. Values of pH alternated between acidic to alkaline throughout the annum. The physical and chemical water quality fluctuated significantly throughout the annual period. Water quality was recorded as saline to extremely saline and very hard with moderate to high concentrations of inorganic salts and nutrients on average. Concentrations of fluoride and heavy metals (aluminium, iron, manganese, copper and nickel) were recorded when the pH was acidic. Increasing acidity (lowering op pH value) results in the mobilisation of suspended metals into solution, often resulting in an increase in recorded metal concentrations (if present in suspension). A graph showing increased EC and Ni concentrations when the pH decreases is shown in Figure 17. WUL, Domestic, irrigation and livestock watering guidelines are exceeded and freeboard should be managed to prevent overflows.

The new WUL (2018) does not include any guidelines for water to be stored in a process water dam or wastewater to be disposed of into a waste water facility. The general authorisation limit guidelines and the WUL limits for surface water are therefore used for comparative purposes in Table 23. The Stiff diagrams below also show how the physical and chemical water quality is altered over the annual period.

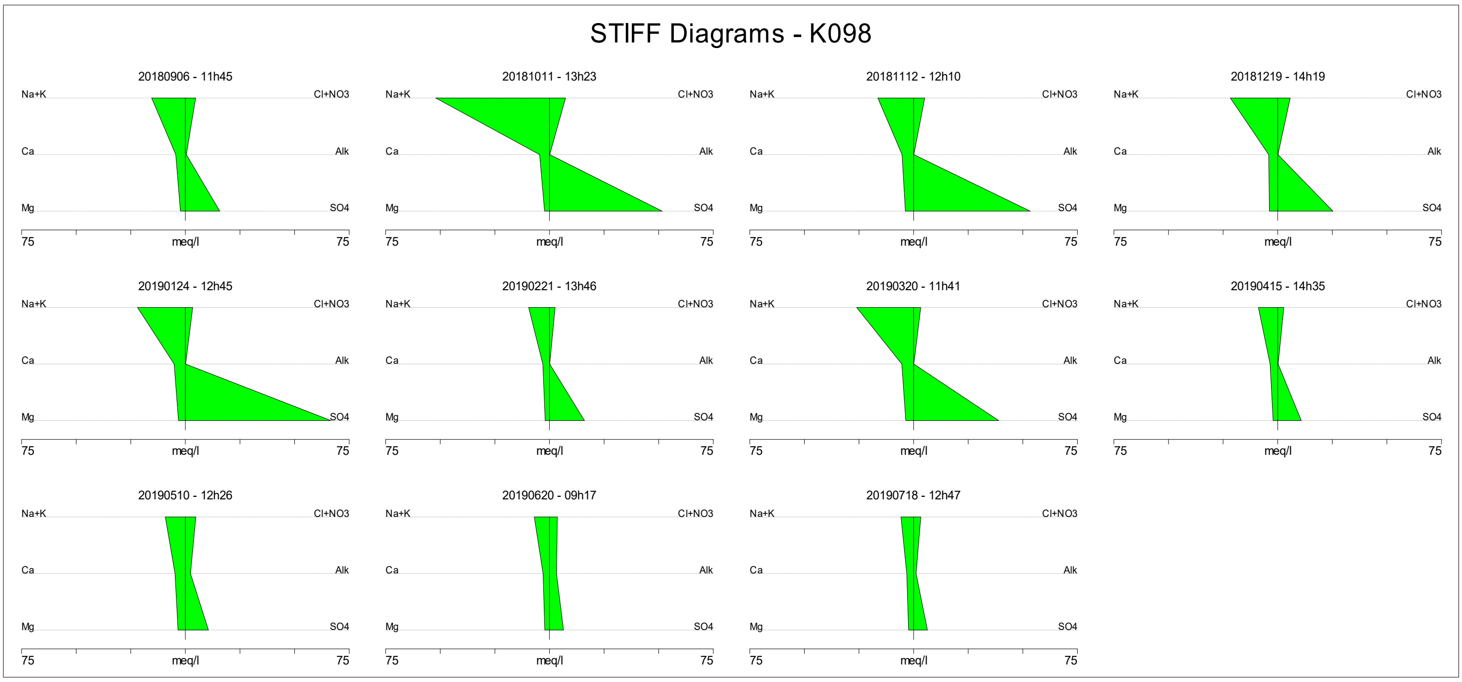



**Figure 16: Time-series STIFF diagrams of the ACP Pollution Control Dam.**

**Table 23: Average Waterval Smelter and ACP process dam data table for the annual monitoring period**

| AVERAGE DATA TABLE: | | | | |
|---|---|---|---|---|
| PROJECT NAME | | | | Anglo Rustenburg Surface water monitoring |
| ASSESSMENT SET 1 | | | | General Authorisation Limit, Section 21f and h, 2013 |
| ASSESSMENT SET 2 | | | | AAP Rustenburg - Surface water WUL |
| | | | | Value exceeds the assessment set 1 |
| VARIABLE | UNITS | ASSESSMENT 1 | ASSESSMENT 2 | MONITORING LOCALITIES |
| | | | | K098 |
| pH @ 25°C | pH | 5.5/9.5 | 6.0/9.0 | 4.62 |
| Electrical conductivity (EC) @ 25°C | mS/m | 150 | 85 | 432 |
| Total dissolved solids (TDS) | mg/l | - | - | 2068 |
| Total hardness | mg CaCO3/l | - | 50 | 350 |
| Calcium (Ca) | mg/l | - | - | 84.3 |
| Magnesium (Mg) | mg/l | - | - | 33.9 |
| Sodium (Na) | mg/l | - | - | 391 |
| Potassium (K) | mg/l | - | - | 24 |
| Chloride (Cl) | mg/l | - | - | 134 |
| Sulphate ($SO_4$) | mg/l | - | - | 1318 |
| Fluoride (F) | mg/l | 1 | 0.75 | *1.27* |
| Nitrate ($NO_3$) as N | mg/l | 15 | - | 6.51 |
| Ammonium ($NH_4$) as N | mg/l | 6 | 1 | 1.09 |
| Orthophosphate ($PO_4$) as P | mg/l | 10 | 0.125 | *0.758* |
| Aluminium (Al) | mg/l | - | 5 | *5.59* |
| Iron (Fe) | mg/l | 0.3 | 0.5 | *47.2* |
| Manganese (Mn) | mg/l | 0.1 | 0.18 | *0.407* |
| Chromium (Cr) | mg/l | - | - | *0.166* |
| Copper (Cu) | mg/l | 0.01 | 0.3 | 4.6 |
| Nickel (Ni) | mg/l | - | - | 10.1 |

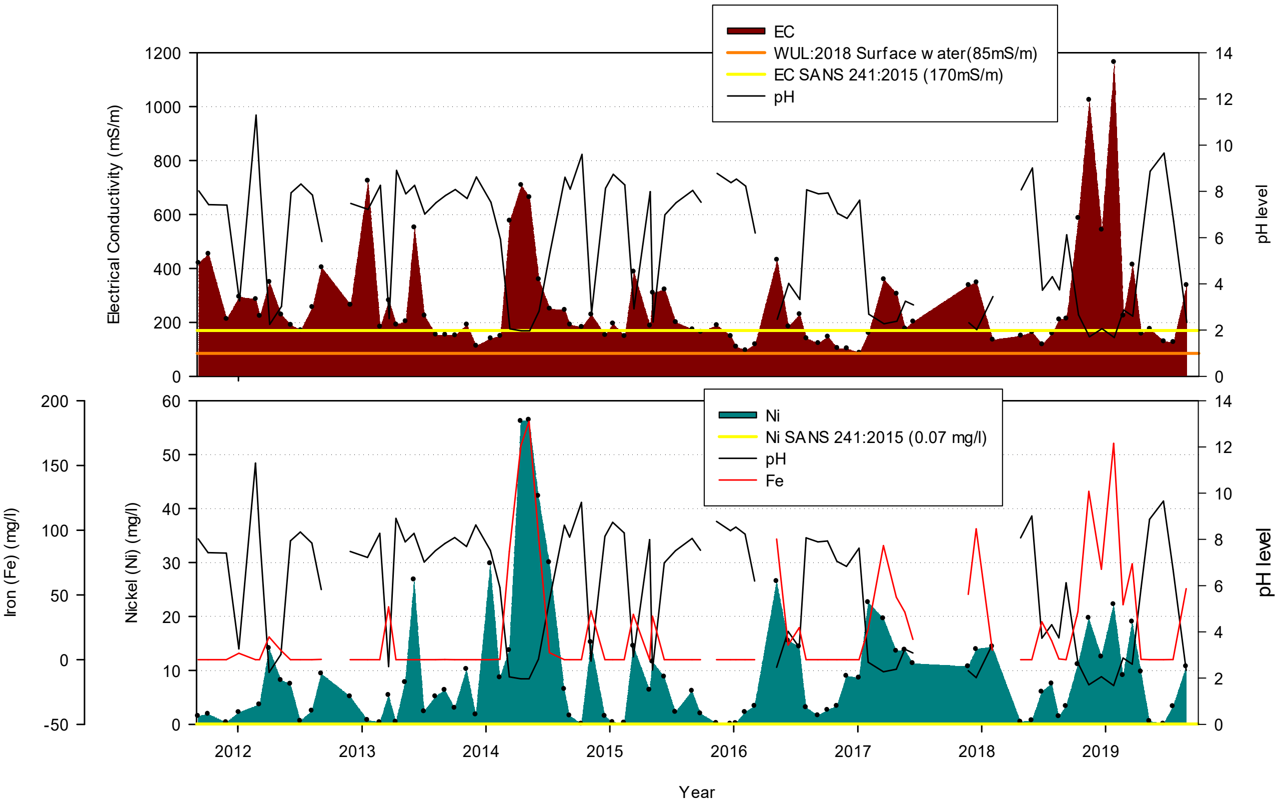



**Figure 17: ACP pollution control dam (K098) time-series data for pH, EC, iron and nickel**

### 7.3.2. Discharges, effluents and seepages

**K025** (Stormwater from ACP into Klipfonteinspruit between K014 and K028) was sampled once throughout the annual period and recorded neutral, very saline and very hard water quality. High concentrations of fluoride and nickel was detected in the water sample.

**K168** (Cut off trench north of Waterval Smelter into Klipfonteinspruit) will flow towards the Klipfonteinspruit during high flow events. This locality was sampled on five occasions during the annual period. The average water quality was recorded as neutral, extremely saline and very hard with high concentrations of inorganic salts. High average concentrations of fluoride, manganese, nickel, nitrate and ammonium were detected. This source is seen to be an important contributor to the water quality of the Klipfonteinspruit.

**K167** (Cut off trench north of Waterval Smelter into Klipfonteinspruit) was sampled mostly throughout the annual period. Average water quality was similar to K168 with high salinity and hardness and concentrations of fluoride, manganese and nickel. Water discharged from this locality into the Klipfonteinspruit will contribute to negative effects on the water quality of the Klipfonteinspruit.

In the PF Retief culvert (**K169**) the average water quality may be described as neutral, very saline and very hard. Moderate inorganic salt concentrations and sporadic high nutrient and low heavy metal concentrations were detected.

### 7.3.3. Receiving environment

**K023** and **K063** are used as the up- and downstream localities for the Waterval complex on the Klipfonteinspruit. The only significant increases in analysed variables detected were nitrate and nickel. The majority of the analysed variables revealed a noteworthy decrease in concentration which may be explained by the reed bed that the Klipfonteinspruit flows through next to the Waterval complex. The naturally growing reed bed creates an ecological water-filtration system that takes up inorganic salts, nutrients and metals from the water. The presence of the reed bed helps improve water quality in the Klipfonteinspruit. The Klipfonteinspruit as a whole is discussed in greater detail under section 8.1.

**Table 24: Average smelter and ACP impacts on the Klipfonteinspruit**

| VARIABLE | UNIT | AAP Rustenburg - Surface water WUL | Locality | | CALCULATED CHANGE |
|---|---|---|---|---|---|
| | | | Upstream | Downstream | |
| | | | K023 | K063 | |
| pH @ 25°C | pH | 6.0/9.0 | 10.1 | 7.89 | -2.21 |
| Electrical conductivity (EC) @ 25°C | mS/m | 85 | 4840 | 200 | -4640 |
| Total dissolved solids (TDS) | mg/l | - | 42350 | 1382 | -40968 |
| Total hardness | mg CaCO3/l | 50 | 187 | 291 | 104 |
| Total alkalinity | mg CaCO3/l | - | 1867 | 152 | -1715 |
| Chloride (Cl) | mg/l | - | 416 | 138 | -278 |
| Sulphate ($SO_4$) | mg/l | - | 26305 | 636 | -25669 |
| Fluoride (F) | mg/l | 0.75 | 31 | 0.997 | -30 |
| Nitrate ($NO_3$) as N | mg/l | - | 1.15 | 12.5 | 11.4 |
| Ammonium ($NH_4$) as N | mg/l | 1 | *0.099* | 0.162 | 0.063 |
| Orthophosphate ($PO_4$) as P | mg/l | 0.125 | 15 | 2.65 | -12.4 |
| Calcium (Ca) | mg/l | - | 56.5 | 81.3 | 24.8 |
| Magnesium (Mg) | mg/l | - | *11.1* | 21.3 | 10.2 |
| Sodium (Na) | mg/l | - | 14267 | 325 | -13942 |
| Potassium (K) | mg/l | - | 105 | 15.5 | -89.5 |
| Aluminium (Al) | mg/l | 5 | *0.301* | *0.017* | -0.284 |
| Iron (Fe) | mg/l | 0.5 | 0.472 | *0.002* | -0.47 |
| Manganese (Mn) | mg/l | 0.18 | *0.061* | *0.095* | 0.034 |
| Chromium (Cr) | mg/l | - | 0.07 | *0.002* | -0.068 |
| Copper (Cu) | mg/l | 0.3 | *0.2* | 0.114 | -0.086 |
| Nickel (Ni) | mg/l | - | *0.063* | 1.24 | 1.18 |

**Table 25: Average Waterval Smelter and ACP receiving environment data table for the annual monitoring period**

| AVERAGE DATA TABLE: | |
|---|---|
| PROJECT NAME | Anglo Rustenburg Surface water monitoring |
| ASSESSMENT SET 1 | AAP Rustenburg - Surface water WUL |
| ASSESSMENT SET 2 | SANS 241-1:2015 Drinking Water Standard (SABS, 2015) |
| | Value exceeds the assessment set 1 |

| VARIABLE | UNITS | ASSESSMENT 1 | ASSESSMENT 2 | MONITORING LOCALITIES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | K025 | K167 | K168 | K169 | K014 | K023 | K028 | K063 |
| pH @ 25°C | pH | 6.0/9.0 | 5.0/9.7 | 8.44 | 7.6 | 7.71 | 8.03 | 9.95 | 10.1 | 8.74 | 7.89 |
| Electrical conductivity (EC) @ 25°C | mS/m | 85 | 170 | 234 | 542 | 415 | 155 | 3421 | 4840 | 1318 | 200 |
| Total dissolved solids (TDS) | mg/l | - | 1200 | 1996 | 4222 | 3431 | 1203 | 18619 | 42350 | 8749 | 1382 |
| Total hardness | mg CaCO3/l | 50 | - | 1256 | 1572 | 1481 | 771 | 267 | 187 | 822 | 291 |
| Calcium (Ca) | mg/l | - | - | 305 | 478 | 390 | 166 | 76.8 | 56.5 | 189 | 81.3 |
| Magnesium (Mg) | mg/l | - | - | 120 | 91.7 | 123 | 86.8 | 18.3 | 11.1 | 84.7 | 21.3 |
| Sodium (Na) | mg/l | - | 200 | 139 | 733 | 493 | 105 | 6350 | 14267 | 2631 | 325 |
| Potassium (K) | mg/l | - | - | 17 | 54.7 | 44.1 | 7.12 | 79.4 | 105 | 41.3 | 15.5 |
| Chloride (Cl) | mg/l | - | 300 | 239 | 820 | 607 | 156 | 393 | 416 | 267 | 138 |
| Sulphate ($SO_4$) | mg/l | - | 500 | 1000 | 1969 | 1631 | 506 | 10738 | 26305 | 5113 | 636 |
| Fluoride (F) | mg/l | 0.75 | 1.5 | 21.6 | 1.07 | 3.72 | 0.415 | 23.1 | 31 | 11.3 | 0.997 |
| Nitrate ($NO_3$) as N | mg/l | - | 11 | 2.8 | 4.57 | 11.1 | 1.55 | 1.63 | 1.15 | 0.692 | 12.5 |
| Ammonium ($NH_4$) as N | mg/l | 1 | 1.5 | 0.054 | 0.402 | 6.68 | 4.85 | 0.378 | 0.099 | 0.235 | 0.162 |
| Orthophosphate ($PO_4$) as P | mg/l | 0.125 | - | 0.088 | 0.014 | 0.003 | 0.801 | 6.73 | 15 | 1.95 | 2.65 |
| Ortophosphate as $PO_4$ | mg/l | 0.234 | - | 0.27 | 0.043 | 0.008 | 2.46 | 20.6 | 46 | 5.97 | 8.13 |
| Aluminium (Al) | mg/l | 5 | 0.3 | 0.001 | 0.003 | 0.005 | 0.002 | 0.445 | 0.301 | 0.005 | 0.017 |
| Iron (Fe) | mg/l | 0.5 | 0.3 | 0.002 | 0.069 | 0.002 | 0.002 | 0.171 | 0.472 | 0.1 | 0.002 |
| Manganese (Mn) | mg/l | 0.18 | 0.1 | 0.418 | 0.208 | 1.12 | 0.097 | 0.539 | 0.061 | 0.48 | 0.095 |
| Chromium (Cr) | mg/l | - | 0.05 | 0.013 | 0.002 | 0.004 | 0.002 | 0.037 | 0.07 | 0.011 | 0.002 |
| Copper (Cu) | mg/l | 0.3 | 2 | 0.761 | 0.029 | 0.199 | 0.007 | 0.192 | 0.2 | 0.369 | 0.114 |
| Nickel (Ni) | mg/l | - | 0.07 | 40.1 | 1.27 | 19.8 | 0.487 | 0.082 | 0.063 | 11.4 | 1.24 |
| Dissolved oxygen (DO) | mg/l | 7.0/8.0 | - | 3.22 | 3.28 | 2.54 | 1.38 | 3.05 | 1.95 | 3.58 | 3.33 |
| Lead (Pb) | mg/l | - | 0.01 | 0.002 | 0.002 | 0.002 | 0.004 | 0.019 | 0.043 | 0.018 | 0.003 |
| Zinc (Zn) | mg/l | - | 5 | 0.27 | 0.045 | 0.11 | 0.089 | 0.028 | 0.081 | 0.108 | 0.01 |
| Boron (B) | mg/l | - | 2.4 | 0.16 | 0.852 | 0.619 | 0.18 | 23.2 | 29.7 | 10.3 | 0.868 |
| Phenol | mg/l | - | 0.01 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.006 | 0.005 |
| Hexavalent chromium ($Cr^{6+}$) | mg/l | 0.0049 | - | 0.001 | 0.001 | 0.001 | 0.001 | 0.011 | 0.009 | 0.001 | 0.001 |
| Arsenic (As) | mg/l | - | 0.01 | 0.003 | 0.003 | 0.003 | 0.003 | 0.03 | 0.042 | 0.009 | 0.003 |
| Cadmium (Cd) | mg/l | - | 0.003 | 0.001 | 0.003 | 0.002 | 0.001 | 0.007 | 0.004 | 0.004 | 0.001 |
| Mercury (Hg) | mg/l | - | 0.006 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Selenium (Se) | mg/l | - | 0.04 | 0.001 | 0.001 | 0.001 | 0.001 | 0.021 | 0.024 | 0.013 | 0.001 |
| Oil and grease (SOG) | mg/l | - | - | - | 405 | 0.899 | 2.81 | - | - | - | - |
| E.coli | CFU/100ml | - | 0 | - | - | - | - | - | - | 8.96 | 659.67 |
| Total coliform | CFU/100ml | - | 10 | - | - | - | - | - | - | 72.38 | 2771.67 |

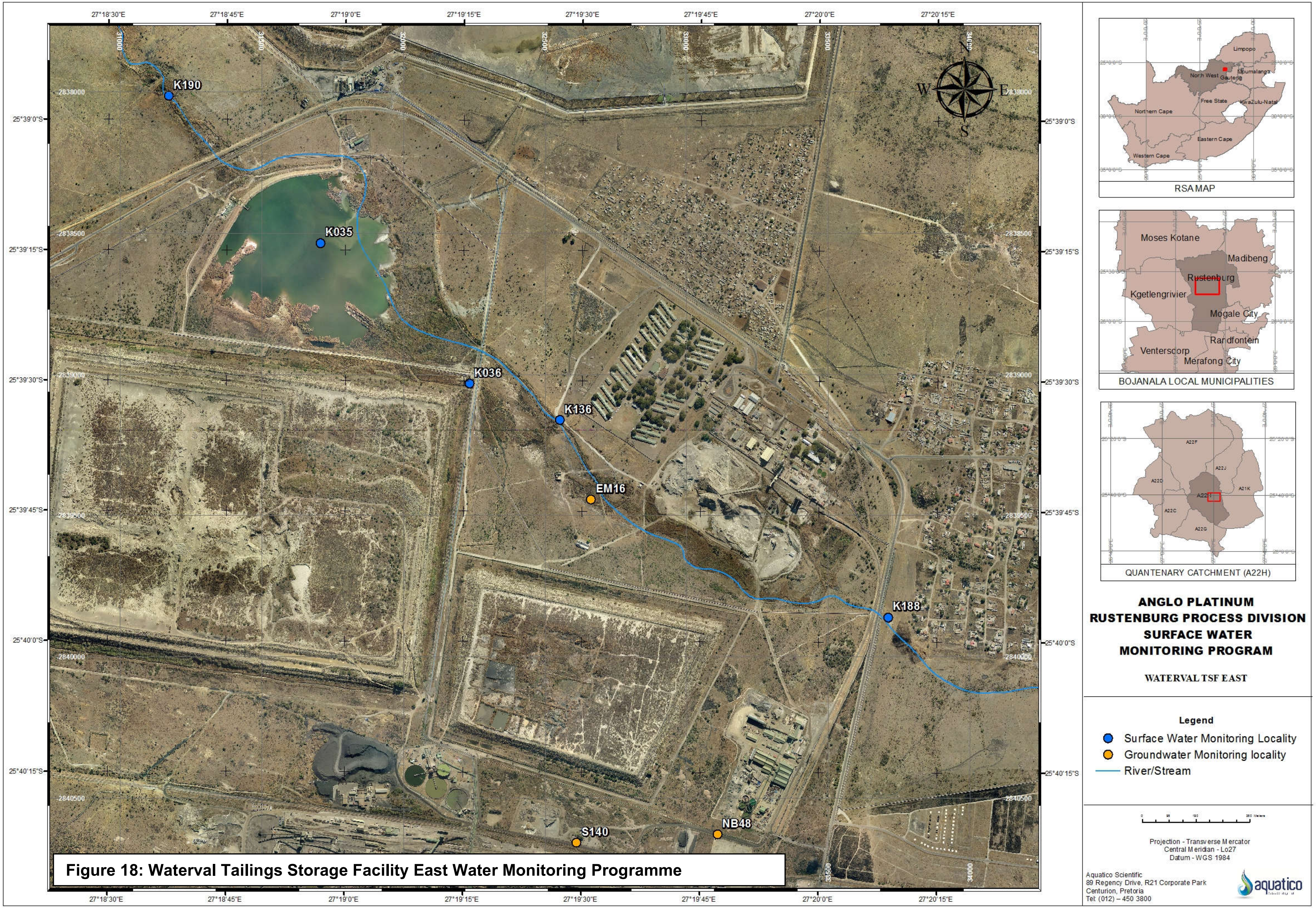



**Figure 18: Waterval Tailings Storage Facility East Water Monitoring Programme**

**Table 26: WVE TSF sampling register of the surface water monitoring conducted during the annual period**

| Anglo Rustenburg Surface water monitoring | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Effluent | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K036 | Inflow into Klipgat return water dam from Waterval tailings dam 7-stream and Khomanani I Shaft sump canal | • | • | • | • | • | • | • | • | • | • | • | • |
| K034 | Spillway overflow of Klipgat Return Water Dam | Dry | Dry | Dry | Dry | Dry | Dry | Dry | • | Dry | Dry | • | Dry |
| River or stream | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K188 | Klipgatspruit, downstream of Mfidikoe village, upstream of Khomanani I Shaft (Frank I Shaft), Frank Concentrator and Waterval Complex | Dry | Dry | Dry | Dry | Dry | Dry | Dry | • | Dry | Dry | • | • |
| K136 | Klipgatspruit, downstream of Entabeni Hostel at Khomanani I Shaft (Frank I Shaft) | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| K190 | Klipgatspruit, downstream of Klipgat Return Water Dam and Waterval Tailings | • | • | • | • | Dry | • | • | • | • | • | • | • |
| Return water dam | | | | | | | | | | | | | |
| Monitoring Localities | | Sep 2018 | Oct 2018 | Nov 2018 | Dec 2018 | Jan 2019 | Feb 2019 | Mar 2019 | Apr 2019 | May 2019 | Jun 2019 | Jul 2019 | Aug 2019 |
| K035 | Klipgat Return Water Dam of Waterval Tailings | • | • | • | • | • | • | • | • | • | • | • | • |

*• – Sampled

## 7.4. WATERVAL-EAST TAILINGS STORAGE FACILITY

Presented in Table 26 is the frequency of sampling at each Waterval East TSF monitoring locality during the annual period. Additionally the average data tables are illustrated within Table 27 and Table 29, results are discussed separately according to the relevant sections below.

### 7.4.1. Process water

Klipgat RWD (**K035**), part of the Waterval Tailings Storage Facility, is characterised by elevated TDS/EC and total hardness dominated by the sulphate anion and sodium cation. Average TDS for the current annum measured 4420 mg/l, with an average total hardness of 1560 mg/l. Inorganic salt concentrations and nutrients in the form of nitrate and ammonium were high throughout the annum. Most metals were below detection limits while sporadic high concentrations of manganese, chrome and nickel were detected during the annual period. *E.coli* and total coliforms recorded high counts throughout the monitoring period. The water quality is classified as *Unacceptable (class 04)* for Domestic Use. Domestic, irrigation, aquatic ecosystems and livestock watering guidelines at the Klipgat Dam were exceeded. There are no WUL conditions for wastewater disposed of into the dams for the new 2018 WUL. The general authorisation limits and WUL for surface water limits were exceeded for multiple variables, including EC, nitrate, ammonium and SOG. The water quality profile remained stable throughout the annum, as indicated by the STIFF diagrams (Figure 19).

Water quality for the inflow into Klipgat dam (**K036**) also had elevated average TDS (4395 mg/l) and inorganic salt concentrations. This locality revealed similar STIFF diagrams (water quality) as compared to **K035**. Average nutrient concentrations (nitrate, ammonium and phosphate) were lower than those found at **K035**. **K036** also recorded high concentrations of manganese, copper and nickel which fluctuated throughout the annum.

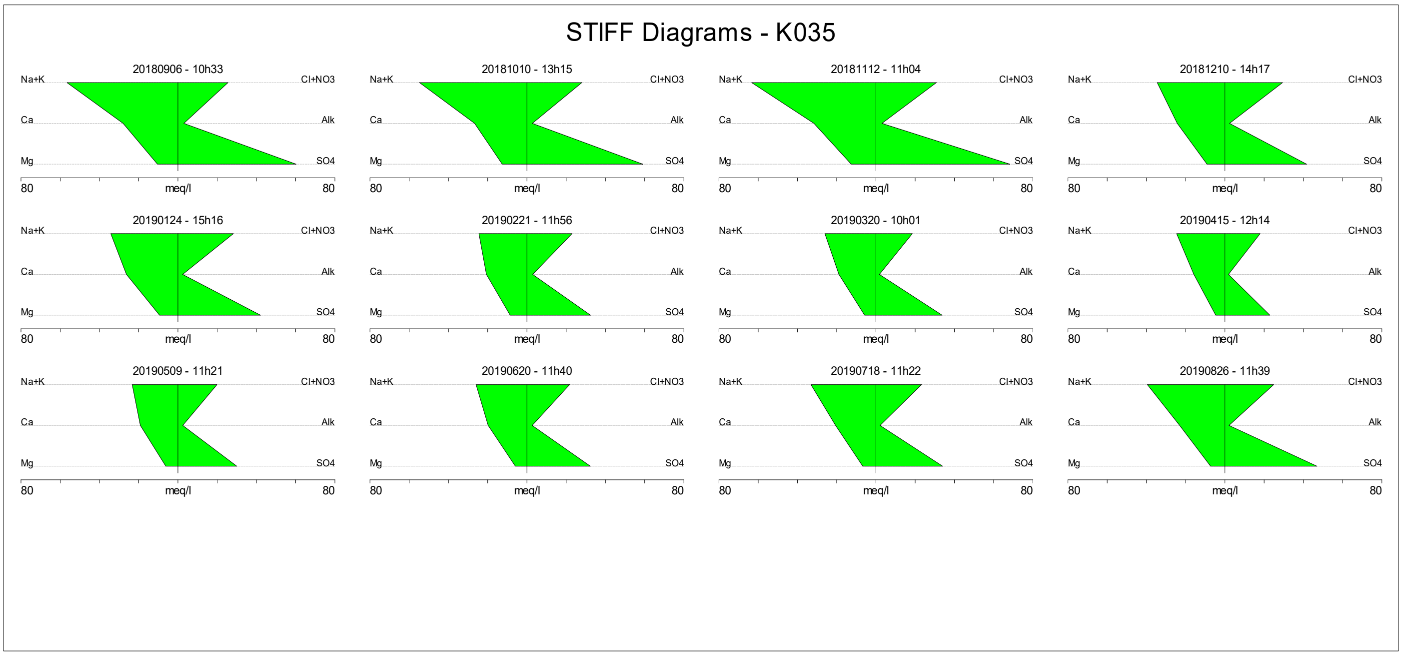



**Figure 19: Time series STIFF diagrams representing the Klipgat RWD water quality for the past annual period**

**Table 27: Average WVE TSF process dams data table for the annual monitoring period**

| AVERAGE DATA TABLE: | |
|---|---|
| PROJECT NAME | Anglo Rustenburg Surface water monitoring |
| ASSESSMENT SET 1 | General Authorisation Limit, Section 21f and h, 2013 |
| ASSESSMENT SET 2 | AAP Rustenburg - Surface water WUL |

| VARIABLE | UNITS | ASSESSMENT 1 | ASSESSMENT 2 | MONITORING LOCALITIES | | |
|---|---|---|---|---|---|---|
| | | | | K034 | K035 | K036 |
| pH @ 25°C | pH | 5.5/9.5 | 6.0/9.0 | 8.01 | 7.98 | 7.95 |
| Electrical conductivity (EC) @ 25°C | mS/m | 150 | 85 | 639 | 571 | 584 |
| Total dissolved solids (TDS) | mg/l | - | - | 4437 | 4420 | 4395 |
| Total hardness | mg CaCO3/l | - | 50 | 1443 | 1560 | 1713 |
| Calcium (Ca) | mg/l | - | - | 418 | 459 | 491 |
| Magnesium (Mg) | mg/l | - | - | 97.1 | 101 | 118 |
| Sodium (Na) | mg/l | - | - | 869 | 809 | 786 |
| Potassium (K) | mg/l | - | - | 56 | 58.7 | 53.7 |
| Chloride (Cl) | mg/l | - | - | 785 | 829 | 893 |
| Sulphate ($SO_4$) | mg/l | - | - | 2063 | 2016 | 1916 |
| Fluoride (F) | mg/l | 1 | 0.75 | 0.621 | *0.524* | *0.416* |
| Nitrate ($NO_3$) as N | mg/l | 15 | - | 4.9 | 12.6 | *2.48* |
| Ammonium ($NH_4$) as N | mg/l | 6 | 1 | 6.32 | 6 | 0.68 |
| Orthophosphate ($PO_4$) as P | mg/l | 10 | 0.125 | *0.011* | *0.062* | *0.081* |
| Aluminium (Al) | mg/l | - | 5 | *0.008* | *0.007* | *0.046* |
| Iron (Fe) | mg/l | 0.3 | 0.5 | *0.002* | *0.005* | *0.024* |
| Manganese (Mn) | mg/l | 0.1 | 0.18 | 1.1 | *0.046* | 0.305 |
| Chromium (Cr) | mg/l | - | - | *0.002* | *0.002* | *0.003* |
| Copper (Cu) | mg/l | 0.01 | 0.3 | *0.021* | *0.016* | *0.016* |
| Nickel (Ni) | mg/l | - | - | 1.2 | 0.953 | 0.793 |
| Zinc (Zn) | mg/l | 0.1 | - | *0.008* | *0.033* | *0.038* |
| Hexavalent chromium ($Cr^{6+}$ ) | mg/l | 0.05 | 0.0049 | *0.001* | *0.001* | *0.001* |
| Oil and grease (SOG) | mg/l | 2.5 | - | - | *6.65* | - |
| E.coli | CFU/100ml | 1000 | - | - | *18.21* | - |
| Total coliform | CFU/100ml | - | - | - | 52.67 | - |

### 7.4.2. Receiving environment

**K188** (Klipgatspruit, downstream of Mfidikoe village, upstream of Waterval TSF) was sampled in April, July and August 2019, recording neutral, non-saline and hard water quality based on the average data with low salts, nutrients and metals. Water quality is typical of stormwater run-off.

**K136** (Klipgatspruit downstream from the Entabeni Hostel) was recorded as dry throughout the annual period.

**K190** (Klipgatspruit downstream of Klipgat Dam) was sampled for most of the annum; samples were however taken from pooled-up water and not necessarily from the flowing Klipgatspruit. Average water quality can be described as neutral, extremely saline and very hard, resembling process water from Klipgat dam. Inorganic salt concentrations were high, with sporadic high nitrate concentrations. Trace metals were detected on some occasions at low concentrations.

Water quality from the upstream locality **K188** to the downstream locality **K190** revealed an overall deterioration in water quality as may be seen in the table below; this is due to the tailings storage facilities and Klipgat dam situated between these two monitoring sites.

**Table 28: Average Waterval TSF-East impacts on the Klipfonteinspruit**

| VARIABLE | UNIT | AAP Rustenburg - Surface water WUL | Locality | | CALCULATED CHANGE |
|---|---|---|---|---|---|
| | | | Upstream | Downstream | |
| | | | K188 | K190 | |
| pH @ 25°C | pH | 6.0/9.0 | 8.24 | 8.29 | 0.05 |
| Electrical conductivity (EC) @ 25°C | mS/m | 85 | 63.9 | 629 | 565 |
| Total dissolved solids (TDS) | mg/l | - | 371 | 4854 | 4483 |
| Total hardness | mg CaCO3/l | 50 | 201 | 2359 | 2158 |
| Total alkalinity | mg CaCO3/l | - | 218 | 269 | 51 |
| Chloride (Cl) | mg/l | - | 46.8 | 1334 | 1287 |
| Sulphate ($SO_4$) | mg/l | - | 35.8 | 1733 | 1697 |
| Fluoride (F) | mg/l | 0.75 | *0.181* | *0.146* | -0.035 |
| Nitrate ($NO_3$) as N | mg/l | - | 1.74 | 10 | 8.26 |
| Ammonium ($NH_4$) as N | mg/l | 1 | 5.59 | 0.993 | -4.6 |
| Orthophosphate ($PO_4$) as P | mg/l | 0.125 | 1.16 | *0.023* | -1.14 |
| Calcium (Ca) | mg/l | - | 51.6 | 530 | 478 |
| Magnesium (Mg) | mg/l | - | 17.4 | 251 | 234 |
| Sodium (Na) | mg/l | - | 42.2 | 748 | 706 |
| Potassium (K) | mg/l | - | 11.8 | 20.2 | 8.4 |
| Aluminium (Al) | mg/l | 5 | 0.117 | *0.002* | -0.115 |
| Iron (Fe) | mg/l | 0.5 | *0.018* | *0.002* | -0.016 |
| Manganese (Mn) | mg/l | 0.18 | *0.006* | *0.201* | 0.195 |
| Chromium (Cr) | mg/l | - | *0.002* | *0.002* | 0 |
| Copper (Cu) | mg/l | 0.3 | 0.012 | *0.054* | 0.042 |
| Nickel (Ni) | mg/l | - | 0.027 | *0.087* | 0.06 |

**Table 29: Average WVE TSF receiving environment data table for the annual monitoring period**

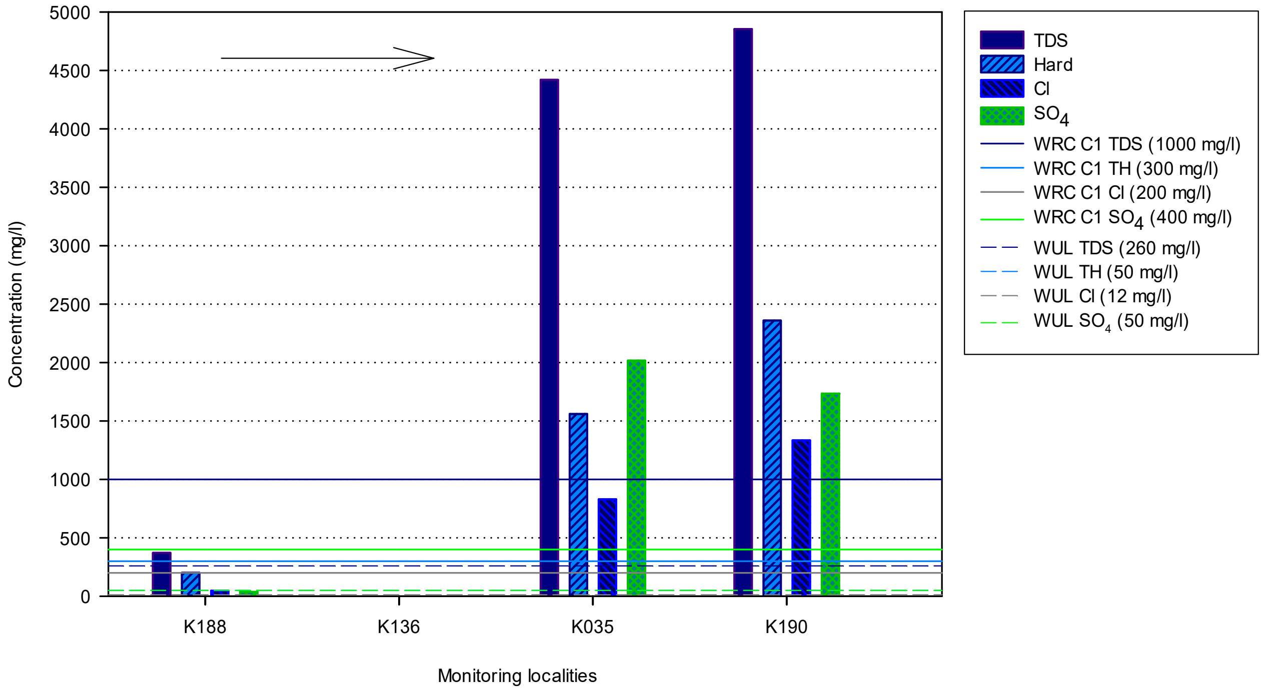
| AVERAGE DATA TABLE: | | | | | | |
|---|---|---|---|---|---|---|
| PROJECT NAME | | | Anglo Rustenburg Surface water monitoring | | | |
| ASSESSMENT SET 1 | | | AAP Rustenburg - Surface water WUL | | | |
| ASSESSMENT SET 2 | | | SANS 241-1:2015 Drinking Water Standard (SABS, 2015) | | | |
| | | | | | | Value exceeds the assessment set 1 |
| VARIABLE | UNITS | ASSESSMENT 1 | ASSESSMENT 2 | MONITORING LOCALITIES | | |
| | | | | K188 | K136 | K190 |
| pH @ 25°C | pH | 6.0/9.0 | 5.0/9.7 | 8.24 | - | 8.29 |
| Electrical conductivity (EC) @ 25°C | mS/m | 85 | 170 | 63.9 | - | 629 |
| Total dissolved solids (TDS) | mg/l | - | 1200 | 371 | - | 4854 |
| Total hardness | mg CaCO3/l | 50 | - | 201 | - | 2359 |
| Calcium (Ca) | mg/l | - | - | 51.6 | - | 530 |
| Magnesium (Mg) | mg/l | - | - | 17.4 | - | 251 |
| Sodium (Na) | mg/l | - | 200 | 42.2 | - | 748 |
| Potassium (K) | mg/l | - | - | 11.8 | - | 20.2 |
| Chloride (Cl) | mg/l | - | 300 | 46.8 | - | 1334 |
| Sulphate ($SO_4$) | mg/l | - | 500 | 35.8 | - | 1733 |
| Fluoride (F) | mg/l | 0.75 | 1.5 | *0.181* | - | *0.146* |
| Nitrate ($NO_3$) as N | mg/l | - | 11 | 1.74 | - | 10 |
| Ammonium ($NH_4$) as N | mg/l | 1 | 1.5 | 5.59 | - | 0.993 |
| Orthophosphate ($PO_4$) as P | mg/l | 0.125 | - | 1.16 | - | *0.023* |
| Ortophosphate as $PO_4$ | mg/l | 0.234 | - | 3.56 | - | *0.069* |
| Aluminium (Al) | mg/l | 5 | 0.3 | 0.117 | - | *0.002* |
| Iron (Fe) | mg/l | 0.5 | 0.3 | *0.018* | - | *0.002* |
| Manganese (Mn) | mg/l | 0.18 | 0.1 | *0.006* | - | *0.201* |
| Chromium (Cr) | mg/l | - | 0.05 | *0.002* | - | *0.002* |
| Copper (Cu) | mg/l | 0.3 | 2 | 0.012 | - | *0.054* |
| Nickel (Ni) | mg/l | - | 0.07 | 0.027 | - | *0.087* |
| Dissolved oxygen (DO) | mg/l | 7.0/8.0 | - | 2.53 | - | 4.2 |
| Lead (Pb) | mg/l | - | 0.01 | *0.002* | - | *0.003* |
| Zinc (Zn) | mg/l | - | 5 | *0.008* | - | *0.125* |
| Boron (B) | mg/l | - | 2.4 | 0.026 | - | 0.672 |
| Phenol | mg/l | - | 0.01 | *0.007* | - | *0.006* |
| Hexavalent chromium ($Cr^{6+}$ ) | mg/l | 0.0049 | - | *0.001* | - | *0.001* |
| Arsenic (As) | mg/l | - | 0.01 | *0.003* | - | *0.003* |
| Cadmium (Cd) | mg/l | - | 0.003 | *0.001* | - | *0.001* |
| Mercury (Hg) | mg/l | - | 0.006 | *0.002* | - | *0.002* |
| Selenium (Se) | mg/l | - | 0.04 | *0.001* | - | *0.001* |

# 8. RECEIVING ENVIRONMENT SUMMARY

## 8.1. Klipgatspruit

A schematic diagram showing selected sampling localities and relevant Rustenburg Process Division facilities relative to the Klipgatspruit is shown in Figure 21. The direction of flow of the Klipgatspruit towards the Hex river is also show. Please note that the diagram is not to scale and all other non-Rustenburg Process Division contributors are not indicated in the diagram.

Upstream from the Waterval tailings storage facilities, the Klipgatspruit water quality is seen to be fairly un-impacted; samples were also indicative of stormwater run-off. Downstream from the Waterval tailings storage facilities (including the Klipgat dam) water quality is seen to change significantly. As may be seen from Figure 20 water quality from Klipgat dam is the main contributor to the noted change. During high-flow events water flowing in the Klipgatspruit will eventually end up in the Hex River. Although no overflow was recorded at the Klipgat dam, it is evident that some seepage occurs, either from Klipgat dam or the tailings storage facility.



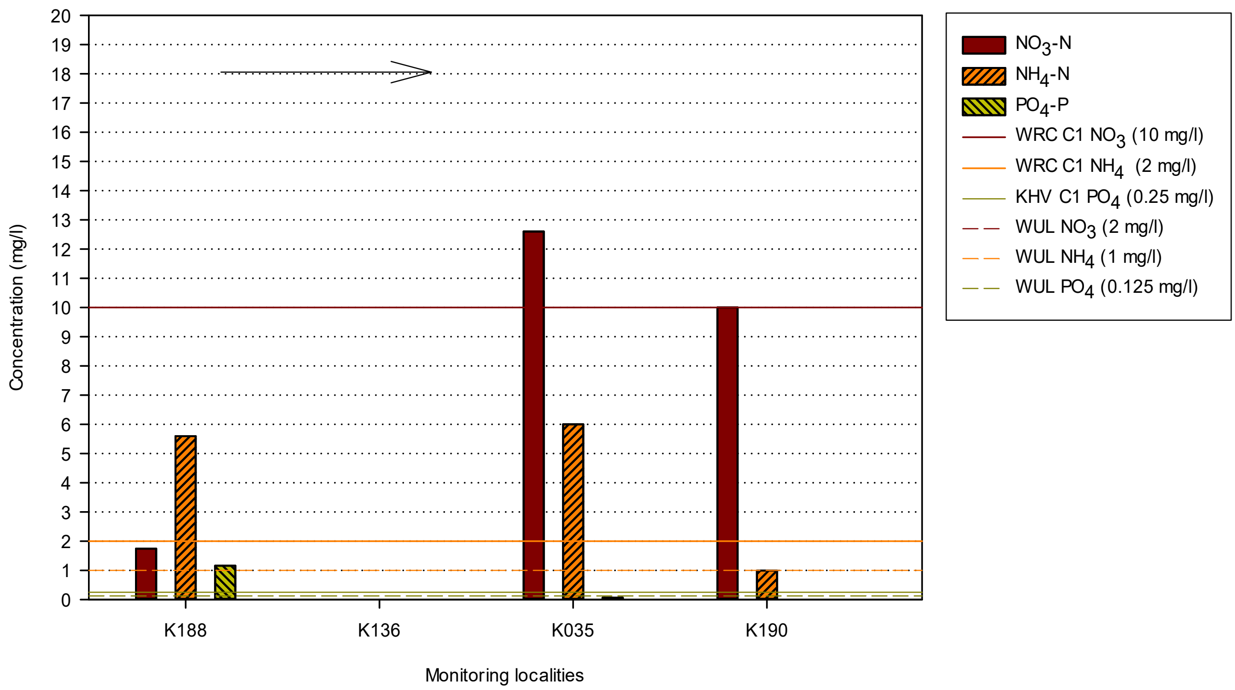




**Figure 20: Average data for in-stream localities in the Klipgatspruit for the annual period September 2018 to August 2019**

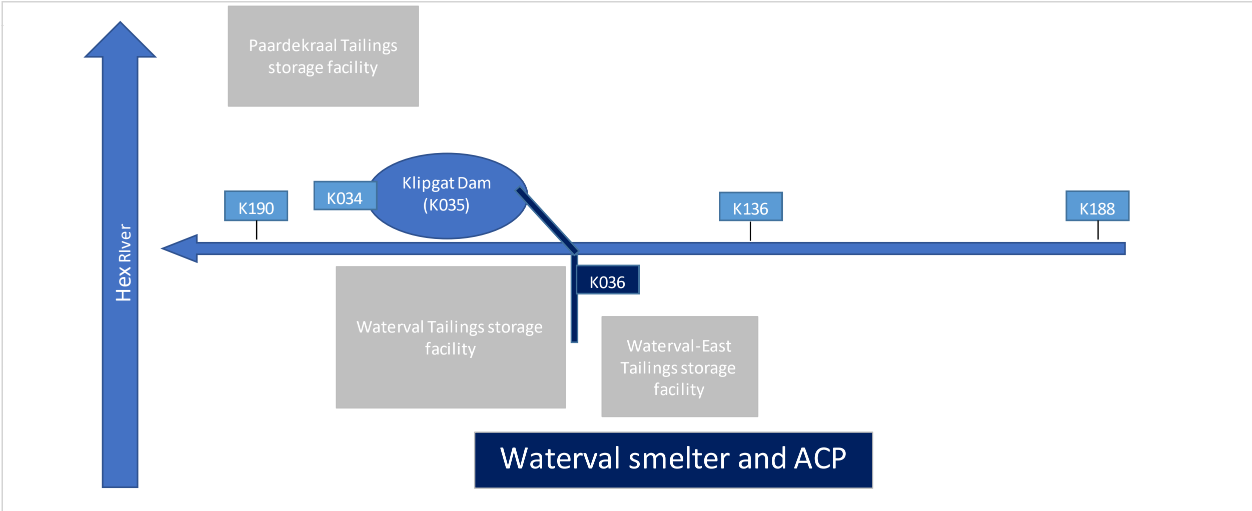



**Figure 21: Schematic diagram of the Klipgatspruit relative to Rustenburg Process Division localities**

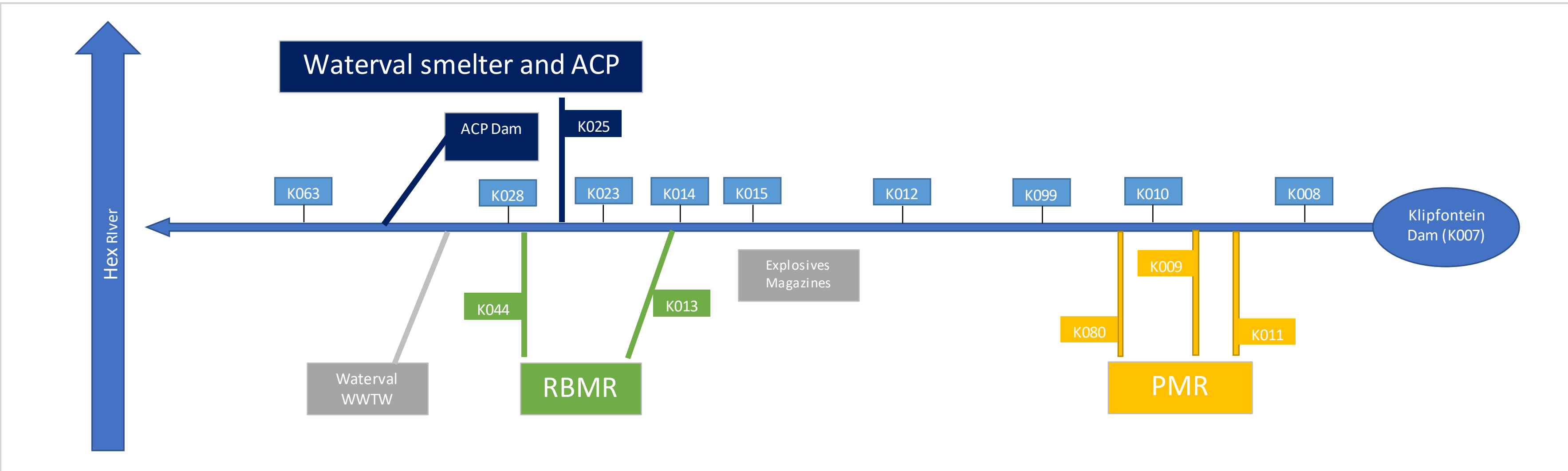



**Figure 22: Schematic diagram of the Klipfonteinspruit relative to Rustenburg Process Division localities**

## 8.2. Klipfonteinspruit

Various mining shafts, concentrators, smelters and waste rock dumps are situated within the Klipfontein catchment and have been identified as possible stressors on the Klipfonteinspruit. These include various Anglo process plants as well as other mining shafts and facilities (selected contributors are shown in Figure 22).

The Klipfontein dam (**K007**) was added to the monitoring programme to be used as an additional upstream locality at PMR, and therefore the whole Rustenburg Process Division. Three samples were collected between April and August 2019; average water quality being neutral, very saline and very hard. Very high concentrations of nitrates were also detected.

Locality **K008** (Klipfonteinspruit at PMR bridge) is an upstream locality in the Klipfonteinspruit for monitoring at PMR and was recorded as dry for most of the year. One sample was taken in January 2019 where physical water quality was neutral, saline and very hard with low nutrients and trace amounts of nickel detected.

**K010** (downstream from K008 and K009) was sampled during most of the annual period. It must be noted however that this locality is thought to represent stagnant water as the upstream K008 was recorded as dry. This locality is seen to have fluctuating water qualities; a significant increase in salinity concentrations was seen from June 2019 where nutrient and metal concentrations also increased. On average sodium and chloride concentrations dominate this locality; water quality profiles resemble that of the PMR PCDs.

Further downstream at **K099** samples were taken a few times during the annual period; annual average water quality was recorded as extremely saline and very hard. Sporadic high concentrations of fluoride, nitrate and metals were detected.

Locality **K012** (downstream from PMR and upstream from RBMR) was sampled on three occasions and was recorded as dry during the remainder of the annual period. Moderate fluctuating salinity was noted at this locality.

**K015** was sampled between January 2019 and July 2019, with the exception of March 2019. Water quality was alkaline, extremely saline and hard, dominated by sodium and sulphate concentrations. Very high concentrations of fluoride, phosphate and various metals were also detected. Water quality of this nature is indicative of process water seen at RBMR.

**K014** was sampled on various occasions during the annual period. Water quality was similar to K015 and representative of RBMR process water.

Locality **K023** (upstream of the Waterval complex) was sampled between January 2019 and August 2019. Water quality was alkaline, extremely saline and hard, dominated by sodium and sulphate concentrations. Again, very high concentrations of fluoride, phosphate and various metals were detected, indicating seepage or discharge from RBMR process water.

Locality **K028** (mid-Waterval complex and downstream of RBMR) was sampled throughout the annum with water quality fluctuating constantly; this may be caused by several discharges entering the Klipfonteinspruit before K028. High concentrations of sulphate, fluoride and nickel reveal the impact of the RBMR dams (either by discharge or seepage) on the

Klipfonteinspruit. Long term data is presented in Figure 23. Water quality profiles (STIFF diagrams, Vol. II site reports) show that water quality remained relatively constant, a significant increase in salinity was however noted in May 2019.

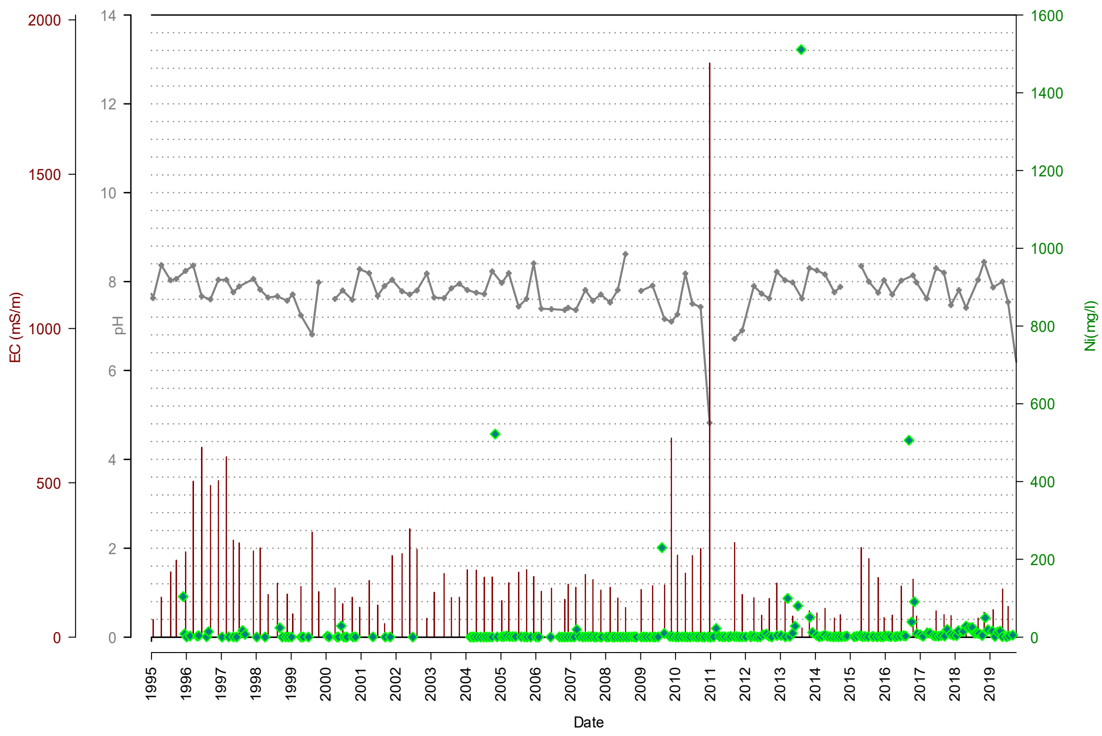



**Figure 23: Time series data for pH, EC and Ni concentrations at K028 from 1995 to August 2019**

**K063** was sampled throughout the annual period and recorded an average water quality that could be described as neutral, saline and hard with moderate inorganic salt concentrations and high nutrients (nitrates and phosphates). Nickel concentrations remained high due to discharges or seepages from RBMR dams. Effluent from Waterval Sewage entering the Klipfonteinspruit between localities K028 and K063 explains the sudden increase in nitrate concentrations, as seen in Figure 24. High phosphate was already present upstream.

Water quality of the Klipfonteinspruit, relevant to the Rustenburg Process Division, is shown in Figure 24. The in-stream Klipfontein Dam is situated upstream from the Rustenburg Process Division and receives impacts from multiple sources (mining and settlements) before it reaches Anglo Platinum facilities. An increase in TDS and hardness concentrations was noted at K010, where after the concentration decreased in a downstream direction toward K012 and downstream from PMR. From K015 (after impacts from RBMR) TDS and sulphates increase significantly towards K028. Decreased salinity concentrations are seen at K063.

Nutrients fluctuated in the Klipfonteinspruit with a significant increase in nitrate concentration noted at K099. Nitrate decreased at K015 where phosphate concentrations increased significantly; this nitrate-phosphate ratio remains stable towards K063 where nitrate is increases and phosphate decreased. This nitrate increase is caused by the inflow of sewage-effluent from the nearby Waterval water treatment works flowing directly into the Klipfonteinspruit.

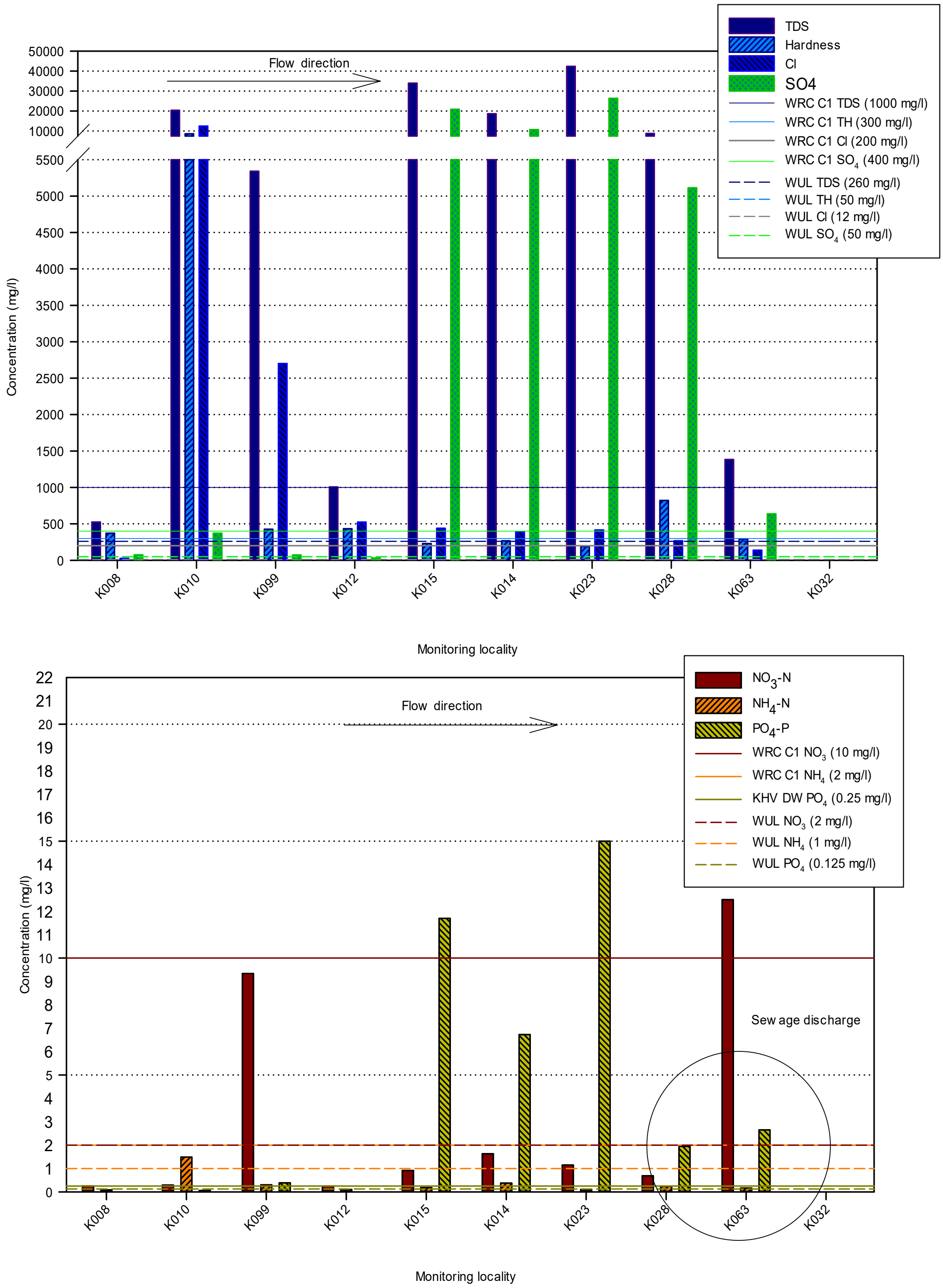



**Figure 24: Average data for in-stream localities in the Klipfonteinspruit for the annual period September 2018 to August 2019**

Nickel concentrations reached a maximum at locality K028 (11.4 mg/l annual average concentration) and remained in the Klipfonteinspruit further downstream (Figure 25). Various pollution control dams at PMR, RBMR and the Waterval complex contribute to the high nickel concentration.

