Exxaro Matla Coal Mine Biomonitoring Project 2016/2017 Annual Aquatic Ecology Biomonitoring Report 2016/2017

Aquatic Biomonitoring Report

Project Number:

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Prepared for:

Exxaro Coal Mpumalanga (Pty) Ltd

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Name	**Responsibility**	**Signature**	**Date**
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EXECUTIVE SUMMARY

Digby Wells Environmental (Digby Wells) was commissioned by Exxaro Coal Mpumalanga (Pty) Ltd to conduct biannual aquatic ecology biomonitoring as per the conditions of the three approved Water Use Licence conditions at the Exxaro Matla Coal Mine, Mpumalanga, South Africa. The specific Water Use Licences' (WUL) applicable are:

- Matla Colliery, a division of Eyesizwe Coal (Licence No. 24084303 2007/07/16);
- Matla Coal Water Treatment Plant and Brine Ponds (Licence No: 04/B11E/ABCFGIJ/2446 2014/03/17); and
- Matla Coal Mpumalanga (PTY) Ltd (Licence No: 04/B11E/ACFGIJ/3734 2015/07/16).

The watercourses associated with the various approved WUL's conditions are located within the Olifants Water Management Area (WMA) in the B11E and B11D quaternary catchments. Based on the layout of the applicable WUL's the waterbodies were divided into relevant sections namely:

- The Conveyor Tributary;
- The New Shaft Tributary;
- The Rietspruit; and
- The Pans and Impoundments.

Standard River Health Programme (RHP) and ecotoxicological techniques were applied to determine the Present Ecological Status (PES) of the various waterbodies for surveys completed in October 2016 and March 2017. Based on the overall results of the 2016/2017 assessments the following conclusions can be drawn.

The Conveyor Tributary

This study serves as the second monitoring study for the various infrastructures and activities. Based on the results of the assessment, no water quality impacts could be associated with the licensed infrastructure. With regards to habitat quality, limited impacts can be attributed to the infrastructure as no erosion or physical alterations can be observed in the downstream areas. The modified status recorded for the habitat can mainly be attributed to farming activities along the tributary as well as poor rainfall.

The New Shaft Tributary

The PES for the New Shaft Tributary has remained the same as the baseline PES determined by Digby Wells (2015/2016). Overall, no impacts to local aquatic ecology could be identified as a result of the licenced activities for the 2016/2017 survey period.

The Rietspruit

River Diversion Sites

The activities within the Rietspruit catchment have resulted in the largely modified PES classification of the system. The river diversion has altered the instream habitat and subsequently modified the ecological status of the downstream conditions. Based on the previous studies, the biological responses indicate a negative trend which appears to be on the rise. This trend can be attributed to below normal rainfall and subsequent loss of aquatic habitats.

Water Treatment Plant Discharge Sites:

The impact of the discharge of treated water in the lower Rietspruit has appears to be beneficial for biological responses. It has allowed for the presence of sensitive aquatic biota such as *Barbus neefi* and several invertebrate taxa to be present even in poor rainfall conditions. However, an overall increase in Total Dissolved Solids (TDS) was observed at the sites when comparing results to the previous high flow survey (Digby Wells, February 2016). Therefore, attention needs to be given to this overall increase.

The Impoundments and Pans

The limnological assessment of the various partitions of the PCD's at the Matla Coal Mine show that conductivity levels are higher in the water bodies when compared to the river systems. The elevated concentrations of dissolved solids have also led to toxicity assessments showing signs of toxicity at Mine 2 and Mine 3 PCD's with effects to two of the three taxonomic groups of aquatic organisms. Metal content in sediments of the PCD's indicated an overall decrease in the number of enriched elements. This is to be expected in PCD and the water is contained. However, the enrichment of chromium and manganese is still of concern, at all sites not just the impoundments, where future monitoring will develop further temporal trends and confirm the contamination status of the sediments in the PCD's.

Recommendations

Based on the outcomes of the 2016/2017 study the following recommendations can be made:

- Additional sites, at least one, should be selected immediately downstream of the various PCD's at the Exxaro Matla Coal Mine. The selection of these sites would allow for the determination of potential seepage emanating from the polluted water bodies;
- A change was made in the two upper river diversion sites (MAT1 and MAT2) where the newly selected sites monitor the water entering the river diversion. These sites should be monitored in future studies instead of the previously selected sites which were dry during both the high and low flow surveys;
- Based on the assessment of the river diversion and illustrated in the remote sensing monitoring of vegetation study, the banks of the river diversion should be vegetated and erosion issues must be addressed to ensure long-term stability. In addition,

connectivity between the upper and lower Rietspruit requires confirmation and should be further surveyed; and

- The presence of livestock agriculture within the Rietspruit channel should be limited, by increasing the numbers of "no-go areas", as per the approved Wetland Management Plan. In addition, cracks/fractures on the banks of the upper Rietspruit, caused as a result of subsidence should be rehabilitated.

Based on the outcomes of the previous study (Digby Wells 2015/2016) and this study the following monitoring programme will be completed for the duration of the remaining study periods of the Matla Biomonitoring Project (Table 1-1).

Table 1-1: Monitoring Program

Key Performance Indicator	Threshold of Concern	Target
SASS5	-20%	No significant deterioration of SASS5 scores.
ASPT	-10%	No significant differences between upstream and downstream regions
Beatidae	None present	All sites
Pseudocrenilabrus philander or *Tilapia sparmanni*	Absence	Presence

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1 Introduction

Standard water quality monitoring techniques fail to record the dynamic fluctuations of water chemistry within river systems (Wepener, 2005). Aquatic biota, which are permanently exposed to the dynamic conditions, have been used extensively as a means to obtain information pertaining to the fluctuations of contaminants in river systems (Moore and Murphy, 2015).

The aim of the biomonitoring programme was to identify the extent of aquatic related impacts, if any, within the various water bodies associated with the Exxaro Matla Coal Mine during the 2016/17 period. This was done by applying standard River Health Programme (RHP) and ecotoxicological techniques to determine the Present Ecological Status (PES) of the associated water bodies. The study is being carried out to ensure compliance with the conditions of the current Water Use Licenses (WUL).

2 Terms of Reference

Exxaro Coal Mpumalanga (Pty) Ltd acquired the services of Digby Wells Environmental (Digby Wells) to conduct aquatic ecological specialist studies as per the conditions of a various environmental authorizations (EIA - according to the National Environmental Management Act, Act no. 107 of 1998; EMP - according to the Mineral and Petroleum Resources Development Act, Act No. 28 of 2002 and the three approved WUL's - according to the National Water Act, Act No. 36 of 1998) at the Exxaro Matla Coal Mine, Mpumalanga, South Africa. The specific Water Use Licences' (WUL) applicable are (as quoted directly from the three licences):

- Matla Colliery, a division of Eyesizwe Coal (Licence No. 24084303);
- Matla Coal Water Treatment Plant and Brine Ponds (Licence No: 04/B11E/ABCFGIJ/2446); and
- Matla Coal Mpumalanga (PTY) Ltd (Licence No: 04/B11E/ACFGIJ/3734).

3 Study Area

The waterbodies that are associated with the various approved environmental authorizations/licences and conditions are located within the Olifants Water Management Area (WMA) in the B11E and B11D quaternary catchments as illustrated in Figure 3-1. Various types of water bodies are associated with the study area and include:

- River systems;
- Un-channelled Wetlands;
- Pollution Control Dams; and
- Freshwater pans.

Based on the location of the activities, three Sub-Quaternary Reaches (SQR's) are associated with the study area. It is noted that the watercourse in the B11D quaternary catchment has not been designated a SQR value. However, the tributary assessed in this catchment reports to the B11D-01366 SQR. This tributary is referred to as the New Shaft Tributary in this study. The PES assessment will be calculated based on the layout of the SQR's and monitoring points as detailed in Figure 3-2.

The selection of sites was based on the approved WUL conditions which stipulated the location of various sites. In addition, sites were selected based on the previous studies which have taken place in the project area (e.g. No 3 Mine River diversion sampling sites). It is further noted that sites have been selected around certain infrastructures and activities such as discharge points and conveyor crossings. Fixed point photographs obtained at the various sites during the surveys are presented in Appendix A.

Sites MAT1 and MAT2 are situated along the upstream section of the Rietspruit, below a farm dam near the upper end of the Matla river diversion. MAT1 lies directly below the farm dam and runs into MAT2 which is an impoundment along the river course. In the previous study conducted by Digby Wells during the 2015/2016 study period, site MAT1 was recorded as dry during both surveys and the start of the river diversion below the farm dam was assessed instead (dry during both surveys as well). The impoundment (MAT2) found just below the initial MAT1 site contained water during both surveys during the 2015/2016 study.

However, no water appeared to be flowing out of the impoundment and it was found to be dry during the 2016/2017 study period. Therefore, it is proposed that the sites officially shift to monitor the water quality entering the river diversion. The proposed new sites are depicted in Appendix A where MAT1 represents the farm dam and MAT2 represents the river diversion below the dam. The initial sites were used in this study (both dry during both surveys) but it is suggested that the new sites are monitored in the future studies. Lastly, a new site (MAT New) was selected downstream of the initial impoundment (MAT2) and was assessed during the high flow survey. The GPS coordinates for this site are 26°15'4.69"S 29° 02'18.10"E. This site provides a better indication of the aquatic health compared to the upstream impounded site. Therefore, it is proposed that this site is also included in future monitoring.

An official change has also occurred with the sites situated along the New Shaft Tributary. Site NS2 in this study now represents the downstream site along this watercourse which was previously named NS3. The previous NS2 site has now been moved slightly upstream to an impoundment located along the tributary in order to conduct chemical analyses. This new impounded site is now named NS3. This site acts as a more permanent water body allowing for accurate or reliable chemical analysis of water along this reach. The downstream site, NS2, is also sufficient enough to monitor impacts coming from the previous side channel NS2 site as well as from the upper impounded site and NS1 site.

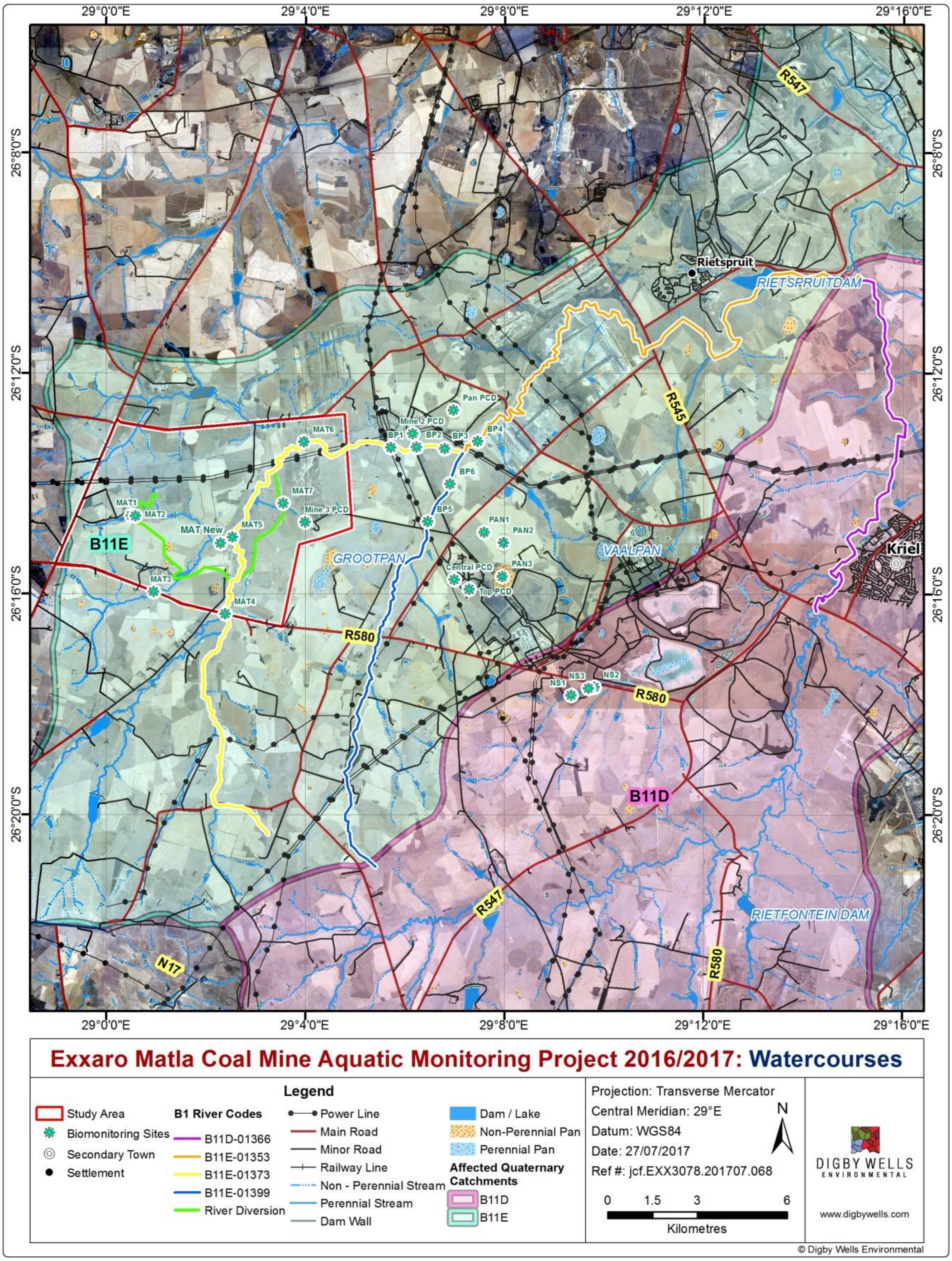

Figure 3-1: B11E and B11D quaternary catchments associated with the Matla Coal Mine biomonitoring project

Figure 3-2: Sub-Quaternary-Reaches associated with the Exxaro Matla Coal Mine biomonitoring project

4 Desktop Information

4.1 Blesbokspruit (B11E-01399)

The current land uses in the relevant SQR catchment area includes extensive underground coal mining, livestock farming, irrigated and dryland maize/soya agriculture. The SQR B11E-01373 is predominantly a typical Highveld river system, with grasslands and limited woody riparian vegetation. The SQR B11E-01399 is an un-channelled wetland system and thus does not conform to River Health Program (RHP) methods and thus will only include habitat based and water quality assessments. This SQR (B11E-01399) is referred to in this study as the Conveyor Tributary.

