Water quality overview and literature review of the ecology of the Olifants River

Ralph Heath, Trevor Coleman & Johan Engelbrecht

WATER RESEARCH COMMISSION

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WATER QUALITY OVERVIEW AND LITERATURE REVIEW OF THE ECOLOGY OF THE OLIFANTS RIVER

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1. BACKGROUND

The Olifants River in Mpumalanga is presently one of the most threatened river systems in South Africa (Ballance *et al*., 2001; De Villiers and Mkwelo, 2009; Van Vuren, 2009). Reports of unexplained fish and crocodile deaths within the catchment, including recently in the Kruger National Park (KNP) have been reported for several years and have received a media attention, including the establishment of the 'Consortium for the Restoration of the Olifants Catchment' initiative (Van Vuren, 2009; De Villiers and Mkwelo, 2009).

Despite signs that water quality in the Olifants River has been deteriorating as a result of industrial, mining and agriculture activities, the trigger for episodic fish and crocodile deaths in the river system remains elusive (De Villiers and Mkwelo, 2009).

This report is a summary of the status of the water quality data and is further a synthesis of the available aquatic ecology literature in the Olifants River.

2. DESCRIPTION OF THE STUDY AREA

The Olifants River originates from the east of Johannesburg and initially flows northwards before curving eastwards towards the Kruger National Park where it is joined by the Letaba River before flowing into Mozambique. The study area is the Olifants River Catchment. It extends from the upper reaches of the Olifants River along the catchment divide with the Vaal river to the Loskop Dam and down to the Flag Boshielo dam and then on to Phalaborwa and into the Kruger National Park (Figure 1).

The Upper Olifants River catchment comprises the drainage areas of the Olifants River, Klein Olifants River and Wilge River with tributaries down to the Loskop Dam. The headwaters of these rivers are located along the Highveld Ridge in the Secunda-Bethal area and the rivers then flow in a northerly direction towards Loskop Dam.

The major tributaries are the Steenkoolspruit, Klein Olifants River, Wilge River and Elands River. It has large urban centres located in the Emalahleni (Witbank), Steve Tshwete (Middelburg) and also a number of smaller urban centres such as Bronkhorstspruit, Kriel, Hendrina, Kinross and Trichardt. Satellite townships are also associated with most of the mining operations and power stations.

The natural rivers and streams have been extensively dammed with the result the stream flow is now highly regulated. The major impoundments upstream of Loskop Dam include Witbank Dam, Middelburg Dam, Bronkhorstspruit Dam and Premiere Mine Dam. Many smaller farm dams and water supply structures associated with the mining operations have also been constructed in the catchment.

Extensive coal mining takes place in the catchment, most of which occurs in the Witbank Coalfields and Highveld Coalfields. The landscape in the southern and central part of the catchment is dominated by mining operations and mining-related infrastructure. Agriculture, both dryland and irrigated, is another important land use in the catchment with many areas in the southern and central portions producing high yields of maize. Irrigation farming of diverse crops takes place in various parts of the catchment the largest of which is the Loskop Dam Irrigation Scheme.

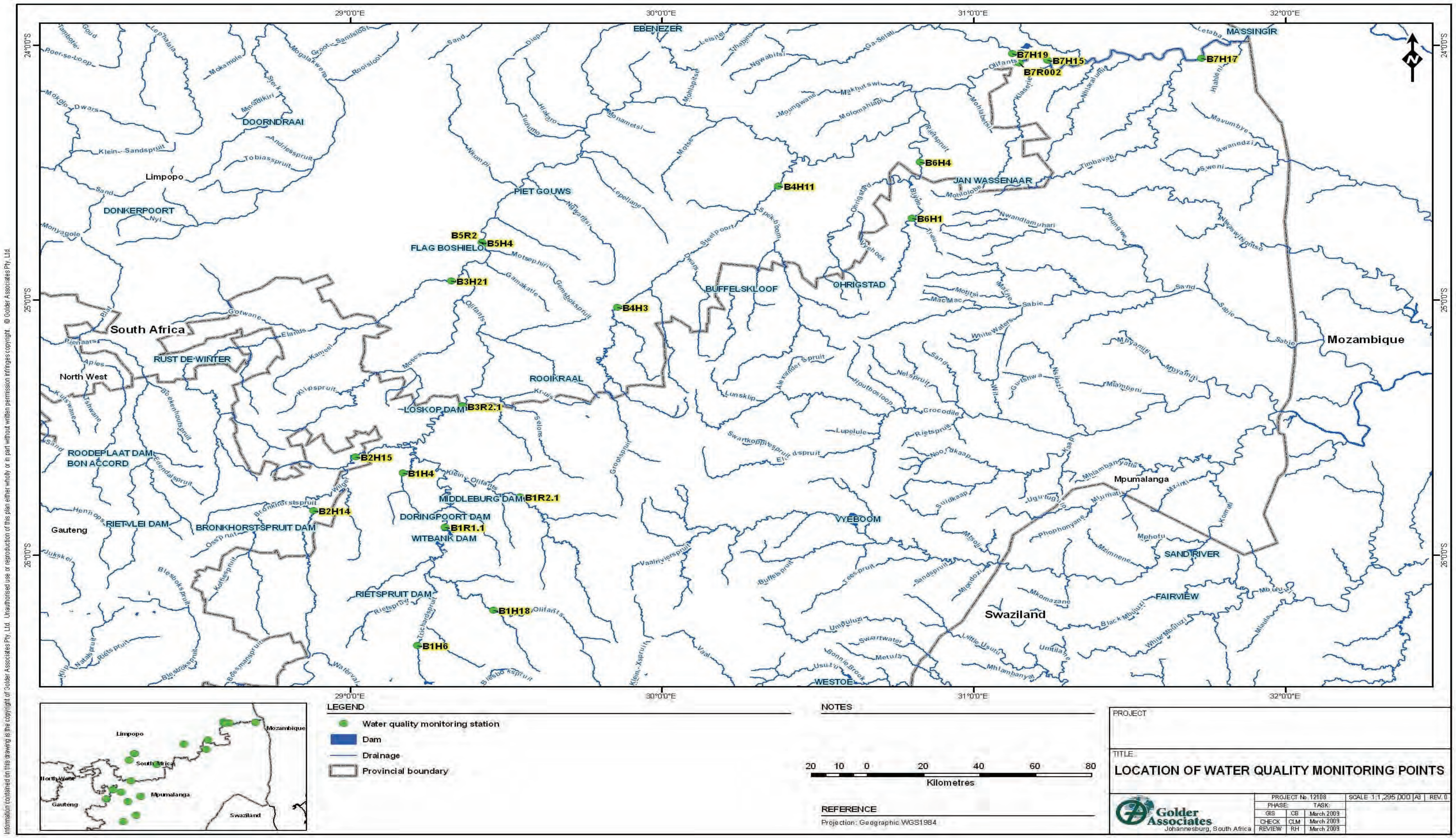

Figure 1: Location of selected DWAF water quality monitoring points across the Olifants River catchment

The Upper Olifants River basin water resources are under constant pressure from both a supply/demand perspective as well as from a water quality perspective.

The Middle Olifants catchment comprises the drainage areas of the Olifants River downstream of Loskop Dam and down to the Flag Boshielo Dam. Major tributaries are the Selons River, Moses River, Bloed River and the Elands River. There are no metropolitan areas situated in the area but smaller towns like Groblersdal, Marble Hall and Settlers are located in the area. The Western Highveld region, including towns like Siyabuswa and Dennilton is located in the Elands River catchment. Several rural townships are also located in the area. The major dams in the catchment include the Rust de Winter Dam, Renosterkop Dam and Rooikraal Dam. Many smaller farm dams are also found in the area.

Agriculture, both dryland and irrigated, is the most important land use in the catchment. Irrigation farming of diverse crops takes place in various parts of the catchment, the largest of which is the Elands River Irrigation Scheme. Subsistence farming also forms a substantial part of the catchment.

Small mining areas are found in the catchments of Klipspruit, Moses River and Loopspruit as well as the area east of Marble Hall.

The Lower Olifants catchment comprises the drainage areas from Flag Boshielo Dam, downstream to the Kruger National Park. After crossing the Mozambique border, the Olifants River flows into the Massingire Dam. The major tributaries include the Steelpoort River, the Blyde River and the Ga-Selati River. There are no metropolitan areas in this part of the catchment aside from Phalaborwa, but there are a number of small towns.

Figure 2 indicates the generalized land use in the Olifants River catchment.

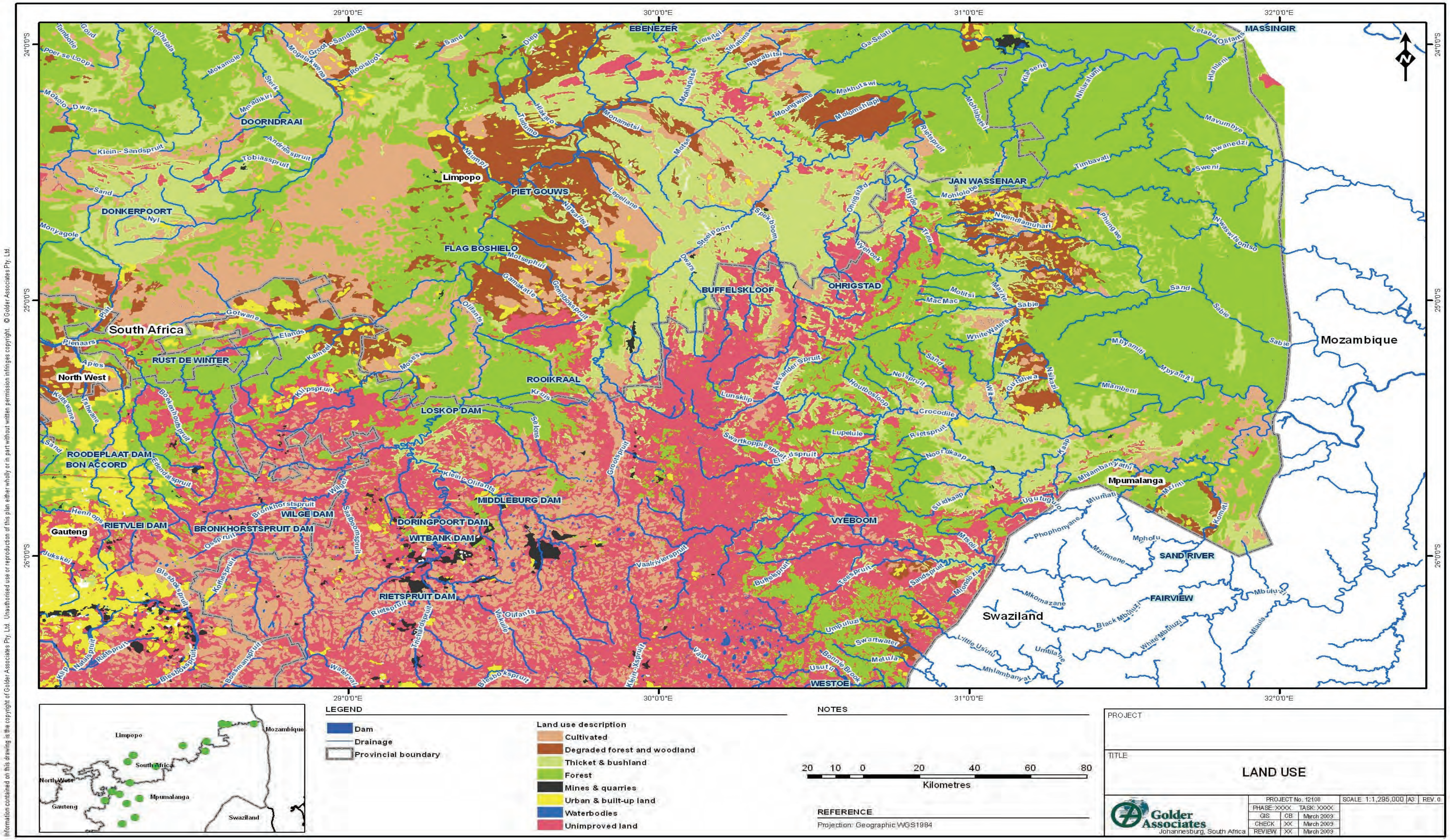

Figure 2: Summarized land use map of the Olifants River catchment area

3. WATER QUALITY PARAMETERS

The Department of Water Affairs (DWA) Resource Quality Services (RQS) water quality database was used as the source of the water quality data for this analysis. The water quality variables that were analysed are: Electrical Conductivity (EC), Total Dissolved Salts (TDS), pH, Sodium, Magnesium, Calcium, Potassium, Fluoride, Chloride, Sulphate, Phosphate as P, Total Alkalinity as CaCO3, Ammonium as N, Nitrate + Nitrite as N. No trace metal or organic analysis is performed as part of this routine monitoring (Pers. Comm. DWAF Regional Office – Mpumalanga). For the purposes of this study, the indicator variables (pH, EC, nitrate, sulphate and phosphate) were used. Sulphate and pH are useful as indicators of mining-related impacts, phosphate is an indicator of farming-related impacts, nitrate is indicative of both farming- and sewage-related impacts, and EC is a general indicator of salts-related impacts, either from mining or farming or natural origins.

4. OLIFANTS RIVER MAIN STEM

4.1 Water Quality Monitoring Points

Four water quality monitoring points were identified on the Olifants River main stem and used in the assessment of the water quality status of the river. Table 1 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 1: Selected water quality monitoring points on the Olifants River main stem

DWAF Station Identification Number	River/Stream/ Dam	Site description and Province	Land use impacting water quality
B1H18	Olifants River	At Middelkraal, Mpumalanga	Maize and coal mining
B5H4	Olifants River	Flag Boshielo downstream weir, Mpumalanga	Maize and coal mining
B7H15	Olifants River	Mamba Weir in KNP, Limpopo	Mining and industry
B7H17	Olifants River	Balule Rest Camp in KNP, Mpumalanga	National Park

The most upstream site (B1H18) is located on the Olifants River at Middelkraal, upstream of the confluence with the Trichardspruit and above Witbank Dam. The water quality in the Olifants River at this point is relatively unpolluted with low concentrations of sulphate and metals, with the pH tending towards the alkaline side. The water quality is taken to be representative of the background situation, upstream of mining and power generation operations. However, the water quality is not pristine and does reflect the aggregate impact associated with natural weathering, agriculture and atmospheric deposition.

The next site (B5H4) is located immediately downstream of Flag Boshielo Dam and downstream of the confluences with the Wilge and Elands Rivers. The two remaining sites are located on the lower Olifants River. The first (B7H15) is at Mamba Weir in the Kruger National Park, not far downstream of the Olifants River confluence with the Ga-Selati River. The second (B7H17) is also within the Kruger National Park at Balule Rest Camp, upstream of the confluence with the Letaba River and the border with Mozambique.

4.1.1 Frequency of Sampling

Water quality monitoring started between 1991 and 1993 at B1H018 and B5H004. Monitoring began in 1983 at the two sites within the Kruger National Park boundary. The yearly frequency of sampling is tabulated in Appendix A.

4.2 Water quality trends

4.2.1 pH trends

The pH on the main stem of the Olifants River does not show any significant changes, with the median values at each station all between 8.1 and 8.3 (Figure 3). Historically, the data at these sites indicate that there has been little or no pH-related impact and the pH trend is neutral (i.e. no increase or decrease over time).

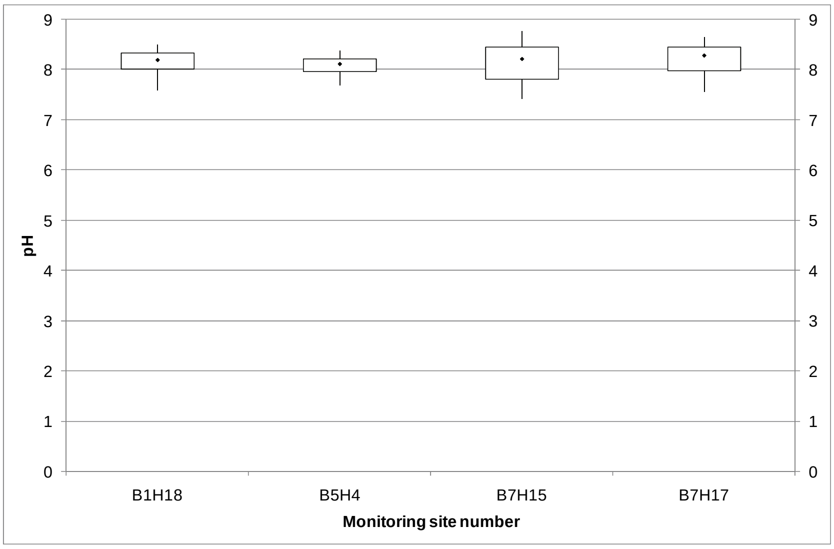

Figure 3: Box and whiskers plots based on pH percentile statistics for the main stem of the Olifants River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

The pH at site B7H15 has more variability that indicated at the other three sites. This is due to the downstream proximity of the site to the Phalaborwa Barrage, which shows similarly variable pH.

4.2.2 Nutrients trend

In this study, nutrients are represented by nitrate and phosphate variables.

Figure 4 indicates an increase in nitrate concentration down the Olifants River, with an improvement once the river passes into the Kruger National Park – in fact a return to levels similar to those in the upper reaches (B7H17 vs. B1H18). The increase in nitrate concentration at sites B5H4 and B7H15 can be attributed to inputs from the Elands and Ga-Selati Rivers, respectively. Both of these tributaries flow through urban areas with associated townships. The increase in nitrate concentration in the rivers may be as a result of sewage treatment plant inputs to the rivers.

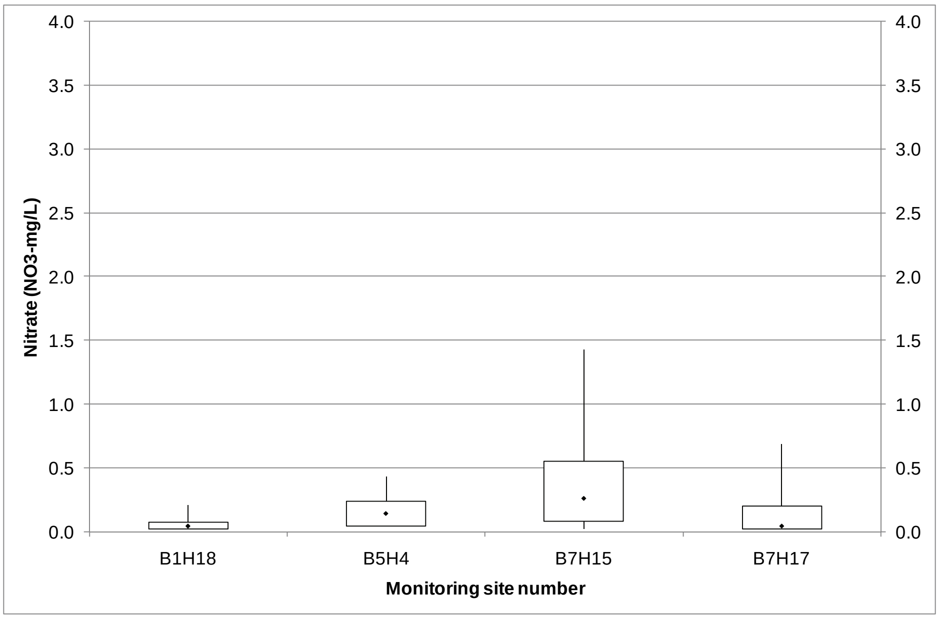

Figure 4: Box and whiskers plots based on nitrate percentile statistics for the main stem of the Olifants River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

The median phosphate concentration along the Olifants River lies between 0.016 and 0.022 mg/L (Figure 5). The variability of the phosphate concentration at each monitoring site does change, with B1H18 and B7H15 is registering the widest variation in concentration. Site B1H18 is situated in a cultivated area and the variability may be due to seasonality of the flow in that particular reach of the river.

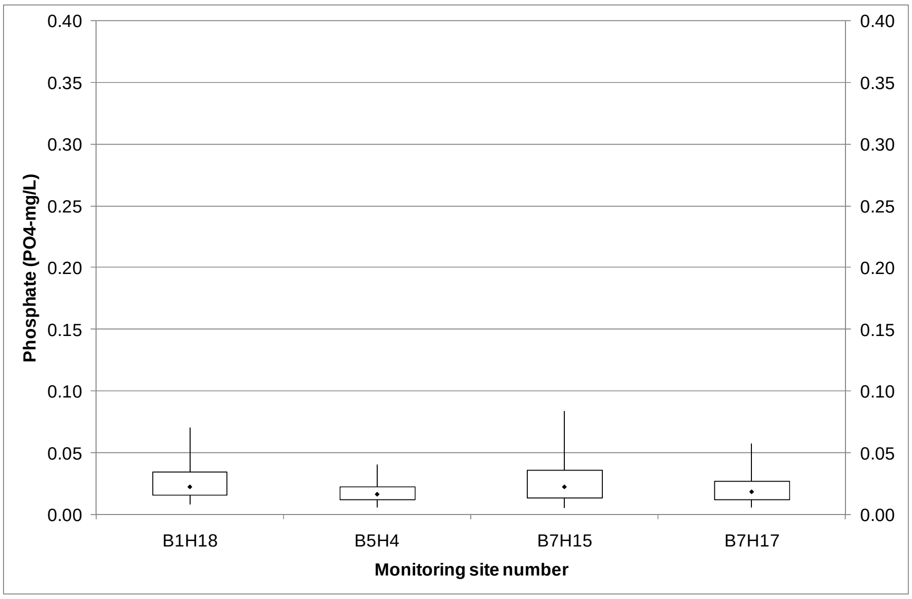

Figure 5: Box and whiskers plots based on phosphate percentile statistics for the main stem of the Olifants River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

4.2.3 Salts trends

The EC increases substantially along the length of the Olifants River (Figure 6). The upper reaches show far lower variation in EC than in the lower reaches, where values greater than 100 mS/m are recorded in more than 25% of the samples. Historically, the upper reaches show an increase in EC and the lower reaches show a decrease. This trend may be due to improvements in water quality management in the lower reaches and an increase in mining pressure in the upper reaches.

The impact of sulphates on the Olifants main stem shows similar trends to that of EC (Figure 7). An increase in sulphate concentration from the upper reaches to the lower reaches, with similar historical trends.

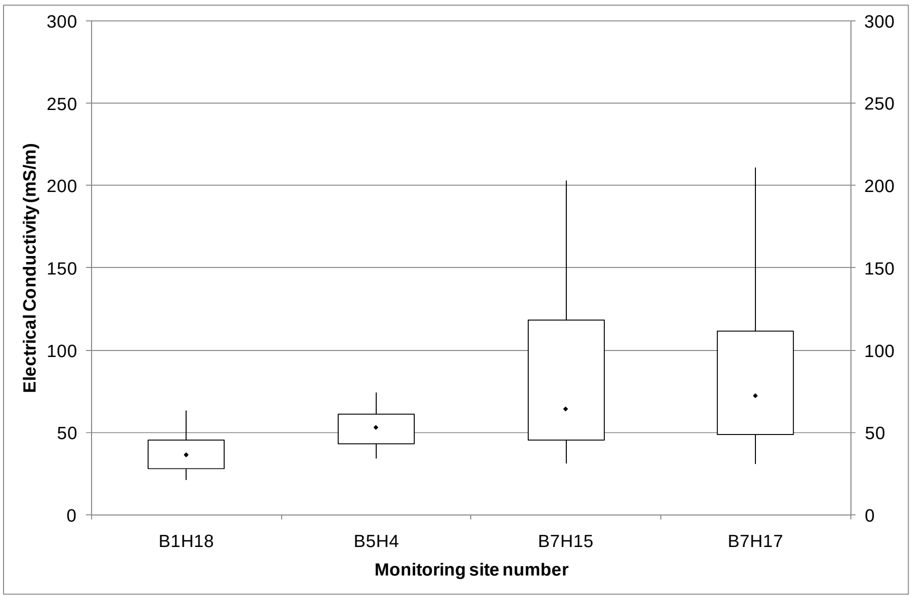

Figure 6: Box and whiskers plots based on EC percentile statistics for the main stem of the Olifants River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

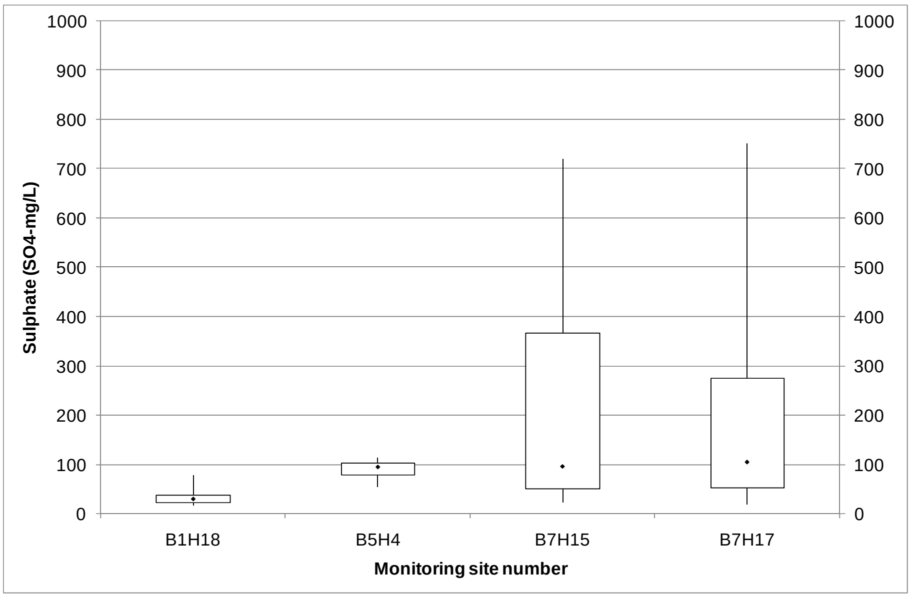

Figure 7: Box and whiskers plots based on sulphate percentile statistics for the main stem of the Olifants River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5. MAJOR TRIBUTARIES OF THE OLIFANTS RIVER

5.1 Unit 1 – Trichardspruit and Klipspruit

5.1.1 Water quality monitoring points

Two water quality monitoring points were identified in this subcatchment and used in the assessment of the water quality status of the area. Table 2 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 2: Selected water quality monitoring points on the Trichardspruit and Klipspruit

DWAF Station Identification Number	River/Stream/ Dam	Site description and Province	Land use impacting water quality
B1H6	Trichardspruit	Rietfontein, Mpumalanga	Trichardt town, agriculture
B1H4	Klipspruit	Zaaihoek, Mpumalanga	Coal mining, agriculture, maize

The first site, B1H6, is located on the Trichardspruit at Rietfontein, upstream of the confluence with the Rietspruit. The next site (B1H4) is located on the Klipspruit, which has its confluence with the Olifants River upstream of the Wilge River confluence and downstream of the confluence with the Klein Olifants River.

5.1.1.1 <u>Frequency of Sampling</u>

Water quality monitoring started in 1982 on the Trichardspruit (B1H6) and in 1966 on the Klipspruit (B1H4). The yearly frequency of sampling is tabulated in Appendix A.

5.1.2 Water quality trends

5.1.2.1 <u>pH trends</u>

The pH in the Trichardspruit is similar to that of the Olifants main stem and does not indicate any pH-related impacts. The Klipspruit, however, is significantly impacted (Figure 8). The pH in this tributary is highly impacted by the surrounding mining industries, with mine drainage seeping into the river at various points, resulting in water of low pH and high dissolved salts concentrations (RHP, 2001).

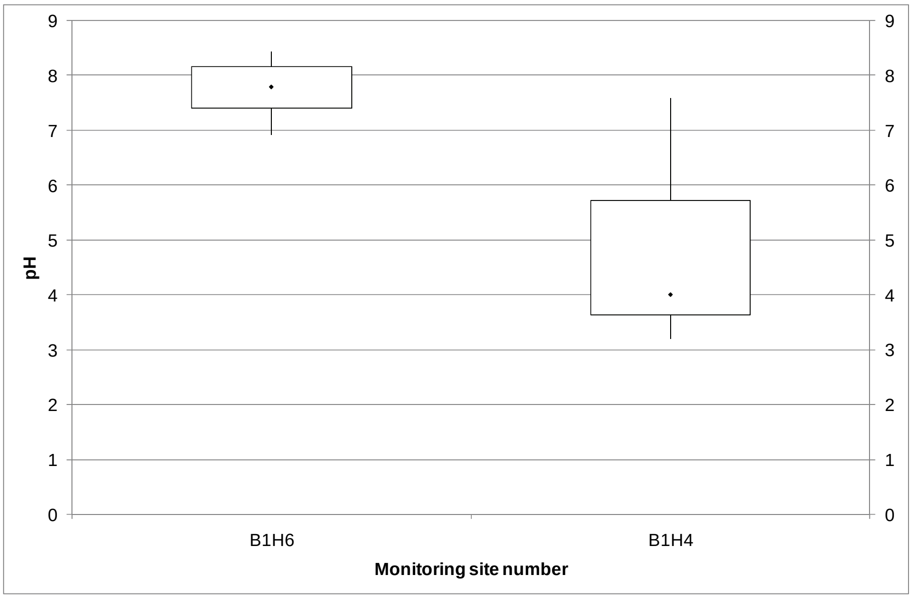

Figure 8: Box and whiskers plot based on pH percentile statistics for the upper Olifants River – Unit 1 (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.1.2.2 <u>Nutrients trends</u>

The nitrate levels in these two tributaries differ vastly (Figure 9). The Klipspruit exhibits far greater levels, for the most part due to the higher degree of human activity compared to the Trichardspruit area. The increased nitrate levels could result from both human impacts (sewage from mining activity) and direct mine-related impacts (blasting agents, etc.)

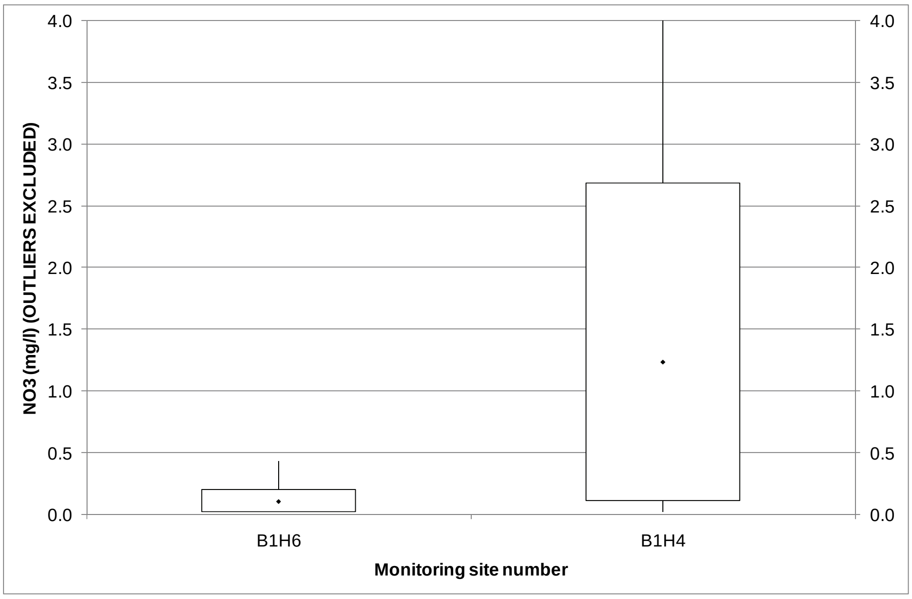

Figure 9: Box and whiskers plot based on nitrate percentile statistics for the upper Olifants River – Unit 1 (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

The plots in Figure 10 confirm that the nitrate impacts seen in the Klipspruit are not due to farming impacts. If this were so, the phosphate levels would be similarly elevated due to fertilizer use. The phosphate levels are similar to those seen along the main stem of the Olifants River.

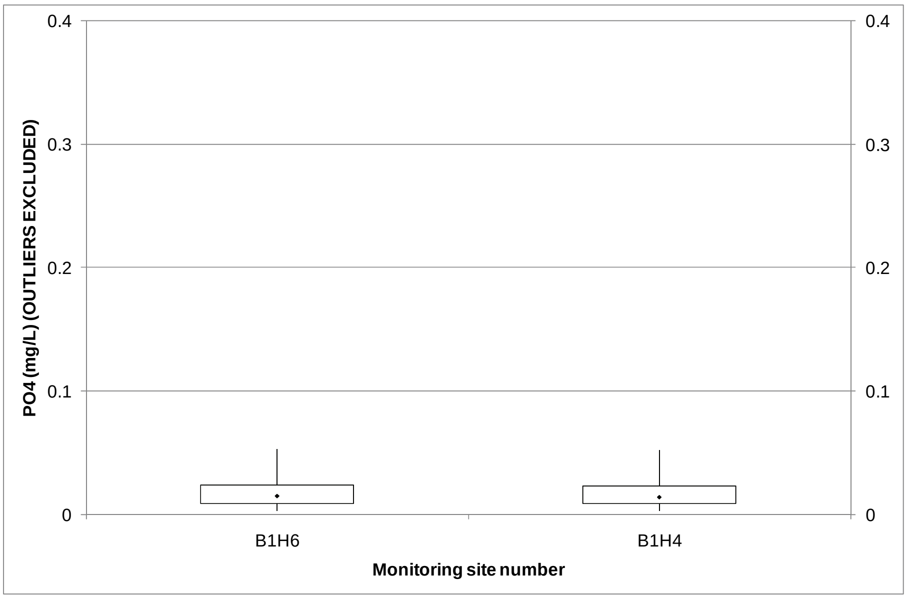

Figure 10: Box and whiskers plot based on phosphate percentile statistics for the upper Olifants River – Unit 1 (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.1.2.3 Salts trends

The EC and sulphate plots further confirm the highly impacted status of the Klipspruit tributary (Figure 11 and Figure 12). Analysis of the historical trends indicates that both sulphate and EC levels are increasing in the Klipspruit and the Trichardspruit.

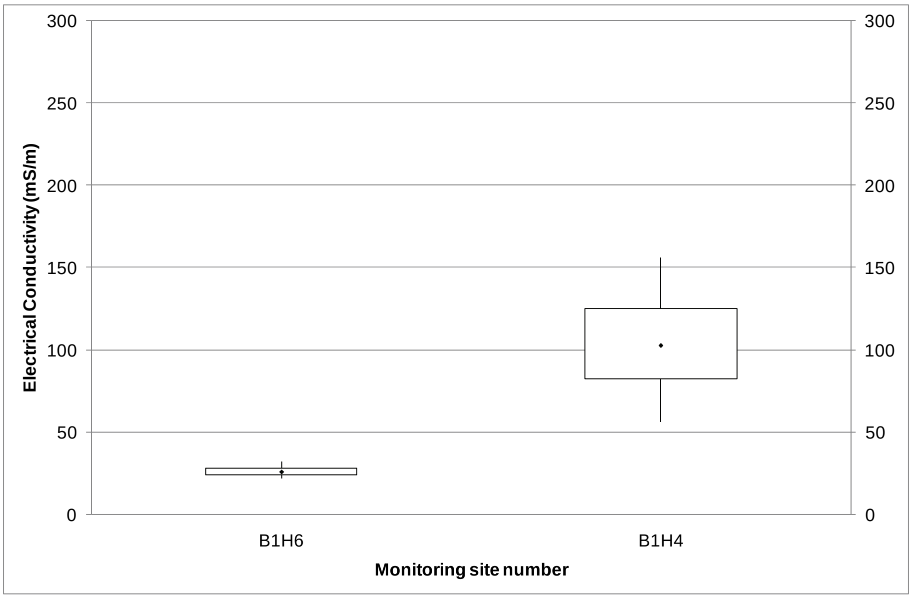

Figure 11: Box and whiskers plot based on EC percentile statistics for the upper Olifants River – Unit 1 (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

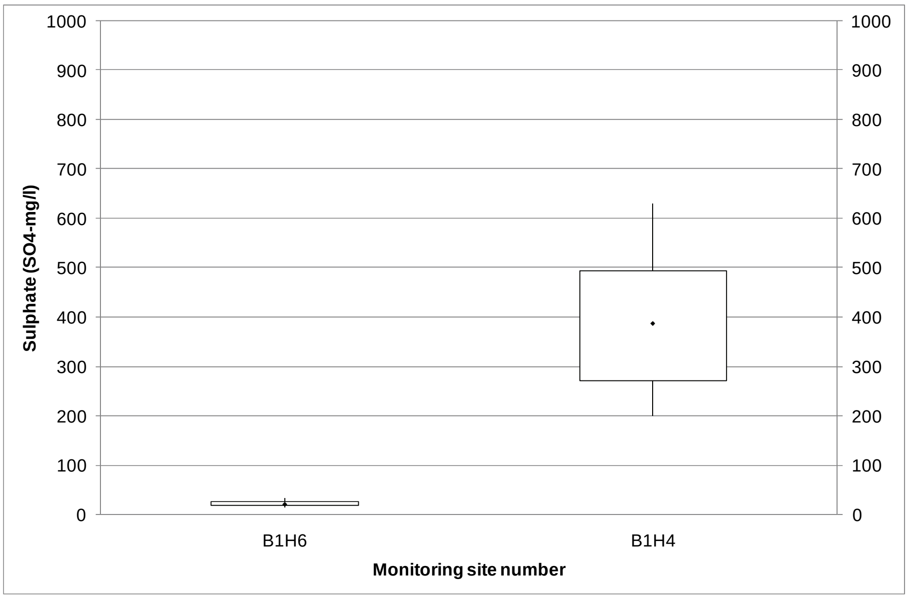

Figure 12: Box and whiskers plot based on sulphate percentile statistics for the upper Olifants River – Unit 1 (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.2 Unit 2 – Wilge River

5.2.1 Water quality monitoring points

Two water quality monitoring points were identified in this subcatchment and used in the assessment of the water quality status of the area.