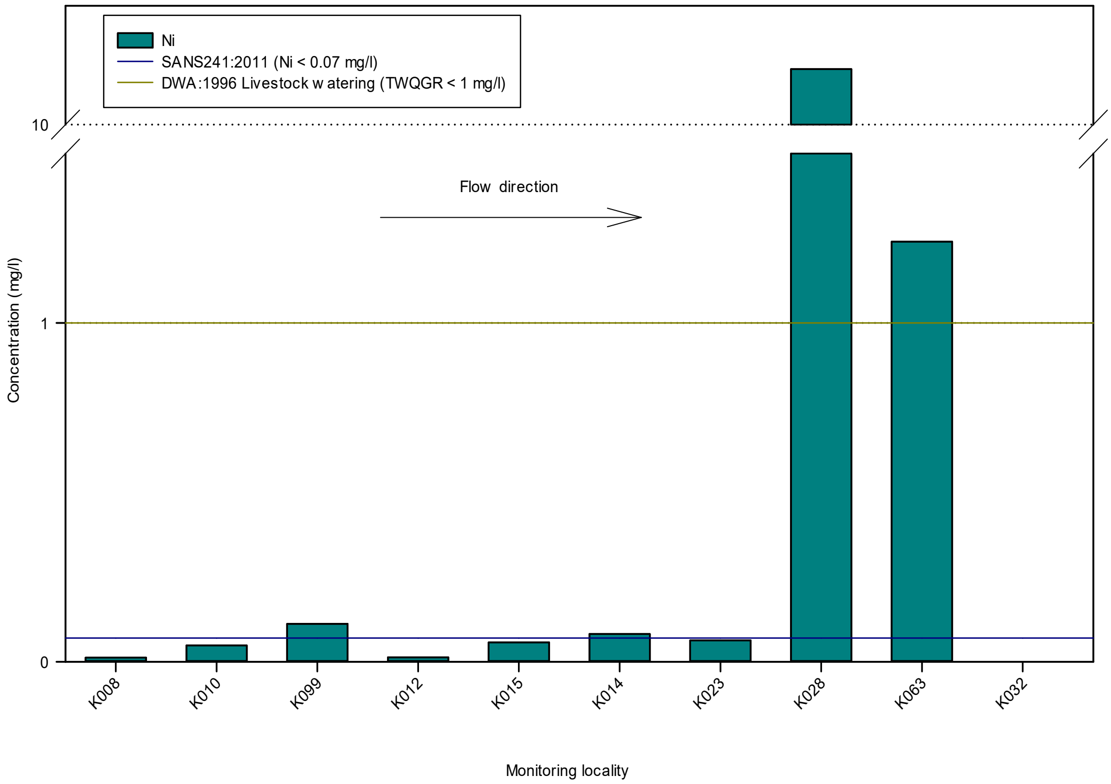



**Figure 25: Annual average Nickel concentrations in the Klipfonteinspruit**

Figure 25 indicates that nickel concentrations detected at most Klipfonteinspruit localities remained relatively stable throughout the monitoring period. Only locality K028 revealed a significant variating concentration of nickel (Figure 26). Nickel concentrations at K028 are seen to be strongly influenced by the nickel concentrations of the ACP dam (K098). The nickel content in the ACP dam is further seen to be a function of its pH value (also see Figure 17). Nickel concentrations further downstream at K063 follows the same trend as at K028, albeit at a much lower concentration, due to the absorption action of the natural reeds as well as possible oxidation and settling out.

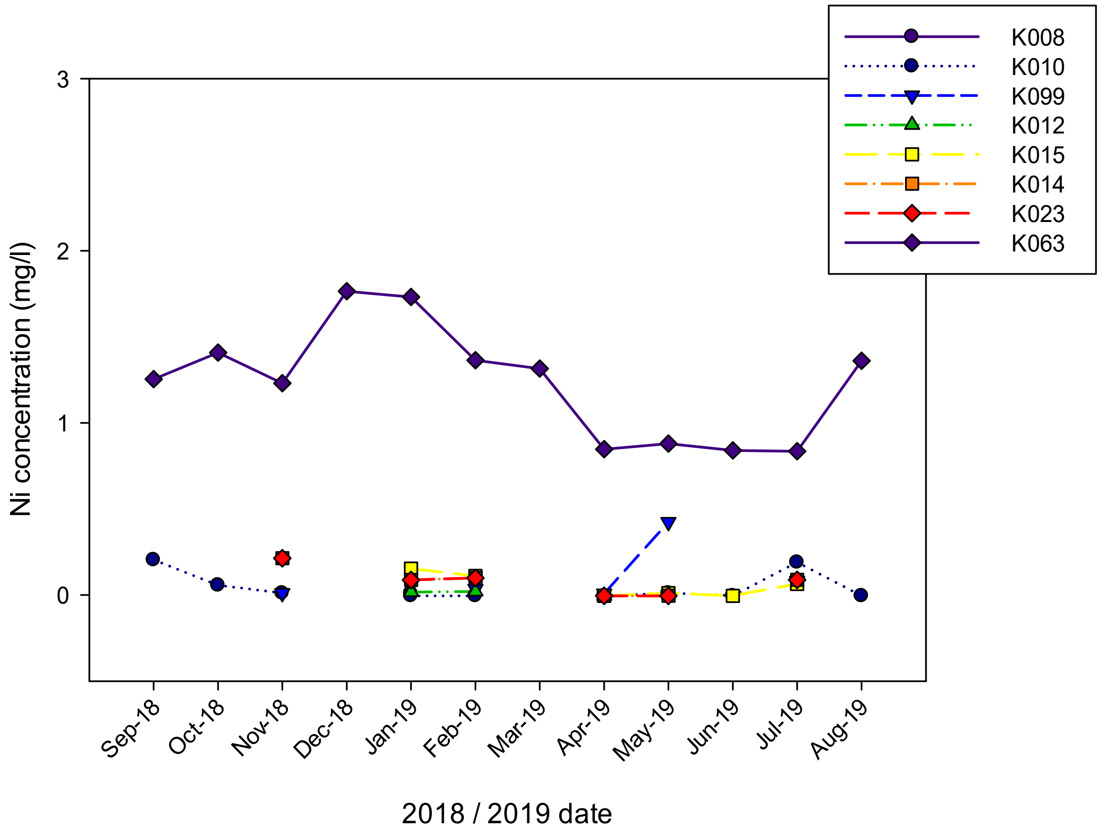



**Figure 26: Nickel concentrations per selected localities over the monitoring period**

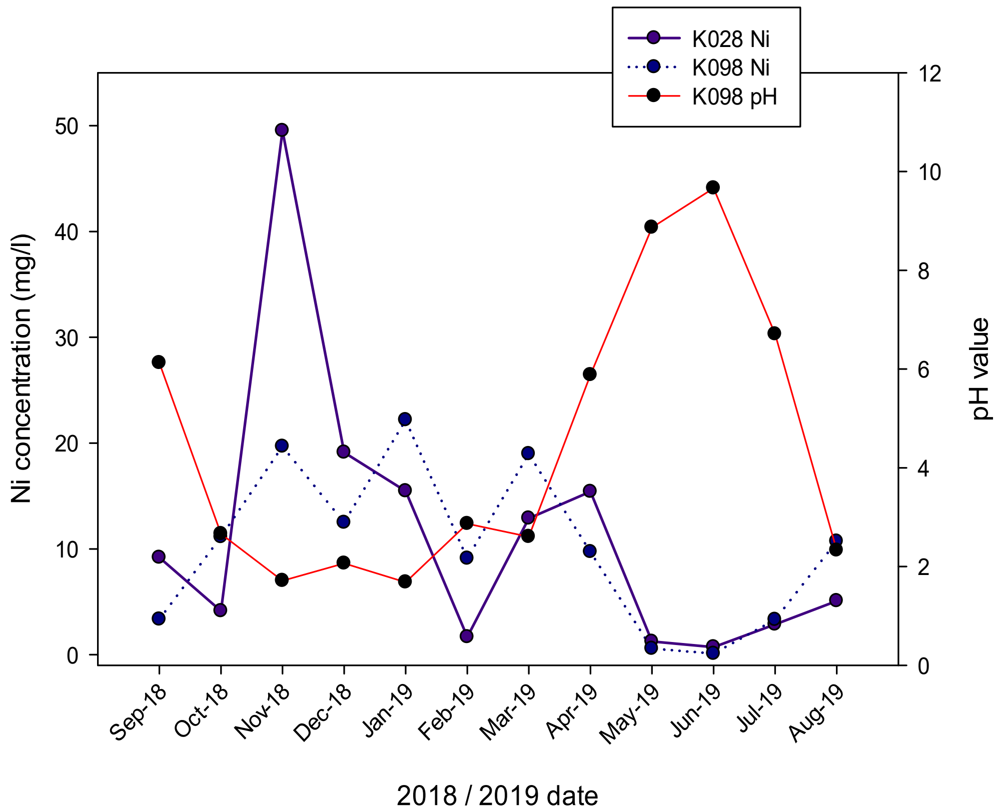
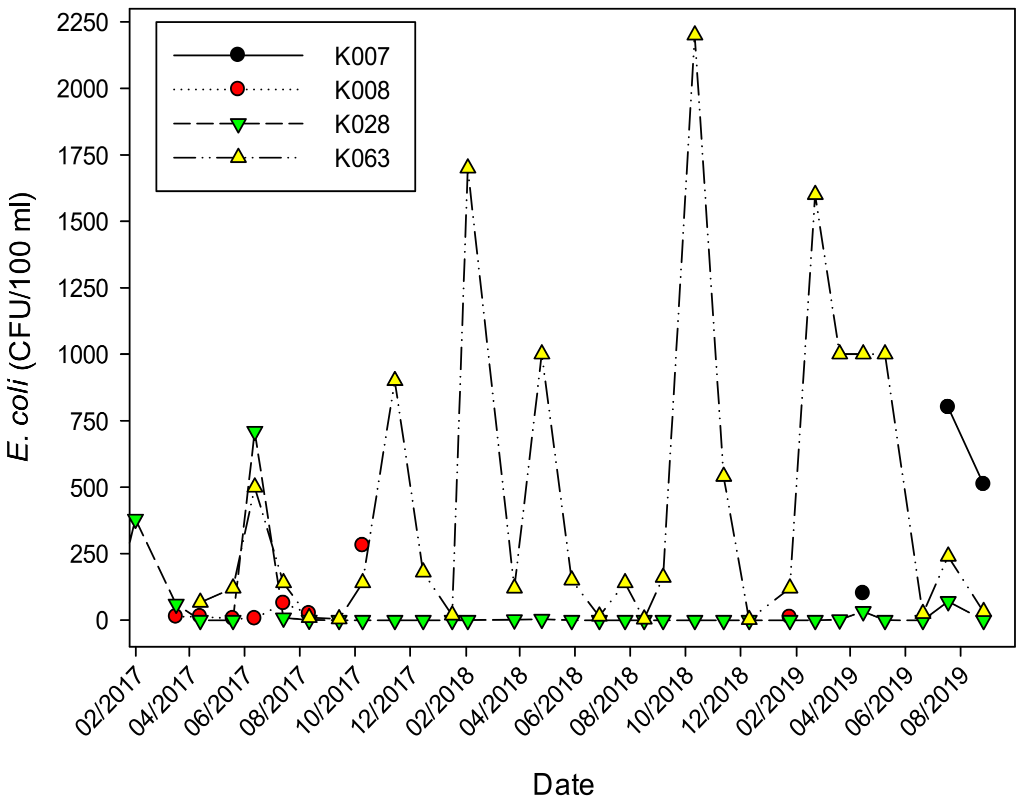



**Figure 27: Nickel concentrations over time at localities K028 and K098**

*E. coli* counts in the Klipfonteinspruit (relevant to the Anglo process division) are seen to vary over the time-frame and indicate an increasing trend (Figure 28). A spatial increase in counts is also noted at K063 in accordance with the nutrient load seen in Figure 24. This increase in bacterial count is due to the sewage effluent from the nearby Waterval sewage works




K007: Klipfontein dam
K008: Klipfonteinspruit at PMR Bridge
K028: Klipfonteinspruit d/s Waterval sewage & RBMR at bridge
K063: Klipfonteinspruit at stormwater discharge from Waterval smelter

**Figure 28: *E.coli* counts detected in the Klipfonteinspruit catchment for the annual period**

The exceedance graphs below indicate the number of times the Klipfonteinspruit localities (average data) exceeded the Anglo surface water WUL limits and SANS 241-1:2015 drinking water standards respectively. The most prominent variables to exceed the Anglo surface water WUL limits were EC and hardness. Other variable that regularly exceeded were pH, fluoride, phosphate, manganese and copper concentrations.

The SANS 241-1:2015 drinking water standards were exceeded by variables including EC, sodium, chloride and nickel. The SANS241-1 :2015 standard is only for comparative purposes and should not be interpreted for compliance.

**Table 30: Exceedance table for the Klipfonteinspruit measuring percentage non-compliance to the Anglo surface water WUL conditions**

| EXCEEDANCE TABLE: | | | | |
|---|---|---|---|---|
| PROJECT NAME | Anglo Rustenburg Surface water monitoring | DATE COMPILED | 17 September 2019 | |
| LOCALITY GROUP | Monitoring Localities | COMPILED BY | Werner Rossouw | |
| DATE RANGE | September 2018 to August 2019 | | | |
| ASSESSMENT SET | AAP Rustenburg - Surface water WUL | **Non-compliance** | 0% - 25% | 25% - 75% | 75% - 100% |

| VARIABLE | UNIT | ASSESMENT VALUE | MONITORING LOCALITIES | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K008 | K010 | K099 | K012 | K015 | K014 | K023 | K028 | K063 | K188 | K190 |
| NUMBER OF RECORDS | | | 1 | 10 | 5 | 3 | 6 | 6 | 8 | 12 | 12 | 3 | 11 |
| pH @ 25°C | pH | 6.0/9.0 | 0 | 0 | 40 | 0 | 100 | 83 | 100 | 33 | 0 | 0 | 0 |
| Electrical conductivity (EC) @ 25°C | mS/m | 85 | 0 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 75 | 0 | 100 |
| Total dissolved solids (TDS) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total hardness | mg CaCO3/l | 50 | 100 | 100 | 80 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Calcium (Ca) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Magnesium (Mg) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sodium (Na) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Potassium (K) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total alkalinity | mg CaCO3/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chloride (Cl) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sulphate ($SO_4$) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fluoride (F) | mg/l | 0.75 | 0 | 0 | 60 | 0 | 100 | 83 | 100 | 100 | 25 | 0 | 0 |
| Nitrate ($NO_3$) as N | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nitrite ($NO_2$) as N | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ammonium ($NH_4$) as N | mg/l | 1 | 0 | 30 | 0 | 0 | 0 | 17 | 0 | 8 | 0 | 33 | 18 |
| Orthophosphate ($PO_4$) as P | mg/l | 0.125 | 0 | 10 | 40 | 0 | 100 | 83 | 100 | 58 | 100 | 100 | 9 |
| Aluminium (Al) | mg/l | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Iron (Fe) | mg/l | 0.5 | 0 | 30 | 0 | 0 | 17 | 0 | 12 | 8 | 0 | 0 | 0 |
| Manganese (Mn) | mg/l | 0.18 | 0 | 60 | 0 | 0 | 17 | 17 | 12 | 58 | 8 | 0 | 18 |
| Chromium (Cr) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Copper (Cu) | mg/l | 0.3 | 0 | 0 | 20 | 0 | 17 | 33 | 38 | 50 | 0 | 0 | 0 |
| Nickel (Ni) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 31: Exceedance table for the Klipfonteinspruit measuring percentage non-compliance to the SANS 241-1:2015 Drinking Water Standard**

| EXCEEDANCE TABLE: | | |
|---|---|---|
| PROJECT NAME | Anglo Rustenburg Surface w ater monitoring | DATE COMPILED: 17 September 2019 |
| LOCALITY GROUP | Monitoring Localities | COMPILED BY: Werner Rossouw |
| DATE RANGE | September 2018 to August 2019 | |
| ASSESSMENT SET | SANS 241-1:2015 Drinking Water Standard (SABS, 2015) | **Non-compliance** 0% - 25%, 25% - 75%, 75% - 100% |

| VARIABLE | UNIT | ASSESMENT VALUE | MONITORING LOCALITIES | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | K008 | K010 | K099 | K012 | K015 | K014 | K023 | K028 | K063 | K188 | K190 |
| NUMBER OF RECORDS | | | 1 | 10 | 5 | 3 | 6 | 6 | 8 | 12 | 12 | 3 | 11 |
| pH @ 25°C | pH | 5.0/9.7 | 0 | 0 | 20 | 0 | 67 | 50 | 62 | 25 | 0 | 0 | 0 |
| Electrical conductivity (EC) @ 25°C | mS/m | 170 | 0 | 70 | 100 | 67 | 100 | 100 | 100 | 100 | 17 | 0 | 100 |
| Total dissolved solids (TDS) | mg/l | 1200 | 0 | 60 | 100 | 33 | 100 | 100 | 100 | 100 | 17 | 0 | 91 |
| Total hardness | mg CaCO3/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Calcium (Ca) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Magnesium (Mg) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sodium (Na) | mg/l | 200 | 0 | 60 | 100 | 67 | 100 | 100 | 100 | 100 | 25 | 0 | 91 |
| Potassium (K) | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total alkalinity | mg CaCO3/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chloride (Cl) | mg/l | 300 | 0 | 70 | 100 | 100 | 67 | 33 | 75 | 42 | 0 | 0 | 100 |
| Sulphate ($SO_4$) | mg/l | 500 | 0 | 30 | 0 | 0 | 100 | 100 | 100 | 100 | 17 | 0 | 91 |
| Fluoride (F) | mg/l | 1.5 | 0 | 0 | 20 | 0 | 100 | 83 | 100 | 100 | 17 | 0 | 0 |
| Nitrate ($NO_3$) as N | mg/l | 11 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 67 | 0 | 27 |
| Nitrite ($NO_2$) as N | mg/l | 0.9 | 0 | 0 | 40 | 0 | 17 | 33 | 25 | 0 | 0 | 0 | 9 |
| Ammonium ($NH_4$) as N | mg/l | 1.5 | 0 | 10 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 33 | 18 |
| Orthophosphate ($PO_4$) as P | mg/l | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aluminium (Al) | mg/l | 0.3 | 0 | 30 | 40 | 0 | 17 | 50 | 25 | 0 | 0 | 0 | 0 |
| Iron (Fe) | mg/l | 0.3 | 0 | 40 | 0 | 0 | 17 | 17 | 25 | 8 | 0 | 0 | 0 |
| Manganese (Mn) | mg/l | 0.1 | 0 | 60 | 0 | 0 | 17 | 17 | 25 | 67 | 17 | 0 | 27 |
| Chromium (Cr) | mg/l | 0.05 | 0 | 10 | 20 | 0 | 17 | 50 | 50 | 8 | 0 | 0 | 0 |
| Copper (Cu) | mg/l | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nickel (Ni) | mg/l | 0.07 | 0 | 20 | 40 | 0 | 33 | 67 | 62 | 100 | 100 | 0 | 45 |

# 9. STANDARD ANGLO RISK RATING

Remediation is necessary where risks exist towards human health or health to the environment. These risks are assessed with relation to the current or intended use of the land and the wider environmental setting and the risk of contaminant spreading. Risk is commonly defined as the probability that a substance will produce harm (for example adverse health effects) under specified conditions. When dealing with contaminated land management, risks occur when the following three components are present: i) source, ii) receptor, and iii) pathway. Generally, remediation is carried out due to the following reasons:

- To protect human health or the environment;
- To enable redevelopment;
- To limit potential liabilities; and
- To repair or enhance previous remediation efforts.

Table 32 below tabulates the potential risks and quantified risks on the surface water regime resulting from Anglo Platinum process activities. The risks given are based on the ANGLO AMERICAN 5×5 RISK RATING MATRIX and the probability of the unwanted event occurring as shown on the next page.

**Table 32: Anglo American Risk Matrix**

| ANGLO AMERICAN Plc RISK MATRIX | | Hazard Effect/Consequence (Where an event has more than one Loss Type , choose the Consequence with the highest rating) | | | | |
|---|---|---|---|---|---|---|
| Loss Type (Additional 'Loss Types' may exist for an event: identify and rate accordingly) | | 1. INSIGNIFICANT | 2. MINOR | 3. MODERATE | 4. MAJOR | 5. CATASTROPHIC |
| (EI) Environmental Impact | | Minimal environmental harm L1 incident | Material environmental harm L2 incident remediable short term | Serious environmental harm L2 incident remediable within LOM | Major environmental harm L2 incident remediable with post LOM | Extreme environmental harm L3 incident irreversible |
| Likelihood | Examples (Consider near hits as well as actual events) | RISK RATING | | | | |
| 5 (Almost Certain) | The unwanted event has occurred frequently; occurs in order of one or more times per year and is likely to reoccur within 1 year | 11 (M) | 16 (H) | 20 (H) | 23 (EX) | 25 (EX) |
| 4 (Likely) | The unwanted event has occurred infrequently; occurs in order of less than once per year and is likely to reoccur within 5 years. | 7 (M) | 12 (M) | 17 (H) | 21 (EX) | 24 (EX) |
| 3 (Possible) | The unwanted event has happened in the business at some time; or could happen within 10 years | 4 (L) | 8 (M) | 13(H) | 18 (H) | 22 (EX) |
| 2 (Unlikely) | The unwanted event has happened in the business at some time; or could happen within 20 years | 2 (L) | 5 (L) | 9 (M) | 14 (H) | 19 (H) |
| 1 (Rare) | The unwanted event has never been known to occur in the business; or it is highly unlikely it will occur within 20 years | 1 (L) | 3 (L) | 6 (M) | 10 (M) | 15 (H) |

| RISK RATING | RISK LEVEL | GUIDELINES FOR RISK MATRIX | PRIORITY |
|---|---|---|---|
| 21 to 25 | (Ex) Extreme | Eliminate, avoid, implement specific actions plans/procedures to manage and monitor | 1 |
| 13 to 20 | (H) High | Proactively manage | 2 |
| 6 to 12 | (M) Medium | Actively manage | 3 |
| 1 to 5 | (L) Low | Monitor and manage as appropriate | 4 |

**Table 33: Environmental risk table for surface water regime at Anglo Platinum Process Division**

| Name of Facility | Potential Impact (pre-control) | | | | |
|---|---|---|---|---|---|
| | **Nature of Environmental Impact/Risk** | **Point sources of pollution** | **Distance from community** | **Potential Impact Ranking** | **Management plan** |
| **Tailings facilities** | | | | | |
| Waterval Tailings | Waterval Tailings solution trench (K107N) and water from Waterval Tailings K036 discharges into Klipgat Dam which regularly overflows. Quality of these localities is of poor quality with high salinity, nitrate and nickel. | K034 (Klipgat Dam overflow) records irregular overflow | 1000 m | High | Remediate TSF seepage. Prevent RWD discharge – closed circuit management. |
| **Processing Units** | | | | | |
| Waterval Smelter + Acid Plant | Klipfonteinspruit downstream from Waterval Complex is of Marginal to Poor quality with TDS, Ni, $NO_3$ and *E.coli* exceeding acceptable domestic use guidelines. | K025 (ACP), K167 (Conc.), K168 (Conc.), K169 (PF Lab) & Waterval WWTW | 2200 m | High | Closed circuit management, effective separation of clean and dirty water, prevent discharge of substandard water |
| RBMR | Impact in terms of salinity, nickel and nitrate on Klipfonteinspruit downstream from RBMR. Significant increases in Ni concentration in Klipfonteinspruit exceeding acceptable domestic standards | K015, K024, K044, K062 | 2000 m | High | Contain in dirty water circuit, prevention of discharge or dam overflows of substandard quality. Delineate groundwater pollution plume |
| PMR | Effluent and stormwater discharge E of PMR K080 is of Poor quality with elevated TDS, inorganic nitrogen, Ni and Cu. TDS and $NO_3$ impacts on already impacted Klipfonteinspruit. | K010, K080 | 1000 m | High | Prevention of discharge, separate clean and dirty water, prevention of dam overflows |

## 10. SURFACE WATER CONCLUSION

- Raised salinity (TDS and EC), total hardness, inorganic salts and heavy metals are indicative of the water type associated with the refining processes at the Rustenburg Process Division.

- The pollution control dams at PMR had (on average) significant concentrations of calcium, chloride and sodium while the dams at RBMR had significant concentrations of sodium and sulphate. PCD localities sampled at PMR, RBMR and the Waterval complex recorded very high concentrations of metals, these included iron, cobalt, copper, manganese and nickel. Spills at the dams should be prevented and precautions must be taken in times of heavy rains.

- Impact in the Klipfonteinspruit was seen from discharge or spillage from RBMR. The exact point source or sources should be established to prevent such occurrences.

- It is of utmost importance that impacted water and seepages at the Anglo process division's business units be contained within the mine's dirty water circuit to minimize the pollution potential towards the different streams and therefore ultimately to the Hex River.

- Discharge localities that may introduce process water to receiving environments (K044, K168, K169, etc.) recorded water qualities with high salinity and metals that may prove to be detrimental to the environment.

- Organic pollution probably deriving from sewage (introducing harmful bacteria, oils and greases and $NH_4$ and $PO_4$) is also a hazard, and enters the Klipfonteinspruit from the Waterval WWTW.

- Process and refinery complexes remain a high risk to the environment especially in terms of salt load, nutrient load and metals to the surrounding receiving environment, including the groundwater resources.

- Most localities had variables that exceeded the WUL conditions for surface water localities. These WUL conditions are however very stringent for the typical expected water qualities.

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# Anglo American Platinum
# Rustenburg Process Division

## Annual Integrated Surface and Groundwater Quality, Biomonitoring and Toxicity Testing Assessment Report, Vol I (Continued)

**September 2018 to August 2019**

# Appendix A

*Annual report on groundwater monitoring*

Anglo American Platinum – Rustenburg Operations
Annual integrated water monitoring report
Volume I

# ANGLO PLATINUM MINES
# RUSTENBURG SECTION

# ANNUAL REPORT ON GROUNDWATER MONITORING RESULTS FOR 2018/2019

## SEPTEMBER 2019

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# ANGLO PLATINUM MINES, RUSTENBURG SECTION: ANNUAL REPORT ON GROUNDWATER MONITORING RESULTS FOR 2018/2019, AUGUST 2019

## 1 INTRODUCTION

Groundwater Complete was contracted by Aquatico Scientific to evaluate the groundwater quality and water level monitoring results for Anglo Platinum's Rustenburg Section (herein after referred to as RPM) for the 2018/2019 monitoring year. This evaluation therefore focuses on the monitoring data from September 2018 to September 2019, but also correlates with earlier data where necessary.

The distribution of all the groundwater monitoring points that were actively sampled during the past year is presented on a regional map of the RPM operations area in **Figure 1**. **More detailed site maps on a larger scale are provided in each section with the discussion of the water quality properties in each area and are orientated with north at the top of all maps and figures.** The regional groundwater seepage directions (flow lines) are also indicated as blue arrows on each of the maps in the source areas.

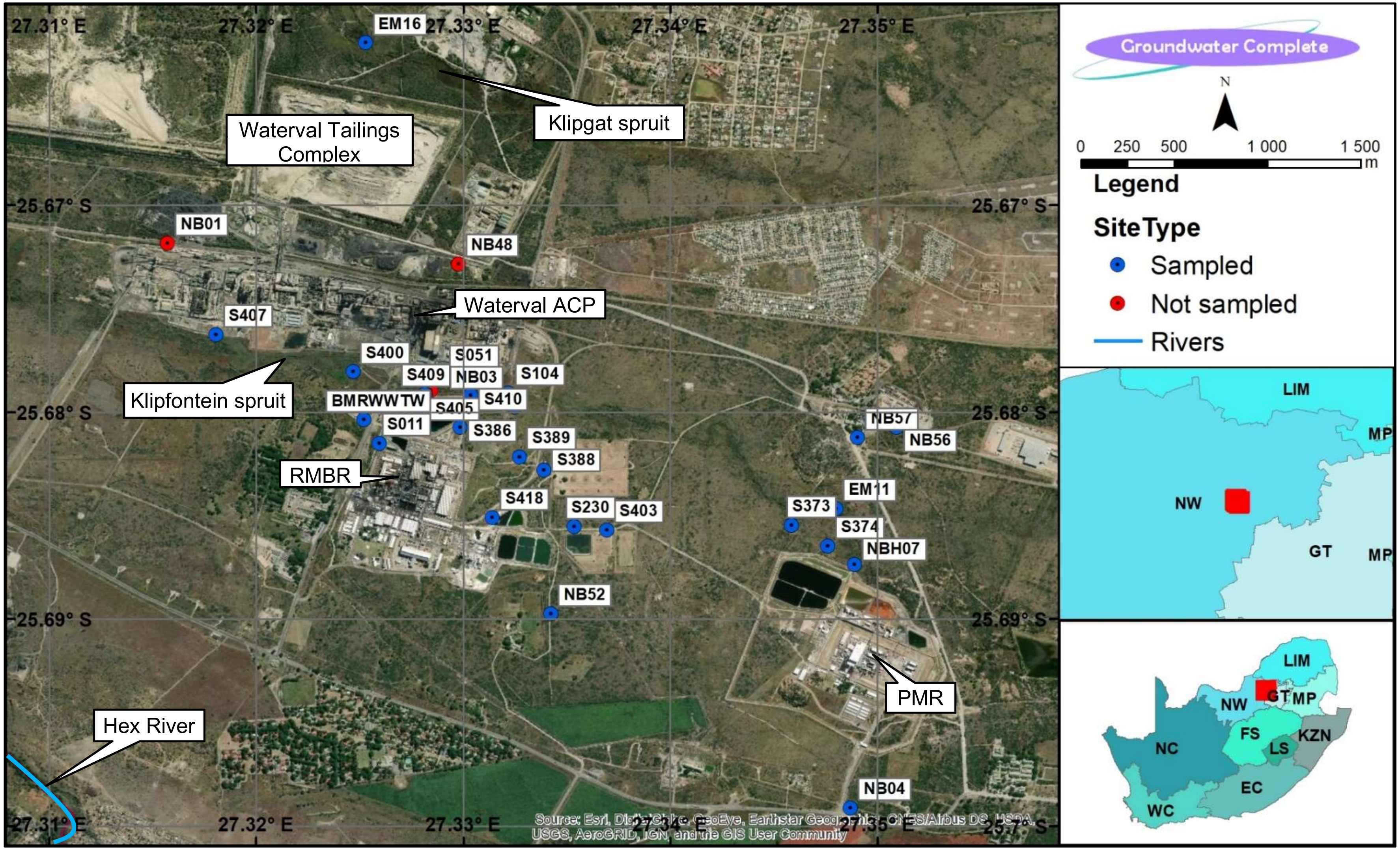


**Figure 1: Map of the RPM area with distribution of groundwater monitoring points during 2018/2019**

# 2 INTERPRETATION OF MONITORING DATA

Five chemical parameters, namely Total Dissolved Solids (TDS), nitrate ($NO_3$), sulphate ($SO_4$), chloride (Cl) and sodium (Na) were chosen from the full list of analytes as indicators of the specific type of contamination commonly occurring at RPM:

- The **TDS** value provides a holistic measurement of the total inorganic ion content of the water.
- **Nitrate** content often increases in the vicinity of shafts, discard dumps and tailings facilities as a result of traces of nitrate-based explosives used in the mining process. As will be discussed frequently in this report, nitrate contamination is the most direct and prominent parameter that is influenced by the mining activities at RPM. Nitrate is affected because of remnants of explosives attached to run-of-mine rocks, including ore, waste and discard – wet or dry. These nitrates are very soluble in water and any contact with water of blasted rock results into dissolution in water or leachate formation when rainwater percolates through rock dumps, stockpiles or discard facilities. One of the areas where the most pronounced impacts of the nitrate contamination occur is discard rock dumps and settling dams at the shaft areas. Nitrate concentrations are also elevated in the tailings dam water but dilution with make-up water imported from outside source aid significantly in reducing the concentrations.
- **Sulphate** is a prominent and widespread contaminant in the base metal processing areas such as the concentrators, smelters and refineries. Most ore and gangue minerals occur in the form of metal sulphides. When liberated, crushed and washed in the mining process oxidation of these materials occurs and a reactions chain forms commonly referred to as acid-mine-drainage. Sulphuric acid forms in this process and sulphate levels increase significantly. Sulphate is therefore a common indicator of pollution resulting from the processing facilities and waste products.
- **Sodium** and **chloride** are usually present in high concentrations in connate water within the crystal structure or matrix of rocks. When blasted, crushed, smelted or processed in some other way, sodium and chloride are liberated and serve as a conservative indicator of the impact of mining and processing activities on the environment.

These parameters will be plotted for all the different areas and all boreholes where data exists. Although only the five parameters will be plotted in each case, all inorganic parameters will be assessed and anomalies will be discussed. Groundwater quality conditions are compared to the water quality objectives set by the RPM Water Use Licence *(WUL)* as well as the South African National Standards for drinking water *(SANS 241:2015)*. The respective standards are provided in **Tables 1** and **2**.

The purpose with the time-series plots is not to show exact concentrations for each monitoring point and each parameter, but rather to present an overall impression of the trends over the past year.

One of the most appropriate ways to interpret the type of water at a sampling point is to assess the plot position of the water quality on different analytical diagrams like a Piper, Expanded Durov and Stiff diagrams. Of these three types, the Expanded Durov diagram probably gives the most holistic water quality signature. The characteristics of the different fields of the Expanded Durov diagram (EDD) are discussed briefly in **Figure 2.**

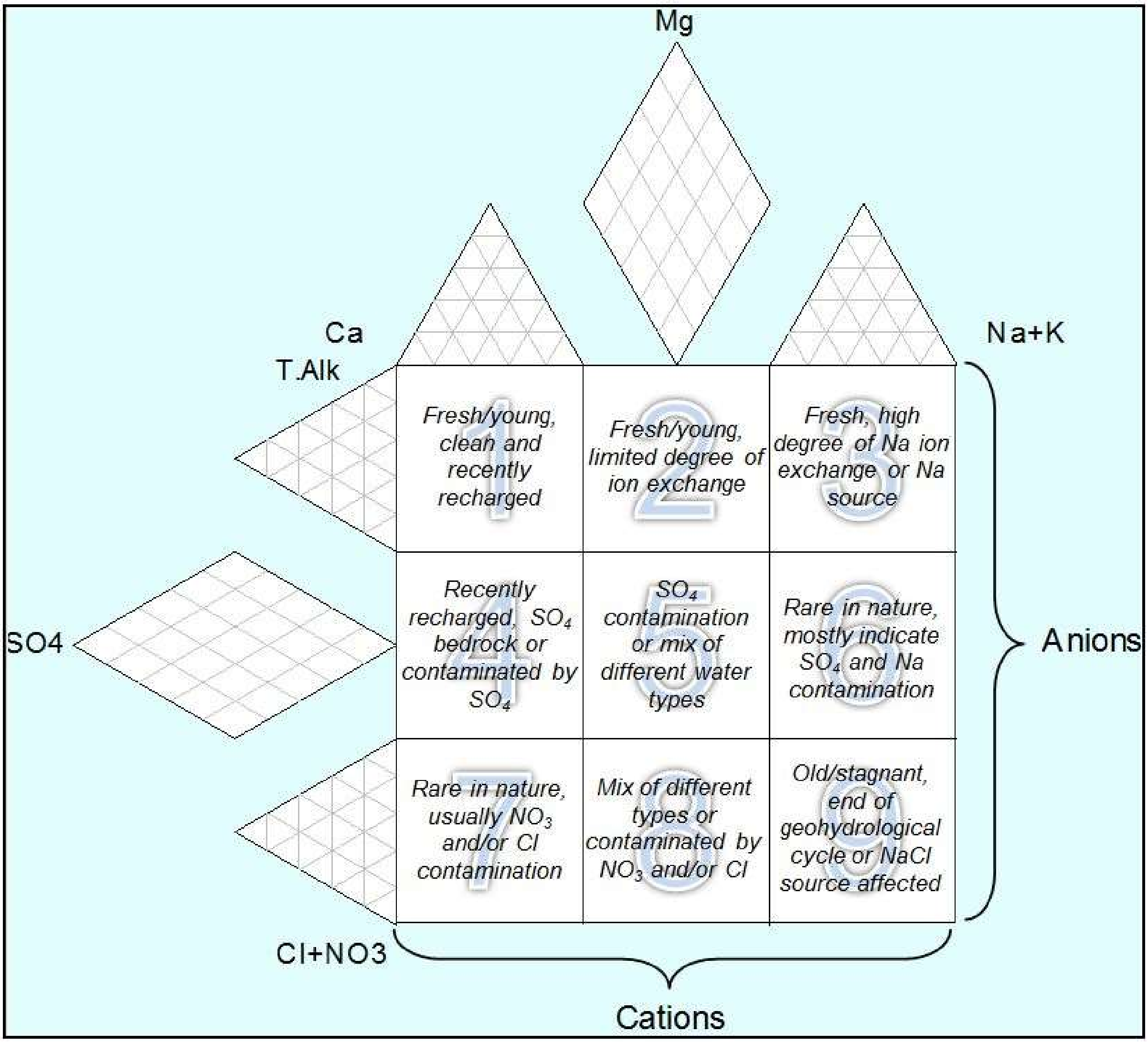


**Figure 2: Layout of the Expanded Durov diagram**

Another way of presenting the signature or water type distribution in an area is by means of Stiff diagrams. These diagrams plot the equivalent concentrations of the major cations and anions on a horizontal scale on opposite sides of a vertical axis. The plot point on each parameter is linked to the adjacent one resulting in a polygon around the cation and anion axes. The result is a small figure/diagram of which the geometry typifies the groundwater composition at the point. Ambient groundwater qualities in the same aquifer type and water polluted by the same source will for example display similar geometries.

**Table 1: Guideline concentrations according to RPM Water Use Licence**

| Chemical Parameter | *Unit* | RPM WUL Guideline Concentration |
|---|---|---|
| Calcium | *mg/l* | 34 |
| Chloride | *mg/l* | 14 |
| EC | *mS/m* | 45 |
| Fluoride | *mg/l* | 0.4 |
| Magnesium | *mg/l* | 16 |
| Nitrate | *mg/l* | 0.2 |
| pH | *N/A* | 6 - 9.5 |
| Sodium | *mg/l* | 22 |
| Sulphate | *mg/l* | 20 |

**Table 2: South African National Standards for drinking water *(SANS 241:2011)***

| Determinant | Risk | *Unit* | Standard limits |
|---|---|---|---|
| **Physical and aesthetic determinants** | | | |
| Free chlorine | Chronic health | *mg/L* | ≤ 5 |
| Monochloramine | Chronic health | *mg/L* | ≤ 3 |
| Conductivity at 25 °C | Aesthetic | *mS/m* | ≤ 170 |
| Total dissolved solids | Aesthetic | *mg/L* | ≤ 1 200 |
| Turbidity | Operational | *NTU* | ≤ 1 |
| | Aesthetic | *NTU* | ≤ 5 |
| pH at 25 C | Operational | *pH units* | ≥ 5 to ≤ 9.7 |
| **Chemical determinants - macro-determinants** | | | |
| Nitrate as N | Acute health – 1 | *mg/L* | ≤ 11 |
| Nitrite as N | Acute health – 1 | *mg/L* | ≤ 0.9 |
| Sulphate as $SO_4^{2-}$ | Acute health – 1 | *mg/L* | ≤ 500 |
| | Aesthetic | *mg/L* | ≤ 250 |
| Fluoride as $F^-$ | Chronic health | *mg/L* | ≤ 1.5 |
| Ammonia as N | Aesthetic | *mg/L* | ≤ 1.5 |
| Chloride as $Cl^-$ | Aesthetic | *mg/L* | ≤ 300 |
| Sodium as Na | Aesthetic | *mg/L* | ≤ 200 |
| Zinc as Zn | Aesthetic | *mg/L* | ≤ 5 |
| **Chemical determinants - micro-determinants** | | | |
| Aluminium as Al | Operational | *mg/L* | ≤ 0.3 |
| Antimony as Sb | Chronic health | *mg/L* | ≤ 0.02 |
| Arsenic as As | Chronic health | *mg/L* | ≤ 0.01 |
| Barium Ba | Chronic health | *mg/L* | ≤ 0.7 |
| Boron B | Chronic health | *mg/L* | ≤ 2.4 |
| Cadmium as Cd | Chronic health | *mg/L* | ≤ 0.003 |
| Total chromium as Cr | Chronic health | *mg/L* | ≤ 0.05 |
| Cobalt as Co | Chronic health | *mg/L* | ≤ 0.5 |

| Determinant | Risk | *Unit* | Standard limits |
|---|---|---|---|
| Copper as Cu | Chronic health | *mg/L* | ≤ 2 |
| Cyanide (recoverable) as $CN^{-}$ | Acute health – 1 | *mg/L* | ≤ 0.07 |
| Iron as Fe | Chronic health | *mg/L* | ≤ 2 |
| | Aesthetic | *mg/L* | ≤ 0.3 |
| Lead as Pb | Chronic health | *mg/L* | ≤ 0.01 |
| Manganese as Mn | Chronic health | *mg/L* | ≤ 0.4 |
| | Aesthetic | *mg/L* | ≤ 0.1 |
| Mercury as Hg | Chronic health | *mg/L* | ≤ 0.006 |
| Nickel as Ni | Chronic health | *mg/L* | ≤ 0.07 |
| Selenium as Se | Chronic health | *mg/L* | ≤ 0.04 |
| Uranium as U | Chronic health | *mg/L* | ≤ 0.015 |
| Vanadium as V | Chronic health | *mg/L* | ≤ 0.2 |
| **Organic determinants** | | | |
| Total organic carbon | Acute health – 1 | *mg/L* | ≤ 10 |

**Table 3: Average concentrations of indicator parameters for the 2018/2019 monitoring year**

| Site Name | pH | TDS | Ca | Mg | Na | K | Cl | SO4 | NO3 | Fe | Mn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l |
| BMRWWTW | 8.4 | 951 | 99 | 60 | 135 | 2 | 23 | 460 | 3.016 | -0.009 | 0.081 |
| EM11 | 7.5 | **2179** | 264 | 236 | **223** | 12 | **886** | 331 | 0.692 | 0.263 | 0.888 |
| EM16 | 8.1 | **3437** | 402 | 266 | **410** | 4 | **1083** | **1018** | 0.781 | -0.009 | 3.525 |
| NB01 | - | - | - | - | - | - | - | - | - | - | - |
| NB03 | 8.3 | **1104** | 91 | 110 | 109 | 18 | 64 | **533** | -0.459 | -0.009 | 0.196 |
| NB04 | 8.0 | 451 | 30 | 27 | 43 | 12 | 18 | 1 | 0.085 | -0.009 | 0.166 |
| NB48 | - | - | - | - | - | - | - | - | - | - | - |
| NB52 | 7.9 | **1797** | 104 | 41 | 87 | 57 | 58 | 119 | **54.429** | 0.830 | 0.567 |
| NB56 | 8.4 | 681 | 17 | 47 | 133 | 18 | 68 | 84 | 0.596 | -0.009 | 0.080 |
| NB57 | 8.4 | 775 | 13 | 50 | 138 | 18 | 61 | 114 | 0.152 | -0.009 | 0.061 |
| NBH07 | 7.4 | **25630** | 3332 | 824 | **4674** | 121 | **15538** | 1 | 0.097 | 0.505 | **53.760** |
| S011 | 7.4 | **6664** | 565 | 203 | **1218** | 5 | 78 | **4074** | 10.480 | 0.017 | **4.873** |
| S051 | 8.0 | **1406** | 117 | 133 | 158 | 7 | 104 | **594** | 2.249 | -0.009 | 0.058 |
| S102 | 8.2 | **6448** | 115 | 265 | **1822** | 15 | **1209** | **2567** | -0.212 | -0.002 | 0.091 |
| S104 | 8.2 | **1123** | 93 | 63 | 197 | 4 | 43 | 466 | 1.222 | 0.038 | 0.243 |
| S120 | 9.3 | **20319** | 29 | 185 | **6708** | 43 | **596** | **11796** | -0.034 | 0.159 | 0.328 |
| S160 | 8.2 | **2223** | 163 | 98 | **463** | 4 | **530** | **675** | 0.746 | -0.009 | 0.024 |
| S230 | 8.4 | **6175** | 142 | 74 | **1785** | 81 | **352** | **2395** | -0.459 | 0.019 | 0.496 |
| S373 | 8.1 | **2982** | 334 | 264 | **359** | 10 | **1198** | 380 | 0.696 | 0.000 | 0.050 |
| S374 | 7.0 | **6781** | 778 | 512 | **915** | 47 | **3816** | 363 | **47.432** | 0.007 | 1.351 |
| S386 | 7.8 | **4448** | 759 | 136 | **610** | 7 | **723** | **1927** | -0.459 | -0.009 | 0.138 |
| S388 | 7.2 | **3333** | 480 | 174 | **365** | 26 | 56 | **1678** | -0.459 | 1.930 | 1.920 |
| S389 | 8.0 | **15305** | 422 | 430 | **4360** | 18 | **2235** | **7148** | -0.459 | 0.126 | 0.331 |
| S400 | 7.5 | **3055** | 281 | 208 | **461** | 2 | 299 | **1483** | 2.770 | -0.009 | 0.188 |
| S403 | 7.8 | **1471** | 119 | 60 | **298** | 8 | 33 | **744** | 1.688 | -0.002 | 0.023 |
| S405 | - | - | - | - | - | - | - | - | - | - | - |
| S407 | 8.2 | **2756** | 213 | 184 | **479** | 4 | 287 | **1252** | 2.493 | -0.009 | 0.057 |
| S409 | 8.5 | **2749** | 146 | 151 | **481** | 18 | 99 | **1209** | 2.599 | 0.013 | 0.045 |
| S410 | 8.3 | **2271** | 160 | 182 | **313** | 9 | 136 | **1025** | 3.370 | -0.009 | 0.076 |
| S418 | 7.2 | **56992** | 480 | 136 | **18210** | 66 | **481** | **36978** | -0.264 | **18.306** | **27.906** |

***RED – Exceeds SANS maximum limit for drinking water**

## 2.1 WATERVAL SMELTER, CONCENTRATOR, AND ACID PLANT

Three boreholes were in use to monitor groundwater impacts at the Waterval Processing area during the 2006/07 monitoring year. Thirteen monitoring boreholes were added in order to sufficiently cover the area. Ten boreholes were monitored during the 2015/2016 monitoring year. In the 2018/2019 monitoring year, 7 boreholes remained as part of the monitoring plan of which 5 were sampled and their positions are indicated in **Figure 3**

This processing complex consists of a number of processing modules including the Waterval Concentrator, Waterval Smelter, UG2 Concentrator and the Acid Plant. The larger part of the surface area underlying the Waterval Processing area is lined by concrete surfaces and effluent dams like storm water control, settling and return water dams are lined with synthetic or clay liners. Seepage and leachate formation however still emanates from the Waterval Processing area.

The Waterval Processing area is situated to the south of an east-west trending surface water divide and groundwater flow will be in the same direction as surface flow, namely southwards. Groundwater seepage and mass transport will thus also occur southwards and then west in the direction of flow of the Klipfontein Spruit.

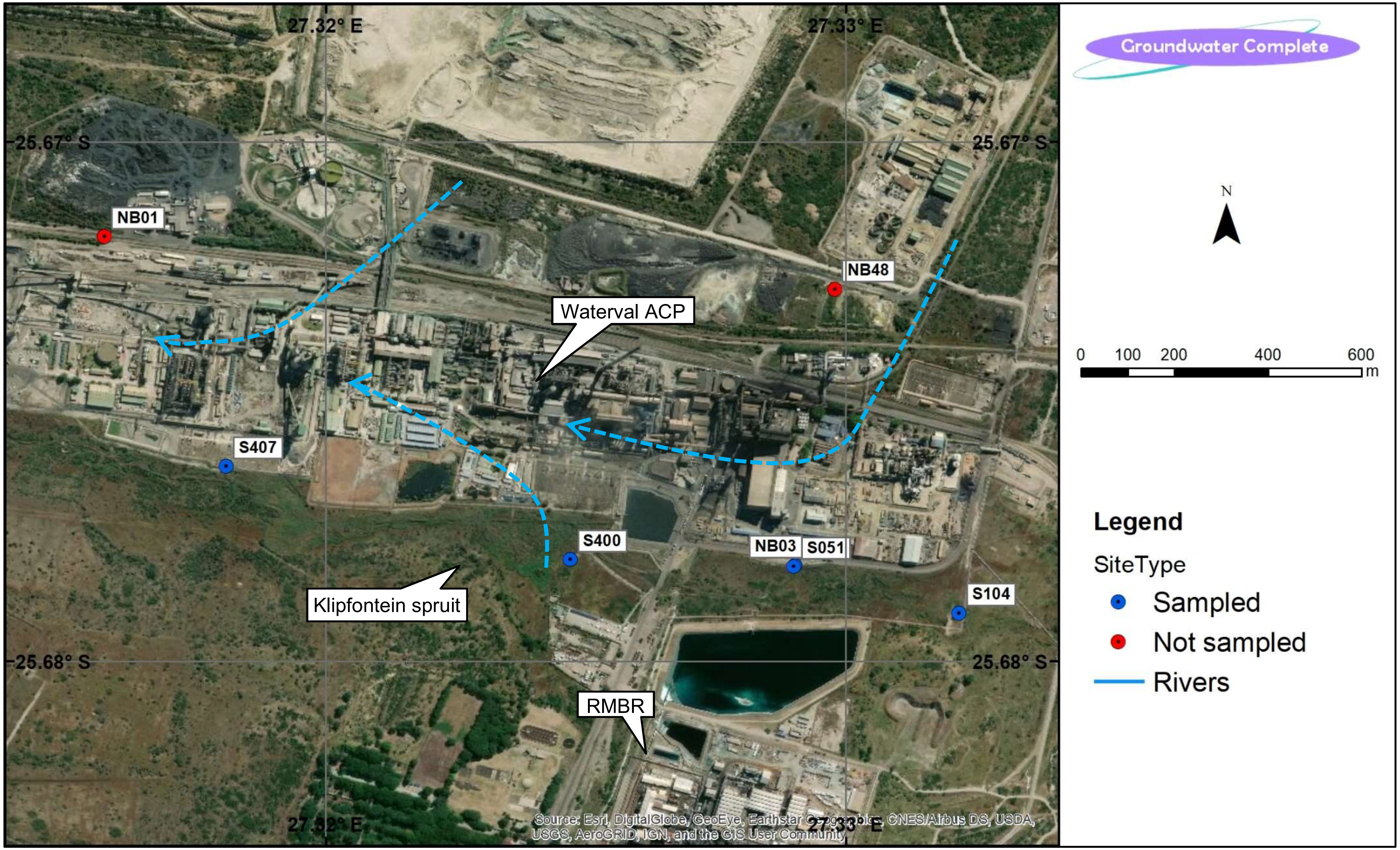


**Figure 3: Positions of monitoring boreholes in the Waterval Processing area**

Time-series plots of indicator chemical parameters for the Waterval Processing area are presented in **Figures 4** and **5**.

Average groundwater **TDS** concentrations for the 2018/2019 monitoring year in S104 and NB03 varied between ± 1100 mg/l and 1 125 mg/l, which are just below the permissible SANS value of 1 200 mg/l, however, they did on numerous sampling runs exceed the permissible levels. Groundwater salinity measured in monitoring boreholes S051, S400 and S407 exceeded the maximum concentration allowed in drinking water and displayed averages of between ± 1 400 mg/l and 3 060 mg/l. The highest concentration was measured in S407 and time-series graphs provided in **Figure 4** display an increasing trend for this borehole. **No guideline TDS value is specified by the Water Use License for RPM.**

The **sulphate** content measured in S051, S400, S407 and NB03 exceeded the SANS guideline value of 500 mg/l and displayed averages of between ± 530 mg/l and 1 480 mg/l. Again, the highest concentrations were measured in monitoring borehole 407, which also displayed a general increase in the groundwater sulphate content **(Figure 4)**. An average of 466 mg/l was measured in borehole S104, which just falls short of the maximum concentration allowed in drinking water. **The groundwater sulphate content measured in all monitoring boreholes far exceeded the RPM WUL guideline concentration of 20 mg/l throughout the entire evaluation period**.

Groundwater **chloride** concentrations measured in the majority of monitoring boreholes remained below the permissible SANS value of 300 mg/l during the 2018/2019 monitoring period **(Figure 5)**. The highest concentrations were once again measured in monitoring boreholes S400 and S407, which displayed an average ± 300 and 290 mg/l respectively. The downgradient monitoring borehole S407 also displayed an increasing concentration trend for chloride, not exceeding the maximum permissible limits for drinking water (300 mg/l). **The groundwater chloride content within the immediate vicinity of the Waterval Processing area exceeded the RPM WUL guideline concentration of 14 mg/l**.

Groundwater **sodium** concentrations measured in monitoring boreholes S400 and S407 exceeded the permissible SANS value of 200 mg/l during the past monitoring year and displayed averages of ± 460 mg/l and 480 mg/l respectively. Averages of between ± 110 mg/l and 200 mg/l were measured in the remainder of groundwater monitoring boreholes, which are within the maximum concentration allowed in drinking water. The groundwater sodium content in S140 seems to have decreased during the past monitoring year, while the concentrations in S407 and S102 increased **(Figure 5)**. **The WUL guideline concentration of 22 mg/l was exceeded in all boreholes during the 2018/2019 monitoring year.**

Groundwater **nitrate** concentrations remained below the permissible SANS value of 11 mg/l throughout the entire monitoring period. Monitoring boreholes displayed averages from less than 1 mg/l to 2.8 mg/l. Higher than ambient nitrate concentrations were observed in S051, S400 and S407. Increasing nitrate concentration trends were also observed in both these boreholes over the monitoring period. **The nitrate content of groundwater within the immediate vicinity of the Waterval Processing area exceeded the RPM WUL guideline concentration of 0.2 mg/l in all boreholes, except for NB03**.

According to **Figures 6** and **7** the Waterval Processing area is mainly dominated by groundwater that is usually a mix of different types – either clean water from fields 1 and 2 of the Expanded Durov diagram (EDD) that has undergone sulphate and sodium chloride mixing/contamination or old stagnant sodium chloride dominated water that has mixed with clean water – groundwater is therefore dominated by **magnesium/sodium** cations, while **sulphate/chloride** dominates the anion content. This indicates that the groundwater has definitely experienced adverse effects from the Waterval processing area activities.

**The dominant plot position in field 5 of the EDD confirms definite impacts of the Waterval Processing area on the natural groundwater environment.**

Average **water levels** for the Smelter and ACP monitoring boreholes varied between 2 and 4 meters below surface (mbs). NB03 displayed a decreasing water level trend **(Figure 8)**.

**Summary:**

- Definite impacts from the Waterval Processing area occur on the down gradient groundwater environment.
- Sulphate is especially of concern, as the majority of groundwater monitoring boreholes indicated elevated concentrations.
- Up gradient groundwater monitoring borehole S407 displayed the highest levels of pollution throughout the 2018/2019 monitoring year, however the pollution is unlikely to originate from the Waterval Processing area.
- S400 also had overall high borehole concentration levels, however it only had a single sample taken and its level of pollution can't be determined definitively.
- Increasing parameter concentrations in the downgradient monitoring borehole, S407 are often observed over the monitoring period.
- **Concentrations of indicator chemical parameters do not comply with the water quality objectives stated in the RPM Water Use License.**
- Water levels vary between 2 and 4 mbs.