When considering the abovementioned potential impacts and the most recent desktop information available, it is important to consider the desktop information in the form of the PES; Attainable Ecological Class (AEC); Ecological Importance (EI) and Ecological Sensitivity (ES) which are presented below (Table 4-1) (DWS 2013).

Table 4-1: Ecological status of the B11E-01373 SQR (DWS, 2013)

Component	Category
PES	Largely natural (class B)
AEC	Largely natural (class B)
EI	Moderate
ES	High

Predominant impacts associated with the SQR are listed below:

- Small impacts from algal growth, low water crossings, exotic vegetation, fire, and roads;
- Moderate impacts from agricultural lands, erosion, sedimentation, small dams, trampling and vegetation removal;
- Large impacts from abstraction, increased flows, and mining runoff/effluent;
- No serious impacts were identified; and
- No critical impacts were identified.

According to the National Freshwater Ecological Priority Area's (NFEPA) the catchment is not considered a priority area (Nel et al., 2011).

4.2 Rietspruit (B11E-01353)

This SQR is the endpoint for activities taking place in upstream B11E-01373 and B11E-01399 SQR's. This SQR will only be considered up to site BP4 and thus does not include the river reach below it. This river course will be assessed with the B11E-01373 SQR and together are referred to the Rietspruit. The current land uses in the relevant SQR catchment area includes extensive underground and opencast coal mining and dryland maize/soya agriculture. When considering the abovementioned potential impacts and the most recent desktop information available, it is important to consider the desktop information below (Table 4-2).

Table 4-2: Ecological status of the B11E-01353 SQR (DWS, 2013)

Component	Category
PES	Seriously Modified (class E)
AEC	Class B
EI	Moderate
ES	High

This modified PES is a result of:

- Small impacts from agricultural lands, exotic vegetation and inundation;
- Moderate impacts from low water crossings;
- Large impacts from abstraction, increased flows, erosion, sedimentation, and small dams;
- Serious impacts from canalization; and
- Critical impacts mining, vegetation removal and mining effluent and runoff.

According to the National Freshwater Ecological Priority Area's (NFEPA) the catchment is not considered a priority area (Nel et al, 2011). Although wetlands associated with the SQR regions are considered to be wetland priority areas.

5 Methodology

Two surveys were completed during the course of the aquatic assessment, these included surveys during the low flow period (October 2016), and the high flow period (March 2017). A breakdown of the different methods/techniques used in the study are explained in the below sections.

5.1 Water Quality

The physical and chemical properties of water that determine its fitness for a variety of uses and for the protection of the health and integrity of aquatic ecosystems refers to the quality of water (DWAF, 1996). The various water quality parameters were all taken *in situ*. These parameters include pH, temperature (°C), conductivity (µS/cm) and oxygen content (mg/l) using calibrated water quality meters. These values were measured using an Extech DO610 multimeter water quality instrument.

The chemical analysis of water at the sites was also determined using standard methods based on the water sampling guidelines (WRC, 2000). Water quality samples were taken once during the low flow assessment at sites in impoundments and once during the high flow survey in the impoundments and selected river sites. This adjustment was made based on an update in the approved WUL (04/B11E/ABCFGIJ/2446) at the Exxaro Matla Coal Mine.

5.1.1 Toxicity

Screening toxicity assessments using three taxonomic groups was completed in the various Pollution Control Dams (PCD's). Each sample is 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.

5.2 Diatoms

Diatom samples from the pans and PCD's were collected and analysed according to the methodology described by Taylor *et al.* (2005). Two indices, namely the Specific Pollution Sensitivity Index (SPI; CEMAGREF, 1982) and the Biological Diatom Index (BDI; Lenoir & Coste, 1996) were used in the diatom assessment. In addition, the Percentage of Pollution Tolerant Valves (%PTV; Kelly & Whitton, 1995) was used to indicate organic pollution.

5.3 Sediment Quality

Sediment samples were collected in triplicate using a plastic spoon, where the top 2/3 cm of the sediment surface was utilised (Simpson et al. 2005). Triplicates were then combined to form a composite sample of each site. Sediment samples were then placed into polyethylene containers and analysed according to USEPA 1999 guidelines with ICP-Mass Spectrophotometer (MS) at Waterlab (PTY) Ltd in South Africa. The Enrichment Factor (EF) was applied according to the methods set out in Pheiffer et al. (2014) with iron being used as the reference element. Average upper crustal values from Wedephol (1995) were used in this study. Only sites which were inundated are included in the sediment assessment.

5.4 Intermediate Habitat Integrity Assessment

Habitat was assessed and characterised according to section D of the "Procedure for Rapid Determination of Resource Directed Measures for River Ecosystems, 1999."

The IHIA model was used to assess the integrity of the habitats from a riparian and in-stream perspective. The habitat integrity of a river refers to the maintenance of a balanced composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region (Kleynhans 1996). The criteria utilised in the assessment of habitat integrity in the current study are presented in the table below (Table 5-1).

Table 5-1: Criteria used in the assessment of habitat integrity (Kleynhans, 1996)

Criterion	Relevance
Water abstraction	Direct impact on habitat type, abundance and size. Also implicated in flow, bed, channel and water quality characteristics. Riparian vegetation may be influenced by a decrease in the supply of water.
Flow modification	Consequence of abstraction or regulation by impoundments. Changes in temporal and spatial characteristics of flow can have an impact on habitat attributes such as an increase in duration of low flow season, resulting in low availability of certain habitat types or water at the start of the breeding, flowering or growing season.
Bed modification	Regarded as the result of increased input of sediment from the catchment or a decrease in the ability of the river to transport sediment (Gordon et al. 1993). Indirect indications of sedimentation are stream bank and catchment erosion. Purposeful alteration of the stream bed, e.g. the removal of rapids for navigation (Hilden & Rapport, 1993) is also included.
Channel modification	May be the result of a change in flow, which may alter channel characteristics causing a change in marginal instream and riparian habitat. Purposeful channel modification to improve drainage is also included.
Water quality modification	Originates from point and diffuse point sources. Measured directly or alternatively agricultural activities, human settlements and industrial activities may indicate the likelihood of modification. Aggravated by a decrease in the volume of water during low or no flow conditions.
Inundation	Destruction of riffle, rapid and riparian zone habitat. Obstruction to the movement of aquatic fauna and influences water quality and the movement of sediments (Gordon et al. 1992).
Exotic macrophytes	Alteration of habitat by obstruction of flow and may influence water quality. Dependent upon the species involved and scale of infestation.
Exotic aquatic fauna	The disturbance of the stream bottom during feeding may influence the water quality and increase turbidity. Dependent upon the species involved and their abundance.
Solid waste disposal	A direct anthropogenic impact which may alter habitat structurally. Also a general indication of the misuse and mismanagement of the river.
Indigenous vegetation removal	Impairment of the buffer of vegetation forms to the movement of sediment and other catchment runoff products into the river (Gordon et al. 1992). Refers to physical removal for farming, firewood and overgrazing.
Exotic vegetation encroachment	Excludes natural vegetation due to vigorous growth, causing bank instability and decreasing the buffering function of the riparian zone. Allochtonous organic matter input will also be changed. Riparian zone habitat diversity is also reduced.

Criterion	Relevance
Bank erosion	Decrease in bank stability will cause sedimentation and possible stability and or collapse of the river bank resulting in a loss or modification of both instream and riparian habitats. Increased erosion can be the result of natural vegetation removal, overgrazing or exotic vegetation encroachment.

The relevant criteria is then weighted and scored according to Kleynhans (1996), as seen in Table 5-2 and Table 5-3.

Table 5-2: Table giving descriptive classes for the assessment of modifications to habitat integrity (Kleynhans, 1996)

Impact Category	Description	Score
None	No discernible impact or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are also very small.	1-5
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are also limited.	6-10
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced.	11-15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	16-20
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	21-25

Table 5-3: Criteria and weights used for the assessment of habitat integrity (Kleynhans, 1996)

Instream Criteria	Weight	Riparian Zone Criteria	Weight
Water abstraction	14	Indigenous vegetation removal	13
Flow modification	13	Exotic vegetation encroachment	12
Bed modification	13	Bank erosion	14
Channel modification	13	Channel modification	12
Water quality	14	Water abstraction	13

Instream Criteria	Weight	Riparian Zone Criteria	Weight
Inundation	10	Inundation	11
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Water quality	13
Solid waste disposal	6		
TOTAL	**100**	**TOTAL**	**100**

Scores are then calculated based on ratings received from the assessment. The estimated impacts of the criteria are then summed and expressed as a percentage to arrive at a provisional habitat integrity assessment. The scores are then placed into the Intermediate habitat integrity categories (Kleynhans, 1996) as seen in Table 5-4.

It should be noted that the IHIA was based on regions assessed in the current studies and therefore may only constitute the assessment of conditions within a 50 km length of the potentially effected water courses.

Table 5-4: Intermediate habitat integrity categories (Kleynhans, 1996)

Category	Description	Score
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-90
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0-19

5.5 Aquatic Invertebrate Assessment

Macroinvertebrate assemblages are good indicators of localised conditions because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life. They are particularly well-suited for assessing site-specific impacts (upstream and downstream studies) (Barbour et al. 1999). Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects (Barbour et al. 1999). The assessment and monitoring of benthic macroinvertebrate communities forms an integral part of the monitoring of the health of an aquatic ecosystem.

5.5.1 Integrated Habitat Assessment System (IHAS)

The IHAS was specifically designed to be used in conjunction with the SASS5, benthic macroinvertebrate assessment. The IHAS assesses the availability of the biotopes at each site and expresses the availability and suitability of habitat for macroinvertebrates, this is determined as a percentage, where 100% represents "ideal" habitat availability. A description based on the IHAS percentage scores is presented in Table 5-5.

Table 5-5: Description of IHAS scores with the respective percentage category (McMillan, 1998)

IHAS Score (%)	Description
>75	Very Good
65–74	Good
55–64	Fair/Adequate
<55	Poor

5.5.2 South African Scoring System

The SASS5 is the current index being used to assess the status of riverine macroinvertebrates in South Africa. According to Dickens and Graham (2002), the index is based on the presence of aquatic invertebrate families and the perceived sensitivity to water quality changes of these families. Different families exhibit different sensitivities to pollution, these sensitivities range from highly tolerant families (e.g. Chironomidae) to highly sensitive families (e.g. Perlidae). SASS results are expressed both as an index score (SASS score) and the Average Score Per recorded Taxon (ASPT value).

Sampled invertebrates were identified using the “Aquatic Invertebrates of South African Rivers” Illustrations book, by Gerber and Gabriel (2002). Identification of organisms was made to family level (Thirion et al, 1995; Dickens & Graham, 2002; Gerber & Gabriel, 2002).

All SASS5 and ASPT scores are compared with the SASS5 Data Interpretation Guidelines (Dallas, 2007) for the Highveld lower ecoregion. This method seeks to develop biological bands depicting the various ecological states and is derived from data contained within the Rivers Database and supplemented with other data not yet in the database.