Table 3 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 3: Selected water quality monitoring points on the Wilge River

DWAF Station Identification Number	River/Stream/Dam, Province	Description	Land use
B2H14	Wilge River, Gauteng	Onverwacht	Bronkhorstspruit Town, agriculture
B2H15	Wilge River, Gauteng	Zusterstroom	Agriculture

The first site, B2H14 is located on the Wilge River at Onverwacht, immediately upstream of the confluence with the Bronkhorstpsruit. The second site (B2H15) is located on the Wilge River at Zusterstroom, downstream of Bronkhorstspruit confluence.

5.2.1.1 Frequency of Sampling

Water quality monitoring started in 1991 at Onverwacht (B2H14) and in 1994 at Zusterstroom (B2H15). The yearly frequency of sampling is tabulated in Appendix A.

5.2.2 Water quality trends

5.2.2.1 pH trends

The pH measured across the sites on the Wilge River does not indicate any negative impacts. The pH does not vary by much and is neutral to slightly alkaline (Figure 13).

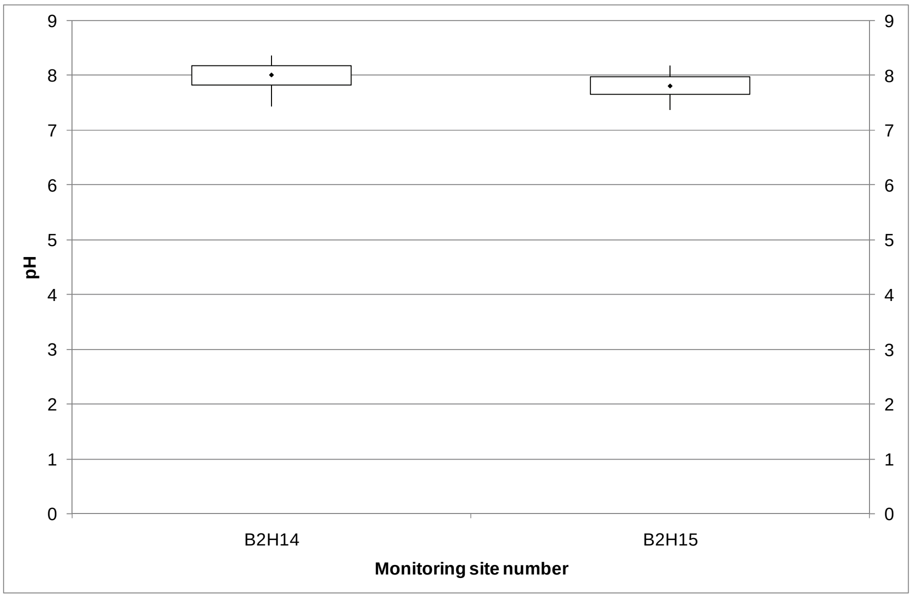

Figure 13: Box and whiskers plot based on pH percentile statistics for the upper Olifants River – Unit 2 Wilge River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.2.2.2 Nutrient trends

The Wilge River flows through areas of unimproved land interspersed with areas of cultivation. There is very little urbanization in the area. As a result, the nitrate levels measured along the river are very low (Figure 14), as are the phosphate levels (Figure 15).

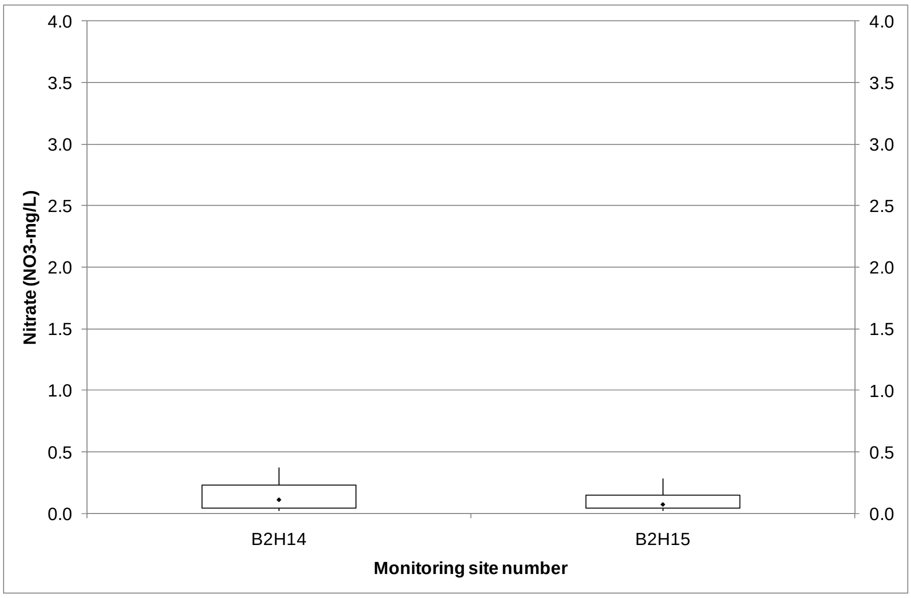

Figure 14: Box and whiskers plot based on nitrate percentile statistics for the upper Olifants River – Unit 2, Wilge River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

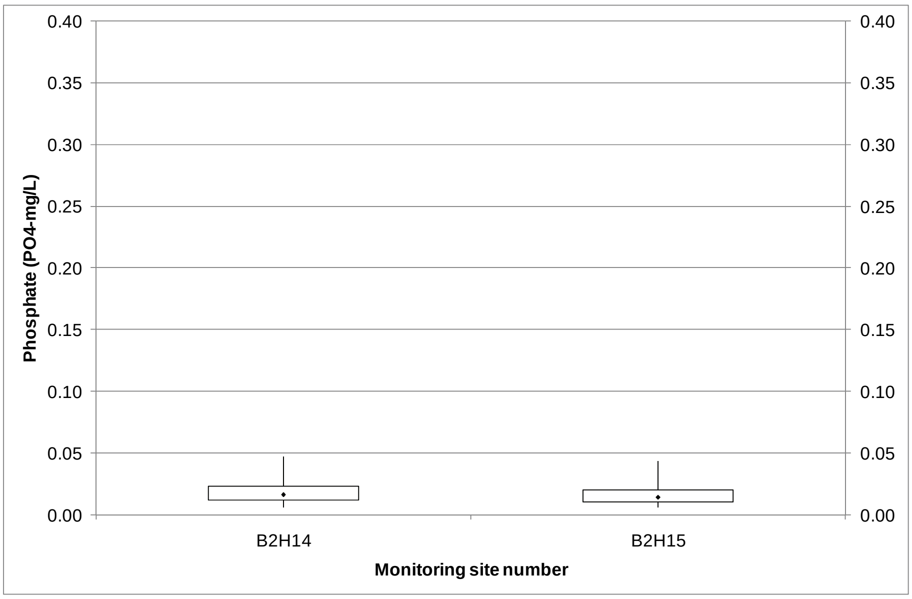

Figure 15: Box and whiskers plot based on phosphate percentile statistics for the upper Olifants River – Unit 2, Wilge River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.2.2.3 Salts trends

The EC and sulphate concentrations measured along the Wilge River show little or no impact on the river (Figure 16 and Figure 17), similar to the nitrate and phosphate results. The largely undeveloped nature of the area leads to little or no impact on the water quality of the river.

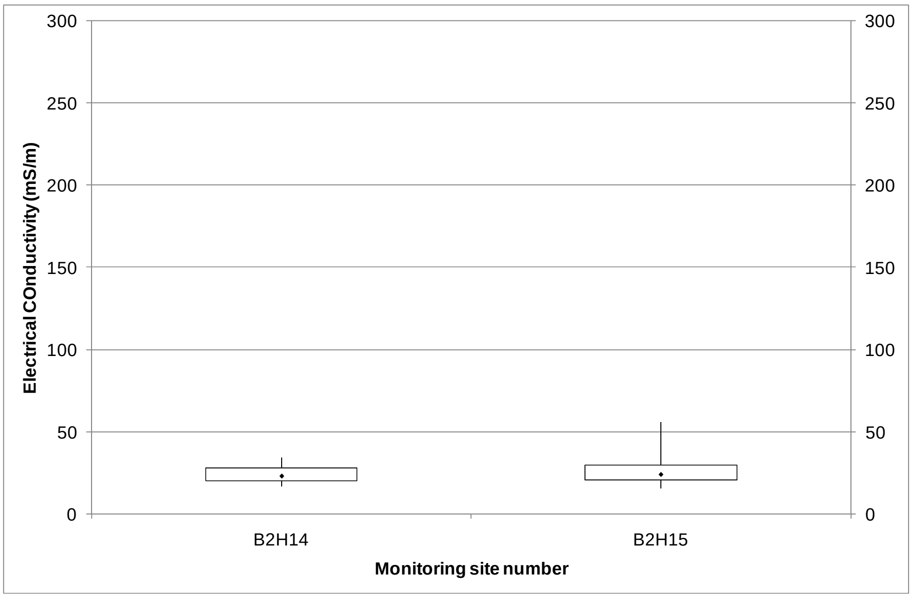

Figure 16: Box and whiskers plot based on EC percentile statistics for the upper Olifants River – Unit 2, Wilge River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

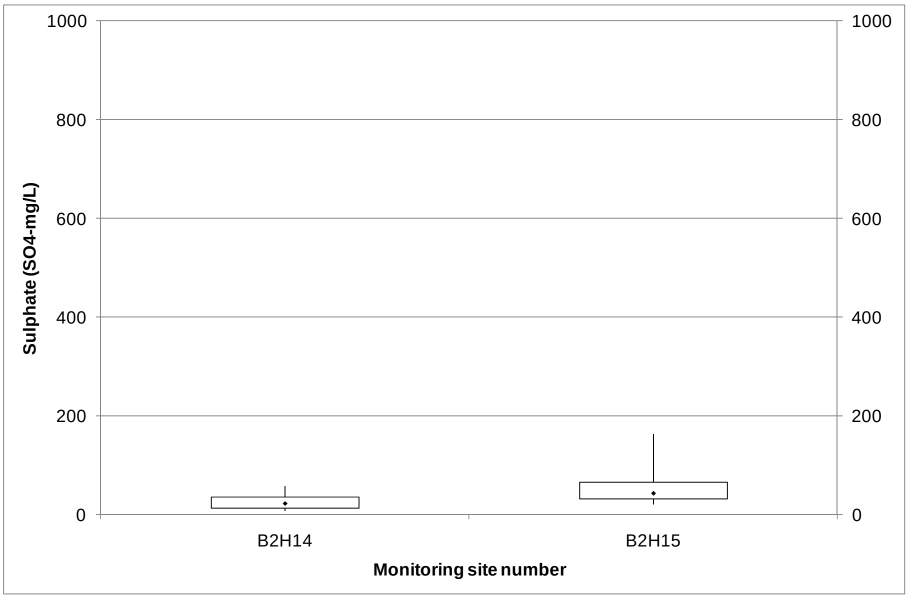

Figure 17: Box and whiskers plot based on sulphate percentile statistics for the upper Olifants River – Unit 2, Wilge River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.3 Unit 3 – Elands River

5.3.1 Water quality monitoring points

One water quality monitoring point was identified in this subcatchment and used in the assessment of the water quality status Elands River at its confluence with the Olifants River. Table 4 presents the description of the water monitoring station. The location of this point is indicated in Figure 1.

Table 4: Selected water quality monitoring point on the Elands River

DWAF Station Identification Number	River/Stream/Dam, Province	Description	Land use
B3H21	Elands River, Mpumalanga	Skerp Arabie	Dry land agriculture

The site, B3H21 is located on the Elands River at Skerp Arabie, not far upstream of the confluence with the Olifants River.

5.3.1.1 Frequency of Sampling

Water quality monitoring started in 1994. The yearly frequency of sampling is tabulated in Appendix A.

5.3.2 Water quality trends

5.3.2.1 pH trends

The pH of the Elands River is alkaline, with a mean of 8.3. No significant pH-related impacts emanating from the Elands River are anticipated.

5.3.2.2 Nutrients trends

The Elands River flows through areas of urbanization and agricultural land. There are also areas where the natural vegetation has been heavily degraded. These factors result in elevated nitrate concentrations at the confluence with the Olifants River. The agricultural impacts are further confirmed by the elevated phosphate levels at this point.

5.3.2.3 Salts trends

The electrical conductivity and sulphate levels in the Elands River are elevated. The EC in particular, has a mean value of 116 mS/m and in 5% of the measurements, was greater than 250 mS/m. This is due to the impacts of the urban and peri-urban areas along the river.

5.4 Unit 4 – Steelpoort River

5.4.1 Water quality monitoring points

Two water quality monitoring points were identified in this subcatchment and used in the assessment of the water quality status of the area. Table 5 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 5: Selected water quality monitoring points on the Steelpoort River

DWAF Station Identification Number	River/Stream/Dam	Description
B4H3	Steelpoort River, Mpumalanga	Buffelskloof, dense informal settlements, cattle grazing
B4H11	Steelpoort River, Mpumalanga	Alverton, dense informal settlements, cattle grazing

The first site, B4H3 is located on the Steelpoort River at Buffelskloof, upstream of the confluence with the Klip River. The second site (B4H11) is located on the Steelpoort River at Alverton, upstream of the confluence with the Olifants River.

5.4.1.1 Frequency of Sampling

Water quality monitoring started in 1977 at Buffelskloof (B4H3) and in 1984 at Alverton (B4H11). The yearly frequency of sampling is tabulated in Appendix A.

5.4.2 Water quality trends

5.4.2.1 pH trends

The pH increases slightly along the Steelpoort River, from a mean of 8.1 at Buffelskloof to 8.3 at Alverton. No pH-related impacts can be inferred from the statistical analysis of the historical record (Figure 18).

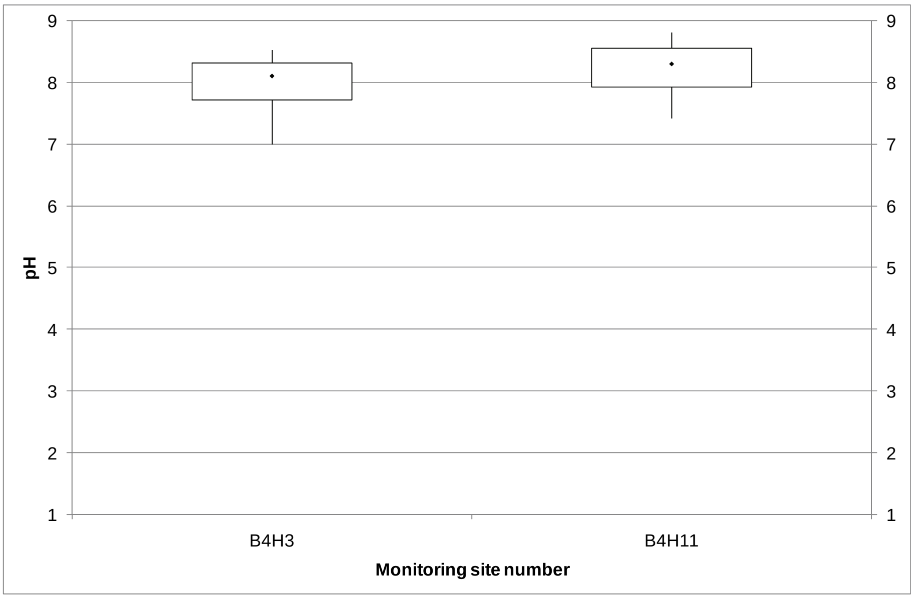

Figure 18: Box and whiskers plot based on pH percentile statistics for the lower Olifants River – Unit 4, Steelpoort River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.4.2.2 Nutrient trends

The nitrate load in the Steelpoort River increases from the upper to the lower reaches (Figure 19). There is an increase in the degree of cultivation and urbanization in the lower reaches which contributes to this impact. There are two small mining areas in the Steelpoort catchment that would also contribute to the increase in the nitrate load along the river.

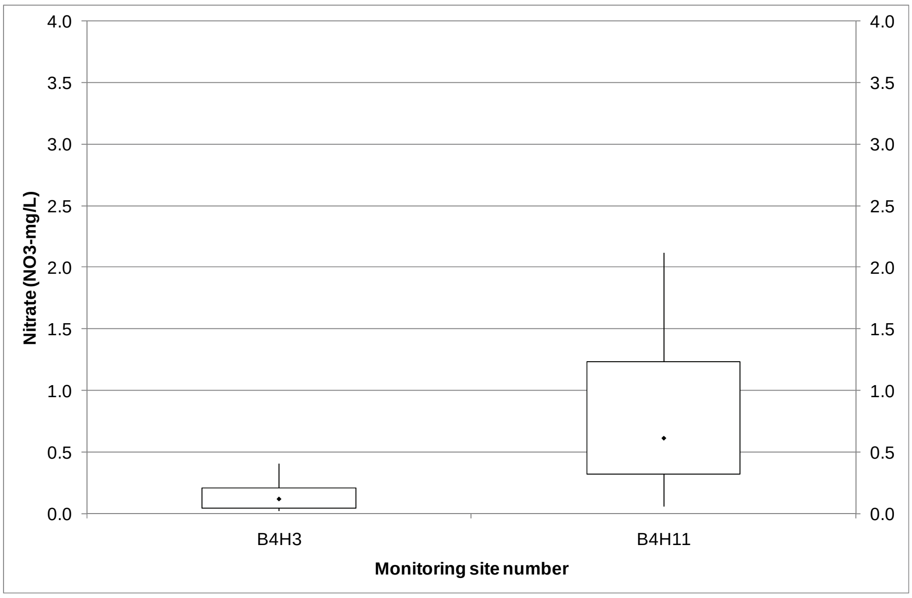

Figure 19: Box and whiskers plot based on nitrate percentile statistics for the lower Olifants River – Unit 4, Steelpoort River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

The phosphate concentrations from the upper to the lower Steelpoort River do not reflect an increase similar to that seen in the nitrate results (Figure 20). This indicates that the nutrient load is predominantly due to human impacts rather than agricultural impacts.

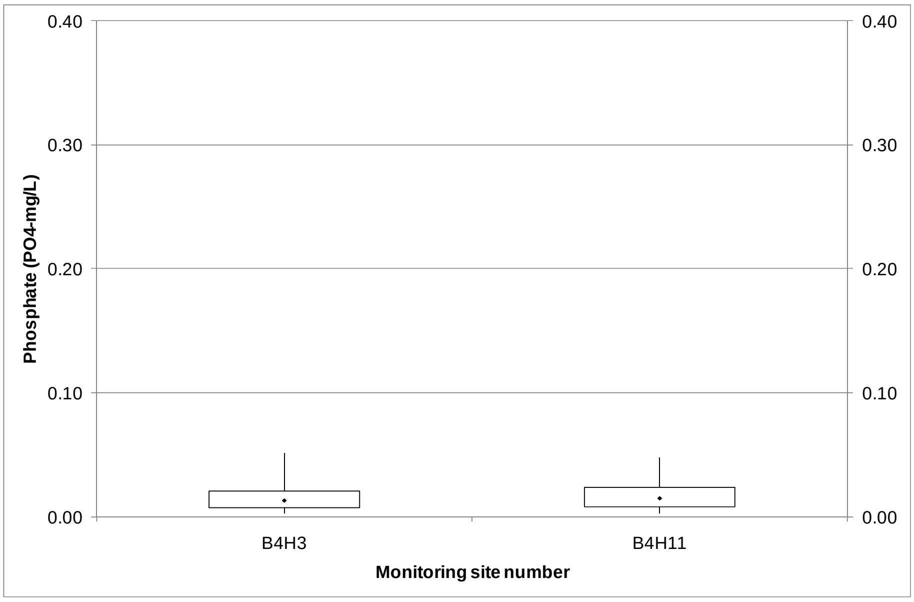

Figure 20: Box and whiskers plot based on phosphate percentile statistics for the lower Olifants River – Unit 4, Steelpoort River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.4.2.3 Salts trends

The electrical conductivity (Figure 20) and sulphate (Figure 21) indicate an increase in salts load from the upper to the lower reaches of the Steelpoort River. Again this is due to the flow of the lower reaches through much more urbanized and cultivated areas. The runoff/seepage from these developments has resulted in an increase in the salts load in the river. The increase in sulphate in particular, could be a result of the small amount of mining that takes place between the two monitoring sites. The runoff from these industries would result in an increase in the sulphate load in the river.

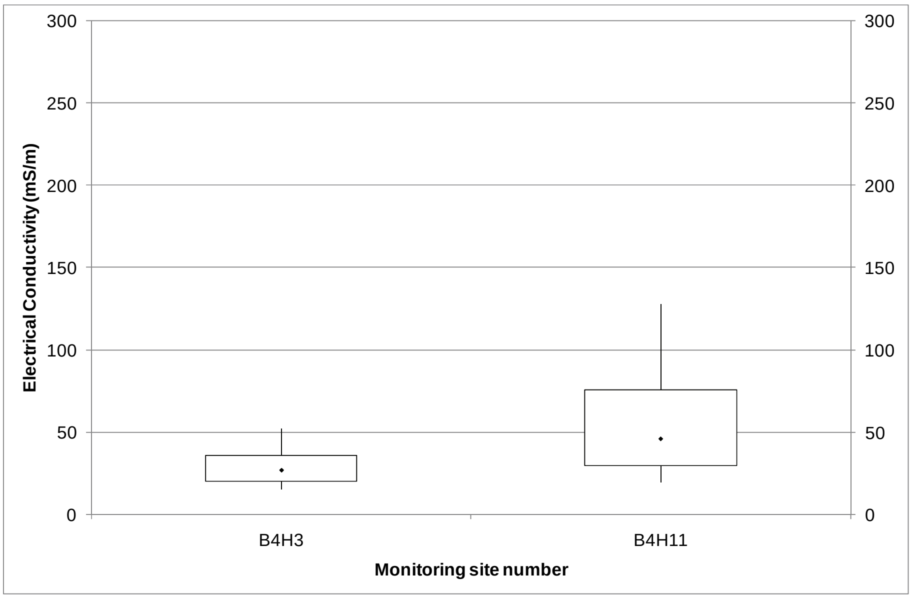

Figure 21: Box and whiskers plot based on EC percentile statistics for the lower Olifants River – Unit 4, Steelpoort River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

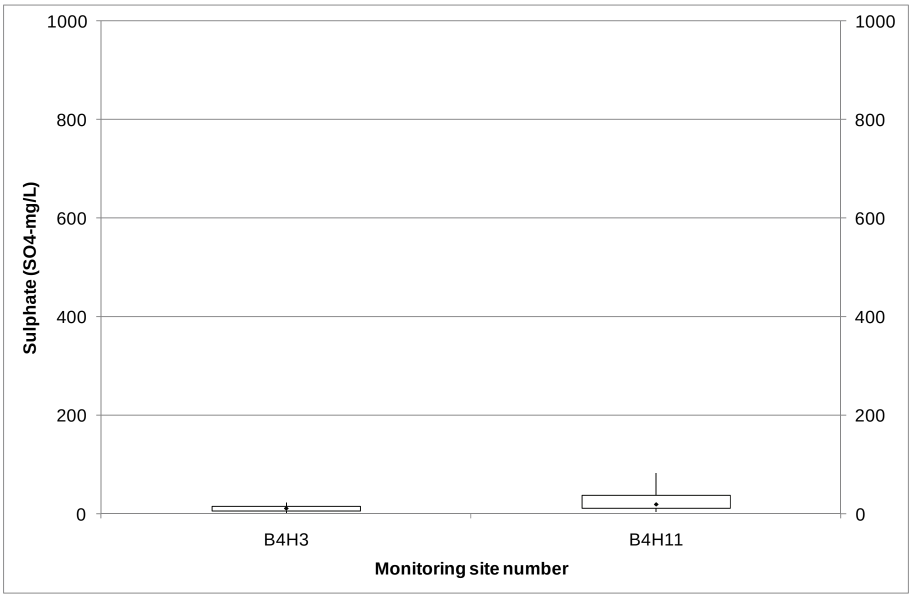

Figure 22: Box and whiskers plot based on sulphate percentile statistics for the lower Olifants River – Unit 4, Steelpoort River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.5 Unit 6 – Blyde River

5.5.1 Water quality monitoring points

Two water quality monitoring points were identified in this subcatchment and used in the assessment of the water quality status of the area. Table 6 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 6: Selected water quality monitoring points on the Blyde River

DWAF Station Identification Number	River/Stream/Dam	Description
B6H1	Blyde River, Mpumalanga	Willemsoord, commercial forestry
B6H4	Blyde River, Mpumalanga	Chester, dry land agriculture, cattle ranches

The first site, B6H1 is located on the Blyde River at Willemsoord, at the confluence with the Treur River. The second site (B6H4) is located on the Blyde River at Chester, upstream of the confluence with the Olifants River.

5.5.1.1 Frequency of Sampling

Water quality monitoring started in 1966 at Willemsoord (B6H1) and in 1978 at Chester (B6H4). The yearly frequency of sampling is tabulated in Appendix A.

5.5.2 Water quality trends

5.5.2.1 pH trends

The pH in the Blyde River is neutral to slightly alkaline (Figure 22). There is no evidence of pH-related impacts on the water quality in this catchment.

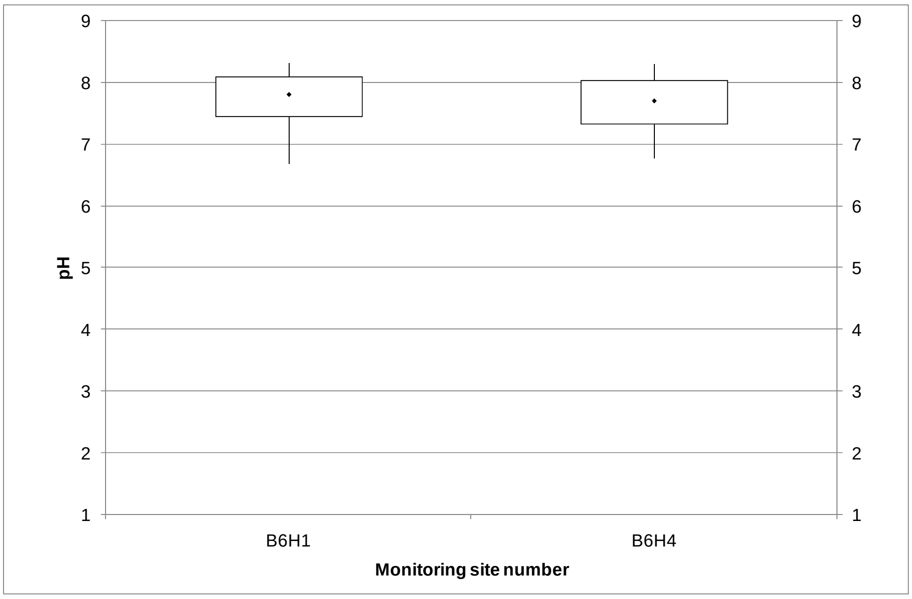

Figure 23: Box and whiskers plot based on pH percentile statistics for the lower Olifants River – Unit 6, Blyde River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.5.2.2 Nutrient trends

The nitrate levels (Figure 24) and the phosphate levels (Figure 24) are low. This is due to the largely unimproved area through which it flows. There is very little urbanization and only a small area of cultivated land at the lower reaches of the river.

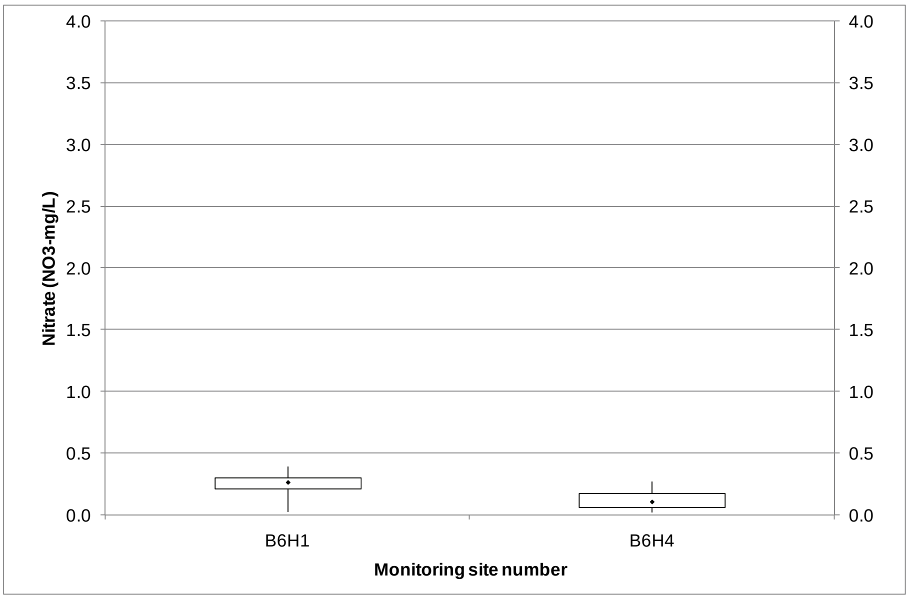

Figure 24: Box and whiskers plot based on nitrate percentile statistics for the lower Olifants River – Unit 6, Blyde River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.5.2.3 Salts trends

Both the EC (Figure 25) and sulphate (Figure 26) concentrations are very low. Again this is due to the largely pristine nature of the area through which the Blyde River flows.

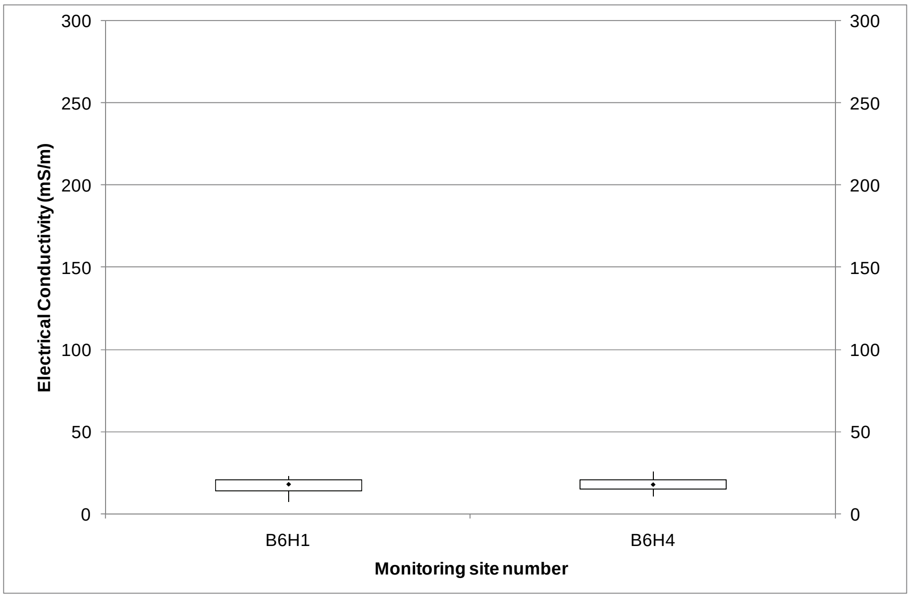

Figure 25: Box and whiskers plot based on EC percentile statistics for the lower Olifants River – Unit, Blyde River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

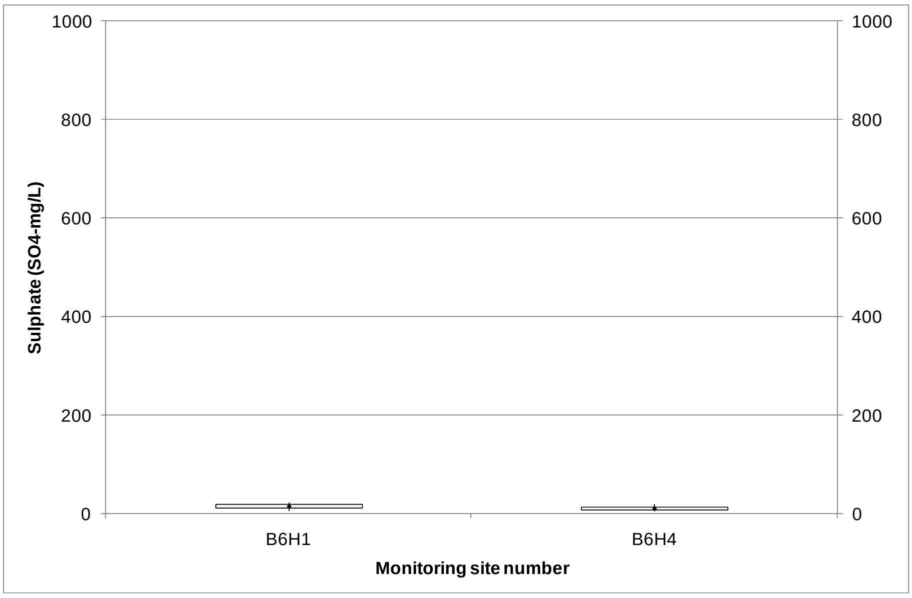

Figure 26: Box and whiskers plot based on sulphate percentile statistics for the lower Olifants River – Unit 6, Blyde River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.6 Unit 7 – Ga-Selati River

5.7 Water quality monitoring points

One water quality monitoring point was identified in this river and was used in the assessment of the water quality status of the Ga-Selati River at its confluence with the Olifants River. Table 6 presents the description of the water monitoring station. The location of this point is indicated in Figure 1.

Table 7: Selected water quality monitoring point on the Ga-Selati River

DWAF Station Identification Number	River/Stream/Dam	Description
B7H19	Ga-Selati River	Loole/Foskor, urban settlement of Phalaborwa, mining

The site, B7H19 is located on the Ga-Selati River at Foskor, not far upstream of the confluence with the Olifants River.

5.7.1 Frequency of Sampling

Water quality monitoring started in 1989. The yearly frequency of sampling is tabulated in Appendix A.

5.7.2 Water quality trends

5.7.2.1 pH trends

The pH of the Ga-Selati River is alkaline, with a mean of 8.3. No significant pH-related impacts emanating from the Ga-Selati River are anticipated.

5.7.2.2 Nutrients trends

The Ga-Selati River flows through areas of urbanization and intensive mining in Phalaborwa. There are also areas where the natural vegetation has been heavily degraded. These factors result in elevated nitrate concentrations at the confluence with the Olifants River. The phosphate levels in the Ga-Selati River are also very high.

5.7.2.3 Salts trends

The electrical conductivity and sulphate levels in the Ga-Selati River are highly elevated due to the significant mining impact on the river water quality through mine drainage leakage and possibly contaminated groundwater seepage.

5.8 Dam water quality

5.8.1 Water quality monitoring points

Two water quality monitoring points were identified in this subcatchment and used in the assessment of the water quality status of the area. Table 7 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 8: Selected dam water quality points in the Olifants River catchment

DWAF Station Identification Number	River/Stream/Dam	Description
B1R1	Witbank Dam	Olifants River
B1R2	Middelburg Dam	Klein Olifants River
B3R2	Loskop Dam	Olifants River
B5R2	Flag Boshielo Dam	Olifants River
B7R2	Phalaborwa Barrage	Olifants River

The first site, B1R1 is located on the Olifants River after the confluences with the Rietspruit, and the Trichardspruit. The second site (B1R2) is located on the Klein Olifants River. The third site (B3R2) is located on the Olifants River downstream of the confluence with the Wilge River and the Klein Olifants River. The fourth dam site (B5R2) is located further downstream in the middle Olifants catchment area, downstream of the confluence with the Elands River. The fifth site (B7R2), the Phalaborwa Barrage is located upstream of the Ga-Selati River confluence and before the river passes into the Kruger National Park.