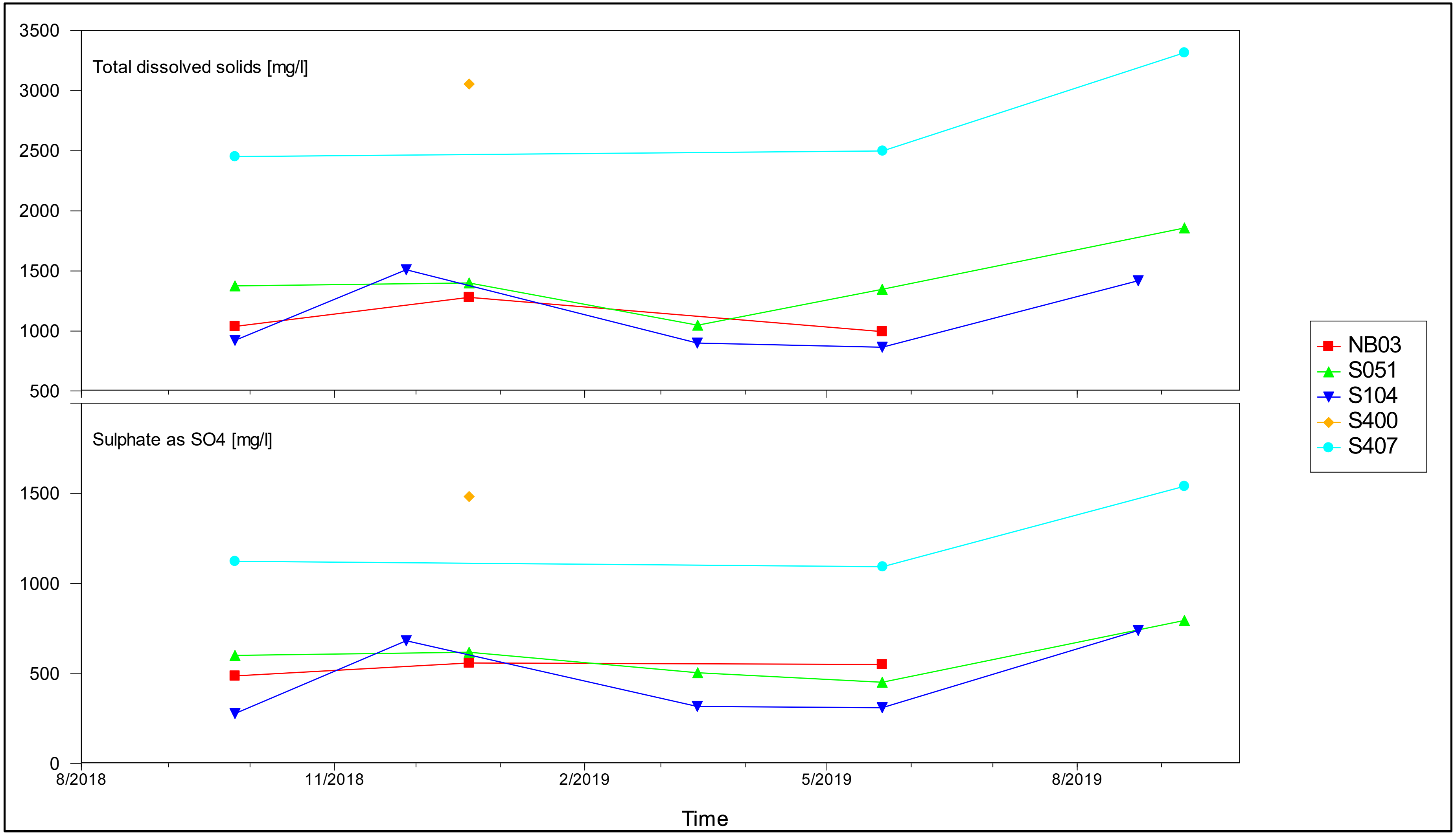


**Figure 4: Time-series plot of indicator chemical parameters in the Waterval Processing area – TDS and $SO_4$**

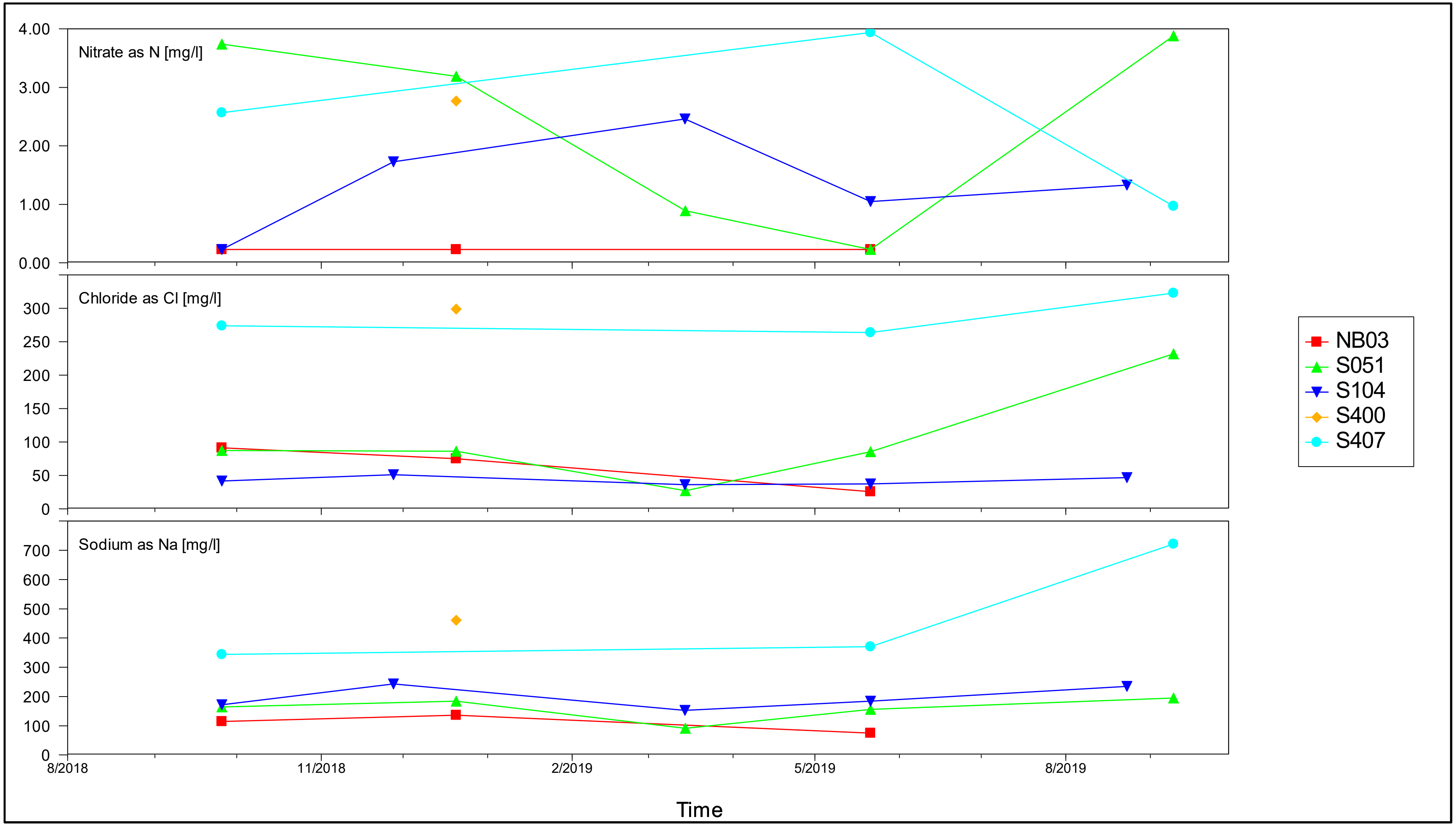


**Figure 5: Time-series plot of indicator chemical parameters in the Waterval Processing area – $NO_3$, Cl and Na**

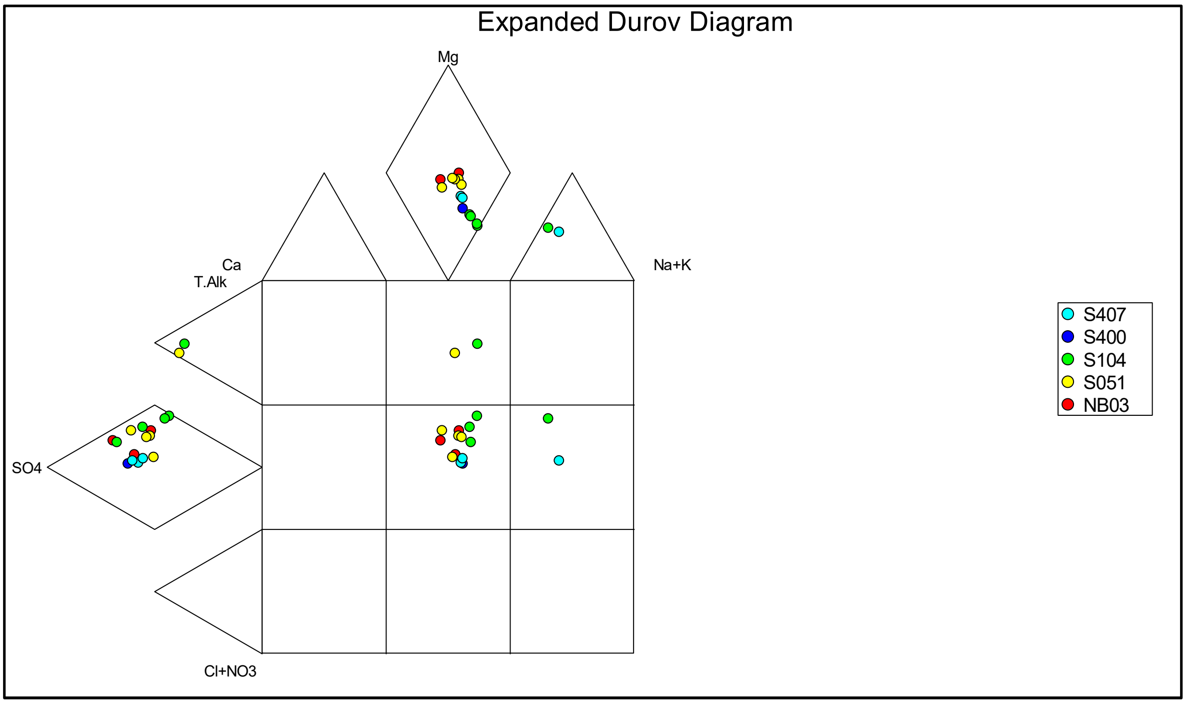


**Figure 6: EDD of groundwater chemistry in the Waterval Processing area**

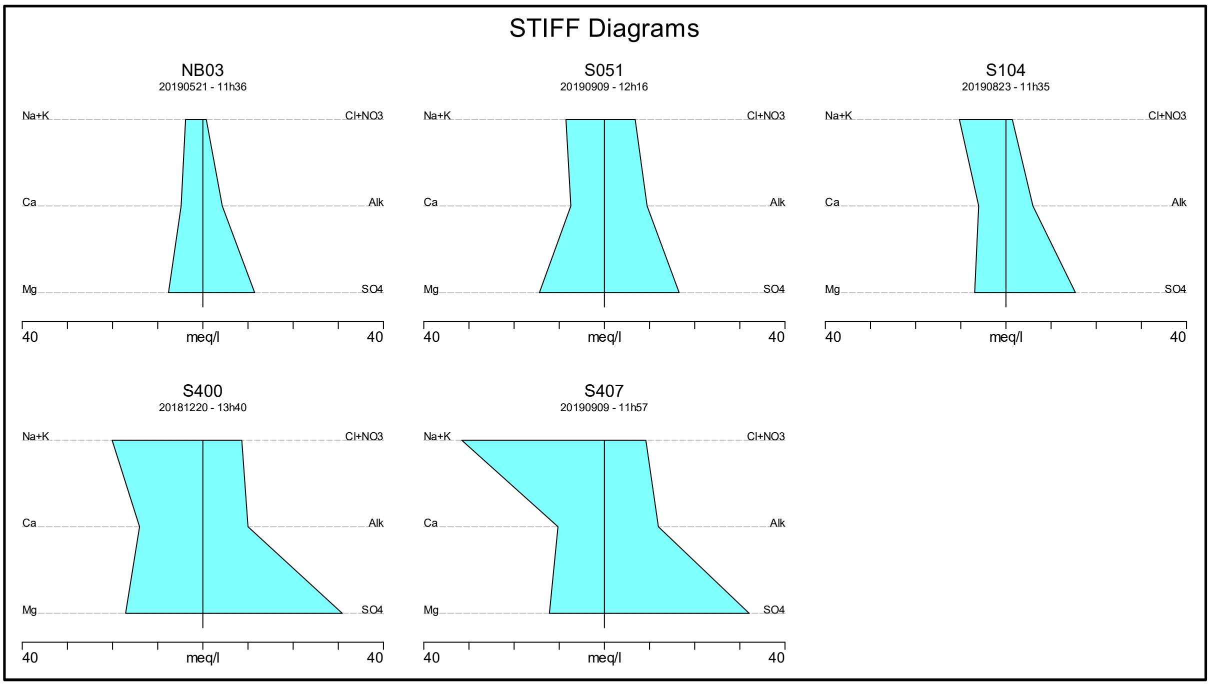


**Figure 7: Stiff diagrams of groundwater chemistry in the Waterval Processing area**

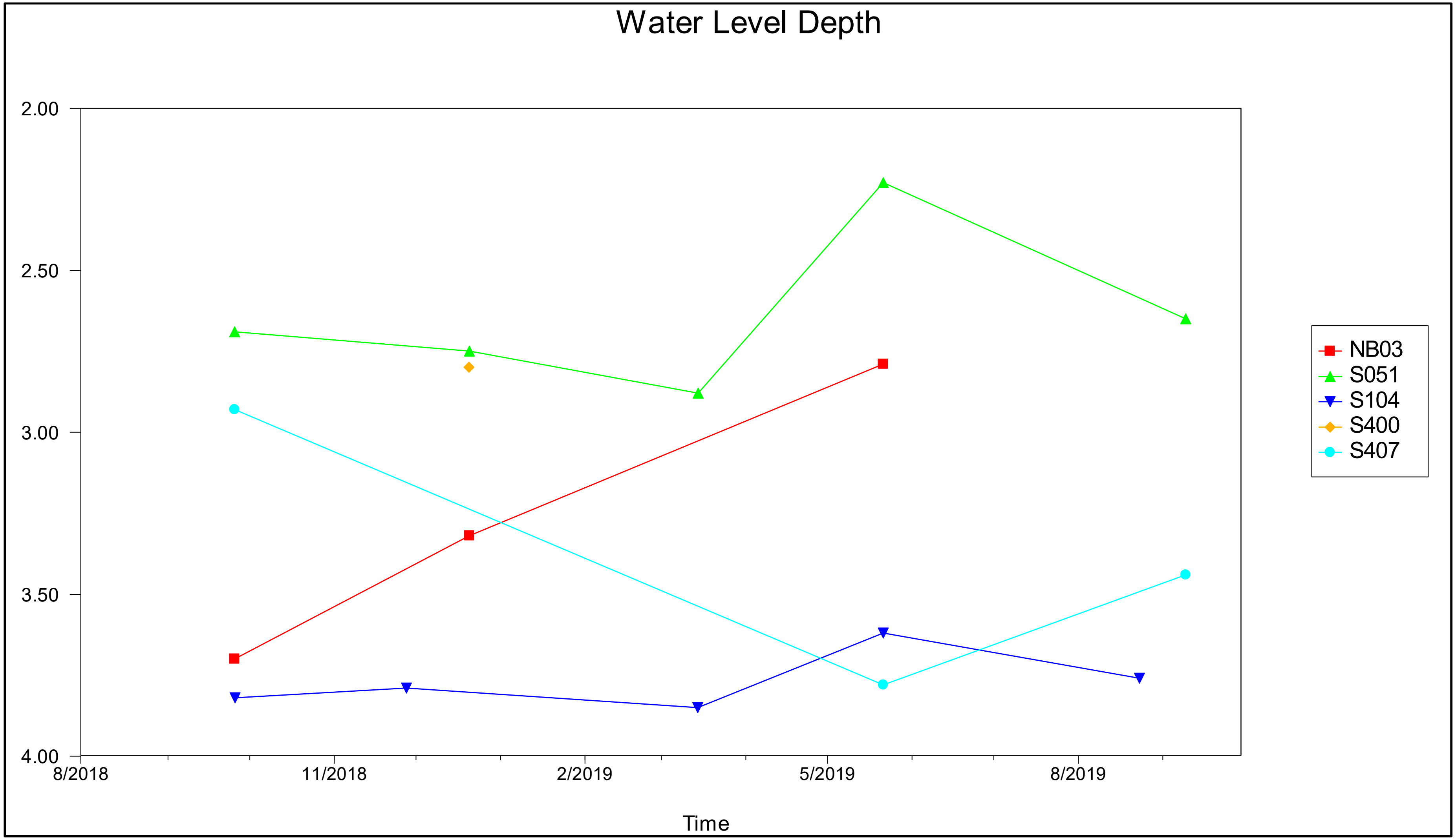


**Figure 8: Time series plot of water levels for in the Waterval Processing area**

## 2.2 THE RUSTENBURG BASE METAL REFINERY (RBMR)

Seven boreholes were historically used to monitor groundwater impacts at the Rustenburg Base Metal Refinery (RBMR). The distribution and number of monitoring boreholes were insufficient during previous monitoring years, after which boreholes were drilled and existing ones were added to the more extensive monitoring programme.

A total of 15 boreholes were monitored in the Rustenburg Base Metal Refinery area during the 2018/2019 monitoring period and their positions are indicated in **Figure 9**.

This processing complex consists of a large base metal refinery area with associated effluent dams for storage of process water. The most notable of these are the sodium sulphate solution area to the south-east of the refinery where highly concentrated sodium sulphate solution by-product is treated and dried. The groundwater pollution in this area is by far the dominant impact of the RBMR area as a result of leachate formation as well as seepage from effluent dams where historical liners were not fully impervious.

The larger part of the surface area underlying the actual refinery is lined by concrete surfaces, but historical leaks and dumping caused the formation of a large diffuse source area for contamination. Seepage and leachate formation thus still emanates from the RBMR area and remediation plans target the RBMR as the first priority area. The RBMR is situated on the southern banks of the Klipfontein Spruit directly opposite the Waterval Processing area. Groundwater flow and mass transport from the site is northwards in the direction of the Klipfontein Spruit **(Figure 9)**.

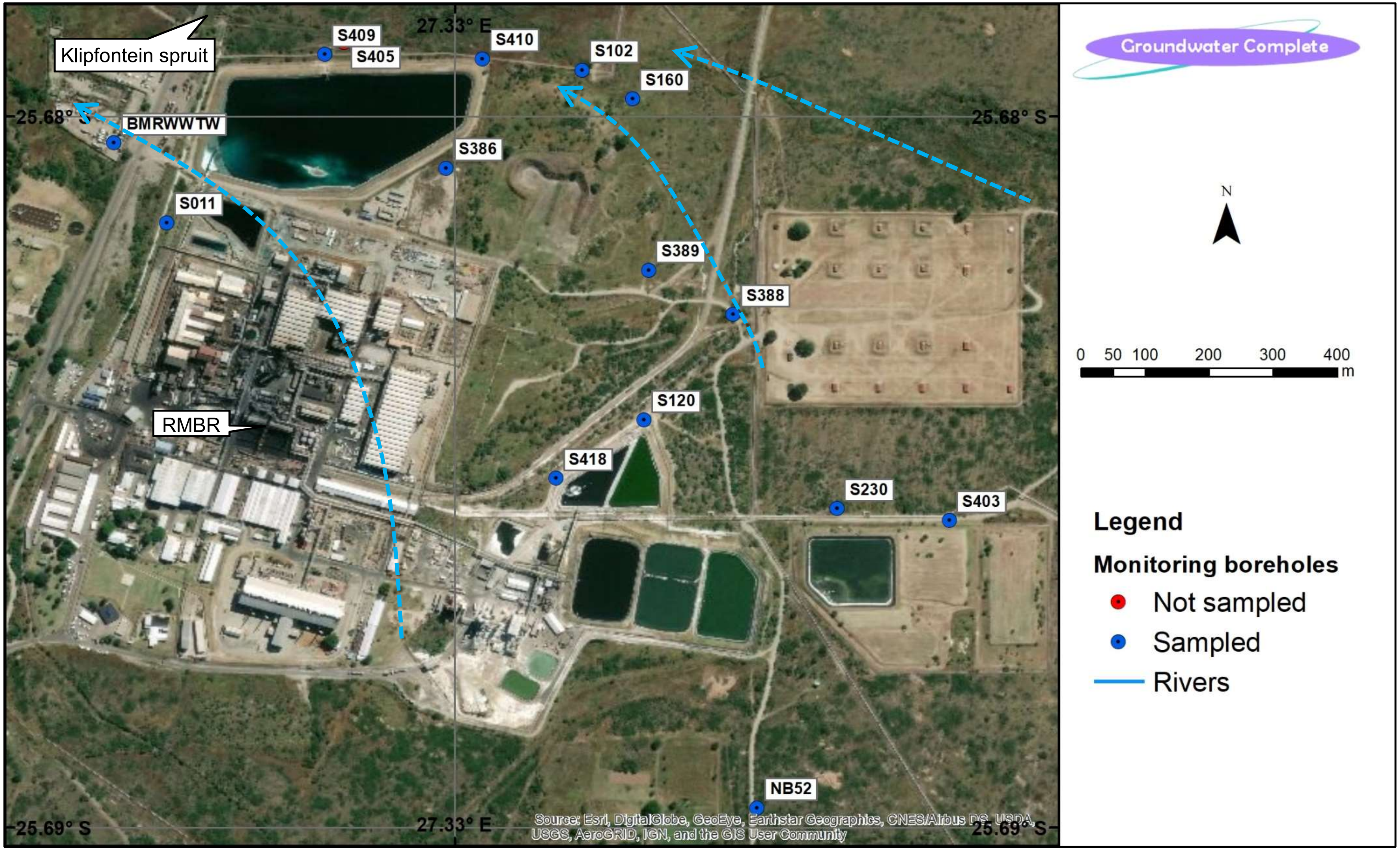


**Figure 9: Positions of monitoring boreholes in the RBMR area**

Time-series plots of the indicator chemical parameters for the RBMR area are presented in **Figures 10** and **11**.

The groundwater **TDS** concentrations for all the RBMR boreholes, except BMRWWTW, far exceeded the permissible SANS value of 1 200 mg/l during the 2018/2019 monitoring year. Averages in the down gradient groundwater flow direction varied between ± 1 470 mg/l and 57 000 mg/l. The highest concentrations by far were measured down gradient from the sodium sulphate solution area in monitoring borehole S418. The TDS concentration in S418 increased further over the monitoring period with the highest concentration measured in May 2019 at 86 750 mg/l. The TDS concentrations in the remainder of the boreholes remained relatively constant over the monitoring period **(Figure 10)**. Exceptions did occur and some boreholes displayed much lower salinities throughout the year. Variations within such short distances might indicate the presence of groundwater compartments created by low transmissivity dykes. **No guideline TDS value is specified by the Water Use License for RPM.**

Sulphate and sodium **(Figures 12** and **13)** make up most of the inorganic salinity in the groundwater. Average **sulphate** concentrations measured in the majority of groundwater monitoring boreholes varied between ± 740 mg/l and 36 980 mg/l, which far exceed the permissible SANS value of 500 mg/l. The groundwater sulphate content measured in boreholes BMRWWTW and NB52 did however remain below the SANS acute health guideline value for drinking water throughout the evaluation period, with averages of 460 and 120 mg/l respectively. Borehole S418 is located directly down gradient from the sodium sulphate solution area and indicated the most profound sulphate pollution. Similar to groundwater salinity, the sulphate content in S418 have increased during the past monitoring year **(Figure 10)**. A concentration exceeding 55 000 mg/l was measured in May 2019 in this borehole. **The RPM WUL guideline concentration of 20 mg/l was exceeded by all monitoring boreholes.**

Groundwater **sodium** and sulphate concentrations displayed much the same distribution and trends with the highest levels of pollution being measured down gradient from the sodium sulphate solution area in monitoring borehole S418. The groundwater sodium content measured in the majority of the monitoring boreholes far exceeded the permissible SANS concentration of 200 mg/l and displayed averages of between ± 300 mg/l and 18 200 mg/l. Once again similar to groundwater salinity and sulphate, the sodium content in S418 has increased during the past monitoring year **(Figure 10)**. **The groundwater sodium content measured in all monitoring boreholes exceeded the RPM WUL guideline concentration of 22 mg/l throughout most of the past monitoring year.**

Average **nitrate** concentrations measured in groundwater both up and down gradient from the RBMR area are below the permissible SANS value of 11 mg/l. Monitoring borehole S409 displayed an average concentration of 10 mg/l, which is higher than the surrounding monitoring boreholes. The remainder of the boreholes had average nitrate concentrations from below detection limit to 3.5 mg/l. Some fluctuation in concentrations were measured in most boreholes throughout the past monitoring year **(Figure 11)**. The nitrate concentration in NB52 increased significantly over the past monitoring year. The reason for the increase is unknown, but definitely not caused by the RBMR, as it is in the up-gradient direction of groundwater flow. **The RPM WUL guideline concentration of 0.2 mg/l was exceeded in all monitoring boreholes, except S386, S389, S388 and S230, of which the concentrations were all below detection level.**

Groundwater monitoring boreholes S102, S120, S160, S230, S386, S389 and S418 displayed average groundwater **chloride** concentrations of between ± 350 mg/l and 2 230 mg/l, which exceed the permissible SANS value of 300 mg/l. Averages measured in the remainder of boreholes are within the maximum concentration allowed in drinking water. The highest concentrations were measured in S389, which, however, displayed a decreasing trend over the monitoring period **(Figure 11)**. The concentration in S102 also decreased significantly over the monitoring period. **The chloride content of groundwater within the immediate vicinity of the RBMR operations exceeded the RPM WUL guideline concentration of 14 mg/l.**

The groundwater **iron** content measured in the majority of monitoring boreholes remained below the detection limit of 0.0045 mg/l throughout the past monitoring year. Monitoring borehole S418 was however the exception and displayed an average of ± 18 mg/l, which far exceeds the permissible SANS concentration of 2 mg/l. Significant fluctuations in the groundwater iron content have been measured in S418 throughout the past 10 years, which is only possible under unstable groundwater pH conditions. **No guideline concentration is specified for iron in the Water Use License for RPM.**

According to **Figures 12** and **13** the following types of groundwater are predominant within the immediate vicinity of the RBMR area:

- Fresh, clean, relatively young groundwater – groundwater is therefore dominated by **calcium/magnesium/sodium** cations, while the anion content is dominated by **bicarbonate alkalinity**.
- Groundwater that is usually a mix of different types – either clean water from fields 1 and 2 of the EDD that has undergone sulphate and sodium chloride mixing/contamination or old stagnant sodium chloride dominated water that has mixed with clean water – groundwater is therefore dominated by **magnesium** cations and **sulphate** anions.
- Groundwater that has been in contact with a source rich in sodium or old stagnant sodium chloride dominated water that resides in sodium rich host rock/material – groundwater is therefore dominated by **sodium/potassium** cations, while **sulphate** dominates the anion content.

**The plot positions in fields 5 and 6 of the EDD confirm definite impacts of the processing facilities on the natural groundwater environment.**

From the stiff diagrams in **Figure 13** it is clear that S120, S389 and S418 are the most significantly impacted on by the processing facilities with sulphate and sodium being the dominant ions.

The average **water levels** of the RBMR area are between 3 and 15 mbs. No significant increasing or decreasing water level trends **(Figure 14)** occur.

**Summary:**

- Significant pollution impacts from the RBMR occur on the groundwater environment.
- Impacts are by far the most significant in the sodium sulphate solution area to the south-east of the refinery.
- Groundwater iron concentrations measured in monitoring borehole S418 fluctuated significantly throughout the year, which may be the result of varying groundwater pH conditions.
- The most significant impacts from the refinery were measured in groundwater from boreholes S120, S389 and S418.
- The main contaminants of concern are sodium and sulphate.
- The extent of impact (plume) is however limited to within a few meters of the sources due to poor aquifer hydraulic properties.
- **The indicator chemical parameters do not comply with the water quality objectives stated in the RPM Water Use License.**

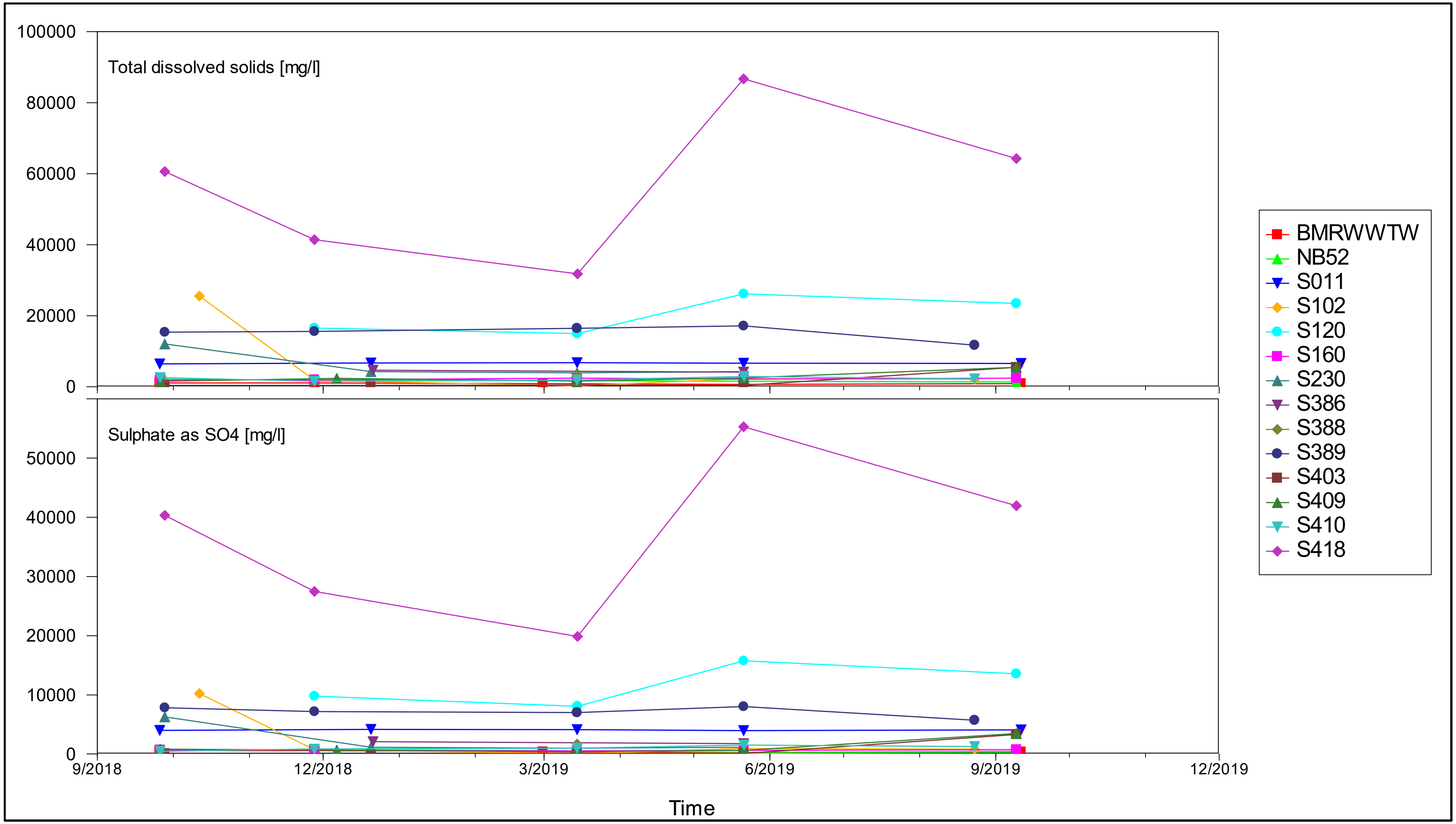


**Figure 10: Time-series plot of indicator chemical parameters in the RBMR area – TDS and $SO_4$**

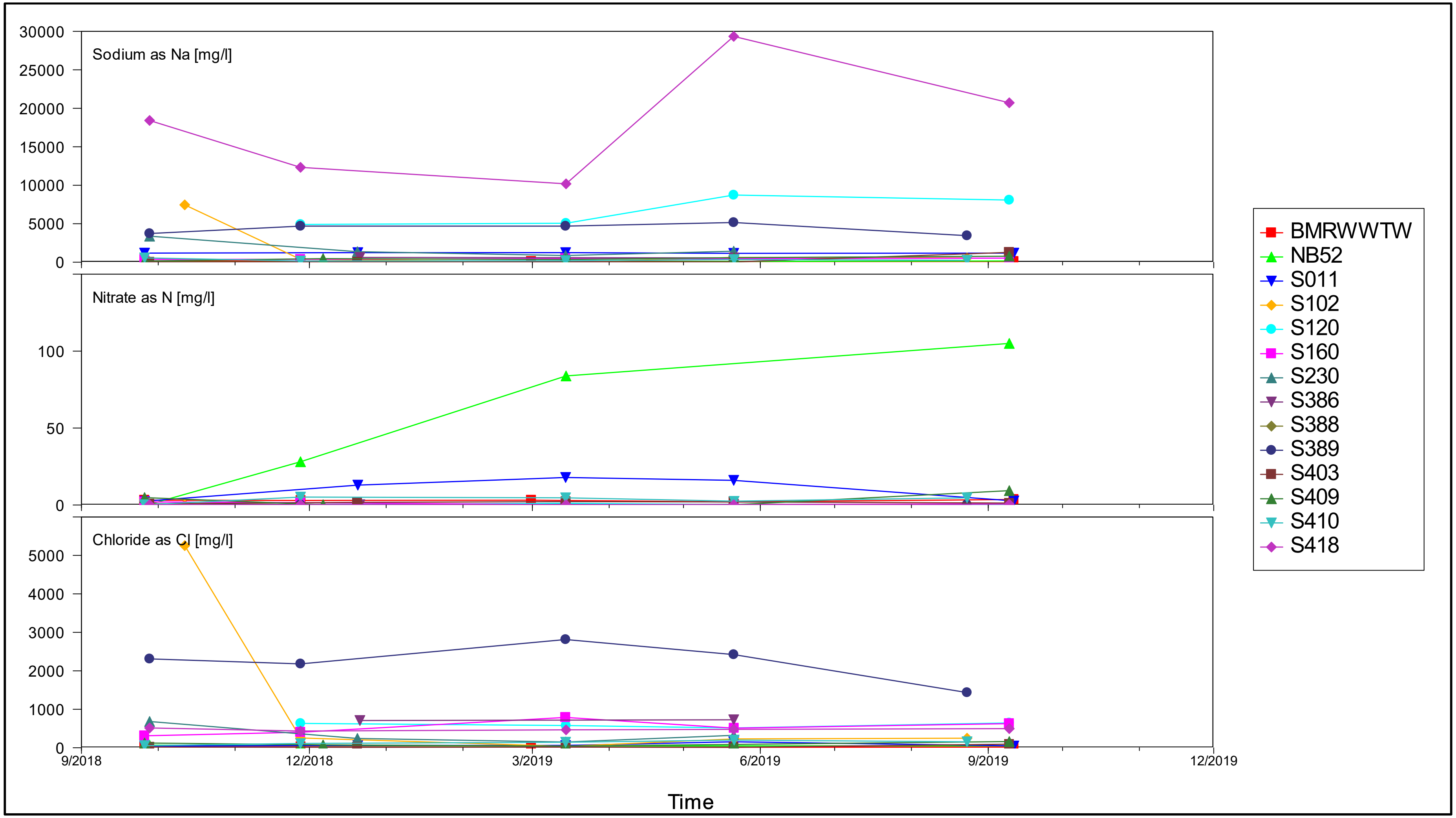


**Figure 11: Time-series plot of indicator chemical parameters in the RBMR area – Na, $NO_3$ and Cl**

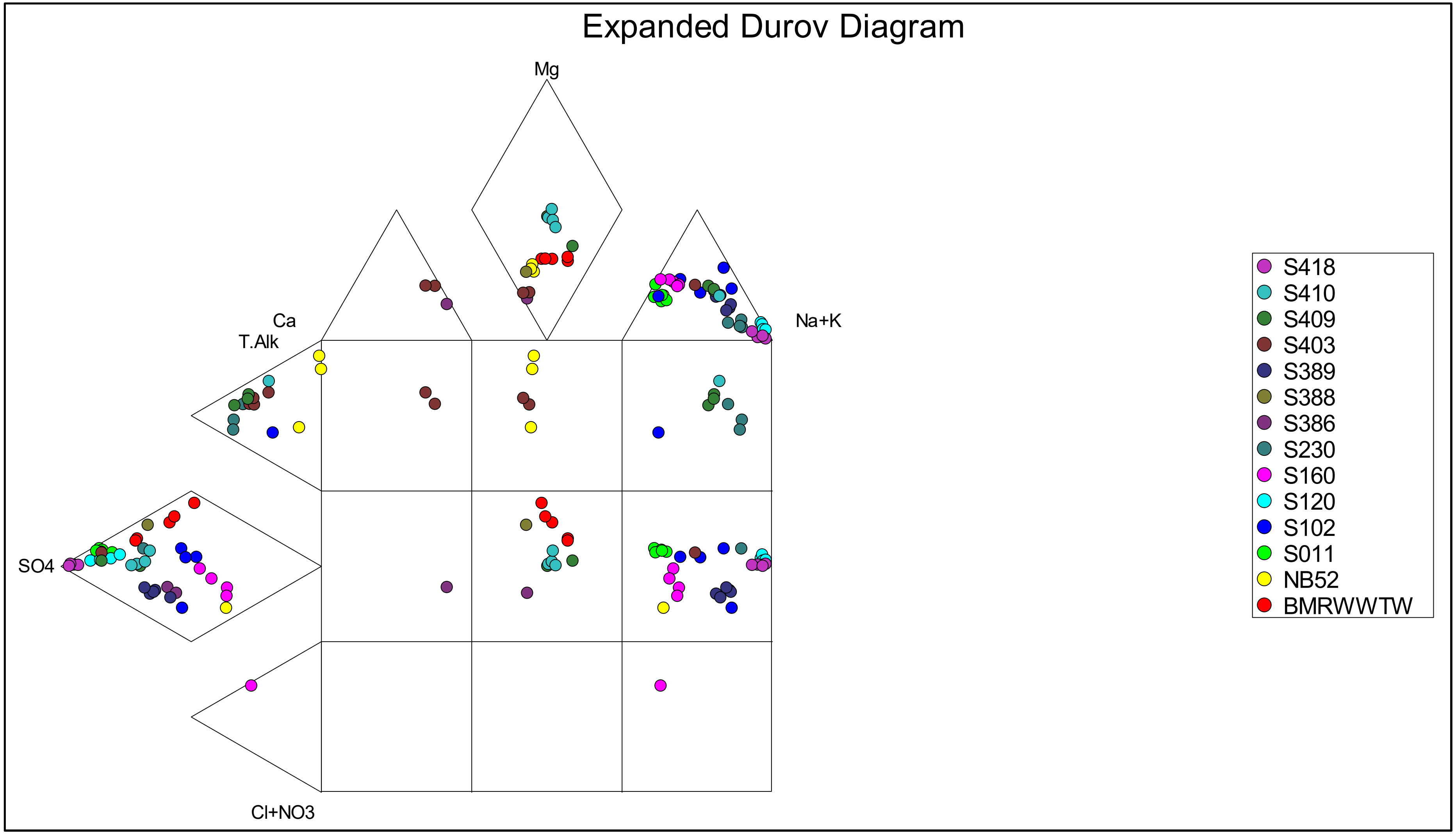


**Figure 12: EDD of groundwater chemistry in the RBMR area**

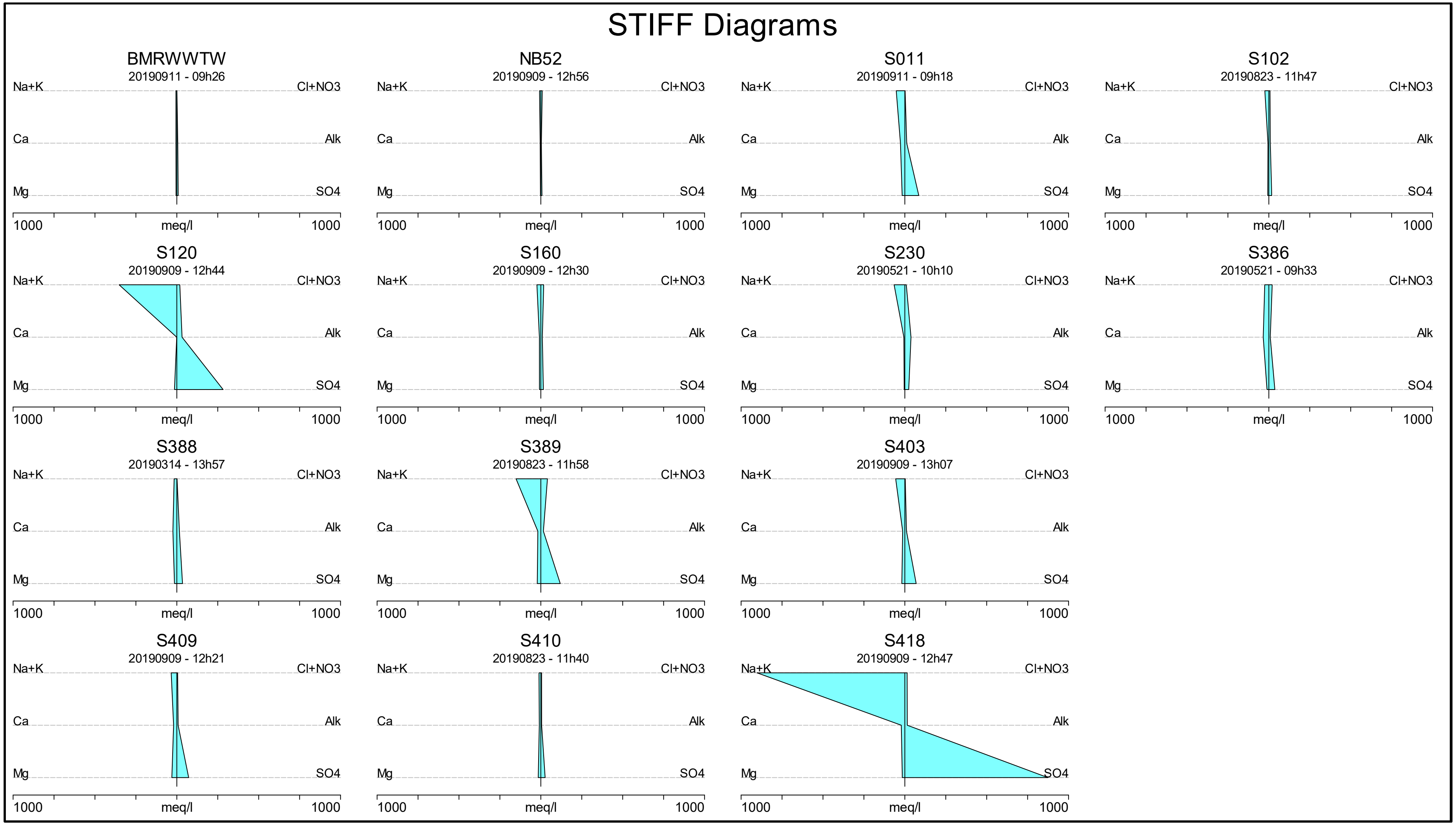


**Figure 13: Stiff diagrams of groundwater chemistry in the RBMR area**

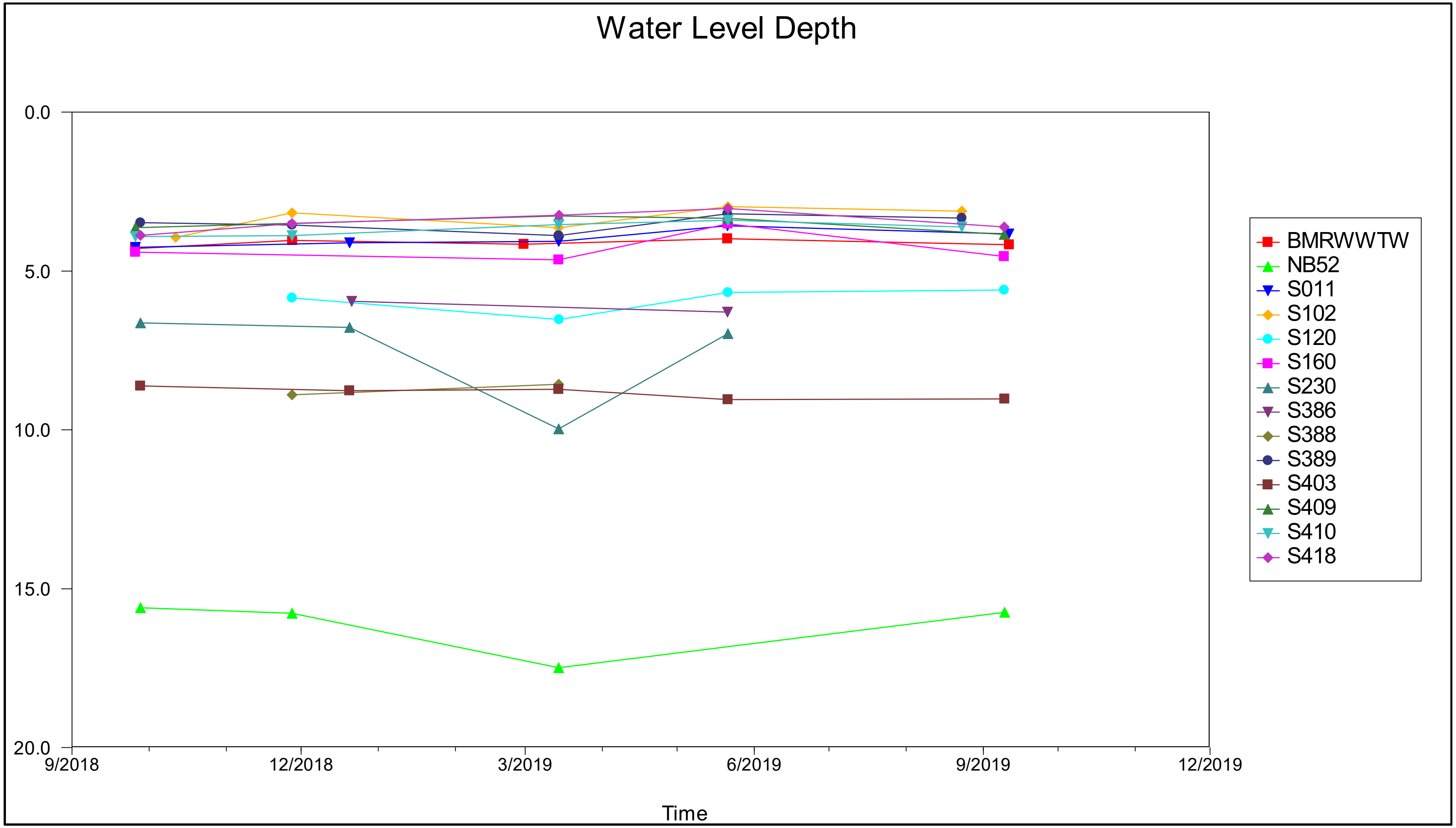


**Figure 14: Time series plot of water levels for in the RBMR area**

## 2.3 THE PRECIOUS METAL REFINERY (PMR) AND CENTRAL DEEPS SHAFT

Three boreholes were in use to monitor groundwater impacts at the Precious Metal Refinery (PMR) in 2006/2007. In an effort to increase the accuracy and efficiency of monitoring five existing boreholes were added to the monitoring program. Over the years boreholes became blocked and/or demolished and an additional source monitoring borehole, namely NBH07 was drilled approximately 60 meters down gradient from the refinery in 2013. The PMR consists of a refinery with a number of effluent dams for process water storage, settling and re-use. The precious platinum group metals are extracted at the PMR. The Central Deeps Shaft, which is located approximately 900 meters north of the PMR, is also included in this evaluation. A total of seven boreholes were monitored during the 2018/2019 monitoring year and their positions are indicated in **Figure 15**.

The PMR is a relatively new facility compared to other infrastructure at RPM and pollution control measures have been constructed according to more advanced pollution prevention technology. Leaking dam liners have however resulted in some groundwater contamination occurring in the area. The PMR is situated on the southern banks of the Klipfontein Spruit approximately 1.6 km east and up gradient from the RBMR. Groundwater flow and mass transport from the site is northwards in the direction of the Klipfontein Spruit **(Figure 15)**.

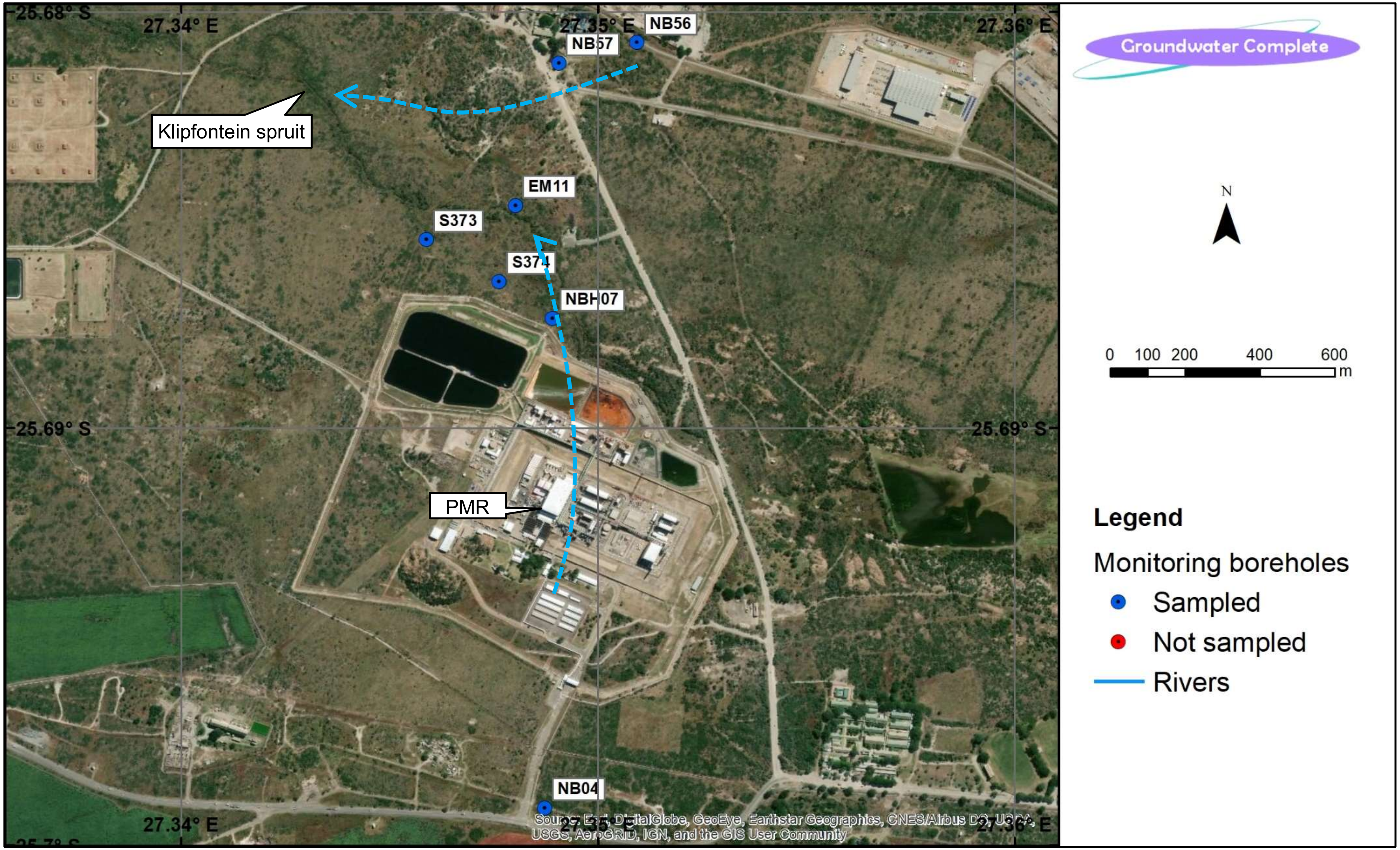


**Figure 15: Positions of monitoring boreholes in the PMR and Central Deeps Shaft areas**

Time-series plots of the indicator chemical parameters for the PMR and Central Deeps Shaft areas are presented in **Figures 16** and **17**.

Groundwater **TDS** concentrations directly down gradient from the refinery exceeded the permissible SANS value of 1 200 mg/l and displayed averages of between ± 2180 mg/l and 25 630 mg/l. This indicates severe adverse impacts associated with polluted seepage from the refinery. Concentrations measured up gradient from the refinery and down gradient from the Central Deeps Shaft area remained below the SANS guideline value for drinking water purposes **(Figure 16)**. **No guideline TDS value is specified by the Water Use License for RPM.**

The **sulphate** content of groundwater within the immediate vicinity of the PMR and Central Deeps Shaft remained below the permissible SANS concentration of 500 mg/l and displayed averages of between ± 1 mg/l and 380 mg/l. The relatively low sulphate content measured in NBH07 suggests that sulphate is not the dominant anion in the polluted seepage from the refinery.

Elevated sulphate concentrations were however measured in monitoring boreholes EM11, S373, S374, NB56 and NB57 during the monitoring year, but the concentration decreased significantly over the period from exceeding maximum permissible limits to within acute health and aesthetic limits **(Figure 16)**. **The RPM WUL guideline concentration of 20 mg/l was exceeded in all monitoring boreholes except NB04 and NBH07.**

Groundwater **sodium** concentrations measured down gradient from the PMR exceeded the permissible SANS value of 200 mg/l with average concentrations varying between ± 220 mg/l and 4 670 mg/l. The sodium content in NBH07 has increased over the monitoring period **(Figure 17)**. The sodium content of groundwater up gradient from the refinery and down gradient from the Central Deeps Shaft area remained well below the SANS guideline value for drinking water. **The RPM WUL guideline concentration of 22 mg/l was exceeded in all groundwater monitoring boreholes.**

Average groundwater **chloride** concentrations measured in boreholes EM11, S373 and S374 exceeded the permissible SANS value of 300 mg/l and displayed averages of between 890 mg/l and 3 800 mg/l. A much higher average concentration of approximately 15 540 mg/l was measured in monitoring borehole NBH07. Average concentrations measured in the remainder of boreholes were within the maximum concentration allowed for drinking water. Once again, the chloride concentration in NBH07 increased over the monitoring period **(Figure 17)**. **The groundwater chloride content within the immediate vicinity of the PMR and Central Deeps Shaft areas exceeded the RPM WUL guideline concentration of 14 mg/l.**

**The exceptionally high levels of sodium and chloride pollution that were measured in NBH07 are clear indications that both parameters are dominant ions in pollution emanating from the PMR.**

N**itrate** concentrations in most boreholes in the PMR and Central Deeps Shaft areas are not of concern and remained below the permissible SANS value of 11 mg/l/ during the past monitoring year. Monitoring borehole S374 was however the exception and displayed an average concentration of ± 47 mg/l. **The RPM WUL guideline concentration of 0.2 mg/l was exceeded in all groundwater monitoring boreholes.**

According to **Figures 18** and **19** the following types of groundwater are predominant within the immediate vicinity of the PMR and Central Deeps Shaft areas:

- Fresh, clean, relatively young groundwater that has started to undergo magnesium and sodium ion exchange – groundwater is therefore dominated by **magnesium/sodium** cations and **bicarbonate alkalinity**.
- Relatively old, stagnant groundwater that has undergone a significant degree of ion exchange reactions – groundwater is therefore dominated by **magnesium** cations and **chloride** anions.

**The plot positions in fields 8 of the EDD confirm definite impacts of the processing facilities on the natural groundwater environment, especially with regards to sodium and chloride pollution.**

**Water levels** for the PMR area range from 2 mbs to 20 mbs, of which none of the boreholes display increasing or decreasing concentration trends **(Figure 20)**.

**Summary:**

- Monitoring borehole EM11 is affected by groundwater contamination, but the PMR is not considered to be the source.
- The Central Deeps Shaft and its discard area north of the Klipfontein Spruit are also not considered to be significant sources of groundwater contamination.
- Exceptionally high levels of sodium and chloride pollution were measured in all boreholes directly down gradient from the PMR, indicating clear impacts from PMR.
- **The majority of indicator chemical parameters do not comply with the water quality objectives stated in the RPM Water Use License.**

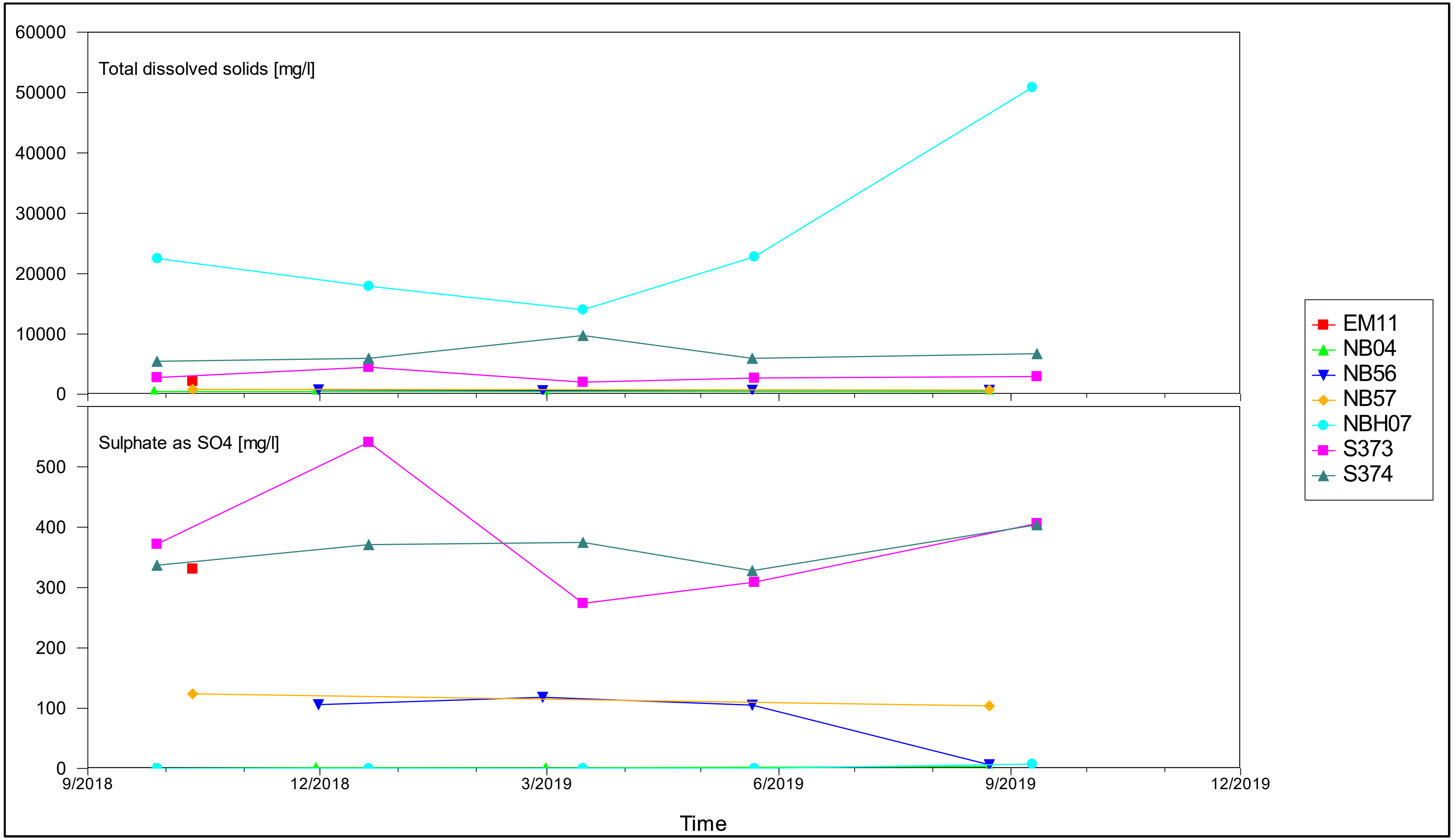


**Figure 16: Time-series plot of indicator chemical parameters in the PMR and Central Deeps Shaft areas – TDS and $SO_4$**

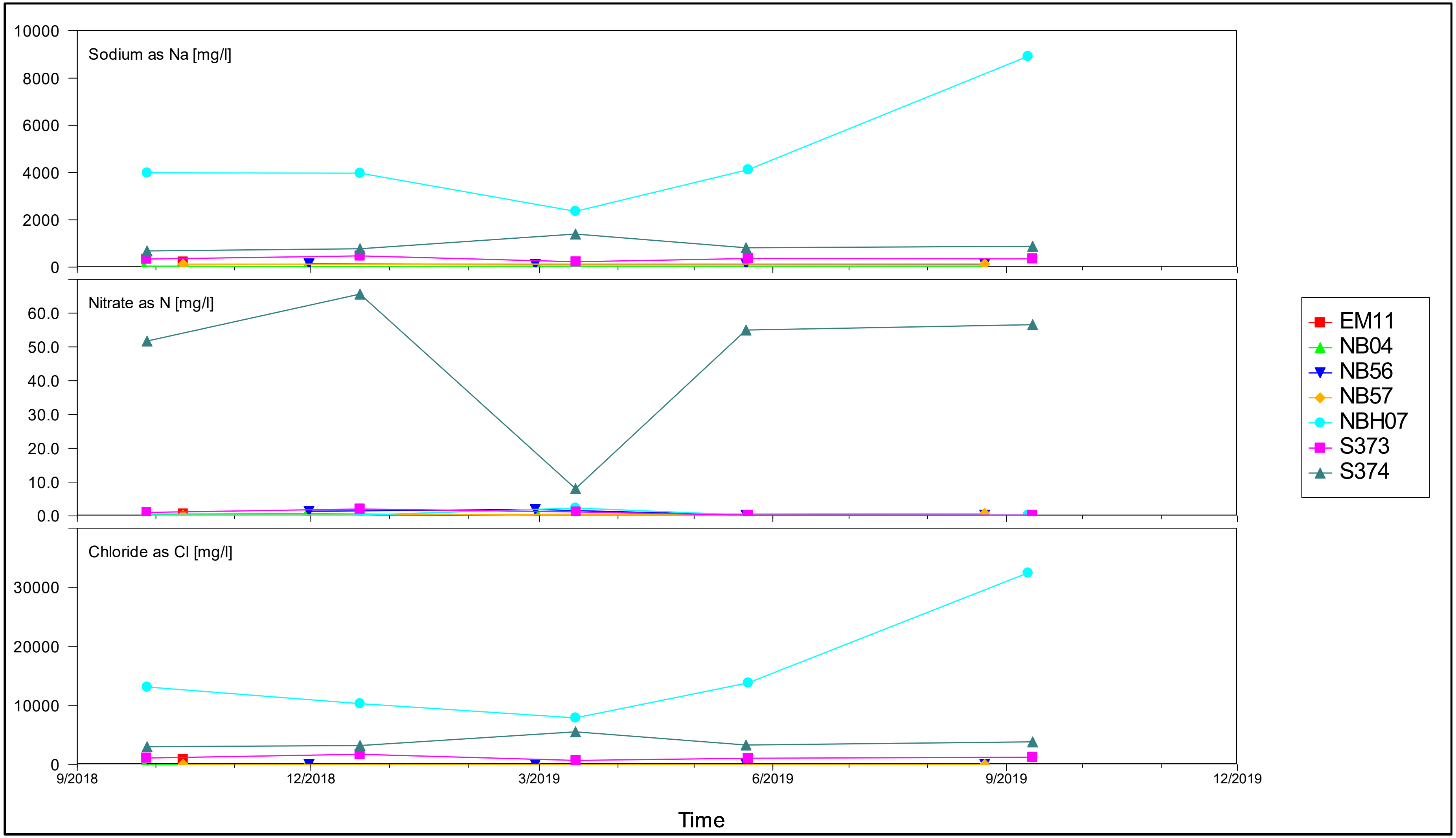


**Figure 17: Time-series plot of indicator chemical parameters in the PMR and Central Deeps Shaft areas – Na, $NO_3$ and Cl**

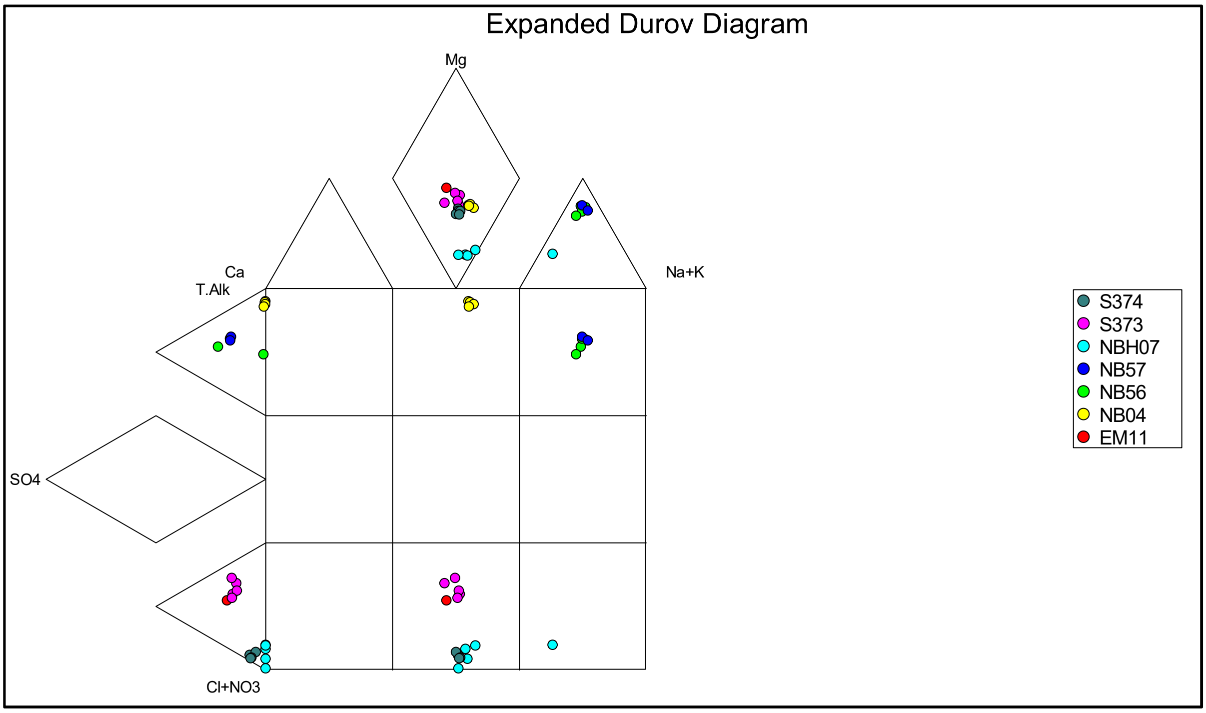


**Figure 18: EDD of groundwater chemistry in the PMR area**

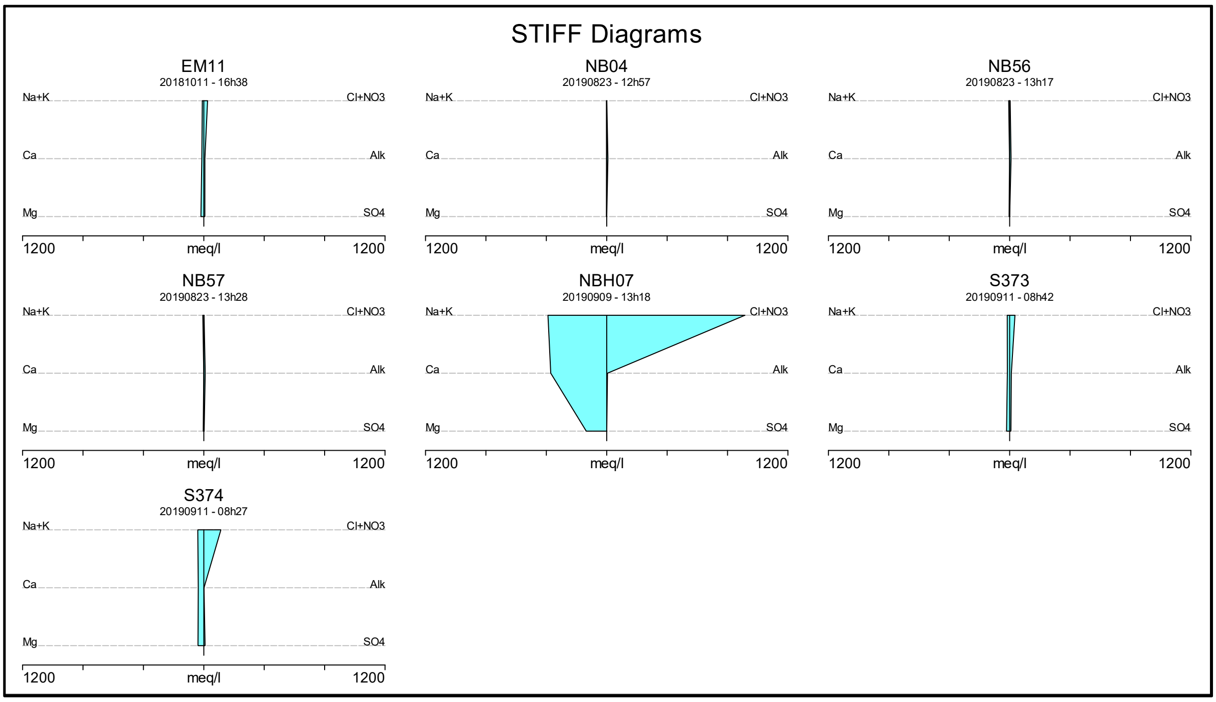


**Figure 19: Stiff diagrams of groundwater chemistry in the PMR area**

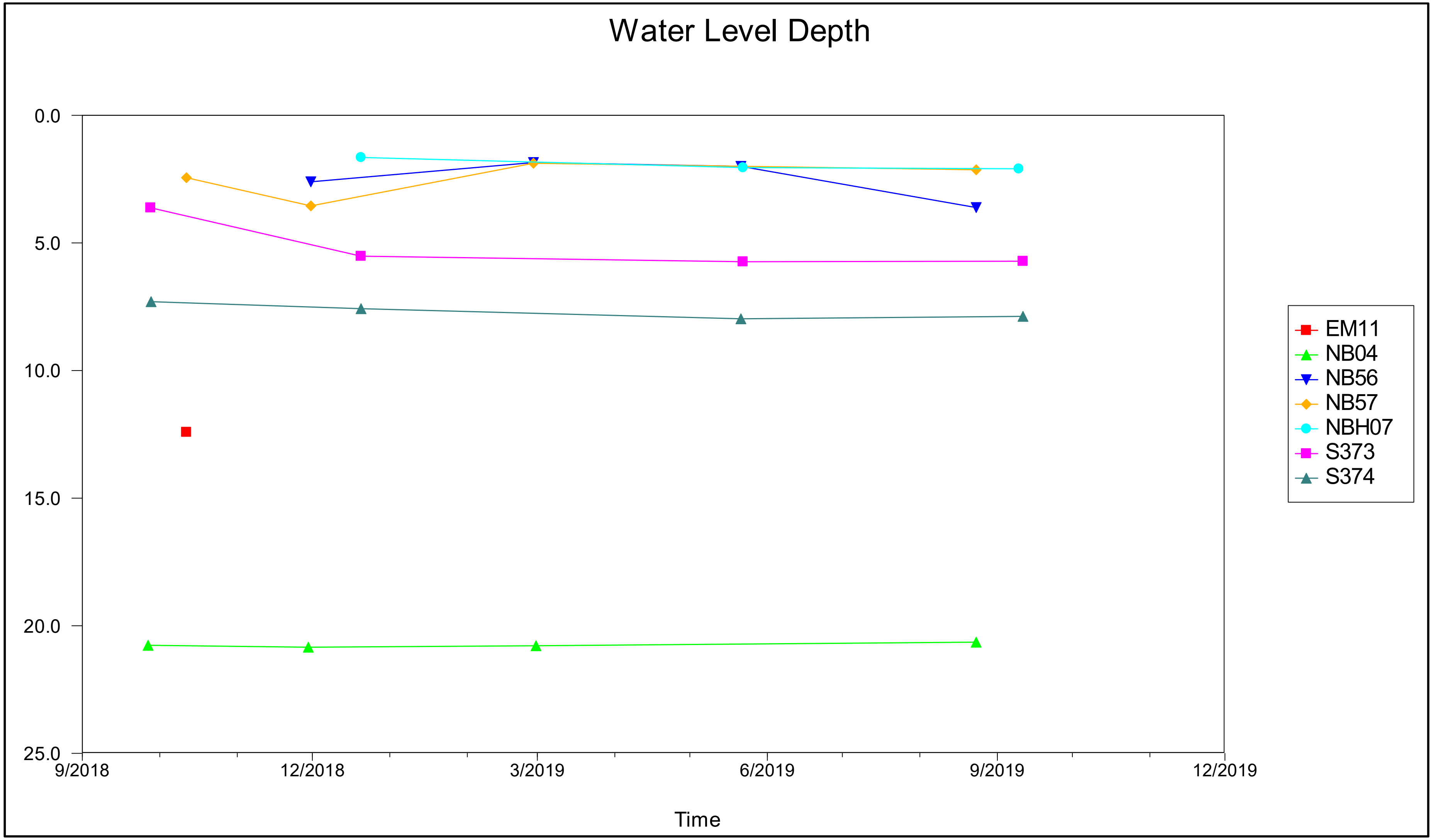


**Figure 20: Time series plot of water levels for in the PMR area**

## 2.4 THE WATERVAL TAILINGS COMPLEX

The Waterval Tailings Complex straddles a north-west trending groundwater divide and seepage from the tailings is towards the west/south-west and north-west in the direction of the Klipfontein Spruit and Klipgat Spruit respectively. Only one monitoring borehole was sampled during the 2018/2019 monitoring year and its position is indicated in **Figure 21**.