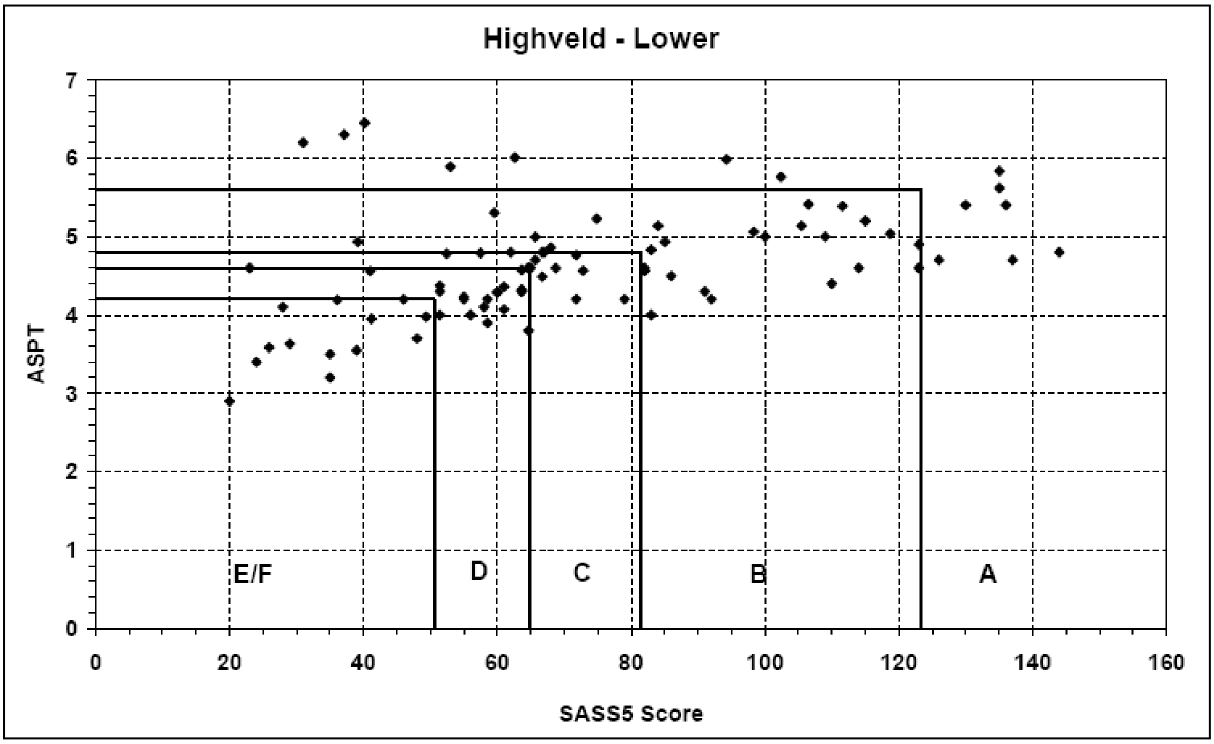

Figure 5-1: Guidelines used for the interpretation and classification of the SASS5 scores (Dallas, 2007)

5.5.3 Macroinvertebrate Assessment Index

The Macroinvertebrate Response Assessment Index (MIRAI) was used to provide a habitat-based cause-and-effect foundation to interpret the deviation of the aquatic invertebrate community from the calculated reference conditions for the Highveld Lower. This does not preclude the calculation of SASS5 scores if required (Thirion, 2007). The four major components of a stream system that determine productivity for aquatic macroinvertebrates are as follows:

- Flow regime;
- Physical habitat structure;
- Water quality; and
- Energy inputs from the watershed Riparian vegetation assessment.

The results of the MIRAI will provide an indication of the current ecological category and therefore assist in the determination of the PES.

5.6 Fish Response Assessment Index (FRAI)

The information gained using the Fish Response Assessment Index (FRAI) gives an indication of the PES of the river based on the fish assemblage structures observed. All fish were identified in the field and released at the point of capture. Fish species were identified using the guide Freshwater Fishes of Southern Africa (Skelton, 2001). The identified fish species were compared to those expected to be present for the quaternary catchment. The expected fish species list was developed from a literature survey and included sources such as (Kleynhans et al. 2007) and Skelton (2001). It is noted that the FRAI Frequency of Occurrence ratings are calculated based on the habitat present at the sites.

5.7 Present Ecological Status (Ecostatus)

Ecological classification refers to the determination and categorisation of the integrity of the various selected biophysical attributes of ecosystems compared to the natural or close to natural reference conditions (Kleynhans and Louw, 2007). For the purpose of this study ecological classifications have been determined for biophysical attributes for the associated water course. This was completed using the river ecoclassification manual by Kleynhans and Louw (2007).

6 Results

A breakdown of the results obtained during the study are presented in the below sections.

6.1 Water Quality

6.1.1 *In situ* Analyses

Table 6-1 presents the *in situ* water quality results for the river biomonitoring points considered during the study. Table 6-2 presents the *in situ* results obtained during the March 2017 high flow survey for the tested PCDs and pans.

Table 6-1: In situ water quality results for the October 2016 and March 2017 surveys (rivers)

Site	Guidelines	MAT3	MAT4	MAT5	MAT6	MAT7	MAT New	BP1	BP2	BP3	BP4	BP5	BP6	NS1	NS2	NS3
Low flow (October 2016)																
pH	6.5–9	DRY	7.3	DRY	6.9	DRY	-	6.5	7.7	6.4	6.6	DRY	DRY	DRY	6.2	6.6
Temperature ºC	5–30	DRY	21	DRY	20	DRY	-	25	28	25	26	DRY	DRY	DRY	26	25
Conductivity	<700	DRY	470	DRY	308	DRY	-	37.0	185	73.0	730	DRY	DRY	DRY	635	160
Dissolved oxygen	>5	DRY	6.7	DRY	7.0	DRY	-	7.9	8.2	5.8	4.2	DRY	DRY	DRY	2.0	4.2
High flow (March 2017)																
pH	6.5–9	6.8	7.3	7.3	7.5	7.7	7.2	7.6	8.1	8.7	7.8	DRY	DRY	7.1	6.6	7.6
Temperature ºC	5–30	24	28	23	25	21	24	23	24	24	26	DRY	DRY	21	24	23
Conductivity	<700	20.0	183	192	165	15.0	220	350	270	293	274	DRY	DRY	250	587	224
Dissolved oxygen	>5	3.2	6.1	4.6	5.2	5.1	4.1	6.0	6.1	5.7	6.1	DRY	DRY	3.0	2.5	7.6
*Red shading indicates water quality constituents that exceed the recommended guideline values stipulated by DWAF (1996).																

The pH at BP3 and NS2 did not fall within the recommended guideline values during the low flow survey. The conductivity values at BP4 as well as the dissolved oxygen concentration at BP4, NS2 and NS3 did not meet the recommended guideline values during the low flow survey. The dissolved oxygen concentration at MAT3, MAT5, MAT New, NS1 and NS2 were the only water quality values (for the river biomonitoring sites) that did not meet the recommended guidelines during the high flow survey.

Table 6-2: In situ water quality results for the March 2016 survey (impoundments and pans)

Site	Guidelines	Pan 1	Pan 2	Central PCD	Top PCD	Mine 2 PCD	Mine 3 PCD	Pan PCD
pH	6.5–9	9.5	9.2	9.4	8.8	8.2	11	8.8
Temperature ºC	5–30	28	30	25.5	24.4	26	25	25
Conductivity	<700	6000	1600	1448	1680	370	4200	2300
Dissolved oxygen	>5	2.1	3.2	5.12	3.73	5.1	4.5	6.1
*Red shading indicates water quality constituents that exceed the recommended guideline values stipulated by DWAF (1996).								

It is important to note that the red shading indicates constituents that are exceeding the guideline values. However, these guidelines do not apply for pans.

The *in situ* pH value for the Central PCD and Mine 3 PCD exceeded the recommended guideline values (DWAF, 1996). The conductivity recorded at the Central PCD, Top PCD, Mine 3 PCD and the Pan PCD exceeded the guideline value of 700 µS/cm. The dissolved oxygen concentration at the Top PCD and the Mine 3 PCD was recorded below the guideline value of 5 mg/l. This is usually expected in stagnant water bodies as explained in The Impoundments and Pans discussion section.

6.1.2 *Ex Situ* Analyses

The chemical analysis of the water samples taken from the various river biomonitoring sites as well as the PCDs and pans are represented in Table 6-3, Table 6-4 and Table 6-5.

Table 6-3: Chemical analysis of water (in mg/l) from the upper Rietspruit sites and site NS2 along the New Shaft Tributary (March 2017)

Constituent/Site	MAT2	MAT5	MAT6	MAT7	MAT New	NS2
Al	<0.100	<0.100	<0.100	0.230	<0.100	<0.100
As	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cd	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Co	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Cr	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Cu	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Fe	0.480	0.181	0.079	0.382	0.073	<0.025
Mn	0.496	0.029	0.081	<0.025	<0.025	<0.025
Ni	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Pb	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sulphate	<2.000	16.00	20.00	14.00	<2.000	38.00
Nitrate	<0.100	0.200	<0.100	0.300	0.200	0.400
Nitrite	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphate	2.800	2.500	0.200	**10.00**	<0.200	**13.00**
Ammonia	1.200	0.300	0.600	0.300	0.400	0.300
Bold values indicate elements in high concentrations and should be carefully monitored in future studies.						

Table 6-4: Water quality results of sites (in mg/l) associated with the pumping of treated effluent in March 2017 (Lower Rietspruit sites)

Constituent/Site	BP1	BP2	BP3
Al	<0.100	0.190	0.253
As	<0.010	<0.010	<0.010
Cd	<0.003	<0.003	<0.003
Co	<0.025	<0.025	<0.025
Cr	<0.025	<0.025	<0.025
Cu	<0.010	<0.010	<0.010

Constituent/Site	BP1	BP2	BP3
Fe	0.117	0.272	0.321
Mn	<0.025	<0.025	<0.025
Ni	<0.025	<0.025	<0.025
Pb	<0.010	<0.010	<0.010
Sulphate	35.00	25.00	34.00
Nitrate	0.400	0.300	0.300
Nitrite	<0.050	<0.050	<0.050
Phosphate	0.300	4.800	1.400
Ammonia	0.200	0.200	0.100

Table 6-5: Chemical analysis of water from the pollution control impoundments and pans (mg/l)

Constituent/Site	Pan PCD	Top PCD	Central PCD	Mine 2 PCD	Mine 3 PCD	Pan 1	Pan 2
Low flow							
Al	<0.100	<0.100	<0.100	<0.100	0.100	DRY	DRY
As	<0.010	<0.010	0.011	<0.010	<0.010	DRY	DRY
Cd	0.009	0.003	0.006	<0.003	<0.003	DRY	DRY
Co	0.091	0.078	0.087	<0.025	<0.025	DRY	DRY
Cr	<0.025	<0.025	<0.025	<0.025	<0.025	DRY	DRY
Cu	<0.010	<0.010	<0.010	<0.010	<0.010	DRY	DRY
Fe	0.036	0.044	0.091	0.116	0.028	DRY	DRY
Mn	<0.025	<0.025	<0.025	0.060	0.268	DRY	DRY
Ni	<0.025	<0.025	<0.025	<0.025	0.032	DRY	DRY
Pb	0.014	0.041	<0.010	<0.010	<0.010	DRY	DRY
Sulphate	1427	782.0	580.0	39.00	139.0	DRY	DRY
Nitrate	0.600	0.100	0.200	0.200	<0.100	DRY	DRY
Nitrite	<0.050	0.200	0.300	<0.050	<0.050	DRY	DRY
Phosphate	0.400	<0.200	0.700	0.600	4.700	DRY	DRY
Ammonia	0.700	0.300	0.200	3.600	0.100	DRY	DRY

Constituent/Site	Pan PCD	Top PCD	Central PCD	Mine 2 PCD	Mine 3 PCD	Pan 1	Pan 2
High flow							
Al	<0.100	<0.100	<0.100	<0.100	<0.100	**11.00**	0.201
As	0.013	0.021	<0.010	<0.010	<0.010	<0.010	<0.010
Cd	<0.003	<0.003	<0.003	<0.003	<0.003	0.010	<0.003
Co	0.030	<0.025	<0.025	<0.025	<0.025	0.082	<0.025
Cr	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Cu	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Fe	<0.025	<0.025	<0.025	0.172	<0.025	8.840	1.940
Mn	0.054	<0.025	0.354	0.058	0.192	0.293	0.630
Ni	<0.025	<0.025	<0.025	<0.025	<0.025	0.033	<0.025
Pb	0.015	0.014	0.022	<0.010	<0.010	0.043	0.013
Sulphate	937.0	828.0	495.0	41.00	92.00	686.0	6.000
Nitrate	0.100	0.400	<0.100	0.100	<0.100	1.500	<0.100
Nitrite	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphate	0.300	0.700	1.000	0.700	6.500	3.900	0.700
Ammonia	0.300	0.200	1.100	0.200	4.600	0.100	**9.800**
Bold values indicate elements in high concentrations and should be carefully monitored in future studies.							

6.2 Toxicity

The results of the toxicity assessment in the pollution control dams are presented in Table 6-6.

Table 6-6: Toxicity results for the impoundments during the March 2017 survey

Site	Taxa			Weight (%)	Hazard
	Water Fleas	Guppies/ *Selanstrum*	Algae		
Top PCD	<1	<1	<1	0	No acute/chronic hazard
Central PCD	<1	<1	<1	0	No acute/chronic hazard
Mine 2 PCD	>100	>100	<1	67	High acute hazard

Site	Taxa			Weight (%)	Hazard
	Water Fleas	Guppies/ *Selanstrum*	Algae		
Mine 3 PCD	>100	>100	<1	67	High acute hazard
Pan PCD	<1	<1	<1	0	No acute/chronic hazard

Mine 2 and Mine 3 PCDs were the only samples that showed toxicity hazard and were classified as class IV samples (high acute environmental hazard). This is to be expected from PCDs. Water is assumed to be contained and downstream monitoring sites are proposed.

6.3 Diatoms

All diatom samples from the PCD's and Pans were prepared for analysis. However, there were insufficient diatom valves in the Pan 2 and Mine 2 PCD samples in order make correct environmental inferences as illustrated in Table 6-7.

