Overview of Water Quality and Quantity

Olifants River Catchment

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AWARD series:
Climate change impacts on the Olifants River Catchment

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To support building resilience in support of improved water governance in the Olifants River Catchment

1 Keeping the Olifants River flowing
[Booklet]

Systemic, collective action duringthe most severe drought on record

2 Integrated Water Resources Decision Support System [INWARDS] for the Olifants Catchment

Facilitating real-time monitoring, early warning & systemic decision-making for water resources

3 Overview of Water Quality & Quantity: Olifants River Catchment
[Booklet]

An analysis and review of water quality and quantity of the Olifants River Catchment to provide a systemic picture of the Olifants as a whole in a user-friendly format

4 Predicted Impacts of Climate Change on Water Resources of the Olifants River Catchment
[Booklet]

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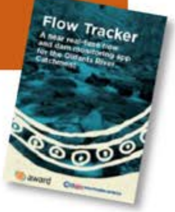
[Booklet]

For water resource practitioners and managers as well as those interested in the theories and practice - or praxis - of systems and social learning approaches --- a different way of thinking that recognises interrelationships and uncertainty and sees people as part of governing water

6 Flow Tracker
[Flyer]



A near real-time flow and dam monitoring app for the Olifants River Catchment

Download the Flow Tracker app from Google Playstore. This flyer describes how to use the app.

7 Turnaround Plan Mopani/Ba-Phalaborwa Municipal Wastewater Treatment Plants
[Brochure]

Set within the Department of Water & Sanitation's requirements and Green Drop certification, this plan focuses on supporting the essential aspects of wastewater treatment in the Phalaborwa, Lulelani, and Namakgale treatment plants.

8 Water Conservation & Water Demand in the Olifants Catchment: A Pilot Project
[Technical Report 15]

Support and capacity development for Maruleng and Ba-Phalaborwa local municipalities for water demand and water conservation management

9 Historical Trends & Climate Projections for Local Municipalities
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Insights based on localised climate analysis to support planning at the municipal scale. Available for Mopani District:
25] Ba-Phalaborwa
26] Maruleng
27] Greater Tzaneen
28] Elias Motsoaledi, Sekhukhune District Municipality
29] Lepelle-Nkumpi, Capricorn District Municipality