Due to the fact that only a single borehole was monitored for the Tailings complex and it was only sampled twice in the 2018/2019 monitoring year, no meaningful time series information can be gained. Therefore, no time series graphs will be included in this section.

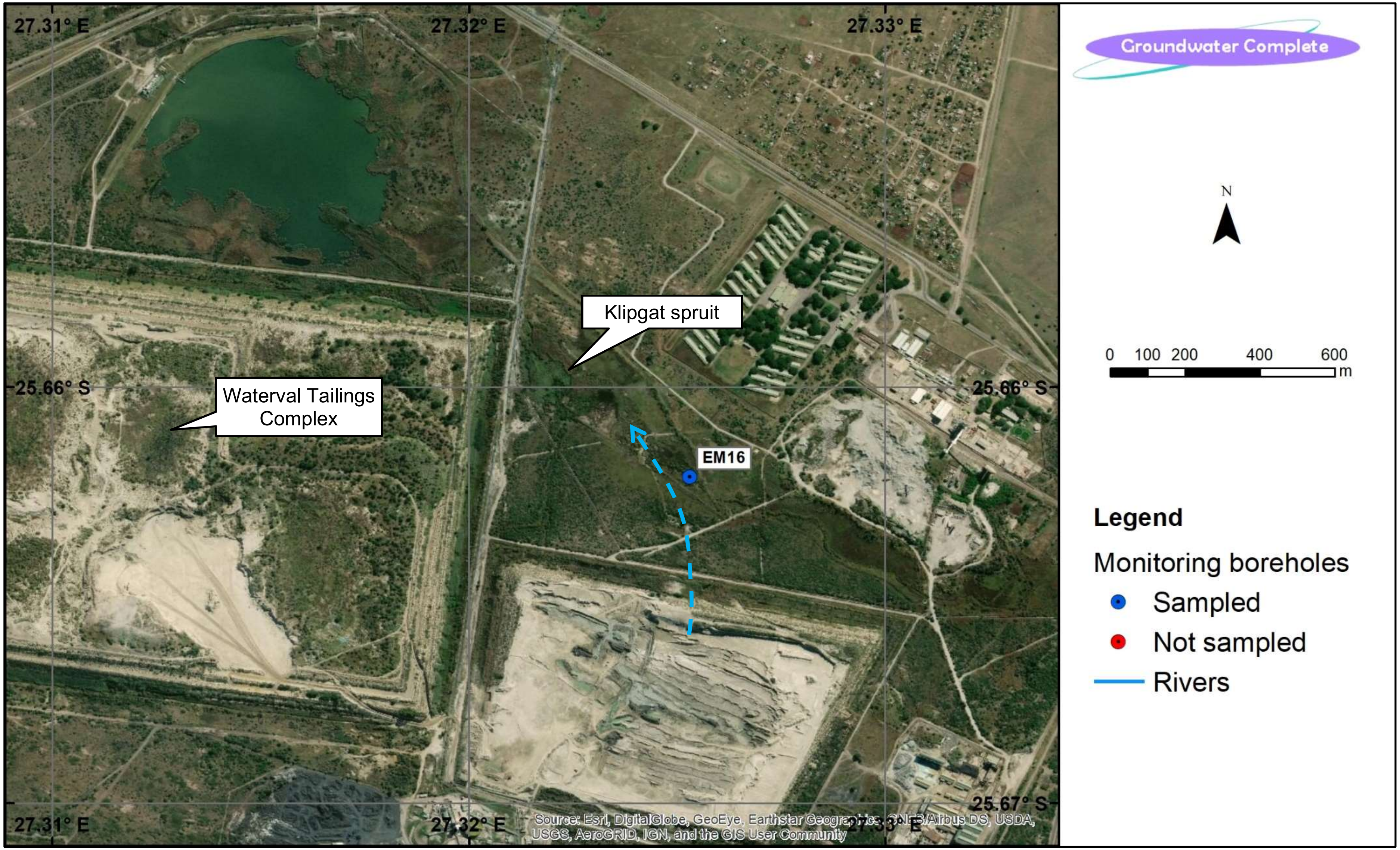


**Figure 21: Positions of monitoring boreholes in the Waterval Tailings Complex area**

Average groundwater **TDS** concentrations for borehole EM16 during the 2018/2019 monitoring year was 3 440 mg/l, which exceeds the permissible SANS value of 1 200 mg/l. **No guideline concentration is specified for TDS in the Water Use License for RPM.**

The groundwater **sulphate** content measured in the monitoring borehole exceeded the permissible SANS concentration of 500 mg/l and displayed an average of 1018 mg/l **(Table 3)**. **The sulphate content of groundwater down gradient from the tailings facility exceeded the RPM WUL guideline concentration of 20 mg/l during the past monitoring year.**

Average groundwater **sodium** concentration for the past monitoring year was 410 mg/l, which exceeded the permissible SANS value of 200 mg/l. **The RPM WUL guideline concentration of 22 mg/l was exceeded in monitoring borehole EM16.**

Groundwater **nitrate** concentrations remained well below the permissible SANS value of 11 mg/l during the past monitoring year. Monitoring borehole EM16 displayed an average of ± 1.1 mg/l. **The RPM WUL guideline concentration of 0.2 mg/l was exceeded in EM16 during the evaluation period.**

Groundwater **chloride** concentrations measured in EM16 exceeded the permissible SANS value of 300 mg/l and displayed an average of 1083 mg/l. **The chloride content of groundwater within the immediate vicinity of the tailings complex exceeded the RPM WUL guideline concentration of 14 mg/l during the 2018/2019 monitoring year.**

According to **Figures 24** and **25** Relatively old, stagnant groundwater that has undergone a significant degree of ion exchange reactions - groundwater is therefore dominated by **magnesium** cations, while the anion content is dominated by **chloride** and **nitrate** is predominant within the immediate vicinity of the Waterval Tailings Complex area:

**The dominant plot positions in field 8 of the EDD confirms definite impacts of the Waterval Tailings Complex on the natural groundwater environment.**

The average **water level** in borehole EM16 is 2 mbs.

**Summary:**

- Significant groundwater pollution occurs in the down gradient direction with magnesium and sulphate/chloride being the dominant contaminants.
- Its is recommended that more boreholes be drilled to supplement the monitoring of the tailings complex.
- **The majority of indicator chemical parameters do not comply with the water quality objectives stated in the RPM Water Use License.**

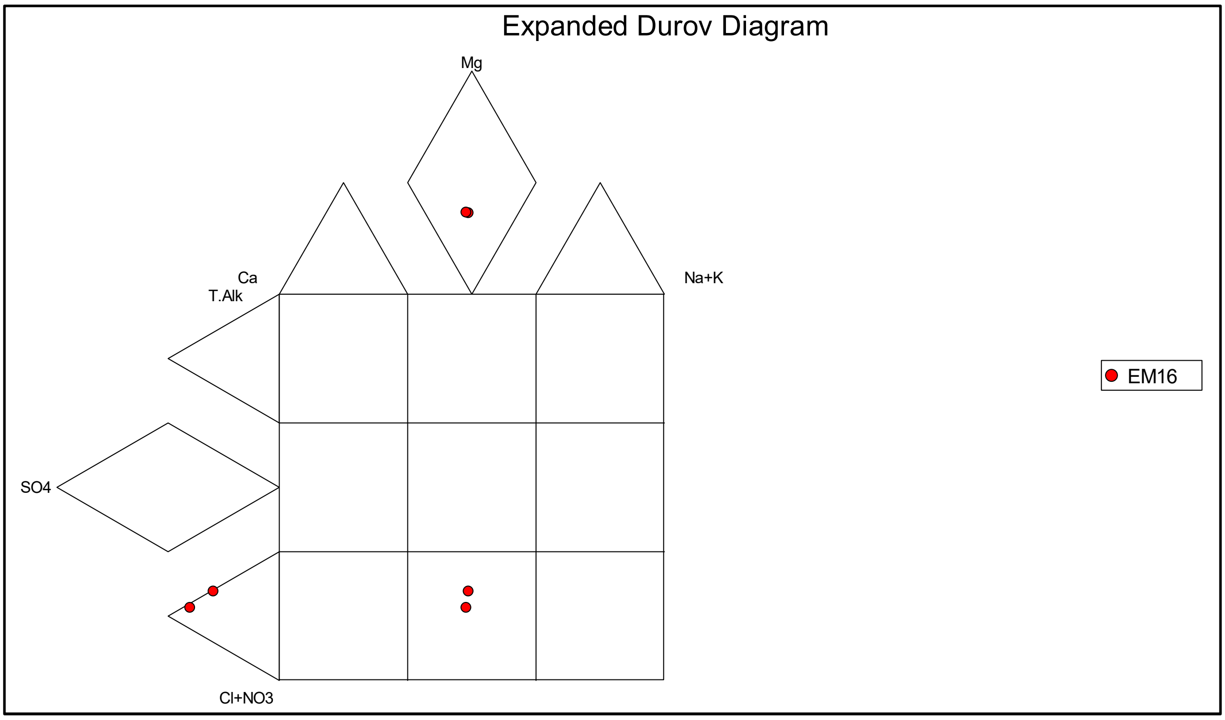


**Figure 22: EDD of groundwater chemistry in the Waterval Tailings Complex area**

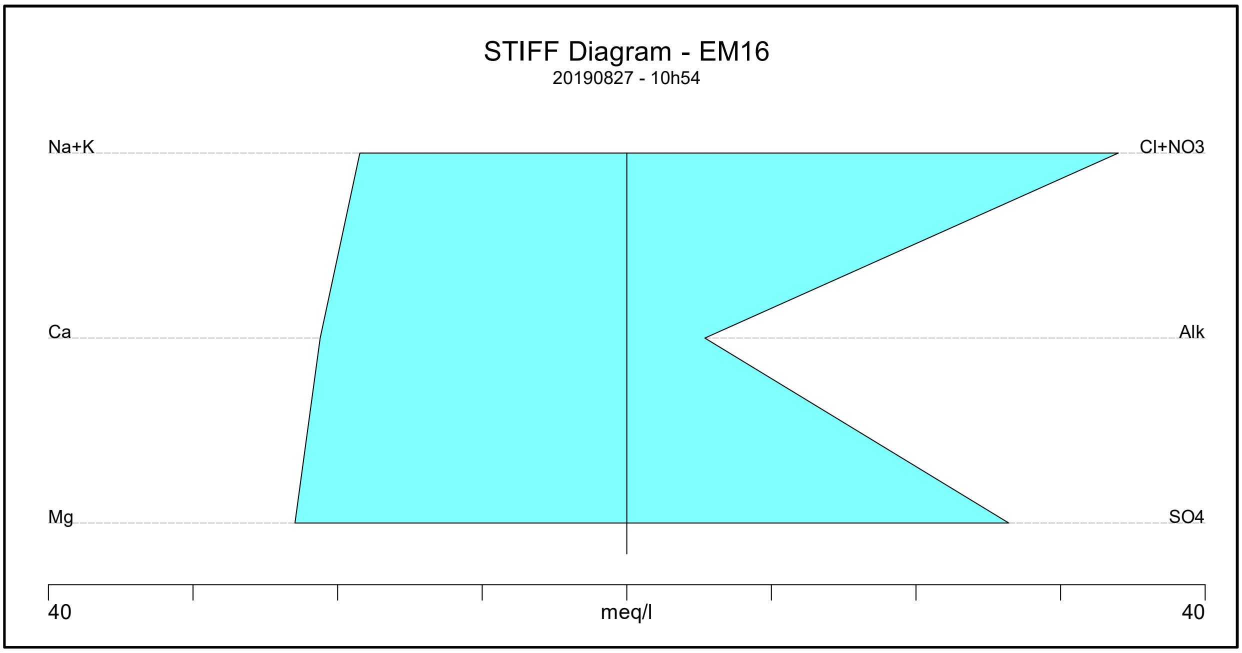


**Figure 23: Stiff diagrams of groundwater chemistry in the Waterval Tailings Complex area**

# 3 CONCLUSIONS AND RECOMMENDATIONS

The RPM area is a diverse mining and processing area with numerous source areas and varying degrees of impact on the groundwater regime.

- **Sulphate** is a prominent and widespread contaminant in the base metal processing areas such as the concentrators, smelters and refineries. The most significant sulphate pollution occurs at the RBMR, followed by the Waterval Processing Complex. Sulphate is also most commonly the pollutant at the tailings facilities.

- **Magnesium** is generally associated with sulphate-type pollution because magnesium exchanges calcium in the normal geohydrological cycle.

- **Sodium** and **chloride** are usually present in high concentrations in connate water within the crystal structure or matrix of rocks. When blasted, crushed, smelted or processed in some other way, sodium and chloride are liberated. Elevated chloride concentrations occur in groundwater at most of the processing areas like the RBMR and PMR but chloride pollution also occurs at the Waterval tailings facilities.

- **Nitrate** contamination occurs at most of the shaft areas as a result of traces of nitrate-based explosives used in the mining process and dissolving in process and mine water. Nitrate contamination is more prominent in the shaft areas.

- Where groundwater pollution has been confirmed, mitigation and remediation measures should be rolled out as evaluated in the groundwater management plan.

- Due to neutral or slightly basic pH conditions heavy and trace metals are present in very low concentrations in the groundwater of the entire RPM lease area due to the poor solubility.

- Distribution of groundwater monitoring points in the recent monitoring program is mostly adequate, but a number of areas occur where borehole distribution is inadequate for accurate impact characterisation.

- Several boreholes have been blocked or demolished and these boreholes should be reinstated in the monitoring program.

- Monitoring boreholes up gradient from sources are especially important as such monitoring data enables more accurate quantification and delineation of impacts related to specific sources.

**Summary:**

**Waterval Smelter and Concentrator and Acid Plant**

- Definite impacts from the Waterval Processing area occur on the down gradient groundwater environment.
- Sulphate is especially of concern, as the majority of groundwater monitoring boreholes indicated elevated concentrations.
- Up gradient groundwater monitoring borehole S407 displayed the highest levels of pollution throughout the 2018/2019 monitoring year, however the pollution is unlikely to originate from the Waterval Processing area.
- S400 also had overall high borehole concentration levels, however it only had a single sample taken and its level of pollution can't be determined definitively.
- Increasing parameter concentrations in the downgradient monitoring borehole, S407 are often observed over the monitoring period.
- **Concentrations of indicator chemical parameters do not comply with the water quality objectives stated in the RPM Water Use License.**
- Water levels vary between 2 and 4 mbs.

**The Rustenburg Base Metal Refinery**

- Significant pollution impacts from the RBMR occur on the groundwater environment.
- Impacts are by far the most significant in the sodium sulphate solution area to the south-east of the refinery.
- Groundwater iron concentrations measured in monitoring borehole S418 fluctuated significantly throughout the year, which may be the result of varying groundwater pH conditions.
- The most significant impacts from the refinery were measured in groundwater from boreholes S120, S389 and S418.
- The main contaminants of concern are sodium and sulphate.
- The extent of impact (plume) is however limited to within a few meters of the sources due to poor aquifer hydraulic properties.
- **The indicator chemical parameters do not comply with the water quality objectives stated in the RPM Water Use License.**

**The Precious Metal Refinery (PMR) and Central Deeps Shaft**

- Monitoring borehole EM11 is affected by groundwater contamination, but the PMR is not considered to be the source.
- The Central Deeps Shaft and its discard area north of the Klipfontein Spruit are also not considered to be significant sources of groundwater contamination.
- Exceptionally high levels of sodium and chloride pollution were measured in all boreholes directly down gradient from the PMR, indicating clear impacts from PMR.
- **The majority of indicator chemical parameters do not comply with the water quality objectives stated in the RPM Water Use License.**

**The Waterval Tailings Complex**

- Significant groundwater pollution occurs in the down gradient direction with magnesium and sulphate/chloride being the dominant contaminants.
- It is recommended that more boreholes be drilled to supplement the monitoring of the tailings complex. One monitoring borehole is not sufficient.

- **The majority of indicator chemical parameters do not comply with the water quality objectives stated in the RPM Water Use License.**

# Appendix B

*Biomonitoring report*

Anglo American Platinum – Rustenburg Operations
Annual integrated water monitoring report
Volume I

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# AMGLO AMERICAN PLATINUM: HEX RIVER CATCHMENT BIOMONITORING PROGRAMME

## OCTOBER 2018 SURVEY

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# 1. INTRODUCTION

This report is based on the results of the bi-annual biomonitoring survey conducted during October 2018 on the selected sites in the Hex River, Klipfonteinspruit and Klipgatspruit in the Anglo American Platinum (Rustenburg) mining area. Since the sale to Sibanye Stillwater, the study area assigned to Clean Stream Biological Services for biomonitoring has decreased considerably. To avoid confusion with areas tasked by Sibanye Stillwater to other consulting firm/s, the client for the purpose of this report will be referred to as Process Division Services. This long-term monitoring program commenced during December 1999. A comprehensive 20-year temporal database pertaining to the health of aquatic communities, as well as the water quality environment that may be affected by the RPM operations, has been amassed. This continuity of information will be invaluable for any future assessments of impacts to the receiving environment. RPM has thereby diligently maintained their biomonitoring programme on a twice-per-annum schedule (at least) since the inception of the program during 1999. See Table 1 below for a list of surveys performed, with their corresponding report numbers. Report naming will henceforth include the lettering sequence of “AAPL”, referring to Anglo American Platinum and in specific the Process Division Services.

Table 1: Biomonitoring surveys conducted and reports compiled in the period December 1999 to October 2018.

| Year | Month | Report numbers |
|---|---|---|
| 1999 | December | CS-A-2000 |
| 2000 | April, July and November | CS-G-2000, CS-K-2000 and CS-A-2001 |
| 2001 | May and September | CS-H-2001 and CS-L-2001 |
| 2002 | February, May, August and November | CS-G-2002, CS-I-2002, CS-N-2002 and CS-E 2003 |
| 2003 | Januaury and May | CS-G2003 and CS-O-2003 |
| 2004 | April, August and October | CS-H-2004 and AMP-A-05 |
| 2005 | February, April and November | AMP-B-05, AMP-C-05 and AMP-D-05 |
| 2006 | April and November | AMP-A-06, AMP-C-06 |
| 2007 | April and October | ANP-A-07 and ANP-A-08 |
| 2008 | April and October | ANP-B-08 and ANP-A-09 |
| 2009 | April and October | ANP-B-09 and RPM-A-09 |
| 2009 | April and October | RPM-A-10 and RPM-B-10 |
| 2011 | April and October | RPM-A-11 and RPM-B-11 |
| 2012 | April and November | RPM-A-12 and RPM-A-13 |
| 2013 | April and October | RPM-B-13 and RPM-C-13 |
| 2014 | April and October | RPM-A-14 and RPM-B-14 |
| 2015 | April and October | RPM-A-15 and RPM-C-15 |
| 2016 | May and October | RPM-A-16-Ver2 and RPM-B-16 |
| 2017 | June and November | RPM-A-17 and RPM-B-17 |
| 2018 | May and October | RPM-A-18 and AAPL-A-18 |

Rivers are continuum systems, so a river reach can be influenced by activities both upstream and downstream. Pollution incidences upstream of a site will have a negative impact, not only locally, but on the entire ecosystem (depending on the extent of the pollution).

Biological communities reflect overall ecological integrity by integrating different stressors over time, thereby providing a broad measure of their aggregate impact. The monitoring of biological communities hence provides a reliable ecological measure of fluctuating environmental conditions. The biomonitoring protocols applied in this project should give a good reflection of the human impacts on the system under investigation.

The results contained in this report should firstly be interpreted as **spatial** impact monitoring. [Note that spatial impact monitoring in terms of the fish communities considers the last two fish surveys, and not only the last survey, as in the case of macro-invertebrate communities]. **Temporal** (long- and medium-term trends) impact monitoring is also performed and considers all of the data since 2002 (after initial project design and refinement of the biomonitoring programme between 1999 and 2001).

# 2. MATERIALS & METHODS

Refer to appendix 1 for a description of methodology applied during this assessment.

# 3. RESULTS & DISCUSSION

## 3.1 Study area

Biomonitoring sites were selected to be easily accessible and representative of as many habitats as possible. Four biomonitoring sites were selected within the Hex River (receiving water body) and 3 sites were selected in Hex River tributaries.

The criteria for site selection are as follows:

- The locations should ideally be selected to be both upstream and downstream of potential pollution sources, and as far as possible, exclude other potential impacts not related to the biomonitoring programme (non-AAPL impacts).
- The habitat diversity should be representative of the river/stream being monitored and, as far as possible, be comparable between sites on a spatial scale.
- The habitats should, as far as possible, be suitable for the application of the selected biomonitoring protocols.
- The sampling sites should at least be accessible to off-road vehicle to enable the transport of the required sampling equipment.

Although sampling sites were previously selected to isolate potential and known RPM (Sibanye Stillwater) impacts and hence measure the effect of RPM impacts on the biotic integrity of the receiving water bodies, several additional sites were also selected to illustrate the potential impact of non-RPM related activities. This was done to gain an insight into other potential impacts on the Hex River, in the area upstream of RPM activities as well as up- and downstream of the Klipfonteinspruit (not including the Paardekraal Angling Dam) to isolate the potential impact/s from the Klipfonteinspruit and the Dorpspruit catchment. This approach has now been adapted (since 2018-10) to mainly focus on the possible impact of the AAPL Process Division Services, with possible impacts reaching the final receiving water body (Hex River), via the Klipfonteinspruit and the Klipgatspruit (Table 2; Figure 1).

Various sites/samples were selected for toxicity testing. These include pollution control dams and the Klipfonteinspruit and Klipgatspruit tributaries (included since April 2012, but narrowed down to the two mentioned tributaries since October 2018) joining the Hex River within the study area. Based on the historic electrical conductivity (EC) results (illustrating cumulative water quality deterioration from various sources) and spatial variation in biotic integrity, it is evident that the various tributaries of the Hex River, both upstream and within the newly-refined study area contribute significantly to the spatial variation in ecological integrity of the Hex River. It is therefore of great value for the biomonitoring programme to include DEEEP toxicity testing on all the key tributaries entering the Hex River.

See Table 2 below for sampling site description, its relation to AAPL Process Division Services activities and the frequency of different biomonitoring protocols applied.

Table 2: Latitude/Longitude and sampling protocols of selected sampling sites for routine biomonitoring.

| Monitoring site | Description | Potential direct upstream impact | Biomonitoring protocols | | GPS coordinates (degrees) | |
|---|---|---|---|---|---|---|
| | | | Protocol | Frequency per annum | Latitude (South) | Longitude (East) |
| H1 | Hex River, most upstream site. | Not relevant | Discontinued from the Clean Stream Biological Services scope of work, since 2018-10 | | 25.7269 | 27.3043 |
| H-US-Sand | Hex River, upstream from the Sandspruit confluence. | Non-RPM | | | 25.7148 | 27.2992 |
| H-DS-Sand | Hex River, downstream from the Sandspruit confluence. | Non-RPM | | | 25.7025 | 27.3105 |
| Hex00 | Hex River, upstream from RPM activities, adjacent to possible future mining activities. | Non-RPM | | | 25.6966 | 27.3081 |
| H4 | Hex River, between sites Hex00 and Hex01, but downstream from H3. | RPM and non-RPM | | | 25.6835 | 27.2813 |
| Hex01 | Hex River, upstream from Klipfonteinspruit. | RPM | | | 25.6765 | 27.2778 |
| H-US-KF | Hex River, upstream from the Klipfonteinspruit confluence but downstream from the Paardekraal Angling Dam. | AAPL and non-AAPL | *SASS5 | Twice | 25.6492 | 27.2906 |
| KF | Klipfonteinspruit, downstream from Waterfall concentrator but upstream from Paardekraal shaft runoff. | AAPL | *SASS5 | Twice | 25.6578 | 27.2964 |
| KFD | Klipfonteinspruit, downstream from site KF and the Paardekraal shaft runoff. | AAPL | *SASS5 | Twice | 25.6496 | 27.2926 |
| H-DS-KF | Hex River, directly downstream from the Klipfonteinspruit confluence. | AAPL | *SASS5 | Twice | 25.6473 | 27.2913 |
| Hex03 | Hex River, upstream from Klipgatspruit. | Non-AAPL | *SASS5 | Twice | 25.6332 | 27.2903 |
| | | | **FAII | Once | | |
| KGT | Klipgatspruit, downstream from tailings complex seepage. | AAPL | *SASS5 | Twice | 25.6319 | 27.2951 |
| Hex3B | Hex River, downstream from Klipgatspruit confluence. Newly adopted site (since 2018-10) | AAPL | *SASS5 | Twice | 25.6237 | 27.2900 |
| | | | **FAII | Once | | |
| DPS | Dorp Spruit, 100m before it confluence with the Hex River | Non-RPM | Discontinued from the Clean Stream Biological Services scope of work, since 2018-10 | | 25.6228 | 27.2885 |
| Hex04 | Hex River, downstream from HEX03. | RPM | | | 25.6081 | 27.2886 |
| PDK | Paardekraal Spruit, just before confluence with Hex River. | RPM | | | 25.5933 | 27.2983 |
| Hex4B | Hex River, downstream from Paardekraal Spruit. | RPM | | | 25.5916 | 27.2993 |
| 2 | PMR Dam 2 | To be confirmed as per AAPL Process Division requirements | | | | |
| 3A | PMR Dam 3A | | | | | |
| 3B | PMR Dam 3B | | | | | |
| 4&5 | PMR Dams 4 and 5 | | | | | |
| DPS | Dorpspruit, just upstream from confluence with Hex River | Non-RPM | Discontinued from the Clean Stream Biological Services scope of work, since 2018-10 | | | |
| K035 | Klipgat RWD | To be confirmed as per AAPL Process Division requirements | | | | |
| K048 | Paardekraal Dam 1 RWD | | | | | |
| K064 | Paardekraal Dam 3 RWD | | | | | |
| K086 | Waterval PCD West | | | | | |
| K098 | ACP PCD | | | | | |
| K105 | Klipfontain Tailings RWD | | | | | |
| K125 | Hoedspruit Tailings RWD | | | | | |
| K133 | UG2 PCD | | | | | |
| K176 | Paardekraal Phase 4 RWD | | | | | |
| PDKS | Paardekraalspruit just upstream from confluence with Hex River | RPM and non-RPM | Discontinued from the Clean Stream Biological Services scope of work, since 2018-10 | | 25.5933 | 27.2983 |
| SS | Sandspruit, just upstream from confluence with Hex River | Non-RPM | | | 25.7115 | 27.3174 |

**Key:**

* **SASS5** = South African Scoring System, version5 (macro-invertebrate index and associated habitat assessment indices i.e. IHAS ver2 and biotope availability and suitability indices)

** **FAII** = Fish Assemblage Integrity Index (and associated habitat indices i.e. SHI and HCR)

Site name shaded green = Hex River mainstem

Site name shaded blue = Tributary of Hex River

Site name shaded red = Toxicity testing

Impact shaded gray = Potential RPM and non-RPM impacts (directly upstream)

Impact shaded pink = Potentially impacted by RPM/AAPL (directly upstream)

Impact shaded yellow = No RPM/AAPL impacts (directly upstream)

Site name shaded Orange = Discontinued from Clean Stream Biological Services scope

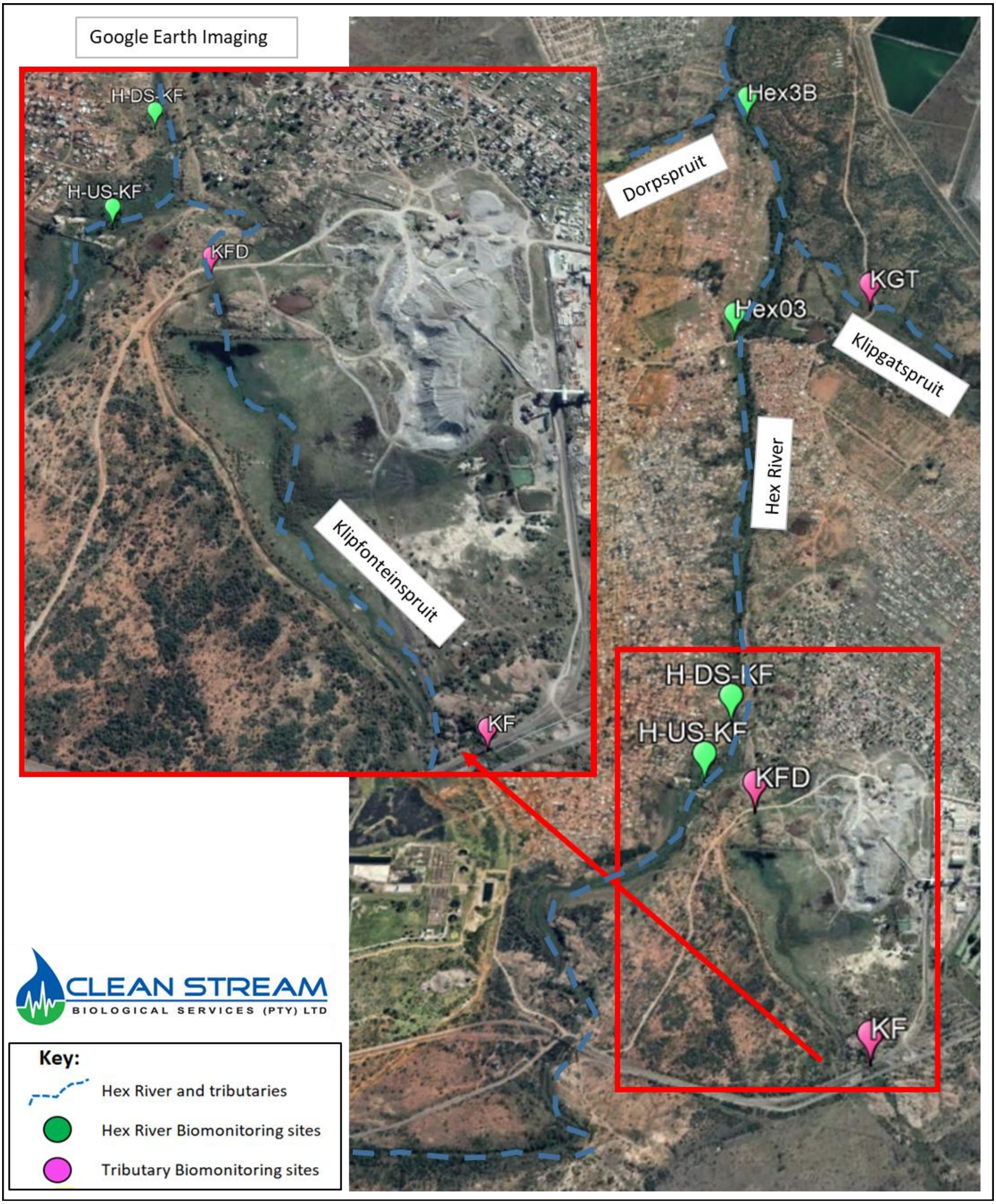


Figure 1: Google Earth image of study area, indicating Hex River and tributary biomonitoring sites.

## 3.2 *In-situ* water quality (October 2018)

Selected water quality variables were measured on-site at the time of biological sampling. The purpose of these measurements is to assist in the interpretation of biological results (refer to Aquatico Scientific's Water Quality Report for a detailed water quality assessment of the Rustenburg Platinum mining area).

As recorded during most surveys, the EC increased from site H-US-KF to H-DS-KF in the Hex River (104.0 mS/m to 178.3 mS/m) (Table 3; Figure 2). The Klipfonteinspruit joins the Hex River between these sites and probably played a large role in the increased salinity during most preceding surveys (no perceptible surface flow was recorded from the Klipfonteinspruit during many surveys but a subsurface contribution of affected mine water cannot be ruled out). The EC value was relatively high in the Klipfonteinspruit (site KF) during most previous surveys and the latest dataset again confirms this tributary as a potential source of elevated salinity levels, especially during periods of flow (Table 3).

Table 3: *In-situ* water quality variables measured at the time of sampling at the selected biomonitoring sites

| Monitoring site | EC (mS/m) | pH | Oxygen saturation (%) | Dissolved oxygen (mg/l) | Water temp (ºC) | Turbidity (visual) | Flow (visual) |
|---|---|---|---|---|---|---|---|
| H-US-KF | 104.0 | 7.8 | 79.5 | 5.2 | 21.2 | Slightly turbid | Moderate |
| KF | 509.0 | 7.6 | 84.2 | 5.5 | 22.3 | Clear | Low |
| H-DS-KF | 178.3 | 7.7 | 107.1 | 7.0 | 23.2 | Slightly turbid | Moderate |
| Hex-03 | 195.2 | 7.5 | 48.6 | 3.2 | 20.9 | Slightly turbid | Moderate |
| KGT | | Dry | | | | | |
| Hex-03-B | 189.4 | 7.7 | 79.9 | 5.1 | 21.7 | Slightly turbid | Moderate |

**Key:**
- Site name shaded in green = Hex River mainstem
- Site name shaded in blue = Tributary of the Hex River
- Values relatively high
- Values exceeding/below guidelines

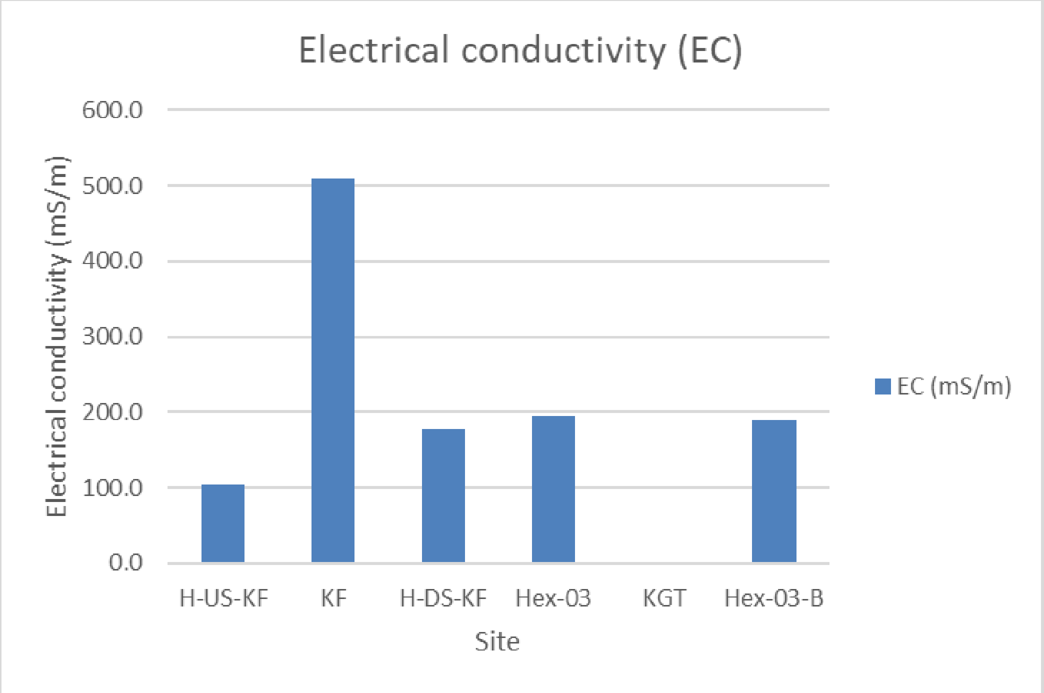


Figure 2: Electrical conductivity levels (mS/m) at the time of sampling at the different biomonitoring sites.

The EC level increased, from site H-DS-KF (178.3 mS/m) to Hex03 (195.2 mS/m). This is a clear indication of non-Anglo Platinum Process Division (APPD) activities impacting on the water quality of the Hex River.

From site Hex03 towards site Hex03B (the most downstream site), the EC values decreased slightly (195.2 mS/m to 189.4 mS/m), thus indicating that the contribution from the Klipgatspruit (dry at the time of sampling) did not affect the salinity of the receiving environment.

The pH fell within the target water quality ranges for fish health (Aquaculture), and marginally within the aquatic ecosystem guideline at all sites during the October 2018 survey (Table 3; Figure 3). The target for fish health is between 6.5 and 9.0. It is expected that most aquatic species will tolerate and reproduce successfully within this pH range (DWAF, 1996).

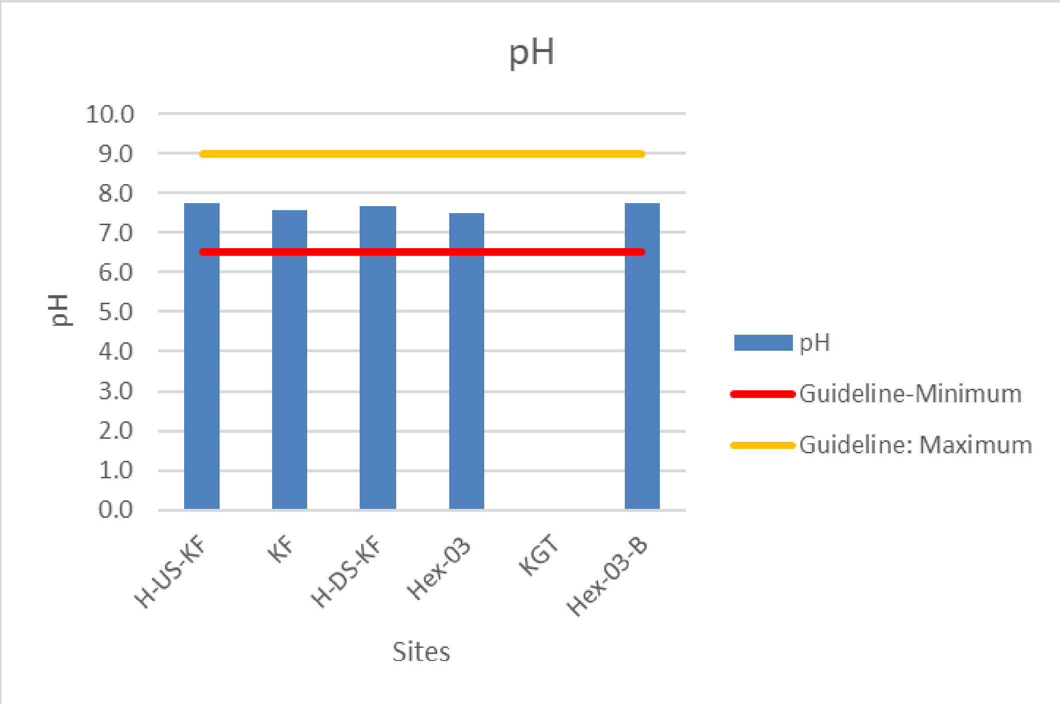


Figure 3: pH levels at the time of sampling at the different biomonitoring sites.

During October 2018, the dissolved oxygen level fell below the target range (> 5 mg/l, as set by Kempster *et.al.,* 1980) at site Hex03 (Table 3; Figure 4). This was also the case during the previous (May 2018) and many preceding surveys. The noted low oxygen levels could therefore possibly have posed a risk to aquatic biota and was probably related to a combination of factors including:

- Elevation and accumulation of organic loads,
- Aquatic vegetation and algal proliferation in response to eutrophication,
- Low flow (all affected sites).

It has to be noted that the cause of lowered dissolved oxygen levels is unlikely to be related to APPD activities because levels were within the guideline at site H-DS-KF and no further APPD activities take place toward site Hex03.

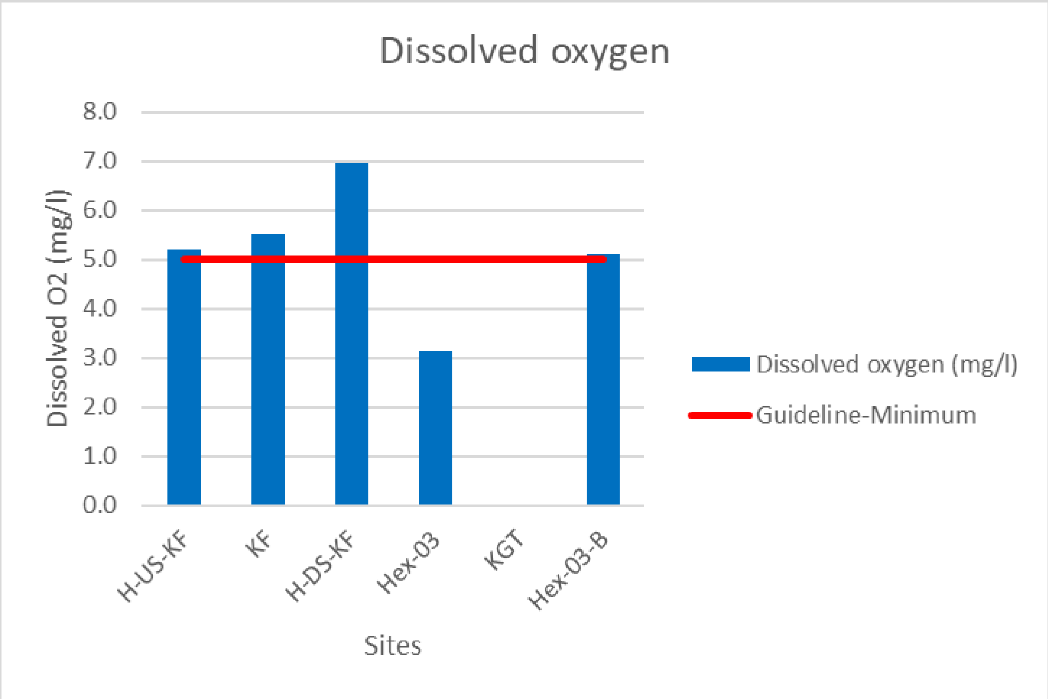


Figure 4: Dissolved oxygen levels (mg/l) at the time of sampling at the different biomonitoring sites.

As a standard management procedure, a full statistical evaluation of water quality data at these biomonitoring localities (as performed by Aquatico Scientific) will be required to conclude whether specific variables or a combination of variables, not included in the biota specific range, are impacting on the aquatic ecosystems.

### 3.3 Toxicity testing

At the time of compiling this biomonitoring report, the latest toxicity testing results for the Pollution Control Facilities available to Clean Stream Biological Services were based on the May 2018 dataset, as submitted as a separate toxicity testing report by Biotox Laboratory Services (Report no. RPM-A-18_TOX).

The latest tributary toxicity testing report, as performed in conjunction with the October 2018 biomonitoring survey, is also included and discussed in this biomonitoring report.

As per SANAS requirements, the above-mentioned toxicity testing reports were produced independently by Biotox Laboratory Services (Pty) Ltd. All results contained in this section are therefore sourced from the Biotox reports, which are included in Addendum 1.

Toxicity testing (as conducted in this biomonitoring programme) is applied by exposing biota under laboratory conditions to water sources (pollution control dams, effluent streams or streams/rivers) to accurately determine the risk of such water types to the biota of the receiving water bodies. Toxicity results indicate the risk posed to the Hex River and its tributaries in the event of release, seepage or overflow from possible sources of pollution. Up to four trophic levels (at least 3, including acute and chronic approaches) of biota, *i.e.,* vertebrates (*Poecilia reticulata*), invertebrates (*Daphnia magna*), bacteria (*Vibrio fischeri*) and primary producers (*Selenastrum capricornutum*) are exposed to the samples per standard procedures under laboratory conditions and thereafter a risk/hazard category is determined by application of the latest **DEEEP**[1] DWS recommended protocols and hazard classification. The final risk classification is expressed in terms of **acute**[2] and **chronic**[3] toxicity risk. The *Poecilia reticulata* and *Daphnia magna* test results are based on mortality rates over a relatively short period of the lifespan of the organisms, hence allowing for acute interpretation. *Selenastrum capricornutum* and *Vibrio fischeri* individual test results are based on inhibition rates over relatively long periods of the lifespan of the organisms, hence allowing for short-chronic toxicity hazard interpretation.

Selected toxicity samples (Hex River tributaries) were tested on a twice per annum schedule, while the PCD (pollution control dam) samples are tested once per annum, on either a **screening**[4] acute level or a **definitive**[5] acute level, at this stage. The frequency of testing is informed by the level of toxicity. If toxicity levels increase, it may become relevant and useful to increase the frequency of testing. The frequency and type of toxicity testing required (screening vs. definitive) should be revised from time to time based on the outcome of the specific year's assessments.

#### Hazard classification for screening tests (undiluted samples)

After the determination of the percentage effect[6] (EP), obtained with each of the ***battery of toxicity screening*** tests performed, the sample is ranked into one of the following five classes:

[1] DEEEP = Direct Estimation of Ecological Effect Potential. This is a battery of tests that can measure toxicity of complex mixtures based on a set of parameters stemming from the results of effects, even if all constituents are not known. Thereafter a hazard class is determined based on the resulting parameters of the battery of tests.

[2] Acute = Acute refers to an exposure over a relatively short period of the lifespan of biota, of which the result is generally based on mortality rates.

[3] Chronic = Chronic refers to prolonged exposures over an extended period of the lifespan of test organisms, of which the results are generally based on growth inhibition rates.

[4] Screening = A screening toxicity test refers to an undiluted (100% concentration) sample. This is usually performed on a sample from the biomonitoring sites in the receiving water bodies (river/streams) to determine if any toxicity is present. This is performed both up- and downstream of the potential impacts to enable the determination of downstream increases or decreases in toxicity.

[5] Definitive = A definitive toxicity test refers to the exposure of test organisms to both the 100% concentration as well as a range of dilutions, generally used to determine the risk of a pollution source that may have a toxicity effect on the receiving water body (such as effluents and PCD's). The range of dilutions are therefore useful in the event that the 100% sample concentration presents acute toxicity, and allows for the determination of a safe dilution factor, to negate toxicity effects on the receiving water bodies.

[6] EP (Percentage effect) = an effect measured either as a mortality rate or inhibition rate (depending on the type of test). A 10% effect is regarded as a slight acute toxicity for daphnia and guppies, while a 20% effect is regarded as a slight acute toxicity for algae and bacteria (vibrio). A 50% effect is regarded as an acute toxicity for all of the tests (daphnia, guppies, algae and bacteria)

| | | |
|---|---|---|
| Screening | Class I | **No acute/chronic environmental hazard -** none of the tests shows a toxic effect |
| | Class II | **Slight acute/chronic environmental hazard -** a statistically significant percentage effect is reached in at least one test, but the effect level is below 50% |
| | Class III | **Acute/chronic environmental hazard -** the percentage effect level is reached or exceeded in at least one test, but the effect level is below 100% |
| | Class IV | **High acute/chronic environmental hazard -** the 100% percentage effect is reached in at least one test |
| | Class V | **Very high acute/chronic environmental hazard -** the 100% percentage effect is reached in all the tests |

**Toxicity classification system definitive tests (undiluted samples plus range of dilutions)**

The samples are classified into one of the following five classes on the basis of the highest toxicity unit (TUa) found in the ***battery of toxicity definitive tests*** performed. The toxicity unit is a function of the L(E)C50, where (TUa) = 100/L(E)C50. The 50% Lethal/Effective concentration (LC50 or LE50) is the linear calculated (derived) concentration at which a 50% mortality or inhibition rate can be expected. Hence, the lower this value is, the higher the acute toxicity level. Conversely, the higher the toxicity unit (TUa) is, the higher the acute toxicity level is. The conversion of L(E)C50 values to TUa values is therefore merely done to achieve a classification scale of increasing values related to increasing toxicity risk:

| | | |
|---|---|---|
| Definitive | Class I | **No acute/chronic environmental hazard -** none of the tests shows a toxic effect |
| | Class II | **Slight acute/chronic environmental hazard -** the percentage effect observed in at least one toxicity test is significantly higher than in the control, but the effect level is below 50% (TU is <1) |
| | Class III | **Acute/chronic environmental hazard -** the L(E)C50 is reached or exceeded in at least one test, but in the 10 fold dilution of the sample the effect level is below 50% (TU is between 1 and 10) |
| | Class IV | **High acute/chronic environmental hazard -** the L(E)C50 is reached in the 10 fold dilution for at least one test, but not in the 100 fold dilution (TU is between 10 and 100) |
| | Class V | **Very high acute/chronic environmental hazard -** the L(E)C50 is reached in the 100 fold dilution for at least one test (TU is >100) |

**Weighting:** Each sample is furthermore weighed according to its relative toxicity levels (out of 100%). Higher values indicate that more of the individual tests indicated toxicity within a specific class.

### 3.3.1 May 2018 and October 2018

**Toxicity testing of pollution control facilities (May 2018 only)**

Various toxicity hazards were identified during the May 2018 survey, ranging from "slight hazard" (Class II) to "very high hazard" (Class III), implying that some effluents/potential effluents could pose a serious risk to the receiving water bodies if released (Table 4).

Sample K035, K086, K105, K125 and K176 showed "no acute/chronic environmental toxicity hazard" (Class I). As a result of macro-invertebrate mortality rates of 20% for samples K046 and K048; as well as 15% mortality recorded for sample K133, these samples were classified as having a "slight acute environmental toxicity hazard" (Class II). Sample K194 showed a "chronic environmental toxicity hazard" (Class II) based on the TU of 2.6.

Table 4: Toxicity results and hazard classification for selected pollution facilities (May 2018).

| | Results | K035 | K046 | K048 | K086 | K105 | K125 | K133 | K176 | K194 |
|---|---|---|---|---|---|---|---|---|---|---|
| WQ Water quality | pH @ 25°C (A) | 7,8 | 7,4 | 7,6 | 7,7 | 7,6 | 7,6 | 7,7 | 7,4 | 7,4 |
| | EC (Electrical conductivity) (mS/m) @ 25°C (A) | 584,0 | 612,0 | 654,0 | 537,0 | 296,0 | 360,0 | 209,3 | 608,0 | 562,0 |
| | Dissolved oxygen (mg/l) (NA) | 6,4 | 7,2 | 6,7 | 6,1 | 7,4 | 7,7 | 5,9 | 7,1 | 4,6 |
| *V. fischeri* (bacteria) (A) | Test started on yy/mm/dd | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/18 |
| | %30min inhibition (-) / stimulation (+) (%) | 6 | 8 | 2 | 1 | 2 | -2 | -7 | -2 | -87 |
| | EC/LC20 (30 mins) | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | 16 |
| | EC/LC50 (30 mins) | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | 39 |
| | Toxicity unit (TU) / Description | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 2,6 |
| *S. capricornutum* (micro-algae) (A) | Test started on yy/mm/dd | 18/05/15 | 18/05/15 | 18/05/15 | 18/05/15 | 18/05/15 | 18/05/15 | 18/05/15 | 18/05/15 | 18/05/15 |
| | %72hour inhibition (-) / stimulation (+) (%) | 1 | 0 | -8 | ** | 5 | -7 | -1 | -7 | -9 |
| | EC/LC20 (72hours) | n.r. | n.r. | n.r. | ** | n.r. | n.r. | n.r. | n.r. | n.r. |
| | EC/LC50 (72hours) | n.r. | n.r. | n.r. | ** | n.r. | n.r. | n.r. | n.r. | n.r. |
| | Toxicity unit (TU) / Description | <1 | <1 | <1 | ** | <1 | <1 | <1 | <1 | <1 |
| *D. magna* (waterflea) (A) | Test started on yy/mm/dd | 18/05/14 | 18/05/14 | 18/05/14 | 18/05/14 | 18/05/14 | 18/05/14 | 18/05/14 | 18/05/14 | 18/05/14 |
| | %48hour mortality rate (-%) | -10 | -20 | -20 | 0 | 0 | 0 | -15 | -10 | -10 |
| | EC/LC10 (48hours) | n.r. | 50 | 50 | n.r. | n.r. | n.r. | 83 | n.r. | n.r. |
| | EC/LC50 (48hours) | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. |
| | Toxicity unit (TU) / Description | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| *P. reticulata* (guppy) (A) | Test started on yy/mm/dd | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 | 18/05/17 |
| | %96hour mortality rate (-%) | -8 | 0 | 0 | 0 | 0 | -8 | 0 | 0 | -8 |
| | EC/LC10 (96hours) | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. |
| | EC/LC50 (96hours) | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. | n.r. |
| | Toxicity unit (TU) / Description | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| | *Estimated safe dilution factor (%) [for definitive testing only]* | None required | 50 | 50 | None required | None required | None required | 83 | None required | 16 |
| | Overall classification - Hazard class*** | Class I - No acute/chronic hazard | Class II - Slight acute hazard | Class II - Slight acute hazard | Class I - No acute/chronic hazard | Class I - No acute/chronic hazard | Class I - No acute/chronic hazard | Class II - Slight acute hazard | Class I - No acute/chronic hazard | Class III - Chronic hazard |
| | Weight (%) | 0 | 25 | 25 | 0 | 0 | 0 | 25 | 0 | 25 |

Key:

**WQ** = Water quality at the time of starting the *Daphnia magna* testing.

% = for definitive testing, only the 100% concentration (undiluted) sample mortality/inhibition/stimulation is reflected by this summary table. The dilution series results are considered for EC/LC values and Toxicity unit determinations.