Table 6-7: Diatom species and their abundances for the PCD's and Pans

Taxa	Mine 3 PCD	PAN1	PAN2	PAN PCD	Top PCD	Central PCD	Mine 2 PCD
Achnanthes oblongella Oestrup	0	0	0	0	0	12	0
Achnanthes subaffinis Cholnoky	6	0	13	5	0	15	0
Achnanthidium exiguum (Grunow) Czarnecki	0	0	0	0	0	22	0
Achnanthidium minutissimum (Kützing) Czarnecki	0	0	0	0	0	4	0
Amphora copulata (Kütz) Schoeman & Archibald	0	0	0	4	0	0	0
Amphora ovalis (Kützing) Kützing var.*ovalis*	0	10	0	0	0	6	0
Amphora veneta Kützing	0	33	0	0	0	6	0
Anomoeoneis sphaerophora (Ehr.) Pfitzer	25	0	0	0	0	0	0
Aulacoseira granulata (Ehr.) Simonsen	0	0	0	0	0	38	0
Caloneis bacillum (Grunow) Cleve	0	0	0	0	6	6	0
Cocconeis pediculus Ehrenberg	0	0	0	0	5	0	0
Cocconeis placentula Ehrenberg var. *placentula*	0	0	0	3	0	0	0

Taxa	Mine 3 PCD	PAN1	PAN2	PAN PCD	Top PCD	Central PCD	Mine 2 PCD
Craticula buderi (Hustedt) Lange-Bertalot	6	0	18	0	6	0	0
Craticula halophila (Grunow ex Van Heurck) Mann	0	0	16	0	0	0	0
Cyclotella meneghiniana Kützing	3	0	0	80	19	11	6
Cymbella turgidula Grunow	0	0	0	0	6	0	0
Diadesmis confervacea Kützing var. *confervacea*	0	0	0	0	0	3	2
Diploneis ovalis (Hilse) Cleve	0	0	0	0	8	0	0
Encyonema minutum (Hilse in Rabh.) D.G. Mann	0	0	0	3	0	2	0
Encyonema species	0	0	0	0	0	3	0
Eolimna subminuscula (Manguin) Moser Lange-Bertalot & Metzeltin	5	0	9	0	0	0	0
Epithemia *adnata* (Kützing) Brebisson	6	0	0	0	27	20	0
Fragilaria capucina Desmazieres var.*capucina*	0	0	0	4	0	0	12
Frustulia crassinervia (Breb.) Lange-Bertalot et Krammer	0	0	0	0	19	0	0
Gomphonema affine Kützing	0	0	0	0	6	0	0
Gomphonema gracile Ehrenberg	0	0	0	2	6	8	0
Gomphonema minutum(Ag.) Agardh f. *minutum*	0	0	8	9	6	0	0
Gomphonema parvulum (Kützing)	0	0	0	8	0	0	0
Luticola goeppertiana (Bleisch in Rabenhorst) D.G. Mann	0	0	0	0	0	9	0
Luticola mutica (Kützing) D.G. Mann	0	0	11	0	0	11	0
Mastogloia smithii Thwaites	0	0	0	0	51	6	0
Melosira varians Agardh	0	0	0	0	0	31	0
Navicula antonii Lange-Bertalot	30	0	15	50	7	6	0
Navicula cryptotenella Lange-Bertalot	6	0	0	0	0	0	0
Navicula cryptocephala Kützing	3	0	0	0	15	5	0
Navicula erifuga Lange-Bertalot	3	0	0	31	19	0	6
Navicula gregaria Donkin	22	0	0	4	0	0	0
Navicula rostellata Kützing	3	0	0	10	0	0	0

Taxa	Mine 3 PCD	PAN1	PAN2	PAN PCD	Top PCD	Central PCD	Mine 2 PCD
Navicula symmetrica Patrick	6	0	0	0	0	0	0
Navicula trivialis Lange-Bertalot var. *trivialis*	0	0	0	22	16	6	0
Navicula veneta Kützing	15	15	0	49	0	10	0
Navicula zanoni Hustedt	0	0	0	0	20	0	0
Nitzschia amphibia Grunow f.*amphibia*	26	35	36	22	6	42	5
Nitzschia palea (Kützing) W.Smith	119	145	105	50	36	54	20
Nitzschia sp.1	0	132	0	12	16	10	3
Planothidium frequentissimum(Lange-Bertalot) Lange-Bertalot	0	0	0	0	0	3	0
Planothidium rostratum (Oestrup) Lange-Bertalot	0	0	0	0	0	0	2
Planothidium engelbrechtii (Choln.) Round & Bukhtiyarova	0	0	0	0	0	6	0
Pleurosigma salinarum (Grunow) Cleve & Grunow	0	0	0	3	65	14	0
Pseudostaurosira brevistriata (Grun.in Van Heurck) Williams & Round	0	0	0	0	0	6	0
Tabularia fasciculata (Agardh)Williams et Round	0	30	0	29	22	25	0
Tryblionella hungarica (Grunow) D.G. Mann	116	0	19	0	7	0	0
Tryblionella littoralis (Grunow in Cl. & Grun.) D.G. Mann	0	0	0	0	6	0	0
Total	400	400	250	400	400	400	56
Nutrients							
Salinity							
Dominant							
Insufficient cells							

A total of 53 diatom species were recorded in PCD's and Pans. The dominant diatom species recorded at the sites, included *Nitzschia palea* and *Nitzschia amphibia* which indicate eutrophic and polluted waters. The subdominant species, *Tabularia fasciculata* and *Nitzschia sp.* also indicate eutrophic waters and polluted conditions. Table 6-8 below provides the ecological classification for water quality at the PCD's and Pans according to the sampled diatom assemblages.

Table 6-8: Ecological descriptors for the PCD's and Pans

Sites	pH	Salinity	Nitrogen uptake	Oxygen requirements	Saprobity	Trophic state
Mine 3 PCD	Alkaline	Brackish-fresh	N-autotrophic tolerant	Low	α-mesosaprobic	Eutrophic
PAN 1	Circumneutral	Fresh-brackish	N-heterotrophic facultative	Low	Polysaprobic	Hyper-eutrophic
PAN PCD	Alkaline	Brackish-fresh	N-heterotrophic obligatory	Low	α-meso-polysaprobic	Eutrophic
Top PCD	Alkaline	Fresh-brackish	N-autotrophic tolerant	Moderate	α-mesosaprobic	Eutrophic
Bot PCD	Alkaline	Fresh-brackish	N-autotrophic tolerant	Moderate	α-mesosaprobic	Eutrophic

The diatom assemblages mainly comprised of species with a preference for fresh brackish (<500 µS/cm) to brackish-fresh (500 - 1000 µS/cm), circumneutral (pH 7) to alkaline (pH >7) waters and eutrophic to hypereutrophic conditions.

The %PTV scores for the diatom samples are provided in Table 6-9 below.

Table 6-9: Diatom index scores for the PCD's and Pans

Sites	%PTV	SPI	BDI	Ecological Water Quality
Mine 3 PCD	35.8	7.1	6.3	**Poor**
PAN1	33	3.3	4.4	**Bad**
PAN PCD	6	6.4	7.9	**Moderate**
Top PCD	7.3	9.8	11.9	**Moderate**
Central PCD	3.3	8.9	9.2	**Moderate**

The %PTV scores varied amongst the sites ranging from 3.3% at the Central PCD to 35.8% at Mine 3 PCD indicating good to bad water quality.

6.4 Sediment Quality

The results of the sediment assessment are provided in the Table 6-10 and Table 6-11 below.

Table 6-10: Metal content in sediment obtained during the Low flow (October 2016) (mg/kg)

Site/Element	Al	As	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	U	Zn
BP1	41441.02	0.833328	<4.00	38.8307	9.512069	4.390897	25644.94	0	1300.68	185.1277	25.69639	<4.00	9.154475
Mat3	13356.26	0.784954	<4.00	52.36878	0.601077	1.831849	13173.93	0	1684.526	113.8706	17.53262	<4.00	0
Mat4	18802.08	0.276786	<4.00	20.94436	0.502941	2.544598	15005.2	0	752.8988	114.1827	12.33225	<4.00	3.019835
Mat6	43840.06	0.601101	<4.00	42.22983	0.484232	5.732706	29459.42	0	604.5582	212.9682	17.46927	<4.00	8.24456
NS2	81704.92	0.993011	<4.00	56.77396	2.752856	7.60694	40415.03	0	402.6389	303.8791	29.05715	<4.00	17.881
NS3	12676.53	0.195183	<4.00	10.17025	0.135721	0.547306	8243.902	0	144.7421	60.93692	8.989639	<4.00	0
Pan PCD	23872.05	4.935709	<4.00	231.0923	1.459789	15.82122	100511	0	1863.255	672.3426	68.58771	<4.00	4.822524
Mine 2 PCD	41960.82	0.713065	<4.00	22.90525	1.306628	3.130953	8575.77	0	200.7197	63.83106	23.2961	<4.00	9.512245
Mine 3 PCD	27330.67	0.936056	<4.00	32.9438	2.877614	4.44736	27152.34	0	668.9324	188.1197	26.2841	<4.00	7.15653

Table 6-11: Metal content in sediment obtained during the High flow (March 2017) (mg/kg)

Site/Element	Al	As	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	U	Zn
BP1	21911.71	0.399521	0	6.392329	21.17459	3.595685	15011.99	0	1246.105	116.66	17.97843	<4.00	1.997603
BP2	8931.282	0.399521	0	1.598082	16.77986	1.598082	10805.03	0	419.0971	77.10747	7.19137	<4.00	0
BP3	9322.813	0.399521	0	3.196165	10.38753	1.997603	8232.121	0	460.6472	57.93048	12.38514	<4.00	0
BP4	24025.17	0.399521	0.399521	1.997603	17.17938	2.796644	12083.5	0	258.8893	86.69596	15.98082	<4.00	1.598082
Mat5	20193.77	0.799041	0	3.595685	19.17699	3.196165	16294.45	0	598.4818	114.6624	16.38034	<4.00	0.799041
Mat6	36050.74	0.399521	0	4.794247	46.34439	7.19137	30305.63	0	623.2521	199.3608	43.54774	<4.00	11.98562
Mat7	27385.14	2.796644	0	57.93048	55.53336	15.18178	41923.69	0	9046.344	404.7143	80.70316	<4.00	1.598082
MAT New	52307.23	0.799041	0	13.5837	77.90651	30.36356	61460.25	0	3178.186	450.6592	19.17699	<4.00	20.37555
NS2	11879.74	0	0	0.799041	11.98562	1.198562	9190.971	0	86.69596	60.32761	8.789453	<4.00	0
Top PCD	44626.45	2.796644	0	26.36836	94.28686	13.18418	64417.1	0	3003.596	484.2189	75.50939	<4.00	5.193767
Central PCD	47680	3.2	35.6	6	114.4	13.6	75214.4	0	343.2	558	29.2	<4.00	12.4
Pan PCD	18160	2.4	32	6	121.6	8.4	54894.4	0	928	373.6	40	<4.00	9.2
Mine 2 PCD	35644	1.2	3.2	3.2	36.4	4.8	20310.4	0	529.6	130.8	27.2	<4.00	25.2
Mine 3 PCD	24016	2	88.8	11.2	46.8	7.6	44374.4	0	1712	275.2	48.4	<4.00	4
Pan 1	44720	0.4	15.6	2.8	33.2	3.6	21746.4	0	601.2	152	23.6	<4.00	6.4
Pan 2	33928	1.2	14.4	2.8	24	4	22602.4	0	434	154.4	16.8	<4.00	13.6

Table 6-12: Enrichment Factor

Site/Element	As	Cu	Cr	Co	Pb	Mn	Zn	Al
MAT5	0.76	0.42	1.04	0.59	0.27	2.15	0.03	0.49
MAT6	0.20	0.51	1.35	0.42	0.38	1.21	0.23	0.47
MAT7	1.03	0.78	1.17	3.68	0.51	12.65	0.02	0.26
MAT New	0.20	1.08	1.12	0.59	0.08	3.03	0.20	0.34
NS2	0.00	0.28	1.15	0.23	0.25	0.55	0.00	0.52
BP1	0.41	0.52	1.24	1.13	0.32	4.87	0.08	0.58
BP2	0.57	0.32	1.37	0.39	0.18	2.27	0.00	0.33
BP3	0.75	0.52	1.11	1.03	0.40	3.28	0.00	0.45
BP4	0.51	0.50	1.25	0.44	0.35	1.26	0.08	0.79
Pan PCD	0.68	0.33	1.96	0.29	0.19	0.99	0.10	0.13
Top PCD	0.67	0.44	1.29	1.09	0.31	2.73	0.05	0.28
Bottom PCD	0.66	0.39	1.34	0.21	0.10	0.27	0.10	0.25
Mine 2 PCD	0.91	0.51	1.58	0.42	0.35	1.53	0.74	0.70
Mine 3 PCD	0.70	0.37	0.93	0.67	0.29	2.26	0.05	0.22
Pan 1	0.28	0.36	1.35	0.34	0.29	1.62	0.17	0.82
Pan 2	0.82	0.38	0.94	0.33	0.20	1.13	0.36	0.60
Scale	<1 Natural							
	1–3 Minor Anthropogenic							
	3–5 Moderate							
	5–10 Moderate-Severe							
	10-25 Severe							
	>50 Extremely Severe							

6.5 Habitat Quality

The results of the assessment of the New Shaft Tributary are presented in Table 6-13.