5.8.1.1 Frequency of Sampling

Water quality monitoring started in 1972 at Witbank Dam (B1R1), in 1978 at Middelburg Dam (B1R2), in 1968 at Loskop Dam (B3R2), in 1994 at Flag Boshielo Dam (B5R2) and in 1975 at the Phalaborwa Barrage (B7R2). The yearly frequency of sampling is tabulated in Appendix A.

5.8.2 Water quality trends

5.8.2.1 pH trends

The pH across the selected dams in the Olifants River catchment is neutral to slightly alkaline (Figure 27). The pH in Loskop Dam shows slightly more variability than the other dams, and the mean value is slightly lower than the others, but still within the expectations for good water quality.

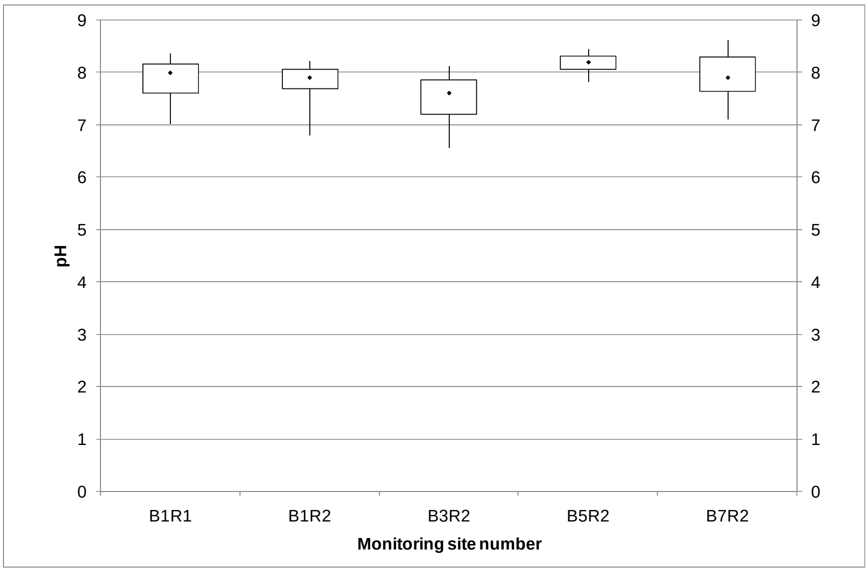

Figure 27: Box and whiskers plot based on pH percentile statistics for the Olifants River catchment dams (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.8.2.2 Nutrients trends

The nutrient trends across the selected dams show no significant difference between the dams, and all of the values are relatively low. This is to be expected as dams will act as “sinks”, collecting and reducing the nutrient content via utilization by macrophytes and micro-organisms present in the dams. Both the nitrate (Figure 28) and phosphate (Figure 29) results show a stable trend across the dams in the catchment.

5.8.2.3 Salts trends

The electrical conductivity (Figure 30) trend across the selected dams in the catchment shows a decrease in EC at Loskop Dam, with slightly elevated levels at Middelburg and Flag Boshielo Dams. There is intensive mining upstream of Middelburg Dam, which would contribute to the elevated levels, whereas Flag Boshielo Dam is in an area of highly degraded land with some urbanization which may give rise to the elevated results at that point.

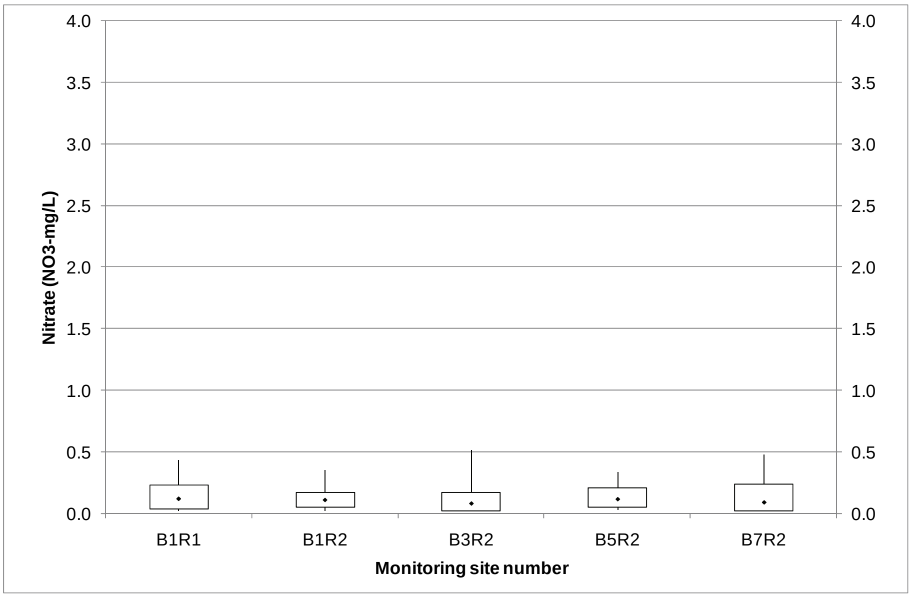

Figure 28: Box and whiskers plot based on nitrate percentile statistics for the Olifants River catchment dams (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

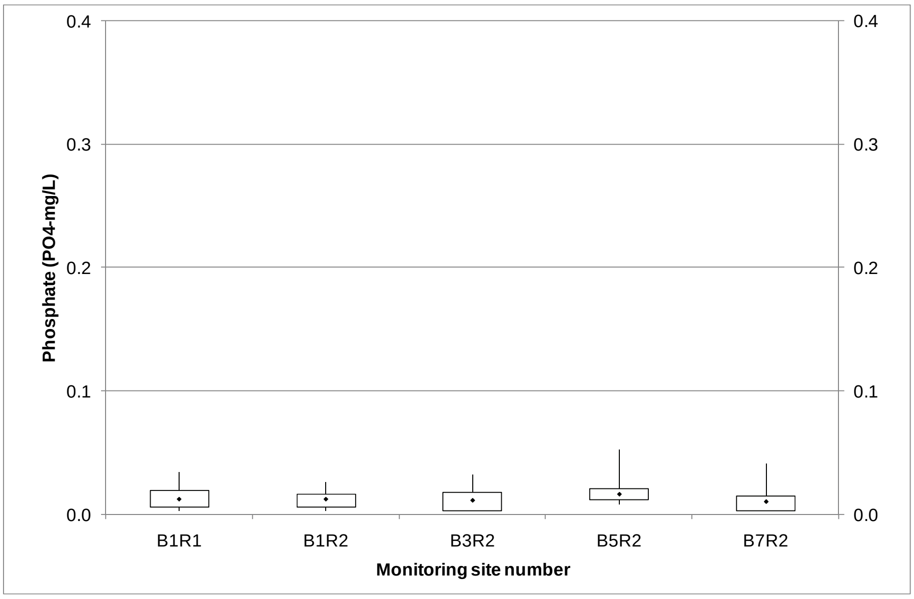

Figure 29: Box and whiskers plot based on phosphate percentile statistics for the Olifants River catchment dams (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

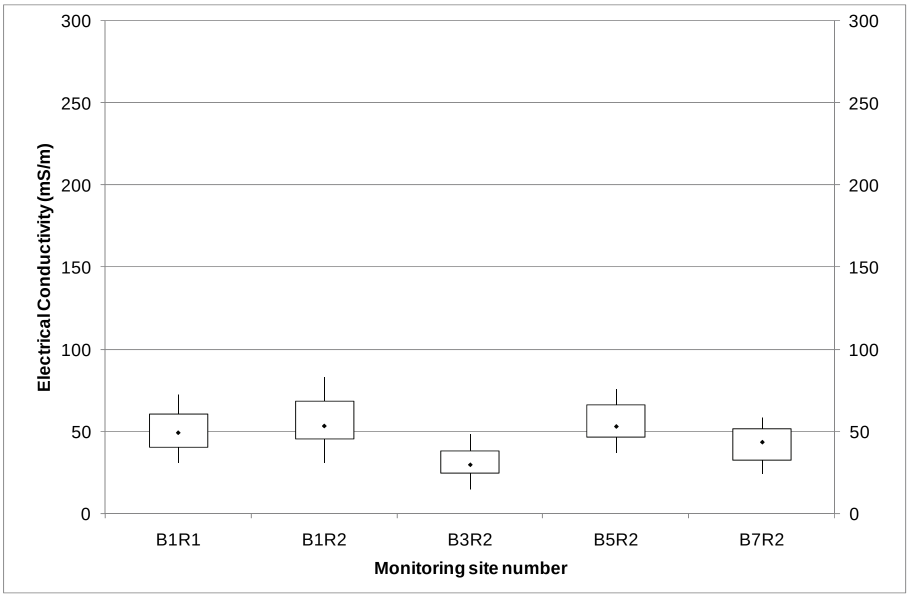

Figure 30: Box and whiskers plot based on EC percentile statistics for the Olifants River catchment dams (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

The sulphate results (Figure 31) indicate the location of the major mining impacts within the catchment, with the highest impacts being felt in Witbank and Middelburg Dams. This high sulphate load has been reduced somewhat by the time the water reaches Loskop Dam, with further significant decreases in sulphate load through Flag Boshielo and the Phalaborwa Barrage.

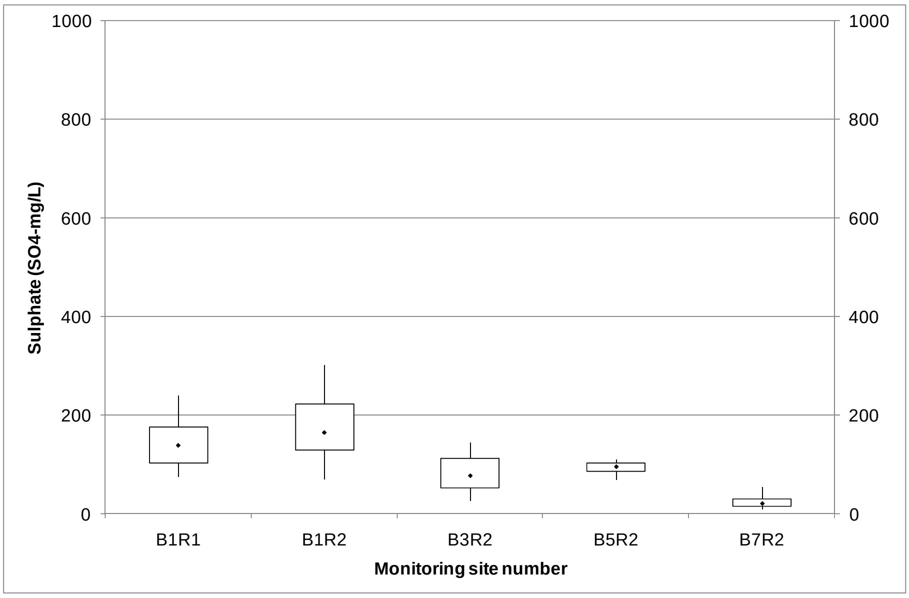

Figure 31: Box and whiskers plot based on sulphate percentile statistics for the Olifants River catchment dams (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

6. GENERAL WATER QUALITY TRENDS ACROSS THE OLIFANTS RIVER CATCHMENT

6.1 pH trends

Figure 32 summarizes the pH trend across the Olifants River catchment. The pH in the upper Olifants catchment is neutral to alkaline for the most part. A major negative impact at this point in the reach is the water coming into the system from the Klipspruit. The mean pH of the water from the Klipspruit is 4, and will drop below that at least 25% of the time due to constant mine drainage seepage from the extensive mining in the area. The Wilge River does not contribute to any negative impacts, but a slight decrease in pH was noted for Loskop Dam due to the impacts received via the Klipspruit.

In the middle Olifants catchment, the pH is again neutral to alkaline with no negative impacts from the selected tributaries (Elands and Steelpoort River). Downstream of the Steelpoort River confluence, the lower Olifants catchment shows some variability in pH, but is neutral to alkaline with no further pH-related negative impacts

6.2 Nutrients trends

Figure 33 summarizes the nitrate trend across the Olifants River catchment and selected associated tributaries.

The nitrate trend in the upper Olifants catchment is generally low, excluding the high impact received from the Klipspruit, again due to the high density mining area with associated urbanization. Very little nitrate load is introduced from the Wilge River system, and Loskop Dam absorbs a significant proportion of the nitrate coming into the dam from the upper reaches of the catchment.

In the middle Olifants catchment the Elands River contributes nitrate to the overall load of the Olifants River, predominantly through urban and peri-urban impacts. Similarly the Steelpoort River introduces a high nitrate load as a result of agricultural activities and small urban areas in the lower reaches.

The Blyde River does not contribute to the nitrate load in the lower Olifants catchment, and the levels at the Phalaborwa Barrage are similarly low. After the confluence with the Ga-Selati River, the nitrate levels in the Olifants River are increased *via* negative impacts received from the Ga-Selati River and the associated mining activity.

The summarized phosphate trend across the catchment in Figure 34 indicates that in the upper catchment area there is no significant input of phosphate to the Olifants River. The slightly elevated levels measured at Middelkraal (B1H18) on the Olifants River reflect the agricultural land use through which the river flows.

In the middle catchment, the Elands River adds to the phosphate load in the Olifants River, but at Flag Boshielo Dam this load is reduced to concentrations seen upstream of the Elands River confluence.

In the lower Olifants catchment, the Ga-Selati introduces a significant amount of phosphate to the system, but this is greatly reduced at the “sink” formed by Mamba weir (B7H15).

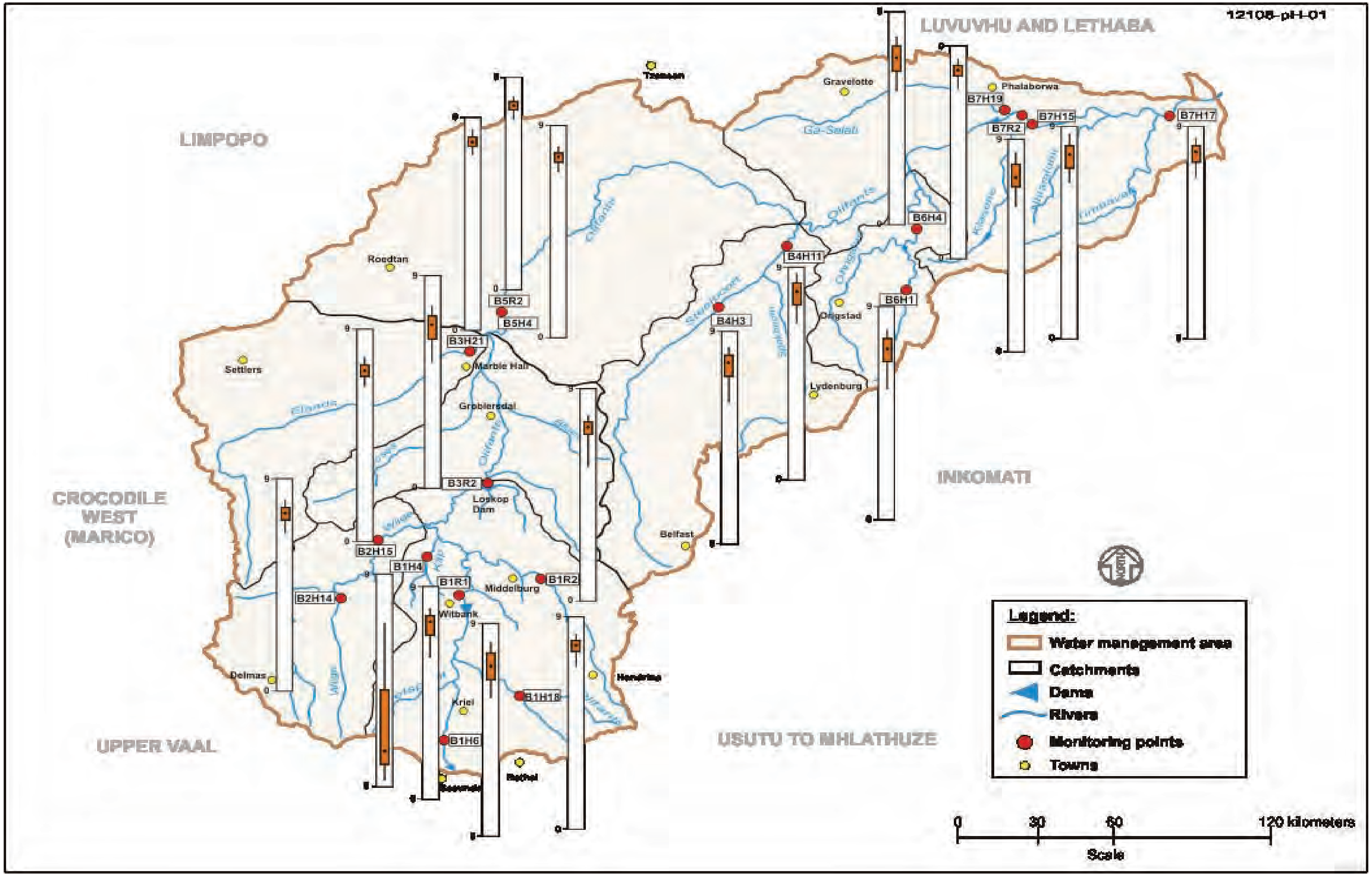

Figure 32: Summarized pH trend across the Olifants River catchment

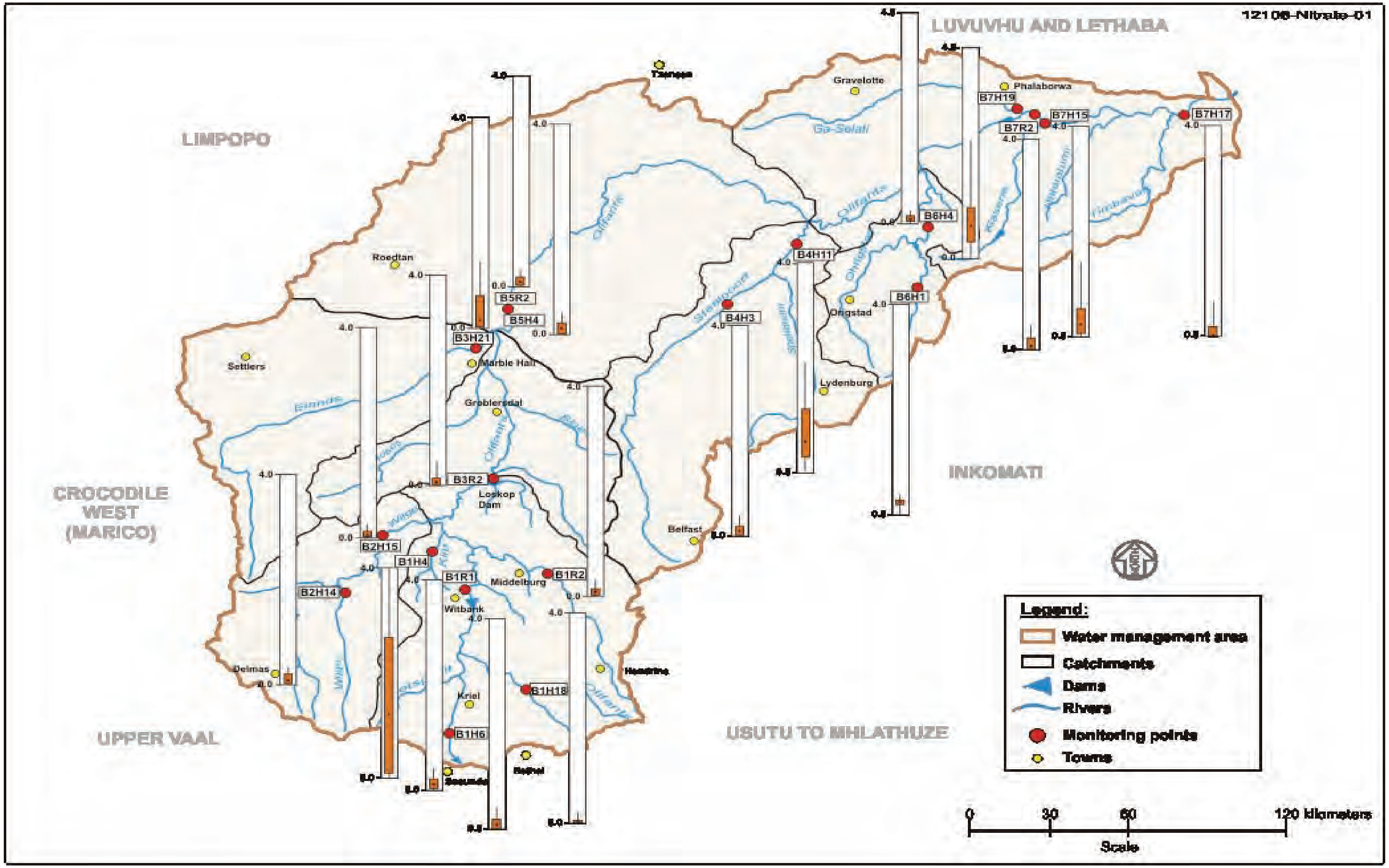

Figure 33: Summarized nitrate trend across the Olifants River catchment

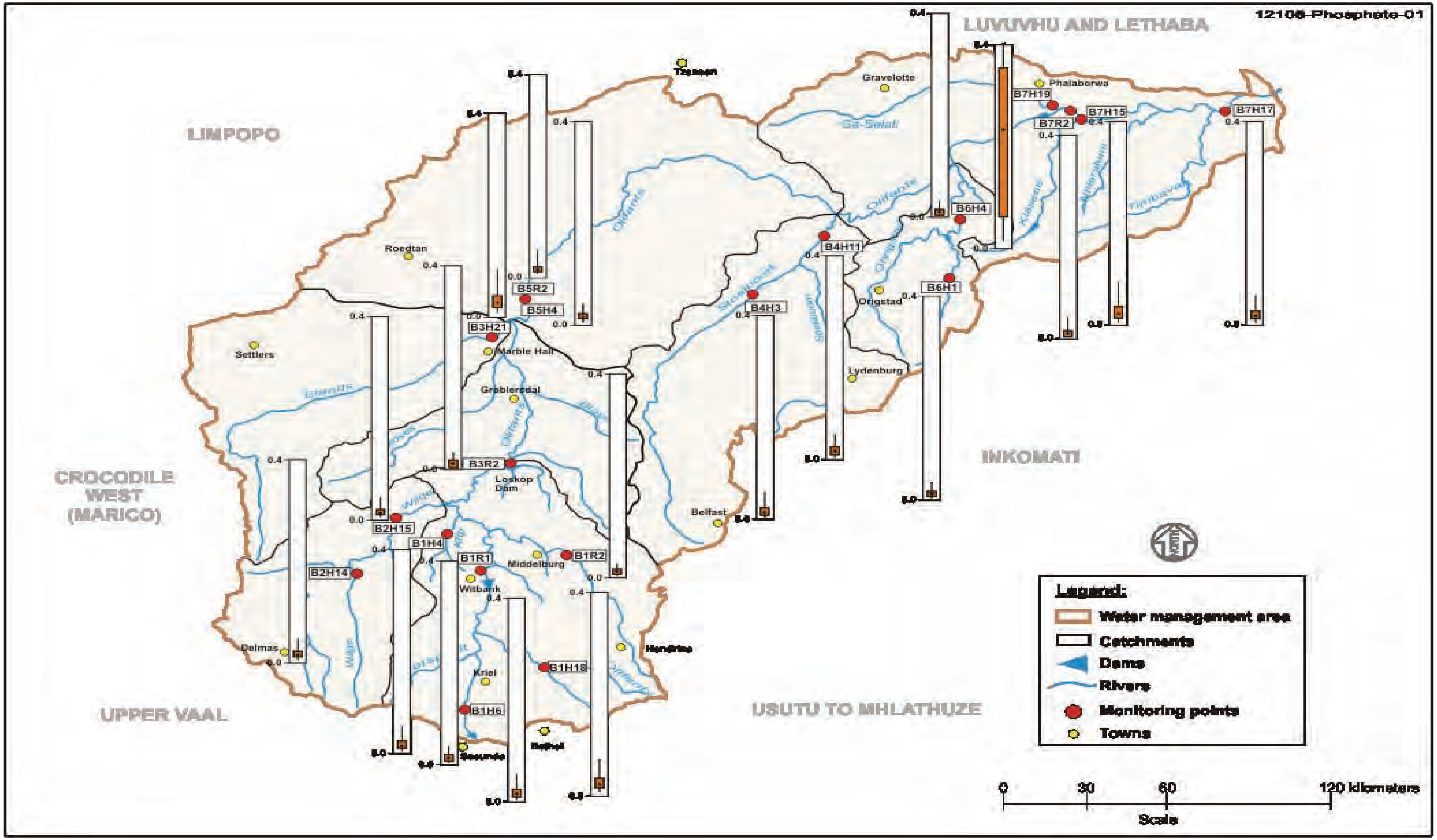

Figure 34: Summarized phosphate trend across the Olifants River catchment

6.3 Salts trend

The electrical conductivity (EC) data for the upper Olifants River catchment show that the river is impacted by salts from the upper reaches (Figure 35). The water quality at Middelkraal on the Olifants River is elevated, and this trend increases from Witbank Dam to Middelburg Dam. The EC results for the Klipspruit are significantly higher than the rest of the upper reach of the catchment. The high salts concentrations in the upper reaches are a direct result of the intensive mining activity in the area. Loskop Dam, however, greatly reduces this via the salt “sink” effect.

In the middle Olifants catchment the Elands River contributes a high concentration of salts to the Olifants River, as does the Steelpoort – both a result of urban and agricultural runoff

The lower reaches of the catchment are negatively impacted by salts inputs from the Ga-Selati River. This concentration is diminished, but not returned to acceptable levels by the time it enters the Kruger National Park.

An analysis of the sulphate concentrations across the Olifants River catchment (Figure 36) shows a similar trend for the upper reaches of the catchment area. High sulphate levels were recorded in the Witbank and Middelburg Dams, with significantly higher impacts being introduced below these dams via the Klipspruit.

The Elands River is again a contributor to the salts concentration in the Olifants River. The sulphate levels measured are again elevated.

The lower Olifants catchment receives no significant sulphate inputs from the Blyde River, but the Ga-Selati River (mean sulphate = 800 mg/L) contributes significantly. Similar to the conductivity data, the sulphate concentration is still elevated when the river enters the border of the Kruger National Park.

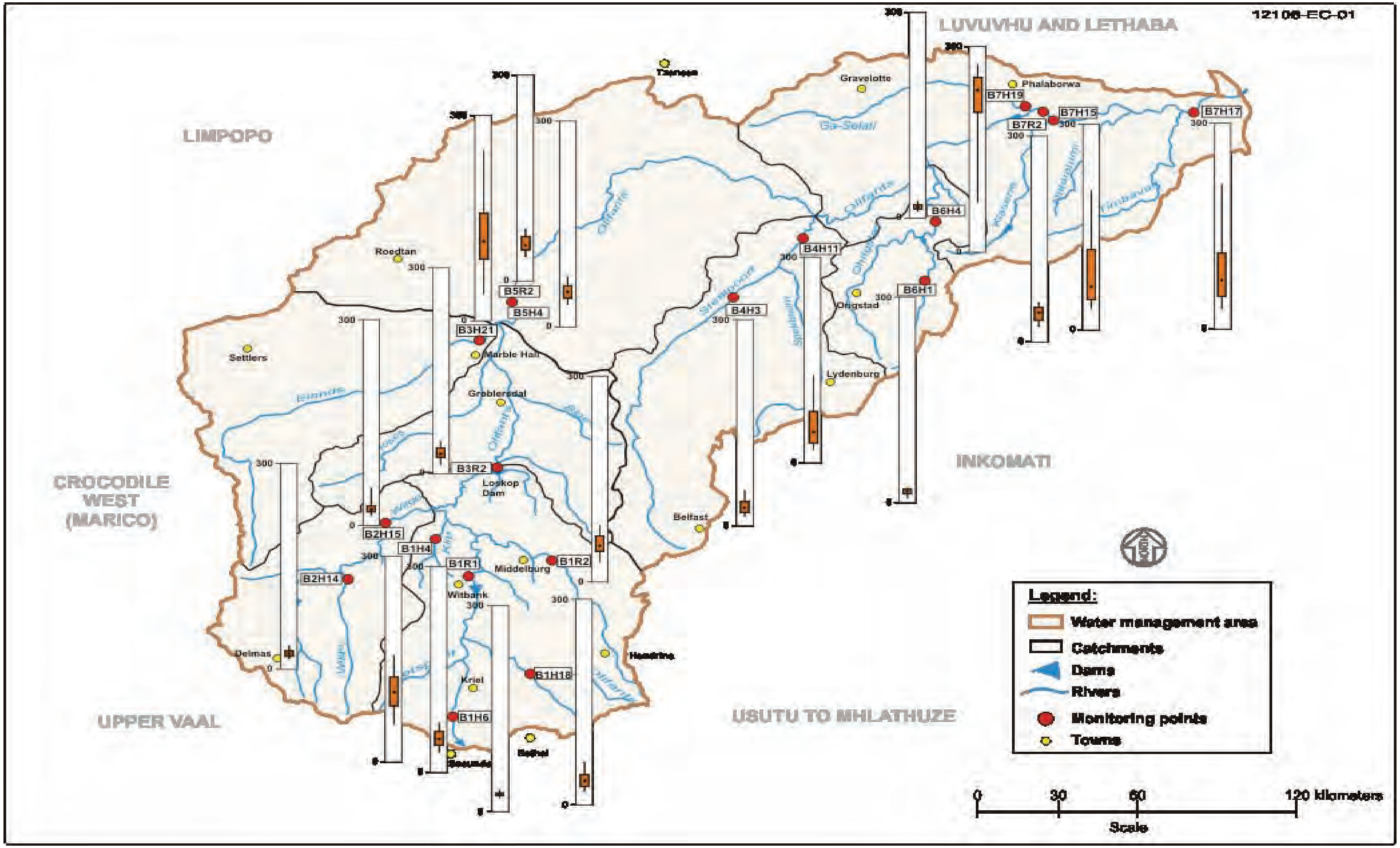

Figure 35: Summarized electrical conductivity trend across the Olifants River catchment

7. ECOLOGICAL DATA AVAILABLE

In the light of the water quality and the massive mortality of aquatic organisms experienced in the Olifants River system (Figure 37) during the last two years, it has become essential to review and summarize the current knowledgebase and available information on the ecology of the Olifants River System with possible relationship to the water quality.

Figure 36: Crocodile mortalities in Olifants River 2008

Pre 1990 studies in the Olifants River mainly focused on biodiversity issues in the Olifants River Catchment. Very few studies placed emphasis on the water quality problems in the Olifants River catchment. Few of the studies had indirect relationship to water quality and some of these studies may be useful with respect to establishing some reference conditions for the aquatic ecosystem in the in the Olifants River pre 1990. The Former Transvaal Directorate of Nature Conservation and Potchefstroom University was possibly the most active in the area during this period. Although only a moderate number of published articles for the Olifants exist it is clear that a huge amount of data and information may still be available in the form of monitoring data, communications, unpublished reports and personal experience of some scientist that has been involved with studies in the Olifants River System.

Post 1990 until recently several aquatic ecological studies concentrated on the bioaccumulation of trace metals in selected fish species and some impacts relating to sediments and its effect on the fish community. These studies focused mainly on the lower Olifants River indicating that bioaccumulation are taking place but the variation were difficult to define. Some studies suggested that bioaccumulation could be more prevalent during periods of high flow and increased sediments.

However, more recently the massive fish and crocodile deaths in Loskop Dam and in the Kruger National Park has renewed interest in the water quality problems experienced in the Olifants River System. Recent pathological and, histopathology studies of fish showed changes consistent with lipid-autoxidation, suggesting an excessive pro-oxidant challenge related to chronic pollution that may be affecting the entire aquatic food chain. Depleted antioxidants (vitamin E) and excessive fat in fish may have lead to insufficient protection of the fish lipids consumed by predators precipitating the development of pansteatitis in predators such as the crocodiles and terrapins. The disruption to the food chain is also supported by a recent study that has concluded that Loskop dam are now hypertrophic and that changes in functional groups of phytoplankton has occurred. This would imply that the quality of food and the structure of available habitat for benthic invertebrates have also been impacted.

Several studies have recently been initiated to investigate water quality and its impact on the aquatic ecosystem.

7.1 Literature review method

This review concentrated on ecological information that could have direct or indirect bearing on water quality issues in the Olifants River System and is largely based on internet searches, scanning through some of the Former Transvaal Directorate of Nature Conservation (Lydenburg) literature and reports and communications with several scientists previously or presently involved with aquatic projects in Olifants River system.

7.2 Literature review

Based on the available information it would seem as if there were three distinct eras in term of the type of research and information gathered in the Olifants River System on aquatic ecosystems.

7.2.1 Pre 1990

Prior to 1990 the impact of water quality in the Olifants River was largely unnoticed and ecological studies in the Olifants River catchment focused largely on biodiversity issues. Very few studies had any direct relationship to water quality but these studies may be useful with respect to baseline or reference conditions of aquatic organisms in the in the Olifants River for future studies. Although a fair number of published articles for the Olifants exist it was clear that a huge amount of data and information may still be available in monitoring data, unpublished reports and personal experience of some scientist that has been involved with studies in the Olifants River System. The Former Transvaal Directorate of Nature Conservation and Potchefstroom University was possibly the most active in the area during this period. Although the impact of mining and urban pollution on invertebrates in the former Transvaal was studied during this period by Allanson (1961) and Harrison (1958) was one of the only authors to describe the impact of acid mine drainage on invertebrates in the Olifants River System during this period.

Some of the most important studies during this period included the following:

- Several fish distribution studies giving a broad perspective of the historical distribution of fish in the Olifants River system (Gaigher, 1969; Gaigher and Pott, 1973). Electronic databases from the South African Institute of Aquatic Biodiversity (SAIAB) and former Transvaal Directorate of Nature Conservation also contain important information in this regard. However, a huge amount of information are still be locked up in unpublished reports and monitoring data.

- One of the studies during this period concentrated on benthos and the epifauna of Loskop Dam (Mulder, 1969). It is noteworthy that, based on this data, this author considered the water of Loskop Dam to be still unpolluted and showing very little evidence of the acid pollution from the coal mines upstream. Some of this information could be useful in determining reference conditions for Loskop Dam.

- A few ecological studies and population estimates of angling species were done during this period in Loskop Dam. These included studies by Goldner, (1969), Goldner et al. (1972) and Malan (1988) for Loskop Dam. These studies largely looked at relative abundances, growth rates, age structures, Condition Factor of angling species and population estimates. Internal reports by the former Transvaal Directorate of Nature Conservation and other data relating to several dams in the catchment are still available. Population estimates of fish in Loskop Dam by Goldner et al., (1972) were repeated during 1990 (Engelbrecht, 1990). One of the main problems with these studies was the selectivity of the sampling methods and behavioral differences of the different species which influenced the number of captures and recaptures and consequently skewed the results. Differences in the population estimates by the two studies could not be related to water quality at that stage but our improved understanding may contribute. Some of this information in these studies could be useful in determining reference conditions for Loskop Dam for future studies.

- A study of the freshwater mollusks upstream of Marble Hall (Pretorius et al., 1980) could be of importance based on the fact that some species could be sensitive to heavy metal pollution. It is possible that several other similar studies may have been done by Potchefstroom University and may still be available.

- It was not until 1983 that the first massive fish mortalities in the Olifants River system directly related to the impact of mine spillage was recorded in the Kruger National Park (Engelbrecht, 1983). Some aquatic species collected during 1992 (*Marcobrachium* spp. and *Opsaridium peringueyi*) has not been collected from this part of the system since. This event may have focused some attention of former managers in the Former Transvaal Directorate of Nature Conservation and the Kruger National Park on the vulnerability of the river systems flowing through the park. But is not until post 1990 that specific studies were conducted to address some of these problems.

7.2.2 Post 1990

Post 1990 until about 2002 several aquatic ecological studies concentrated on the bioaccumulation of heavy metals in selected fish species and some impacts relating to sediments on the fish community. Engelbrecht (1992a and b) describes some of the water quality issues in the upper Olifants River and predicts the serious water quality issues presently experienced.