**n.r.** = not relevant, i.e. the 100% concentration caused less than 10/20/50% (effective concentration) mortalities or inhibition.

** = Algal test result inconclusive due to interference (caused either by precipitate forming in the sampling during testing). As the degree of inhibition/stimulation is unknown, individual test result was not used for overall hazard classification.

*** = The overall hazard classification takes into account the full battery of tests and is not based on a single test result. Note that the overall hazard classification is expressed as acute/chronic level of toxicity, due to the fact that the *S. capricornutum* (micro-algae) and the *V. fischeri* tests are regarded as short-chronic levels of toxicity tests and the overall classification therefore contains a degree of chronic toxicity assessment.

**Weight (%)** = relative toxicity levels (out of 100%), higher values indicate that more of the individual tests indicated toxicity within a specific class.

site/sample name shaded in purple = screening test | site/sample name shaded in orange = definitive test

## Toxicity testing of Hex River tributaries (October 2018)

As noted earlier in the report, the electrical conductivity (EC) levels are almost always very high within the Klipfonteinspruit. EC is often an indication of reduced water quality but toxicity testing results revealed that no hazard (Class I) was observed at the Klipfonteinspruit sites (KF), before entering the Hex River (Table 5). This is an encouraging improvement since the October 2014 and April 2015 surveys, when a high hazard (Class IV) and a slight hazard (Class II) was presented by this tributary. It was noted that the Klipfonteinspruit was not flowing during the October 2014 survey and that contamination was therefore contained within isolated pools. It is important to note that APPD activities potentially contribute to this tributary.

It is now recommended to include both site KF and KFD for toxicity testing in the Klipfonteinspruit. The effect of different sources of pollution can then be distinguished more accurately.

Table 5: Toxicity results and hazard classification for selected Hex River tributary samples (October 2018).

| | Results | KF |
|---|---|---|
| wq Water quality | pH @ 25°C (A) | 7,7 |
| | EC (Electrical conductivity) (mS/m) @ 25°C (A) | 501,0 |
| | Dissolved oxygen (mg/l) (NA) | 7,6 |
| *V. fischeri* (bacteria) (A) | Test started on yy/mm/dd | 18/11/01 |
| | %30min inhibition (-) / stimulation (+) (%) | 44 |
| | EC/LC20 (30 mins) | * |
| | EC/LC50 (30 mins) | * |
| | Toxicity unit (TU) / Description | no short-chronic hazard |
| *D. magna* (waterflea) (A) | Test started on yy/mm/dd | 18/10/29 |
| | %48hour mortality rate (-%) | 0 |
| | EC/LC10 (48hours) | * |
| | EC/LC50 (48hours) | * |
| | Toxicity unit (TU) / Description | no acute hazard |
| *P. reticulata* (guppy) (A) | Test started on yy/mm/dd | 18/10/29 |
| | %96hour mortality rate (-%) | 0 |
| | EC/LC10 (96hours) | * |
| | EC/LC50 (96hours) | * |
| | Toxicity unit (TU) / Description | no acute hazard |
| **Overall classification - Hazard class*****| | Class I - No acute/short-chronic hazard |
| Weight (%) | | 0 |

**Key:**

* = EC/LC values not determined, definitive testing required if a hazard was observed and persists over subsequent sampling runs.

*** = The overall hazard classification takes into account the full battery of tests and is not based on a single test result. Note that the overall hazard classification is expressed as acute/chronic level of toxicity, due to the fact that the *S. capricornutum* (micro-algae) and the *V. fischeri* tests are regarded as short-chronic levels of toxicity tests and the overall classification therefore contains a degree of chronic toxicity assessment.

**Weight (%) =** relative toxicity levels (out of 100%), higher values indicate that more of the individual tests indicated toxicity within a specific class.

site/sample name shaded in purple = screening test

site/sample name shaded in orange = definitive test

### 3.3.2 Temporal variation of toxicity results (2008 to 2018)

To determine temporal (over time) trends of increasing/decreasing toxicity levels, the risk class for each sample was plotted for each survey. Thereafter, linear trends over time were determined for the risk class at each site (Figures 5 & 6). It is important to note that these trends were not based on the actual mortalities/inhibition or lethal concentrations, but on the derived risk class for each survey and is merely included to gain a general understanding of increased/decreased risk over time.

#### Annually tested PCD's and selected streams

From the temporal database, it is clear that most samples have varying degrees of toxicity and that almost all of the samples have fallen within the Class II or higher classes from time to time (Figure 5). Samples Dam2 and Dam 4/5 consistently fall into the higher hazard classes and are therefore never suitable for undiluted release[7] (including uncontrolled releases) to the environment. Some samples have, however, improved notably over time, such as sample K105, which has improved from an acute hazard (Class III) during 2008/2009 to no acute hazard (Class I) over the past five years. Environmental managers should take note of these hazard classes to plan licenced releases and/or contain hazardous water types at the appropriate times.

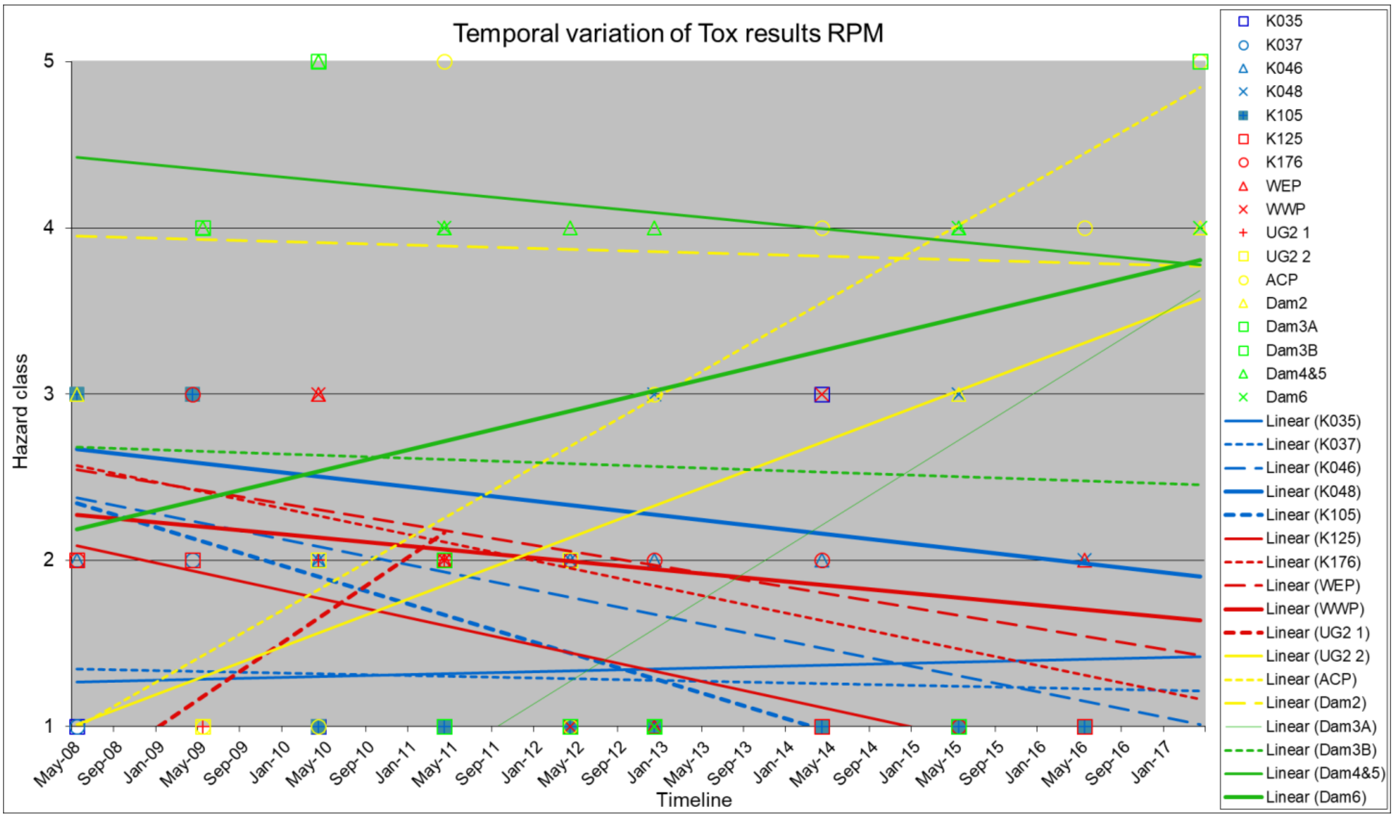

Figure 5: Temporal trends of toxicity results (annually tested PCD's and selected streams).

It is strongly recommended that definitive toxicity testing be continued for the samples that regularly display positive toxicity levels of Class III or higher. Definitive toxicity testing will allow for the estimation of safe dilution factors should the mine wish to apply for a water use licence to legally discharge such water types. These factors will also be essential for environmental managers to predict whether the toxicity of polluted water can be negated by natural dilution if accidentally released (e.g. spills, leaks or seepage) to the receiving environment. Definitive testing will furthermore assist in the suitable scheduling for planned releases (*i.e.* whether water could be released during the dry season and, if not, whether sufficient dilution is only likely to be achieved during the wet season/times of high river flow).

### Bi-annually tested tributaries

From the temporal database, it is clear that the relevant tributaries (Klipfonteinspruit and Klipgatspruit) have displayed toxicity hazards at times (Figure 6). It is encouraging that both tributaries have recently displayed lower toxicity. The Klipfonteinspruit is therefore also displaying a decreasing trend (improved hazard over time) as noted in Figure 6.

[7] Although theoretical predictions in terms of suitability for release are provided, releases remain bound by licensing conditions and are not prescribed/permitted by toxicity testing results.

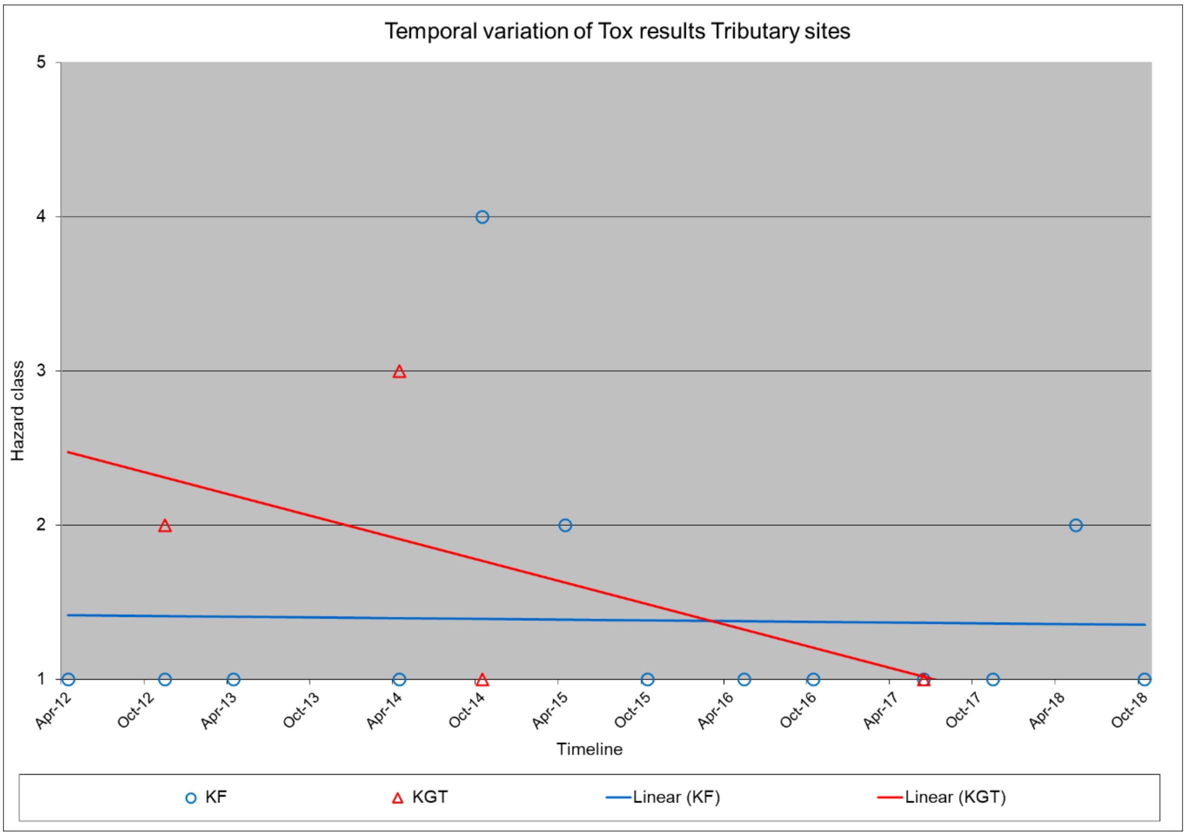


Figure 6: Temporal trends of toxicity results (bi-annually tested tributaries).

### 3.4 Aquatic invertebrate assessment: South African Scoring System 5

The South African Scoring System (Version 5) is a site-specific index which, together with associated habitat index (biotope suitability index), gives a general perspective of the biotic integrity (based on macro-invertebrates) and the impact of water quality on the biotic integrity of the specific sites (Thirion *et.al*., 1995; Dickens and Graham, 2001). The biotope suitability index considers the suitability of the different sampled biotopes in terms of quality and availability. It thereby firstly assesses whether the total SASS5 scores of two sites are directly comparable by comparing the total biotope suitability scores. If the total biotope suitability scores are very different this would imply that the total SASS5 scores should not be compared, but instead the most comparable SASS biotope scores. The most comparable SASS biotope scores are identified by comparing the various individual biotope suitability scores. In addition to the biotope suitability index, the Integrated Habitat Assessment System version 2 (IHAS) was also applied and included to give the macro-invertebrate specific habitat descriptions (Table 6).

Average score per taxon (ASPT) values are also useful in the assessment and comparison of biotic conditions at different sites. Based on field trials assessed by Dickens and Graham (2001) the ASPT was less variable than total SASS5 scores when conducted within a given river reach by different operators, considering all biotopes. ASPT is therefore included in the discussion below.

Biotic conditions, based on the total SASS5 and ASPT scores, decreased slightly from site H-US-KF to site H-DS-KF (opposite spatial trend observed during the May 2018 survey) (Table 7; Figure 7). This is in contrast with most previous surveys when no spatial deterioration was observed. The most similar biotope[8] between

[8] To compare the effect of water quality on SASS scores on a spatial scale, habitat differences are considered. Therefore, the most comparable $SASS_{biotpe}$ scores, in terms of habitat are also contrasted to gain insight regarding the effect of water quality on the biotic conditions (biotic integrity)

the two sites was GSM, confirming the probability of downstream deterioration in water quality (Table 7). Although biotic conditions at site KF in the Klipfonteinspruit were relatively low, it appeared to be similar to the adjoining Hex River sites. Furthermore, SASS scores (and hence biotic conditions) are expected to be affected by an intermittent flow regime (as regularly observed in the seasonal Klipfonteinspruit).

Table 6: Integrated Habitat Assessment (IHAS) description of the different biomonitoring sites.

| Sampling Habitat | H-US-KF | | KF | | H-DS-KF | | Hex-03 | | Hex-03-B | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Desc | Score | Desc | Score | Desc | Score | Desc | Score | Desc | Score |
| **Stones In Current (SIC)** | | | | | | | | | | |
| Total length of white water rapids (ie: bubbling water) (in meters) | 0-1 | 1 | 0-1 | 1 | none | 0 | none | 0 | none | 0 |
| Total length of submerged stones in current (run) (in meters) | >2-5 | 2 | >2-5 | 2 | >2-5 | 2 | >2-5 | 2 | >2-5 | 2 |
| Number of separate SIC area's kicked | 2-3 | 2 | 6+ | 4 | 4-5 | 3 | 4-5 | 3 | 4-5 | 3 |
| Average stone sizes kicked (in cm's) | 11-20 | 3 | 11-20 | 3 | 11-20 | 3 | 11-20 | 3 | 11-20 | 3 |
| Amount of stone surface clear (in %) | 26-50 | 2 | 51-75 | 3 | 0-25 | 1 | 0-25 | 1 | 26-50 | 2 |
| Protocol: time spent actually kicking SIC's (in mins) | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| **SIC score (max 20)** | | 13 | | 16 | | 12 | | 12 | | 13 |
| **Vegetation (VEG)** | | | | | | | | | | |
| Length of fringing vegetation sampled (banks) (in meters) | 2 | 4 | 2 | 4 | >1-2 | 3 | 2 | 4 | 2 | 4 |
| Amount of aquatic vegetation/algae sampled (in square meters) | 0-0.5 | 1 | >0.5-1 | 2 | 0-0.5 | 1 | >0.5-1 | 2 | >0.5-1 | 2 |
| Fringing vegetation sampled in | mix | 5 | mix | 5 | run | 2 | mix | 5 | mix | 5 |
| Type of veg. (percent leafy as apposed to stems/shoots) | 26-50 | 3 | 26-50 | 3 | 26-50 | 3 | 26-50 | 3 | 26-50 | 3 |
| **Veg score (max 15)** | | 13 | | 14 | | 9 | | 14 | | 14 |
| **Other Habitat / General (O.H.)** | | | | | | | | | | |
| Stones Out Of Current (SOOC) sampled (in square meters) | 0-0.5 | 1 | 0-0.5 | 1 | 0-0.5 | 1 | 0-0.5 | 1 | 0-0.5 | 1 |
| Sand sampled (in minutes) | none | 0 | none | 0 | none | 0 | 0-0.5 | 2 | 0-0.5 | 2 |
| Mud sampled (in minutes) | 0.5 | 3 | 0.5 | 3 | 0.5 | 3 | 0-0.5 | 2 | 0-0.5 | 2 |
| Gravel sampled (in minutes) | none | 0 | none | 0 | none | 0 | 0-0.5 | 1 | 0-0.5 | 1 |
| Bedrock sampled (all = no SIC, sand, gravel) | none | 0 | some | 1 | some | 1 | some | 1 | some | 1 |
| Algal presence ($m^2$) | >1sqm | 3 | >1-2sqm | 2 | rocks | 1 | >2sqm | 0 | >1-2sqm | 2 |
| Tray identification | correct | 3 | correct | 3 | correct | 3 | correct | 3 | correct | 3 |
| **O.H. score (max 20)** | | 10 | | 10 | | 9 | | 10 | | 12 |
| **Sampling habitat totals (max 55)** | | 36 | | 40 | | 30 | | 36 | | 39 |
| **Stream Condition** | | | | | | | | | | |
| **Physical** | | | | | | | | | | |
| River make up | 2 mix | 4 | 2 mix | 4 | run | 2 | 2 mix | 4 | 2 mix | 4 |
| Average width of stream (in meters) | 1-2 | 4 | >2-5 | 5 | >5-10 | 2 | >2-5 | 5 | >2-5 | 5 |
| Average depth of stream (in meters) | >0.5 | 5 | 0.5 | 4 | >0.5 | 5 | 0.5 | 4 | >0.5 | 5 |
| Approximate velocity of stream | mix | 5 | mix | 5 | medium | 3 | mix | 5 | mix | 5 |
| Water colour | discoloured | 3 | discoloured | 3 | discoloured | 3 | discoloured | 3 | discoloured | 3 |
| Recent disturbances | none | 5 | none | 5 | none | 5 | none | 5 | none | 5 |
| Bank/Riparian vegetation | mix | 4 | mix | 4 | grass | 2 | mix | 4 | mix | 4 |
| Surrounding impacts | farming | 1 | other | 3 | erosion | 0 | farming | 1 | farming | 1 |
| Left bank cover (rocks and vegetation) (in % | 51-80 | 1 | 51-80 | 1 | 0-50 | 0 | 51-80 | 1 | 51-80 | 1 |
| Right bank cover (rocks and vegetation) (in % | 51-80 | 1 | 51-80 | 1 | 0-50 | 0 | 51-80 | 1 | 51-80 | 1 |
| **Stream condition total (max 45)** | | 33 | | 35 | | 22 | | 33 | | 34 |
| **Total IHAS score (%)** | | 69 | | 75 | | 52 | | 69 | | 73 |

Biotic conditions, based on the total SASS5 scores and ASPT values, decreased largely from site H-DS-KF to Hex03 (Table 7; Figure 5). This was not habitat related as availability and suitability was better at the downstream site. A comparison of similar SASS-biotopes confirmed lowered biotic conditions, suggesting that the water quality was further affected between these sites, during October 2018. It has to be noted that organic enrichment and solid waste disposal appears extensively at this site and will likely affect biotic integrity if not mitigated (Plate 2). This was further supported by low dissolved oxygen levels (Refer to Section 3.2). It is again noted that the reason for lowered dissolved oxygen levels are unlikely to be related to APPD activities because levels were within the guideline at site H-DS-KF and no further APPD activities take place towards site Hex03.

Table 7: SASS5, ASPT and habitat suitability/availability index scores for different monitoring sites (October 2018).

| Monitoring site | SASS5 score | ASPT | SASS5-score per biotope | | | Biotope availability and suitability (Scores) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $SASS_{Stones}$ | $SASS_{Vegetation}$ | $SASS_{GSM}$ | Stones | Vegetation | GSM | Combined |
| H-US-KF | 49 | 3.77 | 7 | 46 | 21 | 3 | 6 | 3 | 12 |
| KF | 46 | 3.54 | 19 | 45 | 6 | 5 | 11 | 3 | 19 |
| H-DS-KF | 37 | 3.70 | 19 | 22 | 10 | 6 | 5 | 3 | 14 |
| Hex-03 | 14 | 2.80 | 11 | 14 | 11 | 4 | 9 | 6 | 19 |
| KGT | Dry | | | | | | | | |
| Hex-03-B | 28 | 4.00 | 28 | 20 | 8 | 5 | 14 | 5 | 24 |

**Key:**
ASPT - Average Score Pre Taxon S-Stones Veg-Vegetation GSM-Gravel, sand & mud

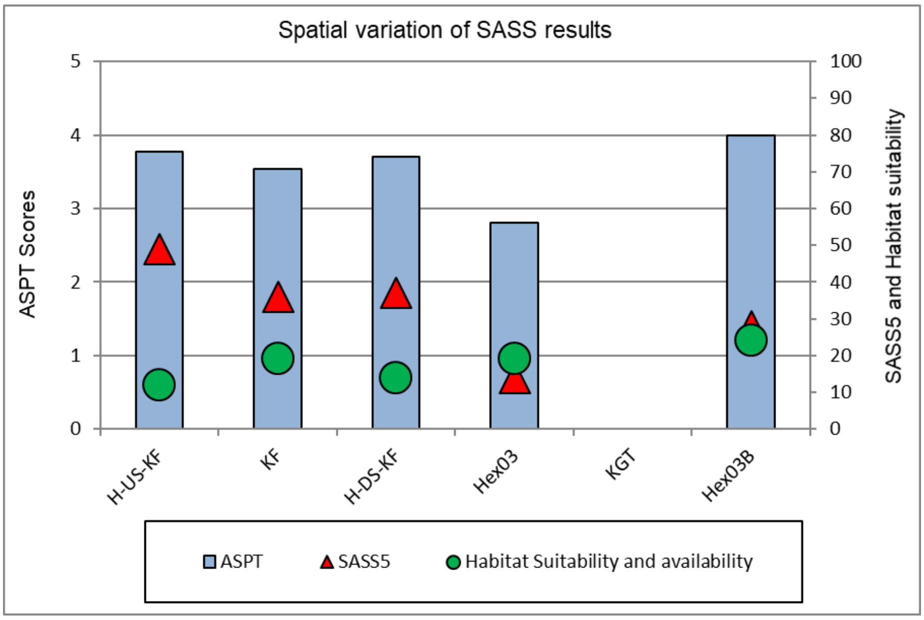


Figure 7: ASPT, SASS5 and total habitat suitability scores at biomonitoring sites during October 2018.

Biotic conditions, based on the total SASS5 scores and ASPT values, recovered largely from site Hex03 to Hex03-B (Table 7; Figure 5). This was at least partly habitat related as availability and suitability was better at the downstream site. Comparison of similar SASS-biotopes confirmed improved biotic conditions, suggesting that the water quality was not further affected between these sites, during October 2018. Site Hex03-B was included for the first time during the October 2018 survey. This was done to gauge the point-source effect, on the spatial integrity of the Hex River taking into consideration the Klipgatspruit. APPD is a potential contributor to pollution of the Klipgatspuit and continued monitoring (comparison of sites Hex03 and Hex03-B) will be essential to verify any possible impact and the severity thereof.

In conclusion, it can be stated that various sections of the Hex River within the study area show clear signs of reduced biotic integrity, based on macro-invertebrates. This was especially evident with the previous extended study area (now reduced due to Sibanye Stillwater sale and the complete scope no longer tasked to Clean Stream Biological Services). As such, a steady deterioration in biotic integrity in a downstream direction has consistently been recorded (Figure 8). However, the biotic integrity of the Hex River currently does improve on a spatial scale at certain sites (Figure 9) and appears to be more stable within the recently adopted reduction of the study area.

Plate 2: Indication of organic enrichment (algal proliferation) and solid waste disposal at site Hex03.

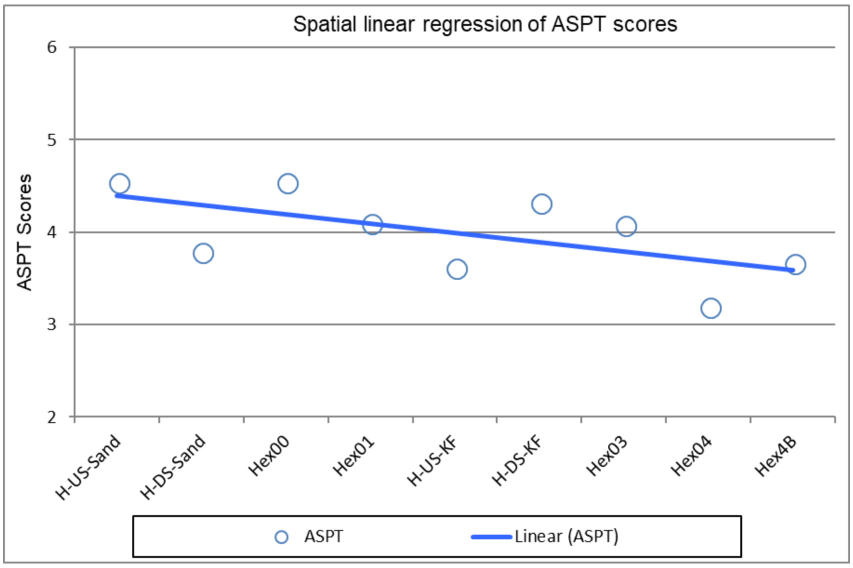


Figure 8: Linear regression of biotic integrity (as indicated by invertebrate ASPT scores) of the Hex River on a spatial scale (arranged sequentially in a downstream direction) during May 2018 (extended study area).

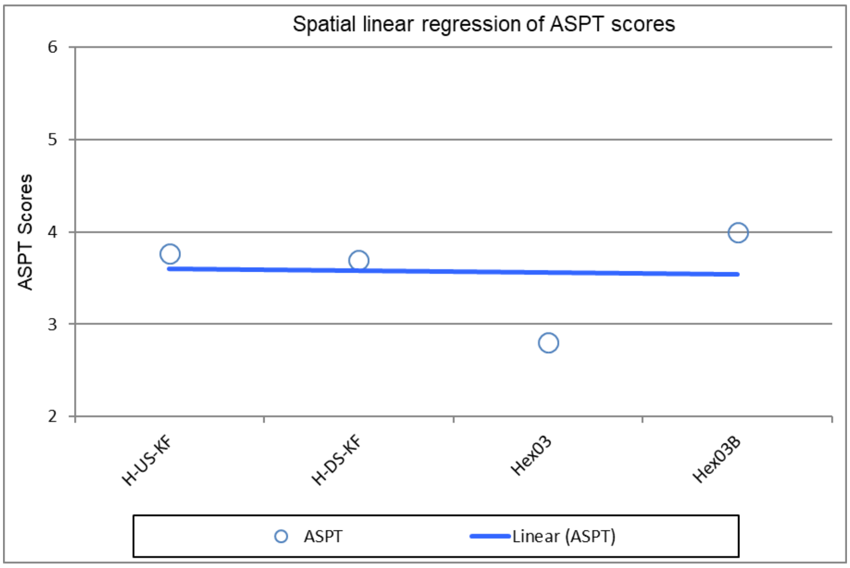


Figure 9: Linear regression of biotic integrity (as indicated by invertebrate ASPT scores) of the Hex River on a spatial scale (arranged sequentially in a downstream direction) during October 2018 (reduced study area).

## Temporal (long- and medium-term) trends

All of the datasets collected since May 2002 were compared to evaluate long-term and medium-term temporal trends in the biotic condition of the Hex River (Figures 10 & 11). Linear regression of historic ASPT values were calculated and plotted in order to achieve this. For the purpose of this monitoring programme, temporal trends are differentiated into long-term (more than four years) and medium-term (last 4 years) trends. The long-term trend gives a perspective on whether the biotic integrity (at the different sites) has improved or deteriorated since the inception of the monitoring programme. The medium-term trend confirms whether observed long-term trends are likely to continue or are in the process of being reversed.

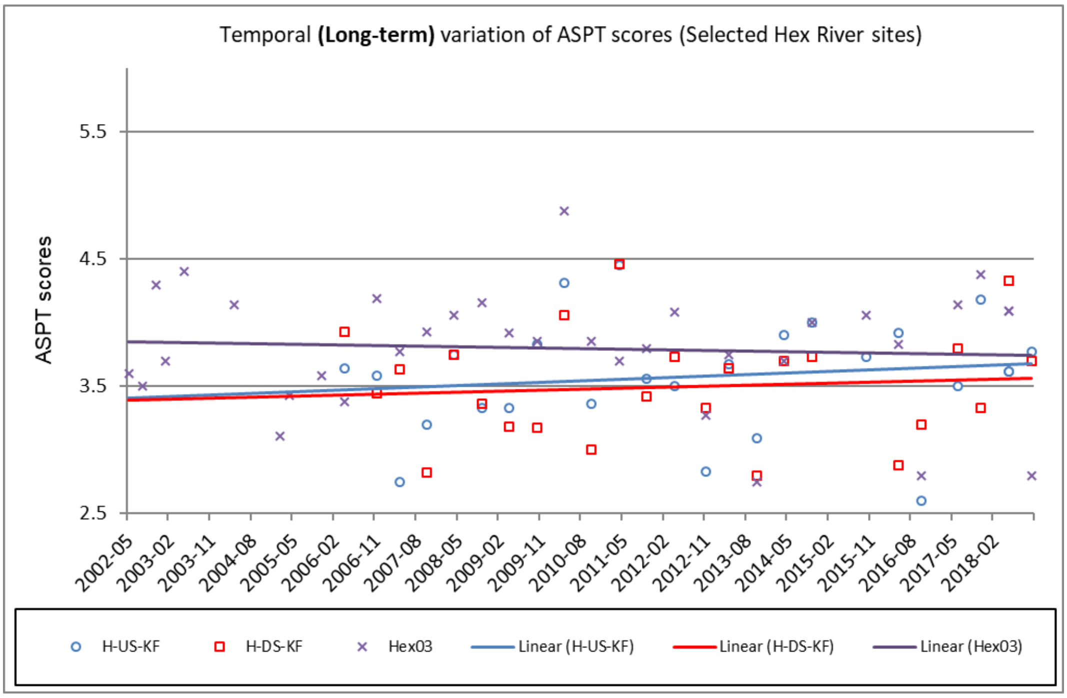


Figure 10: Long-term trends of biotic integrity in terms of macro-invertebrates at biomonitoring sites.

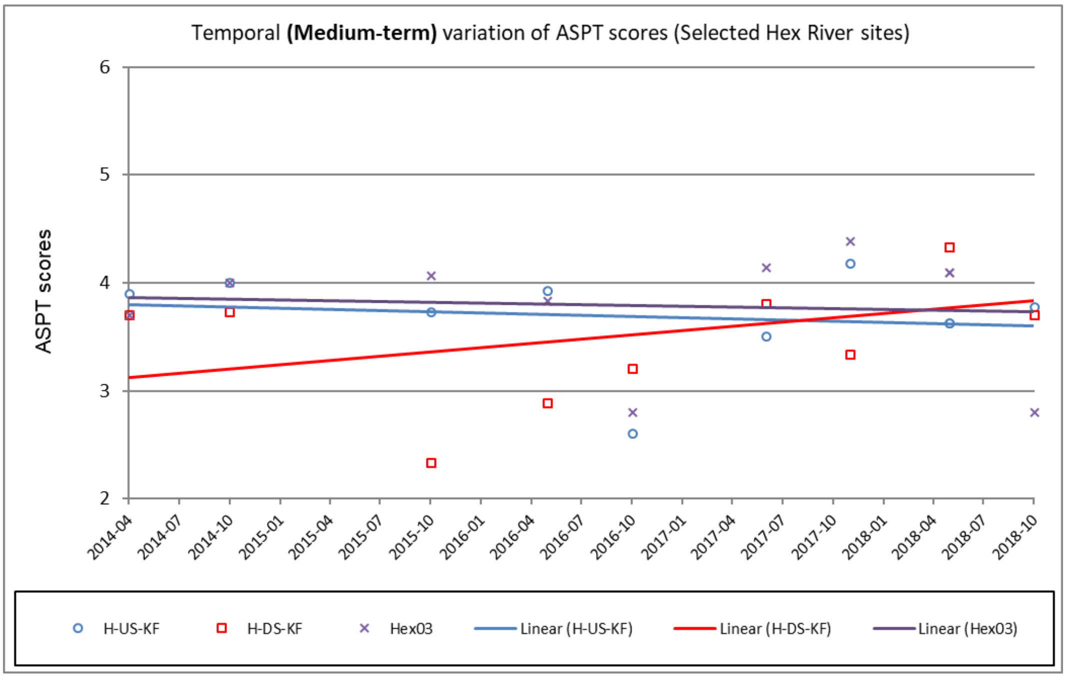


Figure 11: Medium-term trends of biotic integrity in terms of macro-invertebrates at biomonitoring sites.

Long-term trends indicated fair but stable biotic conditions at the three relevant Hex River sites (Figure 10). A slight improvement is in fact visible at sites H-US-KF and H-DS-KF. Medium term analyses (Figure 11) confirm generally lower biotic conditions at the latter site but, encouragingly, also eludes to recent improvement.

The long-term trend at site Hex03 is slightly negative as confirmed by the medium-term trends. The recently observed organic pollution is almost certainly the cause, being **unrelated** to APPD activities.

Continued monitoring will be essential to amass a database at the newly adopted downstream site (Hex03-B). This will serve to gauge the temporal effect of water users (including APPD) within the Klipgatspruit catchment, on the receiving environment (Hex River).

## 3.5 Fish Assessment

***Fish sampling is only scheduled once per annum and was last performed during May 2018, based on the extended scope (prior to Sibanye Stillwater sale). The approach and study area will therefore change in future, taking into consideration the reduced scope of this specific study, as performed by Clean Stream Biological Services. The complete extract (report RPM-A-18) of the fish results, is again repeated below for reference value and the sake of comprehensiveness. It should be kept in mind that various sampled sites are no longer part of this scope of work (since October 2018).***

The state and health of fish communities have been noted to give a reliable indication of short and long-term stress on aquatic systems. Fish communities possess various characteristics that render them important in the assessment of river health. They occupy positions throughout the aquatic food web, and are typically present in all but the most polluted of waters. Because fish often move over considerable distances, they have the potential to integrate diverse aspects of relatively large-scale habitats. Fish can therefore provide an integrated view of watershed conditions. Compared to other aquatic organisms, fish are furthermore relatively long-lived, and are therefore useful in providing a temporal dimension. They are also relatively easy to identify and after data is gathered, they can be released again. For the general public, fish are also the most well-known of aquatic organisms, and they are more likely to understand information about the condition of the fish community than about other taxa such as invertebrates. There are, however, some difficulties in using fish as biomonitoring indicators. Amongst these problems is the selective sampling attained by certain sampling equipment (for specific biotopes and for certain sizes and species of fish), the mobility of fish on spatial and temporal time scales, and the labour intensity of fish sampling.

Seven naturally occurring (native) fish species (*Barbus*[9] *paludinosus; Barbus trimaculatus; Barbus unitaeniatus; Clarias gariepinus; Oreochromis mossambicus; Pseudocrenilabrus philander* and *Tilapia sparrmanii*) were sampled at the five sampling sites in the Hex River during the 2017 to 2018 period (Table 8). The diversity of observed fish species was lower than expected at all of the sampling sites, indicating lowered biotic integrity (when compared to natural expected conditions). Possible reasons for lowered species diversity are outlined in the paragraphs below, which deal with the Fish Assemblage Integrity Index (FAII) and Fish Response Assessment Index (FRAI) results.

[9] Recent literature (Yang *et al*., 2015) recommend a name change of the genus '*Barbus*' to '*Enteromius*'. This was however contested and rejected by various authors (i.e. Schmidt and Bart, 2015) and requires further verification. Skelton (2016) supports the recommended name change and started implementing this in recent studies and literature.

### The Fish Assemblage Integrity Index (FAII) and Fish Response Assessment Index (FRAI)

For the purpose of this study, a simplified version of the FAII was used (presence / absence) to enable comparisons between each site (spatial analyses), while the FRAI was used to determine the estimated biotic integrity, based on fish, of the entire Hex River reach under investigation which would provide a valuable tool to provide an overall status of the reach under investigation and to determine long-term (temporal) changes.

Table 8: Fish species expected and observed during the last two surveys.

| Species | Native/Exotic | Sites | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hex00 | | Hex01 | | Hex03 | | Hex04 | | Hex4B | |
| | | Exp | Obs | Exp | Obs | Exp | Obs | Exp | Obs | Exp | Obs |
| *Amphillius uranoscopus* | Native | | | | | | | | | | |
| *Enteromius*# *paludinosus* | Native | | | | | | | | | | |
| *Enteromius*# *trimaculatus* | Native | | | | | | | | | | |
| *Enteromius*# *unitaeniatus* | Native | | | | | | | | | | |
| *Chiloglanis pretoriae* | Native | | | | | | | | | | |
| *Clarias gariepinus* | Native | | | | | | | | | | |
| *Cyprinus carpio** | Exotic | | | | | | | | | | |
| *Labeobarbus marequensis* | Native | | | | | | | | | | |
| *Labeo cylindricus* | Native | | | | | | | | | | |
| *Labeo molybdinus* | Native | | | | | | | | | | |
| *Mesobola brevianalis* | Native | | | | | | | | | | |
| *Oreochromis mossambicus* | Native | | | | | | | | | | |
| *Pseudocrenilabrus philander* | Native | | | | | | | | | | |
| *Tilapia sparrmanii* | Native | | | | | | | | | | |
| No. of naturally occuring species expected/present | | 9 | 4 | 10 | 3 | 10 | 5 | 13 | 4 | 13 | 3 |
| % expected / observed | | 44 | | 30 | | 50 | | 31 | | 23 | |

**Key:** sampled previous survey, sampled this survey, sampled last two surveys

* Exotic species are by definition not expected to occur under natural conditions and therefore not taken into account for FAII calculations
# Previous genus name: Barbus

## Fish Assemblage Integrity Index (FAII)

Based on morphological characteristics and the limited number of sites, each sampling site was classified as a separate fish habitat segment. Therefore, the "frequency of occurrence of fish within segments" was omitted from FAII for separate monitoring sites. Comparison of relative FAII scores for different sites would firstly give a perspective on the relative condition of the fish community at different sites and secondly indicate the impact of various anthropogenic activities up- and downstream of the different sites. Scores should however be treated with circumspection because the *frequency of occurrence* criterion was not considered, and the FAII scores are therefore less accurate. The list of fish species expected to occur at the sites under investigation is based on information from Skelton (1993) and Le Roux & Steyn (1968), as well as experience from previous surveys (this biomonitoring programme as well as various other mining related biomonitoring programmes, research and Department of Water Affairs' reserve determination studies). The expected species list is also updated with the knowledge gained from this biomonitoring programme. The species intolerance ratings used in the calculation of the FAII were taken from Kleynhans (2002) and were based on specialisation of preferences towards habitat, food, flowing water and water quality.

The composition of the fish community and the relative FAII (Fish Assemblage Integrity Index) are based on the last two surveys. This is done to increase the accuracy of the results and to avoid the incidental omission of a particular species at a particular site. Furthermore, fish generally take longer to react to stressors (compared with macro-invertebrates) and are therefore more applicable as an indicator over a period of time (as opposed to a snapshot at any given time).

The biotic integrity (as reflected by the fish assemblage integrity index) increased slightly from site Hex00 (23%) to Hex01 (27%) (Table 9 & Appendix tables; Figure 12). This is an indication that the biotic integrity (based on the fish communities) was not recently deteriorated due to by impacts in the area between these two sites. This is a similar trend as observed with the macro-invertebrate results, which indicated stable biotic conditions between these sites.

Table 9: Relative FAII scores calculated at different sampling sites (2017 to 2018).

| Locality | Relative FAII (%) |
|---|---|
| Hex00 | 23 |
| Hex01 | 27 |
| Hex03 | 46 |
| Hex04 | 22 |
| Hex4B | 22 |

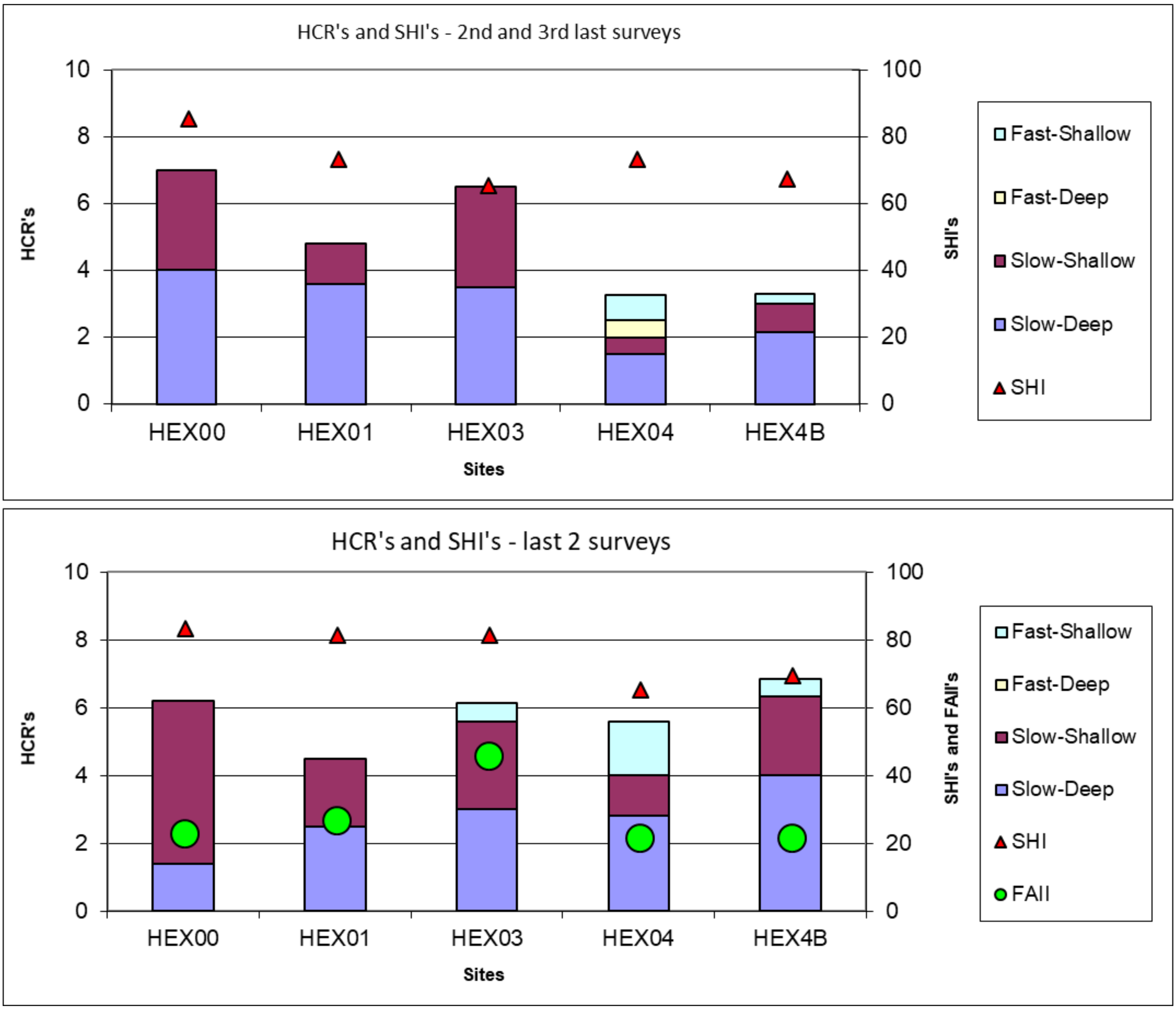


Figure 12: Relative FAII scores, HCR's and SHI at the different biomonitoring sites.

A spatial improvement was observed from site Hex01 to Hex03, as shown by the FAII scores increasing from 27% to 46% (Table 9; Figure 12). The spatial improvement was mainly attributed to the presence of *Enteromius trimaculatus* and *Enteromius unitaeniatus* at site Hex03. Both species are tolerant to moderately intolerant to water quality changes (Table 10) and their absence from site Hex01 is therefore not likely to be water quality related. Its absence from site Hex 00 during the 2017 to 2018 period is likely to be a response to lower habitat diversity and availability at this site. Based on these results, it appears that biotic integrity (based on fish) was probably not reduced by deteriorating water quality originating from the Klipfonteinspruit (possibly RPM-related) and/or from the sewage plant (non-RPM-related). This deduction is similar to the macro-invertebrate based deduction between these sites.

Table 10: The relative tolerance of each species towards changes in the environment.

| SPECIES NAME | Common name | Trophic specialisation | Habitat specialisation | Flow dependance | Requirement for high water quality | Total intolerance ratings |
|---|---|---|---|---|---|---|
| *Amphilius uranoscopus* | Stargazer | 4.7 | 4.9 | 4.8 | 4.8 | 4.8 |
| *Chiloglanis pretoriae* | Shortspine suckermouth | 4.4 | 4.8 | 4.8 | 4.5 | 4.6 |
| *Labeo molybdinus* | Leaden labeo | 3.3 | 3.0 | 3.3 | 3.2 | 3.2 |
| *Labeo cylindricus* | Redeye labeo | 3.3 | 3.0 | 3.1 | 3.1 | 3.1 |
| *Labeobarbus marequensis* | Largescale yellowfish | 2.4 | 2.8 | 3.2 | 2.1 | 2.6 |
| *Mesobola brevianalis* | River sardine | 3.1 | 2.2 | 1.1 | 2.8 | 2.3 |
| *Enteromius trimaculatus* | Threespot barb | 3.1 | 1.4 | 2.7 | 1.8 | 2.2 |
| *Enteromius paludinosus* | Straightfin barb | 1.6 | 1.4 | 2.3 | 1.8 | 1.8 |
| *Enteromius unitaeniatus* | Longbeard barb | 1.1 | 1.3 | 2.3 | 2.2 | 1.7 |
| *Oreochromis mossambicus* | Mazambique tilapia | 1.2 | 1.9 | 0.9 | 1.3 | 1.3 |
| *Pseudocrenilabrus philander* | Southern mouthbrooder | 1.3 | 1.4 | 1.0 | 1.4 | 1.3 |
| *Tilapia sparrmanii* | Banded tilapia | 1.6 | 1.4 | 0.9 | 1.4 | 1.3 |
| *Clarias gariepinus* | Sharptooth catfish | 1.0 | 1.2 | 1.7 | 1.0 | 1.2 |

**Key:**
Intolerance ratings are colour shaded on a scale from green to red, with green being least intolerant and red being most intolerant
Species are sorted in decending order from most intolerant (total intolerance rating) to least intolerant
1-2 = Tolerant 2-3 = Moderate tolerant 3-4 = Moderately intolerant 4-5 = Intolerant

As also observed previously, the FAII scores were largely reduced from site Hex03 towards site Hex04 (Table 9). The potential impact of water quality on the biotic integrity of the Hex River (as measured by the FAII at site Hex04) should therefore not be disregarded as both macro-invertebrates (during 2016 and 2018) and fish (last 4 years) are now indicating as such. Potential sources of reduced water quality between sites Hex03 and Hex04 include the Klipgatspruit and the Dorpspruit (see also previous discussions regarding potential Dorpspruit impacts).

The biotic integrity (based on fish) was similar between site Hex04 to site Hex4B (Table 9 & Appendix tables; Figure 12), being very poor at both sites. The same poor conditions (albeit spatially increased) was indicated by the macro-invertebrate assessment for these sites.

### Fish Response Assessment Index (FRAI)

As mentioned earlier, the Fish Response Assessment Index was adopted to assist in the classification of the Ecological Status, based on fish, of the entire Hex River reach under investigation. The results are therefore pooled for all sites. The resulting classification is therefore not a reflection of RPM mining impacts, but rather a reflection of the overall cumulative impact/s derived from the catchment.

The section below shows the individual metric driver results (Velocity-Depth, Cover, Flow, Physico-chemical, Migration and Introduced species), as well as the overall FRAI categories and category descriptions for the Hex River (Table 11).

Table 11: Fish Response Assessment Index (FRAI) results for the Hex River reach (all sites) (2017/8 results).

| METRIC GROUP | METRIC | *RATING (CHANGE) | METRIC GROUP WEIGHT (%) |
|---|---|---|---|
| VELOCITY-DEPTH CLASSES METRICS | Response of species with high to very high preference for FAST-DEEP conditions | -5 | 97 |
| | Response of species with high to very high preference for FAST-SHALLOW conditions | -5 | |
| | Response of species with high to very high preference for SLOW-DEEP conditions | -2.5 | |
| | Response of species with high to very high preference for SLOW-SHALLOW conditions | -2 | |
| COVER METRICS | Response of species with a very high to high preference for overhanging vegetation | -1.5 | 100 |
| | Response of species with a very high to high preference for undercut banks and root wads | -0.5 | |
| | Response of species with a high to very high preference for a particular substrate type | -5 | |
| | Response of species with a high to very high preference for instream vegetation | -0.5 | |
| | Response of species with a very high to high preference for the water column | -3 | |
| FLOW DEPENDANCE METRICS | Response of species intolerant of no-flow conditions | -5 | 94 |
| | Response of species moderately intolerant of no-flow conditions | -5 | |
| | Response of species moderately tolerant of no-flow conditions | -2 | |
| | Response of species tolerant of no-flow conditions | -1.5 | |
| PHYSICO-CHEMICAL METRICS | Response of species intolerant of modified physico-chemical conditions | -5 | 64 |
| | Response of species moderately intolerant of modified physico-chemical conditions | -5 | |
| | Response of species moderately tolerant of modified physico-chemical conditions | -4 | |
| | Response of species tolerant of modified physico-chemical conditions | -1 | |
| MIGRATION METRICS | Response in terms of distribution/abundance of spp with catchment scale movements | 0 | 61 |
| | Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments | 4 | |
| | Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment | 2 | |
| INTRODUCED SPECIES METRICS | The impact/potential impact of introduced competing/predaceous spp? | 0 | 45 |
| | How widespread (frequency of occurrence) are introduced competing/predaceous spp? | 0 | |
| | The impact/potential impact of introduced habitat modifying spp? | 2 | |
| | How widespread (frequency of occurrence) are habitat modifying spp? | 1 | |
| FRAI SCORE (%) | | 32.3 | |
| FRAI CATEGORY | | E | |
| FRAI CATEGORY DESCRIPTION | | Seriously modified | |

- Reduced flows and altered flooding regime of the river.
- Cover metrics: Seriously deterioration in substrate as cover, most probably associated with extensive algal growth (as described earlier in this report), flow modification (decreased riffle/rapid habitats) and sedimentation.
- Flow dependence metrics: Serious modification of fish species intolerant to moderately intolerant to no-flow conditions, again indicating on altered hydrological regime (altered flows and floods).
- Physico-chemical metrics: Seriously modified conditions indicated by fish species that are intolerant to moderately intolerant of modified water quality, indicating on seriously deteriorated water quality prevailing in this river reach.
- Migration metrics: Indicating seriously modified migratory impacts, associated with various physical and potentially also chemical migration barriers within this reach.
- Introduced species metrics: Slight impacts associated with the presence of the habitat modifying alien Common carp (*Cyprinus carpio*).

Table 12: Descriptive categories used to describe the present ecological status (PES) of biotic components (adapted from Kleynhans, 1999).

| CATEGORY | BIOTIC INTEGRITY | DESCRIPTION OF GENERALLY EXPECTED CONDITIONS |
|---|---|---|
| A | Excellent | Unmodified, or approximates natural conditions closely. The biotic assemblages compares to that expected under natural, unperturbed conditions. |
| B | Good | Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modifications. Most aspects of the biotic assemblage as expected under natural unperturbed conditions. |
| C | Fair | Moderately modified. A lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from its naturally expected condition. Some impairment of health may be evident at the lower end of this class. |
| D | Poor | Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Most characteristics of the biotic assemblages have been largely modified from its naturally expected condition. Impairment of health may become evident at the lower end of this class. |
| E | Very Poor | Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately tolerant species. Most of the characteristics of the biotic assemblages have been seriously modified from its naturally expected condition. Impairment of health may become very evident. |
| F | Critical | Critically modified. Extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only intolerant species may be present with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from its naturally expected conditions. Impairment of health generally very evident. |

# 4 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based on the aquatic macro-invertebrate assessments performed during October 2018. Reference is not made to fish based conclusions since the new scope of work (study area) has invalidated spatial and temporal findings, which will be refined when fish assessment are once again performed (scheduled once per annum).

The most important **spatial** conclusions are as follows:

- Biotic conditions, based on the total SASS5 and ASPT scores, decreased slightly from site H-US-KF to site H-DS-KF (opposite spatial trend observed during the May 2018 survey). This is in contrast with most previous surveys when no spatial deterioration was observed. The most similar biotope between the two sites was GSM, confirming the probability of downstream deterioration in water quality. Although biotic conditions at site KF in the Klipfonteinspruit were relatively low, it appeared to be similar to the adjoining Hex River sites. Furthermore, SASS scores (and hence biotic conditions) are expected to be affected by an intermittent flow regime (as regularly observed in the seasonal Klipfonteinspruit).
- Biotic conditions, based on the total SASS5 scores and ASPT values, decreased largely from site H-DS-KF to Hex03. This was not habitat related as availability and suitability was better at the downstream site. A comparison of similar SASS-biotopes confirmed lowered biotic conditions, suggesting that the water quality was further affected between these sites, during October 2018. It has to be noted that organic enrichment and solid waste disposal appears extensively at this site and will likely affect biotic integrity if not mitigated. This was further supported by low dissolved oxygen levels. It is again noted that the reason for lowered dissolved oxygen levels are unlikely to be related to APPD activities because levels were within the guideline at site H-DS-KF and no further APPD activities take place towards site Hex03.
- Biotic conditions, based on the total SASS5 scores and ASPT values, recovered largely from site Hex03 to Hex03-B. This was at least partly habitat related as availability and suitability was better at the downstream site. Comparison of similar SASS-biotopes confirmed improved biotic conditions, suggesting that the water quality was not further affected between these sites, during October 2018. Site Hex03-B was included for the first time during the October 2018 survey. This was done to gauge the point-source effect, on the spatial integrity of the Hex River taking into consideration the Klipgatspruit. APPD is a potential contributor to pollution of the Klipgatspuit and continued monitoring (comparison of sites Hex03 and Hex03-B) will be essential to verify any possible impact and the severity thereof.

The most important **temporal (long- and medium-term)** conclusions regarding the biotic integrity of the Hex River are as follows:

- Long-term trends indicated fair but stable biotic conditions at the three relevant Hex River sites. A slight improvement is in fact visible at sites H-US-KF and H-DS-KF. Medium term analyses confirm generally lower biotic conditions at the latter site but, encouragingly, also eludes to recent improvement.
- The long-term trend at site Hex03 is slightly negative as confirmed by the medium-term trends. The recently observed organic pollution is almost certainly the cause, being **unrelated** to APPD activities.
- Continued monitoring will be essential to amass a database at the newly adopted downstream site (Hex03-B). This will serve to gauge the temporal effect of water users (including APPD) within the Klipgatspruit catchment, on the receiving environment (Hex River).

**General conclusions and recommendations**

In conclusion, it can be stated that various sections of the Hex River within the study area show clear signs of reduced biotic integrity, based on macro-invertebrates. This was especially evident with the previous extended study area (now reduced due to Sibanye Stillwater sale and the complete scope no longer tasked to Clean Stream Biological Services). As such, a steady deterioration in biotic integrity in a downstream direction has consistently been recorded. However, the biotic integrity of the Hex River currently does improve on a spatial scale at certain sites and appears to be more stable within the recently adopted reduction of the study area.

Future biomonitoring should be maintained on at least a biannual interval to gauge the trend of deterioration/improvement. This would facilitate the identification of possible impacts by APPD (and others) to this aquatic ecosystem. Early identification of impacts to the biota should prompt the identification of contaminants and the implementation of mitigation measures to reduce or prevent continued risk to the aquatic ecosystem.

It is strongly recommended that definitive toxicity testing be continued for the PCDs that regularly display toxicity levels of Class III or higher. Definitive toxicity testing will allow for the calculation of safe dilution ratios and will allow for the process of risk assessment. The risk assessment involves predicting the amount of a substrate that may enter the environment and comparing this with definitive toxicity results.

Calculated dilution ratios will be essential for environmental managers to predict whether the toxicity of polluted water will be negated if released or accidentally spilled into the receiving environment. Definitive testing will furthermore assist with scheduling planned licenced releases (*i.e.* whether water could be released during the dry season and, if not, whether sufficient dilution is likely to be achieved during the wet season/times of high river flow). All discharges should fall within the ambit of an approved water use licence, with biomonitoring and toxicity data being essential for the licensing process. In addition, increasing the frequency of testing of the pollution control facilities to at least twice a year should be considered. The confidence of results is relatively low if testing is only performed once a year, especially since toxicity hazards could conceivably change on a daily basis. More regular testing will therefore increase the confidence of results and lead to more informed management decisions.

It is now recommended to include both site KF and KFD (in the Klipfonteinspruit) for toxicity testing (in addition to the Klipgatspruit; site KGT). The effect of different sources of pollution can then be distinguished more accurately.

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# Appendix 1: Methodology applied during this biomonitoring assessment.

**1.*In-situ* water quality**
The following surface water quality variables were measured on site: pH, Conductivity, water temperature, dissolved oxygen and oxygen saturation (Hach HQ40d Multimeter; Serial Number: 130300086148).

**2.Habitat assessment**
An evaluation of habitat quality and availability to biota is critical to any assessment of ecological integrity and should be conducted at each site at the time of biological sampling. On site habitat assessments were conducted by using existing habitat evaluation indices.

**2.1 Habitat condition**
The United States Environment Protection Agency Habitat Assessment Index (HAI) index was used to determine the general physical habitat condition at each site. Habitat parameters used by this index in this assessment of habitat integrity include the following: Epifaunal substrate/Available cover, Pool substrate characteristics, Pool variability, Channel alteration, Sediment deposition, Channel sinuosity, Channel flow status, Bank vegetative protection, Bank stability and Riparian vegetative zone width. Each of the above mentioned criteria was assessed and according to its condition, rated in one of the following classes, namely: Optimal/Excellent, Sub optimal/Good, Marginal/Fair or Poor. For each criterion, a score was given within the selected class. The sum of these scores gives a final score for this Index, and can be used in comparison to other sites or, if possible, to the baseline or reference condition to indicate its physical integrity (Barbour *et al*., 1999).

***2.2 Fish Habitat Assessment***
This assessment is aimed at the determination of the potential of a site to provide habitat for fish (Fish habitat cover ratings) and to identify the potential human impact on the fish habitat (Site fish habitat integrity) (Kleynhans, 1997).

*Fish Habitat Cover Rating (HCR)*
This approach was developed to assess habitats according to different attributes that are surmised to satisfy the habitat requirements of various fish species (Kleynhans, 1997). At each site, the following depth-flow (df) classes are identified, namely:
Slow (<0.3m/s), shallow (<0.5m) - Shallow pools and backwaters.
Slow, deep (>0.5m) - Deep pools and backwaters.
Fast (>0.3m/s), shallow - Riffles, rapids and runs.
Fast, deep - Usually rapids and runs.