Table 6-13: IHIA results for the New Shaft Tributary (NS1-NS3)

Criterion	Average	Score	Category
Instream			
Water abstraction	16.50	9.24	E
Flow modification	20.00	10.40	
Bed modification	16.00	8.32	
Channel modification	20.00	10.40	
Water quality	13.50	7.56	
Inundation	20.00	8.00	
Exotic macrophytes	5.00	1.80	
Exotic fauna	10.00	3.20	
Solid waste disposal	5.00	1.20	
Total Instream			**39.88**
Riparian			
Indigenous vegetation removal	19.00	9.88	E
Exotic vegetation encroachment	12.00	5.76	
Bank erosion	10.00	5.60	
Channel modification	12.50	6.00	
Water abstraction	17.50	9.10	
Inundation	20.00	8.80	
Flow modification	17.50	8.40	
Water quality	13.50	7.02	
Total Riparian			**39.44**

The results of the habitat assessment in the New Shaft Tributary indicates that both riparian and instream habitats are seriously modified (class E).

The results of the IHIA for the un-channelled wetland system (SQR) referred to as the Conveyor Tributary in this study is presented below (Table 6-14).

Table 6-14: IHIA results for the Conveyor Tributary (BP5-BP6)

Criterion	Average	Score	Category
Instream			
Water abstraction	9.33	5.23	D
Flow modification	12.67	6.59	
Bed modification	13.67	7.11	
Channel modification	13.67	7.11	
Water quality	15.00	8.40	
Inundation	11.67	4.67	
Exotic macrophytes	6.00	2.16	
Exotic fauna	15.00	4.80	
Solid waste disposal	5.00	1.20	
Total Instream			**52.75**
Riparian			
Indigenous vegetation removal	9.67	5.03	C
Exotic vegetation encroachment	8.00	3.84	
Bank erosion	9.67	5.41	
Channel modification	11.33	5.44	
Water abstraction	10.00	5.20	
Inundation	11.00	4.84	
Flow modification	10.00	4.80	
Water quality	10.00	5.20	
Total Riparian			**60.24**

The results of the habitat assessment in the Conveyor Tributary indicate that the riparian habitat is largely modified (class D) with the instream habitat as moderately modified (class C).

The results of the IHIA for the Rietspruit are presented below in Table 6-15.

Table 6-15: IHIA results for the Rietspruit (MAT1-BP4)

Criterion	Average	Score	Category
Instream			
Water abstraction	10.00	5.60	D
Flow modification	21.67	11.27	
Bed modification	23.33	12.13	
Channel modification	21.67	11.27	
Water quality	11.67	6.53	
Inundation	9.33	3.73	
Exotic macrophytes	5.00	1.80	
Exotic fauna	10.00	3.20	
Solid waste disposal	5.00	1.20	
Total Instream			**43.27**
Riparian			
Indigenous vegetation removal	8.33	4.33	D
Exotic vegetation encroachment	10.00	4.80	
Bank erosion	18.33	10.27	
Channel modification	18.67	8.96	
Water abstraction	9.33	4.85	
Inundation	6.67	2.93	
Flow modification	16.67	8.00	
Water quality	8.33	4.33	
Total Riparian			**51.52**

The results of the habitat assessment in the Rietspruit indicates that both riparian and instream habitats are largely modified (class D).

6.6 Aquatic Macroinvertebrate Assessment

6.6.1 Macroinvertebrate Habitat

The results of the biotope assessment are presented in Table 6-16.

Table 6-16: Biotope ratings for the 2016/2017 survey

Site	Biotope Rating (%)	Interpretation
Low Flow		
NS2	8	Poor
NS3	18	Poor
BP1	28	Poor
BP2	50	Good
BP3	28	Poor
BP4	19	Poor
MAT4	9	Poor
MAT6	11	Poor
High Flow		
NS1	12	Poor
NS3	22	Poor
BP1	24	Poor
BP2	49	Good
BP3	33	Fair
BP4	24	Poor
MAT3	4	Poor
MAT4	7	Poor
MAT5	9	Poor
MAT6	13	Poor
MAT7	20	Poor
MAT NEW	26	Poor

The majority of the macroinvertebrate habitat at the sites was classified as poor according to the biotope ratings. The habitat at BP2 was classified as good during the low flow survey with the habitat at BP3 being classified as fair and at BP2 as good during the high flow survey.

The results of the IHAS assessment are provided in Table 6-17.

Table 6-17: IHAS results for the 2016/2017 survey

Site	IHAS Score	Interpretation
Low Flow		
NS2	21	Poor
NS3	43	Poor
BP1	46	Poor
BP2	58	Fair
BP3	40	Poor
BP4	52	Poor
MAT4	29	Poor
MAT6	33	Poor
High Flow		
NS1	44	Poor
NS3	44	Poor
MAT3	36	Poor
MAT4	37	Poor
MAT5	34	Poor
MAT6	39	Poor
MAT7	49	Poor
MAT NEW	60	Fair
BP1	58	Fair
BP2	74	Good
BP3	37	Poor
BP4	62	Fair

6.6.2 SASS5

The results of the SASS5 are provided in Table 6-18.

Table 6-18: SASS5 results for the low and high flow surveys (2016/2017)

Site	SASS	Taxa	ASPT	Category
Low Flow				
NS2	6	3	2.0	E/F
NS3	64	15	4.3	D
MAT4	56	13	4.3	D
MAT6	38	9	4.2	E/F
BP1	57	15	3.8	D
BP2	113	23	4.9	B
BP3	100	21	4.8	B
BP4	62	15	4.1	D
High Flow				
NS1	67	15	4.5	C
NS3	83	16	5.2	B
MAT3	42	12	3.5	E/F
MAT4	52	13	4.4	D
MAT5	35	10	3.5	E/F
MAT6	53	11	4.8	C
MAT7	114	23	5.0	B
MAT NEW	79	16	4.9	B
BP1	63	13	4.8	D
BP2	102	19	5.4	B
BP3	75	15	5.0	B
BP4	90	18	5.0	B

6.6.3 MIRAI

The results of the MIRAI for the New Shaft Tributary are presented in Table 6-19.

Table 6-19: MIRAI for the New Shaft Tributary (2016/2017)

Invertebrate Metric Group	Score Calculated
Flow modification	43.4
Habitat	51.6
Water Quality	44.2
Ecological Score	**46.4**
Invertebrate Category	**D**

The overall MIRAI ecological category for the new Shaft Tributary is class D or largely modified. The results of the MIRAI in the Rietspruit are presented in Table 6-19.

Table 6-20: MIRAI for the Rietspruit (2016/2017)

Invertebrate Metric Group	Score Calculated
Flow modification	54.7
Habitat	50.0
Water Quality	49.4
Ecological Score	**51.47**
Invertebrate Category	**D**

The overall MIRAI ecological category for the Rietspruit is class D or largely modified.

6.7 Fish Assessment

Photographs of the fish species sampled during the study are presented in the table below (Table 6-21). Table 6-22 represents the expected species and the distribution of the sampled species sampled along the Rietspruit. The results of the FRAI for the Rietspruit are presented in Table 6-23.

Table 6-21: Fish species sampled at the Matla Colliery during the 2016/2017 survey

Fish Species	Photograph	Conservation status
Barbus anoplus		LC

Fish Species	Photograph	Conservation status
Barbus neefi		LC
Barbus paludinosus		LC
Labeo umbratus		LC
**Cyprinus carpio*		LC
Clarias gariepinus		LC
Tilapia sparmanni		LC
Pseudocrenilabrus philander		LC

Fish Species	Photograph	Conservation status
**Gambusia affinis*		LC
**Micropterus salmoides*		LC
* Depicts alien invasive species		

A total of ten different species were sampled during the study. Three of the ten species were alien invasive species. These ranged from habitat modifiers (*Cyprinus carpio*) to aquatic predators such as *Micropterus salmoides*.

Table 6-22: Species expected and captured at the lower (BP1-BP4) and upper (MAT4-MAT7) Rietspruit sites during the high and low flow surveys (2016/2017)

Site	*Barbus anoplus*	*Barbus neefi*	*Barbus trimaculatus*	*Barbus paludinosus*	*Labeo umbratus*	**Cyprinus carpio*	*Clarias gariepinus*	*Chiloglanis pretoriae*	*Tilapia sparmanni*	*Pseudocrenilabrus philander*	**Gambusia affinis*	**Micropterus salmoides*
BP1	✓	•	•	•	•	•	•	•	•	•	✓	•
BP2	✓	✓	•	✓	✓	•	✓	•	✓	✓	✓	✓
BP3	•	•	•	•	•	✓	•	•	✓	✓	✓	•
BP4	✓	•	•	✓	•	•	•	•	✓	✓	✓	•
MAT4	•	•	•	•	•	•	•	•	•	✓	•	•
MAT5	•	•	•	•	•	•	•	•	✓	•	✓	•
MAT6	✓	•	•	✓	✓	•	✓	•	✓	•	•	•
MAT7	✓	✓	•	✓	✓	•	•	•	•	•	✓	•

A total of seven of the nine expected indigenous fish species were sampled during the study. *Barbus trimaculatus* and *Chiloglanis pretoriae* were not sampled during any of the surveys. Only a single *Cyprinus carpio* (invasive habitat modifier) and a single *Micropterus salmoides* (invasive predator) were sampled during the study.

Table 6-23: FRAI results for the Rietspruit

Species	**Expected Frequency of Occurrence rating**	**Recorded Frequency of Occurrence rating**
Barbus anoplus	4	4
Barbus neefi	3	3
Barbus paludinosus	4	4
Barbus trimaculatus	1	0
Labeo umbratus	3	3
Clarias gariepinus	3	3
Chiloglanis pretoriae	3	0
Tilapia sparmanni	3	4
Pseudocrenilabrus philander	4	4
Adjusted FRAI %	55.3	
Ecological Category	Class D	

According to the FRAI the fish community in the Rietspruit is in a largely modified state (class D).

6.8 Present Ecological Status

The results of the PES assessment are presented in Table 6-24 for the New Shaft Tributary, Table 6-25 for the Conveyor Tributary and Table 6-26 for the Rietspruit.

Table 6-24: Present Ecological Status of the New Shaft Tributary for 2016/2017

Instream Vegetation Ecological Category	39.8
Riparian Habitat Category	39.4
Macroinvertebrate Ecological Category	46.4
Present Ecological Status	Class D

Table 6-25: Present Ecological Status of the Conveyor Tributary for 2016/2017

Instream Ecological Category	52.75
Riparian Habitat Category	60.24
Present Ecological Status	Class D

Table 6-26: Present Ecological Status of the Rietspruit for 2016/2017

Instream Vegetation Ecological Category	43.27
Riparian Ecological Category	51.52
Macroinvertebrate Ecological Category	51.47
Fish Ecological Category	55.3
Present Ecological Status	Class D

Based on the PES assessments completed the three river courses considered have been all classified as largely modified or class D.

7 Discussion

For the purposes of ease of reading the discussion has been divided into the various waterbodies considered. Thus four sections are discussed namely:

- The Conveyor Tributary
- The New Shaft Tributary;
- The Rietspruit; and
- Impoundments and Pans.

7.1 The Conveyor Tributary

Two sites (BP5 and BP6) were selected along this tributary to monitor any potential water quality impacts the mining activities upstream may have on the tributary. The activities which are monitored in this catchment consist of a coal conveyor, roadway and pipeline.

7.1.1 Water Quality

7.1.1.1 In Situ

Sites BP5 and BP6 were dry during both the low and high flow surveys with site BP5 having a nearby impoundment containing water. Thus, this impoundment was tested as a reference. The conductivity at the BP5 impoundment during the low flow survey was recorded as 940 µS/cm. This was the highest recorded conductivity value out of the entire river monitoring sites during the study. The dissolved oxygen value was also below the threshold effect value of 5 mg/l (DWAF, 1996). It appears that these impacts are not coming from the mining activities or PCDs located upstream due to the dry conditions of the upper reaches. The dry conditions downstream at site BP6 also indicate that the poor water quality is not leaving the impoundment. The high conductivity and low dissolved oxygen concentration recorded at the site may be due to the lack of flow through the site resulting in a concentration of the dissolved solids and low dissolved oxygen.

7.1.2 Habitat

According to the IHIA the instream habitat for the tributary is in a largely modified state (class D). This appears to be mainly a result of farming activities along the tributary. A large number of impoundments have been built along the tributary as a result of the farming activities which have led to flow, bed and channel modifications. Exotic fauna in the form of cattle are also impacted the instream habitat quality and decreasing the water quality of the tributary due to defecation in the river.

The riparian habitat was classified to be in a moderately modified state (class C) according to the IHIA. This modified state also appears to be a result of the farming activities along the tributary. Some of the farming activities are taking place directly in the riparian zones of the tributary which have resulted in physical vegetation removal, bank erosion, water abstraction channel modification which all affect the quality of the riparian habitat. Despite these modifications, the riparian habitat considered along this tributary was in the least modified state (according to the IHIA).

7.1.3 Present Ecological Status

The PES of the conveyor tributary was calculated based solely on the results of the IHIA and therefore should be interpreted with caution. According to the PES calculated, the ecostatus of the tributary is in a largely modified state. This modified state appears to be mainly due to habitat related impacts caused mainly by farming activities (impoundments and livestock) along the tributary.