Some of the most important studies during this period included the following:

- Several studies largely driven by RAU between 1992 and 2002 which focused on bioaccumulation. These studies were largely done on the lower Olifants River on a few indicator species such as tiger fish (Du Preez and Steyn, 1992), yellowfish (Seymore et al., 1995; Seymore et al., 1996; Seymore et al., 1996), sharptooth catfish (Du Preez et al., 1997; Marx et al., 1998; Avenant-Oldewage and Marx, 2000a; Avenant-Oldewage and Marx, 2000b) and Mozambique tilapia (Robinson and Avenant-Oldewage, 1997; Kotzè et al., 1999; Barnhoorn and Van Vuuren, 2001). A few studies were also conducted in the upper Olifants River on moggel (Nussey et al., 1999; Coetzee et al., 2002). Most of these studies indicated that bioaccumulation were taking place, but was difficult to define the observed variation. Some studies indicated that bioaccumulation could be more prevalent during periods of high flow and increased sediments. The importance of sediments and its relation to metal concentrations and changes in water quality was investigated by Buermann et al., 1995; Seymore et al., 1994). These studies concluded that the releases of sediments from Phalaborwa Barrage created serious water quality problems.

- A recommendation for the development and implementation of a water quality monitoring tool was developed but was never implemented (Wepener et al., 1992; Wepener et al., 1999).

7.2.3 Recent studies

More recently the massive fish and crocodile deaths in Loskop Dam and in the Kruger National Park have renewed interest in the water quality problems experienced in the Olifants River System. The findings of these studies is summarised below.

Pathology, histopathology and blood smear examinations of fish in the Kruger National Park during the 2008 mass crocodile mortalities showed changes consistent with fish suffering from lipid autoxidation which has been described in literature for rainbow trout, channel catfish and bluefin tuna. Lipid autoxidation is consistent with a vitamin E deficiency and is unlikely to be normal in wild caught fish. Fish severely affected by lipid autoxidation would become easy prey for predators, possibly before a mass mortality of fish is even noticed (Huchzermeyer, 2009). He also suggested that lipid autoxidation may be caused by anthropogenic pollutants entering the Olifants River system affecting the primary production and availability of Vitamin E in the aquatic ecosystem. Such excessive pro-oxidant challenges are likely to affect the entire food chain. Increased nutrients and the presence of large impoundments along the Olifants River, like Loskop and Massingire Dam, have caused the proliferation of some species like sharp tooth catfish (*Clarias gariepinus*) and Mozambique Tilapia (*Oreochromis mossambicus*). The large impoundments mentioned above contributed to the abundant availability of excessively fat fish for predators to feed on. Depleted antioxidants (vitamin E) and excessive fat in the fish may have lead to insufficient protection of the fish lipids consumed by the crocodiles precipitating the development of pansteatitis in the crocodiles (*personal communications* with Huchzermeyer, Myburgh and Steyl). These studies also aim to:

- Establish histological and hematological baseline data of pathology in fish in Olifants River System and establish comparable histological baseline data from unpolluted rivers in the region.
- Establish extent of pollution related pathology in fish along the length of the Olifants River from the source of pollution on the Highveld to and including Massingire Dam.
- Determine vitamin E levels in liver and fat of selected fish species in the Olifants River and compare these to values from unpolluted sources.
- Further toxicological evaluation of selected fish tissues.

The impacts of pollution and its impact on to the food chain are greatly amplified at the inflow of Loskop dam where severe toxicity of pore water in the sediments is indicated. This result was in strong contrast to the section of river directly above, which still indicated relative acceptable ecological conditions (Driesher, 2008; Myburgh, pers. comm.). This and the above studies highlight the urgent need for further research specifically on the dams

The above mentioned findings are also supported by a recent study that has concluded that Loskop dam are now hypertrophic and that changes in its functional groups of phytoplankton has occurred. This would imply that the quality of food and the structure of available habitat for benthic invertebrates have also been impacted (Grobler et al., submitted). It is remarkable that Mulder, 1969 classified this same water body as not impacted by coal mining exactly 40 years ago.

7.2.4 Recommendation from Bollmohr et al., 2008

A survey was undertaken on the Agricultural Pesticides in the Upper Olifants River Catchment by Bollmohr *et al.* (2008). The following are the recommendations of this report:

The extend of pesticide contamination in the water and sediment within the upper Olifants River catchment has been assessed and the levels of various variables are of concern and need to be addressed in different ways by different departments. Hazard associated with the quality of the water resource in the Groblersdal area due to pesticide application can only be managed if the identified problems will be addressed in future management and monitoring approaches:

Inadequate monitoring system:

- Many of the variables of concern are not covered in any current monitoring programme. The National Toxicity Monitoring Programme (NTMP) only covers POPs and some of the pesticides of concern but lacks pesticides like the organophosphates chlorpyrifos, dimethoate, fenamiphos, etamidophos, mevinphos, prothiofos and terbufos due to the lack of resources. This study also showed elevated levels of aluminum, copper, zinc and iron, which are not included in the NTMP.
- Many variables were detected in the sediment and more concentrations exceeded guideline values compared to concentrations in the water. However, sediment as a sampling medium is currently not included in any monitoring programme and need to be addressed (probably in a separate monitoring programme).

- Existing toxicity tests (within the NTMP) did not show any response to the pesticide/ trace metal contamination in the water and did not reflect the predicted effect of water quality guidelines. An investigation is recommended to relook at various test including endocrine disrupting activity and other chronic toxicity tests in order to understand the effect of these pesticides on the aquatic ecosystem.

Inadequate guidelines

- The current South African Water Quality Guidelines (DWAF, 1996) do not include many of the variables of concern and it is recommended to include frequently detected variables like DDE-4,4, DDD-4,4, phthalates, phenanthrene, dibenzo furan, chlorpyrifos, dimethoate, metamidophos and others.

- It is recommended to DWAF that the guidelines be site specific. Especially the Olifants River faces simultaneous contamination of various pesticides as well as trace metals originating from coal mining including arsenic. The interaction of these chemicals in terms of toxicity need to be taken into consideration.

- There are no sediment quality guidelines developed yet. The frequent detection of chemicals in the sediment requires that sediment specific guidelines are developed.

Inadequate protection of surface water resources

- A higher hazard for the water resource, originated by aerial application, is suspected compared to ground application, which needs to be taken into consideration by DoA during the regulation of pesticide application. This needs to be confirmed in a more intensive study together with DEAT (air sampling) and DoA (application patterns).

- Awareness campaigns on safe and responsible use of pesticides for farmers, pesticide applicators, community members is recommended to DoA.

7.2.5 Current studies

Several studies have recently been initiated to investigate water quality and its impact on the aquatic ecosystem namely a WRC funded project being undertaken by Professor A Jooste (University of Limpopo) on water quality and catchment management. Discussions with Dr Peter Ashton of the CSIR (Aston 2010 personal communication) indicated that the following studies are in the process of being undertaken by the CSIR (funders in brackets):

- The potential impacts on water quality due to intensive irrigation in the Groblersdal area (Groblersdal Irrigation Board)
- The impacts of water quality on the aquatic ecosystem and generics in the upper Olifants River (Olifants River Forum and Coaltech)
- Overview of water quality status of the Olifants River (WRC)

7.2.6 Gaps in literature and ecological research needs

Based on the communications with several scientists the following further research needs were identified.

- It is clear that the water quality situation is deteriorating and that extensive catchment rehabilitation will be required to slow down the process. There is a lot of ecological information available in the catchment but not necessarily accessible, as it is considered confidential.

- Water treatment plants and the use of passive water treatment systems (wetlands) to alleviate AMD problems may become critically important

- Expanded/more intensive biomonitoring in the catchment. Although indications are that water quality in some areas is way beyond thresholds of concern. Some of this biomonitoring may be addressed by current projects

- Large dams in catchment serve as traps for sediments, nutrients toxins and heavy metals. These areas have been the epicenter of all the recent mortalities in aquatic organisms. Some specific issues in terms of dams raised include:

  - Sediment toxicity analysis and mapping in the dams. This analysis should possibly look at aspects such as trace metals, toxins and organic compounds from coal. The effect of carbon substrates on nitrite accumulation in sediments and interactive effects of pore water on benthic organisms has also been raised

  - Remobilization of trace metals induced by spawning behavior in fish and/or microbiological activities near sediment-water interface may also be of concern.

  - Surveys and fish and other organisms for comparison with existing data and investigate the use of aquatic organisms in dams as sentinels of water quality problems.

  - Eutrophication, algal blooms, changes in functional algal groups and its relation to the potential changes in the food chain and mortalities in aquatic species.

8. CONCLUSIONS

Analysis of the historical water quality information from selected points on the Olifants River catchment have provided an overview of the water quality in the catchment with respect to the standard physical and chemical water quality parameters. The land used of the Olifants River in South Africa can be broadly divided into coal mining in the upper catchment, intense irrigated agriculture and rural development in the middle catchment and mining and nature conservation in the lower catchment (Figure 38).

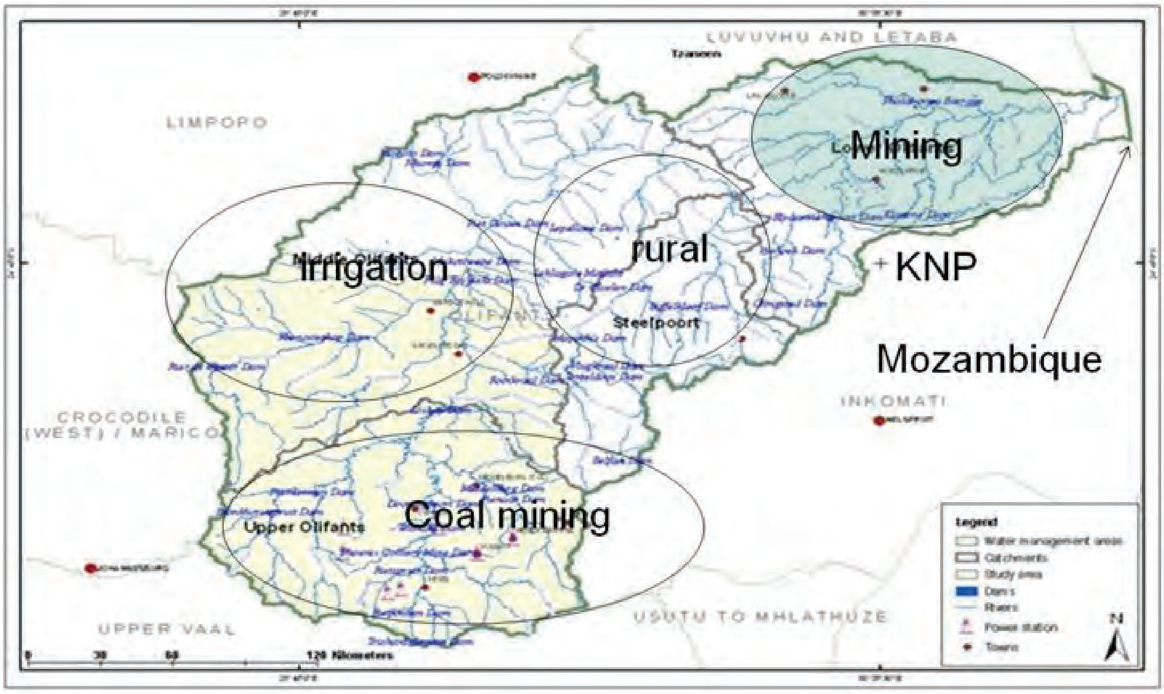

Figure 37: Land use associated with the Olifants River

The analysis highlighted a number of issues related to the water quality of some of the tributaries to the Olifants River. In particular, the Klipspruit in the upper catchment and the Ga-Selati River in the lower catchment introduce water of very low quality into the main stem of the river. This is directly related to the intensive mining activity and associated urbanization along the reaches of these particular tributaries.

Of the two rivers pinpointed as major contributors to low water quality in the Olifants River, the impacts from the Ga-Selati River are of most importance to the quality of the water entering the Kruger National Park. This is due to the lack of a major impoundment between the confluence with the Olifants and the border of the KNP. It can be seen higher up in the catchment, that dams play a role in improving the quality of the water. This is evidenced by the improvement in the water quality downstream of Loskop Dam after the inputs from the Klipspruit.

There is little historical data available regarding heavy metal and pesticide inputs to the Olifants River. Some short-term studies have been completed through the WRC. These include a study of the effects of metals on the physiology of fish in the river. This study found that in more than 60% of their study sites, the metal load exceeded water quality guideline limits – in some cases significantly (Van Vuren *et al*., 1999). A study by Heath and Claassen in 1999 also showed that the Olifants River is significantly impacted by the mining and agriculture taking place within the catchment. They found no significantly high levels of heavy metals in the Olifants River apart from low levels of copper and high levels of aluminium (emanating from the Klipspruit). The study also showed that a variety of pesticides are present in the Olifants River.

Many of the variables of concern are not covered in any current monitoring programme. The water quality available from DWA raises serious concerns about the adequacy of monitoring efforts in the Olifants River system. Environmental monitoring is the repetitive and systematic measurement of environmental characteristics, with the purpose of testing hypotheses of the effects of human activity on the environment. This requires the design of scientifically robust sampling and measurement programs, based on testable hypotheses, which involve repetitive sampling over an appropriate period of time. The detection of temporal and/or spatial differences is the most basic requirement of an environmental monitoring programme. A study by De Villiers and Mkwelo (2009) has concluded that the water quality monitoring programme in the Olifants River has failed to determine why the water quality is deteriorating. An extract from their report is as follows "One of the most disconcerting aspects of the Olifants River long-term water quality data is the non-systematic nature thereof, especially in light of clear evidence for dramatically worsening conditions. Monthly sampling frequencies will capture pollution events of short duration by chance only. A second major concern is that current monitoring efforts do not include routine measurement of toxic substances such as heavy metals in mining areas, or pesticides in agricultural areas. Most of the water quality parameters currently measured routinely are very interesting from a geochemical point of view (e.g. major cations and anions and alkalinity), but is of much less relevance to human health and environmental issues than trace levels of toxic substances. This, together with non-systematic sampling strategies and the absence of monitoring at several key sites, such as in close proximity of point sources such as the Phalabora Copper Mine, makes it difficult to test hypotheses and to pin- point the exact sources of increasing pollution in the Olifants River system. It is true that there are 'uncertainties regarding the relation- ship between concentrations of the substances in the water and their health effects' (Kempster et al., 2007). It is also true that most South African water quality guideline values are not as stringent as those adopted by developed countries. It can be argued that water quality guidelines in developing countries such as South Africa should in fact be more stringent, to safeguard the well-being of generally poorer and less healthy human populations. Are the relevant authorities carrying out research to reduce these 'uncertainties' (Kempster et al., 2007), and on which side of these uncertainties do we choose to err? It is true that improved water quality monitoring programmes will have significant cost implications, both in 'instrumentation needed for monitoring and analysis', 'as well as trained operators' (Kempster et al., 2007). It is also true that the cost implications of environmental remediation will be even more substantial, and the cost to ecosystem and human health, immeasurable".

Limited POPs and some of the pesticides of concern are proposed to be covered in the NTMP. Due to the lack of resources and the difficulties of implementing this programme it has not been initiated in the Olifants River.

The Bollmohr et al. (2008) study as well as many of the bioaccumulation studies showed elevated levels of aluminium, copper, zinc and iron, which are not included in the NTMP or the DWA Chemical monitoring programme.

Many variables were detected in the sediments; however, sediment as a sampling medium is currently not included in any monitoring programme and need to be addressed. Existing toxicity tests (within the NTMP) did not show any response to the pesticide/ trace metal contamination in the water and did not reflect the predicted effect of water quality guidelines. It is suggested that the toxicity tests be expanded to include endocrine disrupting activity and other chronic toxicity tests in order to understand the effect of these pesticides on the aquatic ecosystem.

According to the South African Water Quality guidelines (DWAF, 1996), the target water quality range (TWQR) for dissolved sulphate is below 200 mg/ℓ for human consumption. This is similar to the maximum contaminant levels prescribed by the Environmental Protection Agency in the USA and the European Union (WHO, 2004). There is no prescribed TWQR value available for aquatic ecosystems in the South African water quality guidelines (DWAF, 1996). However, aquatic ecosystems are almost without exception more sensitive than humans to environmental pollutants and as a result TWQR values, where available, are usually lower. Maximum dissolved sulphate levels of 100 mg/ℓ have been proposed for aquatic ecosystems in for example Canada (Ministry of Environment, Lands and Parks, Province of British Columbia, 2000).

Copper mining activities on the Ga-Selati River, just upstream of the KNP monitoring site are important and relevant for another reason. Copper sulphate is highly toxic to fish and also invertebrates such as crabs and shrimps (Chen and Lin, 2001). It is classified as a highly toxic substance, because of its harmful effects on aquatic species and also humans. The South African TWQR for water copper levels is < 1 mg/ℓ for drinking water and < 0.3 and 1.2 to 1.4 mg/ℓ for soft and hard water aquatic ecosystems, respectively (DWAF, 1996a). These TWQR values (and those for other toxic water constituents such as lead, arsenic, chrome-VI etc.) are meaningless, however, if copper measurements are not carried out routinely as part of DWA's water quality monitoring programme. Dissolved copper levels far in excess of these TWQR values have, however, been reported in the scientific literature, in the proximity of mining areas in the Witwatersrand area (Naicker *et al*., 2003).

Oberholster *et al*.(2009) In line with our results which highlight a potential shift in certain phytoplankton communities against a background of eutrophication, the authors predict an increase in blooms of cyanophytes and poisoning incidences by previously non dominant species in different geographical climatic regions of South Africa in the near future, if the current trends in climate change continue. This is due to cyanobacterial preference for higher surface water temperature ranges. In addition, the occurrence of cyanobacteria species that have previously been hampered to form blooms due to low temperature and nutrient concentrations, may form mix blooms with existing species which potentially can lead to the simultaneous occurrence of both neuro and hepatic biotoxins in one bloom.

8.1 Management tools to be applied to the Olifants River

There are at least 200 years of coal reserves left in the Olifants River catchment and currently there are **many small and junior mines opening**. This trend is a worry as historically these types of mines have not had a good environmental record in a period when the implementation of regulations is not strict. If these mines are not managed in a sustainable manner and appropriate closures strategies not applied throughout the life of mine they will further contribute to the ongoing pollution of the Olifants River.

Water quality management in a complex catchment such as the Olifants River requires **strong institutional capacity** (well trained resources, active, effective and appropriate finances) at a national and regional level. Unless DWA increases its capacity and works cooperatively with DMR, DEA and

DOA the water quality in the Olifants River will continue to deteriorate and the episodic fish and crocodile kills will become a more regular occurrence.

The DWA is responsible for the management of the nation's water resources. The water quality issues in the Olifants River are complex and no single organisation (even if fully capacitated) will be able to manage these complex issues in the Olifants River. Hence there is a need for **broad scale cooperation** in this management with Central Governments cooperation, regional government, mines, industry, agriculture, nature conservation and civil society working together for a joint solution. One such initiative that has some success is the **Olifants River Forum (ORF)**. This forum is active but has no regulatory responsibilities. In order for the sustainable management of the water quality of the Olifants River there is a need for the expansion of the participation of industries and mines in the direct management and self regulation. DWA is currently under resourced to manage the water quality issues in the catchment.

The DWA has the regulator tools but these need to be applied in an effective ad consistent manner. These tools **include source regulation through licences,** the **Waste Discharge Charge System (WDCS) and load reduction strategies.**

Load reduction is crucial to the management of the water quality in the Olifants River. This includes strategies such as centralised mine water treatment works which can be modularly expanded in as more water needs to be treated. The Emalahleni mine water treatment works and the currently water treatment works being constructed Optimum works are good examples of how industry and local government have cooperated to turn a waste resource (mine water) into a product (drinking water) a revenue stream.

The deterioration of the quality of our water resources is one of the major threats to South Africa's capability to provide sufficient water of appropriate quality to meet developmental needs while ensuring environmental sustainability. The water quality problems are influenced by uncontrolled sources of pollution and internal challenges in executing measures to manage pollution. The DWA is developing a **WDCS**, based on the polluter pays principle, to promote waste reduction and water conservation. It forms part of the Pricing Strategy and is being established under the National Water Act 9 (Act 36 of 1998).

The WDCS aims to:

- promote the sustainable development and efficient use of water resources;
- promote the internalisation of environmental costs by impactors;
- create financial incentives for dischargers to reduce waste and use water resources in an optimal way; and
- recover the costs of mitigating the impacts of waste discharge on water quality.

The basis of the polluter pays principle is that the costs of environmental impact should be borne by those responsible for the impact. The National Water Act specially refers to the polluter pays principle as a- economic mechanism for achieving effective and efficient water use. Water resource management in South Africa links the acceptable level of impact to the concept of **Resource Quality Objectives (RQOS)**, which balance the need to protect water resources with the need for development. The setting of ROOs is catchment specific, based on the social, economic and political drivers, or development and utilisation, of a specific water resource.

The WDCS is a response to a pollution problem that is already imposing a cost on society. The WDCS endeavours to shift some of the cost back to dischargers according to the polluter pays principle. The WDCS will be implemented in a manner that seeks to charge a discharger for the amount of waste load added to a water resource where RQOS are being exceeded. The registration of waste discharge-related water users the first building block of the WDCS. While registration is intended to proceed nationally, the implementation of the WDCS will commence in three priority catchments, namely the Upper Vaal, Upper Olifants, and the Crocodile-Marico. The implementation of a pilot WDCS in the Olifants River is schedules for 2010/12.

Compulsory licences need to be applied and managed throughout the Olifants river catchment. If this is applied and the licensee reports back on a regular basis to DWA and an appropriate forum

(ORF?) then water quality management becomes more transparent and collective solutions can be sought in a cooperative manner.

Implement/revisit the Reserve allocations and associated environmental flows. If these environmental flows are implemented and their effectiveness monitored there should be an improvement in the present ecological status of the aquatic organisms in the Olifants River catchment. It is important that the proposed Ecospecs and associated monitoring programme is implemented and revised according to the ongoing monitoring findings.

The controlled release scheme that is in place in the upper Olifants River is a self regulating scheme that is managed cooperatively by a committee of mainly mines and DWA officials. Compliance monitoring is undertaken by this scheme on a regular basis. This scheme should be re-evaluated as there have not been any substantial releases since 2002 as there has not been any assimilative capacity in the river.

8.2 Integrated water resource management plan for the upper and middle Olifants River catchment (DWA, 2009).

Implementation in a holistic manner the water quality, mine water management and catchment plans that have been developed over the past years such as the Integrated Water Resource Management Plan for the upper and middle Olifants catchment (DWA, 2009). These plans need to be jointly implemented by industry, agriculture and the mines with support and guidance from DWA. The following are summary recommendations from this report.

The key elements of the water quality management strategy are the setting of the RWQO's, based on salinity and nutrient management, as well as bolstering of management resources and information systems. The RWQO were determined based on the current set of RWQO in the Witbank, Klipspruit and Middelburg Dam catchments modified to account for the available water quality component of the ecological Reserve. The current ecological Reserve for salinity water quality variables was developed using outdated methodology. Where RWQO were not set, the South African Water Quality Guidelines together with the present water quality status were used to determine RWQO. The set of RWQO determined in the study are interim RWQO that will be reviewed in 5 years time once the water quality component of the ecological Reserve has been updated.

The management of salinity involves the reduction of loads into the system. The strategy has been divided into the management of the defunct and operational mines. The defunct mine strategy involves refurbishing the Brugspruit neutralisation plant and collection system which will address the acidity issue. A committee needs to be set up to develop a defunct mine strategy which prioritises and determines synergies with operating mines in order to manage decants. The required reductions in load from the operational mines, power stations and industries will be achieved by source management through audits, Integrated Waste and Water Management Plans (IWWMP's), Water Use Licencing (WUL), compliance monitoring and reporting. The waste discharge charge will also be implemented to ensure that the source reductions are achieved and that money is raised to fund an appropriate institutional structure to manage water quality.

The nutrient management strategy involves the upgrading of the five major WWTP and sanitation systems as well as revising the phosphate discharge standard to 1 mg/ℓ for the major works. The smaller WWTP must be audited to ensure that the plant performance is aligned with the technology installed.

Reconciliation strategy

The application of the yield model to investigate the further development of surface water resources showed that the construction of additional dams did not increase the yield of the system of dams in the study area. The yield was merely transferred from the downstream dams to the upstream dams. This highlights the need for the development of an integrated reconciliation strategy for the entire catchment. The immediate concerns are the augmentation of the water supply to Steve Tshwete and Emalahleni Local Municipality. The use of excess mine water was investigated. The available volumes of mine water were determined over time and compared to the water requirement projections. The findings are that there is sufficient mine water available however the water will require treatment and the process of allocating the water will need management. The other actions that will be implemented to assist with reaching reconciliation are the elimination of the unlawful water use, ongoing application of the catchment modelling systems, trading of water rights and the development of groundwater for supply to rural areas.

Institutional

The Department's Regional Office is currently responsible for the management of the water resource. The office is under stress with a high staff turnover. The study area needs strong, proactive management by a well staffed institution. Staffing requirements for such an institution were proposed with an estimate of the budget requirements. Further to the management institution, an institutional structure was proposed which includes the establishment of a catchment management committee (CMC) which will oversee and co-ordinate the activities in the catchment. One of the major roles of the CMC will be to implement the strategy. The CMC will be supported by the management/regulatory authority which could be the Regional Office of DWA or the Catchment Management Agency (CMA). There are a number of committees which are focused on specific management actions. The Mining and Industry Water Action Committee (Minwac) will address licensing, controlled release, status of mine water, defunct mine strategy, compliance and implementation of commitments. The Municipal Managers Forum will deal with matters related to the municipalities which includes water requirement projections and WWTP and sanitation system upgrades. The mine water companies set up to treat the mine water will be represented as they play an important role in the co-ordination of the use of the mine water. DWA is currently busy with an initiative to set up Water User Associations (WUA) across the catchment to represent the interests of the water users at the local catchment level.

Actions

The implementation of the strategy will be the responsibility of the Regional Office of DWA. The implementation of the strategy should be completed by 2015 at which time the strategy can be reviewed. The actions and responsibilities are summarized in the Table 9.

Table 9 Implementation of the strategy to be completed by 2015 by DWA

Action	Responsibility
RWQO	
Water Quality Reserve Determination for entire Olifants WMA	RDM office[1]
Scenario analyses for water quality (consider including in Olifants Reconciliation Strategy Project)	NWRP[2]/ RDM office
Development of an integrated set of RWQO for Olifants WMA and revision of Interim RWQO for the Upper and Middle Olifants	WRP Systems[3]
Defunct mines – Klipspruit	
Set up defunct mines management committee	RO[4], DMR[5]
Brugspruit Plant and collection system operational	RO
Investigate regional mine water collection system in Klipspruit, including Phase 2 of original White Paper.	RO, DMR, Mines, Industries
Implement regional plan with other mining companies.	RO, DMR
Take regulatory action to prevent ongoing pollution from Vanchem industrial site.	RO
Defunct Mines – Outside Klipspruit Catchment	
Develop a defunct mines water management plan, including possible integration into operating mines management.	RO, DMR
Implement the defunct mine water management and rehabilitation plan	RO, DMR
Operating mines, industries and power stations	
Set up MINWAC	RO
Audit of mines, power stations and industries water management	RO

plans and systems	
Implement program to update water and salt balances	RO
Develop a set of commitments and implementation programs of remediation measures with each mine, power station and industry	RO, mines, industries and power stations
Set up annual reporting system and agree on level of technical input	RO, mines, industries and power stations
Implement annual reporting system	RO, mines, industries and power stations
Ongoing update of IWWMP and IWUL	RO, mines, industries and power stations
Audit mine closure funds	DMR, mines, Eskom
Nutrient Management Strategy	
Agree on scope of work and time frames to upgrade the major WWTP and sanitation systems (use existing Municipal Managers forum).	RO, Local Municipalities and District Municipalities
Audit the small WWTP for performance and compliance with licence conditions.	RO, Local Municipalities
Continue with compliance monitoring and reporting	RO, Local Municipalities
WDCS	
Implement WDCS in the Loskop Dam catchment	NWRP
Water Quality Monitoring Program	
Produce an integrated water quality monitoring program	RO
Human Resourcing Strategy	
Investigate staffing structure and appropriate funding mechanisms	RO
Water reconciliation and institutional	
Develop annual reporting required on water requirement projections, progress with WC&DM implementation and wastewater treatment plant and sanitation system upgrades	RO, Local Municipalities
Set up institutional structure to manage the use of excess mine water	RO, mines
Develop TOR, commission PSP and carry out a water use Verification Study to follow on from the Validation Study on irrigation water use.	NWRP
Commission PSP to carry out annual operating WRPM and WRYM runs and provide ongoing model support.	NWRP
Investigate the scenarios for meeting the EWR. (This will form part of the Olifants Reconciliation Strategy Study)	NWRP
Set up CMC and supporting committees	RO

Where: *1 – Resource Directed Measures Directorate of the Department*

2-Directorate of National Water Resources Planning of the Department

3-Directorate of Water Resource Planning Systems of the Department

4-The Department's Mpumalanga Regional Office in Bronkhorstspruit

5- Department of Mineral Resources

9. RECOMMENDATIONS

The basic principle on if you cannot measure it you cannot manage it applied to the Olifants River. Monitoring needs to take place and should include water, sediments, aquatic organisms (fish) and whole effluent toxicity. The monitoring data should be reviewed so that adaptive management can be applied and the monitoring programme as well as management plans changed according to these results.

A thorough baseline assessment throughout the catchment, during low flows, should be undertaken to assess the following parameters:

- POP's (water, sediments and fish)
- Sediment metal concentrations
- Fish bioaccumulation (compare to the many literature studies undertaken)
- Whole effluent toxicity tests
- Surface water quality samples (to include nutrients, salts and metals)

- The following are broad recommendations from the water quality and ecology assessment of the Olifants River:
- Establish histological, hematological and genetic baseline data of pathology in fish in Olifants River System
- Establish comparable histological baseline data from unpolluted rivers in the region.
- Establish extent of pollution related pathology in fish along the length of the Olifants River from the source of pollution on the Highveld to and including Massingire Dam.
- Determine vitamin E levels in liver and fat of selected fish species in the Olifants River and compare these to values from unpolluted sources.
- River tested positive for EDC activity – continue
- Risk assessment linking ecology to human health required
- Develop nonlethal methods of monitoring fish health
- Further toxicological evaluation of selected fish tissues
- Improving management of the water resources of the system by more effective monitoring (include organics and metals)
- The defunct mines need to be revisited to priorities the mines that need management and develop rehabilitation and management plans for implementation. The DMR and tax payers will need to assist with this programme.
- The mines need to update their water balances and improve their understanding of their water management systems, storages and the water in workings. The mines all need to be at the same level of confidence and accuracy. This is essential to determine the excess water volumes and timing of when mine water is available for reuse. The is a need for annual water quality and water management plans reports to be reinstated so that DWA, DMR and the appropriate forums can realistically and cooperatively manage the catchment.
- Institutional cooperation and expansion of the responsibilities. This will require and urgent up scaling of resources from DWA especially with the regional office.

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APPENDIX A

Frequency of water quality monitoring

Table A1: Yearly frequency of DWAF water quality monitoring in the upper Olifants River catchment.

	Monitoring point DWAF identification number							
YEAR	B1H6	B1H18	B1R1.1	B1R2.1	B1H4	B2H14	B2H15	B3R2.1
1966	0	0	0	0	2	0	0	0
1967	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	8
1969	0	0	0	0	0	0	0	20
1970	0	0	0	0	1	0	0	3
1971	0	0	0	0	0	0	0	1
1972	0	0	3	0	1	0	0	4
1973	0	0	0	0	0	0	0	2
1974	0	0	0	0	0	0	0	0
1975	0	0	3	0	0	0	0	17
1976	0	0	0	0	10	0	0	24
1977	0	0	0	0	11	0	0	15
1978	0	0	2	1	47	0	0	11
1979	0	0	0	4	4	0	0	5
1980	0	0	4	9	16	0	0	10
1981	0	0	0	9	14	0	0	7
1982	3	0	0	10	8	0	0	5
1983	46	0	0	2	12	0	0	1
1984	50	0	1	1	12	0	0	2
1985	45	0	2	6	11	0	0	9
1986	46	0	6	7	10	0	0	22
1987	52	0	16	2	11	0	0	14
1988	52	0	28	3	13	0	0	24
1989	52	0	41	1	11	0	0	27
1990	66	0	37	0	16	0	0	24
1991	62	29	22	0	20	40	0	15
1992	52	47	6	0	42	54	0	30
1993	46	31	33	2	44	51	0	23
1994	15	48	27	12	48	53	51	13
1995	6	38	26	25	51	46	51	6
1996	17	54	27	27	52	26	52	6
1997	13	51	24	23	53	28	51	0
1998	25	52	18	21	52	28	51	1
1999	15	38	21	20	47	25	33	0
2000	9	43	14	18	44	24	24	4
2001	20	43	20	20	51	24	26	23
2002	0	43	12	24	52	17	16	21
2003	0	10	21	22	44	13	14	2
2004	6	21	19	20	26	23	23	14
2005	17	16	22	22	24	24	14	21
2006	17	26	23	14	31	26	25	21
2007	20	20	18	19	25	24	21	19
2008	9	8	4	4	6	9	5	6

Table A2: Yearly frequency of DWAF water quality monitoring in the middle Olifants River catchment.

	Monitoring point DWAF identification number				
YEAR	B3H21	B4H3	B4H11	B5H4	B5R2
1966	0	0	0	0	0
1967	0	0	0	0	0
1968	0	0	0	0	0
1969	0	0	0	0	0
1970	0	0	0	0	0
1971	0	0	0	0	0
1972	0	0	0	0	0
1973	0	0	0	0	0
1974	0	0	0	0	0
1975	0	0	0	0	0
1976	0	0	0	0	0
1977	0	6	0	0	0
1978	0	43	0	0	0
1979	0	2	0	0	0
1980	0	1	0	0	0
1981	0	9	0	0	0
1982	0	10	0	0	0
1983	0	7	0	0	0
1984	0	29	7	0	0
1985	0	46	50	0	0
1986	0	54	47	0	0
1987	0	41	52	0	0
1988	0	48	45	0	0
1989	0	51	33	0	0
1990	0	46	24	0	0
1991	0	27	3	0	0
1992	0	41	0	0	0
1993	0	41	0	8	0
1994	26	47	0	29	1
1995	21	47	0	28	0
1996	23	52	28	25	0
1997	33	51	29	28	0
1998	16	53	38	26	7
1999	24	40	0	25	10
2000	26	24	0	26	13
2001	24	26	10	26	12
2002	16	17	16	26	12
2003	6	11	13	26	11
2004	17	23	24	29	16
2005	20	20	24	34	26
2006	22	20	21	47	39
2007	14	21	18	42	36
2008	4	11	5	12	10

Table A3: Yearly frequency of DWAF water quality monitoring in the lower Olifants River catchment.

	Monitoring point DWAF identification number					
YEAR	B6H1	B6H4	B7H19	B7H15	B7H17	B7R002
1966	1	0	0	0	0	0
1967	0	0	0	0	0	0
1968	0	0	0	0	0	0
1969	0	0	0	0	0	0
1970	0	0	0	0	0	0
1971	0	0	0	0	0	0
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1974	0	0	0	0	0	0
1975	0	0	0	0	0	1
1976	8	0	0	0	0	10
1977	36	0	0	0	0	6
1978	22	38	0	0	0	11
1979	6	7	0	0	0	4
1980	15	24	0	0	0	10
1981	14	18	0	0	0	3
1982	11	11	0	0	0	1
1983	7	10	0	10	7	6
1984	6	29	0	41	20	10
1985	6	41	0	51	36	12
1986	5	42	0	52	1	12
1987	13	48	0	51	16	12
1988	11	47	0	42	40	5
1989	12	50	38	59	22	14
1990	11	47	30	52	32	23
1991	10	23	21	35	24	2
1992	28	32	29	61	38	2
1993	16	39	5	67	43	0
1994	20	12	23	25	25	0
1995	18	22	24	18	8	2
1996	20	29	23	7	11	9
1997	20	28	28	12	0	10
1998	24	35	29	11	0	1
1999	13	21	11	10	19	0
2000	14	14	5	9	1	0
2001	16	17	18	11	6	0
2002	13	114	13	5	12	0
2003	12	12	9	3	7	0
2004	14	15	15	12	6	0
2005	17	15	21	11	19	1
2006	20	13	20	18	12	0
2007	20	17	18	18	6	0
2008	6	6	7	4	4	0

WATER QUALITY OVERVIEW AND LITERATURE REVIEW OF ECOLOGY OF THE OLIFANTS RIVER

Ralph Heath, Trevor Coleman and Johan Engelbrecht

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1. BACKGROUND

The Olifants River in Mpumalanga is presently one of the most threatened river systems in South Africa (Ballance *et al*., 2001; De Villiers and Mkwelo, 2009; Van Vuren, 2009). Reports of unexplained fish and crocodile deaths within the catchment, including recently in the Kruger National Park (KNP) have been reported for several years and have received a media attention, including the establishment of the 'Consortium for the Restoration of the Olifants Catchment' initiative (Van Vuren, 2009; De Villiers and Mkwelo, 2009).