The relative contribution of each of the above mentioned classes at a site was estimated and indicated as:
0 = Absent
1 = Rare (<5%)
2 = Sparse (5-25%)
3 = Moderate (25-75%)
4 = Extensive (>75%)

For each depth-flow class, the following cover features (cf), considered to provide fish with the necessary cover to utilise a particular flow and depth class, were investigated:
- Overhanging vegetation
- Undercut banks and root wads
- Stream substrate
- Aquatic macrophytes

The amount of cover present at each of these cover features (cf) was noted as:
0 = absent
1 = Rare/very poor (<5%)
2 = Sparse/poor (5-25%)
3 = Moderate/good (25-75%)
4 = Extensive/excellent (>75%)

The fish habitat cover rating (HCR) was calculated as follows:
- The contribution of each depth-flow class at the site was calculated ($df/\Sigma df$).
- For each depth-flow class, the fish cover features (cf) were summed ($\Sigma cf$).
$HCR = df/\Sigma df \times \Sigma cf$.

*Site fish habitat integrity (SHI)*
This approach is based on the assessment of physical habitat disturbance and is directed towards the indirect qualitative evaluation of fish habitat integrity, compared to the expected natural condition (Kleynhans, 1997). The following impacts (cause for fish habitat integrity degradation) is investigated, namely: Water abstraction, flow modification, bed modification, channel modification, inundation, exotic macrophytes, solid waste disposal, indigenous vegetation removal, exotic vegetation encroachment and bank erosion. Estimation of the impact of each of these modifications on the fish habitat integrity at a site is scored as follows:
No Impact = 0
Small impact = 1
Moderate Impact = 3
Large impact = 5

**3.Aquatic invertebrate assessment: South African Scoring System, Version 5.**
Benthic macro-invertebrate communities of the selected sites were investigated according to the South African Scoring System, version 5 (SASS5) approach (Dickens & Graham, 2001). This method is based on the British Biological Monitoring Working Party (BMWP) method and has been adapted for South

African conditions by Dr. F. M. Chutter (Thirion *et al*., 1995). The SASS method is a rapid, simple and cost effective method, which has progressed through four different upgrades/versions. The current upgrade is Version 5, which is specifically designed to comply with international accreditation protocols.

**Sample Collection**

An invertebrate net (30 x 30cm square with 1mm mesh netting) was used for the collection of the organisms. The available biotopes at each site were identified on arrival. Each of the biotopes was sampled by different methods explained later (samples should not be collected when the river is in flood).

The biotopes were combined into three different groups, which were sampled and assessed separately:

**a) Stone (S) Biotopes:**

**Stones in current (SIC) or any solid object:** *Movable stones of at least cobble size (3 cm diameter) to approximately 20 cm in diameter, within the fast and slow flowing sections of the river.* Kicksampling is used to collect organisms in this biotope. This is done by putting the net on the bottom of the river, just downstream of the stones to be kicked, in a position where the current will carry the dislodged organisms into the net. The stones are then kicked over and against each other to dislodge the invertebrates (kicksampling) for ± 2 minutes.

**Stones out of current (SOOC):** *Where the river is still, such as behind a sandbank or ridge of stones or in backwaters.* Collection is again done by the method of kicksampling, but in this case the net is swept across the area sampled to catch the dislodged biota. Approximately 1 $m^2$ is sampled in this way.

**Bedrock or other solid substrate:** Bedrock includes stones greater than 30cm, which are generally immovable, including large sheets of rock, waterfalls and chutes. The surfaces are scraped with a boot or hand and the dislodged organisms collected. Sampling effort is included under SIC and SOOC above.

**b) Vegetation (VG) Biotopes:**

**Marginal vegetation (MV):** *This is the overhanging grasses, bushes, twigs and reeds growing on the edge of the stream, often emergent, both in current (MvegIC) and out of current (MvegOOC).* Sampling is done by holding the net perpendicular to the vegetation (half in and half out of the water) and sweeping back and forth in the vegetation (± 2m of vegetation).

**Submerged vegetation (AQV):** *This vegetation is totally submerged and includes Filamentous algae and the roots of floating aquatics such as water hyacinth.* Sampled by pushing the net (under the water) against and amongst the vegetation in an area of approximately one square meter.

**c) Gravel, Sand and Mud (GSM) biotopes:**

**Sand:** *This includes sandbanks within the river, small patches of sand in hollows at the side of the river or sand between the stones at the side of the river.* This biotope is sampled by stirring the substrate by shuffling or scraping of the feet, which is done for half a minute, whilst the net is continuously swept over the disturbed area.

**Gravel:** *Gravel typically consists of smaller stones (2-3 mm up to 3 cm).* Sampling similar to that of sand.

**Mud:** *It consists of very fine particles, usually as dark-collared sediment.* Mud usually settles to the bottom in still or slow flowing areas of the river. Sampling similar to that of sand.

**d) Hand picking and visual observation:**

Before and after disturbing the site, approximately 1 minute of "hand-picking" for specimens that may have been missed by the sampling procedures was carried out.

**Sample preparation**

The organisms sampled in each biotope group were identified and their relative abundance also noted on the SASS5 datasheet.

**SASS-Habitat Assessment**

A SASS-habitat assessment index, according to the habitats sampled, was performed due to the fact that changes in habitat can be responsible for changes in SASS5 scores. This was done by the application of Integrated Habitat Assessment System (IHAS version 2) (McMillan, 1998).

**4.Fish Assemblage Integrity Index (FAII) (Kleynhans, 1997)**

Due to the difficulty of applying the generally used Index of Biotic Integrity (IBI) in rivers of South Africa, Kleynhans (1997) developed an alternative approach. The following procedures were used in the application of the FAII:

*Species tolerance ratings*

The species intolerance ratings used in the calculation of the FAII were taken from Kleynhans (2002). Four components are taken into account in estimating the intolerance of the relevant fish species, namely habitat preferences and specialisation (HS), food preference and specialisation (TS), requirements for flowing water during different life-stages (FW) and water quality requirements (WQ). Each of these aspects are scored for a species according to low requirement/specialisation (rating=1), moderate requirement/ specialisation (rating=3) and high requirement/specialisation (rating=5). The total intolerance (IT) of a fish species is estimated as follows:

IT = (HS+TS+FW+WQ)/4

*Health*

The percentage of fish with externally evident disease or other anomalies are used to score this metric. The following procedure is used to score the health of individual species:

Frequency of affected fish >5%, score = 1
Frequency of affected fish 2 - 5%, score = 3
Frequency of affected fish <2%, score = 5
The expected health for a species living under unperturbed conditions is assumed to be unimpaired and would score 5.

**The FAII is calculated as follows:**

The *expected index score* [FAII (exp.)] per segment:
FAII (exp.) = Σ(TxH)
where: T = Tolerance rating for individual species
H = Expected health rating for individual species.

The *observed index score* [FAII (obs)] is calculated on a similar basis but is based on the information collected during the survey:
FAII (obs) = Σ(TxH).
The observed fish assemblage index score for a segment is expressed as a percentage of the expected total FAII score to arrive at a relative FAII rating:
FAII (obs) / FAII (exp.) x 100

**Fish Response Assessment Index (FRAI)**

The determination and description of the present ecological status (PES) of the aquatic ecosystems in the study area, in terms of fish, was done according to the methodology described for River EcoClassification during Reserve Determinations (Kleynhans & Louw, 2008) using the Fish Response Assessment Index (FRAI) (Kleynhans, 2008). The results were then used to classify the present state of the fish assemblage into a specific descriptive category (A to F) (Table A1).

The FRAI is not in its conventional form designed for the application per site, but rather to a reach with a few sites. Metrics are therefore based on spatial frequency of occurrence of a species within the reach.

Table A1: Descriptive categories used to describe the present ecological status (PES) of biotic components (adapted from Kleynhans, 1999).

| CATEGORY | BIOTIC INTEGRITY | DESCRIPTION OF GENERALLY EXPECTED CONDITIONS |
|---|---|---|
| **A** | Excellent | Unmodified, or approximates natural conditions closely. The biotic assemblages compares to that expected under natural, unperturbed conditions. |
| B | Good | Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modifications. Most aspects of the biotic assemblage as expected under natural unperturbed conditions. |
| C | Fair | Moderately modified. A lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from its naturally expected condition. Some impairment of health may be evident at the lower end of this class. |
| D | Poor | Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Most characteristics of the biotic assemblages have been largely modified from its naturally expected condition. Impairment of health may become evident at the lower end of this class. |
| E | Very Poor | Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately tolerant species. Most of the characteristics of the biotic assemblages have been seriously modified from its naturally expected condition. Impairment of health may become very evident. |
| F | Critical | Critically modified. Extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only intolerant species may be present with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from its naturally expected conditions. Impairment of health generally very evident. |

It must be emphasized that the A→F scale represents a continuum, and that the boundaries between categories are notional, artificially-defined points along the continuum (as presented below). This situation falls within the concept of a fuzzy boundary, where a particular entity may potentially have membership of both classes (Robertson *et al*. 2004). For practical purposes, these situations are referred to as boundary categories and are denoted as B/C, C/D, and so on.

**Appendix 2: Site photos of biomonitoring sites (last two surveys)**

Plate 1: Upstream view of H-US-KF (2018-05)

Plate 2: Downstream view of H-US-KF (2018-05)

Plate 3: Upstream view of H-US-KF (2018-10)

Plate 4: Downstream view of H-US-KF (2018-10)

Plate 5: Upstream view of KF (2018-05)

Plate 6: Downstream view KF (2018-05)

Plate 7: Upstream view of kF (2018-10)

Plate 8: Downstream view KF (2018-10)

Plate 9: Upstream view of KFD (2018-05)

Plate 10: Downstream view of KFD (2018-05)

Not included in this survey

Plate 11: Upstream view of KFD (2018-10)

Plate 12: Downstream view of KFD (2018-10)

Plate 13: Upstream view of H-DS-KF (2018-05)

Plate 14: Downstream view of H-DS-KF (2018-05)

Plate 15: Upstream view of H-DS-KF (2018-10)

Plate 16: Downstream view of site H-DS-KF (2018-10)


Plate 16: Upstream view of Hex03 (2018-05)


Plate 17: Downstream view of Hex03 (2018-05)


Plate 18: Upstream view of Hex03 (2018-10)


Plate 19: Downstream view of site Hex03 (2018-10)


Plate 20: Upstream view of KGT (2018-05)


Plate 21: Downstream view of KGT (2018-05)


Plate 22: Upstream view of KGT (2018-10)


Plate 23: Downstream view of site KGT (2018-10)

Not included in this survey

Plate 24: Upstream view of Hex03B (2018-05)

Plate 25: Downstream view of Hex03B (2018-05)

Plate 26: Upstream view of Hex03B (2018-10)

Plate 27: Downstream view of site Hex03B (2018-10)

## Appendix 3: Tables

**Table A1:** SASS5 analysis including macro-invertebrate families sampled and habitat suitability scores calculated for the various sites (December 2018).

| Taxon | H-US-KF | | | | KF | | | | H-DS-KF | | | | Hex-03 | | | | Hex-03-B | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stones | Veg | GSM | Total | Stones | Veg | GSM | Total | Stones | Veg | GSM | Total | Stones | Veg | GSM | Total | Stones | Veg | GSM | Total |
| TURBELLARIA | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - |
| Oligochaeta | B | - | A | B | - | - | A | A | - | - | B | B | A | 1 | A | A | A | - | - | A |
| Leeches | A | A | A | B | - | - | - | - | - | - | - | - | - | 1 | - | 1 | A | - | A | A |
| Baetidae 1 sp. | - | 1 | A | A | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Coenagrionidae | - | 1 | - | 1 | A | B | - | B | - | A | 1 | A | - | - | - | - | A | B | - | B |
| Aeshnidae | - | - | - | - | - | A | - | A | - | - | - | - | - | - | - | - | - | - | - | - |
| Libelludae | - | - | - | - | 1 | B | - | B | - | - | - | - | - | - | - | - | - | - | - | - |
| Belostomatidae* | - | - | - | - | - | B | - | B | - | - | - | - | - | - | - | - | - | - | - | - |
| Corixidae* | B | B | A | B | B | B | B | B | B | B | B | B | 1 | 1 | 1 | A | - | - | - | - |
| Gerridae* | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| Naucoridae* | - | 1 | - | 1 | - | - | - | - | - | A | - | A | - | - | - | - | - | - | - | - |
| Notonectidae* | - | - | - | - | - | - | - | - | - | A | - | A | - | - | - | - | - | - | - | - |
| Pleidae* | - | - | - | - | - | A | - | A | - | - | - | - | - | - | - | - | - | - | - | - |
| Veliidae* | - | - | - | - | - | A | - | A | - | - | - | - | - | - | - | - | - | - | - | - |
| Hydropsychidae 1sp. | - | B | - | B | - | - | - | - | B | - | - | B | - | - | - | - | A | - | - | A |
| Hydroptilidae | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Leptoceridae | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 |
| Dytiscidae (adults*) | - | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - | - | - | - | - |
| Gyrinidae (adults*) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 |
| Chironomidae | - | - | B | B | B | B | B | C | A | B | B | B | B | B | B | B | A | A | B | B |
| Culicidae* | - | 1 | - | 1 | - | A | - | A | - | - | - | - | - | - | - | - | - | - | - | - |
| Muscidae | - | - | - | - | 1 | A | - | A | - | - | - | - | - | - | - | - | 1 | - | - | 1 |
| Simuliidae | - | B | B | B | B | A | - | B | A | - | - | A | A | A | 1 | B | B | B | - | C |
| Ancylidae | - | A | - | A | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Physidae* | - | A | A | A | - | - | - | - | - | - | - | - | - | - | - | - | B | B | B | B |
| Total SASS5 score | 7 | 46 | 21 | 49 | 19 | 45 | 6 | 46 | 19 | 22 | 10 | 37 | 11 | 14 | 11 | 14 | 28 | 20 | 8 | 34 |
| No. of families | 3 | 11 | 7 | 13 | 6 | 12 | 3 | 13 | 5 | 6 | 4 | 10 | 4 | 5 | 4 | 5 | 9 | 5 | 3 | 10 |
| ASPT | 2.33 | 4.18 | 3.00 | 3.77 | 3.17 | 3.75 | 2.00 | 3.54 | 3.80 | 3.67 | 2.50 | 3.70 | 2.75 | 2.80 | 2.75 | 2.80 | 3.11 | 4.00 | 2.67 | 3.40 |
| Total IHAS | | | | 69 | | | | 75 | | | | 52 | | | | 69 | | | | 73 |
| IHAS - Habs sampled | | | | 36 | | | | 40 | | | | 30 | | | | 36 | | | | 39 |
| IHAS - Stream condition | | | | 33 | | | | 35 | | | | 22 | | | | 33 | | | | 34 |
| Suitability score | 3 | 6 | 3 | 12 | 5 | 11 | 3 | 19 | 6 | 5 | 3 | 14 | 4 | 9 | 6 | 19 | 0 | 0 | 0 | 0 |

**Key:**
- High requirement for unmodified water quality (blue) — Veg=Vegetation
- Moderate requirement for unmodified water quality (green)
- Low requirement for unmodified water quality (yellow)
- Very low requirement for unmodified water quality (red)

A = 1-10 individuals; B = 11-100 individuals; C = 101-1000 individuals; ASPT = Average score per taxon.

**Table A3**: Fish Assemblage Integrity Index (FAII) scores calculated for the various sampling sites (2017-2018).

| | SPECIES | Intolerance rating | | | | | Health rating | | | | | SCORE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | HEX00 | HEX01 | HEX03 | HEX04 | HEX4B | HEX00 | HEX01 | HEX03 | HEX04 | HEX4B | HEX00 | HEX01 | HEX03 | HEX04 | HEX4B |
| EXPECTED | *Amphillius uranoscopus* | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 5 | 5 | 5 | 5 | 5 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 |
| | *Barbus paludinosus* | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 5 | 5 | 5 | 5 | 5 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| | *Barbus trimaculatus* | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 5 | 5 | 5 | 5 | 5 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| | *Barbus unitaeniatus* | | 1.7 | 1.7 | 1.7 | 1.7 | | 5 | 5 | 5 | 5 | 0.0 | 8.5 | 8.5 | 8.5 | 8.5 |
| | *Chiloglanis pretoriae* | | | | 4.6 | 4.6 | | | | 5 | 5 | 0.0 | 0.0 | 0.0 | 23.0 | 23.0 |
| | *Clarias gariepinus* | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 5 | 5 | 5 | 5 | 5 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| | *Labeobarbus marequensis* | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 5 | 5 | 5 | 5 | 5 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 |
| | *Labeo cylindricus* | | | | 3.1 | 3.1 | | | | 5 | 5 | 0.0 | 0.0 | 0.0 | 15.5 | 15.5 |
| | *Labeo molybdinus* | | | | 3.2 | 3.2 | | | | 5 | 5 | 0.0 | 0.0 | 0.0 | 16.0 | 16.0 |
| | *Mesobola brevianalis* | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 5 | 5 | 5 | 5 | 5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 |
| | *Oreochromis mossambicus* | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 5 | 5 | 5 | 5 | 5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| | *Pseudocrenilabrus philander* | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 5 | 5 | 5 | 5 | 5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| | *Tilapia sparrmanii* | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 5 | 5 | 5 | 5 | 5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| | | | | | | | | | | | **Total Expected** | 94.0 | 102.5 | 102.5 | 157.0 | 157.0 |
| OBSERVED | *Amphillius uranoscopus* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Barbus paludinosus* | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 5 | 5 | 5 | 5 | 5 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| | *Barbus trimaculatus* | | | 2.2 | | | | | 5 | | | 0.0 | 0.0 | 11.0 | 0.0 | 0.0 |
| | *Barbus unitaeniatus* | | | 1.7 | | | | | 5 | | | 0.0 | 0.0 | 8.5 | 0.0 | 0.0 |
| | *Chiloglanis pretoriae* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Clarias gariepinus* | | 1.2 | 1.2 | 1.2 | 1.2 | | 5 | 5 | 5 | 5 | 0.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| | *Labeobarbus marequensis* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Labeo cylindricus* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Labeo molybdinus* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Mesobola brevianalis* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Oreochromis mossambicus* | | | 1.3 | 1.3 | 1.3 | | | 5 | 5 | 5 | 0.0 | 0.0 | 6.5 | 6.5 | 6.5 |
| | *Pseudocrenilabrus philander* | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 5 | 5 | 5 | 5 | 5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| | *Tilapia sparrmanii* | 1.3 | 1.3 | | 1.3 | 1.3 | 5 | 5 | | 5 | 5 | 6.5 | 6.5 | 0.0 | 6.5 | 6.5 |
| | | | | | | | | | | | **Total Observed** | **22.0** | **28.0** | **47.5** | **34.5** | **34.5** |
| | | | | | | | | | | | **Relative FAII (%)** | **23** | **27** | **46** | **22** | **22** |

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**END OF REPORT**

## Addendum 1: Toxicity test report/s (Biotox Laboratory Services)

Submitted as separate PDF document/s

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# AMGLO AMERICAN PLATINUM: HEX RIVER CATCHMENT BIOMONITORING PROGRAMME

## JUNE 2019 SURVEY

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# 1. INTRODUCTION

This report is based on the results of the bi-annual biomonitoring survey conducted during June 2019 on the selected sites in the Hex River, Klipfonteinspruit and Klipgatspruit in the Anglo American Platinum (Rustenburg) mining area. Since the sale to Sibanye Stillwater, the study area assigned to Clean Stream Biological Services for biomonitoring has decreased considerably. To avoid confusion with areas tasked by Sibanye Stillwater to other consulting firm/s, the client for the purpose of this report will be referred to as Process Division Services. This long-term monitoring program commenced during December 1999. A comprehensive 20-year temporal database pertaining to the health of aquatic communities, as well as the water quality environment that may be affected by the RPM operations, has been amassed. This continuity of information will be invaluable for any future assessments of impacts to the receiving environment. RPM has thereby diligently maintained their biomonitoring programme on a twice-per-annum schedule (at least) since the inception of the program during 1999. See Table 1 below for a list of surveys performed, with their corresponding report numbers. Report naming will henceforth include the lettering sequence of “AAPL”, referring to Anglo American Platinum and in specific the Process Division Services.

Table 1: Biomonitoring surveys conducted and reports compiled in the period December 1999 to June 2019.

| Year | Month | Report numbers |
|---|---|---|
| 1999 | December | CS-A-2000 |
| 2000 | April, July and November | CS-G-2000, CS-K-2000 and CS-A-2001 |
| 2001 | May and September | CS-H-2001 and CS-L-2001 |
| 2002 | February, May, August and November | CS-G-2002, CS-I-2002, CS-N-2002 and CS-E 2003 |
| 2003 | Januaury and May | CS-G2003 and CS-O-2003 |
| 2004 | April, August and October | CS-H-2004 and AMP-A-05 |
| 2005 | February, April and November | AMP-B-05, AMP-C-05 and AMP-D-05 |
| 2006 | April and November | AMP-A-06, AMP-C-06 |
| 2007 | April and October | ANP-A-07 and ANP-A-08 |
| 2008 | April and October | ANP-B-08 and ANP-A-09 |
| 2009 | April and October | ANP-B-09 and RPM-A-09 |
| 2009 | April and October | RPM-A-10 and RPM-B-10 |
| 2011 | April and October | RPM-A-11 and RPM-B-11 |
| 2012 | April and November | RPM-A-12 and RPM-A-13 |
| 2013 | April and October | RPM-B-13 and RPM-C-13 |
| 2014 | April and October | RPM-A-14 and RPM-B-14 |
| 2015 | April and October | RPM-A-15 and RPM-C-15 |
| 2016 | May and October | RPM-A-16-Ver2 and RPM-B-16 |
| 2017 | June and November | RPM-A-17 and RPM-B-17 |
| 2018 | May and October | RPM-A-18 and AAPL-A-18 |
| 2019 | June | AAPL-A-19 |

Rivers are continuum systems, so a river reach can be influenced by activities both upstream and downstream. Pollution incidences upstream of a site will have a negative impact, not only locally, but on the entire ecosystem (depending on the extent of the pollution).

Biological communities reflect overall ecological integrity by integrating different stressors over time, thereby providing a broad measure of their aggregate impact. The monitoring of biological communities hence provides a reliable ecological measure of fluctuating environmental conditions. The biomonitoring protocols applied in this project should give a good reflection of the human impacts on the system under investigation.

The results contained in this report should firstly be interpreted as **spatial** impact monitoring. [Note that spatial impact monitoring in terms of the fish communities considers the last two fish surveys, and not only the last survey, as in the case of macro-invertebrate communities]. **Temporal** (long- and medium-term trends) impact monitoring is also performed and considers all of the data since 2002 (after initial project design and refinement of the biomonitoring programme between 1999 and 2001).

## 2. MATERIALS & METHODS

Refer to appendix 1 for a description of methodology applied during this assessment.

## 3. RESULTS & DISCUSSION

### 3.1 Study area

Biomonitoring sites were selected to be easily accessible and representative of as many habitats as possible. Four biomonitoring sites were selected within the Hex River.

The criteria for site selection are as follows:

- The locations should ideally be selected to be both upstream and downstream of potential pollution sources, and as far as possible, exclude other potential impacts not related to the biomonitoring programme (non-AAPL impacts).
- The habitat diversity should be representative of the river/stream being monitored and, as far as possible, be comparable between sites on a spatial scale.
- The habitats should, as far as possible, be suitable for the application of the selected biomonitoring protocols.
- The sampling sites should at least be accessible to off-road vehicle to enable the transport of the required sampling equipment.

Although sampling sites were previously selected to isolate potential and known RPM (Sibanye Stillwater) impacts and hence measure the effect of RPM impacts on the biotic integrity of the receiving water bodies, several additional sites were also selected to illustrate the potential impact of non-RPM related activities. This was done to gain an insight into other potential impacts on the Hex River, in the area upstream of RPM activities as well as up- and downstream of the Klipfonteinspruit (not including the Paardekraal Angling Dam) to isolate the potential impact/s from the Klipfonteinspruit and the Dorpspruit catchment. This approach has now been adapted (since 2018-10) to mainly focus on the possible impact of the AAPL Process Division Services, with possible impacts reaching the final receiving water body (Hex River), via the Klipfonteinspruit and the Klipgatspruit (Table 2; Figure 1).

Various sites/samples were selected for toxicity testing. These include pollution control dams and the Klipfonteinspruit and Klipgatspruit tributaries (included since April 2012 but narrowed down to the two mentioned tributaries since October 2018) joining the Hex River within the study area. Based on the historic electrical conductivity (EC) results (illustrating cumulative water quality deterioration from various sources) and spatial variation in biotic integrity, it is evident that the various tributaries of the Hex River, both upstream and within the newly-refined study area contribute significantly to the spatial variation in ecological integrity of the Hex River. It is therefore of great value for the biomonitoring programme to include DEEEP toxicity testing on all the key tributaries entering the Hex River.

See Table 2 below for sampling site description, its relation to AAPL Process Division Services activities and the frequency of different biomonitoring protocols applied.

Table 2: Latitude/Longitude and sampling protocols of selected sampling sites for routine biomonitoring.

| Monitoring site | Description | Potential direct upstream impact | Biomonitoring protocols | | GPS coordinates (degrees) | |
|---|---|---|---|---|---|---|
| | | | Protocol | Frequency per annum | Latitude (South) | Longitude (East) |
| H-US-KF | Hex River, upstream from the Klipfonteinspruit confluence but downstream from the Paardekraal Angling Dam. | AAPL and non-AAPL | *SASS5 | Twice | 25.6492 | 27.2906 |
| KF | Klipfonteinspruit, downstream from Waterfall concentrator but upstream from Paardekraal shaft runoff. | AAPL | Toxicity testing | Twice | 25.6578 | 27.2964 |
| KFD | Klipfonteinspruit, downstream from site KF and the Paardekraal shaft runoff. | AAPL | Toxicity testing | Twice | 25.6496 | 27.2926 |
| H-DS-KF | Hex River, directly downstream from the Klipfonteinspruit confluence. | AAPL | *SASS5 | Twice | 25.6473 | 27.2913 |
| Hex03 | Hex River, upstream from Klipgatspruit. | Non-AAPL | *SASS5 | Twice | 25.6332 | 27.2903 |
| | | | **FAII | Once | | |
| KGT | Klipgatspruit, downstream from tailings complex seepage. | AAPL | Toxicity testing | Twice | 25.6319 | 27.2951 |
| Hex3B | Hex River, downstream from Klipgatspruit confluence. Newly adopted site (since 2018-10) | AAPL | *SASS5 | Twice | 25.6237 | 27.2900 |
| | | | **FAII | Once | | |
| K209 | PMR Dam 2 | To be confirmed as per AAPL Process Division requirements | | | | |
| K210 | PMR Dam 3A | | | | | |
| K211 | PMR Dam 3B | | | | | |
| K212 | PMR Dams 4 and 5 | | | | | |
| K213 | PMR Dam 6 | | | | | |
| K194 | | | | | | |
| K160 | RBMR Dam 3A | | | | | |
| K161 | RBMR Dam 3B | | | | | |
| K162 | RBMR Triangular Dam | | | | | |
| K035 | Klipgat RWD | | | | | |
| K098 | ACP PCD | | | | | |

**Key:** *** SASS5** = South African Scoring System, version5 (macro-invertebrate index and associated habitat assessment indices i.e. IHAS ver2 and biotope availability and suitability indices)

**** FAII** = Fish Assemblage Integrity Index (and associated habitat indices i.e. SHI and HCR)

| | | |
|---|---|---|
| Site name shaded green = Hex River mainstem | Site name shaded blue = Tributary of Hex River | Site name shaded red = Toxicity testing |
| Impact shaded gray = Potential RPM and non-RPM impacts (directly upstream) | Impact shaded pink = Potentially impacted by RPM/AAPL (directly upstream) | Impact shaded yellow = No RPM/AAPL impacts (directly upstream) |
| Site name shaded Orange = Discontinued from Clean Stream Biological Services scope | | |

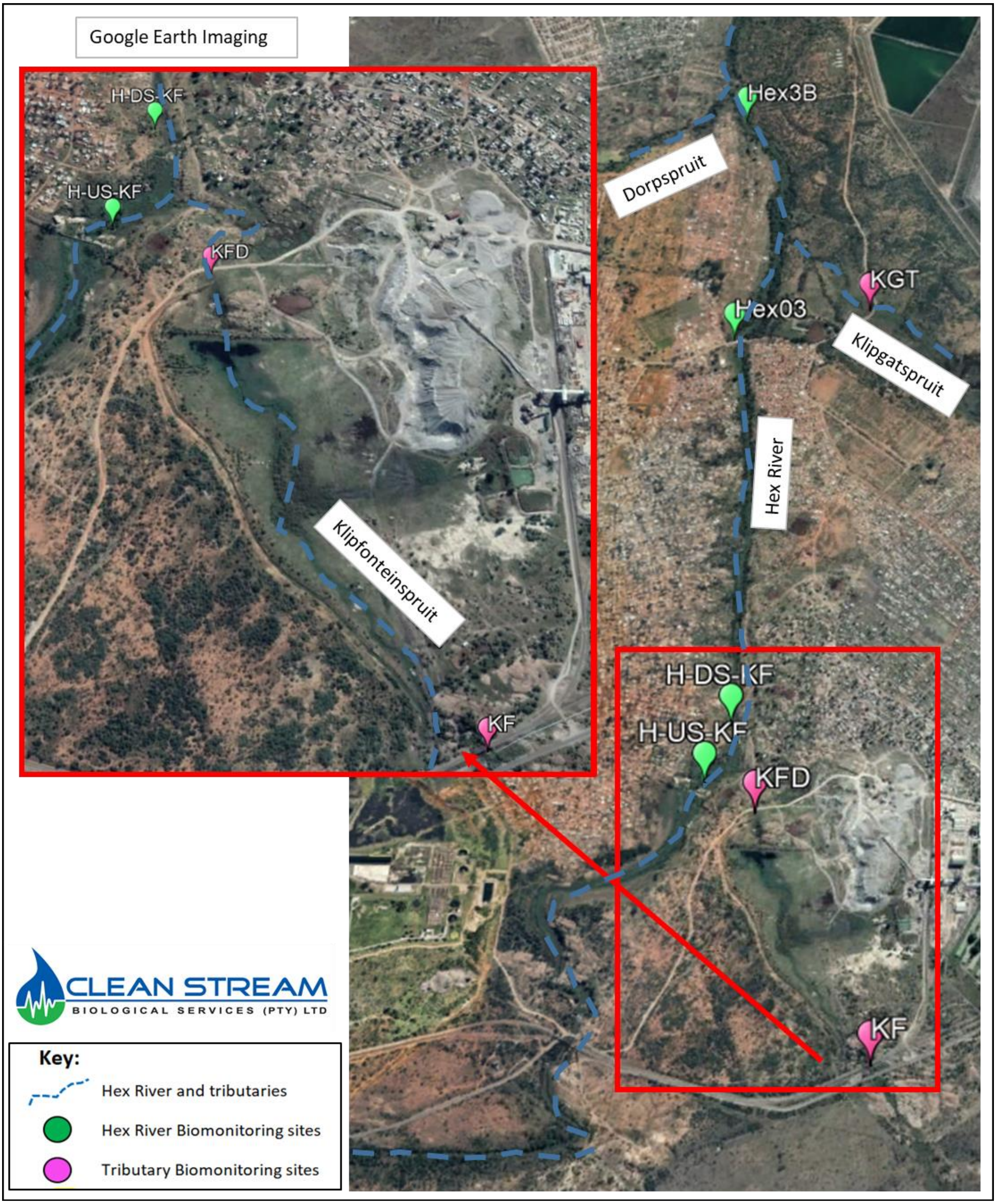



Figure 1: Google Earth image of study area, indicating Hex River and tributary biomonitoring sites.

### 3.2 *In-situ* water quality (June 2019)

Selected water quality variables were measured on-site at the time of biological sampling. The purpose of these measurements is to assist in the interpretation of biological results (refer to Aquatico Scientific's Water Quality Report for a detailed water quality assessment of the Rustenburg Platinum mining area).

As recorded during most surveys, the EC increased from site H-US-KF to H-DS-KF in the Hex River (119.4 mS/m to 142.0 mS/m) (Table 3; Figure 2). The Klipfonteinspruit joins the Hex River between these sites and probably played a large role in the increased salinity during most preceding surveys (no perceptible surface flow was recorded from the Klipfonteinspruit during many surveys, but a subsurface contribution of affected mine water cannot be ruled out). The EC value was high in the Klipfonteinspruit sites KF (565.0 mS/m) and KFD (765.0 mS/m), as during most previous surveys, again confirming this tributary as a potential source of elevated salinity levels, especially during periods of flow (*see section 3.3*).

Table 3: *In-situ* water quality variables measured at the time of sampling at the selected biomonitoring sites

| Monitoring site | EC (mS/m) | pH | Oxygen saturation (%) | Dissolved oxygen (mg/l) | Water temp (ºC) | Turbidity (visual) | Flow (visual) | Time | Date |
|---|---|---|---|---|---|---|---|---|---|
| H-US-KF | 119.4 | 7.2 | 40.5 | 3.3 | 14.8 | Slightly turbid | Moderate | 15:30 | 18/06/2019 |
| H-DS-KF | 142.0 | 7.4 | 73.9 | 6.0 | 14.5 | Clear | Moderate | 12:45 | 19/06/2019 |
| HEX03 | 139.5 | 7.4 | 53.4 | 4.5 | 13.1 | Slightly turbid | Low | 10:30 | 19/06/2019 |
| HEX3B | 26.4 | 7.1 | 63.5 | 5.5 | 12.7 | Slightly turbid | Moderate | 10:02 | 19/06/2019 |

Value outside general guideline.

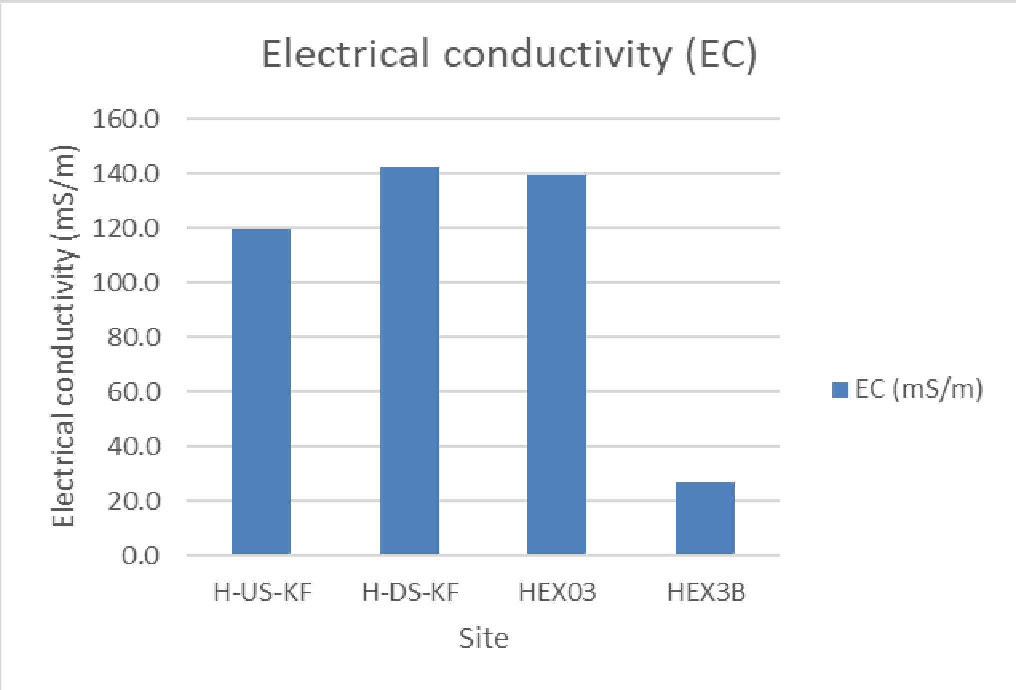



Figure 2: Electrical conductivity levels (mS/m) at the time of sampling at the different biomonitoring sites.

The EC level remained stable from site H-DS-KF (142.0 mS/m) to Hex03 (139.5 mS/m) (Table 3; Figure 2), therefore not indicating on impacts from non-Anglo Platinum Process Division (APPD) activities on the salinity of the Hex River at the time of sampling. This contrasts with the previous survey that showed an increase in salinity from site H-DS-KF to Hex03 (*see report AAPL-A-18*).

From site Hex03 towards site Hex03B (the most downstream site), the EC values decreased notably (195.2 mS/m to 26.4 mS/m) (Table 3; Figure 2), thus indicating that the contribution from the Klipgatspruit (dry at the time of sampling) did not lead to an increase in the salinity of the receiving environment.

The pH fell within the target water quality ranges for fish health (Aquaculture), which is between 6.5 and 9.0, at all sites during June 2019. It is expected that most aquatic species will tolerate and reproduce successfully within this pH range (DWAF, 1996), and the pH values recorded should therefore not be limiting to aquatic biota.

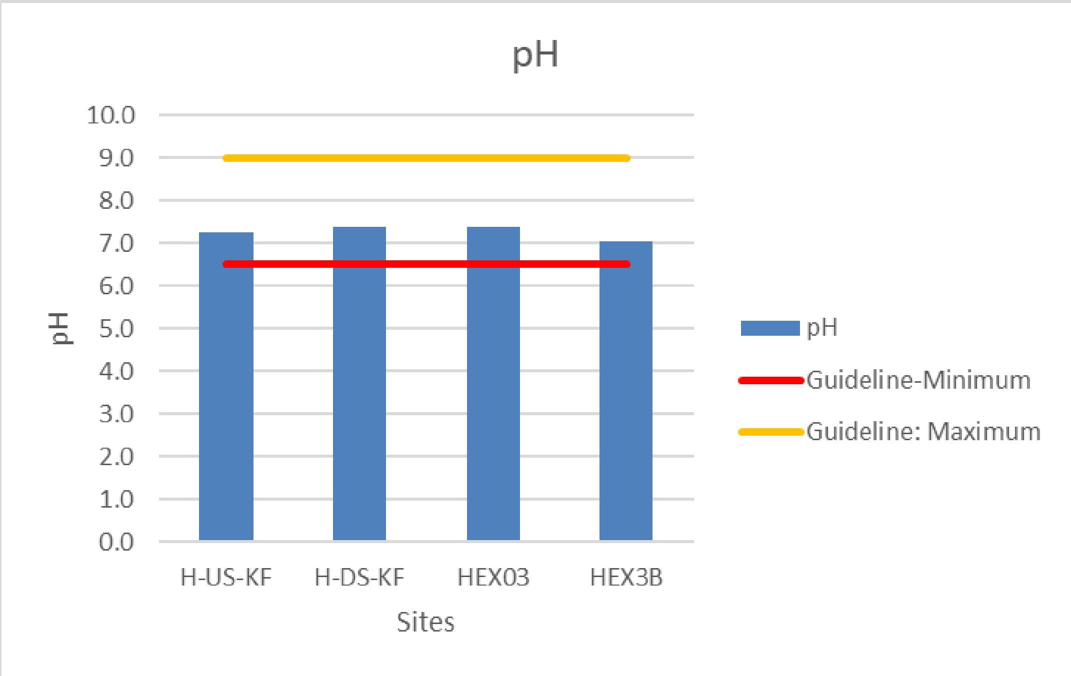



Figure 3: pH levels at the time of sampling at the different biomonitoring sites.

During June 2019, the dissolved oxygen the dissolved oxygen level fell below the target range (> 5 mg/l, as set by Kempster *et.al.,* 1980) at site H-US-KF (3.3 mg/l) (Table 3; Figure 4). These low levels of dissolved oxygen will be limiting to aquatic biota, particularly if persistent or frequently occurring.

As during the previous (October 2018) and many preceding surveys, dissolved oxygen levels were again below the target range at site Hex03 (4.5 mg/l) during the present survey (Table 3; Figure 4). The noted low oxygen levels could therefore possibly have posed a risk to aquatic biota and was probably related to a combination of factors including:

- Elevation and accumulation of organic loads,
- Aquatic vegetation and algal proliferation in response to eutrophication,
- Low flow (all affected sites).

It has to be noted that the cause of lowered dissolved oxygen levels is unlikely to be related to APPD activities because levels were within the guideline at site H-DS-KF and no further APPD activities take place toward site Hex03. Dissolved oxygen levels improved to above the target range towards site Hex03B (5.5 mg/l) (Table 3; Figure 4) and should therefore not be limiting to aquatic biota at this site.

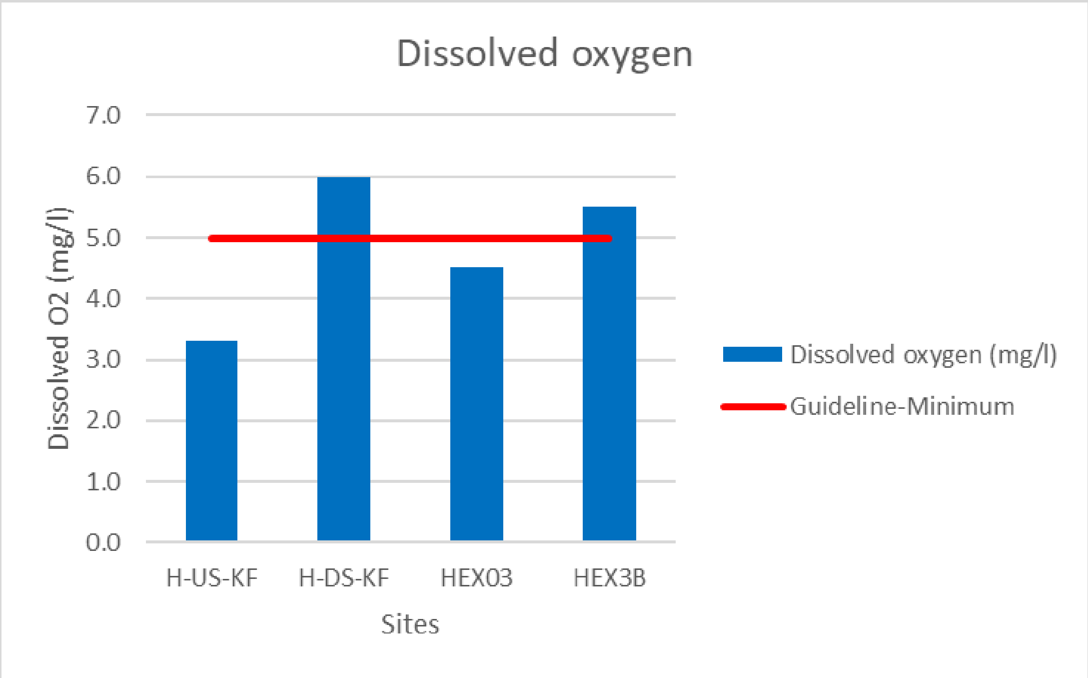



Figure 4: Dissolved oxygen levels (mg/l) at the time of sampling at the different biomonitoring sites.

As a standard management procedure, a full statistical evaluation of water quality data at these biomonitoring localities (as performed by Aquatico Scientific) will be required to conclude whether specific variables or a combination of variables, not included in the biota specific range, are impacting on the aquatic ecosystems.

### 3.3 Toxicity testing

At the time of compiling this biomonitoring report, the latest toxicity testing results for the Pollution Control Facilities available to Clean Stream Biological Services were based on the May 2019 dataset, as submitted as a separate toxicity testing report by Biotox Laboratory Services (Report no. RPM-A-19_TOX).

The latest tributary toxicity testing report, as performed in conjunction with the June 2019 biomonitoring survey, is also included and discussed in this biomonitoring report.

As per SANAS requirements, the above-mentioned toxicity testing reports were produced independently by Biotox Laboratory Services (Pty) Ltd. All results contained in this section are therefore sourced from the Biotox reports, which are included in Addendum 1.

Toxicity testing (as conducted in this biomonitoring programme) is applied by exposing biota under laboratory conditions to water sources (pollution control dams, effluent streams or streams/rivers) to accurately determine the risk of such water types to the biota of the receiving water bodies. Toxicity results indicate the risk posed to the Hex River and its tributaries in the event of release, seepage or overflow from possible sources of pollution. Up to four trophic levels (at least 3, including acute and chronic approaches) of biota, *i.e.,* vertebrates (*Poecilia reticulata*), invertebrates (*Daphnia magna*), bacteria (*Allivibrio fischeri*) and primary producers (*Selenastrum capricornutum*) are exposed to the samples per standard procedures under laboratory conditions and thereafter a risk/hazard category is determined by application of the latest **DEEEP**[1] DWS recommended protocols and hazard classification. The final risk classification is expressed in terms of **acute**[2] and **chronic**[3] toxicity risk. The *Poecilia reticulata* and *Daphnia magna* test results are based on mortality rates over a relatively short period of the lifespan of the organisms, hence allowing for acute interpretation. *Selenastrum capricornutum* and *Vibrio fischeri* individual test results are based on inhibition rates over relatively long periods of the lifespan of the organisms, hence allowing for short-chronic toxicity hazard interpretation.

Selected toxicity samples (Hex River tributaries) were tested on a twice per annum schedule, while the PCD (pollution control dam) samples are tested once per annum, on either a **screening**[4] acute level or a **definitive**[5] acute level, at this stage. The frequency of testing is informed by the level of toxicity. If toxicity levels increase, it may become relevant and useful to increase the frequency of testing. The frequency and type of toxicity testing required (screening vs. definitive) should be revised from time to time based on the outcome of the specific year's assessments.

[1] DEEEP = Direct Estimation of Ecological Effect Potential. This is a battery of tests that can measure toxicity of complex mixtures based on a set of parameters stemming from the results of effects, even if all constituents are not known. Thereafter a hazard class is determined based on the resulting parameters of the battery of tests.

[2] Acute = Acute refers to an exposure over a relatively short period of the lifespan of biota, of which the result is generally based on mortality rates.

[3] Chronic = Chronic refers to prolonged exposures over an extended period of the lifespan of test organisms, of which the results are generally based on growth inhibition rates.

[4] Screening = A screening toxicity test refers to an undiluted (100% concentration) sample. This is usually performed on a sample from the biomonitoring sites in the receiving water bodies (river/streams) to determine if any toxicity is present. This is performed both up- and downstream of the potential impacts to enable the determination of downstream increases or decreases in toxicity.

[5] Definitive = A definitive toxicity test refers to the exposure of test organisms to both the 100% concentration as well as a range of dilutions, generally used to determine the risk of a pollution source that may have a toxicity effect on the receiving water body (such as effluents and PCD's). The range of dilutions are therefore useful in the event that the 100% sample concentration presents acute toxicity, and allows for the determination of a safe dilution factor, to negate toxicity effects on the receiving water bodies.

### Hazard classification for screening tests (undiluted samples)

After the determination of the percentage effect[6] (EP), obtained with each of the ***battery of toxicity screening*** tests performed, the sample is ranked into one of the following five classes:

**Hazard classification system for screening tests**

| | |
|---|---|
| Class I | **No acute/short-chronic environmental toxicity hazard -** none of the tests shows a toxic effect (i.e. an effect value significantly higher than that in the control) |
| Class II | **Slight acute/short-chronic environmental toxicity hazard -** a statistically significant (P<0,05) percentage effect is reached in at least one test, but the effect level is below 50% |
| Class III | **Acute/short-chronic environmental toxicity hazard -** the percentage effect level is reached or exceeded in at least one test, but the effect level is 50-99% |
| Class IV | **High acute/short-chronic environmental toxicity hazard -** the 100% percentage effect is reached in at least one test |
| Class V | **Very high acute/short-chronic environmental toxictiy hazard -** the 100% percentage effect is reached in all the tests |

**Weighting:** Each sample is furthermore weighted according to its relative toxicity levels (out of 100%). Higher values indicate that more of the individual tests indicated toxicity within a specific class.

### Toxicity classification system definitive tests (undiluted samples plus range of dilutions)

The samples are classified into one of the following five classes on the basis of the highest toxicity unit (TUa) found in the ***battery of toxicity definitive tests*** performed. The toxicity unit is a function of the L(E)C50, where (TUa) = 100/L(E)C50. The 50% Lethal/Effective concentration (LC50 or LE50) is the linear calculated (derived) concentration at which a 50% mortality or inhibition rate can be expected. Hence, the lower this value is, the higher the acute toxicity level. Conversely, the higher the toxicity unit (TUa) is, the higher the acute toxicity level is. The conversion of L(E)C50 values to TUa values is therefore merely done to achieve a classification scale of increasing values related to increasing toxicity risk:

**Hazard classification system for definitive tests**

| | |
|---|---|
| Class I | **No acute/short-chronic environmental toxicity hazard -** none of the tests shows a toxic effect (i.e. an effect value significantly higher than that in the control) |
| Class II | **Slight acute/short-chronic environmental toxicity hazard -** the percentage effect observed in at least one toxicity test is significantly higher than in the control, but the effect level is below 50% (TU is <1) |
| Class III | **Acute/short-chronic environmental toxicity hazard -** the L(E)C50 is reached or exceeded in at least one test, but in the 10 fold dilution of the sample the effect level is less than 50% (1≤TU≤9,99) |
| Class IV | **High acute/short-chronic environmental toxicity hazard -** the L(E)C50 is reached in the 10 fold dilution for at least one test, but not in the 100 fold dilution (10≤TU≤99,99) |
| Class V | **Very high acute/short-chronic environmental toxcity hazard -** the L(E)C50 is reached in the 100 fold dilution for at least one test (TU is ≥100) |

**Note:**

The samples are classified into one of the above five classes on the basis of the highest toxicity unit (TU) found in the battery of toxicity definitive tests performed

**Weighting:** Each sample is furthermore weighted according to its relative toxicity levels (out of 100%). Higher values indicate that more of the individual tests indicated toxicity within a specific class.

[6] EP (Percentage effect) = an effect measured either as a mortality rate or inhibition rate (depending on the type of test). A 10% effect is regarded as a slight acute toxicity for daphnia and guppies, while a 20% effect is regarded as a slight acute toxicity for algae and bacteria (vibrio). A 50% effect is regarded as an acute toxicity for all of the tests (daphnia, guppies, algae and bacteria)

### 3.3.1 May 2019 and June 2019

**Toxicity testing of pollution control facilities (May 2019 only)**

Various toxicity hazards were identified during the May 2019 survey, ranging from "no acute/short-chronic environmental toxicity hazard" (Class I) to "very high acute/short-chronic environmental toxicity hazard" (Class V), implying that some effluents/potential effluents could pose a serious risk to the receiving water bodies if released (Table 4).

Sample K035 (Klipgat Dam) was tested as posing "no acute/short-chronic environmental toxicity hazard" (Class I) using the normal range of dilutions at a macro-invertebrate level (Table 4). ***However, from a 0.1% dilution level, significant mortalities (100%) were noted potentially indicating sources of pollution affecting organisms more severely at lower concentration, e.g. nano materials, and further testing is recommended (see Addendum 1).***

Sample K211 (PMR Dam 3B) displayed a "slight acute/short-chronic hazard" (Class II) based on the 31% bacterial light emission inhibition effect noted during testing (Table 4). A safe dilution factor of 89% (ratio of 89 parts K211 water to 11 parts unpolluted water) was calculated for this sample. Sample K210 (PMR Dam 3A) showed an "acute/short chronic hazard" (Class III) based on the highest toxicity unit (2.2) calculated on a bacterial testing level (Table 4). A safe dilution factor of 36% was estimated for this sample.

Samples K098 (ACP Dam), K162 (RBMR Triangular Dam), K212 (PMR Dam 4+5), and K213 (PMR Dam 6E) showed a "high acute/short-chronic hazard" (Class IV), based on the 100% mortality effects on at least one trophic level test and toxicity units ranging from 5.4 - >100 (Table 4). A safe dilution factor of 2% was calculated for samples K098 (ACP Dam) and K162 (RBMR Triangular Dam). Very low safe dilution factors (<1%) were calculated for samples K212 (PMR Dam 4+5), and K213 (PMR Dam 6E) and ***water from these facilities should not be allowed to reach the natural environment.***

Samples K160 (RBMR Dam 3A), K161 (RBMR Dam 3B) and K209 (PMR Dam 2) showed a "very high acute/short-chronic environmental toxicity hazard" (Class V) based on the toxicity units >100 calculated for these samples during testing at all 3 trophic levels (Table 4). Very low safe dilution factors (<1%) were calculated for these samples and ***water from these facilities should not be allowed to reach the natural environment***. The toxicity effects observed for sample K160 (RBMR Dam 3A) were particularly severe and could not be diluted out (tested to dilutions of 0.195% of original sample).

Table 4: Toxicity results and hazard classification for selected pollution facilities (May 2019).

| | Results | K035 (Klipgat Dam) | K098 (ACP Dam) | K160 (RBMR Dam 3A) | K161 (RBMR Dam 3B) | K162 (RBMR Triangular Dam) | K209 (PMR Dam 2) | K210 (PMR Dam 3A) | K211 (PMR Dam 3B) | K212 (PMR Dam 4+5) | K213 (PMR Dam 6E) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WQWater quality | pH @ 25°C (A) | 7.3 | 2.7 | 3.2 | 5.2 | 10.5 | 1.2 | 9.8 | 9.4 | 5.5 | 5.6 |
| | EC (Electrical conductivity) (mS/m) @ 25°C (A) | 539.0 | 186.9 | 6340.0 | 3880.0 | 6090.0 | 10650.0 | 42.4 | 63.7 | 18940.0 | 24000.0 |
| | Dissolved oxygen (mg/l) (NA) | 9.4 | 7.5 | 7.4 | 7.5 | 7.3 | 7.6 | 8.6 | 7.8 | 7.6 | 7.5 |
| *A. fischeri* (bacteria) (A) | Test started on yy/mm/dd | 19/05/29 | 19/05/29 | 19/05/29 | 19/05/29 | 19/05/30 | 19/05/30 | 19/06/05 | 19/06/05 | 19/06/05 | 19/06/06 |
| | %30min inhibition (-) / stimulation (+) (%) | 55 | -100 | -100 | -100 | -100 | -100 | -97 | -31 | -100 | -100 |
| | EC/LC20 (30 mins) | n.r | 2 | n.c | n.c. | 2 | n.c | 36 | 89 | n.c | n.c |
| | EC/LC50 (30 mins) | n.r | 9 | n.c | 0.5 | 3 | n.c | 45 | n.r. | 4 | 3 |
| | Toxicity unit (TU) / Description | <1 | 11.8 | >100 | 25.6 | 29.5 | >100 | 2.2 | <1 | 27.1 | 30.6 |
| *D. magna* (waterflea) (A) | Test started on yy/mm/dd | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 |
| | %48hour mortality rate (-%) | -5 | -100 | -100 | -100 | -100 | -100 | -5 | 0 | -100 | -100 |
| | EC/LC10 (48hours) | n.r | 10 | n.c | n.c | 2 | n.c | n.r | n.r | n.c | n.c |
| | EC/LC50 (48hours) | n.r | 19 | n.c | n.c | 8 | 0.3 | n.r | n.r | 4 | 3 |
| | Toxicity unit (TU) / Description | <1 | 5.4 | >100 | >100 | 12.9 | >100 | <1 | <1 | 28.0 | 32.5 |
| *P. reticulata* (guppy) (A) | Test started on yy/mm/dd | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 |
| | %96hour mortality rate (-%) | 0 | -100 | -100 | -100 | -100 | -100 | -25 | 0 | -100 | -100 |
| | EC/LC10 (96hours) | n.r | 12 | n.c | n.c | 10 | 2 | 70 | n.r | 5 | 2 |
| | EC/LC50 (96hours) | n.r | 18 | n.c | 0.3 | 17 | 6 | n.r. | n.r | 7 | 6 |
| | Toxicity unit (TU) / Description | <1 | 5.7 | >100 | >100 | 5.9 | 18.2 | <1 | <1 | 14.3 | 18.2 |
| | *Estimated safe dilution factor (%) [for definitive testing only]* | None required | 2 | <1 | <1 | 2 | <1 | 36 | 89 | <1 | <1 |
| | Overall classification - Hazard class*** | Class I - No acute/short-chronic hazard | Class IV - High acute/short-chronic hazard | Class V - Very high acute/short-chronic hazard | Class V - Very high acute/short-chronic hazard | Class IV - High acute/short-chronic hazard | Class V - Very high acute/short-chronic hazard | Class III - Acute/short-chronic hazard | Class II - Slight short-chronic hazard | Class IV - High acute/short-chronic hazard | Class IV - High acute/short-chronic hazard |
| | Weight (%) | 0 | 78 | 100 | 100 | 89 | 100 | 67 | 33 | 100 | 100 |

Key:

% = for definitive testing, only the 100% concentration (undiluted) sample mortality/inhibition/stimulation is reflected by this summary table. The dilution series results are considered for EC/LC values and Toxicity unit determinations

n.r. = not relevant, i.e. the 100% concentration caused less than 10/20/50% (effective concentration) mortalities or inhibition

n.c. = not calculable, although the 100% concentration led to more than 10/20/50% mortalities/inhibtion, the 10/20/50% mortality/inhition rate was exceeded throughout the test

*** = The overall hazard classification takes into account the full battery of tests and is not based on a single test result. Note that the overall hazard classification is expressed as acute/short-chronic level of toxicity, due to the fact that the *A. fischeri* test is regarded as short-chronic level of toxicity test and the overall classification therefore contains a degree of short-chronic toxicity assessment.

**Weight (%)** = relative toxicity levels (out of 100%), higher values indicate that more of the individual tests indicated toxicity within a specific class

site/sample name shaded in purple = screening test

site/sample name shaded in orange = definitive test

### Toxicity testing of Hex River tributaries (June 2019)

Toxicity testing was scheduled for the Hex River tributaries of the Klipfonteinspruit (samples KF and KFD) and the Klipgatspruit (sample KGT) for the June 2019 survey. The Klipgatspruit site was however dry at time of the survey precluding sampling.

As noted earlier in the report, the electrical conductivity (EC) levels are almost always very high within the Klipfonteinspruit. EC is often an indication of reduced water quality, but toxicity testing results revealed that no hazard (Class I) was observed at the Klipfonteinspruit sites (KF and KFD), before entering the Hex River (Table 5). This is an encouraging improvement since the October 2014 and April 2015 surveys, when a high hazard (Class IV) and a slight hazard (Class II) was presented by this tributary. It was noted that the Klipfonteinspruit was not flowing during the October 2014 survey and that contamination was therefore contained within isolated pools. It is important to note that APPD activities potentially contribute to this tributary.

Table 5: Toxicity results and hazard classification for selected Hex River tributary samples (June 2019).

| | Results | KF | KFD |
|---|---|---|---|
| Water quality | pH @ 25°C (A) | 8.4 | 8.4 |
| | EC (Electrical conductivity) (mS/m) @ 25°C (A) | 565.0 | 765.0 |
| | Dissolved oxygen (mg/l) (NA) | 7.8 | 8.1 |
| *A. fischeri* (bacteria) (A) | Test started on yy/mm/dd | 19/06/28 | 19/06/28 |
| | %30min inhibition (-) / stimulation (+) (%) | 21 | 33 |
| | EC/LC20 (30 mins) | * | * |
| | EC/LC50 (30 mins) | * | * |
| | Toxicity unit (TU) / Description | no short-chronic hazard | no short-chronic hazard |
| *D. magna* (waterflea) (A) | Test started on yy/mm/dd | 19/07/01 | 19/07/01 |
| | %48hour mortality rate (-%) | -5 | 0 |
| | EC/LC10 (48hours) | * | * |
| | EC/LC50 (48hours) | * | * |
| | Toxicity unit (TU) / Description | no acute hazard | no acute hazard |
| *P. reticulata* (guppy) (A) | Test started on yy/mm/dd | 19/06/24 | 19/06/24 |
| | %96hour mortality rate (-%) | 0 | 0 |
| | EC/LC10 (96hours) | * | * |
| | EC/LC50 (96hours) | * | * |
| | Toxicity unit (TU) / Description | no acute hazard | no acute hazard |
| Overall classification - Hazard class*** | | Class I - No acute/short-chronic hazard | Class I - No acute/short-chronic hazard |
| Weight (%) | | 0 | 0 |

**Key:**

* = EC/LC values not determined, definitive testing required if a hazard was observed and persists over subsequent sampling runs

*** = The overall hazard classification takes into account the full battery of tests and is not based on a single test result. Note that the overall hazard classification is expressed as acute/short-chronic level of toxicity, due to the fact that the *A. fischeri* test is regarded as a short-chronic level of toxicity test and the overall classification therefore contains a degree of short-chronic toxicity assessment.

**Weight (%)** = relative toxicity levels (out of 100%), higher values indicate that more of the individual tests indicated toxicity within a specific class

site/sample name shaded in purple = screening test

site/sample name shaded in orange = definitive test

### 3.3.2 Temporal variation of toxicity results (2008 to 2019)

To determine temporal (over time) trends of increasing/decreasing toxicity levels, the risk class for each sample was plotted for each survey. Thereafter, linear trends over time were determined for the risk class at each site (Figures 5 & 6). It is important to note that these trends were not based on the actual mortalities/inhibition or lethal concentrations, but on the derived risk class for each survey and is merely included to gain a general understanding of increased/decreased risk over time.