7.1.4 Future Monitoring Objectives

It is proposed that the number of sites remain the same as they are sufficient to determine whether the mining activities upstream of the sites are impacting the tributary or not. However, it is suggested that a new site is situated directly upstream of the conveyor to determine the difference in water quality between the upstream and downstream sections as well as taking a water sample from one of the sites (the upper impounded site/BP5) to test for any signs of metal contamination. This suggestion is due to the fact that high conductivity was recorded at the site during the low flow survey.

If a better representative PES is wished to be determined, then it is suggested that the number of monitoring sites increases to attempt to obtain more representative data where alternative sites may contain more water.

7.2 New Shaft Tributary

7.2.1 Water Quality

7.2.1.1 In Situ

Only the river sites (NS1 and NS3) were considered for aquatic biological studies. Therefore, *in situ* water quality testing was conducted at these sites and a water sample was taken and tested at the impounded site (NS2) during the high flow survey. NS1 was observed as dry during the low flow survey and as a result no water quality constituents could be recorded. The water quality results recorded at NS3 during the low flow survey indicated that only the dissolved oxygen concentration was below the threshold effect value of 5mg/l (DWAF, 1996). The water quality values for this site were all within the recommended guideline values with only the dissolved oxygen concentration at NS1 being below 5mg/l during the high flow survey. The low oxygen value recorded at NS1 appears to be a result of the turbid and stagnant water observed at the site and can be regarded as natural.

7.2.1.2 Ex Situ

The water chemistry analysis conducted at the impounded site (NS2) during the high flow survey (March 2017) indicated fairly healthy conditions for aquatic biota. None of the tested toxic elements (lead, cadmium, chromium, cobalt and arsenic) were detected above the relevant detection limits. This provides indication that these elements are fairly low in concentration in the impoundment. However, limited flow may be the cause for these low concentrations.

7.2.2 Sediment Quality

No sediment samples were taken at the downstream site (NS3) during the previous study (Digby Wells, 2015/2016). However, according the results of the sediment quality enrichment index, the metals considered at NS3 are regarded as natural levels with the exception of chromium. The amount of chromium at the site was classified as minor anthropogenic indicating possible impacts relating to human activities. The enrichment factor determined for the impounded site (NS2) during the low flow survey was 1.24, also classifying the chromium levels at the site as minor anthropogenic. Compared to the previous study's findings, the chromium levels increased from an enrichment factor of 0.01. This indicates possible contamination even though the values indicate minor anthropogenic impacts. However, further assessments are needed to determine if these findings persist or if they are a result of the poor rainfall conditions.

7.2.3 Habitat Quality

According to the previous IHIA conducted by Digby Wells during the 2015/2016 study period, the instream and riparian habitat for the New Shaft Tributary was in a largely modified state (class D). This modified state was attributed mainly to the presence of an impoundment in the watercourse as well as the farming activities taking place in the riparian zone. Despite the fairly good habitat observed at the river monitoring sites (NS1 and NS3), the IHIA conducted during this study (2016/2017) categorised the instream and riparian habitat as seriously modified (class E).

The main reason behind this modified state is due to the fact that this assessment was conducted on a reach basis. Therefore the assessment included the major river related impacts caused by the mining operations taking place directly in the middle of the tributary. Higher modification scores were attributed to flow, bed and channel modification due to the inclusion of the river diversion built in the middle of the reach in the assessment. Higher scores were also attributed to the physical removal of indigenous vegetation as well as higher scores for inundation due to the downstream mining. As a result of these higher modification scores the habitat class is categorised as seriously modified (class E) than only largely modified (class D).

7.2.4 Aquatic Macroinvertebrates

Site NS1 was the only site dry during the low flow survey and as a result no invertebrate data was collected during this survey.

The overall biotope ratings for the habitat sampled was recorded as poor during both the low and high flow surveys. Despite the presence of good quality vegetation (marginal and aquatic) at the river monitoring sites (NS1 and NS3) the sites lacked flow and a number of different habitats, such as cobbles and gravel, resulting in poor biotope ratings. The image below (Figure 7-1) illustrates the inundated state of the downstream NS3 site as well as the abundance of aquatic vegetation.

Figure 7-1: Typical invertebrate habitat at NS3 (March 2017)

The IHAS conducted during both surveys also categorised the available aquatic macroinvertebrate habitat at all of the assessed New Shaft Tributary sites as poor. Similarly to the biotope ratings, the lowered scores were mainly a result of lack of flow as well as missing habitat structures such as cobbles.

Despite the poor habitat scores obtained at the New Shaft Tributary sites, the macroinvertebrate assemblages observed during the study were in a fairly good condition. According to the SASS scores obtained for the downstream site (NS3), the invertebrate assemblage went from a largely modified state (class D) during the low flow survey to a minimally modified state (class B) during the high flow survey. This improvement in score can be attributed to the fact that the site contained water throughout the study, allowing aquatic macroinvertebrates to establish and maintain a population without desiccation during the dry season, as well as to the increase in the amount of vegetation available. The macroinvertebrate assemblage at the upper river monitoring site (NS1) was categorised as moderately modified (class C) during the high flow survey. This score is fairly good despite the dry conditions observed at the site during the low flow survey. The good water quality observed at these sites also can be attributed to the fairly healthy macroinvertebrate assemblages observed during the study.

According to the MIRAI, the overall macroinvertebrate ecological category is largely modified (class D). The main attributing factor to this modified state appears to be the loss of flow dependent taxa due to the flow modification/inundation observed at the sites. It is important to note that this calculated macroinvertebrate ecological category speaks mainly to the assemblages in the upper reaches of the tributary. This is so as only upstream sites were sampled which may provide skew results. However, from the invertebrate assessments it is clear that the lack of specific habitat has resulted in the modified macroinvertebrate states and not the activities of the New Shaft.

7.2.5 Present Ecological Status

The overall PES for the tributary was determined to be largely modified (class D). This largely modified state can primarily attributed to habitat related impacts caused by farming and mining activities taking place near and directly in the watercourse and not to the New Shaft activities.

7.2.6 Future Monitoring Plans

Future monitoring should be conducted at the three selected sites as explained in the above study area section of the report. The two river monitoring sites should be sufficient to monitor future impacts, if any, that the New Shaft may have on the associated tributary. Sediment and water chemistry analysis should be continued at the impounded site (NS2) previously to assess any changes that may be resulting from the New Shaft.

7.3 The Rietspruit

The activities which are monitored in this river system are the Mine 3 river diversion (MAT1-MAT7) and the water treatment effluent (BP1-BP4).

For the purpose of this study MAT1 and MAT2 were kept as the initial monitoring sites which were observed as dry throughout the study. The following image illustrates the dry conditions observed at the initial impounded site (MAT2).

Figure 7-2: Dry conditions observed at the initial MAT2 site

As explained in the previous study conducted by Digby Wells (2015/2016), a loss of connectivity between the Upper and Lower Rietspruit has occurred. Aerial imagery from 1955 suggests that connectivity between the upper and lower Rietspruit has been lost and continues to this day as illustrated in the image below (Figure 7-3). The loss of connectivity can therefore not be attributed to the construction of the river diversion. The likely cause of the loss of connectivity can be attributed to historical mining activities whereby a river was diverted and rehabilitation did not reconstitute the river channel.

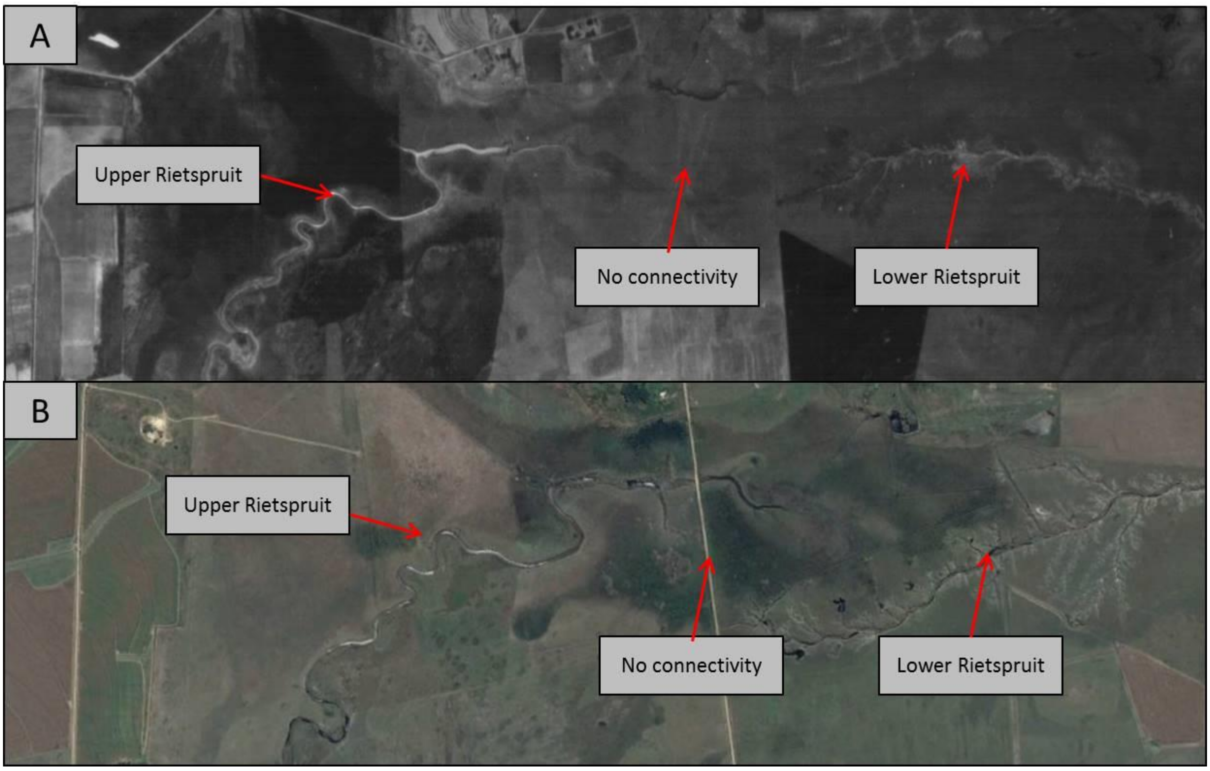

Figure 7-3: Loss of connectivity between upstream and downstream Rietspruit. A: 1955; B: 2016 (Google earth™)

Due to the loss of connectivity the sites located in the upper Rietspruit (MAT1-MAT7) cannot be compared to sites located in the lower Rietspruit (BP1-BP4). Therefore, for the purpose of the discussion the Upper and Lower Rietspruit sites have been separated.

Rainfall during the 2015/2016 study period was below normal volumes. Thus, it is likely that aquatic ecology was negatively affected by extreme low flow conditions towards the low flow survey month (October 2016). However, as illustrated by the image below (Figure 7-4) the rainfall for the Mpumalanga area has been above normal conditions from December 2016. This may be the cause for any extreme discrepancies recorded between the low and high flow surveys.

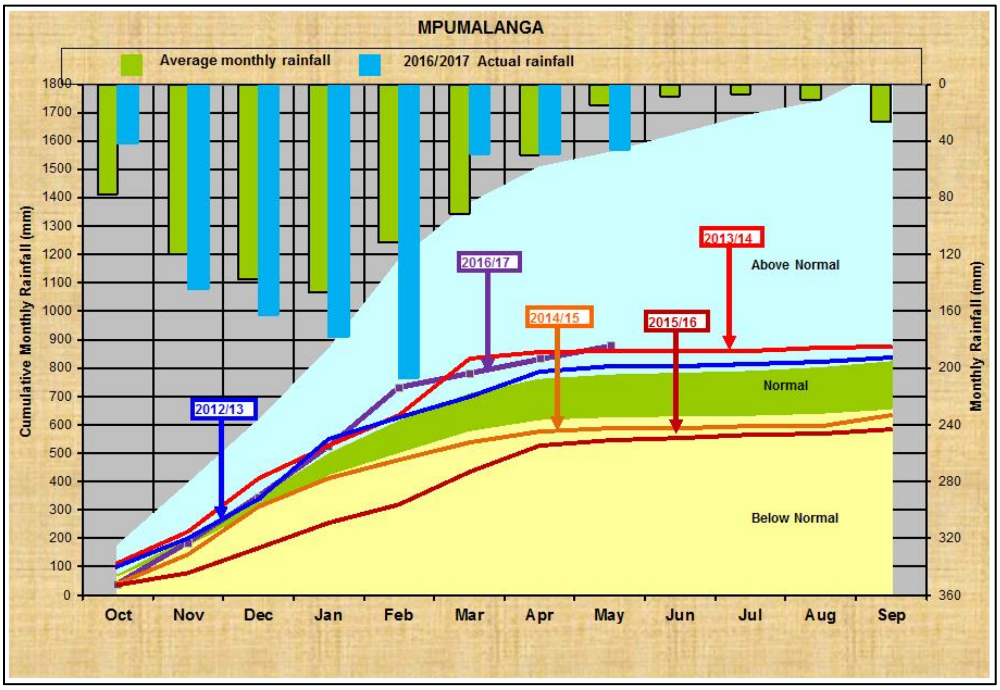

Figure 7-4: Rainfall trends illustrating below normal rainfall in Mpumalanga in 2015/2016 and the above normal conditions from December 2016 to May 2017 (DWS, 2017)

7.3.1 Water Quality

7.3.1.1 Upper Rietspruit

Sites MAT1 and MAT2 were dry during both surveys with MAT3, MAT5 and MAT7 being dry during the low flow survey. As a result no water quality data was collected for these sites during the respective surveys. The *in situ* water quality results obtained for MAT4 and MAT6 during the low flow survey indicated that all the recorded constituents were below the threshold effect values as stipulated by DWAF (1996). The results recorded during the high flow survey indicated that only the dissolved oxygen concentrations at MAT3, MAT5 and MAT New were below the guideline value of 5mg/l. This appears to be a result of the extreme inundated conditions observed at MAT3 and MAT5 and due to algal presence at the MAT New site.