Despite signs that water quality in the Olifants River has been deteriorating as a result of industrial, mining and agriculture activities, the trigger for episodic fish and crocodile deaths in the river system remains elusive (De Villiers and Mkwelo, 2009).

This report is a summary of the status of the water quality data and is further a synthesis of the available aquatic ecology literature in the Olifants River.

2. DESCRIPTION OF THE STUDY AREA

The Olifants River originates from the east of Johannesburg and initially flows northwards before curving eastwards towards the Kruger National Park where it is joined by the Letaba River before flowing into Mozambique. The study area is the Olifants River Catchment. It extends from the upper reaches of the Olifants River along the catchment divide with the Vaal river to the Loskop Dam and down to the Flag Boshielo dam and then on to Phalaborwa and into the Kruger National Park (Figure 1).

The Upper Olifants River catchment comprises the drainage areas of the Olifants River, Klein Olifants River and Wilge River with tributaries down to the Loskop Dam. The headwaters of these rivers are located along the Highveld Ridge in the Secunda-Bethal area and the rivers then flow in a northerly direction towards Loskop Dam.

The major tributaries are the Steenkoolspruit, Klein Olifants River, Wilge River and Elands River. It has large urban centres located in the Emalahleni (Witbank), Steve Tshwete (Middelburg) and also a number of smaller urban centres such as Bronkhorstspruit, Kriel, Hendrina, Kinross and Trichardt. Satellite townships are also associated with most of the mining operations and power stations.

The natural rivers and streams have been extensively dammed with the result the stream flow is now highly regulated. The major impoundments upstream of Loskop Dam include Witbank Dam, Middelburg Dam, Bronkhorstspruit Dam and Premiere Mine Dam. Many smaller farm dams and water supply structures associated with the mining operations have also been constructed in the catchment.

Extensive coal mining takes place in the catchment, most of which occurs in the Witbank Coalfields and Highveld Coalfields. The landscape in the southern and central part of the catchment is dominated by mining operations and mining-related infrastructure. Agriculture, both dryland and irrigated, is another important land use in the catchment with many areas in the southern and central portions producing high yields of maize. Irrigation farming of diverse crops takes place in various parts of the catchment the largest of which is the Loskop Dam Irrigation Scheme.

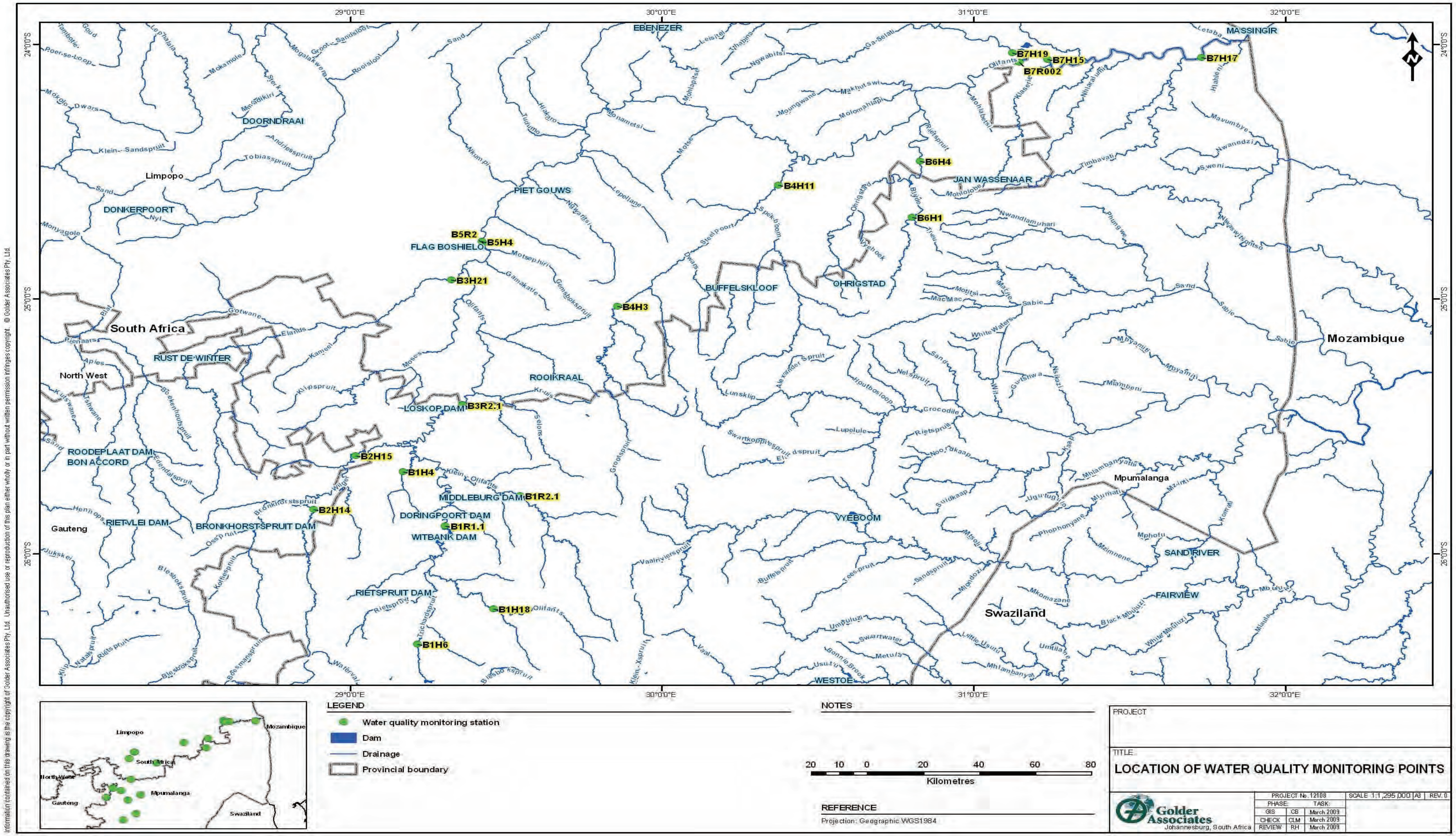

Figure 1: Location of selected DWAF water quality monitoring points across the Olifants River catchment

The Upper Olifants River basin water resources are under constant pressure from both a supply/demand perspective as well as from a water quality perspective.

The Middle Olifants catchment comprises the drainage areas of the Olifants River downstream of Loskop Dam and down to the Flag Boshielo Dam. Major tributaries are the Selons River, Moses River, Bloed River and the Elands River. There are no metropolitan areas situated in the area but smaller towns like Groblersdal, Marble Hall and Settlers are located in the area. The Western Highveld region, including towns like Siyabuswa and Dennilton is located in the Elands River catchment. Several rural townships are also located in the area. The major dams in the catchment include the Rust de Winter Dam, Renosterkop Dam and Rooikraal Dam. Many smaller farm dams are also found in the area.

Agriculture, both dryland and irrigated, is the most important land use in the catchment. Irrigation farming of diverse crops takes place in various parts of the catchment, the largest of which is the Elands River Irrigation Scheme. Subsistence farming also forms a substantial part of the catchment.

Small mining areas are found in the catchments of Klipspruit, Moses River and Loopspruit as well as the area east of Marble Hall.

The Lower Olifants catchment comprises the drainage areas from Flag Boshielo Dam, downstream to the Kruger National Park. After crossing the Mozambique border, the Olifants River flows into the Massingire Dam. The major tributaries include the Steelpoort River, the Blyde River and the Ga-Selati River. There are no metropolitan areas in this part of the catchment aside from Phalaborwa, but there are a number of small towns.

Figure 2 indicates the generalized land use in the Olifants River catchment.

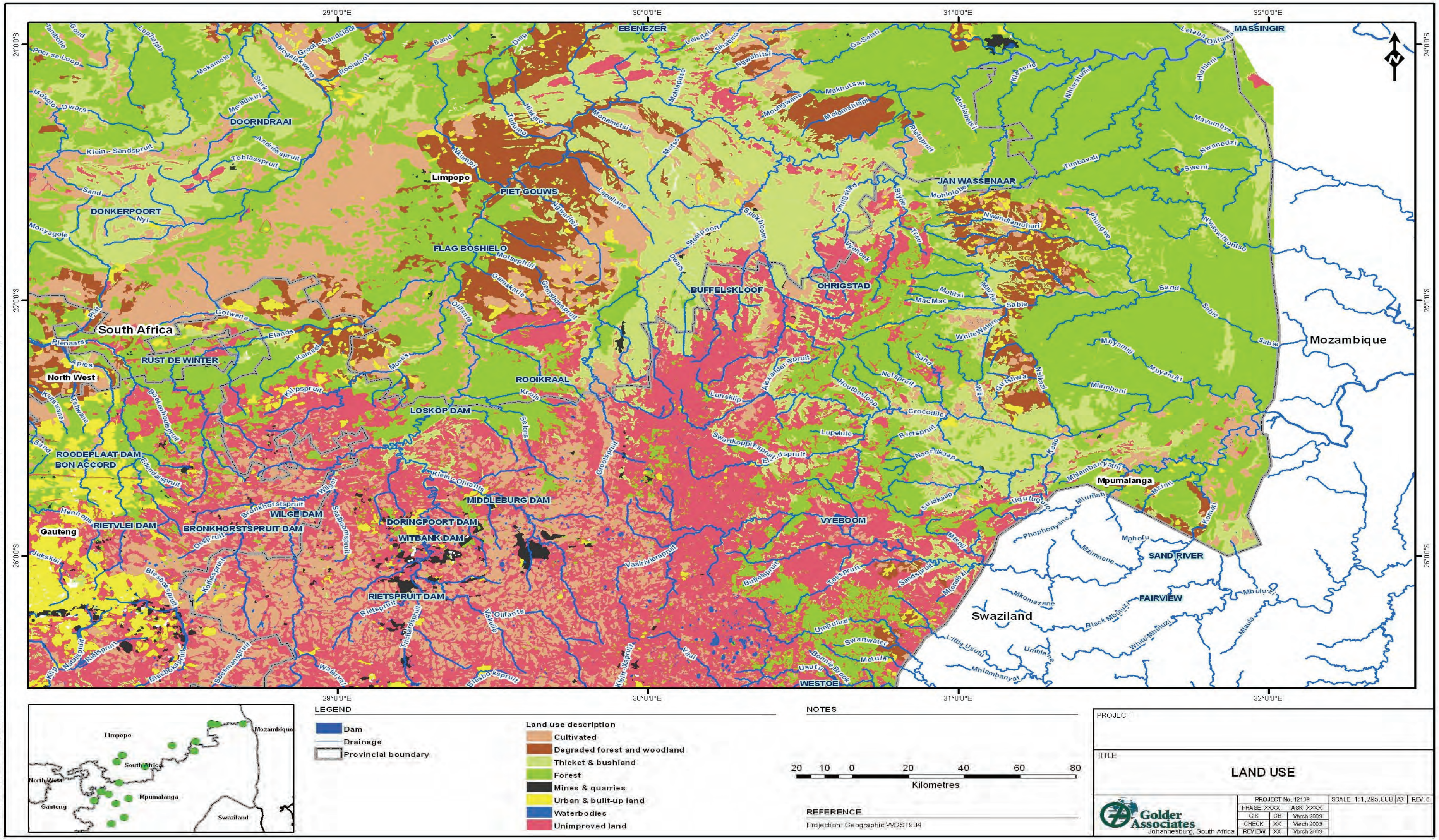

Figure 2: Summarized land use map of the Olifants River catchment area

3. WATER QUALITY PARAMETERS

The Department of Water Affairs (DWA) Resource Quality Services (RQS) water quality database was used as the source of the water quality data for this analysis. The water quality variables that were analysed are: Electrical Conductivity (EC), Total Dissolved Salts (TDS), pH, Sodium, Magnesium, Calcium, Potassium, Fluoride, Chloride, Sulphate, Phosphate as P, Total Alkalinity as CaCO3, Ammonium as N, Nitrate + Nitrite as N. No trace metal or organic analysis is performed as part of this routine monitoring (Pers. Comm. DWAF Regional Office – Mpumalanga). For the purposes of this study, the indicator variables (pH, EC, nitrate, sulphate and phosphate) were used. Sulphate and pH are useful as indicators of mining-related impacts, phosphate is an indicator of farming-related impacts, nitrate is indicative of both farming- and sewage-related impacts, and EC is a general indicator of salts-related impacts, either from mining or farming or natural origins.

4. OLIFANTS RIVER MAIN STEM

4.1 Water Quality Monitoring Points

Four water quality monitoring points were identified on the Olifants River main stem and used in the assessment of the water quality status of the river. Table 1 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 1: Selected water quality monitoring points on the Olifants River main stem

DWAF Station Identification Number	River/Stream/ Dam	Site description and Province	Land use impacting water quality
B1H18	Olifants River	At Middelkraal, Mpumalanga	Maize and coal mining
B5H4	Olifants River	Flag Boshielo downstream weir, Mpumalanga	Maize and coal mining
B7H15	Olifants River	Mamba Weir in KNP, Limpopo	Mining and industry
B7H17	Olifants River	Balule Rest Camp in KNP, Mpumalanga	National Park

The most upstream site (B1H18) is located on the Olifants River at Middelkraal, upstream of the confluence with the Trichardspruit and above Witbank Dam. The water quality in the Olifants River at this point is relatively unpolluted with low concentrations of sulphate and metals, with the pH tending towards the alkaline side. The water quality is taken to be representative of the background situation, upstream of mining and power generation operations. However, the water quality is not pristine and does reflect the aggregate impact associated with natural weathering, agriculture and atmospheric deposition.

The next site (B5H4) is located immediately downstream of Flag Boshielo Dam and downstream of the confluences with the Wilge and Elands Rivers. The two remaining sites are located on the lower Olifants River. The first (B7H15) is at Mamba Weir in the Kruger National Park, not far downstream of the Olifants River confluence with the Ga-Selati River. The second (B7H17) is also within the Kruger National Park at Balule Rest Camp, upstream of the confluence with the Letaba River and the border with Mozambique.

4.1.1 Frequency of Sampling

Water quality monitoring started between 1991 and 1993 at B1H018 and B5H004. Monitoring began in 1983 at the two sites within the Kruger National Park boundary. The yearly frequency of sampling is tabulated in Appendix A.

4.2 Water quality trends

4.2.1 pH trends

The pH on the main stem of the Olifants River does not show any significant changes, with the median values at each station all between 8.1 and 8.3 (Figure 3). Historically, the data at these sites indicate that there has been little or no pH-related impact and the pH trend is neutral (i.e. no increase or decrease over time).

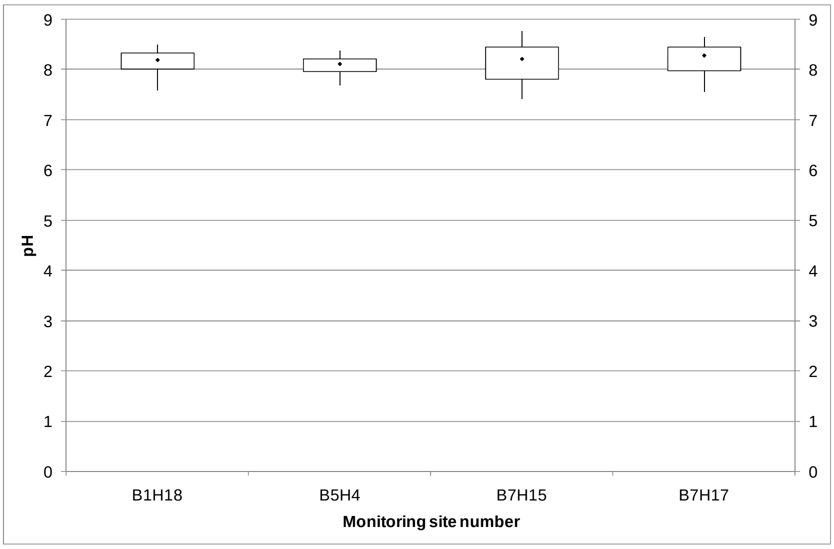

Figure 3: Box and whiskers plots based on pH percentile statistics for the main stem of the Olifants River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

The pH at site B7H15 has more variability that indicated at the other three sites. This is due to the downstream proximity of the site to the Phalaborwa Barrage, which shows similarly variable pH.

4.2.2 Nutrients trend

In this study, nutrients are represented by nitrate and phosphate variables.

Figure 4 indicates an increase in nitrate concentration down the Olifants River, with an improvement once the river passes into the Kruger National Park – in fact a return to levels similar to those in the upper reaches (B7H17 vs. B1H18). The increase in nitrate concentration at sites B5H4 and B7H15 can be attributed to inputs from the Elands and Ga-Selati Rivers, respectively. Both of these tributaries flow through urban areas with associated townships. The increase in nitrate concentration in the rivers may be as a result of sewage treatment plant inputs to the rivers.

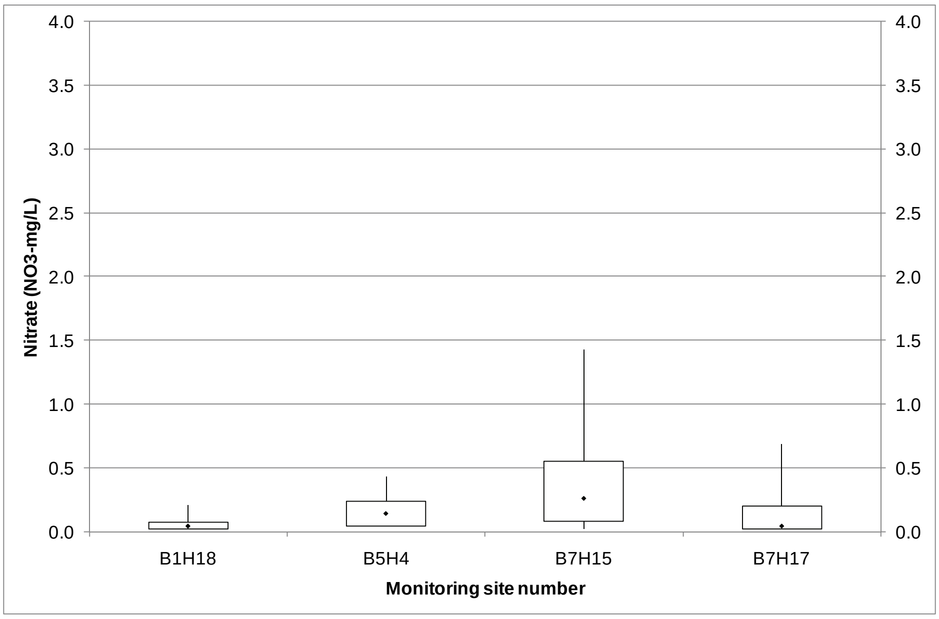

Figure 4: Box and whiskers plots based on nitrate percentile statistics for the main stem of the Olifants River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

The median phosphate concentration along the Olifants River lies between 0.016 and 0.022 mg/L (Figure 5). The variability of the phosphate concentration at each monitoring site does change, with B1H18 and B7H15 is registering the widest variation in concentration. Site B1H18 is situated in a cultivated area and the variability may be due to seasonality of the flow in that particular reach of the river.

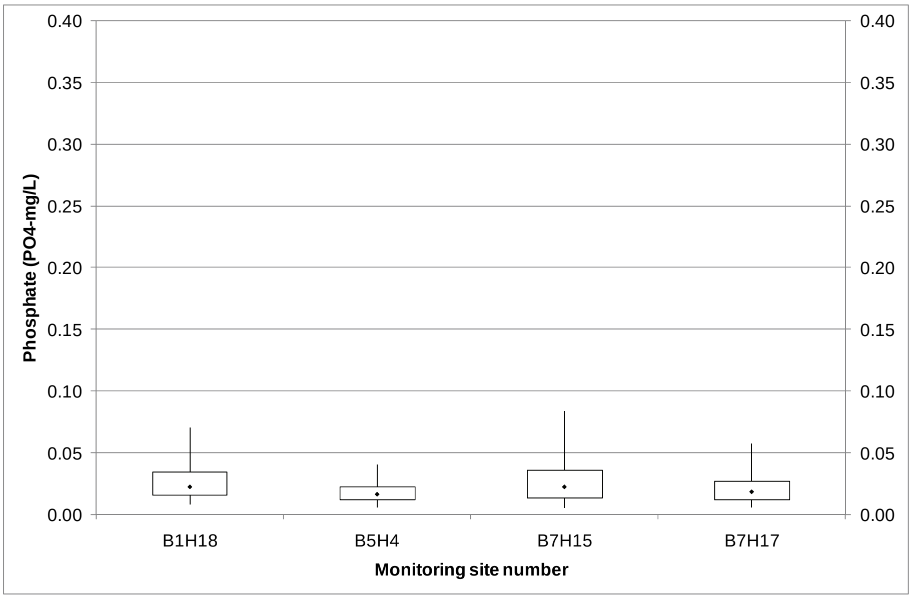

Figure 5: Box and whiskers plots based on phosphate percentile statistics for the main stem of the Olifants River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

4.2.3 Salts trends

The EC increases substantially along the length of the Olifants River (Figure 6). The upper reaches show far lower variation in EC than in the lower reaches, where values greater than 100 mS/m are recorded in more than 25% of the samples. Historically, the upper reaches show an increase in EC and the lower reaches show a decrease. This trend may be due to improvements in water quality management in the lower reaches and an increase in mining pressure in the upper reaches.

The impact of sulphates on the Olifants main stem shows similar trends to that of EC (Figure 7). An increase in sulphate concentration from the upper reaches to the lower reaches, with similar historical trends.

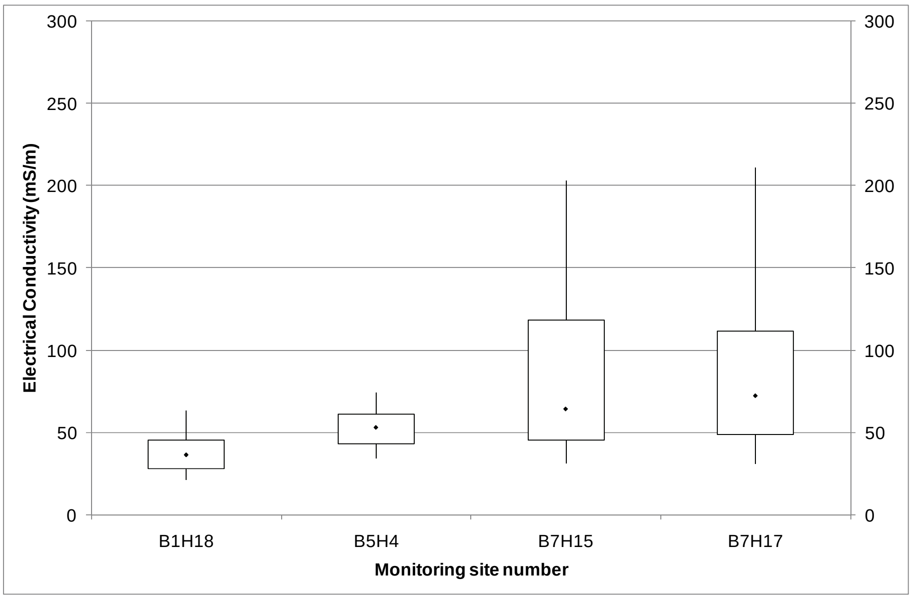

Figure 6: Box and whiskers plots based on EC percentile statistics for the main stem of the Olifants River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

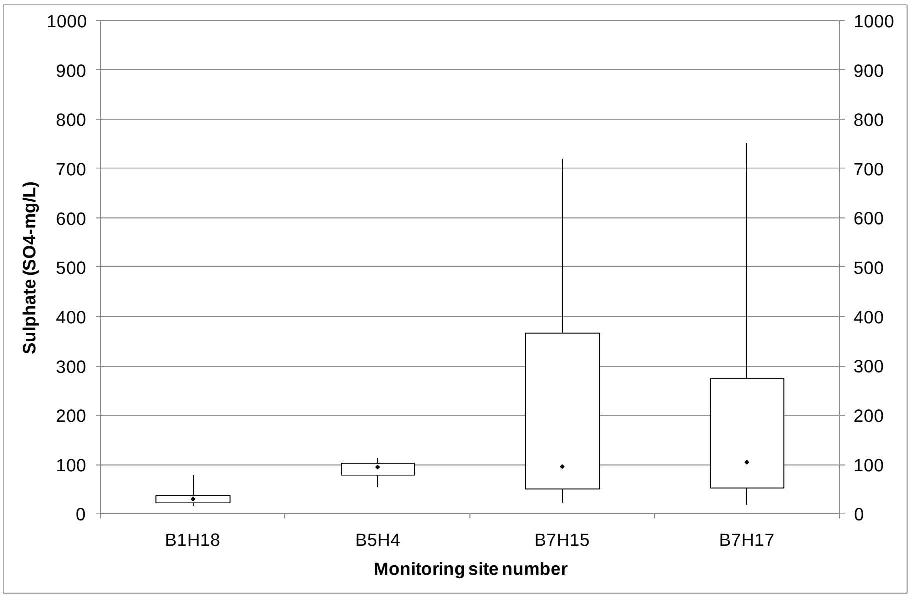

Figure 7: Box and whiskers plots based on sulphate percentile statistics for the main stem of the Olifants River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5. MAJOR TRIBUTARIES OF THE OLIFANTS RIVER

5.1 Unit 1 – Trichardspruit and Klipspruit

5.1.1 Water quality monitoring points

Two water quality monitoring points were identified in this subcatchment and used in the assessment of the water quality status of the area. Table 2 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 2: Selected water quality monitoring points on the Trichardspruit and Klipspruit

DWAF Station Identification Number	River/Stream/ Dam	Site description and Province	Land use impacting water quality
B1H6	Trichardspruit	Rietfontein, Mpumalanga	Trichardt town, agriculture
B1H4	Klipspruit	Zaaihoek, Mpumalanga	Coal mining, agriculture, maize

The first site, B1H6, is located on the Trichardspruit at Rietfontein, upstream of the confluence with the Rietspruit. The next site (B1H4) is located on the Klipspruit, which has its confluence with the Olifants River upstream of the Wilge River confluence and downstream of the confluence with the Klein Olifants River.

5.1.1.1 Frequency of Sampling

Water quality monitoring started in 1982 on the Trichardspruit (B1H6) and in 1966 on the Klipspruit (B1H4). The yearly frequency of sampling is tabulated in Appendix A.

5.1.2 Water quality trends

5.1.2.1 pH trends

The pH in the Trichardspruit is similar to that of the Olifants main stem and does not indicate any pH-related impacts. The Klipspruit, however, is significantly impacted (Figure 8). The pH in this tributary is highly impacted by the surrounding mining industries, with mine drainage seeping into the river at various points, resulting in water of low pH and high dissolved salts concentrations (RHP, 2001).

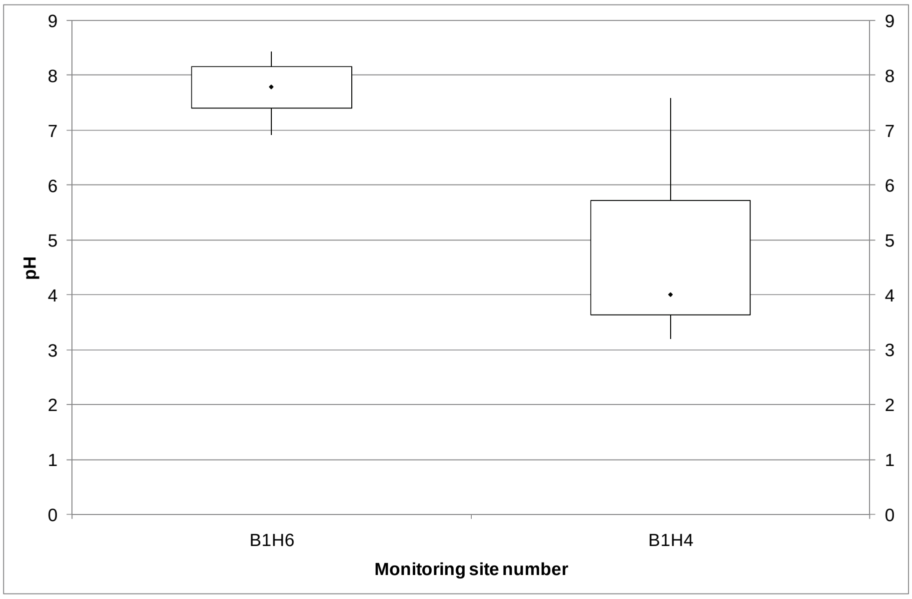

Figure 8: Box and whiskers plot based on pH percentile statistics for the upper Olifants River – Unit 1 (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.1.2.2 Nutrients trends

The nitrate levels in these two tributaries differ vastly (Figure 9). The Klipspruit exhibits far greater levels, for the most part due to the higher degree of human activity compared to the Trichardspruit area. The increased nitrate levels could result from both human impacts (sewage from mining activity) and direct mine-related impacts (blasting agents, etc.)

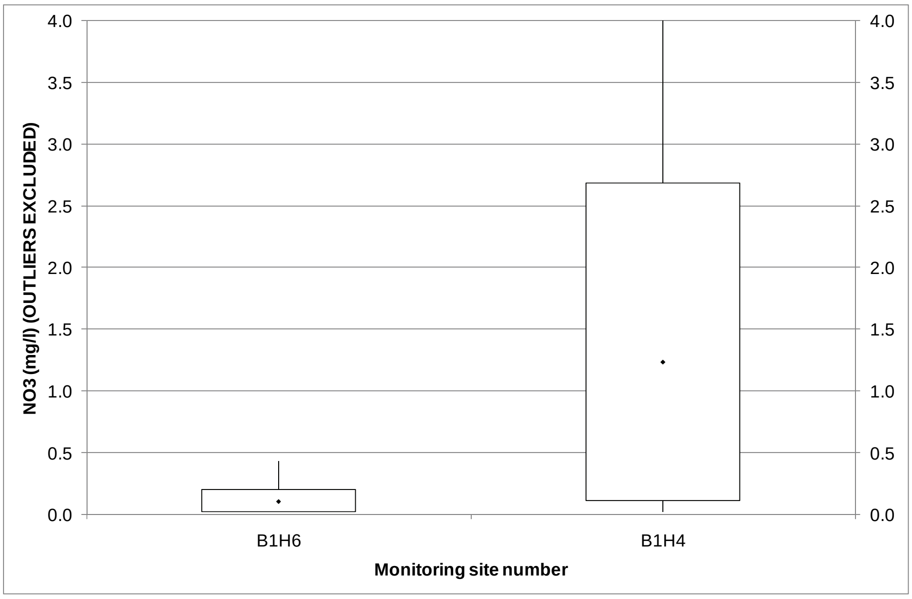

Figure 9: Box and whiskers plot based on nitrate percentile statistics for the upper Olifants River – Unit 1 (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

The plots in Figure 10 confirm that the nitrate impacts seen in the Klipspruit are not due to farming impacts. If this were so, the phosphate levels would be similarly elevated due to fertilizer use. The phosphate levels are similar to those seen along the main stem of the Olifants River.

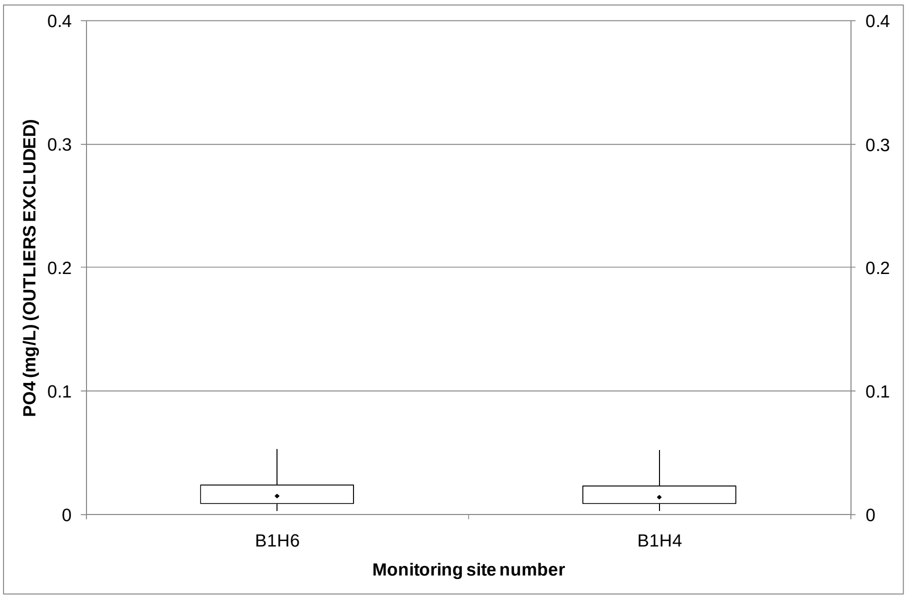

Figure 10: Box and whiskers plot based on phosphate percentile statistics for the upper Olifants River – Unit 1 (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.1.2.3 Salts trends

The EC and sulphate plots further confirm the highly impacted status of the Klipspruit tributary (Figure 11 and Figure 12). Analysis of the historical trends indicates that both sulphate and EC levels are increasing in the Klipspruit and the Trichardspruit.

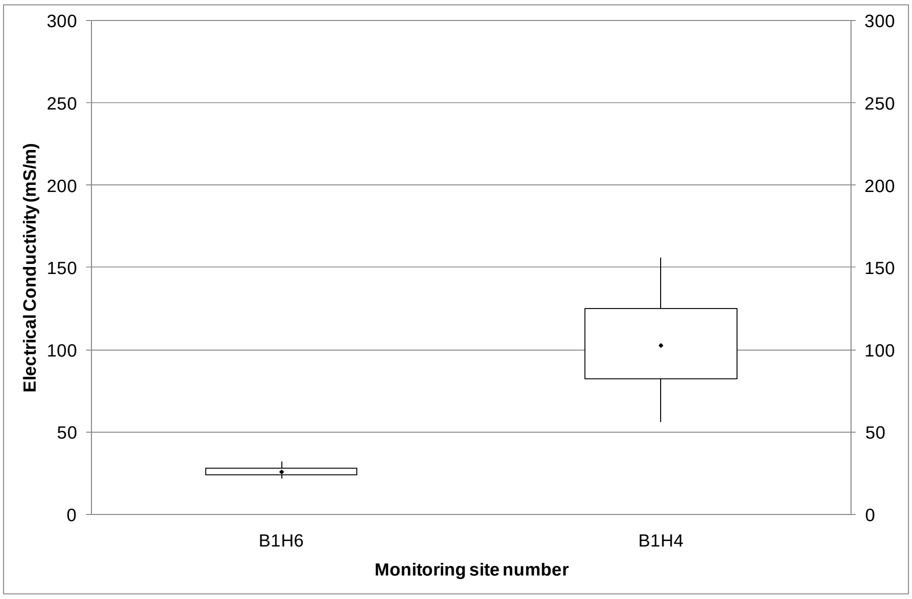

Figure 11: Box and whiskers plot based on EC percentile statistics for the upper Olifants River – Unit 1 (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

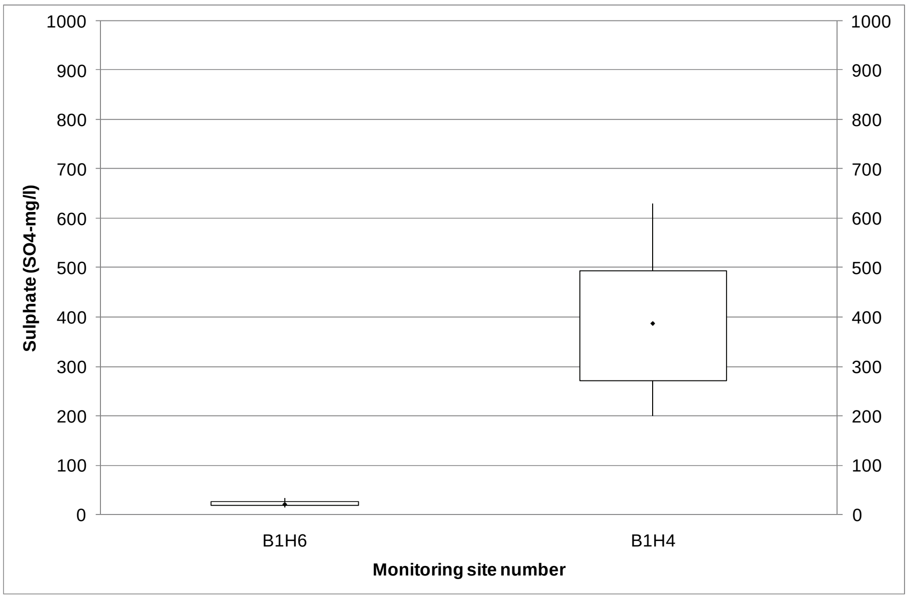

Figure 12: Box and whiskers plot based on sulphate percentile statistics for the upper Olifants River – Unit 1 (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.2 Unit 2 – Wilge River

5.2.1 Water quality monitoring points

Two water quality monitoring points were identified in this subcatchment and used in the assessment of the water quality status of the area.