**Annually tested PCD's and selected streams**

From the temporal database, most samples show varying degrees of toxicity and almost all the samples have fallen within the Class II or higher classes from time to time (Figure 5). Samples Dam2 and Dam 4/5 consistently fall into the higher hazard classes and are therefore never suitable for undiluted release[7] (including uncontrolled releases) to the environment. Some samples have, however, improved notably over time, such as sample K105, which has improved from an acute hazard (Class III) during 2008/2009 to no acute hazard (Class I) over the past five years. Samples from Dam6 and ACP have shown notably increasing trends in toxicity hazard over time. Environmental managers should take note of these hazard classes to plan licensed releases and/or contain hazardous water types at the appropriate times.

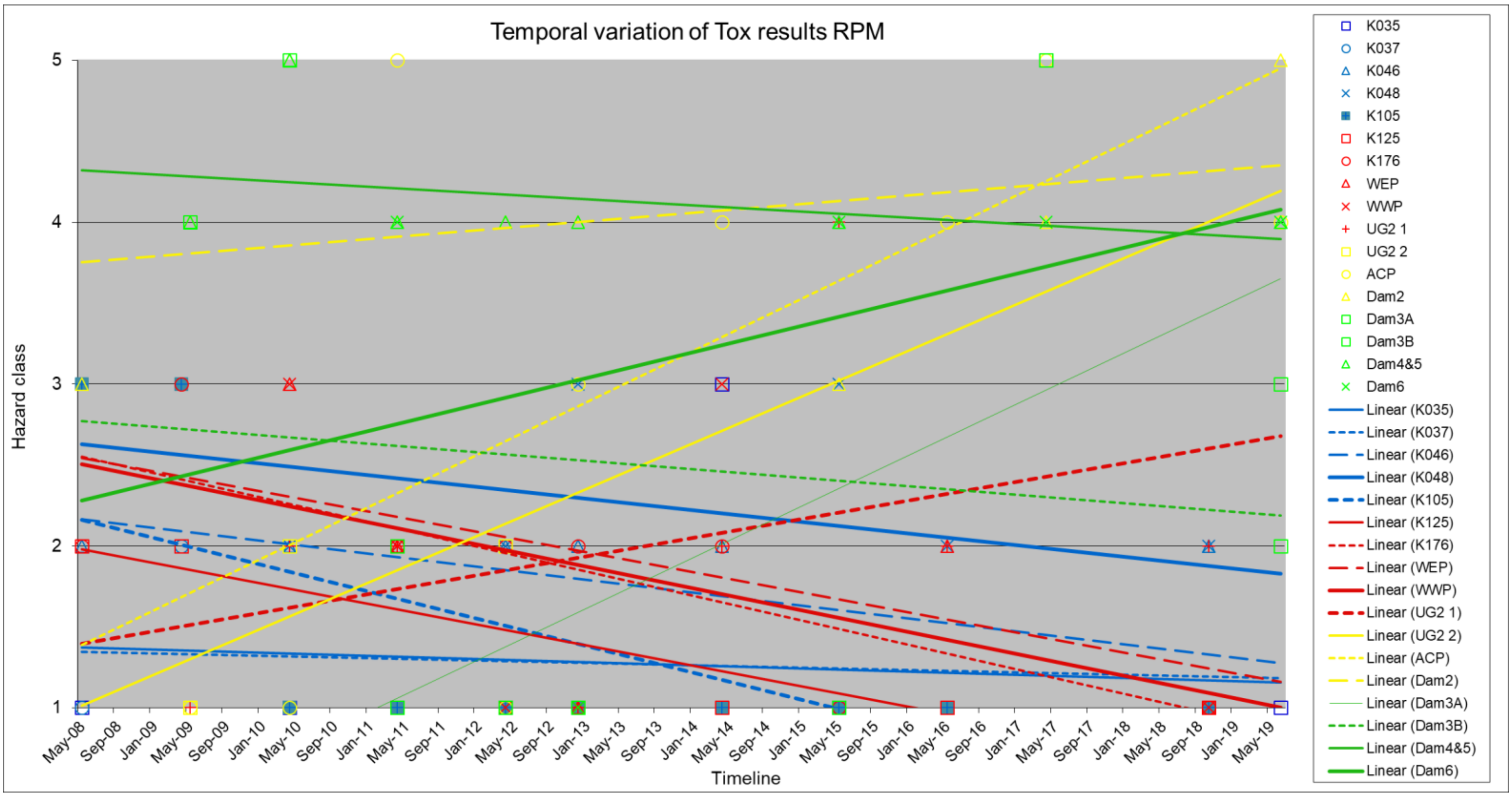



Figure 5: Temporal trends of toxicity results (annually tested PCD's and selected streams).

It is strongly recommended that definitive toxicity testing be continued for the samples that regularly display positive toxicity levels of Class III or higher. Definitive toxicity testing will allow for the estimation of safe dilution factors should the mine wish to apply for a water use licence to legally discharge such water types. These factors will also be essential for environmental managers to predict whether the toxicity of polluted water can be negated by natural dilution if accidentally released (e.g. spills, leaks or seepage) to the receiving environment. Definitive testing will furthermore assist in the suitable scheduling for planned releases (*i.e.* whether water could be released during the dry season and, if not, whether sufficient dilution is only likely to be achieved during the wet season/times of high river flow).

[7] Although theoretical predictions in terms of suitability for release are provided, releases remain bound by licensing conditions and are not prescribed/permitted by toxicity testing results.

**Bi-annually tested tributaries**

From the temporal database, it is clear that the relevant tributaries (Klipfonteinspruit and Klipgatspruit) have displayed toxicity hazards at times (Figure 6). It is encouraging that both tributaries have recently displayed lower toxicity. The Klipfonteinspruit is therefore also displaying a decreasing trend (improved hazard over time) as noted in Figure 6.

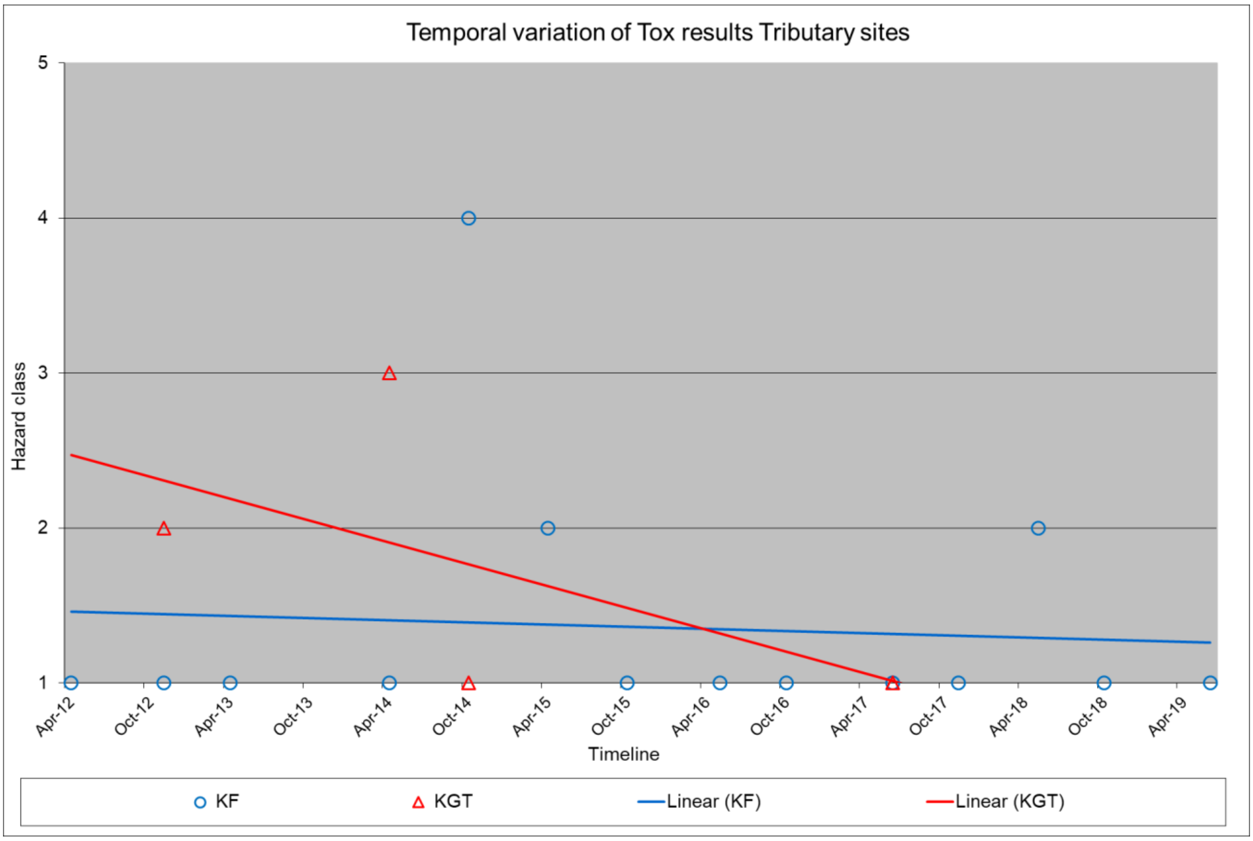



Figure 6: Temporal trends of toxicity results (bi-annually tested tributaries).

## 3.4 Aquatic invertebrate assessment: South African Scoring System 5

The South African Scoring System (Version 5) is a site-specific index which, together with associated habitat index (biotope suitability index), gives a general perspective of the biotic integrity (based on macro-invertebrates) and the impact of water quality on the biotic integrity of the specific sites (Thirion *et.al*., 1995; Dickens and Graham, 2001). The biotope suitability index considers the suitability of the different sampled biotopes in terms of quality and availability. It thereby firstly assesses whether the total SASS5 scores of two sites are directly comparable by comparing the total biotope suitability scores. If the total biotope suitability scores are very different this would imply that the total SASS5 scores should not be compared, but instead the most comparable SASS biotope scores. The most comparable SASS biotope scores are identified by comparing the various individual biotope suitability scores. In addition to the biotope suitability index, the Integrated Habitat Assessment System version 2 (IHAS) was also applied and included to give the macro-invertebrate specific habitat descriptions (Table 6).

Average score per taxon (ASPT) values are also useful in the assessment and comparison of biotic conditions at different sites. Based on field trials assessed by Dickens and Graham (2001) the ASPT was less variable than total SASS5 scores when conducted within a given river reach by different operators, considering all biotopes. ASPT is therefore included in the discussion below.

Table 6: Integrated Habitat Assessment (IHAS) description of the different biomonitoring sites.

| Sampling Habitat | H-US-KF | | H-DS-KF | | HEX03 | | HEX3B | |
|---|---|---|---|---|---|---|---|---|
| | Desc | Score | Desc | Score | Desc | Score | Desc | Score |
| **Stones In Current (SIC)** | | | | | | | | |
| Total length of white water rapids (ie: bubbling water) (in meters) | 0-1 | 1 | 0-1 | 1 | none | 0 | none | 0 |
| Total length of submerged stones in current (run) (in meters) | 0-2 | 1 | >2-5 | 2 | none | 0 | >2-5 | 2 |
| Number of separate SIC area's kicked | 2-3 | 2 | 2-3 | 2 | 0 | 0 | 1 | 1 |
| Average stone sizes kicked (in cm's) | 11-20 | 3 | 11-20 | 3 | none | 0 | >2-10 | 2 |
| Amount of stone surface clear (in %) | 0-25 | 1 | 0-25 | 1 | n/a | 0 | 0-25 | 1 |
| Protocol: time spent actually kicking SIC's (in mins) | 2 | 3 | 2 | 3 | none | 0 | >1-2 | 2 |
| **SIC score (max 20)** | | 11 | | 12 | | 0 | | 8 |
| **Vegetation (VEG)** | | | | | | | | |
| Length of fringing vegetation sampled (banks) (in meters) | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 |
| Amount of aquatic vegetation/algae sampled (in square meters) | >1 | 3 | none | 0 | 0-0.5 | 1 | >1 | 3 |
| Fringing vegetation sampled in | mix | 5 | mix | 5 | pool | 3 | mix | 5 |
| Type of veg. (percent leafy as apposed to stems/shoots) | 26-50 | 3 | 1-25 | 2 | 1-25 | 2 | 26-50 | 3 |
| **Veg score (max 15)** | | 15 | | 11 | | 10 | | 15 |
| **Other Habitat / General (O.H.)** | | | | | | | | |
| Stones Out Of Current (SOOC) sampled (in square meters) | >0.5-1 | 2 | >0.5-1 | 2 | none | 0 | 0-0.5 | 1 |
| Sand sampled (in minutes) | 0-0.5 | 2 | 0-0.5 | 2 | none | 0 | 0-0.5 | 2 |
| Mud sampled (in minutes) | 0-0.5 | 2 | 0-0.5 | 2 | 0.5 | 3 | 0-0.5 | 2 |
| Gravel sampled (in minutes) | 0.5 | 2 | none | 0 | none | 0 | none | 0 |
| Bedrock sampled (all = no SIC, sand, gravel) | some | 1 | some | 1 | none | 0 | none | 0 |
| Algal presence ($m^2$) | isolated | 4 | >1sqm | 3 | >1sqm | 3 | >1-2sqm | 2 |
| Tray identification | correct | 3 | correct | 3 | correct | 3 | correct | 3 |
| **O.H. score (max 20)** | | 16 | | 13 | | 9 | | 10 |
| **Sampling habitat totals (max 55)** | | 42 | | 36 | | 19 | | 33 |
| | | | | | | | | |
| **Stream Condition** | | | | | | | | |
| **Physical** | | | | | | | | |
| River make up | 2 mix | 4 | run | 2 | pool | 0 | 2 mix | 4 |
| Average width of stream (in meters) | 1-2 | 4 | >2-5 | 5 | 1-2 | 4 | 1-2 | 4 |
| Average depth of stream (in meters) | >0.5-1 | 3 | 0.5 | 4 | >0.5-1 | 3 | 1-2 | 1 |
| Approximate velocity of stream | medium | 3 | medium | 3 | medium | 3 | mix | 5 |
| Water colour | discoloured | 3 | discoloured | 3 | discoloured | 3 | discoloured | 3 |
| Recent disturbances | other | 3 | other | 3 | other | 3 | other | 3 |
| Bank/Riparian vegetation | mix | 4 | mix | 4 | mix | 4 | mix | 4 |
| Surrounding impacts | other | 3 | other | 3 | other | 3 | other | 3 |
| Left bank cover (rocks and vegetation) (in %) | 51-80 | 1 | 51-80 | 1 | 51-80 | 1 | 51-80 | 1 |
| Right bank cover (rocks and vegetation) (in % | 51-80 | 1 | 51-80 | 1 | 51-80 | 1 | 51-80 | 1 |
| **Stream condition total (max 45)** | | 29 | | 29 | | 25 | | 29 |
| **Total IHAS score (%)** | | 71 | | 65 | | 44 | | 62 |

Biotic conditions, based on the total SASS5 and ASPT scores, remained fairly stable from site H-US-KF to site H-DS-KF (Table 7; Figure 7), in contrast to the October 2018 survey when a clear downstream deterioration was observed. The findings are in line with most previous surveys when no spatial deterioration was observed. The two most similar biotopes[8] between the two sites (GSM and Vegetation), showed contrasting results therefore no conclusions on water quality related differences in biotic integrity could be

[8] To compare the effect of water quality on SASS scores on a spatial scale, habitat differences are considered. Therefore, the most comparable $SASS_{biotpe}$ scores, in terms of habitat are also contrasted to gain insight regarding the effect of water quality on the biotic conditions (biotic integrity)

made. *In-situ* water quality measures showed improvement in terms of dissolved oxygen levels towards site H-DS-KF, but deterioration in terms of salinity (*see section 3.2*). Overall, macroinvertebrate-based biotic integrity in the Hex River did not appear to deteriorate after the inflow of the Klipfonteinspruit tributary (and potentially associated APPD impacts).

As in the October 2018 survey, biotic conditions, based on the total SASS5 scores and ASPT values, decreased from site H-DS-KF to Hex03 (Table 7; Figure 7). Habitat likely played a role, with site Hex03 having lower biotope availability and suitability (no stones biotope), and IHAS scores. Comparison of the most similar SASS-biotope (Vegetation) however indicated that water quality deterioration likely also contributed to the reduction in biotic integrity (Tables 6 and 7), and *in-situ* water quality measures likewise showed downstream deterioration in dissolved oxygen levels with levels below the median guideline recorded at site Hex03 (*see section 3.2*). It must be noted that organic enrichment and solid waste disposal appears extensively at this site and will likely affect biotic integrity if not mitigated (Plate 2). It is again noted that the reason for lowered dissolved oxygen levels are unlikely to be related to APPD activities because levels were within the guideline at site H-DS-KF and no further APPD activities take place towards site Hex03.

Table 7: SASS5, ASPT and habitat suitability/availability index scores for different monitoring sites (June 2019).

| Monitoring site | SASS5 score | ASPT | SASS5-score per biotope | | | Biotope availability and suitability (Scores) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $SASS_{Stones}$ | $SASS_{Vegetation}$ | $SASS_{GSM}$ | Stones | Vegetation | GSM | Combined |
| H-US-KF | 50 | 3.85 | 31 | 42 | 13 | 3 | 4 | 3 | 10 |
| H-DS-KF | 46 | 3.83 | 28 | 30 | 20 | 5 | 4 | 3 | 12 |
| HEX03 | 22 | 3.14 | 0 | 21 | 3 | 0 | 3 | 1 | 4 |
| HEX3B | 26 | 3.25 | 2 | 23 | 8 | 1 | 4 | 2 | 7 |

**Key:**
ASPT - Average Score Pre Taxon S-Stones Veg-Vegetation GSM-Gravel, sand & mud

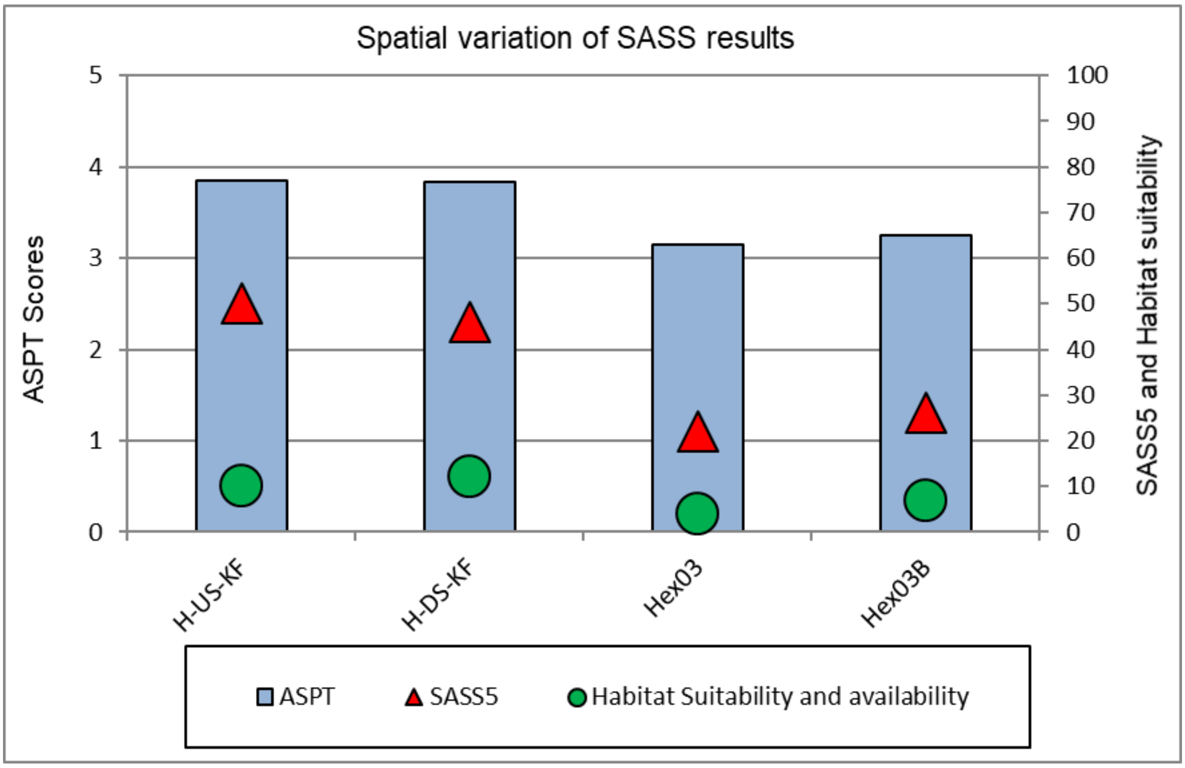



Figure 7: ASPT, SASS5 and total habitat suitability scores at biomonitoring sites during June 2019.

Biotic conditions, based on the total SASS5 scores and ASPT values, were stable to slightly improved from site Hex03 to Hex03-B (Table 7; Figure 7). This was at least partly habitat related as availability and suitability, and IHAS scores were better at the downstream site (Tables 6 and 7). None of the biotopes were directly comparable but all showed stable to improving scores, potentially indicating improved water quality towards the downstream site. *In-situ* water quality measures indicated considerable water quality improvements with a reduction in salinity and increase in dissolved oxygen levels, supporting the notion of improved water quality contributing to increased biotic integrity (*see section 3.2*). Comparisons between sites Hex03 and Hex03B were done to gauge the point-source effect, on the spatial integrity of the Hex River taking into consideration the Klipgatspruit. APPD is a potential contributor to pollution of the Klipgatspuit and continued monitoring (comparison of sites Hex03 and Hex03-B) will be essential to verify any possible impact and the severity thereof. The Klipgatspruit was dry at the time of sampling in June 2019 (although subsurface flow and impacts cannot be excluded), precluding water quality and toxicity testing, but did not appear to cause a deterioration in biotic integrity of the Hex River.

Plate 2: Indication of organic enrichment (algal proliferation) and solid waste disposal at site Hex03.

In conclusion, various sections of the Hex River within the study area show clear signs of reduced biotic integrity, based on macroinvertebrates. This was especially evident with the previous extended study area (now reduced due to Sibanye Stillwater sale and the complete scope no longer tasked to Clean Stream Biological Services). As such, a steady deterioration in biotic integrity in a downstream direction has consistently been recorded (Figure 8). However, the biotic integrity of the Hex River currently does improve on a spatial scale at certain sites and appears to be more stable within the recently adopted reduction of the study area (Figure 9).

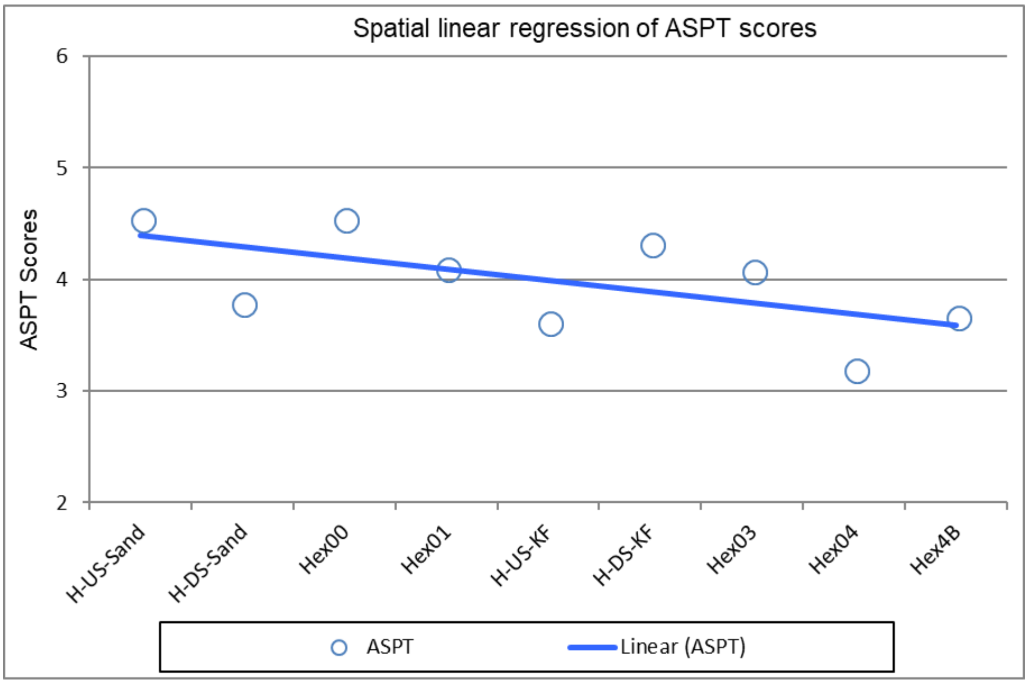



Figure 8: Linear regression of biotic integrity (as indicated by invertebrate ASPT scores) of the Hex River on a spatial scale (arranged sequentially in a downstream direction) during May 2018 (extended study area).

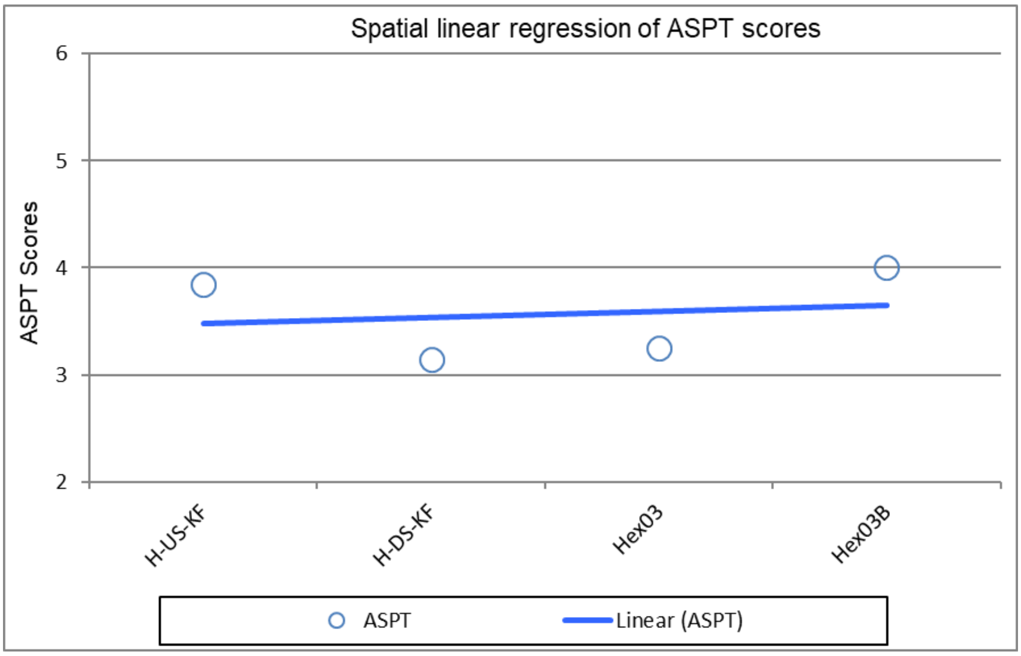



Figure 9: Linear regression of biotic integrity (as indicated by invertebrate ASPT scores) of the Hex River on a spatial scale (arranged sequentially in a downstream direction) during June 2019 (reduced study area).

## Temporal (long- and medium-term) trends

All of the datasets collected since May 2002 were compared to evaluate long-term and medium-term temporal trends in the biotic condition of the Hex River (Figures 10 & 11). Linear regression of historic ASPT values were calculated and plotted in order to achieve this. For the purpose of this monitoring programme, temporal trends are differentiated into long-term (more than four years) and medium-term (last 4 years) trends. The long-term trend gives a perspective on whether the biotic integrity (at the different sites) has improved or deteriorated since the inception of the monitoring programme. The medium-term trend confirms whether observed long-term trends are likely to continue or are in the process of being reversed.

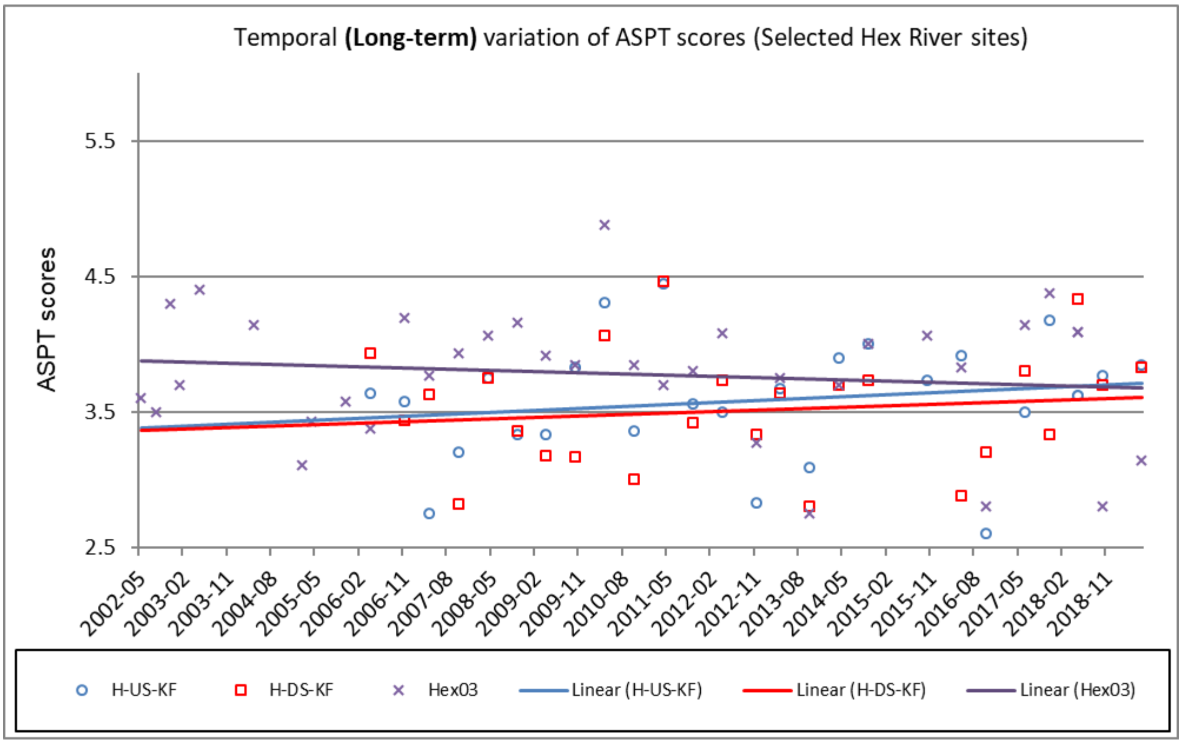



Figure 10: Long-term trends of biotic integrity in terms of macro-invertebrates at biomonitoring sites.

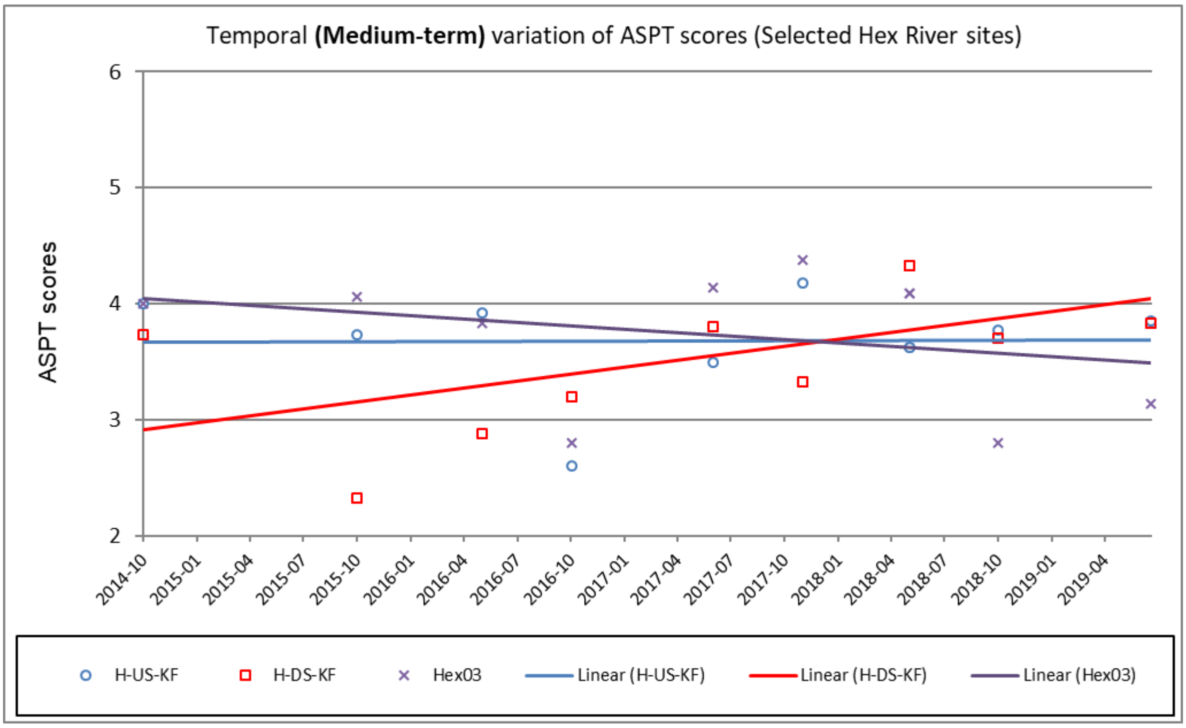



Figure 11: Medium-term trends of biotic integrity in terms of macro-invertebrates at biomonitoring sites.

Long-term trends indicated fair but stable (to slightly improving) biotic conditions at sites H-US-KF and H-DS-KF (Figure 10). However, long-term and medium-term trends at site Hex03 show a steady deterioration in biotic integrity (Figures 10 and 11). The recently observed organic pollution is almost certainly the cause, being **unrelated** to APPD activities.

Medium-term analyses confirm initially lower biotic conditions at site H-DS-KF (downstream of potential APPD impacts) but, encouragingly, biotic conditions at this site has improved at a faster rate than at the upstream site, with biotic integrity now being better at site H-DS-KF than at site H-US-KF (Figure 11). The inflow of the Klipfonteinspruit (and potential associated APPD impacts), therefore do not appear to have affected the macroinvertebrate-based biotic integrity of this reach of the Hex River over the medium to long term.

Continued monitoring will be essential to amass a database at the newly adopted downstream site (Hex03-B). This will serve to gauge the temporal effect of water users (including APPD) within the Klipgatspruit catchment, on the receiving environment (Hex River).

### 3.5 Fish Assessment

***Fish sampling was scheduled for the present survey but, due to safety risks posed to samplers (hostile behaviour from a crowd in the vicinity), could not be performed and sampling will again be attempted during the next scheduled survey.***

***Fish sampling is only scheduled once per annum and was last performed during May 2018, based on the extended scope (prior to Sibanye Stillwater sale). The approach and study area will therefore change in future, taking into consideration the reduced scope of this specific study, as performed by Clean Stream Biological Services. The complete extract (report RPM-A-18) of the fish results, is again repeated below for reference value and the sake of comprehensiveness. It should be kept in mind that various sampled sites are no longer part of this scope of work (since October 2018).***

The state and health of fish communities have been noted to give a reliable indication of short and long-term stress on aquatic systems. Fish communities possess various characteristics that render them important in the assessment of river health. They occupy positions throughout the aquatic food web, and are typically present in all but the most polluted of waters. Because fish often move over considerable distances, they have the potential to integrate diverse aspects of relatively large-scale habitats. Fish can therefore provide an integrated view of watershed conditions. Compared to other aquatic organisms, fish are furthermore relatively long-lived, and are therefore useful in providing a temporal dimension. They are also relatively easy to identify and after data is gathered, they can be released again. For the general public, fish are also the most well-known of aquatic organisms, and they are more likely to understand information about the condition of the fish community than about other taxa such as invertebrates. There are, however, some difficulties in using fish as biomonitoring indicators. Amongst these problems is the selective sampling attained by certain sampling equipment (for specific biotopes and for certain sizes and species of fish), the mobility of fish on spatial and temporal time scales, and the labour intensity of fish sampling.

Seven naturally occurring (native) fish species (*Barbus*[9] *paludinosus; Barbus trimaculatus; Barbus unitaeniatus; Clarias gariepinus; Oreochromis mossambicus; Pseudocrenilabrus philander* and *Tilapia sparrmanii*) were sampled at the five sampling sites in the Hex River during the 2017 to 2018 period (Table 8). The diversity of observed fish species was lower than expected at all of the sampling sites, indicating

[9] Recent literature (Yang *et al*., 2015) recommend a name change of the genus '*Barbus'* to '*Enteromius*'. This was however contested and rejected by various authors (i.e. Schmidt and Bart, 2015) and requires further verification. Skelton (2016) supports the recommended name change and started implementing this in recent studies and literature.

lowered biotic integrity (when compared to natural expected conditions). Possible reasons for lowered species diversity are outlined in the paragraphs below, which deal with the Fish Assemblage Integrity Index (FAII) and Fish Response Assessment Index (FRAI) results.

### The Fish Assemblage Integrity Index (FAII) and Fish Response Assessment Index (FRAI)

For the purpose of this study, a simplified version of the FAII was used (presence / absence) to enable comparisons between each site (spatial analyses), while the FRAI was used to determine the estimated biotic integrity, based on fish, of the entire Hex River reach under investigation which would provide a valuable tool to provide an overall status of the reach under investigation and to determine long-term (temporal) changes.

Table 8: Fish species expected and observed during the last two surveys.

| | | Sites | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Native/Exotic | Hex00 | | Hex01 | | Hex03 | | Hex04 | | Hex4B | |
| | | Exp | Obs | Exp | Obs | Exp | Obs | Exp | Obs | Exp | Obs |
| *Amphillius uranoscopus* | Native | | | | | | | | | | |
| *Enteromius*# *paludinosus* | Native | | | | | | | | | | |
| *Enteromius*# *trimaculatus* | Native | | | | | | | | | | |
| *Enteromius*# *unitaeniatus* | Native | | | | | | | | | | |
| *Chiloglanis pretoriae* | Native | | | | | | | | | | |
| *Clarias gariepinus* | Native | | | | | | | | | | |
| *Cyprinus carpio** | Exotic | | | | | | | | | | |
| *Labeobarbus marequensis* | Native | | | | | | | | | | |
| *Labeo cylindricus* | Native | | | | | | | | | | |
| *Labeo molybdinus* | Native | | | | | | | | | | |
| *Mesobola brevianalis* | Native | | | | | | | | | | |
| *Oreochromis mossambicus* | Native | | | | | | | | | | |
| *Pseudocrenilabrus philander* | Native | | | | | | | | | | |
| *Tilapia sparrmanii* | Native | | | | | | | | | | |
| No. of naturally occuring species expected/present | | 9 | 4 | 10 | 3 | 10 | 5 | 13 | 4 | 13 | 3 |
| % expected / observed | | 44 | | 30 | | 50 | | 31 | | 23 | |

**Key:** sampled previous survey, sampled this survey, sampled last two surveys

* Exotic species are by definition not expected to occur under natural conditions and therefore not taken into account for FAII calculations

\# Previous genus name: Barbus

## Fish Assemblage Integrity Index (FAII)

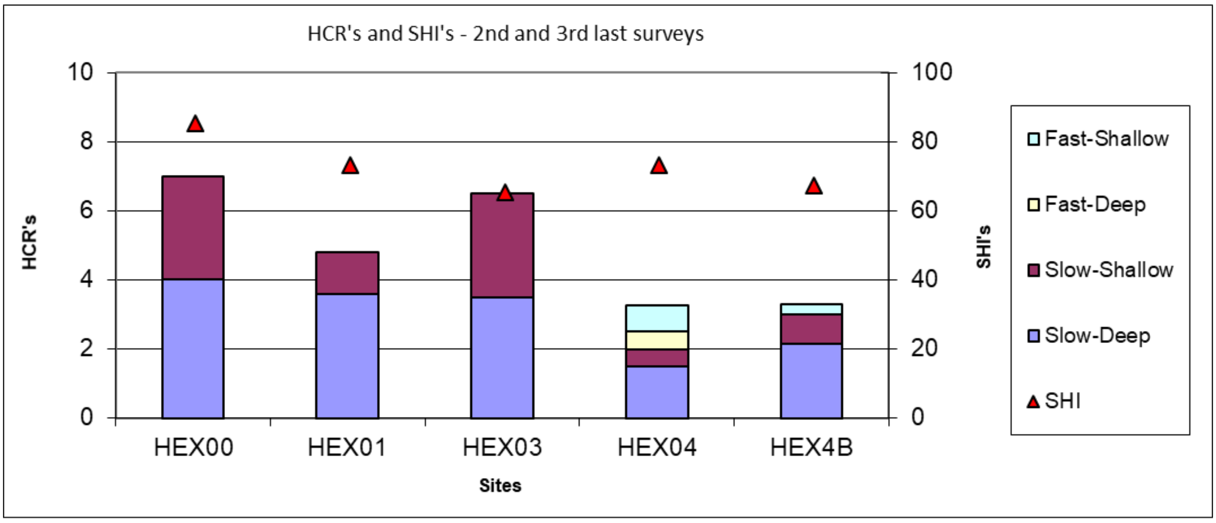
Based on morphological characteristics and the limited number of sites, each sampling site was classified as a separate fish habitat segment. Therefore, the "frequency of occurrence of fish within segments" was omitted from FAII for separate monitoring sites. Comparison of relative FAII scores for different sites would firstly give a perspective on the relative condition of the fish community at different sites and secondly indicate the impact of various anthropogenic activities up- and downstream of the different sites. Scores should however be treated with circumspection because the *frequency of occurrence* criterion was not considered, and the FAII scores are therefore less accurate. The list of fish species expected to occur at the sites under investigation is based on information from Skelton (1993) and Le Roux & Steyn (1968), as well as experience from previous surveys (this biomonitoring programme as well as various other mining related biomonitoring programmes, research and Department of Water Affairs' reserve determination studies). The expected species list is also updated with the knowledge gained from this biomonitoring programme. The species intolerance ratings used in the calculation of the FAII were taken from Kleynhans (2002) and were based on specialisation of preferences towards habitat, food, flowing water and water quality.

The composition of the fish community and the relative FAII (Fish Assemblage Integrity Index) are based on the last two surveys. This is done to increase the accuracy of the results and to avoid the incidental omission of a particular species at a particular site. Furthermore, fish generally take longer to react to stressors (compared with macro-invertebrates) and are therefore more applicable as an indicator over a period of time (as opposed to a snapshot at any given time).

The biotic integrity (as reflected by the fish assemblage integrity index) increased slightly from site Hex00 (23%) to Hex01 (27%) (Table 9 & Appendix tables; Figure 12). This is an indication that the biotic integrity (based on the fish communities) was not recently deteriorated due to by impacts in the area between these two sites. This is a similar trend as observed with the macro-invertebrate results, which indicated stable biotic conditions between these sites.

Table 9: Relative FAII scores calculated at different sampling sites (2017 to 2018).

| Locality | Relative FAII (%) |
|---|---|
| Hex00 | 23 |
| Hex01 | 27 |
| Hex03 | 46 |
| Hex04 | 22 |
| Hex4B | 22 |



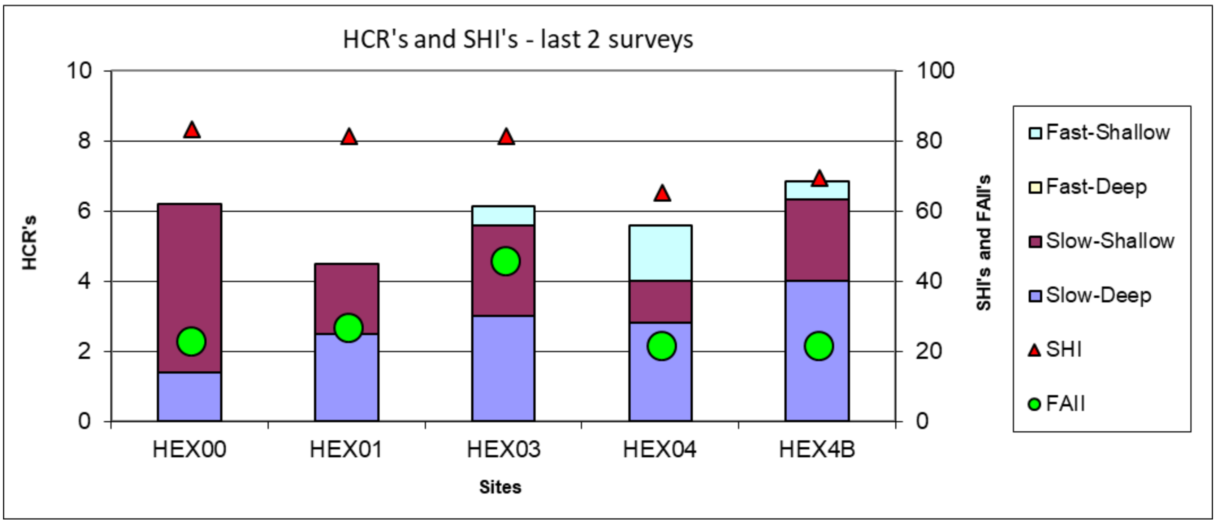




Figure 12: Relative FAII scores, HCR's and SHI at the different biomonitoring sites.

A spatial improvement was observed from site Hex01 to Hex03, as shown by the FAII scores increasing from 27% to 46% (Table 9; Figure 12). The spatial improvement was mainly attributed to the presence of *Enteromius trimaculatus* and *Enteromius unitaeniatus* at site Hex03. Both species are tolerant to moderately intolerant to water quality changes (Table 10) and their absence from site Hex01 is therefore not likely to be water quality related. Its absence from site Hex 00 during the 2017 to 2018 period is likely to be a response to lower habitat diversity and availability at this site. Based on these results, it appears that biotic integrity (based on fish) was probably not reduced by deteriorating water quality originating from the Klipfonteinspruit (possibly RPM-related) and/or from the sewage plant (non-RPM-related). This deduction is similar to the macro-invertebrate based deduction between these sites.

Table 10: The relative tolerance of each species towards changes in the environment.

| SPECIES NAME | Common name | Trophic specialisation | Habitat specialisation | Flow dependance | Requirement for high water quality | Total intolerance ratings |
|---|---|---|---|---|---|---|
| *Amphilius uranoscopus* | Stargazer | 4.7 | 4.9 | 4.8 | 4.8 | 4.8 |
| *Chiloglanis pretoriae* | Shortspine suckermouth | 4.4 | 4.8 | 4.8 | 4.5 | 4.6 |
| *Labeo molybdinus* | Leaden labeo | 3.3 | 3.0 | 3.3 | 3.2 | 3.2 |
| *Labeo cylindricus* | Redeye labeo | 3.3 | 3.0 | 3.1 | 3.1 | 3.1 |
| *Labeobarbus marequensis* | Largescale yellowfish | 2.4 | 2.8 | 3.2 | 2.1 | 2.6 |
| *Mesobola brevianalis* | River sardine | 3.1 | 2.2 | 1.1 | 2.8 | 2.3 |
| *Enteromius trimaculatus* | Threespot barb | 3.1 | 1.4 | 2.7 | 1.8 | 2.2 |
| *Enteromius paludinosus* | Straightfin barb | 1.6 | 1.4 | 2.3 | 1.8 | 1.8 |
| *Enteromius unitaeniatus* | Longbeard barb | 1.1 | 1.3 | 2.3 | 2.2 | 1.7 |
| *Oreochromis mossambicus* | Mazambique tilapia | 1.2 | 1.9 | 0.9 | 1.3 | 1.3 |
| *Pseudocrenilabrus philander* | Southern mouthbrooder | 1.3 | 1.4 | 1.0 | 1.4 | 1.3 |
| *Tilapia sparrmanii* | Banded tilapia | 1.6 | 1.4 | 0.9 | 1.4 | 1.3 |
| *Clarias gariepinus* | Sharptooth catfish | 1.0 | 1.2 | 1.7 | 1.0 | 1.2 |

**Key:**
Intolerance ratings are colour shaded on a scale from green to red, w ith green being least intolerant and red being most intolerant
Species are sorted in decending order from most intolerant (total intolerance rating) to least intolerant
1-2 = Tolerant 2-3 = Moderate tolerant 3-4 = Moderately intolerant 4-5 = Intolerant

As also observed previously, the FAII scores were largely reduced from site Hex03 towards site Hex04 (Table 9). The potential impact of water quality on the biotic integrity of the Hex River (as measured by the FAII at site Hex04) should therefore not be disregarded as both macro-invertebrates (during 2016 and 2018) and fish (last 4 years) are now indicating as such. Potential sources of reduced water quality between sites Hex03 and Hex04 include the Klipgatspruit and the Dorpspruit (see also previous discussions regarding potential Dorpspruit impacts).

The biotic integrity (based on fish) was similar between site Hex04 to site Hex4B (Table 9 & Appendix tables; Figure 12), being very poor at both sites. The same poor conditions (albeit spatially increased) was indicated by the macro-invertebrate assessment for these sites.

### Fish Response Assessment Index (FRAI)

As mentioned earlier, the Fish Response Assessment Index was adopted to assist in the classification of the Ecological Status, based on fish, of the entire Hex River reach under investigation. The results are therefore pooled for all sites. The resulting classification is therefore not a reflection of RPM mining impacts, but rather a reflection of the overall cumulative impact/s derived from the catchment.

The section below shows the individual metric driver results (Velocity-Depth, Cover, Flow, Physico-chemical, Migration and Introduced species), as well as the overall FRAI categories and category descriptions for the Hex River (Table 11).

Table 11: Fish Response Assessment Index (FRAI) results for the Hex River reach (all sites) (2017/8 results).

| METRIC GROUP | METRIC | *RATING (CHANGE) | METRIC GROUP WEIGHT (%) |
|---|---|---|---|
| VELOCITY-DEPTH CLASSES METRICS | Response of species with high to very high preference for FAST-DEEP conditions | -5 | 97 |
| | Response of species with high to very high preference for FAST-SHALLOW conditions | -5 | |
| | Response of species with high to very high preference for SLOW-DEEP conditions | -2.5 | |
| | Response of species with high to very high preference for SLOW-SHALLOW conditions | -2 | |
| COVER METRICS | Response of species with a very high to high preference for overhanging vegetation | -1.5 | 100 |
| | Response of species with a very high to high preference for undercut banks and root wads | -0.5 | |
| | Response of species with a high to very high preference for a particular substrate type | -5 | |
| | Response of species with a high to very high preference for instream vegetation | -0.5 | |
| | Response of species with a very high to high preference for the water column | -3 | |
| FLOW DEPENDANCE METRICS | Response of species intolerant of no-flow conditions | -5 | 94 |
| | Response of species moderately intolerant of no-flow conditions | -5 | |
| | Response of species moderately tolerant of no-flow conditions | -2 | |
| | Response of species tolerant of no-flow conditions | -1.5 | |
| PHYSICO-CHEMICAL METRICS | Response of species intolerant of modified physico-chemical conditions | -5 | 64 |
| | Response of species moderately intolerant of modified physico-chemical conditions | -5 | |
| | Response of species moderately tolerant of modified physico-chemical conditions | -4 | |
| | Response of species tolerant of modified physico-chemical conditions | -1 | |
| MIGRATION METRICS | Response in terms of distribution/abundance of spp with catchment scale movements | 0 | 61 |
| | Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments | 4 | |
| | Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment | 2 | |
| INTRODUCED SPECIES METRICS | The impact/potential impact of introduced competing/predaceous spp? | 0 | 45 |
| | How widespread (frequency of occurrence) are introduced competing/predaceous spp? | 0 | |
| | The impact/potential impact of introduced habitat modifying spp? | 2 | |
| | How widespread (frequency of occurrence) are habitat modifying spp? | 1 | |
| FRAI SCORE (%) | | 32.3 | |
| FRAI CATEGORY | | E | |
| FRAI CATEGORY DESCRIPTION | | Seriously modified | |

- Reduced flows and altered flooding regime of the river.
- Cover metrics: Seriously deterioration in substrate as cover, most probably associated with extensive algal growth (as described earlier in this report), flow modification (decreased riffle/rapid habitats) and sedimentation.
- Flow dependence metrics: Serious modification of fish species intolerant to moderately intolerant to no-flow conditions, again indicating on altered hydrological regime (altered flows and floods).
- Physico-chemical metrics: Seriously modified conditions indicated by fish species that are intolerant to moderately intolerant of modified water quality, indicating on seriously deteriorated water quality prevailing in this river reach.

- Migration metrics: Indicating seriously modified migratory impacts, associated with various physical and potentially also chemical migration barriers within this reach.
- Introduced species metrics: Slight impacts associated with the presence of the habitat modifying alien Common carp (*Cyprinus carpio*).

Table 12: Descriptive categories used to describe the present ecological status (PES) of biotic components (adapted from Kleynhans, 1999).

| CATEGORY | BIOTIC INTEGRITY | DESCRIPTION OF GENERALLY EXPECTED CONDITIONS |
|---|---|---|
| **A** | Excellent | Unmodified, or approximates natural conditions closely. The biotic assemblages compares to that expected under natural, unperturbed conditions. |
| B | Good | Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modifications. Most aspects of the biotic assemblage as expected under natural unperturbed conditions. |
| C | Fair | Moderately modified. A lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from its naturally expected condition. Some impairment of health may be evident at the lower end of this class. |
| D | Poor | Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Most characteristics of the biotic assemblages have been largely modified from its naturally expected condition. Impairment of health may become evident at the lower end of this class. |
| E | Very Poor | Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately tolerant species. Most of the characteristics of the biotic assemblages have been seriously modified from its naturally expected condition. Impairment of health may become very evident. |
| F | Critical | Critically modified. Extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only intolerant species may be present with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from its naturally expected conditions. Impairment of health generally very evident. |

# 4 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based on the aquatic macroinvertebrate assessments performed during June 2019. Reference is not made to fish-based conclusions since the new scope of work (study area) has invalidated spatial and temporal findings, which will be refined when fish assessments are once again performed (scheduled once per annum). Fish sampling was scheduled for the June 2019 survey, but could not be conducted due to safety risks and will again be attempted during the next scheduled survey.

The most important **spatial** conclusions are as follows:

- Biotic conditions, based on the total SASS5 and ASPT scores, remained stable from site H-US-KF to site H-DS-KF (in contrast to the downstream deterioration observed during the October 2018 survey). This is in line with most previous surveys when no spatial deterioration was observed. The most similar biotopes (GSM and Vegetation) showed contrasting results, and *in-situ* water quality measures indicated downstream improvement in dissolved oxygen levels, but deterioration in salinity. Overall the inflow from the Klipfonteinspruit did not appear to impact on the macroinvertebrate-based biotic integrity of the Hex River at the time of sampling.
- Biotic conditions, based on the total SASS5 scores and ASPT values, deteriorated from site H-DS-KF to Hex03. Lowered habitat availability and suitability at site Hex03 likely contributed to this deterioration, however comparison of the most similar biotope indicate that reduced water quality also played a role. Low dissolved oxygen levels measured at site Hex03 further supported reductions in water quality. It must be noted that organic enrichment and solid waste disposal appears extensively at this site and will likely affect biotic integrity if not mitigated. It is again noted that the reason for lowered dissolved oxygen levels are unlikely to be related to APPD activities because levels were within the guideline at site H-DS-KF and no further APPD activities take place towards site Hex03.
- Biotic conditions, based on the total SASS5 scores and ASPT values, were stable to slightly improved from site Hex03 to Hex03-B. Better habitat availability and suitability at Hex03B likely played a part, but *in-situ* measures also showed considerable improvement in water quality towards site Hex03B. None of the biotopes were directly comparable but all showed indicated downstream improvement. Site Hex03-B was included for the first time during the October 2018 survey. This was done to gauge the point-source effect, on the spatial integrity of the Hex River taking into consideration the Klipgatspruit. APPD is a potential contributor to pollution of the Klipgatspuit and continued monitoring (comparison of sites Hex03 and Hex03-B) will be essential to verify any possible impact and the severity thereof.

The most important **temporal (long- and medium-term)** conclusions regarding the biotic integrity of the Hex River are as follows:

- Long-term trends indicated fair but stable (to slightly improving) biotic conditions at sites H-US-KF and H-DS-KF, with site H-US-KF generally displaying slightly better conditions. Medium-term analyses confirm initially lower biotic conditions at site H-DS-KF (downstream of potential APPD impacts) but, encouragingly, biotic conditions have improved to such an extent that biotic integrity is now better at site H-DS-KF than at site H-US-KF. The inflow of the Klipfonteinspruit (and potential associated APPD impacts), therefore do not appear to have affected the macroinvertebrate-based biotic integrity of this reach of the Hex River over the medium to long term.
- Long- and medium-term trends at site Hex03 show a steady deterioration in biotic integrity. The recently observed organic pollution is almost certainly the cause, being **unrelated** to APPD activities.
- Continued monitoring will be essential to amass a database at the newly adopted downstream site (Hex03-B). This will serve to gauge the temporal effect of water users (including APPD) within the Klipgatspruit catchment, on the receiving environment (Hex River).

**General conclusions and recommendations**

In conclusion, it can be stated that various sections of the Hex River within the study area show clear signs of reduced biotic integrity, based on macroinvertebrates. This was especially evident with the previous extended study area (now reduced due to Sibanye Stillwater sale and the complete scope no longer tasked to Clean Stream Biological Services). As such, a steady deterioration in biotic integrity in a downstream direction has consistently been recorded. However, the biotic integrity of the Hex River currently does improve on a spatial scale at certain sites and appears to be more stable within the recently adopted reduction of the study area.

Future biomonitoring should be maintained on at least a biannual interval to gauge the trend of deterioration/improvement. This would facilitate the identification of possible impacts by APPD (and others) to this aquatic ecosystem. Early identification of impacts to the biota should prompt the identification of contaminants and the implementation of mitigation measures to reduce or prevent continued risk to the aquatic ecosystem.

It is strongly recommended that definitive toxicity testing be continued for the PCDs that regularly display toxicity levels of Class III or higher. Definitive toxicity testing will allow for the calculation of safe dilution ratios and will allow for the process of risk assessment. The risk assessment involves predicting the amount of a substrate that may enter the environment and comparing this with definitive toxicity results.

Calculated dilution ratios will be essential for environmental managers to predict whether the toxicity of polluted water will be negated if released or accidentally spilled into the receiving environment. Definitive testing will furthermore assist with scheduling planned licenced releases (*i.e.* whether water could be released during the dry season and, if not, whether sufficient dilution is likely to be achieved during the wet season/times of high river flow). All discharges should fall within the ambit of an approved water use licence, with biomonitoring and toxicity data being essential for the licensing process. In addition, increasing the frequency of testing of the pollution control facilities to at least twice a year should be considered. The confidence of results is relatively low if testing is only performed once a year, especially since toxicity hazards could conceivably change on a daily basis. More regular testing will therefore increase the confidence of results and lead to more informed management decisions.

It is recommended to continue including both site KF and KFD (in the Klipfonteinspruit) for toxicity testing (in addition to the Klipgatspruit; site KGT). The effect of different sources of pollution can then be distinguished more accurately.

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# Appendix 1: Methodology applied during this biomonitoring assessment.

**1.*In-situ* water quality**
The following surface water quality variables were measured on site: pH, Conductivity, water temperature, dissolved oxygen and oxygen saturation (Hach HQ40d Multimeter; Serial Number: 130300086148).

**2.Habitat assessment**
An evaluation of habitat quality and availability to biota is critical to any assessment of ecological integrity and should be conducted at each site at the time of biological sampling. On site habitat assessments were conducted by using existing habitat evaluation indices.

**2.1 Habitat condition**
The United States Environment Protection Agency Habitat Assessment Index (HAI) index was used to determine the general physical habitat condition at each site. Habitat parameters used by this index in this assessment of habitat integrity include the following: Epifaunal substrate/Available cover, Pool substrate characteristics, Pool variability, Channel alteration, Sediment deposition, Channel sinuosity, Channel flow status, Bank vegetative protection, Bank stability and Riparian vegetative zone width. Each of the above mentioned criteria was assessed and according to its condition, rated in one of the following classes, namely: Optimal/Excellent, Sub optimal/Good, Marginal/Fair or Poor. For each criterion, a score was given within the selected class. The sum of these scores gives a final score for this Index, and can be used in comparison to other sites or, if possible, to the baseline or reference condition to indicate its physical integrity (Barbour *et al*., 1999).

***2.2 Fish Habitat Assessment***
This assessment is aimed at the determination of the potential of a site to provide habitat for fish (Fish habitat cover ratings) and to identify the potential human impact on the fish habitat (Site fish habitat integrity) (Kleynhans, 1997).

*Fish Habitat Cover Rating (HCR)*
This approach was developed to assess habitats according to different attributes that are surmised to satisfy the habitat requirements of various fish species (Kleynhans, 1997). At each site, the following depth-flow (df) classes are identified, namely:
Slow (<0.3m/s), shallow (<0.5m) - Shallow pools and backwaters.
Slow, deep (>0.5m) - Deep pools and backwaters.
Fast (>0.3m/s), shallow - Riffles, rapids and runs.
Fast, deep - Usually rapids and runs.