Water samples were taken from MAT2, MAT5, MAT6, MAT7 and MAT New during the high flow survey to determine the potential difference in element composition between the Upper and Lower Rietspruit. The chemical analysis indicated that all of the elements that may cause toxic stress at low concentrations (lead, cadmium, chromium, cobalt and arsenic) were found to be below detection limits at all relevant/tested sites. Iron and manganese was found to be highest at the upper MAT2 site indicating external impacts not related to the mining activities. The iron concentration was found to be above the detection limit at the downstream river diversion site (Mat7). This indicates that the river diversion may be affecting the water chemistry. However, the iron concentration returns to almost below detection limits at the downstream site (MAT6).

7.3.1.2 Lower Rietspruit

The low flow *in situ* water quality results indicated that the pH at BP3 did not meet the recommended guideline values (DWAF, 1996). The conductivity and dissolved oxygen concentration at the downstream site (BP4) also did not meet the guideline values. As stated in the previous study (2015/2016) it appeared that possible contamination of the river water could be taking place between BP2 and BP4. However, as observed in this study the conductivity is only high at the downstream site (BP4). This appears to be a result of accumulating dissolved solids due to the lack of flow through the site as well as the inundated state of the site as observed during the low flow survey. BP4 was also observed to be impacted heavily by cattle activity further attributing to the lowered dissolved oxygen concentration.

All of the water quality constituents were within the recommended guideline values (DWAF, 1996) during the high flow survey. This provides indication that the water treatment plant discharge is operating as intended. However, when comparing the conductivity results to the previous study (2015/2016) it appears that an increase in dissolved solid load has occurred. The following graph (Figure 7-5) represents the differences observed between the two high flow surveys conducted in February 2016 and March 2017.

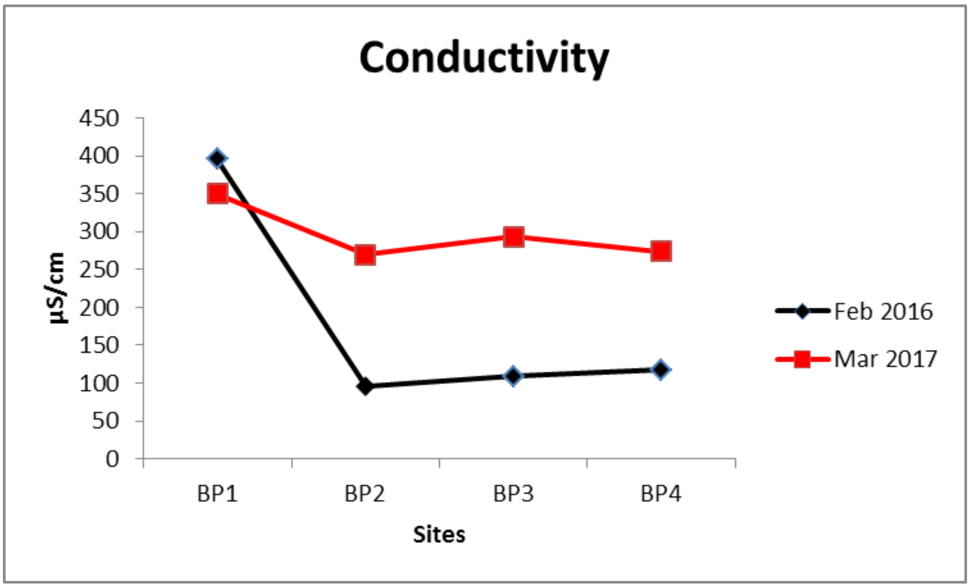

Figure 7-5: Conductivity scores recorded in the Lower Rietspruit during February 2016 and March 2017

As illustrated by the above graph (Figure 7-5), the downstream (BP2-BP4) conductivity values were lower during the 2016 high flow period compared to the 2017 survey. Despite these values being below the threshold effect value of 700 µS/cm, the increase in overall dissolved solids load is of concern and should be carefully monitored.

7.3.2 Sediment Quality

7.3.2.1 Upper Rietspruit

The concentrations of chromium and manganese were found to be enriched in all of the tested sites in the upper Rietspruit with an enrichment of arsenic at MAT7, copper at MAT New and Cobalt at MAT7. As observed in the previous study (Digby Wells 2015/2016) manganese and cobalt was found to be highest at MAT7. These findings were also observed during this study which provides some indication that sediments in the diversion are contaminated with cobalt and manganese. However, temporal trends need to be established for these elements when flow returns to the diversion. The manganese levels at MAT7 were classified as severe and needs to be carefully monitored as the spread of the element is limited and was not observed as severe downstream at MAT6.

7.3.2.2 Lower Rietspruit

Similar findings to the Upper Rietspruit were observed where all sites were enriched with chromium and manganese. This provides indication that contamination is occurring in the whole reach and may be associated to mining impacts. Chromium was also enriched at BP1 and BP2. No sites were enriched with chromium during the previous study (Digby Wells 2015/2016) thus attention needs to be given to this specific element in future studies.

7.3.3 Habitat Quality

The habitat quality assessment combined both the upper and lower Rietspruit as per the SQR delineation. Considering this, the overall results of the IHIA indicate that the instream and riparian habitat is in a largely modified state (class D). This modified status can be attributed primarily to flow, bed and channel modifications as observed in the previous study (Digby Wells, 2015/2016). This can be directly attributed to the implementation of a river diversion in the SQR as well as the discharge of water in the Lower Rietspruit resulting in flow modification.

The fractures that were observed in the previous study (Digby Wells, 2015/2016) were still present throughout this study. The image below (Figure 7-6) illustrates one of the large fractures observed along the banks of MAT5. It appears that these fractures are increasing in size and should be carefully monitored.

Figure 7-6: Fractures in the banks of the Rietspruit at MAT5 (October 2016)

In addition to the fractures, erosion was extensive within the banks of the river diversion itself and in the lower Rietspruit as observed during the 2015/2016 study. The effects of erosion appear to be compounded by the presence of livestock which were observed in abundance within the Rietspruit. The following image (Figure 7-7) represents the bank erosion as well as the resulting sedimentation of the river bed at BP1 during the low flow survey. Large portions of the riparian habitat of the Rietspruit adjacent to the river diversion have been protected from livestock impacts through the implementation of a no-go area for the animals. However, an increase in these no-go areas is suggested as well as the planting of vegetation along the eroded areas of the river diversion banks to maintain long term stability.

Figure 7-7: Erosion and sedimentation observed at BP1 during the low flow survey

7.3.4 Aquatic Macroinvertebrates

7.3.4.1 Upper Rietspruit

The biotope ratings as well as the IHAS scores recorded during the macroinvertebrate sampling categorised the sampled macroinvertebrate habitat at all of the sites, with the exception of MAT New, as poor. The IHAS scored recorded for the MAT New site categorised the macroinvertebrate as fair during the high flow survey. It appears that the lack of habitat, especially the lack of flow and cobbles, has led to the overall poor availability of macroinvertebrate habitat.

According to the SASS5 and ASPT scores, the macroinvertebrate assemblages observed at MAT4 were in a largely modified state (class D) and at MAT6 in a seriously to critically modified state (class E/F) during the low flow survey. The cause of these modified states appears to be primarily related to the low water levels observed during the survey.

The SASS5 and ASPT scores obtained during the high flow survey varied throughout the Upper Rietspruit sites. The lowest scores recorded were at sites MAT3 and MAT5 (class E/F). These seriously to critically modified states appear to be a result of the dry conditions observed at these sites during the previous low flow survey compounded by the low oxygen concentrations recorded due to the stagnant nature of the sites. The macroinvertebrate assemblage recorded at MAT4 did not change from the low flow survey. The water quality at this site remained fairly similar to that observed during the low flow survey. However, a decrease in conductivity did occur which provides some indication that water quality is not the limiting factor. The macroinvertebrates at MAT6 were categorised as moderately modified (class C) and at MAT7 and MAT New as minimally modified (class B). The improved results recorded at MAT6 appear to be due to the fact that water levels have remained consistent at the site, allowing macroinvertebrates to establish and persist throughout the year. The fairly high macroinvertebrate scores recorded at MAT7 and MAT New appear to be a result of an increased abundance in macroinvertebrate habitat. MAT7 was observed to have an abundance of aquatic vegetation as well as sections with consistent flow where the MAT New site was also observed to be flowing fairly consistently with an abundance of instream cobbles providing habitat for the more sensitive macroinvertebrate taxa.

According to the approved WUL for the river diversion the SASS5 scores may not be reduced by 20% with ASPT values not degrading by 10%. Considering the results at MAT6 over the entire study period (Figure 7-8), during the 2016/2017 study period the SASS5 scores have remained in the threshold monitoring value with a value fairly similar to that recorded during the January 2006 survey. The ASPT value for the current survey period has also not been reduced by more than 10% from the mean of the previous surveys.

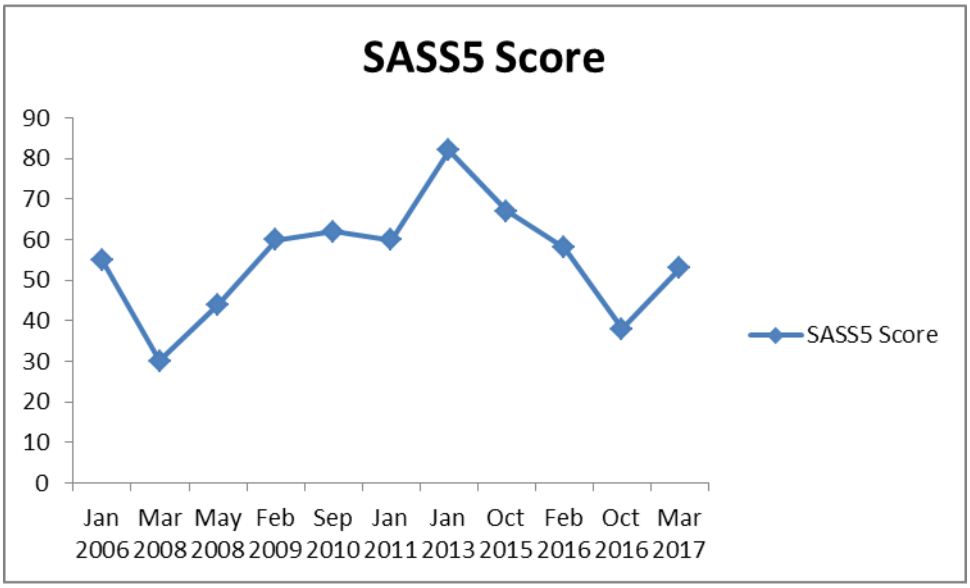

Figure 7-8: Temporal trend in SASS5 scores recorded at MAT6

7.3.4.2 Lower Rietspruit

The biotope ratings recorded at the lower Rietspruit sites classified the sampled macroinvertebrate habitat as poor during both surveys with the exception of BP2, which was classified as good during both surveys, and BP3 which was classified as fair during the high flow survey.

The IHAS scores determined for the sites varied with the overall score resulting in poor habitat during the low flow survey and fair habitat during the high flow survey. However, as explained in the previous study conducted by Digby Wells (2015/2016), the result of the construction of several weirs has led to an abundance of stones in and out of current. This abundance of habitat coupled with the discharge of treated water, resulting in greater flow of the river system downstream, has provided a more diverse habitat for macroinvertebrates compared to the Upper Rietspruit.

The SASS5 and ASPT scores recorded during the low flow survey categorised the macroinvertebrate assemblages at the upstream (BP1) and downstream (BP4) sites as largely modified. This modified state appears to be due to the lack of flow observed at these sites which is most likely compounded by the high conductivity recorded at BP4. The midstream sites (BP2 and BP3) were categorised as minimally modified (class B). The minimally modified macroinvertebrate classes at the midstream sites were most likely a result of the fairly consistent flow observed at the sites. This provides indication that the discharge of treated water is having a positive effect on the macroinvertebrates in the system. However, as stated in the water quality section, the overall increase in dissolved solids must be carefully monitored. The scores obtained during the high flow survey were fairly high. All of the downstream sites associated with the discharge of treated water (BP2-BP4) were categorised as minimally modified (class B). The upstream BP1 site was categorised as largely modified (class D). These results again provide indication that the discharge of treated water is having a positive effect on the macroinvertebrate assemblages downstream.