Introduction

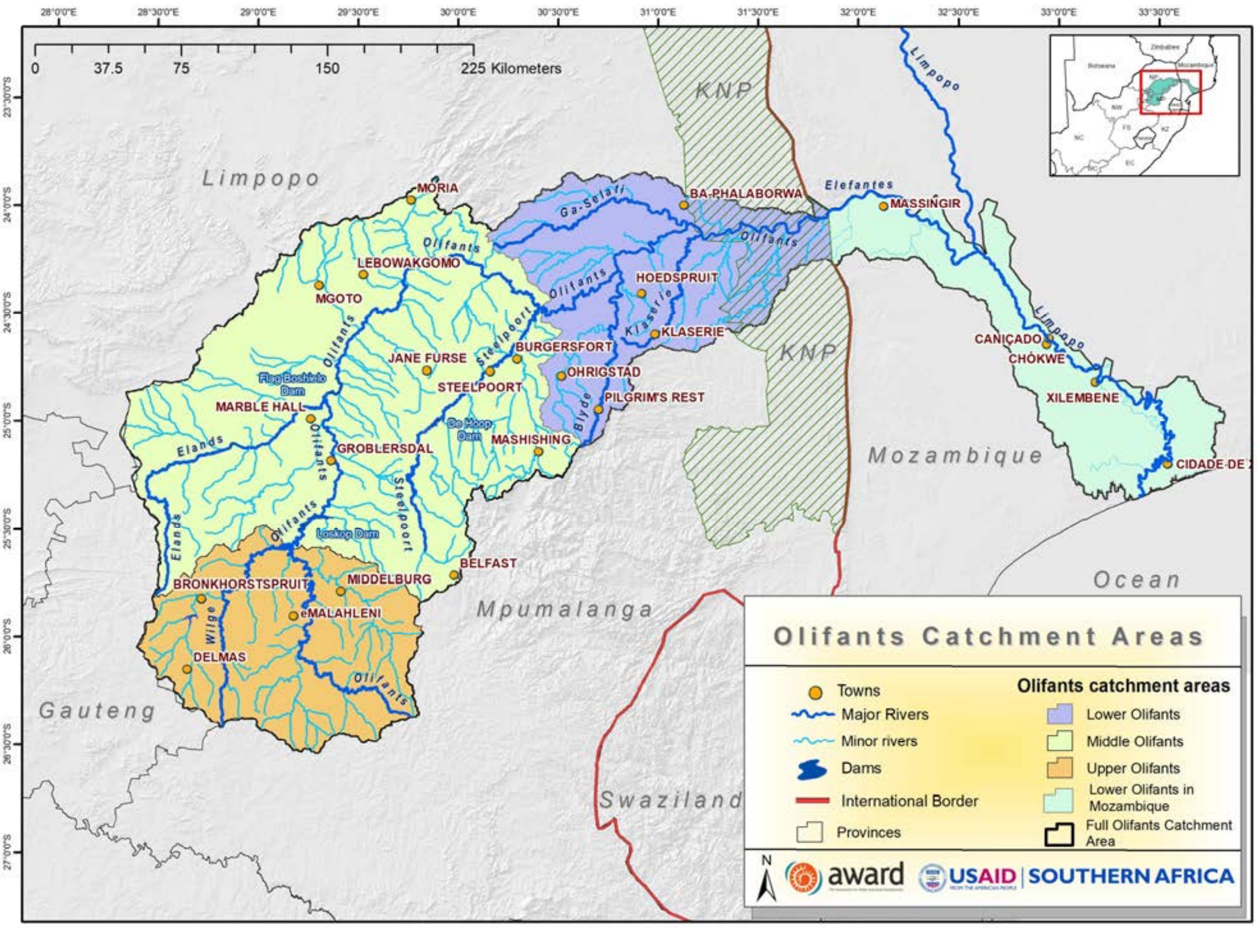

Figure 1: Map of the Olifants River Catchment showing the upper, middle and lower regions of the catchment and the lower Limpopo Basin after the confluence between the Olifants and Limpopo

The Olifants River Catchment falls within the Limpopo River Basin, which is part of an international drainage basin that stretches across South Africa, Mozambique, Zimbabwe and Botswana. The Olifants River contributes nearly 40% of the water that flows in the Limpopo River making it important for the basin as a whole. Currently, the Olifants River is the only tributary that sustains flows of the Limpopo River in the dry season.

Unchecked pollution, inappropriate land and resource use, poor enforcement of regulations and poor protection of habitats and biodiversity have all contributed to the rapid deterioration in the catchment which, in turn, impacts on the livelihoods of all the catchment residents. The major impact in the upper catchment is coal mining and industry which leads to acid mine drainage and salinization. The middle part of the catchment is mainly irrigated and dryland agriculture, and contains a substantial settled population. The lower South African catchment is dominated by agriculture and conservation, although the impact of the mining-industrial centre of Phalaborwa in this stretch is significant (DWAF 2004, Ashton & Dabrowski 2011, DWA 2011a). The Mozambican part of the catchment has conservation and dryland agriculture dominating the landscape, and there is a substantial irrigation project at Chokwe.

Despite the enabling legislative framework for water reform in South Africa since 1998, and the requirements for compliance with the Reserve (or Environmental Water Requirements), the regular non-compliance also pointed to indicated increasing vulnerability (Pollard & du Toit 2011; Pollard & Riddell 2011).

The inability to maintain a healthy river system severely compromises the ability to deliver goods and service to biota and people in the catchment and beyond. *(see Resource 1: Keeping the Olifants River flowing)*[1]

In international terms, the state of the Olifants catchment is a particular concern given that it is the largest contributor of flow to the transboundary Limpopo Basin. Indeed the lower Limpopo floodplain and estuary is maintained mainly through flows from the Olifants River into Massingir Dam.

In sum, this was a catchment in crisis. Given this, the RESILIM-O programme was designed to support good governance and improved water resources. To initiate this, an analysis and review of water resources was undertaken. In this document we provide an overview of water quality and quantity (mainly from the South African portion) of the Olifants River Catchment. We aim to provide a systemic picture of the Olifants as a whole in a 'user-friendly' format. The information is compiled from studies undertaken through RESILIM-Olifants and some additional data where relevant. Readers are also directed to a substantive amount of information on site-specific water quality for Loskop Dam (Ashton & Dabrowski 2011) and the middle Olifants (risks MOSA).

Water quality: Catchment overview

Approach to analysing water quality

We analysed Department of Water & Sanitation (DWS) data (spanning 1970 to 2013) for spatial and temporal trends in the following four key water quality parameters:

Phosphate	an indicator of nutrient enrichment and potential for eutrophication
Sulphate	an indicator of acid mine drainage and general mining impact
Electrical conductivity	an indicator of salinity
pH	a measure of the acidity or alkalinity of the water and an indicator of acidification associated with mining

[1] *See AWARD Resources list on page 2.*

We also assessed levels of various potentially toxic elements and compounds. Data on organic toxins, sediments and microbial pollution were drawn from published literature. Our analysis relied on assessment of data from the Department of Water and Sanitation in South Africa, and Ara-Sul in Mozambique (spanning 2001 to 2013) - see Figure 2 below.