Table 3 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 3: Selected water quality monitoring points on the Wilge River

DWAF Station Identification Number	River/Stream/Dam, Province	Description	Land use
B2H14	Wilge River, Gauteng	Onverwacht	Bronkhorstspruit Town, agriculture
B2H15	Wilge River, Gauteng	Zusterstroom	Agriculture

The first site, B2H14 is located on the Wilge River at Onverwacht, immediately upstream of the confluence with the Bronkhorstpsruit. The second site (B2H15) is located on the Wilge River at Zusterstroom, downstream of Bronkhorstspruit confluence.

5.2.1.1 Frequency of Sampling

Water quality monitoring started in 1991 at Onverwacht (B2H14) and in 1994 at Zusterstroom (B2H15). The yearly frequency of sampling is tabulated in Appendix A.

5.2.2 Water quality trends

5.2.2.1 pH trends

The pH measured across the sites on the Wilge River does not indicate any negative impacts. The pH does not vary by much and is neutral to slightly alkaline (Figure 13).

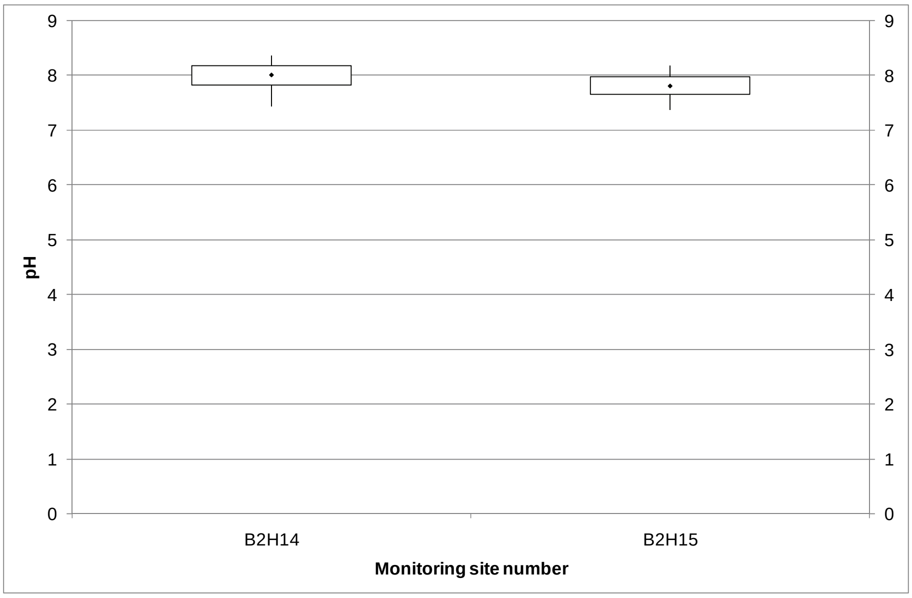

Figure 13: Box and whiskers plot based on pH percentile statistics for the upper Olifants River – Unit 2 Wilge River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.2.2.2 Nutrient trends

The Wilge River flows through areas of unimproved land interspersed with areas of cultivation. There is very little urbanization in the area. As a result, the nitrate levels measured along the river are very low (Figure 14), as are the phosphate levels (Figure 15).

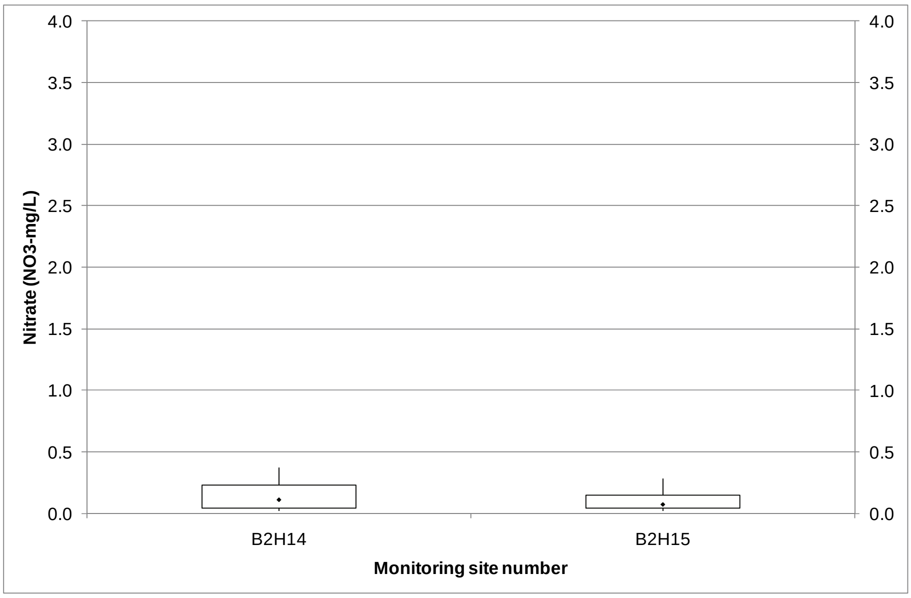

Figure 14: Box and whiskers plot based on nitrate percentile statistics for the upper Olifants River – Unit 2, Wilge River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

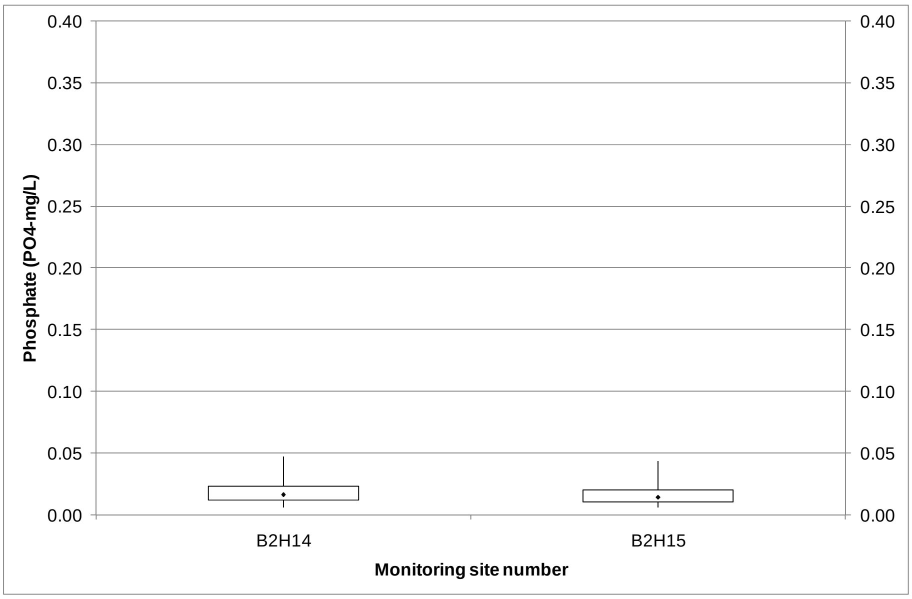

Figure 15: Box and whiskers plot based on phosphate percentile statistics for the upper Olifants River – Unit 2, Wilge River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.2.2.3 <u>Salts trends</u>

The EC and sulphate concentrations measured along the Wilge River show little or no impact on the river (Figure 16 and Figure 17), similar to the nitrate and phosphate results. The largely undeveloped nature of the area leads to little or no impact on the water quality of the river.

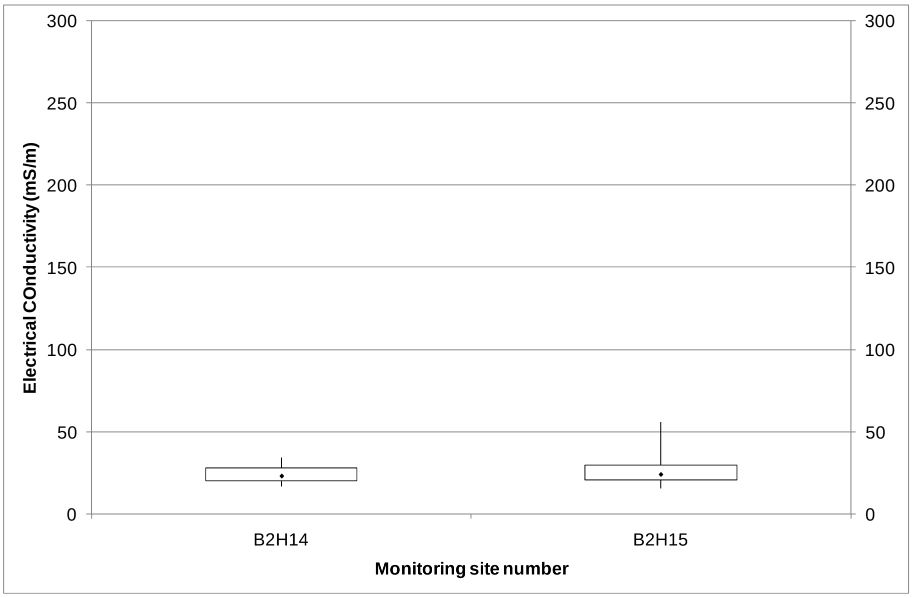

Figure 16: Box and whiskers plot based on EC percentile statistics for the upper Olifants River – Unit 2, Wilge River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

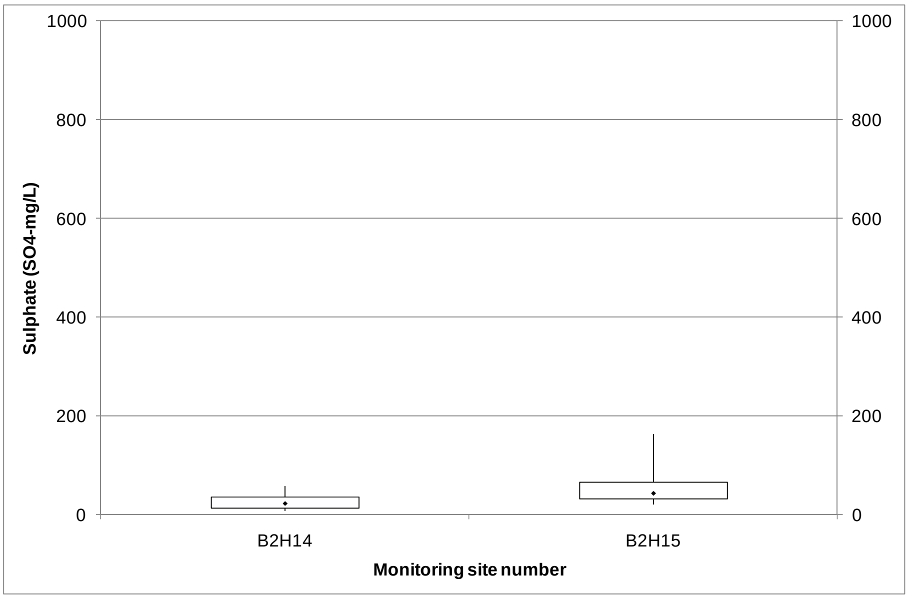

Figure 17: Box and whiskers plot based on sulphate percentile statistics for the upper Olifants River – Unit 2, Wilge River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.3 Unit 3 – Elands River

5.3.1 Water quality monitoring points

One water quality monitoring point was identified in this subcatchment and used in the assessment of the water quality status Elands River at its confluence with the Olifants River. Table 4 presents the description of the water monitoring station. The location of this point is indicated in Figure 1.

Table 4: Selected water quality monitoring point on the Elands River

DWAF Station Identification Number	River/Stream/Dam, Province	Description	Land use
B3H21	Elands River, Mpumalanga	Skerp Arabie	Dry land agriculture

The site, B3H21 is located on the Elands River at Skerp Arabie, not far upstream of the confluence with the Olifants River.

5.3.1.1 Frequency of Sampling

Water quality monitoring started in 1994. The yearly frequency of sampling is tabulated in Appendix A.

5.3.2 Water quality trends

5.3.2.1 pH trends

The pH of the Elands River is alkaline, with a mean of 8.3. No significant pH-related impacts emanating from the Elands River are anticipated.

5.3.2.2 Nutrients trends

The Elands River flows through areas of urbanization and agricultural land. There are also areas where the natural vegetation has been heavily degraded. These factors result in elevated nitrate concentrations at the confluence with the Olifants River. The agricultural impacts are further confirmed by the elevated phosphate levels at this point.

5.3.2.3 Salts trends

The electrical conductivity and sulphate levels in the Elands River are elevated. The EC in particular, has a mean value of 116 mS/m and in 5% of the measurements, was greater than 250 mS/m. This is due to the impacts of the urban and peri-urban areas along the river.

5.4 Unit 4 – Steelpoort River

5.4.1 Water quality monitoring points

Two water quality monitoring points were identified in this subcatchment and used in the assessment of the water quality status of the area. Table 5 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 5: Selected water quality monitoring points on the Steelpoort River

DWAF Station Identification Number	River/Stream/Dam	Description
B4H3	Steelpoort River, Mpumalanga	Buffelskloof, dense informal settlements, cattle grazing
B4H11	Steelpoort River, Mpumalanga	Alverton, dense informal settlements, cattle grazing

The first site, B4H3 is located on the Steelpoort River at Buffelskloof, upstream of the confluence with the Klip River. The second site (B4H11) is located on the Steelpoort River at Alverton, upstream of the confluence with the Olifants River.

5.4.1.1 Frequency of Sampling

Water quality monitoring started in 1977 at Buffelskloof (B4H3) and in 1984 at Alverton (B4H11). The yearly frequency of sampling is tabulated in Appendix A.

5.4.2 Water quality trends

5.4.2.1 <u>pH trends</u>

The pH increases slightly along the Steelpoort River, from a mean of 8.1 at Buffelskloof to 8.3 at Alverton. No pH-related impacts can be inferred from the statistical analysis of the historical record (Figure 18).

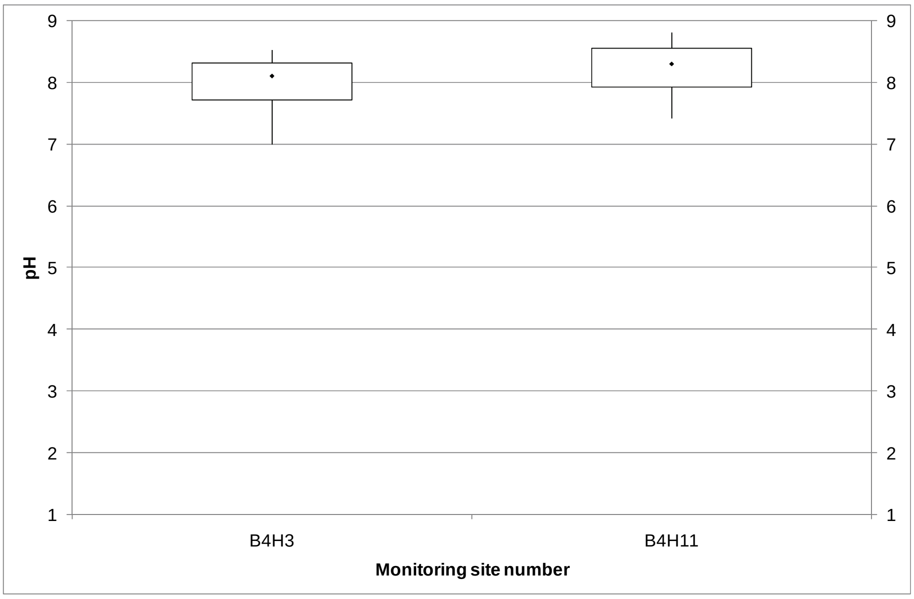

Figure 18: Box and whiskers plot based on pH percentile statistics for the lower Olifants River – Unit 4, Steelpoort River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.4.2.2 <u>Nutrient trends</u>

The nitrate load in the Steelpoort River increases from the upper to the lower reaches (Figure 19). There is an increase in the degree of cultivation and urbanization in the lower reaches which contributes to this impact. There are two small mining areas in the Steelpoort catchment that would also contribute to the increase in the nitrate load along the river.

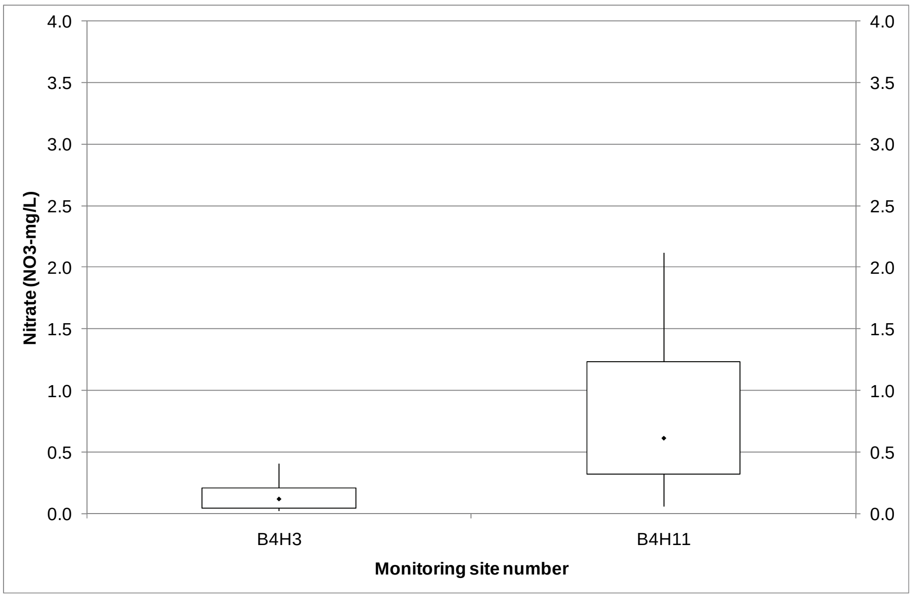

Figure 19: Box and whiskers plot based on nitrate percentile statistics for the lower Olifants River – Unit 4, Steelpoort River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

The phosphate concentrations from the upper to the lower Steelpoort River do not reflect an increase similar to that seen in the nitrate results (Figure 20). This indicates that the nutrient load is predominantly due to human impacts rather than agricultural impacts.

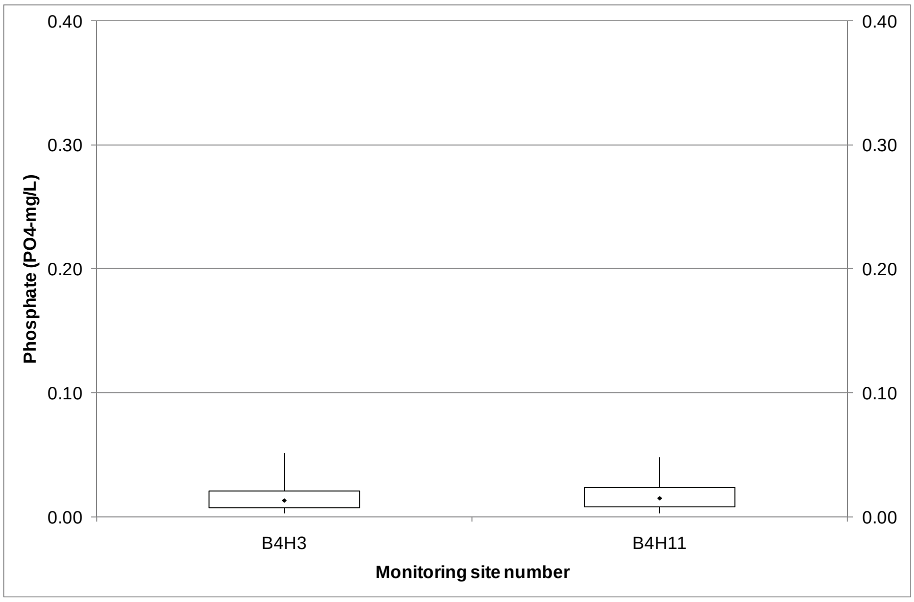

Figure 20: Box and whiskers plot based on phosphate percentile statistics for the lower Olifants River – Unit 4, Steelpoort River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.4.2.3 <u>Salts trends</u>

The electrical conductivity (Figure 20) and sulphate (Figure 21) indicate an increase in salts load from the upper to the lower reaches of the Steelpoort River. Again this is due to the flow of the lower reaches through much more urbanized and cultivated areas. The runoff/seepage from these developments has resulted in an increase in the salts load in the river. The increase in sulphate in particular, could be a result of the small amount of mining that takes place between the two monitoring sites. The runoff from these industries would result in an increase in the sulphate load in the river.

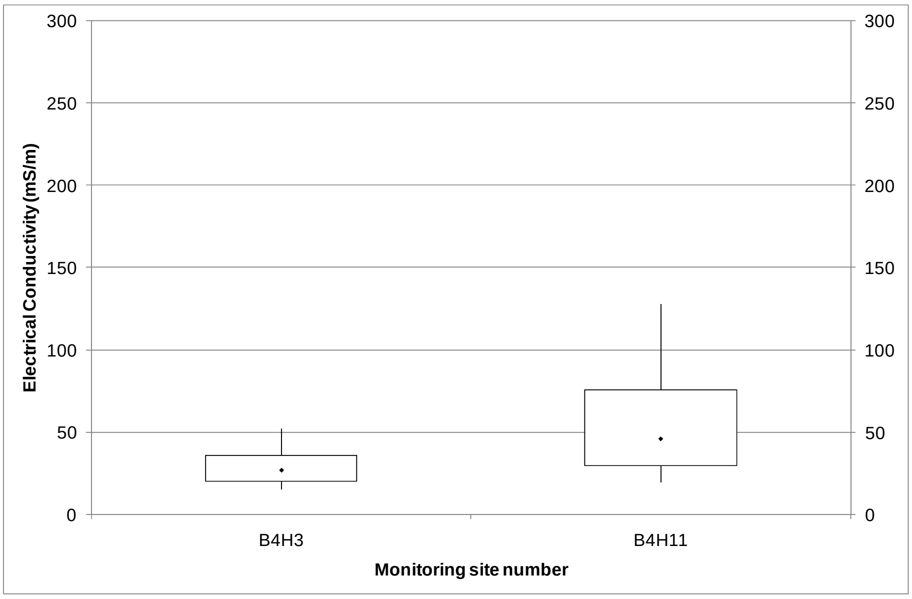

Figure 21: Box and whiskers plot based on EC percentile statistics for the lower Olifants River – Unit 4, Steelpoort River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

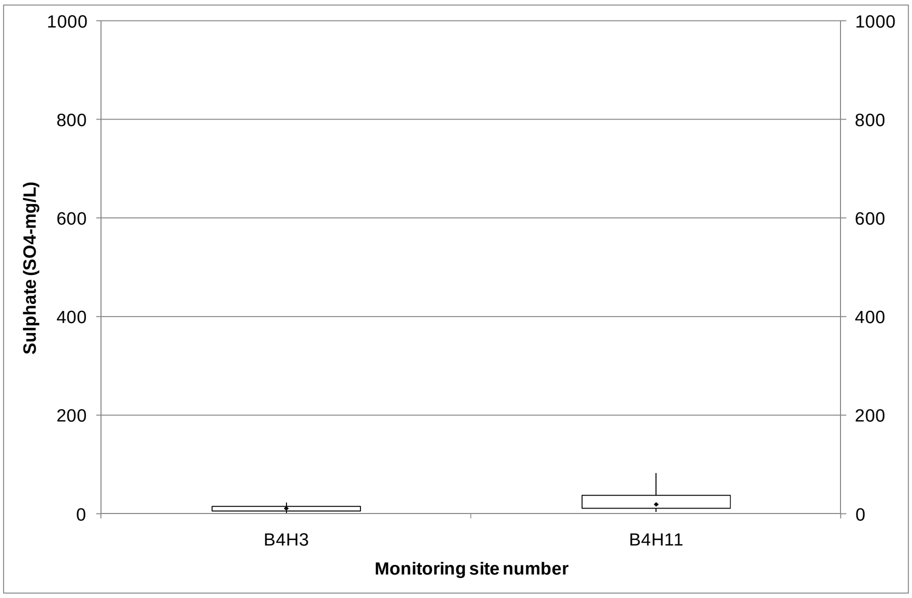

Figure 22: Box and whiskers plot based on sulphate percentile statistics for the lower Olifants River – Unit 4, Steelpoort River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.5 Unit 6 – Blyde River

5.5.1 Water quality monitoring points

Two water quality monitoring points were identified in this subcatchment and used in the assessment of the water quality status of the area. Table 6 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 6: Selected water quality monitoring points on the Blyde River

DWAF Station Identification Number	River/Stream/Dam	Description
B6H1	Blyde River, Mpumalanga	Willemsoord, commercial forestry
B6H4	Blyde River, Mpumalanga	Chester, dry land agriculture, cattle ranches

The first site, B6H1 is located on the Blyde River at Willemsoord, at the confluence with the Treur River. The second site (B6H4) is located on the Blyde River at Chester, upstream of the confluence with the Olifants River.

5.5.1.1 Frequency of Sampling

Water quality monitoring started in 1966 at Willemsoord (B6H1) and in 1978 at Chester (B6H4). The yearly frequency of sampling is tabulated in Appendix A.

5.5.2 Water quality trends

5.5.2.1 pH trends

The pH in the Blyde River is neutral to slightly alkaline (Figure 22). There is no evidence of pH-related impacts on the water quality in this catchment.

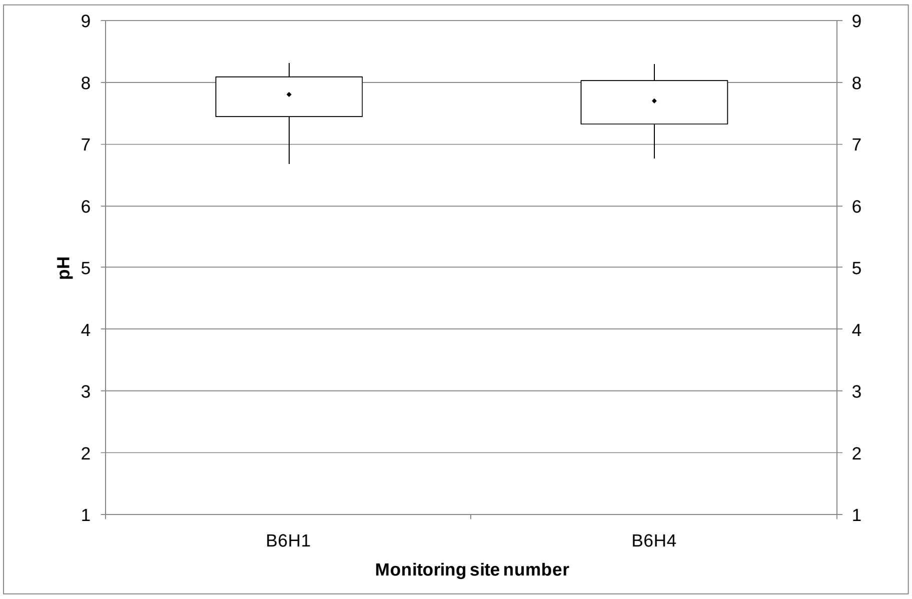

Figure 23: Box and whiskers plot based on pH percentile statistics for the lower Olifants River – Unit 6, Blyde River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.5.2.2 Nutrient trends

The nitrate levels (Figure 24) and the phosphate levels (Figure 24) are low. This is due to the largely unimproved area through which it flows. There is very little urbanization and only a small area of cultivated land at the lower reaches of the river.

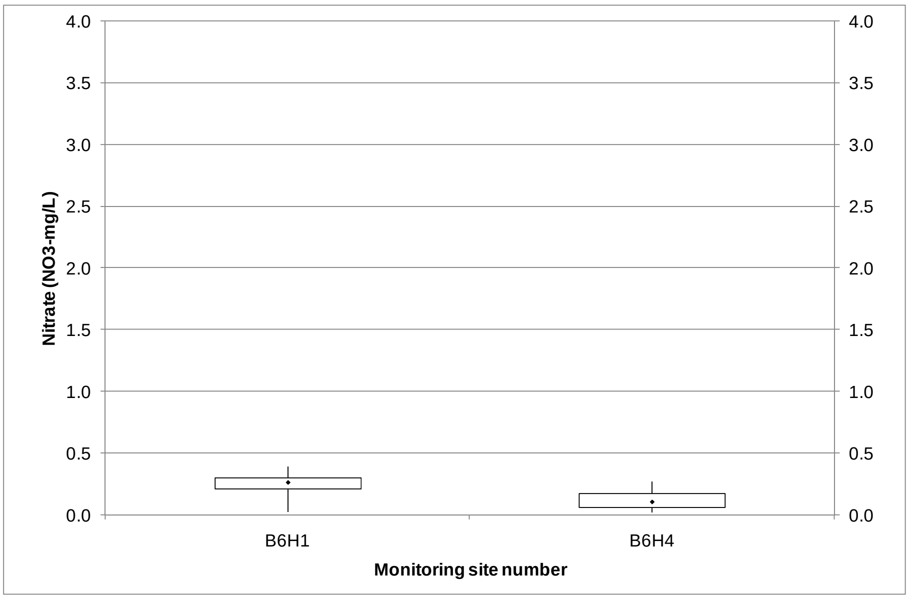

Figure 24: Box and whiskers plot based on nitrate percentile statistics for the lower Olifants River – Unit 6, Blyde River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.5.2.3 Salts trends

Both the EC (Figure 25) and sulphate (Figure 26) concentrations are very low. Again this is due to the largely pristine nature of the area through which the Blyde River flows.

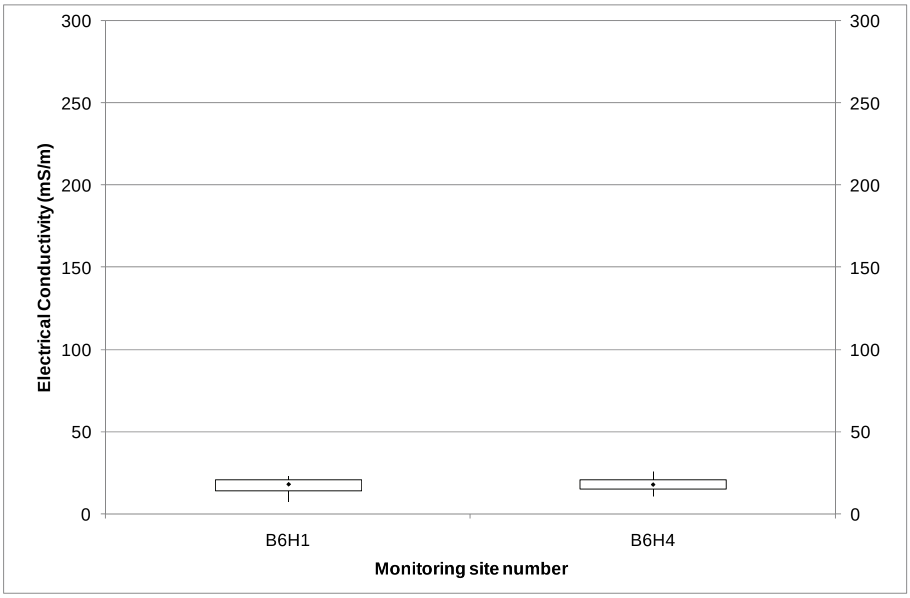

Figure 25: Box and whiskers plot based on EC percentile statistics for the lower Olifants River – Unit, Blyde River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

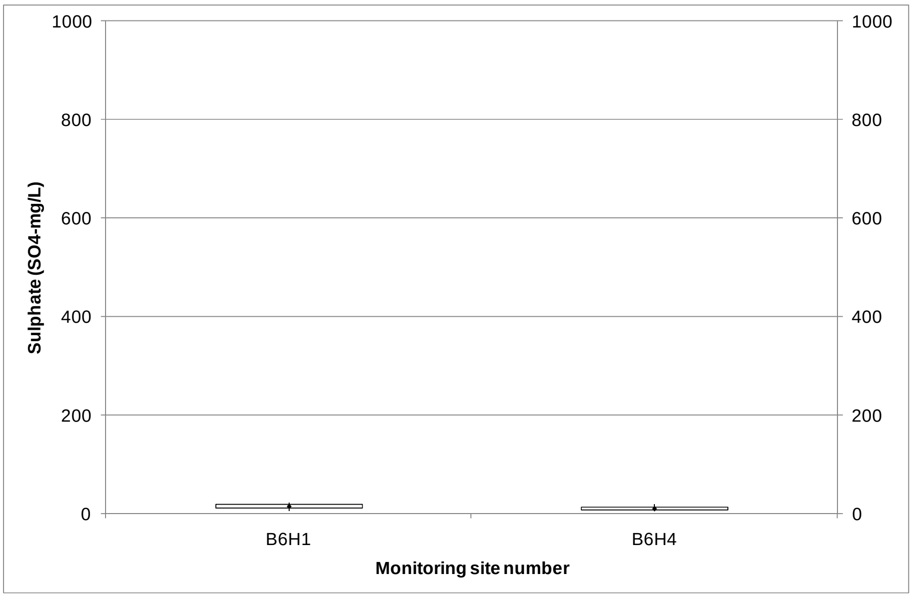

Figure 26: Box and whiskers plot based on sulphate percentile statistics for the lower Olifants River – Unit 6, Blyde River (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.6 Unit 7 – Ga-Selati River

5.7 Water quality monitoring points

One water quality monitoring point was identified in this river and was used in the assessment of the water quality status of the Ga-Selati River at its confluence with the Olifants River. Table 6 presents the description of the water monitoring station. The location of this point is indicated in Figure 1.

Table 7: Selected water quality monitoring point on the Ga-Selati River

DWAF Station Identification Number	River/Stream/Dam	Description
B7H19	Ga-Selati River	Loole/Foskor, urban settlement of Phalaborwa, mining

The site, B7H19 is located on the Ga-Selati River at Foskor, not far upstream of the confluence with the Olifants River.

5.7.1 Frequency of Sampling

Water quality monitoring started in 1989. The yearly frequency of sampling is tabulated in Appendix A.

5.7.2 Water quality trends

5.7.2.1 pH trends

The pH of the Ga-Selati River is alkaline, with a mean of 8.3. No significant pH-related impacts emanating from the Ga-Selati River are anticipated.

5.7.2.2 Nutrients trends

The Ga-Selati River flows through areas of urbanization and intensive mining in Phalaborwa. There are also areas where the natural vegetation has been heavily degraded. These factors result in elevated nitrate concentrations at the confluence with the Olifants River. The phosphate levels in the Ga-Selati River are also very high.

5.7.2.3 Salts trends

The electrical conductivity and sulphate levels in the Ga-Selati River are highly elevated due to the significant mining impact on the river water quality through mine drainage leakage and possibly contaminated groundwater seepage.

5.8 Dam water quality

5.8.1 Water quality monitoring points

Two water quality monitoring points were identified in this subcatchment and used in the assessment of the water quality status of the area. Table 7 presents the description of individual water monitoring stations. The locations of these points are indicated in Figure 1.

Table 8: Selected dam water quality points in the Olifants River catchment

DWAF Station Identification Number	River/Stream/Dam	Description
B1R1	Witbank Dam	Olifants River
B1R2	Middelburg Dam	Klein Olifants River
B3R2	Loskop Dam	Olifants River
B5R2	Flag Boshielo Dam	Olifants River
B7R2	Phalaborwa Barrage	Olifants River

The first site, B1R1 is located on the Olifants River after the confluences with the Rietspruit, and the Trichardspruit. The second site (B1R2) is located on the Klein Olifants River. The third site (B3R2) is located on the Olifants River downstream of the confluence with the Wilge River and the Klein Olifants River. The fourth dam site (B5R2) is located further downstream in the middle Olifants catchment area, downstream of the confluence with the Elands River. The fifth site (B7R2), the Phalaborwa Barrage is located upstream of the Ga-Selati River confluence and before the river passes into the Kruger National Park.