The relative contribution of each of the above mentioned classes at a site was estimated and indicated as:
0 = Absent
1 = Rare (<5%)
2 = Sparse (5-25%)
3 = Moderate (25-75%)
4 = Extensive (>75%)

For each depth-flow class, the following cover features (cf), considered to provide fish with the necessary cover to utilise a particular flow and depth class, were investigated:
- Overhanging vegetation
- Undercut banks and root wads
- Stream substrate
- Aquatic macrophytes

The amount of cover present at each of these cover features (cf) was noted as:
0 = absent
1 = Rare/very poor (<5%)
2 = Sparse/poor (5-25%)
3 = Moderate/good (25-75%)
4 = Extensive/excellent (>75%)

The fish habitat cover rating (HCR) was calculated as follows:
- The contribution of each depth-flow class at the site was calculated ($df/\Sigma df$).
- For each depth-flow class, the fish cover features (cf) were summed ($\Sigma cf$).
$HCR = df/\Sigma df \times \Sigma cf$.

*Site fish habitat integrity (SHI)*
This approach is based on the assessment of physical habitat disturbance and is directed towards the indirect qualitative evaluation of fish habitat integrity, compared to the expected natural condition (Kleynhans, 1997). The following impacts (cause for fish habitat integrity degradation) is investigated, namely: Water abstraction, flow modification, bed modification, channel modification, inundation, exotic macrophytes, solid waste disposal, indigenous vegetation removal, exotic vegetation encroachment and bank erosion. Estimation of the impact of each of these modifications on the fish habitat integrity at a site is scored as follows:
No Impact = 0
Small impact = 1
Moderate Impact = 3
Large impact = 5

**3.Aquatic invertebrate assessment: South African Scoring System, Version 5.**
Benthic macro-invertebrate communities of the selected sites were investigated according to the South African Scoring System, version 5 (SASS5) approach (Dickens & Graham, 2001). This method is based on the British Biological Monitoring Working Party (BMWP) method and has been adapted for South

African conditions by Dr. F. M. Chutter (Thirion *et al*., 1995). The SASS method is a rapid, simple and cost effective method, which has progressed through four different upgrades/versions. The current upgrade is Version 5, which is specifically designed to comply with international accreditation protocols.

**Sample Collection**

An invertebrate net (30 x 30cm square with 1mm mesh netting) was used for the collection of the organisms. The available biotopes at each site were identified on arrival. Each of the biotopes was sampled by different methods explained later (samples should not be collected when the river is in flood).

The biotopes were combined into three different groups, which were sampled and assessed separately:

**a) Stone (S) Biotopes:**

**Stones in current (SIC) or any solid object:** *Movable stones of at least cobble size (3 cm diameter) to approximately 20 cm in diameter, within the fast and slow flowing sections of the river.* Kicksampling is used to collect organisms in this biotope. This is done by putting the net on the bottom of the river, just downstream of the stones to be kicked, in a position where the current will carry the dislodged organisms into the net. The stones are then kicked over and against each other to dislodge the invertebrates (kicksampling) for ± 2 minutes.

**Stones out of current (SOOC):** *Where the river is still, such as behind a sandbank or ridge of stones or in backwaters.* Collection is again done by the method of kicksampling, but in this case the net is swept across the area sampled to catch the dislodged biota. Approximately 1 $m^2$ is sampled in this way.

**Bedrock or other solid substrate:** Bedrock includes stones greater than 30cm, which are generally immovable, including large sheets of rock, waterfalls and chutes. The surfaces are scraped with a boot or hand and the dislodged organisms collected. Sampling effort is included under SIC and SOOC above.

**b) Vegetation (VG) Biotopes:**

**Marginal vegetation (MV):** *This is the overhanging grasses, bushes, twigs and reeds growing on the edge of the stream, often emergent, both in current (MvegIC) and out of current (MvegOOC).* Sampling is done by holding the net perpendicular to the vegetation (half in and half out of the water) and sweeping back and forth in the vegetation (± 2m of vegetation).

**Submerged vegetation (AQV):** *This vegetation is totally submerged and includes Filamentous algae and the roots of floating aquatics such as water hyacinth.* Sampled by pushing the net (under the water) against and amongst the vegetation in an area of approximately one square meter.

**c) Gravel, Sand and Mud (GSM) biotopes:**

**Sand:** *This includes sandbanks within the river, small patches of sand in hollows at the side of the river or sand between the stones at the side of the river.* This biotope is sampled by stirring the substrate by shuffling or scraping of the feet, which is done for half a minute, whilst the net is continuously swept over the disturbed area.

**Gravel:** *Gravel typically consists of smaller stones (2-3 mm up to 3 cm).* Sampling similar to that of sand.

**Mud:** *It consists of very fine particles, usually as dark-collared sediment.* Mud usually settles to the bottom in still or slow flowing areas of the river. Sampling similar to that of sand.

**d) Hand picking and visual observation:**

Before and after disturbing the site, approximately 1 minute of "hand-picking" for specimens that may have been missed by the sampling procedures was carried out.

**Sample preparation**

The organisms sampled in each biotope group were identified and their relative abundance also noted on the SASS5 datasheet.

**SASS-Habitat Assessment**

A SASS-habitat assessment index, according to the habitats sampled, was performed due to the fact that changes in habitat can be responsible for changes in SASS5 scores. This was done by the application of Integrated Habitat Assessment System (IHAS version 2) (McMillan, 1998).

**4. Fish Assemblage Integrity Index (FAII) (Kleynhans, 1997)**

Due to the difficulty of applying the generally used Index of Biotic Integrity (IBI) in rivers of South Africa, Kleynhans (1997) developed an alternative approach. The following procedures were used in the application of the FAII:

*Species tolerance ratings*

The species intolerance ratings used in the calculation of the FAII were taken from Kleynhans (2002). Four components are taken into account in estimating the intolerance of the relevant fish species, namely habitat preferences and specialisation (HS), food preference and specialisation (TS), requirements for flowing water during different life-stages (FW) and water quality requirements (WQ). Each of these aspects are scored for a species according to low requirement/specialisation (rating=1), moderate requirement/ specialisation (rating=3) and high requirement/specialisation (rating=5). The total intolerance (IT) of a fish species is estimated as follows:

IT = (HS+TS+FW+WQ)/4

*Health*

The percentage of fish with externally evident disease or other anomalies are used to score this metric. The following procedure is used to score the health of individual species:

Frequency of affected fish >5%, score = 1

Frequency of affected fish 2 - 5%, score = 3

Frequency of affected fish <2%, score = 5

The expected health for a species living under unperturbed conditions is assumed to be unimpaired and would score 5.

**The FAII is calculated as follows:**

The *expected index score* [FAII (exp.)] per segment:

FAII (exp.) = Σ(TxH)

where: T = Tolerance rating for individual species

H = Expected health rating for individual species.

The *observed index score* [FAII (obs)] is calculated on a similar basis but is based on the information collected during the survey:

FAII (obs) = Σ(TxH).

The observed fish assemblage index score for a segment is expressed as a percentage of the expected total FAII score to arrive at a relative FAII rating:

FAII (obs) / FAII (exp.) x 100

**Fish Response Assessment Index (FRAI)**

The determination and description of the present ecological status (PES) of the aquatic ecosystems in the study area, in terms of fish, was done according to the methodology described for River EcoClassification during Reserve Determinations (Kleynhans & Louw, 2008) using the Fish Response Assessment Index (FRAI) (Kleynhans, 2008). The results were then used to classify the present state of the fish assemblage into a specific descriptive category (A to F) (Table A1).

The FRAI is not in its conventional form designed for the application per site, but rather to a reach with a few sites. Metrics are therefore based on spatial frequency of occurrence of a species within the reach.

Table A1: Descriptive categories used to describe the present ecological status (PES) of biotic components (adapted from Kleynhans, 1999).

| CATEGORY | BIOTIC INTEGRITY | DESCRIPTION OF GENERALLY EXPECTED CONDITIONS |
|---|---|---|
| **A** | Excellent | Unmodified, or approximates natural conditions closely. The biotic assemblages compares to that expected under natural, unperturbed conditions. |
| B | Good | Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modifications. Most aspects of the biotic assemblage as expected under natural unperturbed conditions. |
| C | Fair | Moderately modified. A lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from its naturally expected condition. Some impairment of health may be evident at the lower end of this class. |
| D | Poor | Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Most characteristics of the biotic assemblages have been largely modified from its naturally expected condition. Impairment of health may become evident at the lower end of this class. |
| E | Very Poor | Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately tolerant species. Most of the characteristics of the biotic assemblages have been seriously modified from its naturally expected condition. Impairment of health may become very evident. |
| F | Critical | Critically modified. Extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only intolerant species may be present with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from its naturally expected conditions. Impairment of health generally very evident. |

It must be emphasized that the A→F scale represents a continuum, and that the boundaries between categories are notional, artificially-defined points along the continuum (as presented below). This situation falls within the concept of a fuzzy boundary, where a particular entity may potentially have membership of both classes (Robertson *et al*. 2004). For practical purposes, these situations are referred to as boundary categories and are denoted as B/C, C/D, and so on.

## Appendix 2: Site photos of biomonitoring sites (last two surveys)


Plate 1: Upstream view of H-US-KF (2019-06)


Plate 2: Downstream view of H-US-KF (2019-06)


Plate 3: Upstream view of H-US-KF (2018-10)


Plate 4: Downstream view of H-US-KF (2018-10)


Plate 5: Upstream view of KF (2019-06)


Plate 6: Downstream view KF (2019-06)


Plate 7: Upstream view of kF (2018-10)


Plate 8: Downstream view KF (2018-10)

Plate 9: Upstream view of KFD (2019-06)

Plate 10: Downstream view of KFD (2019-06)

Not included in survey

Plate 11: Upstream view of KFD (2018-10)

Plate 12: Downstream view of KFD (2018-10)

Plate 13: Upstream view of H-DS-KF (2019-06)

Photo not available

Plate 14: Downstream view of H-DS-KF (2019-06)

Plate 15: Upstream view of H-DS-KF (2018-10)

Plate 16: Downstream view of site H-DS-KF (2018-10)


Plate 16: Upstream view of Hex03 (2019-06)


Plate 17: Downstream view of Hex03 (2019-06)


Plate 18: Upstream view of Hex03 (2018-10)


Plate 19: Downstream view of site Hex03 (2018-10)


Plate 20: Upstream view of KGT (2019-06)


Plate 21: Downstream view of KGT (2019-06)


Plate 22: Upstream view of KGT (2018-10)


Plate 23: Downstream view of site KGT (2018-10)

Plate 24: Upstream view of Hex03B (2019-06)

Plate 25: Downstream view of Hex03B (2019-06)

Plate 26: Upstream view of Hex03B (2018-10)

Plate 27: Downstream view of site Hex03B (2018-10)

# Appendix 3: Tables

**Table A1:** SASS5 analysis including macro-invertebrate families sampled and habitat suitability scores calculated for the various sites (June 2019).

| Taxon | Common name | H-US-KF | | | | H-DS-KF | | | | HEX03 | | | | HEX3B | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Stones | Veg | GSM | Total | Stones | Veg | GSM | Total | Stones | Veg | GSM | Total | Stones | Veg | GSM | Total |
| Oligochaeta | Aquatic earthworms | B | A | A | B | A | - | - | A | - | - | A | A | - | - | - | - |
| Leeches | Leaches | A | B | B | B | - | - | 1 | 1 | - | B | - | B | - | - | - | - |
| Potamonautidae* | Crabs | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| Baetidae 1 sp. | Small minnow flies | A | - | - | A | - | - | - | - | - | - | - | - | - | - | - | - |
| Coenagrionidae | Damselflies | - | - | - | - | - | A | - | A | - | - | - | - | - | B | - | B |
| Belostomatidae* | Giant water bug | 1 | A | - | A | - | - | - | - | - | A | - | A | - | A | - | A |
| Corixidae* | Water boatmen | A | A | A | B | - | A | 1 | A | - | - | - | - | - | - | - | - |
| Gerridae* | Pond skater | - | - | - | - | - | A | - | A | - | - | - | - | - | - | - | - |
| Naucoridae* | Creeping water bugs | A | A | - | A | A | A | 1 | A | - | - | - | - | - | 1 | - | 1 |
| Nepidae* | Water scorpions | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 |
| Veliidae* | Broad-shouldered water strid | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| Ecnomidae | Caseless caddisflies | - | - | - | - | A | - | - | A | - | - | - | - | - | - | - | - |
| Hydropsychidae 1sp. | Caseless caddisflies | - | - | - | - | B | - | - | B | - | - | - | - | - | - | - | - |
| Dytiscidae (adults*) | Predacious diving beetles | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | - |
| Hydraenidae (adults*) | Minute moss beetles | - | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| Ceratopogonidae | Biting midges | - | A | - | A | - | - | - | - | - | - | - | - | - | - | - | - |
| Chironomidae | Midges | B | B | - | B | B | A | A | B | - | A | B | B | C | B | C | C |
| Culicidae* | Mosquitoes | - | - | B | B | - | - | - | - | - | - | - | - | - | A | - | A |
| Muscidae | House flies | - | - | - | - | 1 | 1 | - | A | - | - | - | - | - | - | - | - |
| Simuliidae | Black flies | A | B | A | B | B | A | 1 | B | - | A | - | A | - | - | - | - |
| Physidae* | Pouch snails | - | - | - | - | - | A | - | A | - | A | - | A | - | B | A | B |
| Total SASS5 score | | 31 | 42 | 13 | 50 | 28 | 30 | 20 | 46 | 0 | 21 | 3 | 22 | 2 | 23 | 8 | 26 |
| No. of families | | 9 | 10 | 5 | 13 | 7 | 8 | 5 | 12 | 0 | 6 | 2 | 7 | 1 | 7 | 3 | 8 |
| ASPT | | 3.44 | 4.20 | 2.60 | 3.85 | 4.00 | 3.75 | 4.00 | 3.83 | #DIV/0! | 3.50 | 1.50 | 3.14 | 2.00 | 3.29 | 2.67 | 3.25 |
| Total IHAS | | | | | 71 | | | | 65 | | | | 44 | | | | 62 |
| IHAS - Habs sampled | | | | | 42 | | | | 36 | | | | 19 | | | | 33 |
| IHAS - Stream condition | | | | | 29 | | | | 29 | | | | 25 | | | | 29 |
| Suitability score | | 3 | 4 | 3 | 10 | 5 | 4 | 3 | 12 | 0 | 3 | 1 | 4 | 1 | 4 | 2 | 7 |

**Key:** High requirement for unmodified water quality Veg=Vegetation
Moderate requirement for unmodified water quality
Low requirement for unmodified water quality
Very low requirement for unmodified water quality
A = 1-10 individuals; B = 11-100 individuals; C = 101-1000 individuals; ASPT = Average score per taxon.

**Table A3**: Fish Assemblage Integrity Index (FAII) scores calculated for the various sampling sites (2017-2018).

| | SPECIES | Intolerance rating | | | | | Health rating | | | | | SCORE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | HEX00 | HEX01 | HEX03 | HEX04 | HEX4B | HEX00 | HEX01 | HEX03 | HEX04 | HEX4B | HEX00 | HEX01 | HEX03 | HEX04 | HEX4B |
| EXPECTED | *Amphillius uranoscopus* | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 5 | 5 | 5 | 5 | 5 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 |
| | *Barbus paludinosus* | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 5 | 5 | 5 | 5 | 5 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| | *Barbus trimaculatus* | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 5 | 5 | 5 | 5 | 5 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| | *Barbus unitaeniatus* | | 1.7 | 1.7 | 1.7 | 1.7 | | 5 | 5 | 5 | 5 | 0.0 | 8.5 | 8.5 | 8.5 | 8.5 |
| | *Chiloglanis pretoriae* | | | | 4.6 | 4.6 | | | | 5 | 5 | 0.0 | 0.0 | 0.0 | 23.0 | 23.0 |
| | *Clarias gariepinus* | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 5 | 5 | 5 | 5 | 5 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| | *Labeobarbus marequensis* | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 5 | 5 | 5 | 5 | 5 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 |
| | *Labeo cylindricus* | | | | 3.1 | 3.1 | | | | 5 | 5 | 0.0 | 0.0 | 0.0 | 15.5 | 15.5 |
| | *Labeo molybdinus* | | | | 3.2 | 3.2 | | | | 5 | 5 | 0.0 | 0.0 | 0.0 | 16.0 | 16.0 |
| | *Mesobola brevianalis* | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 5 | 5 | 5 | 5 | 5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 |
| | *Oreochromis mossambicus* | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 5 | 5 | 5 | 5 | 5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| | *Pseudocrenilabrus philander* | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 5 | 5 | 5 | 5 | 5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| | *Tilapia sparrmanii* | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 5 | 5 | 5 | 5 | 5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| | | | | | | | | | | | **Total Expected** | 94.0 | 102.5 | 102.5 | 157.0 | 157.0 |
| OBSERVED | *Amphillius uranoscopus* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Barbus paludinosus* | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 5 | 5 | 5 | 5 | 5 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| | *Barbus trimaculatus* | | | 2.2 | | | | | 5 | | | 0.0 | 0.0 | 11.0 | 0.0 | 0.0 |
| | *Barbus unitaeniatus* | | | 1.7 | | | | | 5 | | | 0.0 | 0.0 | 8.5 | 0.0 | 0.0 |
| | *Chiloglanis pretoriae* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Clarias gariepinus* | | 1.2 | 1.2 | 1.2 | 1.2 | | 5 | 5 | 5 | 5 | 0.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| | *Labeobarbus marequensis* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Labeo cylindricus* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Labeo molybdinus* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Mesobola brevianalis* | | | | | | | | | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | *Oreochromis mossambicus* | | | 1.3 | 1.3 | 1.3 | | | 5 | 5 | 5 | 0.0 | 0.0 | 6.5 | 6.5 | 6.5 |
| | *Pseudocrenilabrus philander* | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 5 | 5 | 5 | 5 | 5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| | *Tilapia sparrmanii* | 1.3 | 1.3 | | 1.3 | 1.3 | 5 | 5 | | 5 | 5 | 6.5 | 6.5 | 0.0 | 6.5 | 6.5 |
| | | | | | | | | | | | **Total Observed** | **22.0** | **28.0** | **47.5** | **34.5** | **34.5** |
| | | | | | | | | | | | **Relative FAII (%)** | **23** | **27** | **46** | **22** | **22** |

# END OF REPORT

## Addendum 1: Toxicity test report/s (Biotox Laboratory Services)

Submitted as separate PDF document/s

# Appendix C

*Toxicity test report*

Anglo American Platinum – Rustenburg Operations
Annual integrated water monitoring report
Volume I

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ilac-MRA sanas Testing Laboratory T0663

Toxicity Specialists

# TOXICITY TEST REPORT

**For:**
Aquatico Scientific (Pty) Ltd

89 Regency Drive, Route 21 Corporate Park, Irene
PO Box 905008, Garsfontein, 0042

**Survey:**
2018-10

**Report reference:**
RPM-B-18_TOX

**Revision:**
0

**Project:**
Anglo Rustenburg (RPM)

**Samples:**
KF, KGT (Klipgat)

**Tests performed by: Marrilize Bylsma (Technical Manager); Marlise Brown (Junior Analyst)**
**Inputs and results verified by: Marrilize Bylsma (Technical Manager)**
**Classification (DEEEP) performed by: Lizet Moore (Quality Manager)**

| | | |
|---|---|---|
| **Report authorized by:** | **Technical Signatory** | |
| **Lizet Moore** | **Marrilize Bylsma** | **27 November 2018**<br>**Report Date** |

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## 1. Analyses requested and sample description

**Table 1:** Analyses requested and description for the different samples, including sampling and delivery dates.

| Sample name | Sampling date | Sampled by | Delivery date | Delivered by | Additional comments (sample description or deviations) | Tests requested - Marked with X | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Water | | | | Sediment | |
| | | | | | | Screening | Definitive | *Daphnia magna* | *Poecilia reticulata* | *Vibrio fischeri* | *Selenastrum capricornutum* | Phyto seeds | Ostracod |
| KF | 2018/10/25 | CSBS | 2018/10/25 | CSBS | None | X | | X | X | X | | | |
| KGT | DRY | | | | | | | | | | | | |

Screening = 100% (undiluted) sample tested only
Definitive = Series of sample dilutions tested to enhance classification accuracy and to determine safe dilution
CSBS - Clean Stream Biological Services

## 2. Methodology

### 2.1 Sampling and sample handling

Refer to Technical Standard Operating procedures 05 & 06 (SOP05 & SOP06). These documents are available on request.

### 2.2 Bio-toxicity assessments

Acute (and short-chronic) toxicity testing (as applied for this assessment) is applied by exposing biota to water sources in order to determine the potential risk of such waters to the biota/biological integrity of the receiving water bodies. A risk category is determined based on the percentage of mortalities (or inhibition-stimulation) of the exposed biota. It is important to note that the hazard classification is based on the standardised battery of selected test biota and therefore represents the risk/hazard towards similar biota in the receiving aquatic environment. The **toxicity** hazard is therefore in terms of the aquatic biotic integrity and does in no way represent **toxicology** towards humans or other mammals.

Standard, internationally accepted methods and materials were applied in order to conduct acute and short-chronic toxicity testing and hazard classification based on 3 trophic levels (3 taxonomic groups, namely *Vibrio fischeri* (bacteria), *Daphnia magna* (crustaceans) and *Poecilia reticulata* (fish)) at each of the selected sites/samples, as specifically requested by Aquatico.

All tests were conducted in environmental controlled rooms using the following internationally standardized methods:

#### *2.2.1 Vibrio fischeri* bioluminescent test (A)

Standard method: SANS 11348-3:2013
Deviation from standard method: None
Test species: *Vibrio fischeri* (NRRL B-11177)
Exposure period: 15 and 30 minutes
Test sample volume: 500 µℓ
Number of replicates: 2
Measurement equipment: Luminoscan TL, Hygiena Monitoring System
Test endpoint: Screening test - % growth inhibition or stimulation relative to control; Definitive test - EC20 and EC50 - values
Statistical method used: Biotox software (from supplier)/Manual plotting – Normalized regression of relevant data points
Batch numbers/expiry dates: VF 180328 / 2020-10; RD 180328 / 2020-10; SD 171214 / 2020-7
The percentage uncertainty for this test is 11.07% at a coverage factor of 2.36 and a level of confidence of 95%
Correction factor (validity of test): 0.79 (valid if between 0,6 & 1,8)

### 2.2.2 *Daphnia magna* acute toxicity test (A)

Standard method: SANS 6341:2015
Deviation from standard method: None
Test species: *Daphnia magna*
Test species age: Less than 24h old
Exposure period: 24 and 48h
Test sample volume: 25 mℓ
Number of test organisms per well: 5
Replicate number of wells per sample: 4
Test temperature: 21 ± 2°C
Test endpoint: Screening test - % mortality. Definitive test – $LC_{10}$ and $LC_{50}$ values
Statistical method used: Trimmed Spearman Karber (TSK)/ Graphical interpolation calculated by linear regression of relevant data points, EXCEL spread sheet
Batch numbers: Ephippia - 310518; ISO control medium – 080618
The percentage uncertainty for this test is 17.61% at a coverage factor of 2.05 and a level of confidence of 95%
Control mortality/immobility rate (validity of test): 0% (valid if ≤10%)

### 2.2.3 *Poecilia reticulata* acute toxicity test (A)

Standard method: OECD guide 203
Deviation from standard method: None
Test species: *Poecilia reticulata*
Test species age: Less than 21 days
Exposure period: 96h
Test sample volume: 200 mℓ
Number of test organisms per beaker: 6
Replicate number beakers per sample: 2
Test temperature: 21±2°C
Test endpoint: Screening test - %mortality; Definitive test – $LC_{10}$ and $LC_{50}$ values
Statistical method used: Trimmed Spearman Karber (TSK)/ Graphical interpolation calculated by linear regression of relevant data points, EXCEL spread sheet
Batch numbers: Control medium –080618
The percentage uncertainty for this test is 28.28% at a coverage factor of 2.36 and a level of confidence of 95%
Test validation: 0% control mortalities (valid if ≤10%)

### 2.2.4 pH (A)

Biotox Method 05
Test temperature: 25°C±3°C
Instrument used: HQ440D multimeter
The percentage uncertainty for this test is 0.01%(pH 2), 0.03% (pH 4), 0.01% (pH 7) and 0.10% (pH 10) at a coverage factor of 2 and a level of confidence of 95%
Batch numbers of buffers: pH4 – A7214 pH7 – A7222 pH10 – A7234

### 2.2.5 Electrical conductivity (A)

Biotox Method 06
Test temperature: 25°C±3°C
Instrument used: HQ440D multimeter
The percentage uncertainty for this test is 3.3% (1413µS/cm) and 0.23% (147µS/cm) at a coverage factor of 2 and a level of confidence of 95%
Batch numbers of buffers: 1413µS/cm - A8109

Quality assurance

The following quality assurance information would be made available on request:

- In-house reference toxicant test data and control charts.
- Additional lot, batch numbers and raw test data.
- Participation in proficiency testing scheme (SABS, NLA)

**2.3 Toxicity test results classification system**

A risk/hazard category was determined by application of the DEEEP[1] DWA recommended protocols and hazard classification. This risk category equates to the level of acute/chronic risk posed by the selected potential pollution source (water sample).

After the determination of the percentage effect[1] (EP), obtained with each of the battery of toxicity tests performed, the sample is ranked into one of the following five classes, based on screening testing protocols:

**Hazard classification system for screening tests**

| | |
|---|---|
| **Class I** | **No acute/short-chronic environmental toxicity hazard -** none of the tests shows a toxic effect |
| **Class II** | **Slight acute/short-chronic environmental toxicity hazard -** a statistically significant percentage effect is reached in at least one test, but the effect level is below 50% |
| **Class III** | **Acute/short-chronic environmental toxicity hazard -** the percentage effect level is reached or exceeded in at least one test, but the effect level is below 100% |
| **Class IV** | **High acute/short-chronic environmental toxicity hazard -** the 100% percentage effect is reached in at least one test |
| **Class V** | **Very high acute/short-chronic environmental toxictiy hazard -** the 100% percentage effect is reached in all the tests |

**Weighting:** Each sample is furthermore weighted according to its relative toxicity levels (out of 100%). Higher values indicate that more of the individual tests indicated toxicity within a specific class.

[1] DEEEP = Direct Estimation of Ecological Effect Potential. This is a battery of tests that can measure toxicity of complex mixtures based on a set of parameters stemming from the results of effects, even if all constituents are not known. A hazard class is determined based on the resulting parameters of the battery of tests

[1] EP (Percentage effect) = an effect measured either as a mortality rate or inhibition rate (depending on the type of test). A 10% effect is regarded as slight acute toxicity for *Daphnia* and *Poecilia*, while a 20% effect is regarded as slight short-chronic toxicity for *Vibrio*. A 50% effect is regarded as an acute/short-chronic toxicity for all of the tests (*Daphnia*, *Poecilia* and *Vibrio*)

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## 3. Results and discussion

### 3.1 2018-10 survey - water

Refer to table 2 and table 3 below for individual test results and overall hazard classification of the different samples.

**Table 2:** Test results and risk classification for water samples during October 2018.

| | Results | KF |
|---|---|---|
| wq Water quality | pH @ 25°C (A) | 7,7 |
| | EC (Electrical conductivity) (mS/m) @ 25°C (A) | 501,0 |
| | Dissolved oxygen (mg/l) (NA) | 7,6 |
| *V. fischeri* (bacteria) (A) | Test started on yy/mm/dd | 18/11/01 |
| | %30min inhibition (-) / stimulation (+) (%) | 44 |
| | EC/LC20 (30 mins) | * |
| | EC/LC50 (30 mins) | * |
| | Toxicity unit (TU) / Description | no short-chronic hazard |
| *D. magna* (waterflea) (A) | Test started on yy/mm/dd | 18/10/29 |
| | %48hour mortality rate (-%) | 0 |
| | EC/LC10 (48hours) | * |
| | EC/LC50 (48hours) | * |
| | Toxicity unit (TU) / Description | no acute hazard |
| *P. reticulata* (guppy) (A) | Test started on yy/mm/dd | 18/10/29 |
| | %96hour mortality rate (-%) | 0 |
| | EC/LC10 (96hours) | * |
| | EC/LC50 (96hours) | * |
| | Toxicity unit (TU) / Description | no acute hazard |
| | **Overall classification - Hazard class*** ** | Class I - No acute/short-chronic hazard |
| | Weight (%) | 0 |

**Key:**

***** = EC/LC values not determined, definitive testing required if a hazard was observed and persists over subsequent sampling runs.

******* = The overall hazard classification takes into account the full battery of tests and is not based on a single test result. Note that the overall hazard classification is expressed as acute/chronic level of toxicity, due to the fact that the *S. capricornutum* (micro-algae) and the *V. fischeri* tests are regarded as short-chronic levels of toxicity tests and the overall classification therefore contains a degree of chronic toxicity assessment.

**Weight (%) =** relative toxicity levels (out of 100%), higher values indicate that more of the individual tests indicated toxicity within a specific class.

site/sample name shaded in purple = screening test

site/sample name shaded in orange = definitive test

**4. Literature references**

ABOATOX Oy. 2012. BO1243-500 BioToxTM Kit. Instructions for use. Savikuja 2. FIN-21250, Masku Finland. www.aboatox.com

DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 2003. The Management of Complex Industrial Waste Water Discharges. Introducing the Direct Estimation of Ecological Effect Potential (DEEEP) approach, a discussion document. Institute of Water Quality Studies, Pretoria.

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MICROBIOTEST INC. 2012. DAPHTOXKIT F™ MAGNA. Crustacean Toxicity Screening Test for freshwater. Standard Operational Procedure. Kleimoer 15, 9030 Mariakerke (Gent), Belgium. www.microbiotest.be.

PERSOONE G, BLAHOSLAV M, BLINOVA I, TöRöKNE A, ZARINA T, MANUSADZIANAS L, NALECZ-JAWECKI G, TOFAN L, STEPANOVA L, TOTHOVA L, KOLAR B. A practical and user-friendly toxicity classification system with Microbiotests for natural waters and wastewaters (personal communication).

UNITED STATES ENVIRONMNETAL PROTECTION AGENCY (US EPA), 1996. Ecological effects test guidelines. Fish acute toxicity test – Freshwater and marine. OPPTS 850.1075. Report number EPA-712-c-96-118.

UNITED STATES ENVIRONMNETAL PROTECTION AGENCY (US EPA), 1993. Method for measuring the acute toxicity of effluent and receiving waters to freshwater and marine organisms. EPA/600/4-90/027F, 4th edition. Office of Research and Development, Washington.

## END OF REPORT

BIOTOX LABORATORY SERVICES (PTY) LTD

www.biotoxsa.co.za

Company registration number: 2012/106020/07
VAT number: 4740264959

**Tests performed at: GAUTENG OFFICE:**
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T0663

Toxicity Specialists

# TOXICITY TEST REPORT

**For:**
Aquatico Scientific Services

Route 21, Corporate Park, 89 Regency Drive, Irene
PO Box 905008, Garsfontein, 0042

**Survey:**
2019-05

**Report reference:**
RPM-A-19_TOX

**Revision:**
0

**Project:**
Anglo Rustenburg Process

**Samples:**
K035 (Klipgat Dam), K098 (ACP Dam),
K160 (RBMR Dam 3A), K161 (RBMR Dam 3B),
K162 (RBMR Triangular Dam), K209 (PMR Dam 2),
K210 (PMR Dam 3A), K211 (PMR Dam 3B),
K212 (PMR Dam 4+5), K213 (PMR Dam 6E)

**Tests performed by: Marrilize Bylsma (Technical Manager), Marlise Brown (Senior Analyst)**
**Inputs and results verified by: Marrilize Bylsma (Technical Manager), Marlise Brown (Senior Analyst)**
**Classification (DEEEP) performed by: Marrilize Bylsma (Technical Manager)**

| | | |
|---|---|---|
| **Report authorized by:** | **Technical Signatory** | |
| **Lizet Moore** | **Marrilize Bylsma** | **12 June 2019**<br>**Report Date** |

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## 1. Analyses requested and sample description

**Table 1:** Analyses requested and description for the different samples, including sampling and delivery dates.

| Sample nameB2:O15 | Sampling date | Sampled by | Delivery date | Delivered by | Additional comments (sample description or deviations) | Tests requested - Marked with X | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Water | | | | Sediment | |
| | | | | | | Screening | Definitive | *Daphnia magna* | *Poecilia reticulata* | *Allivibrio fischeri* | *Selenastrum capricornutum* | Phyto seeds | Ostracod |
| K035(Klipgat Dam) | 2019/05/23 | Aquatico | 2019/05/24 | Aquatico | None | | X | X | X | X | | | |
| K098 (ACP Dam) | 2019/05/23 | Aquatico | 2019/05/24 | Aquatico | None | | X | X | X | X | | | |
| K160 (RBMR Dam3A) | 2019/05/23 | Aquatico | 2019/05/24 | Aquatico | None | | X | X | X | X | | | |
| K161 (RBMR Dam 3B) | 2019/05/23 | Aquatico | 2019/05/24 | Aquatico | None | | X | X | X | X | | | |
| K162 (RBMR Triangular Dam) | 2019/05/23 | Aquatico | 2019/05/24 | Aquatico | None | | X | X | X | X | | | |
| K209 (PMR Dam2) | 2019/05/23 | Aquatico | 2019/05/24 | Aquatico | None | | X | X | X | X | | | |
| K210 (PMR Dam 3A) | 2019/05/23 | Aquatico | 2019/05/24 | Aquatico | None | | X | X | X | X | | | |
| K211 (PMR Dam 3B) | 2019/05/23 | Aquatico | 2019/05/24 | Aquatico | None | | X | X | X | X | | | |
| K212 (PMR Dam 4+5) | 2019/05/23 | Aquatico | 2019/05/24 | Aquatico | None | | X | X | X | X | | | |
| K213 (PMR Dam 6E) | 2019/05/23 | Aquatico | 2019/05/24 | Aquatico | None | | X | X | X | X | | | |

## 2. Methodology

### 2.1 Sampling and sample handling

Refer to Technical Standard Operating procedures 05 & 06 (SOP05 & SOP06). These documents are available on request.

### 2.2 Bio-toxicity assessments

Acute (and short-chronic) toxicity testing (as applied for this assessment) is applied by exposing biota to water sources in order to determine the potential risk of such waters to the biota/biological integrity of the receiving water bodies. A risk category is determined based on the percentage of mortalities (or inhibition-stimulation) of the exposed biota. It is important to note that the hazard classification is based on the standardised battery of selected test biota and therefore represents the risk/hazard towards similar biota in the receiving aquatic environment. The **toxicity** hazard is therefore in terms of the aquatic biotic integrity and does in no way represent **toxicology** towards humans or other mammals.

Standard, internationally accepted methods and materials were applied in order to conduct acute and short-chronic toxicity testing and hazard classification based on 3 trophic levels (3 taxonomic groups, namely *Allivibrio fischeri* (bacteria), *Daphnia magna* (crustaceans) and *Poecilia reticulata* (fish)) at each of the selected sites/samples specifically requested by Aquatico.

All tests were conducted in environmental controlled rooms using the following internationally standardized methods:

### *2.2.1 Allivibrio fischeri* **bioluminescent test (A)**

Standard method: SANS 11348-3:2013
Deviation from standard method: None
Exposure period: 15 and 30 minutes
Test sample volume: 500 µℓ
Number of replicates: 2
Measurement equipment: Luminoscan TL, Hygiena Monitoring System
Test endpoint: Screening test - % growth inhibition or stimulation relative to control; Definitive test - EC20 and EC50 - values
Statistical method used: Biotox software (from supplier)/Manual plotting – Normalized regression of relevant data points
Batch numbers/expiry dates: VF 181212 / 2021-04; RD 181212 / 2021-04; SD 181212 / 2021-01
The percentage uncertainty for this test is 11.07% at a coverage factor of 2.36 and a level of confidence of 95%
Correction factor (validity of test): 1.3/1.6/1.2/1.1/1.5/0.9/1.7 (valid if between 0,6 & 1,8)

### *2.2.2 Daphnia magna* **acute toxicity test (A)**

Standard method: SANS 6341:2015
Deviation from standard method: None
Test species: *Daphnia magna*
Test species age: Less than 24h old
Exposure period: 24 and 48h
Test sample volume: 25 mℓ
Number of test organisms per well: 5
Replicate number of wells per sample: 4
Test temperature: 21 ± 2°C
Test endpoint: Screening test - % mortality. Definitive test – $LC_{10}$ and $LC_{50}$ values
Statistical method used: Trimmed Spearman Karber (TSK)/ Graphical interpolation calculated by linear regression of relevant data points, EXCEL spread sheet
Batch numbers: Ephippia - 131218; ISO control medium – 080119
The percentage uncertainty for this test is 17.61% at a coverage factor of 2.05 and a level of confidence of 95%
Control mortality/immobility rate (validity of test): 0% (valid if ≤10%)

### *2.2.3 Poecilia reticulata* **acute toxicity test (A)**

Standard method: OECD guide 203
Deviation from standard method: None
Test species: *Poecilia reticulata*
Test species age: Less than 21 days
Exposure period: 96h
Test sample volume: 200 mℓ
Number of test organisms per beaker: 6
Replicate number beakers per sample: 2
Test temperature: 21±2°C
Test endpoint: Screening test - %mortality; Definitive test – $LC_{10}$ and $LC_{50}$ values
Statistical method used: Trimmed Spearman Karber (TSK)/ Graphical interpolation calculated by linear regression of relevant data points, EXCEL spread sheet
Batch numbers: Control medium –080119
The percentage uncertainty for this test is 28.28% at a coverage factor of 2.36 and a level of confidence of 95%
Test validation: 0% control mortalities (valid if ≤10%)

### 2.2.4 pH (A)

Biotox Method 05
Test temperature: 25°C±3°C
Instrument used: HQ440D multimeter
The percentage uncertainty for this test is 0.01%(pH 2), 0.03% (pH 4), 0.01% (pH 7) and 0.10% (pH 10) at a coverage factor of 2 and a level of confidence of 95%
Batch numbers of buffers: pH4 – A6124 pH7 – A8087 pH10 – A8317

### 2.2.5 Electrical conductivity (A)

Biotox Method 06
Test temperature: 25°C±3°C
Instrument used: HQ440D multimeter
The percentage uncertainty for this test is 3.3% (1413µS/cm) and 0.23% (147µS/cm) at a coverage factor of 2 and a level of confidence of 95%
Batch numbers of buffers: 1413µS/cm - A8275

Quality assurance

The following quality assurance information would be made available on request:

- In-house reference toxicant test data and control charts.
- Additional lot, batch numbers and raw test data.
- Participation in proficiency testing scheme (SABS, NLA)

### 2.3 Toxicity test results classification system

A risk/hazard category was determined by application of the DEEEP[1] DWA recommended protocols and is broadly based on the hazard classification system of Persoone *et.al.* (2003). This risk category equates to the level of acute/chronic risk posed by the selected potential pollution source (water sample).

After the determination of the percentage effect[1] (EP), obtained with each of the battery of toxicity tests performed, the sample is ranked into one of the following five classes, based on definitive testing protocols:

**Hazard classification system for definitive tests**

| | |
|---|---|
| **Class I** | **No acute/short-chronic environmental toxicity hazard -** none of the tests shows a toxic effect (i.e. an effect value significantly higher than that in the control) |
| **Class II** | **Slight acute/short-chronic environmental toxicity hazard -** the percentage effect observed in at least one toxicity test is significantly higher than in the control, but the effect level is below 50% (TU is <1) |
| **Class III** | **Acute/short-chronic environmental toxicity hazard -** the L(E)C50 is reached or exceeded in at least one test, but in the 10 fold dilution of the sample the effect level is less than 50% (1≤TU≤9,99) |
| **Class IV** | **High acute/short-chronic environmental toxicity hazard -** the L(E)C50 is reached in the 10 fold dilution for at least one test, but not in the 100 fold dilution (10≤TU≤99,99) |
| **Class V** | **Very high acute/short-chronic environmental toxcity hazard -** the L(E)C50 is reached in the 100 fold dilution for at least one test (TU is ≥100) |

**Note:**

The samples are classified into one of the above five classes on the basis of the highest toxicity unit (TU) found in the battery of toxicity definitive tests performed

**Weighting:** Each sample is furthermore weighted according to its relative toxicity levels (out of 100%). Higher values indicate that more of the individual tests indicated toxicity within a specific class.

[1] DEEEP = Direct Estimation of Ecological Effect Potential. This is a battery of tests that can measure toxicity of complex mixtures based on a set of parameters stemming from the results of effects, even if all constituents are not known. A hazard class is determined based on the resulting parameters of the battery of tests

[1] EP (Percentage effect) = an effect measured either as a mortality rate or inhibition rate (depending on the type of test). A >10% effect is regarded as slight acute toxicity for *Daphnia* and *Poecilia*, while a >20% effect is regarded as slight short-chronic toxicity for *Allivibrio*. A 50% effect is regarded as an acute/short-chronic toxicity for all of the tests (*Daphnia*, *Poecilia* and *Allivibrio*)

## 3. Results and discussion

### 3.1 2019-05 survey - water

Refer to table 2 below for individual test results and overall hazard classification of the different samples.

**Table 2:** Test results and risk classification for water samples during May 2019.

| | Results | K035 (Klipgat Dam) | K098 (ACP Dam) | K160 (RBMR Dam 3A) | K161 (RBMR Dam 3B) | K162 (RBMR Triangular Dam) | K209 (PMR Dam 2) | K210 (PMR Dam 3A) | K211 (PMR Dam 3B) | K212 (PMR Dam 4+5) | K213 (PMR Dam 6E) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| %Water quality | pH @ 25°C (A) | 7.3 | 2.7 | 3.2 | 5.2 | 10.5 | 1.2 | 9.8 | 9.4 | 5.5 | 5.6 |
| | EC (Electrical conductivity) (mS/m) @ 25°C (A) | 539.0 | 186.9 | 6340.0 | 3880.0 | 6090.0 | 10650.0 | 42.4 | 63.7 | 18940.0 | 24000.0 |
| | Dissolved oxygen (mg/l) (NA) | 9.4 | 7.5 | 7.4 | 7.5 | 7.3 | 7.6 | 8.6 | 7.8 | 7.6 | 7.5 |
| *A. fischeri* (bacteria) (A) | Test started on yy/mm/dd | 19/05/29 | 19/05/29 | 19/05/29 | 19/05/29 | 19/05/30 | 19/05/30 | 19/06/05 | 19/06/05 | 19/06/05 | 19/06/06 |
| | %30min inhibition (-) / stimulation (+) (%) | 55 | -100 | -100 | -100 | -100 | -100 | -97 | -31 | -100 | -100 |
| | EC/LC20 (30 mins) | n.r | 2 | n.c | n.c. | 2 | n.c | 36 | 89 | n.c | n.c |
| | EC/LC50 (30 mins) | n.r | 9 | n.c | 0.5 | 3 | n.c | 45 | n.r. | 4 | 3 |
| | Toxicity unit (TU) / Description | <1 | 11.8 | >100 | 25.6 | 29.5 | >100 | 2.2 | <1 | 27.1 | 30.6 |
| *D. magna* (waterflea) (A) | Test started on yy/mm/dd | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 | 19/05/27 |
| | %48hour mortality rate (-%) | -5 | -100 | -100 | -100 | -100 | -100 | -5 | 0 | -100 | -100 |
| | EC/LC10 (48hours) | n.r | 10 | n.c | n.c | 2 | n.c | n.r | n.r | n.c | n.c |
| | EC/LC50 (48hours) | n.r | 19 | n.c | n.c | 8 | 0.3 | n.r | n.r | 4 | 3 |
| | Toxicity unit (TU) / Description | <1 | 5.4 | >100 | >100 | 12.9 | >100 | <1 | <1 | 28.0 | 32.5 |
| *P. reticulata* (guppy) (A) | Test started on yy/mm/dd | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 | 19/05/30 |
| | %96hour mortality rate (-%) | 0 | -100 | -100 | -100 | -100 | -100 | -25 | 0 | -100 | -100 |
| | EC/LC10 (96hours) | n.r | 12 | n.c | n.c | 10 | 2 | 70 | n.r | 5 | 2 |
| | EC/LC50 (96hours) | n.r | 18 | n.c | 0.3 | 17 | 6 | n.r. | n.r | 7 | 6 |
| | Toxicity unit (TU) / Description | <1 | 5.7 | >100 | >100 | 5.9 | 18.2 | <1 | <1 | 14.3 | 18.2 |
| *Estimated safe dilution factor (%) [for definitive testing only]* | | None required | 2 | <1 | <1 | 2 | <1 | 36 | 89 | <1 | <1 |
| Overall classification - Hazard class*** | | Class I - No acute/short-chronic hazard | Class IV - High acute/short-chronic hazard | Class V - Very high acute/short-chronic hazard | Class V - Very high acute/short-chronic hazard | Class IV - High acute/short-chronic hazard | Class V - Very high acute/short-chronic hazard | Class III - Acute/short-chronic hazard | Class II - Slight short-chronic hazard | Class IV - High acute/short-chronic hazard | Class IV - High acute/short-chronic hazard |
| Weight (%) | | 0 | 78 | 100 | 100 | 89 | 100 | 67 | 33 | 100 | 100 |

**Key:**

**%** = for definitive testing, only the 100% concentration (undiluted) sample mortality/inhibition/stimulation is reflected by this summary table. The dilution series results are considered for EC/LC values and Toxicity unit determinations
**n.r. =** not relevant, i.e. the 100% concentration caused less than 10/20/50% (effective concentration) mortalities or inhibition
**n.c. =** not calculable, although the 100% concentration led to more than 10/20/50% mortalities/inhibtion, the 10/20/50% mortality/inhition rate was exceeded throughout the test

******* = The overall hazard classification takes into account the full battery of tests and is not based on a single test result. Note that the overall hazard classification is expressed as acute/short-chronic level of toxicity, due to the fact that the *A. fischeri* test is regarded as short-chronic level of toxicity test and the overall classification therefore contains a degree of short-chronic toxicity assessment.

**Weight (%) =** relative toxicity levels (out of 100%), higher values indicate that more of the individual tests indicated toxicity within a specific class

site/sample name shaded in purple = screening test
site/sample name shaded in orange = definitive test

Sample K035 (Klipgat Dam) showed "no acute/short-chronic environmental toxicity hazard" (Class I). Sample K211 (PMR Dam 3B) showed a "slight short-chronic enivornmental toxicity hazard" (Class II) based on the 31% bacterial light emission inhibition effect noted during testing (highest toxicity unit <1). Sample K210 (PMR Dam 3A) showed an "acute/short-chronic environmental toxicity hazard" (Class III) based on the highest toxicity unit (2.2) calculated on a bacterial level of tesing. Samples K098 (ACP Dam), K162 (RBMR Tiangular Dam), K212 (PMR Dam 4+5) and K213 (PMR Dam 6E) showed a "high acute/short-chronic environmental toxicity hazard" (Class IV) based on the 100% effect reached in at least one test for each of the samples with toxicity units ranging from 5.4 - >100. Samples K160 (RBMR Dam 3A), K161 (RBMR Dam 3B) and K209 (PMR Dam 2) showed a "very high acute/short-chronic environmental toxicity hazard" (Class V) based on the toxicity units >100 calculated for these samples during testing at all 3 trophic levels. It should also be noted that the toxicity effects noted for K160 was so severe, that neither the LC/EC50 or the LC10/EC20 values could be calculated (thus the toxicity effect could not be diluted out up to a very low dilution concentration (0.195% of the original sample) . Refer to section 2.3 for details on hazard classification.

Very low safe dilution factors (<1) were calculated for samples K160, K161, K209, K212 and K213 and therefore water from these facilities should not be allowed to reach the natural environment. Safe dilution factors ranging between 2% and 89% were calculated for K035, K162, K210 and K211 (e.g. 2 parts of K098 water diluted with 98 parts ‘‘unpolluted’ water should be sufficient to negate toxicity effects at these throphic levels should these waters reach the natural environment).

**IMPORTANT:** Although sample K035(Klipgat Dam) was classified as Class I using the normal range of dilutions at a macro-invertebrate level, for dilutions 100% to 1% (dilutions from original sample) a normal decreasing toxicity effect trend was noted (resulting in the Class I classification). However from a 0.1% dilution level, significant mortalities was noted at this level of testing (100%). It is suggested that the facility investigates probable causes e.g. nano-materials affecting organisms more severely at lower concentrations. This can also be achieved by performing toxicity investigation evaluations (TIE). Even though K098 (ACP Dam) showed mortalities from the highest concentration (100% effect) and also following a normal decreasing trend up to 1% dilution (50% effect), the same significant increasing mortality effect was noted as for sample K035 (Klipgat Dam) at the 0.1% dilution level.

#### 4. Literature references

DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 2003. The Management of Complex Industrial Waste Water Discharges. Introducing the Direct Estimation of Ecological Effect Potential (DEEEP) approach, a discussion document. Institute of Water Quality Studies, Pretoria.

OECD GUIDELINE FOR TESTING OF CHEMICALS (1992). Fish Acute toxicity test.

PERSOONE G, BLAHOSLAV M, BLINOVA I, TöRöKNE A, ZARINA T, MANUSADZIANAS L, NALECZ-JAWECKI G, TOFAN L, STEPANOVA L, TOTHOVA L, KOLAR B (2003). A practical and user-friendly toxicity classification system with Microbiotests for natural waters and wastewaters (personal communication).

SOUTH AFRICAN NATIONAL STANDARD, 2015. “Water quality – Determination of the inhibition of the mobility of *Daphnia magna* Straus (*Cladocera, Crustacea*) – Acute toxicity test.

SOUTH AFRICAN NATIONAL STANDARD, 2013. “Water quality – Determination of the inhibitory effect of water samples on the light emission of Vibrio fischeri (Luminescent bacteria test). Part 3: Method using freeze-dried bacteria

## END OF REPORT

BIOTOX LABORATORY SERVICES (PTY) LTD

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ilac-MRA sanas Testing Laboratory T0663

Toxicity Specialists

# TOXICITY TEST REPORT

**For:**
Aquatico Scientific (Pty) Ltd

89 Regency Drive, Route 21 Corporate Park, Irene
PO Box 905008, Garsfontein, 0042

**Survey:**
2019-06

**Report reference:**
RPM-B-19_TOX

**Revision:**
0

**Project:**
Anglo Platinum Process Division (RPM)

**Samples:**
KF, KFD, KGT

**Tests performed by: Marlise Brown (Senior Analyst), Praise Manyenga (Junior Analyst)**
**Inputs and results verified by: Marrilize Bylsma (Technical Manager), Marlise Brown (Senior Analyst)**
**Classification (DEEEP) performed by: Marrilize Bylsma (Technical Manager)**

| | | |
|---|---|---|
| **Report authorized by:** | **Technical Signatory** | |
| **Lizet Moore** | **Marrilize Bylsma** | **08 July 2019**<br>**Report Date** |

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## 1. Analyses requested and sample description

**Table 1:** Analyses requested and description for the different samples, including sampling and delivery dates.

| Sample name | Sampling date | Sampled by | Delivery date | Delivered by | Additional comments (sample description or deviations) | Tests requested - Marked with X | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Screening | Definitive | Water | | | | Sediment | |
| | | | | | | | | *Daphnia magna* | *Poecilia reticulata* | *Allivibrio fischeri* | *Selenastrum capricornutum* | Phyto seeds | Ostracod |
| KF | 2019/06/18 | CSBS | 2019/06/20 | CSBS | None | X | | X | X | X | | | |
| KFD | 2019/06/18 | CSBS | 2019/06/20 | CSBS | None | X | | X | X | X | | | |
| KGT | DRY | | | | | | | | | | | | |

**Key:**
Screening = 100% (undiluted) sample tested only
Definitive = Series of sample dilutions tested to enhance classification accuracy and to determine safe dilution

## 2. Methodology

### 2.1 Sampling and sample handling

Samples were analysed as received from the Client. Refer to QM7.3/SOP-09.

### 2.2 Bio-toxicity assessments

Acute (and short-chronic) toxicity testing (as applied for this assessment) is applied by exposing biota to water sources in order to determine the potential risk of such waters to the biota/biological integrity of the receiving water bodies. A risk category is determined based on the percentage of mortalities (or inhibition-stimulation) of the exposed biota. It is important to note that the hazard classification is based on the standardised battery of selected test biota and therefore represents the risk/hazard towards similar biota in the receiving aquatic environment. The **toxicity** hazard is therefore in terms of the aquatic biotic integrity and does in no way represent **toxicology** towards humans or other mammals.

Standard, internationally accepted methods and materials were applied in order to conduct acute and short-chronic toxicity testing and hazard classification based on 3 trophic levels (3 taxonomic groups, namely *Allivibrio fischeri* (bacteria), *Daphnia magna* (crustaceans) and *Poecilia reticulata* (fish)) at each of the selected sites/samples as specifically requested by Clean Stream.

All tests were conducted in environmental controlled rooms using the following internationally standardized methods:

#### *2.2.1 Allivibrio fischeri* bioluminescent test (A)

Standard method: SANS 11348-3:2013
Deviation from standard method: None
Exposure period: 15 and 30 minutes
Test sample volume: 500 µℓ
Number of replicates: 2
Measurement equipment: Luminoscan TL, Hygiena Monitoring System
Test endpoint: Screening test - % growth inhibition or stimulation relative to control; Definitive test - EC20 and EC50 - values
Statistical method used: Biotox software (from supplier)/Manual plotting – Normalized regression of relevant data points
Batch numbers/expiry dates: VF 181212 / 2021-04; RD 181212 / 2021-04; SD 181212 / 2021-01
The percentage uncertainty for this test is 11.07% at a coverage factor of 2.36 and a level of confidence of 95%
Correction factor (validity of test): 1.1 (valid if between 0,6 & 1,8)

### 2.2.2 *Daphnia magna* acute toxicity test (A)

Standard method: SANS 6341:2015
Deviation from standard method: None
Test species: *Daphnia magna*
Test species age: Less than 24h old
Exposure period: 24 and 48h
Test sample volume: 25 mℓ
Number of test organisms per well: 5
Replicate number of wells per sample: 4
Test temperature: 21 ± 2°C
Test endpoint: Screening test - % mortality. Definitive test – $LC_{10}$ and $LC_{50}$ values
Statistical method used: Trimmed Spearman Karber (TSK)/ Graphical interpolation calculated by linear regression of relevant data points, EXCEL spread sheet
Batch numbers: Ephippia - 280219; ISO control medium – 070319
The percentage uncertainty for this test is 17.61% at a coverage factor of 2.05 and a level of confidence of 95%
Control mortality/immobility rate (validity of test): 5% (valid if ≤10%)

### 2.2.3 *Poecilia reticulata* acute toxicity test (A)

Standard method: OECD guide 203
Deviation from standard method: None
Test species: *Poecilia reticulata*
Test species age: Less than 21 days
Exposure period: 96h
Test sample volume: 200 mℓ
Number of test organisms per beaker: 6
Replicate number beakers per sample: 2
Test temperature: 21±2°C
Test endpoint: Screening test - %mortality; Definitive test – $LC_{10}$ and $LC_{50}$ values
Statistical method used: Trimmed Spearman Karber (TSK)/ Graphical interpolation calculated by linear regression of relevant data points, EXCEL spread sheet
Batch numbers: Control medium –070319
The percentage uncertainty for this test is 28.28% at a coverage factor of 2.36 and a level of confidence of 95%
Test validation: 0% control mortalities (valid if ≤10%)

### 2.2.4 pH (A)

Biotox Method 05
Test temperature: 25°C±3°C
Instrument used: HQ440D multimeter
The percentage uncertainty for this test is 0.01%(pH 2), 0.03% (pH 4), 0.01% (pH 7) and 0.10% (pH 10) at a coverage factor of 2 and a level of confidence of 95%
Batch numbers of buffers: pH4 – A6124 pH7 – A8219A pH10 – A8150

### 2.2.5 Electrical conductivity (A)

Biotox Method 06
Test temperature: 25°C±3°C
Instrument used: HQ440D multimeter
The percentage uncertainty for this test is 3.3% (1413µS/cm) and 0.23% (147µS/cm) at a coverage factor of 2 and a level of confidence of 95%
Batch numbers of buffers: 1413µS/cm - A8261

Quality assurance

The following quality assurance information would be made available on request:

- In-house reference toxicant test data and control charts.
- Additional lot, batch numbers and raw test data.
- Participation in proficiency testing scheme (SABS, NLA)

### 2.3 Toxicity test results classification system

A risk/hazard category was determined by application of the DEEEP[1] DWA recommended protocols and is broadly based on the hazard classification system of Persoone *et.al.* (2003). This risk category equates to the level of acute/chronic risk posed by the selected potential pollution source (water sample).

After the determination of the percentage effect[1] (EP), obtained with each of the battery of toxicity tests performed, the sample is ranked into one of the following five classes, based on screening testing protocols:

**Hazard classification system for screening tests**

| | |
|---|---|
| Class I | **No acute/short-chronic environmental toxicity hazard -** none of the tests shows a toxic effect (i.e. an effect value significantly higher than that in the control) |
| Class II | **Slight acute/short-chronic environmental toxicity hazard -** a statistically significant (P<0,05) percentage effect is reached in at least one test, but the effect level is below 50% |
| Class III | **Acute/short-chronic environmental toxicity hazard -** the percentage effect level is reached or exceeded in at least one test, but the effect level is 50-99% |
| Class IV | **High acute/short-chronic environmental toxicity hazard -** the 100% percentage effect is reached in at least one test |
| Class V | **Very high acute/short-chronic environmental toxictiy hazard -** the 100% percentage effect is reached in all the tests |

**Weighting:** Each sample is furthermore weighted according to its relative toxicity levels (out of 100%). Higher values indicate that more of the individual tests indicated toxicity within a specific class.

[1] DEEEP = Direct Estimation of Ecological Effect Potential. This is a battery of tests that can measure toxicity of complex mixtures based on a set of parameters stemming from the results of effects, even if all constituents are not known. A hazard class is determined based on the resulting parameters of the battery of tests

[1] EP (Percentage effect) = an effect measured either as a mortality rate or inhibition rate (depending on the type of test). A >10% effect is regarded as slight acute toxicity for *Daphnia* and *Poecilia*, while a >20% effect is regarded as slight short-chronic toxicity for *Allivibrio*. A 50% effect is regarded as an acute/short-chronic toxicity for all of the tests (*Daphnia*, *Poecilia* and *Allivibrio*)

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## 3. Results and discussion

### 3.1 2019-06 survey - water

Refer to table 2 below for individual test results and overall hazard classification of the different samples.

**Table 2:** Test results and risk classification for water samples during June 2019.

| | Results | KF | KFD |
|---|---|---|---|
| wo Water quality | pH @ 25°C (A) | 8.4 | 8.4 |
| | EC (Electrical conductivity) (mS/m) @ 25°C (A) | 565.0 | 765.0 |
| | Dissolved oxygen (mg/l) (NA) | 7.8 | 8.1 |
| *A. fischeri* (bacteria) (A) | Test started on yy/mm/dd | 19/06/28 | 19/06/28 |
| | % 30min inhibition (-) / stimulation (+) (%) | 21 | 33 |
| | EC/LC20 (30 mins) | * | * |
| | EC/LC50 (30 mins) | * | * |
| | Toxicity unit (TU) / Description | no short-chronic hazard | no short-chronic hazard |
| *D. magna* (waterflea) (A) | Test started on yy/mm/dd | 19/07/01 | 19/07/01 |
| | % 48hour mortality rate (-%) | -5 | 0 |
| | EC/LC10 (48hours) | * | * |
| | EC/LC50 (48hours) | * | * |
| | Toxicity unit (TU) / Description | no acute hazard | no acute hazard |
| *P. reticulata* (guppy) (A) | Test started on yy/mm/dd | 19/06/24 | 19/06/24 |
| | % 96hour mortality rate (-%) | 0 | 0 |
| | EC/LC10 (96hours) | * | * |
| | EC/LC50 (96hours) | * | * |
| | Toxicity unit (TU) / Description | no acute hazard | no acute hazard |
| **Overall classification - Hazard class*** ** | | Class I - No acute/short-chronic hazard | Class I - No acute/short-chronic hazard |
| Weight (%) | | 0 | 0 |

**Key:**

***** = EC/LC values not determined, definitive testing required if a hazard was observed and persists over subsequent sampling runs

******* = The overall hazard classification takes into account the full battery of tests and is not based on a single test result. Note that the overall hazard classification is expressed as acute/short-chronic level of toxicity, due to the fact that the *A. fischeri* test is regarded as a short-chronic level of toxicity test and the overall classification therefore contains a degree of short-chronic toxicity assessment.

**Weight (%) =** relative toxicity levels (out of 100%), higher values indicate that more of the individual tests indicated toxicity within a specific class

site/sample name shaded in purple = screening test

site/sample name shaded in orange = definitive test

Samples KF and KFD showed "no acute/short-chronic environmental toxicity hazard" (Class I).

RPM-B-19 TOX

**4. Literature references**

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**END OF REPORT**