The MIRAI conducted for the Rietspruit included both the upper and lower sites. The MIRAI categorised the macroinvertebrate assemblage for the Rietspruit as largely modified (class D). According to the calculated scores for the reach, an almost even contribution of flow modification, lack of habitat and poor water quality has attributed to this modified state. The lack of habitat and flow, mainly observed in the Upper Rietspruit, compounded by the fairly high conductivity recorded at the Lower Rietspruit sites appears to have resulting in the loss of the more sensitive taxa in the river system.

7.3.5 Fish Assessment

A total of seven of the nine expected indigenous fish species were sampled during the survey. None of the expected or sampled species are listed as IUCN species. Only a single *Cyprinus carpio* (invasive habitat modifier) and a single *Micropterus salmoides* (invasive predator) were sampled during the study.

The FRAI conducted included the Upper and Lower Rietspruit and classified the fish community as largely modified (class D). All of the seven sampled fish species were collected in both the Upper and Lower Rietspruit. However, the two species listed in the monitoring program, *Pseudocrenilabrus philander* and *Tilapia sparmanni,* appeared to be more abundant in the Lower Rietspruit. This is most likely due to the abundance of their preferred habitat (submerged marginal vegetation along sandy substrate runs) in the Lower Rietspruit as observed in Figure 7-9. Despite the river diversion impacting the abundance of instream habitat, two more species were observed at the downstream MAT6 site compared to the 2015/2016 study period.

Figure 7-9: Abundance of thick marginal vegetation suited for *Pseudocrenilabrus philander* and *Tilapia sparmanni* observed at BP4

The modified state according to the FRAI for the reach can be attributed to the loss of two sensitive taxa namely *Barbus trimaculatus* and *Chiloglanis pretoriae.* These findings are similar to the previous study conducted by Digby Wells (2016/2017) where habitat loss has resulted in the absence of *Barbus trimaculatus* and historical poor water quality has resulted in the loss of *Chiloglanis pretoriae.* Despite the loss of these two species from the system, the sensitive *Barbus neefi* was sampled during the survey in both the Upper and Lower Rietspruit. This fish species was sampled in the river diversion at the downstream site (MAT7). This provides some indication that the river diversion is functioning as intended and if sampling was extended *Barbus trimaculatus* might have been found to be present.

The presence of the three listed invasive species in the Rietspruit, especially the presence of *Cyprinus carpio* and *Micropterus salmoides* in the Lower Rietspruit, as well as the loss of connectivity between the sites has further attributed to the modified score. It is expected that a larger abundance of species will be present in the system if the flow and water levels return to normal conditions in the Upper Rietspruit as observed in previous studies (Golder, 2013).

7.3.6 Present Ecological Status

The PES calculated for the Rietspruit was determined to be largely modified (class D). This was partially attributed to instream modification as a result of the upstream diversion and the loss of connectivity between the lower and upper Rietspruit. However, the low water levels observed during the study appear to be a large attributing factor to the modified score, especially in the Upper Rietspruit.

7.3.7 Future Monitoring Objectives

It is proposed that monitoring continues at the selected monitoring sites with the inclusion of the newly selected upstream river diversion sites (MAT1 and MAT2 as illustrated in Appendix A). Attention should be given to the erosion and fracturing occurring along the sections of the river diversion with rehabilitation taking place where possible. This will be included in the rehabilitation plan that Digby Wells has been appointed to develop. It is also suggested that an increase in the livestock no-go areas occurs especially around the river diversion. Lastly, the quality of water being discharged in the Lower Rietspruit should be carefully monitored due to the overall increase in conductivity recorded during the high flow survey (March 2017).

7.4 The Impoundments and Pans

7.4.1 Water Quality

As observed during the previous survey (Digby Wells, 2015/2016), which was conducted in order to determine the baseline water quality for the pans, the results of the *in situ* assessment show saline conditions that are typical of freshwater endorheic pans (De Klerk, 2012). Interpretation of the water quality data in these systems is therefore difficult and limited to temporal assessments. The *in situ* results recorded during the high flow survey (March 2017) were compared to those obtained during the March 2016 survey (Digby Wells, 2016). The results indicated that an increase in conductivity occurred at Pan1 with a decrease observed at Pan2.

The overall *in situ* water quality results recorded during the high flow survey (March 2017) indicate better conditions compared to the results obtained during the March 2016 survey with the exception of Mine 3 PCD. Despite the pH at the Central PCD and the dissolved oxygen at the Top PCD being worse from the previous high flow survey (March 2016), the conductivity values at the PCDs (Central, Top, Mine 2 and Pan) decreased. All of the conductivity values, with the exception of Mine 2 PCD, exceeded the recommended guideline value of 700 µS/cm (DWAF, 1996). This can be attributed to the fact that the impoundments are used as pollution storage areas whereby underground water is discharged into them. In addition, workshops and contaminated water from the various activities around the mining operations are channelled into these impoundments. However, the conductivity value at Mine 3 PCD increased from 582 µS/cm during the March 2016 survey to 4200 µS/cm during the March 2017 survey. This is a drastic increase and should a spillage occur the downstream MAT7 site will be severely affected. However, it appears that no signs of leakage of the water from the PCD have occurred as the macroinvertebrate community and conductivity value at MAT7 was indicative of fairly good/healthy conditions.

The chemical water quality analysis shows that the majority of the dissolved elements in the PCD's consist of dissolved sulphate, ammonia, phosphate and amounts of iron and manganese. These elements are anticipated in high concentrations in PCD's used for the storage of coal mine related waters. Elements which cause toxic stress at low concentrations such as lead, cadmium, chromium, cobalt and arsenic were found varied in concentration within the PCD's at some of the sites. A breakdown of the findings of each of the above elements is provided below.

The values in brackets reports to the actual values in mg/l obtained per element at the relevant site.

7.4.1.1 Arsenic

Arsenic was found to be above detection limit of 0.01 mg/l during the low flow survey in only the Bottom PCD (0.011) and at the Pan PCD (0.013) and the Top PCD (0.021) during the high flow survey.

7.4.1.2 Cadmium

Cadmium was found to be above the detection limit of 0.003 mg/l at the Pan PCD (0.009), the Top PCD (0.003) and the Bottom PCD (0.006) during only the low flow survey.

7.4.1.3 Chromium

Chromium was found to be below the detection limit of 0.025 mg/l at all of the PCD's during the low and high flow survey thus indicating low concentrations of the element in the PCD's.

7.4.1.4 Cobalt

Cobalt was recorded above the limit of 0.025 mg/l at the Pan PCD (0.091), the Top PCD (0.078) and the Bottom PCD (0.087) during the low flow survey as well as at the Pan PCD (0.030) during the high flow survey.

7.4.1.5 Lead

Lead was recorded above the detection limit of 0.01 mg/l at the Pan PCD (0.014) and the Top PCD (0.041) during the low flow survey and at the Pan PCD (0.015), the Top PCD (0.014) and the Bottom PCD (0.022) during the high flow survey.

7.4.2 Biological Responses

The results of the toxicity assessment using three taxonomic groups showed that the water within the Top PCD, Central PCD and Pan PCD would not be acutely toxic to aquatic biota should a spillage occur. However, the testing showed that Mine 2 PCD and Mine 3 PCD were classified as high acute hazards due to the 100% mortality of the aquatic biota (water fleas and guppies) in the tests. The aquatic biota downstream of these PCD's would be affected if a spillage occurs. However as stated above, the macroinvertebrate and conductivity recorded at MAT7 (downstream of Mine 3 PCD) was indicative of fairly good/healthy conditions as well as the sites downstream of Mine 2 PCD (BP2-BP4). Therefore, the two PCD's of concern are not impacting the associated rivers but should be carefully monitored with more testing to confirm the relevant toxicity findings.

7.4.3 Diatoms

According to the diatom assemblage analysis, the PAN PCD, Top PCD and Central PCD showed moderate water quality. The Mine 3 PCD and PAN1 showed poor and bad water quality respectively. These results indicate that there is pollution occurring at the aforementioned sites, especially at the Mine 3 PCD and Pan1. The findings for the Pan PCD, Top PCD and Central PCD showed relatively low %PTV scores. This is indicative of low organic pollution in comparison to the findings at the Mine 3 PCD and Pan 1.

Pan 2 had insufficient diatom cell counts and was thus not included in the analyses. However, the dominant diatom species was *N. palea* indicating that this site is impacted by some form of organic pollution. Similarly, the Mine 2 PCD had insufficient cell counts and was thus not included in the analyses.

7.4.4 Sediment Quality

Similar findings as observed in the Rietspruit sites were recorded in the PCD's and pans where enrichment of only chromium and manganese was recorded. Compared to the previous sediment analysis conducted by Digby Wells during the 2015/2016 study, a clear decrease in the overall arsenic, cobalt, lead and zinc enrichment has occurred. However, the overall enrichment of chromium and manganese as well as the enrichment of cobalt at the Top PCD is of concern and should be monitored in future studies when rainfall returns to normal.

7.4.5 Future Monitoring Objectives

As indicated by the water quality discussion, there are traces of elements of toxic concern above limits for aquatic life. Therefore, monitoring of the PCD's, especially the Mine 2 and 3 PCD's is of importance due to the toxicity findings at these sites as well as the diatom findings at the Mine 2 PCD. It is also important to ensure that no spillages occur at the PCD's due to the overall high conductivity values recorded and due to the specific toxic elements, such as the cobalt and lead, recorded above detection limits. Continuous monitoring is needed at the pans, especially at Pan1, to determine the trends of pollution from the diatom analysis.

8 Conclusion

Based on the overall results of the 2016/2017 assessments the following conclusions can be drawn.

8.1 The Conveyor Tributary

This study serves as the second monitoring study for the various infrastructures. Water quality findings were difficult to interpret due to the dry conditions observed at mainly the downstream site. However, the poor water quality recorded at the impounded site near BP5 appears to be a result of the low rainfall conditions and not the infrastructure as there was no connectivity between the infrastructure and site during the study. With regards to habitat quality, limited impacts can be attributed to the infrastructure as no erosion or physical alterations can be observed in the downstream areas. The modified status recorded for the habitat can mainly be attributed to farming activities along the tributary as well as poor rainfall.

8.2 The New Shaft Tributary

The PES has remained as largely modified (class D) from the previous study (Digby Wells 2015/2016). Overall, no impacts to local aquatic ecology could be identified as a result of the licenced activities for the 2016/2017 survey period as they are not in motion yet.

8.3 The Rietspruit

The activities within the Rietspruit catchment have resulted in the largely modified PES classification of the system. The river diversion has altered the instream habitat and subsequently modified the ecological status of the downstream conditions. Based on the previous studies, the biological responses indicate a negative trend which appears to be on the rise. This trend can be attributed to below normal rainfall and subsequent loss of aquatic habitats, specifically at sites associated with the river diversion. The presence of sensitive taxa (*Barbus neefi*) was still observed in the river diversion and biological responses may improve with an improvement in rainfall.

The impact of the discharge of treated water in the lower Rietspruit has appears to be beneficial for biological responses. It has allowed for the presence of sensitive aquatic biota such as *Barbus neefi* and several invertebrate taxa to be present even in poor rainfall conditions. However, an overall increase in dissolved solids was observed at the sites when comparing results to the previous high flow survey (Digby Well, February 2016). Therefore, attention needs to be given to this overall increase.

8.4 The Impoundments and Pans

The limnological assessment of the various partitions of the PCD's at the Matla Coal Mine show that conductivity levels are higher in the water bodies when compared to the river systems. The elevated concentrations of dissolved solids have also led to toxicity assessments showing signs toxicity at Mine 2 and Mine 3 PCD's with effects to two of the three taxonomic groups of aquatic organisms. Metal content in sediments of the PCD's indicated an overall decrease in the number of enriched elements. However, the enrichment of chromium and manganese is still of concern, at all sites not just the impoundments, where future monitoring will develop further temporal trends and confirm the contamination status of the sediments in the PCD's. Continuous monitoring of the Pans is also needed to determine pollution trends as indicated in the diatom analyses.

9 Recommendations

Based on the outcomes of the 2016/2017 study the following recommendations can be made.

Additional sites should be selected immediately downstream of the various PCD's at the Matla Coal Mine. The selection of these sites would allow for the determination of potential seepage emanating from the polluted water bodies.

Based on the assessment of the river diversion and illustrated in the aerial biomonitoring study, the banks of the river diversion should be vegetated. In addition, connectivity between the upper and lower Rietspruit requires confirmation and should be further surveyed.

The resealing of cracks in the Rietspruit should be investigated further. In addition, as per the WMP the limited landuse in proximity of the Rietspruit channel should be adhered to with an increase in livestock no-go areas.

Based on the outcomes of the previous study (Digby Wells 2015/2016) and this study, the following monitoring programme will be completed for the duration of the remaining study periods of the Matla Biomonitoring Project (Table 9-1).

Table 9-1: Monitoring Program

Key Performance Indicator	Threshold of Concern	Target
SASS5	-20%	No significant deterioration of SASS5 scores.
ASPT	-10%	No significant differences between upstream and downstream regions
Beatidae	None present	All sites
Pseudocrenilabrus philander or *Tilapia sparmanni*	Absence	Presence

It is noted that the findings at the river diversion sites were within the recommended monitoring thresholds during the study (2016/2017). However, the SASS5 score at MAT6 during the low flow survey (October 2016) was 20% less than the score recorded during the 2015 survey (Digby Wells, 2015) but returned to within the threshold during the high flow survey (March 2017).

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