5.8.1.1 Frequency of Sampling

Water quality monitoring started in 1972 at Witbank Dam (B1R1), in 1978 at Middelburg Dam (B1R2), in 1968 at Loskop Dam (B3R2), in 1994 at Flag Boshielo Dam (B5R2) and in 1975 at the Phalaborwa Barrage (B7R2). The yearly frequency of sampling is tabulated in Appendix A.

5.8.2 Water quality trends

5.8.2.1 pH trends

The pH across the selected dams in the Olifants River catchment is neutral to slightly alkaline (Figure 27). The pH in Loskop Dam shows slightly more variability than the other dams, and the mean value is slightly lower than the others, but still within the expectations for good water quality.

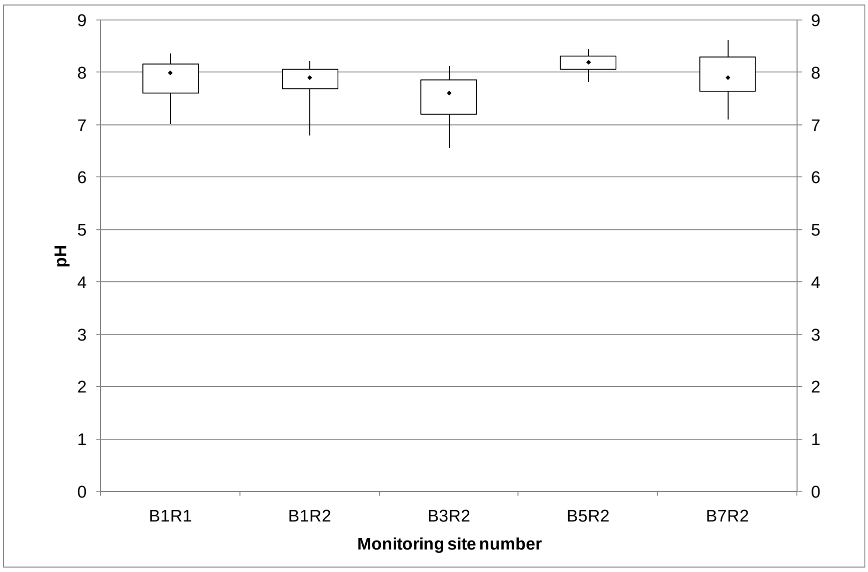

Figure 27: Box and whiskers plot based on pH percentile statistics for the Olifants River catchment dams (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

5.8.2.2 Nutrients trends

The nutrient trends across the selected dams show no significant difference between the dams, and all of the values are relatively low. This is to be expected as dams will act as “sinks”, collecting and reducing the nutrient content via utilization by macrophytes and micro-organisms present in the dams. Both the nitrate (Figure 28) and phosphate (Figure 29) results show a stable trend across the dams in the catchment.

5.8.2.3 Salts trends

The electrical conductivity (Figure 30) trend across the selected dams in the catchment shows a decrease in EC at Loskop Dam, with slightly elevated levels at Middelburg and Flag Boshielo Dams. There is intensive mining upstream of Middelburg Dam, which would contribute to the elevated levels, whereas Flag Boshielo Dam is in an area of highly degraded land with some urbanization which may give rise to the elevated results at that point.

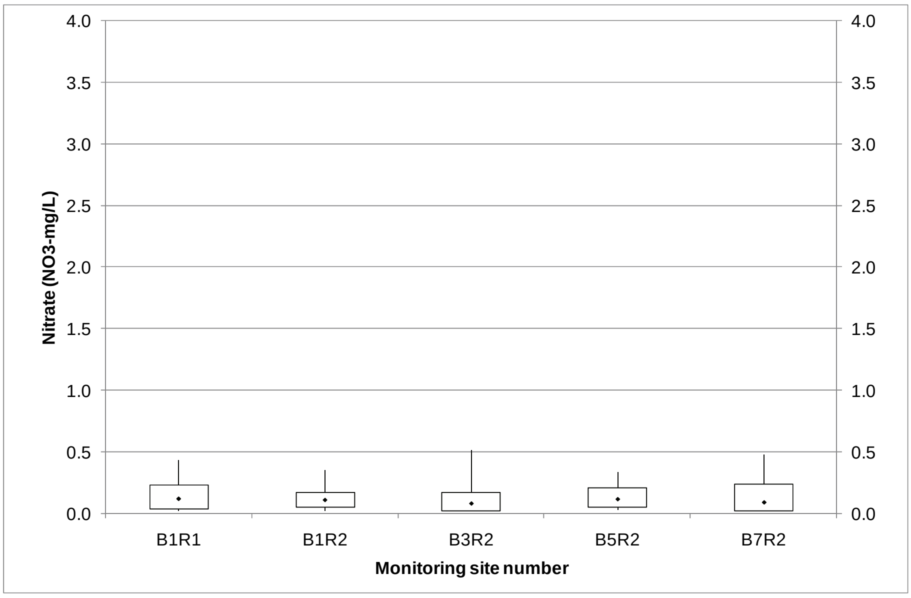

Figure 28: Box and whiskers plot based on nitrate percentile statistics for the Olifants River catchment dams (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

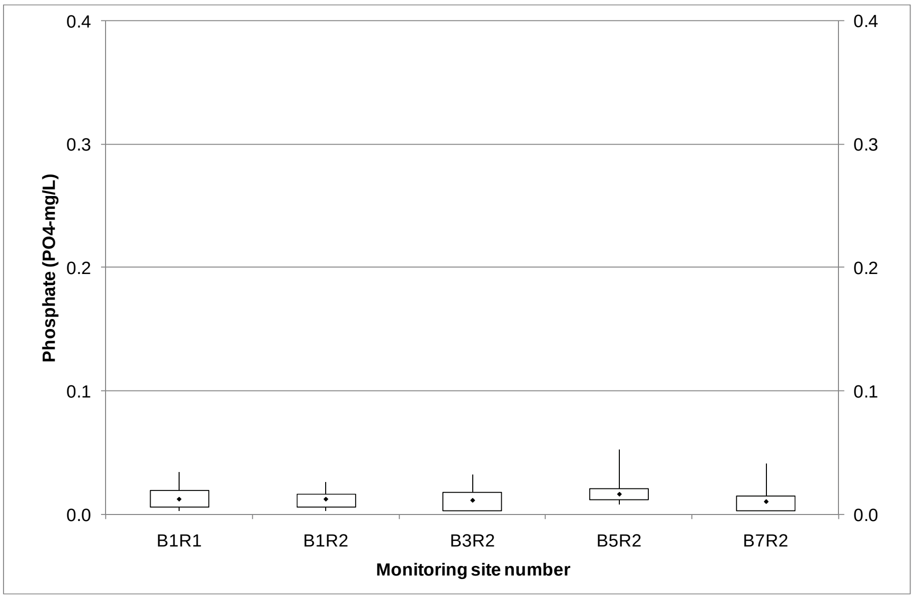

Figure 29: Box and whiskers plot based on phosphate percentile statistics for the Olifants River catchment dams (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

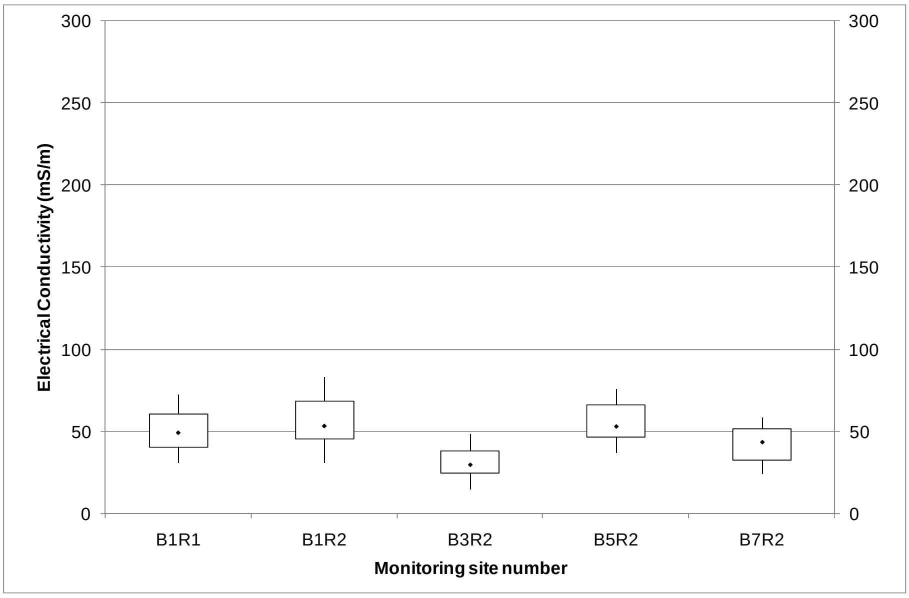

Figure 30: Box and whiskers plot based on EC percentile statistics for the Olifants River catchment dams (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

The sulphate results (Figure 31) indicate the location of the major mining impacts within the catchment, with the highest impacts being felt in Witbank and Middelburg Dams. This high sulphate load has been reduced somewhat by the time the water reaches Loskop Dam, with further significant decreases in sulphate load through Flag Boshielo and the Phalaborwa Barrage.

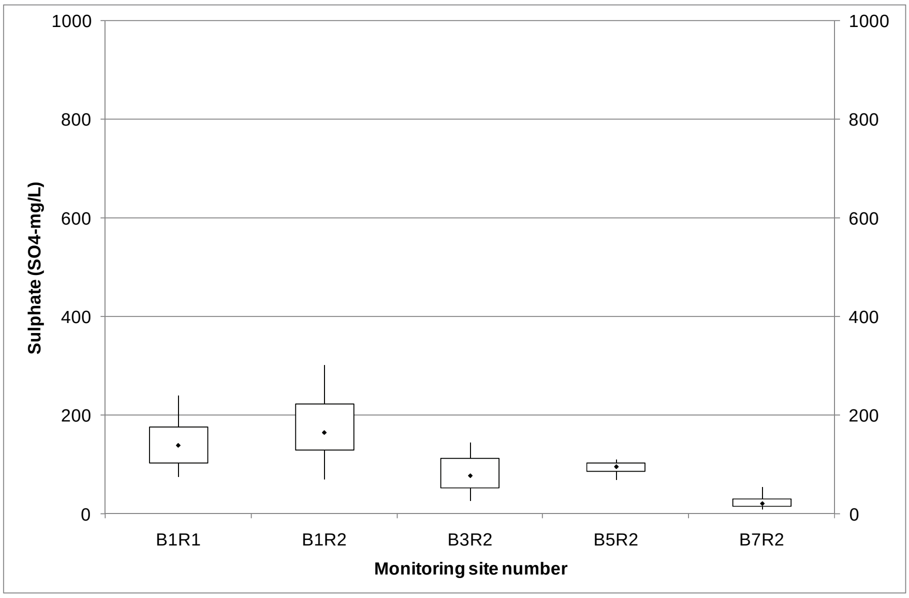

Figure 31: Box and whiskers plot based on sulphate percentile statistics for the Olifants River catchment dams (Box: 25% and 75%, whiskers: 5% and 95%, point: 50%)

6. GENERAL WATER QUALITY TRENDS ACROSS THE OLIFANTS RIVER CATCHMENT

6.1 pH trends

Figure 32 summarizes the pH trend across the Olifants River catchment. The pH in the upper Olifants catchment is neutral to alkaline for the most part. A major negative impact at this point in the reach is the water coming into the system from the Klipspruit. The mean pH of the water from the Klipspruit is 4, and will drop below that at least 25% of the time due to constant mine drainage seepage from the extensive mining in the area. The Wilge River does not contribute to any negative impacts, but a slight decrease in pH was noted for Loskop Dam due to the impacts received via the Klipspruit.

In the middle Olifants catchment, the pH is again neutral to alkaline with no negative impacts from the selected tributaries (Elands and Steelpoort River). Downstream of the Steelpoort River confluence, the lower Olifants catchment shows some variability in pH, but is neutral to alkaline with no further pH-related negative impacts

6.2 Nutrients trends

Figure 33 summarizes the nitrate trend across the Olifants River catchment and selected associated tributaries.

The nitrate trend in the upper Olifants catchment is generally low, excluding the high impact received from the Klipspruit, again due to the high density mining area with associated urbanization. Very little nitrate load is introduced from the Wilge River system, and Loskop Dam absorbs a significant proportion of the nitrate coming into the dam from the upper reaches of the catchment.

In the middle Olifants catchment the Elands River contributes nitrate to the overall load of the Olifants River, predominantly through urban and peri-urban impacts. Similarly the Steelpoort River introduces a high nitrate load as a result of agricultural activities and small urban areas in the lower reaches.

The Blyde River does not contribute to the nitrate load in the lower Olifants catchment, and the levels at the Phalaborwa Barrage are similarly low. After the confluence with the Ga-Selati River, the nitrate levels in the Olifants River are increased *via* negative impacts received from the Ga-Selati River and the associated mining activity.

The summarized phosphate trend across the catchment in Figure 34 indicates that in the upper catchment area there is no significant input of phosphate to the Olifants River. The slightly elevated levels measured at Middelkraal (B1H18) on the Olifants River reflect the agricultural land use through which the river flows.

In the middle catchment, the Elands River adds to the phosphate load in the Olifants River, but at Flag Boshielo Dam this load is reduced to concentrations seen upstream of the Elands River confluence.

In the lower Olifants catchment, the Ga-Selati introduces a significant amount of phosphate to the system, but this is greatly reduced at the “sink” formed by Mamba weir (B7H15).

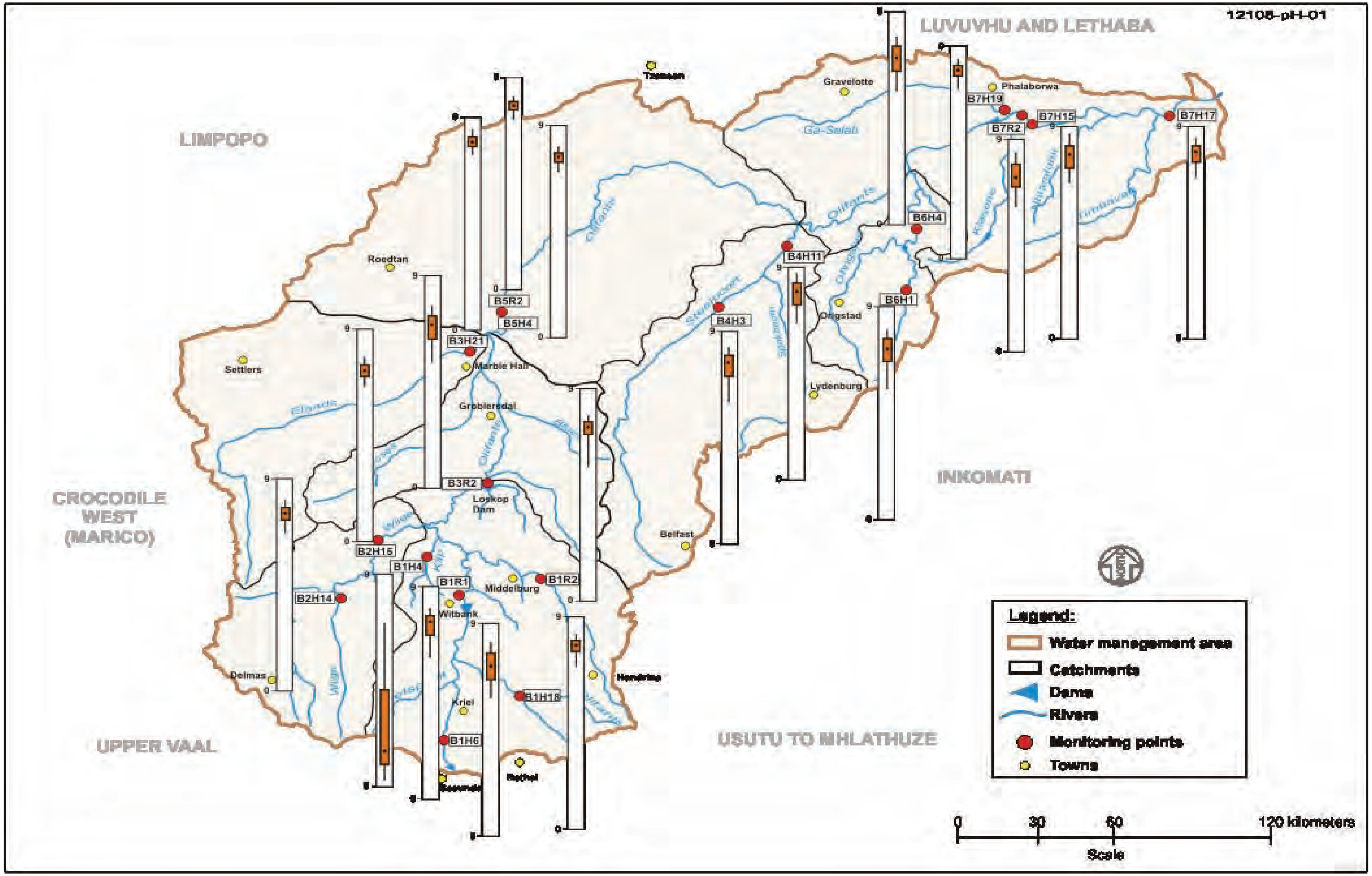

Figure 32: Summarized pH trend across the Olifants River catchment

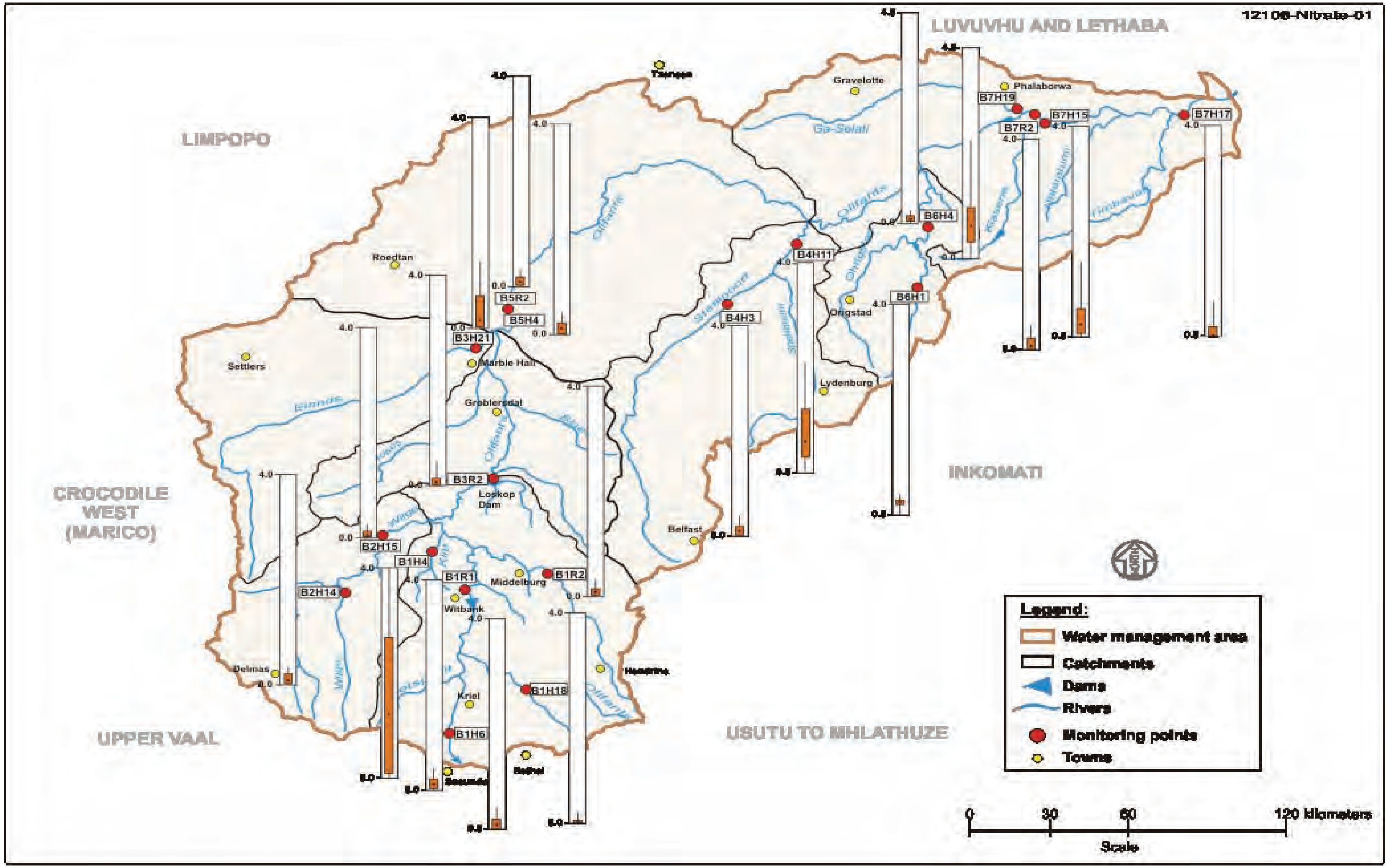

Figure 33: Summarized nitrate trend across the Olifants River catchment

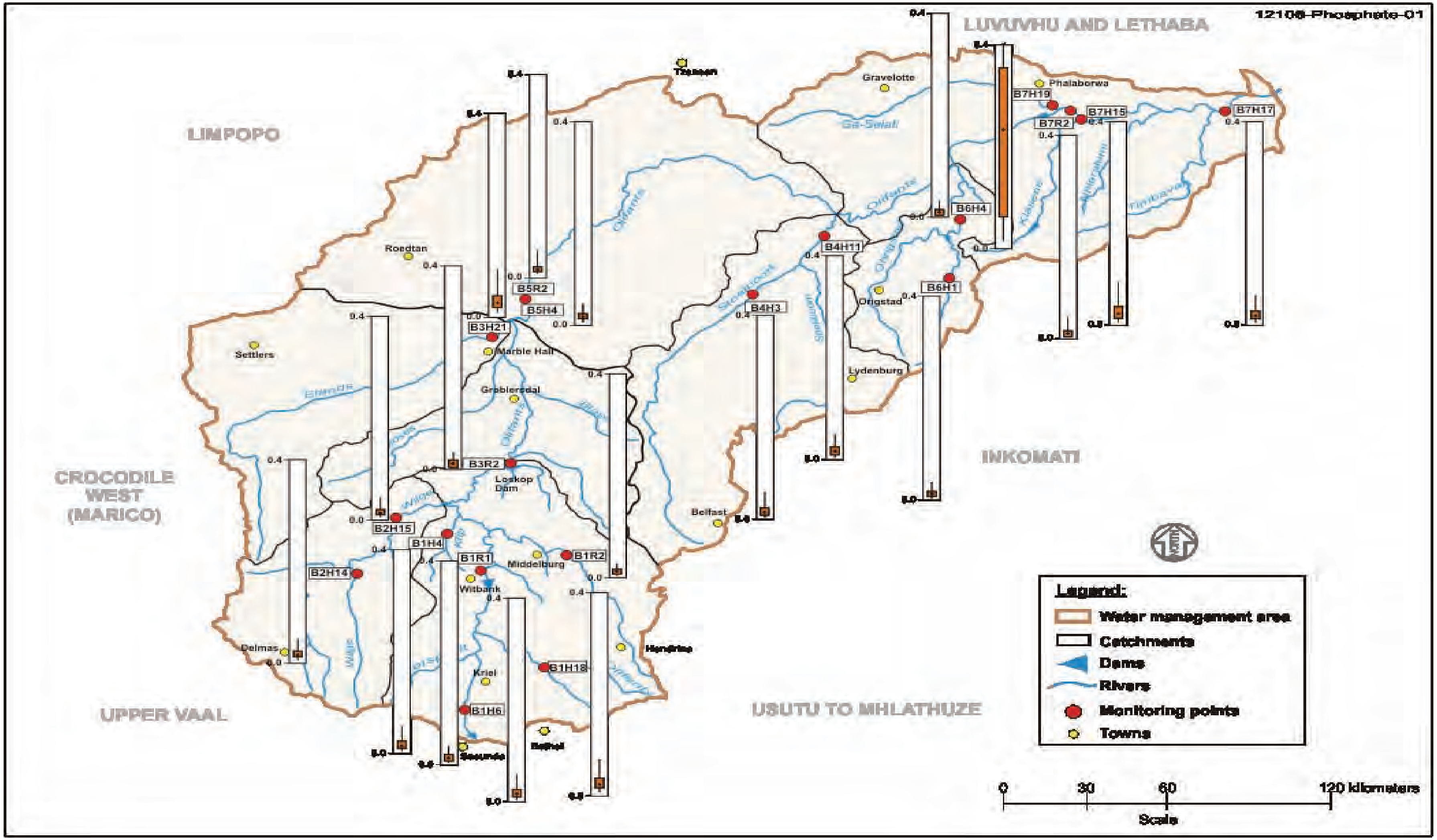

Figure 34: Summarized phosphate trend across the Olifants River catchment

6.3 Salts trend

The electrical conductivity (EC) data for the upper Olifants River catchment show that the river is impacted by salts from the upper reaches (Figure 35). The water quality at Middelkraal on the Olifants River is elevated, and this trend increases from Witbank Dam to Middelburg Dam. The EC results for the Klipspruit are significantly higher than the rest of the upper reach of the catchment. The high salts concentrations in the upper reaches are a direct result of the intensive mining activity in the area. Loskop Dam, however, greatly reduces this via the salt "sink" effect.

In the middle Olifants catchment the Elands River contributes a high concentration of salts to the Olifants River, as does the Steelpoort – both a result of urban and agricultural runoff

The lower reaches of the catchment are negatively impacted by salts inputs from the Ga-Selati River. This concentration is diminished, but not returned to acceptable levels by the time it enters the Kruger National Park.

An analysis of the sulphate concentrations across the Olifants River catchment (Figure 36) shows a similar trend for the upper reaches of the catchment area. High sulphate levels were recorded in the Witbank and Middelburg Dams, with significantly higher impacts being introduced below these dams via the Klipspruit.

The Elands River is again a contributor to the salts concentration in the Olifants River. The sulphate levels measured are again elevated.

The lower Olifants catchment receives no significant sulphate inputs from the Blyde River, but the Ga-Selati River (mean sulphate = 800 mg/L) contributes significantly. Similar to the conductivity data, the sulphate concentration is still elevated when the river enters the border of the Kruger National Park.

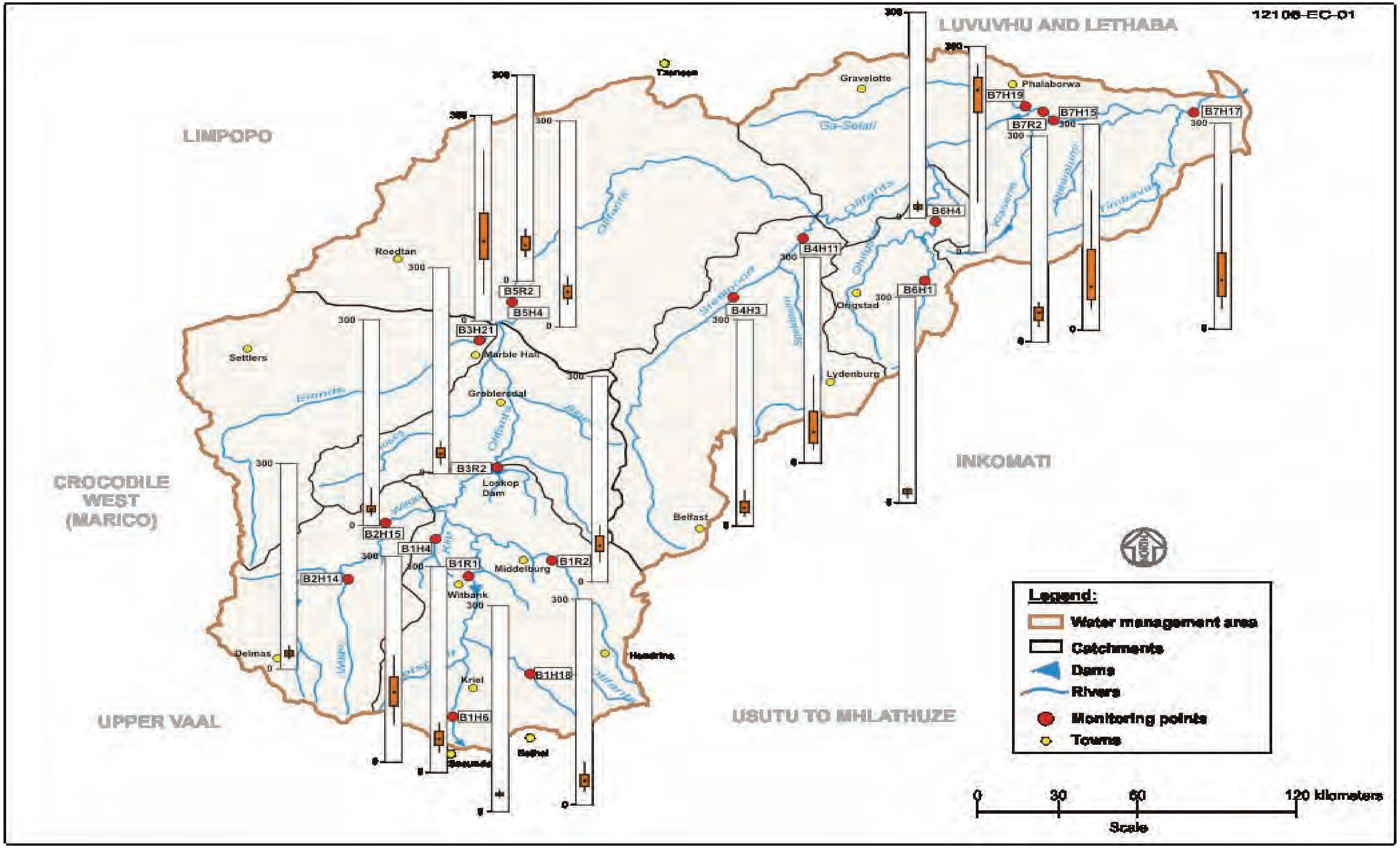

Figure 35: Summarized electrical conductivity trend across the Olifants River catchment

7. ECOLOGICAL DATA AVAILABLE

In the light of the water quality and the massive mortality of aquatic organisms experienced in the Olifants River system (Figure 37) during the last two years, it has become essential to review and summarize the current knowledgebase and available information on the ecology of the Olifants River System with possible relationship to the water quality.

Figure 36: Crocodile mortalities in Olifants River 2008

Pre 1990 studies in the Olifants River mainly focused on biodiversity issues in the Olifants River Catchment. Very few studies placed emphasis on the water quality problems in the Olifants River catchment. Few of the studies had indirect relationship to water quality and some of these studies may be useful with respect to establishing some reference conditions for the aquatic ecosystem in the in the Olifants River pre 1990. The Former Transvaal Directorate of Nature Conservation and Potchefstroom University was possibly the most active in the area during this period. Although only a moderate number of published articles for the Olifants exist it is clear that a huge amount of data and information may still be available in the form of monitoring data, communications, unpublished reports and personal experience of some scientist that has been involved with studies in the Olifants River System.

Post 1990 until recently several aquatic ecological studies concentrated on the bioaccumulation of trace metals in selected fish species and some impacts relating to sediments and its effect on the fish community. These studies focused mainly on the lower Olifants River indicating that bioaccumulation are taking place but the variation were difficult to define. Some studies suggested that bioaccumulation could be more prevalent during periods of high flow and increased sediments.

However, more recently the massive fish and crocodile deaths in Loskop Dam and in the Kruger National Park has renewed interest in the water quality problems experienced in the Olifants River System. Recent pathological and, histopathology studies of fish showed changes consistent with lipid-autoxidation, suggesting an excessive pro-oxidant challenge related to chronic pollution that may be affecting the entire aquatic food chain. Depleted antioxidants (vitamin E) and excessive fat in fish may have lead to insufficient protection of the fish lipids consumed by predators precipitating the development of pansteatitis in predators such as the crocodiles and terrapins. The disruption to the food chain is also supported by a recent study that has concluded that Loskop dam are now hypertrophic and that changes in functional groups of phytoplankton has occurred. This would imply that the quality of food and the structure of available habitat for benthic invertebrates have also been impacted.

Several studies have recently been initiated to investigate water quality and its impact on the aquatic ecosystem.

7.1 Literature review method

This review concentrated on ecological information that could have direct or indirect bearing on water quality issues in the Olifants River System and is largely based on internet searches, scanning through some of the Former Transvaal Directorate of Nature Conservation (Lydenburg) literature and reports and communications with several scientists previously or presently involved with aquatic projects in Olifants River system.

7.2 Literature review

Based on the available information it would seem as if there were three distinct eras in term of the type of research and information gathered in the Olifants River System on aquatic ecosystems.

7.2.1 Pre 1990

Prior to 1990 the impact of water quality in the Olifants River was largely unnoticed and ecological studies in the Olifants River catchment focused largely on biodiversity issues. Very few studies had any direct relationship to water quality but these studies may be useful with respect to baseline or reference conditions of aquatic organisms in the in the Olifants River for future studies. Although a fair number of published articles for the Olifants exist it was clear that a huge amount of data and information may still be available in monitoring data, unpublished reports and personal experience of some scientist that has been involved with studies in the Olifants River System. The Former Transvaal Directorate of Nature Conservation and Potchefstroom University was possibly the most active in the area during this period. Although the impact of mining and urban pollution on invertebrates in the former Transvaal was studied during this period by Allanson (1961) and Harrison (1958) was one of the only authors to describe the impact of acid mine drainage on invertebrates in the Olifants River System during this period.

Some of the most important studies during this period included the following:

- Several fish distribution studies giving a broad perspective of the historical distribution of fish in the Olifants River system (Gaigher, 1969; Gaigher and Pott, 1973). Electronic databases from the South African Institute of Aquatic Biodiversity (SAIAB) and former Transvaal Directorate of Nature Conservation also contain important information in this regard. However, a huge amount of information are still be locked up in unpublished reports and monitoring data.

- One of the studies during this period concentrated on benthos and the epifauna of Loskop Dam (Mulder, 1969). It is noteworthy that, based on this data, this author considered the water of Loskop Dam to be still unpolluted and showing very little evidence of the acid pollution from the coal mines upstream. Some of this information could be useful in determining reference conditions for Loskop Dam.

- A few ecological studies and population estimates of angling species were done during this period in Loskop Dam. These included studies by Goldner, (1969), Goldner et al. (1972) and Malan (1988) for Loskop Dam. These studies largely looked at relative abundances, growth rates, age structures, Condition Factor of angling species and population estimates. Internal reports by the former Transvaal Directorate of Nature Conservation and other data relating to several dams in the catchment are still available. Population estimates of fish in Loskop Dam by Goldner et al., (1972) were repeated during 1990 (Engelbrecht, 1990). One of the main problems with these studies was the selectivity of the sampling methods and behavioral differences of the different species which influenced the number of captures and recaptures and consequently skewed the results. Differences in the population estimates by the two studies could not be related to water quality at that stage but our improved understanding may contribute. Some of this information in these studies could be useful in determining reference conditions for Loskop Dam for future studies.

- A study of the freshwater mollusks upstream of Marble Hall (Pretorius et al., 1980) could be of importance based on the fact that some species could be sensitive to heavy metal pollution. It is possible that several other similar studies may have been done by Potchefstroom University and may still be available.

- It was not until 1983 that the first massive fish mortalities in the Olifants River system directly related to the impact of mine spillage was recorded in the Kruger National Park (Engelbrecht, 1983). Some aquatic species collected during 1992 (*Marcobrachium* spp. and *Opsaridium peringueyi*) has not been collected from this part of the system since. This event may have focused some attention of former managers in the Former Transvaal Directorate of Nature Conservation and the Kruger National Park on the vulnerability of the river systems flowing through the park. But is not until post 1990 that specific studies were conducted to address some of these problems.

7.2.2 Post 1990

Post 1990 until about 2002 several aquatic ecological studies concentrated on the bioaccumulation of heavy metals in selected fish species and some impacts relating to sediments on the fish community. Engelbrecht (1992a and b) describes some of the water quality issues in the upper Olifants River and predicts the serious water quality issues presently experienced.

Some of the most important studies during this period included the following:

- Several studies largely driven by RAU between 1992 and 2002 which focused on bioaccumulation. These studies were largely done on the lower Olifants River on a few indicator species such as tiger fish (Du Preez and Steyn, 1992), yellowfish (Seymore et al., 1995; Seymore et al., 1996; Seymore et al., 1996), sharptooth catfish (Du Preez et al., 1997; Marx et al., 1998; Avenant-Oldewage and Marx, 2000a; Avenant-Oldewage and Marx, 2000b) and Mozambique tilapia (Robinson and Avenant-Oldewage, 1997; Kotzè et al., 1999; Barnhoorn and Van Vuuren, 2001). A few studies were also conducted in the upper Olifants River on moggel (Nussey et al., 1999; Coetzee et al., 2002). Most of these studies indicated that bioaccumulation were taking place, but was difficult to define the observed variation. Some studies indicated that bioaccumulation could be more prevalent during periods of high flow and increased sediments. The importance of sediments and its relation to metal concentrations and changes in water quality was investigated by Buermann et al., 1995; Seymore et al., 1994). These studies concluded that the releases of sediments from Phalaborwa Barrage created serious water quality problems.

- A recommendation for the development and implementation of a water quality monitoring tool was developed but was never implemented (Wepener et al., 1992; Wepener et al., 1999).

7.2.3 Recent studies

More recently the massive fish and crocodile deaths in Loskop Dam and in the Kruger National Park have renewed interest in the water quality problems experienced in the Olifants River System. The findings of these studies is summarised below.

Pathology, histopathology and blood smear examinations of fish in the Kruger National Park during the 2008 mass crocodile mortalities showed changes consistent with fish suffering from lipid autoxidation which has been described in literature for rainbow trout, channel catfish and bluefin tuna. Lipid autoxidation is consistent with a vitamin E deficiency and is unlikely to be normal in wild caught fish. Fish severely affected by lipid autoxidation would become easy prey for predators, possibly before a mass mortality of fish is even noticed (Huchzermeyer, 2009). He also suggested that lipid autoxidation may be caused by anthropogenic pollutants entering the Olifants River system affecting the primary production and availability of Vitamin E in the aquatic ecosystem. Such excessive pro-oxidant challenges are likely to affect the entire food chain. Increased nutrients and the presence of large impoundments along the Olifants River, like Loskop and Massingire Dam, have caused the proliferation of some species like sharp tooth catfish (*Clarias gariepinus*) and Mozambique Tilapia (*Oreochromis mossambicus*). The large impoundments mentioned above contributed to the abundant availability of excessively fat fish for predators to feed on. Depleted antioxidants (vitamin E) and excessive fat in the fish may have lead to insufficient protection of the fish lipids consumed by the crocodiles precipitating the development of pansteatitis in the crocodiles (*personal communications* with Huchzermeyer, Myburgh and Steyl). These studies also aim to:

- Establish histological and hematological baseline data of pathology in fish in Olifants River System and establish comparable histological baseline data from unpolluted rivers in the region.
- Establish extent of pollution related pathology in fish along the length of the Olifants River from the source of pollution on the Highveld to and including Massingire Dam.
- Determine vitamin E levels in liver and fat of selected fish species in the Olifants River and compare these to values from unpolluted sources.
- Further toxicological evaluation of selected fish tissues.

The impacts of pollution and its impact on to the food chain are greatly amplified at the inflow of Loskop dam where severe toxicity of pore water in the sediments is indicated. This result was in strong contrast to the section of river directly above, which still indicated relative acceptable ecological conditions (Driesher, 2008; Myburgh, pers. comm.). This and the above studies highlight the urgent need for further research specifically on the dams

The above mentioned findings are also supported by a recent study that has concluded that Loskop dam are now hypertrophic and that changes in its functional groups of phytoplankton has occurred. This would imply that the quality of food and the structure of available habitat for benthic invertebrates have also been impacted (Grobler et al., submitted). It is remarkable that Mulder, 1969 classified this same water body as not impacted by coal mining exactly 40 years ago.

7.2.4 Recommendation from Bollmohr et al., 2008

A survey was undertaken on the Agricultural Pesticides in the Upper Olifants River Catchment by Bollmohr *et al.* (2008). The following are the recommendations of this report:

The extend of pesticide contamination in the water and sediment within the upper Olifants River catchment has been assessed and the levels of various variables are of concern and need to be addressed in different ways by different departments. Hazard associated with the quality of the water resource in the Groblersdal area due to pesticide application can only be managed if the identified problems will be addressed in future management and monitoring approaches:

Inadequate monitoring system:

- Many of the variables of concern are not covered in any current monitoring programme. The National Toxicity Monitoring Programme (NTMP) only covers POPs and some of the pesticides of concern but lacks pesticides like the organophosphates chlorpyrifos, dimethoate, fenamiphos, etamidophos, mevinphos, prothiofos and terbufos due to the lack of resources. This study also showed elevated levels of aluminum, copper, zinc and iron, which are not included in the NTMP.
- Many variables were detected in the sediment and more concentrations exceeded guideline values compared to concentrations in the water. However, sediment as a sampling medium is currently not included in any monitoring programme and need to be addressed (probably in a separate monitoring programme).

- Existing toxicity tests (within the NTMP) did not show any response to the pesticide/ trace metal contamination in the water and did not reflect the predicted effect of water quality guidelines. An investigation is recommended to relook at various test including endocrine disrupting activity and other chronic toxicity tests in order to understand the effect of these pesticides on the aquatic ecosystem.

Inadequate guidelines

- The current South African Water Quality Guidelines (DWAF, 1996) do not include many of the variables of concern and it is recommended to include frequently detected variables like DDE-4,4, DDD-4,4, phthalates, phenanthrene, dibenzo furan, chlorpyrifos, dimethoate, metamidophos and others.

- It is recommended to DWAF that the guidelines be site specific. Especially the Olifants River faces simultaneous contamination of various pesticides as well as trace metals originating from coal mining including arsenic. The interaction of these chemicals in terms of toxicity need to be taken into consideration.

- There are no sediment quality guidelines developed yet. The frequent detection of chemicals in the sediment requires that sediment specific guidelines are developed.

Inadequate protection of surface water resources

- A higher hazard for the water resource, originated by aerial application, is suspected compared to ground application, which needs to be taken into consideration by DoA during the regulation of pesticide application. This needs to be confirmed in a more intensive study together with DEAT (air sampling) and DoA (application patterns).

- Awareness campaigns on safe and responsible use of pesticides for farmers, pesticide applicators, community members is recommended to DoA.

7.2.5 Current studies

Several studies have recently been initiated to investigate water quality and its impact on the aquatic ecosystem namely a WRC funded project being undertaken by Professor A Jooste (University of Limpopo) on water quality and catchment management. Discussions with Dr Peter Ashton of the CSIR (Aston 2010 personal communication) indicated that the following studies are in the process of being undertaken by the CSIR (funders in brackets):

- The potential impacts on water quality due to intensive irrigation in the Groblersdal area (Groblersdal Irrigation Board)
- The impacts of water quality on the aquatic ecosystem and generics in the upper Olifants River (Olifants River Forum and Coaltech)
- Overview of water quality status of the Olifants River (WRC)

7.2.6 Gaps in literature and ecological research needs

Based on the communications with several scientists the following further research needs were identified.

- It is clear that the water quality situation is deteriorating and that extensive catchment rehabilitation will be required to slow down the process. There is a lot of ecological information available in the catchment but not necessarily accessible, as it is considered confidential.

- Water treatment plants and the use of passive water treatment systems (wetlands) to alleviate AMD problems may become critically important

- Expanded/more intensive biomonitoring in the catchment. Although indications are that water quality in some areas is way beyond thresholds of concern. Some of this biomonitoring may be addressed by current projects

- Large dams in catchment serve as traps for sediments, nutrients toxins and heavy metals. These areas have been the epicenter of all the recent mortalities in aquatic organisms. Some specific issues in terms of dams raised include:

  - Sediment toxicity analysis and mapping in the dams. This analysis should possibly look at aspects such as trace metals, toxins and organic compounds from coal. The effect of carbon substrates on nitrite accumulation in sediments and interactive effects of pore water on benthic organisms has also been raised

  - Remobilization of trace metals induced by spawning behavior in fish and/or microbiological activities near sediment-water interface may also be of concern.

  - Surveys and fish and other organisms for comparison with existing data and investigate the use of aquatic organisms in dams as sentinels of water quality problems.

  - Eutrophication, algal blooms, changes in functional algal groups and its relation to the potential changes in the food chain and mortalities in aquatic species.

8. CONCLUSIONS

Analysis of the historical water quality information from selected points on the Olifants River catchment have provided an overview of the water quality in the catchment with respect to the standard physical and chemical water quality parameters. The land used of the Olifants River in South Africa can be broadly divided into coal mining in the upper catchment, intense irrigated agriculture and rural development in the middle catchment and mining and nature conservation in the lower catchment (Figure 38).

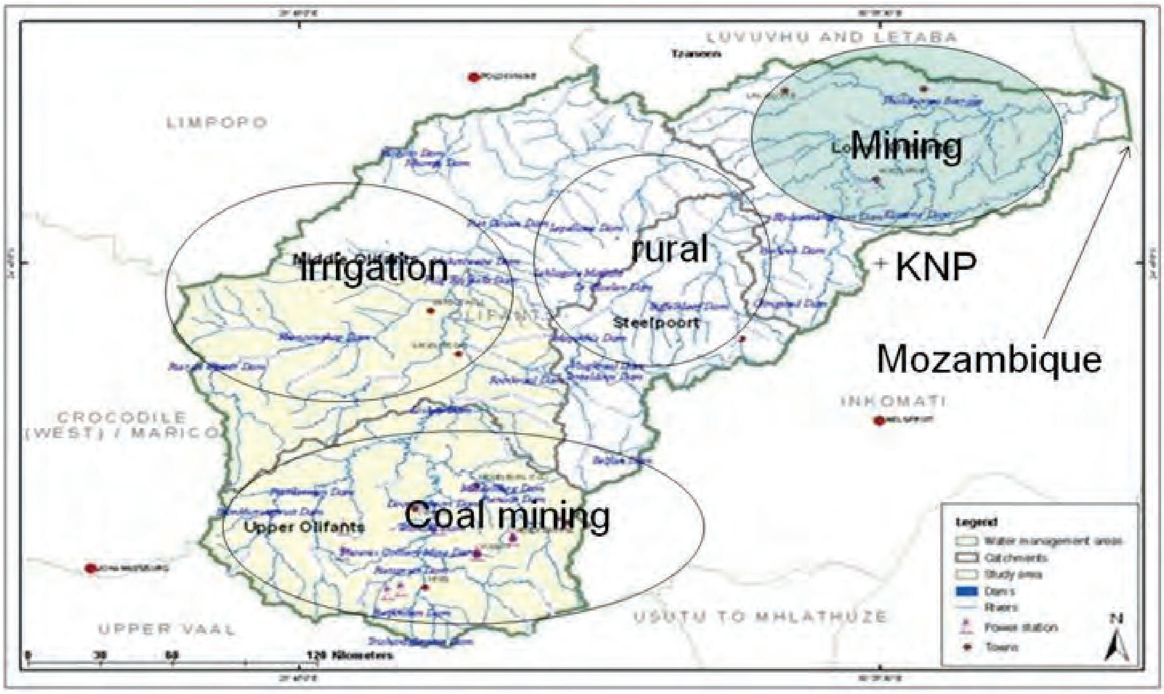

Figure 37: Land use associated with the Olifants River

The analysis highlighted a number of issues related to the water quality of some of the tributaries to the Olifants River. In particular, the Klipspruit in the upper catchment and the Ga-Selati River in the lower catchment introduce water of very low quality into the main stem of the river. This is directly related to the intensive mining activity and associated urbanization along the reaches of these particular tributaries.

Of the two rivers pinpointed as major contributors to low water quality in the Olifants River, the impacts from the Ga-Selati River are of most importance to the quality of the water entering the Kruger National Park. This is due to the lack of a major impoundment between the confluence with the Olifants and the border of the KNP. It can be seen higher up in the catchment, that dams play a role in improving the quality of the water. This is evidenced by the improvement in the water quality downstream of Loskop Dam after the inputs from the Klipspruit.

There is little historical data available regarding heavy metal and pesticide inputs to the Olifants River. Some short-term studies have been completed through the WRC. These include a study of the effects of metals on the physiology of fish in the river. This study found that in more than 60% of their study sites, the metal load exceeded water quality guideline limits – in some cases significantly (Van Vuren *et al*., 1999). A study by Heath and Claassen in 1999 also showed that the Olifants River is significantly impacted by the mining and agriculture taking place within the catchment. They found no significantly high levels of heavy metals in the Olifants River apart from low levels of copper and high levels of aluminium (emanating from the Klipspruit). The study also showed that a variety of pesticides are present in the Olifants River.

Many of the variables of concern are not covered in any current monitoring programme. The water quality available from DWA raises serious concerns about the adequacy of monitoring efforts in the Olifants River system. Environmental monitoring is the repetitive and systematic measurement of environmental characteristics, with the purpose of testing hypotheses of the effects of human activity on the environment. This requires the design of scientifically robust sampling and measurement programs, based on testable hypotheses, which involve repetitive sampling over an appropriate period of time. The detection of temporal and/or spatial differences is the most basic requirement of an environmental monitoring programme. A study by De Villiers and Mkwelo (2009) has concluded that the water quality monitoring programme in the Olifants River has failed to determine why the water quality is deteriorating. An extract from their report is as follows "One of the most disconcerting aspects of the Olifants River long-term water quality data is the non-systematic nature thereof, especially in light of clear evidence for dramatically worsening conditions. Monthly sampling frequencies will capture pollution events of short duration by chance only. A second major concern is that current monitoring efforts do not include routine measurement of toxic substances such as heavy metals in mining areas, or pesticides in agricultural areas. Most of the water quality parameters currently measured routinely are very interesting from a geochemical point of view (e.g. major cations and anions and alkalinity), but is of much less relevance to human health and environmental issues than trace levels of toxic substances. This, together with non-systematic sampling strategies and the absence of monitoring at several key sites, such as in close proximity of point sources such as the Phalabora Copper Mine, makes it difficult to test hypotheses and to pin- point the exact sources of increasing pollution in the Olifants River system. It is true that there are 'uncertainties regarding the relation- ship between concentrations of the substances in the water and their health effects' (Kempster et al., 2007). It is also true that most South African water quality guideline values are not as stringent as those adopted by developed countries. It can be argued that water quality guidelines in developing countries such as South Africa should in fact be more stringent, to safeguard the well-being of generally poorer and less healthy human populations. Are the relevant authorities carrying out research to reduce these 'uncertainties' (Kempster et al., 2007), and on which side of these uncertainties do we choose to err? It is true that improved water quality monitoring programmes will have significant cost implications, both in 'instrumentation needed for monitoring and analysis', 'as well as trained operators' (Kempster et al., 2007). It is also true that the cost implications of environmental remediation will be even more substantial, and the cost to ecosystem and human health, immeasurable".

Limited POPs and some of the pesticides of concern are proposed to be covered in the NTMP. Due to the lack of resources and the difficulties of implementing this programme it has not been initiated in the Olifants River.

The Bollmohr et al. (2008) study as well as many of the bioaccumulation studies showed elevated levels of aluminium, copper, zinc and iron, which are not included in the NTMP or the DWA Chemical monitoring programme.

Many variables were detected in the sediments; however, sediment as a sampling medium is currently not included in any monitoring programme and need to be addressed. Existing toxicity tests (within the NTMP) did not show any response to the pesticide/ trace metal contamination in the water and did not reflect the predicted effect of water quality guidelines. It is suggested that the toxicity tests be expanded to include endocrine disrupting activity and other chronic toxicity tests in order to understand the effect of these pesticides on the aquatic ecosystem.

According to the South African Water Quality guidelines (DWAF, 1996), the target water quality range (TWQR) for dissolved sulphate is below 200 mg/ℓ for human consumption. This is similar to the maximum contaminant levels prescribed by the Environmental Protection Agency in the USA and the European Union (WHO, 2004). There is no prescribed TWQR value available for aquatic ecosystems in the South African water quality guidelines (DWAF, 1996). However, aquatic ecosystems are almost without exception more sensitive than humans to environmental pollutants and as a result TWQR values, where available, are usually lower. Maximum dissolved sulphate levels of 100 mg/ℓ have been proposed for aquatic ecosystems in for example Canada (Ministry of Environment, Lands and Parks, Province of British Columbia, 2000).

Copper mining activities on the Ga-Selati River, just upstream of the KNP monitoring site are important and relevant for another reason. Copper sulphate is highly toxic to fish and also invertebrates such as crabs and shrimps (Chen and Lin, 2001). It is classified as a highly toxic substance, because of its harmful effects on aquatic species and also humans. The South African TWQR for water copper levels is < 1 mg/ℓ for drinking water and < 0.3 and 1.2 to 1.4 mg/ℓ for soft and hard water aquatic ecosystems, respectively (DWAF, 1996a). These TWQR values (and those for other toxic water constituents such as lead, arsenic, chrome-VI etc.) are meaningless, however, if copper measurements are not carried out routinely as part of DWA's water quality monitoring programme. Dissolved copper levels far in excess of these TWQR values have, however, been reported in the scientific literature, in the proximity of mining areas in the Witwatersrand area (Naicker *et al*., 2003).

Oberholster *et al*.(2009) In line with our results which highlight a potential shift in certain phytoplankton communities against a background of eutrophication, the authors predict an increase in blooms of cyanophytes and poisoning incidences by previously non dominant species in different geographical climatic regions of South Africa in the near future, if the current trends in climate change continue. This is due to cyanobacterial preference for higher surface water temperature ranges. In addition, the occurrence of cyanobacteria species that have previously been hampered to form blooms due to low temperature and nutrient concentrations, may form mix blooms with existing species which potentially can lead to the simultaneous occurrence of both neuro and hepatic biotoxins in one bloom.

8.1 Management tools to be applied to the Olifants River

There are at least 200 years of coal reserves left in the Olifants River catchment and currently there are **many small and junior mines opening**. This trend is a worry as historically these types of mines have not had a good environmental record in a period when the implementation of regulations is not strict. If these mines are not managed in a sustainable manner and appropriate closures strategies not applied throughout the life of mine they will further contribute to the ongoing pollution of the Olifants River.

Water quality management in a complex catchment such as the Olifants River requires **strong institutional capacity** (well trained resources, active, effective and appropriate finances) at a national and regional level. Unless DWA increases its capacity and works cooperatively with DMR, DEA and

DOA the water quality in the Olifants River will continue to deteriorate and the episodic fish and crocodile kills will become a more regular occurrence.

The DWA is responsible for the management of the nation's water resources. The water quality issues in the Olifants River are complex and no single organisation (even if fully capacitated) will be able to manage these complex issues in the Olifants River. Hence there is a need for **broad scale cooperation** in this management with Central Governments cooperation, regional government, mines, industry, agriculture, nature conservation and civil society working together for a joint solution. One such initiative that has some success is the **Olifants River Forum (ORF)**. This forum is active but has no regulatory responsibilities. In order for the sustainable management of the water quality of the Olifants River there is a need for the expansion of the participation of industries and mines in the direct management and self regulation. DWA is currently under resourced to manage the water quality issues in the catchment.

The DWA has the regulator tools but these need to be applied in an effective ad consistent manner. These tools **include source regulation through licences,** the **Waste Discharge Charge System (WDCS) and load reduction strategies.**

Load reduction is crucial to the management of the water quality in the Olifants River. This includes strategies such as centralised mine water treatment works which can be modularly expanded in as more water needs to be treated. The Emalahleni mine water treatment works and the currently water treatment works being constructed Optimum works are good examples of how industry and local government have cooperated to turn a waste resource (mine water) into a product (drinking water) a revenue stream.

The deterioration of the quality of our water resources is one of the major threats to South Africa's capability to provide sufficient water of appropriate quality to meet developmental needs while ensuring environmental sustainability. The water quality problems are influenced by uncontrolled sources of pollution and internal challenges in executing measures to manage pollution. The DWA is developing a **WDCS**, based on the polluter pays principle, to promote waste reduction and water conservation. It forms part of the Pricing Strategy and is being established under the National Water Act 9 (Act 36 of 1998).

The WDCS aims to:

- promote the sustainable development and efficient use of water resources;
- promote the internalisation of environmental costs by impactors;
- create financial incentives for dischargers to reduce waste and use water resources in an optimal way; and
- recover the costs of mitigating the impacts of waste discharge on water quality.

The basis of the polluter pays principle is that the costs of environmental impact should be borne by those responsible for the impact. The National Water Act specially refers to the polluter pays principle as a- economic mechanism for achieving effective and efficient water use. Water resource management in South Africa links the acceptable level of impact to the concept of **Resource Quality Objectives (RQOS)**, which balance the need to protect water resources with the need for development. The setting of ROOs is catchment specific, based on the social, economic and political drivers, or development and utilisation, of a specific water resource.

The WDCS is a response to a pollution problem that is already imposing a cost on society. The WDCS endeavours to shift some of the cost back to dischargers according to the polluter pays principle. The WDCS will be implemented in a manner that seeks to charge a discharger for the amount of waste load added to a water resource where RQOS are being exceeded. The registration of waste discharge-related water users the first building block of the WDCS. While registration is intended to proceed nationally, the implementation of the WDCS will commence in three priority catchments, namely the Upper Vaal, Upper Olifants, and the Crocodile-Marico. The implementation of a pilot WDCS in the Olifants River is schedules for 2010/12.

Compulsory licences need to be applied and managed throughout the Olifants river catchment. If this is applied and the licensee reports back on a regular basis to DWA and an appropriate forum

(ORF?) then water quality management becomes more transparent and collective solutions can be sought in a cooperative manner.

Implement/revisit the Reserve allocations and associated environmental flows. If these environmental flows are implemented and their effectiveness monitored there should be an improvement in the present ecological status of the aquatic organisms in the Olifants River catchment. It is important that the proposed Ecospecs and associated monitoring programme is implemented and revised according to the ongoing monitoring findings.

The controlled release scheme that is in place in the upper Olifants River is a self regulating scheme that is managed cooperatively by a committee of mainly mines and DWA officials. Compliance monitoring is undertaken by this scheme on a regular basis. This scheme should be re-evaluated as there have not been any substantial releases since 2002 as there has not been any assimilative capacity in the river.

8.2 Integrated water resource management plan for the upper and middle Olifants River catchment (DWA, 2009).

Implementation in a holistic manner the water quality, mine water management and catchment plans that have been developed over the past years such as the Integrated Water Resource Management Plan for the upper and middle Olifants catchment (DWA, 2009). These plans need to be jointly implemented by industry, agriculture and the mines with support and guidance from DWA. The following are summary recommendations from this report.

The key elements of the water quality management strategy are the setting of the RWQO's, based on salinity and nutrient management, as well as bolstering of management resources and information systems. The RWQO were determined based on the current set of RWQO in the Witbank, Klipspruit and Middelburg Dam catchments modified to account for the available water quality component of the ecological Reserve. The current ecological Reserve for salinity water quality variables was developed using outdated methodology. Where RWQO were not set, the South African Water Quality Guidelines together with the present water quality status were used to determine RWQO. The set of RWQO determined in the study are interim RWQO that will be reviewed in 5 years time once the water quality component of the ecological Reserve has been updated.

The management of salinity involves the reduction of loads into the system. The strategy has been divided into the management of the defunct and operational mines. The defunct mine strategy involves refurbishing the Brugspruit neutralisation plant and collection system which will address the acidity issue. A committee needs to be set up to develop a defunct mine strategy which prioritises and determines synergies with operating mines in order to manage decants. The required reductions in load from the operational mines, power stations and industries will be achieved by source management through audits, Integrated Waste and Water Management Plans (IWWMP's), Water Use Licencing (WUL), compliance monitoring and reporting. The waste discharge charge will also be implemented to ensure that the source reductions are achieved and that money is raised to fund an appropriate institutional structure to manage water quality.

The nutrient management strategy involves the upgrading of the five major WWTP and sanitation systems as well as revising the phosphate discharge standard to 1 mg/ℓ for the major works. The smaller WWTP must be audited to ensure that the plant performance is aligned with the technology installed.

Reconciliation strategy

The application of the yield model to investigate the further development of surface water resources showed that the construction of additional dams did not increase the yield of the system of dams in the study area. The yield was merely transferred from the downstream dams to the upstream dams. This highlights the need for the development of an integrated reconciliation strategy for the entire catchment. The immediate concerns are the augmentation of the water supply to Steve Tshwete and Emalahleni Local Municipality. The use of excess mine water was investigated. The available volumes of mine water were determined over time and compared to the water requirement projections. The findings are that there is sufficient mine water available however the water will require treatment and the process of allocating the water will need management. The other actions that will be implemented to assist with reaching reconciliation are the elimination of the unlawful water use, ongoing application of the catchment modelling systems, trading of water rights and the development of groundwater for supply to rural areas.

Institutional

The Department's Regional Office is currently responsible for the management of the water resource. The office is under stress with a high staff turnover. The study area needs strong, proactive management by a well staffed institution. Staffing requirements for such an institution were proposed with an estimate of the budget requirements. Further to the management institution, an institutional structure was proposed which includes the establishment of a catchment management committee (CMC) which will oversee and co-ordinate the activities in the catchment. One of the major roles of the CMC will be to implement the strategy. The CMC will be supported by the management/regulatory authority which could be the Regional Office of DWA or the Catchment Management Agency (CMA). There are a number of committees which are focused on specific management actions. The Mining and Industry Water Action Committee (Minwac) will address licensing, controlled release, status of mine water, defunct mine strategy, compliance and implementation of commitments. The Municipal Managers Forum will deal with matters related to the municipalities which includes water requirement projections and WWTP and sanitation system upgrades. The mine water companies set up to treat the mine water will be represented as they play an important role in the co-ordination of the use of the mine water. DWA is currently busy with an initiative to set up Water User Associations (WUA) across the catchment to represent the interests of the water users at the local catchment level.

Actions

The implementation of the strategy will be the responsibility of the Regional Office of DWA. The implementation of the strategy should be completed by 2015 at which time the strategy can be reviewed. The actions and responsibilities are summarized in the Table 9.

Table 9 Implementation of the strategy to be completed by 2015 by DWA

Action	Responsibility
RWQO	
Water Quality Reserve Determination for entire Olifants WMA	RDM office[1]
Scenario analyses for water quality (consider including in Olifants Reconciliation Strategy Project)	NWRP[2]/ RDM office
Development of an integrated set of RWQO for Olifants WMA and revision of Interim RWQO for the Upper and Middle Olifants	WRP Systems[3]
Defunct mines – Klipspruit	
Set up defunct mines management committee	RO[4], DMR[5]
Brugspruit Plant and collection system operational	RO
Investigate regional mine water collection system in Klipspruit, including Phase 2 of original White Paper.	RO, DMR, Mines, Industries
Implement regional plan with other mining companies.	RO, DMR
Take regulatory action to prevent ongoing pollution from Vanchem industrial site.	RO
Defunct Mines – Outside Klipspruit Catchment	
Develop a defunct mines water management plan, including possible integration into operating mines management.	RO, DMR
Implement the defunct mine water management and rehabilitation plan	RO, DMR
Operating mines, industries and power stations	
Set up MINWAC	RO
Audit of mines, power stations and industries water management	RO

plans and systems	
Implement program to update water and salt balances	RO
Develop a set of commitments and implementation programs of remediation measures with each mine, power station and industry	RO, mines, industries and power stations
Set up annual reporting system and agree on level of technical input	RO, mines, industries and power stations
Implement annual reporting system	RO, mines, industries and power stations
Ongoing update of IWWMP and IWUL	RO, mines, industries and power stations
Audit mine closure funds	DMR, mines, Eskom
Nutrient Management Strategy	
Agree on scope of work and time frames to upgrade the major WWTP and sanitation systems (use existing Municipal Managers forum).	RO, Local Municipalities and District Municipalities
Audit the small WWTP for performance and compliance with licence conditions.	RO, Local Municipalities
Continue with compliance monitoring and reporting	RO, Local Municipalities
WDCS	
Implement WDCS in the Loskop Dam catchment	NWRP
Water Quality Monitoring Program	
Produce an integrated water quality monitoring program	RO
Human Resourcing Strategy	
Investigate staffing structure and appropriate funding mechanisms	RO
Water reconciliation and institutional	
Develop annual reporting required on water requirement projections, progress with WC&DM implementation and wastewater treatment plant and sanitation system upgrades	RO, Local Municipalities
Set up institutional structure to manage the use of excess mine water	RO, mines
Develop TOR, commission PSP and carry out a water use Verification Study to follow on from the Validation Study on irrigation water use.	NWRP
Commission PSP to carry out annual operating WRPM and WRYM runs and provide ongoing model support.	NWRP
Investigate the scenarios for meeting the EWR. (This will form part of the Olifants Reconciliation Strategy Study)	NWRP
Set up CMC and supporting committees	RO

Where: *1 – Resource Directed Measures Directorate of the Department*

2-Directorate of National Water Resources Planning of the Department

3-Directorate of Water Resource Planning Systems of the Department

4-The Department's Mpumalanga Regional Office in Bronkhorstspruit

5- Department of Mineral Resources

9. RECOMMENDATIONS

The basic principle on if you cannot measure it you cannot manage it applied to the Olifants River. Monitoring needs to take place and should include water, sediments, aquatic organisms (fish) and whole effluent toxicity. The monitoring data should be reviewed so that adaptive management can be applied and the monitoring programme as well as management plans changed according to these results.

A thorough baseline assessment throughout the catchment, during low flows, should be undertaken to assess the following parameters:

- POP's (water, sediments and fish)
- Sediment metal concentrations
- Fish bioaccumulation (compare to the many literature studies undertaken)
- Whole effluent toxicity tests
- Surface water quality samples (to include nutrients, salts and metals)

- The following are broad recommendations from the water quality and ecology assessment of the Olifants River:
- Establish histological, hematological and genetic baseline data of pathology in fish in Olifants River System
- Establish comparable histological baseline data from unpolluted rivers in the region.
- Establish extent of pollution related pathology in fish along the length of the Olifants River from the source of pollution on the Highveld to and including Massingire Dam.
- Determine vitamin E levels in liver and fat of selected fish species in the Olifants River and compare these to values from unpolluted sources.
- River tested positive for EDC activity – continue
- Risk assessment linking ecology to human health required
- Develop nonlethal methods of monitoring fish health
- Further toxicological evaluation of selected fish tissues
- Improving management of the water resources of the system by more effective monitoring (include organics and metals)
- The defunct mines need to be revisited to priorities the mines that need management and develop rehabilitation and management plans for implementation. The DMR and tax payers will need to assist with this programme.
- The mines need to update their water balances and improve their understanding of their water management systems, storages and the water in workings. The mines all need to be at the same level of confidence and accuracy. This is essential to determine the excess water volumes and timing of when mine water is available for reuse. The is a need for annual water quality and water management plans reports to be reinstated so that DWA, DMR and the appropriate forums can realistically and cooperatively manage the catchment.
- Institutional cooperation and expansion of the responsibilities. This will require and urgent up scaling of resources from DWA especially with the regional office.

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APPENDIX A

Frequency of water quality monitoring

Table A1: Yearly frequency of DWAF water quality monitoring in the upper Olifants River catchment.

	Monitoring point DWAF identification number							
YEAR	B1H6	B1H18	B1R1.1	B1R2.1	B1H4	B2H14	B2H15	B3R2.1
1966	0	0	0	0	2	0	0	0
1967	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	8
1969	0	0	0	0	0	0	0	20
1970	0	0	0	0	1	0	0	3
1971	0	0	0	0	0	0	0	1
1972	0	0	3	0	1	0	0	4
1973	0	0	0	0	0	0	0	2
1974	0	0	0	0	0	0	0	0
1975	0	0	3	0	0	0	0	17
1976	0	0	0	0	10	0	0	24
1977	0	0	0	0	11	0	0	15
1978	0	0	2	1	47	0	0	11
1979	0	0	0	4	4	0	0	5
1980	0	0	4	9	16	0	0	10
1981	0	0	0	9	14	0	0	7
1982	3	0	0	10	8	0	0	5
1983	46	0	0	2	12	0	0	1
1984	50	0	1	1	12	0	0	2
1985	45	0	2	6	11	0	0	9
1986	46	0	6	7	10	0	0	22
1987	52	0	16	2	11	0	0	14
1988	52	0	28	3	13	0	0	24
1989	52	0	41	1	11	0	0	27
1990	66	0	37	0	16	0	0	24
1991	62	29	22	0	20	40	0	15
1992	52	47	6	0	42	54	0	30
1993	46	31	33	2	44	51	0	23
1994	15	48	27	12	48	53	51	13
1995	6	38	26	25	51	46	51	6
1996	17	54	27	27	52	26	52	6
1997	13	51	24	23	53	28	51	0
1998	25	52	18	21	52	28	51	1
1999	15	38	21	20	47	25	33	0
2000	9	43	14	18	44	24	24	4
2001	20	43	20	20	51	24	26	23
2002	0	43	12	24	52	17	16	21
2003	0	10	21	22	44	13	14	2
2004	6	21	19	20	26	23	23	14
2005	17	16	22	22	24	24	14	21
2006	17	26	23	14	31	26	25	21
2007	20	20	18	19	25	24	21	19
2008	9	8	4	4	6	9	5	6

Table A2: Yearly frequency of DWAF water quality monitoring in the middle Olifants River catchment.

	Monitoring point DWAF identification number				
YEAR	B3H21	B4H3	B4H11	B5H4	B5R2
1966	0	0	0	0	0
1967	0	0	0	0	0
1968	0	0	0	0	0
1969	0	0	0	0	0
1970	0	0	0	0	0
1971	0	0	0	0	0
1972	0	0	0	0	0
1973	0	0	0	0	0
1974	0	0	0	0	0
1975	0	0	0	0	0
1976	0	0	0	0	0
1977	0	6	0	0	0
1978	0	43	0	0	0
1979	0	2	0	0	0
1980	0	1	0	0	0
1981	0	9	0	0	0
1982	0	10	0	0	0
1983	0	7	0	0	0
1984	0	29	7	0	0
1985	0	46	50	0	0
1986	0	54	47	0	0
1987	0	41	52	0	0
1988	0	48	45	0	0
1989	0	51	33	0	0
1990	0	46	24	0	0
1991	0	27	3	0	0
1992	0	41	0	0	0
1993	0	41	0	8	0
1994	26	47	0	29	1
1995	21	47	0	28	0
1996	23	52	28	25	0
1997	33	51	29	28	0
1998	16	53	38	26	7
1999	24	40	0	25	10
2000	26	24	0	26	13
2001	24	26	10	26	12
2002	16	17	16	26	12
2003	6	11	13	26	11
2004	17	23	24	29	16
2005	20	20	24	34	26
2006	22	20	21	47	39
2007	14	21	18	42	36
2008	4	11	5	12	10

Table A3: Yearly frequency of DWAF water quality monitoring in the lower Olifants River catchment.

	Monitoring point DWAF identification number					
YEAR	B6H1	B6H4	B7H19	B7H15	B7H17	B7R002
1966	1	0	0	0	0	0
1967	0	0	0	0	0	0
1968	0	0	0	0	0	0
1969	0	0	0	0	0	0
1970	0	0	0	0	0	0
1971	0	0	0	0	0	0
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1974	0	0	0	0	0	0
1975	0	0	0	0	0	1
1976	8	0	0	0	0	10
1977	36	0	0	0	0	6
1978	22	38	0	0	0	11
1979	6	7	0	0	0	4
1980	15	24	0	0	0	10
1981	14	18	0	0	0	3
1982	11	11	0	0	0	1
1983	7	10	0	10	7	6
1984	6	29	0	41	20	10
1985	6	41	0	51	36	12
1986	5	42	0	52	1	12
1987	13	48	0	51	16	12
1988	11	47	0	42	40	5
1989	12	50	38	59	22	14
1990	11	47	30	52	32	23
1991	10	23	21	35	24	2
1992	28	32	29	61	38	2
1993	16	39	5	67	43	0
1994	20	12	23	25	25	0
1995	18	22	24	18	8	2
1996	20	29	23	7	11	9
1997	20	28	28	12	0	10
1998	24	35	29	11	0	1
1999	13	21	11	10	19	0
2000	14	14	5	9	1	0
2001	16	17	18	11	6	0
2002	13	114	13	5	12	0
2003	12	12	9	3	7	0
2004	14	15	15	12	6	0
2005	17	15	21	11	19	1
2006	20	13	20	18	12	0
2007	20	17	18	18	6	0
2008	6	6	7	4	4	0