Results of these analyses were complemented by research published by other authors.

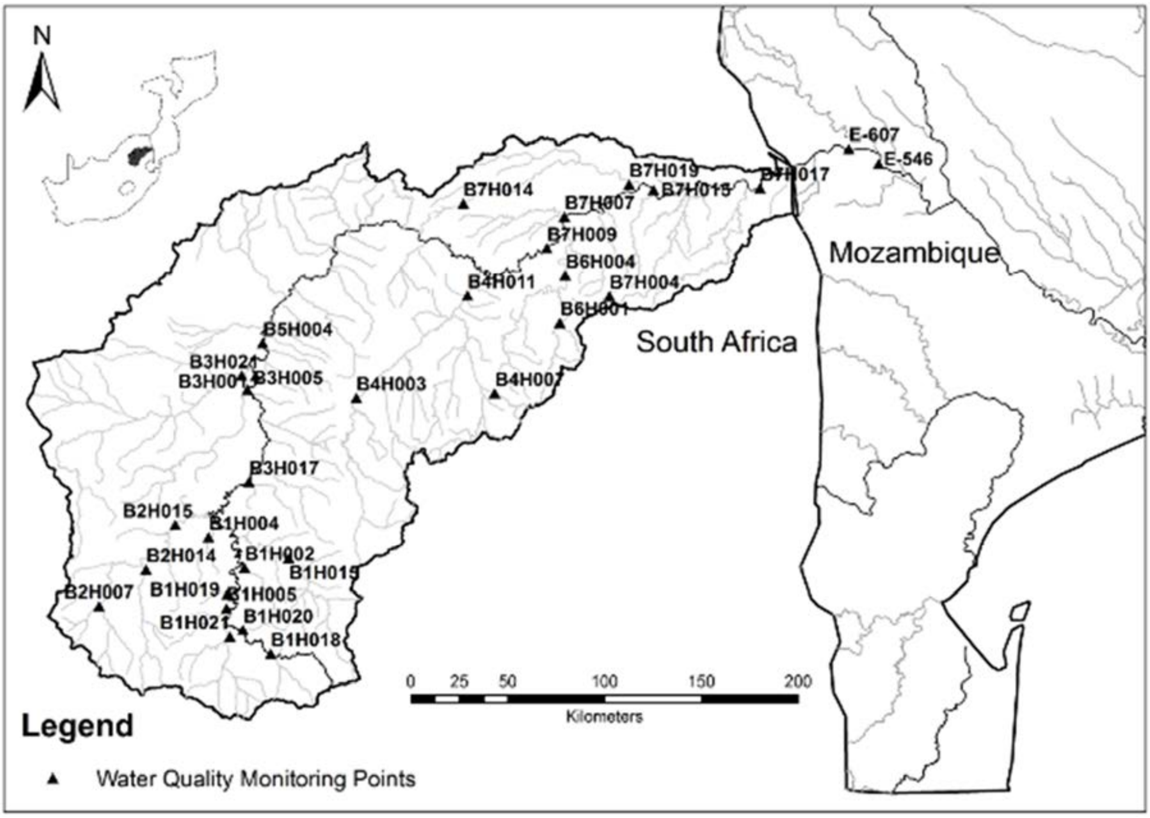

Figure 2: Water quality monitoring stations used for the trend and status analysis

Upper Olifants River Catchment

The extensive coal mining in the upper catchment has a profound impact on water quality (DWAF 2004). Coal mining in South Africa is associated with acid mine drainage (AMD), which is acidic, salty water with a high sulphate content and, potentially, associated with a cocktail of toxic metals. While AMD is only consistently found in the Klipspruit sub-catchment, repeated acid events were noted in the Noupoortspruit and the Spookspruit. Elsewhere in the catchment, the impact of coal mines is apparent in the very high sulphate loads (see Box Below and Figures 4 and 5) and consequent salinization of water, which is a result of the release of treated and untreated mine effluent to rivers in the area. Threatening levels of metals including aluminium, manganese, molybdenum and zinc were found in this region. Finally, phosphate, the primary cause of eutrophication, is high throughout the catchment and is primarily due to non-compliant WWTW discharge.

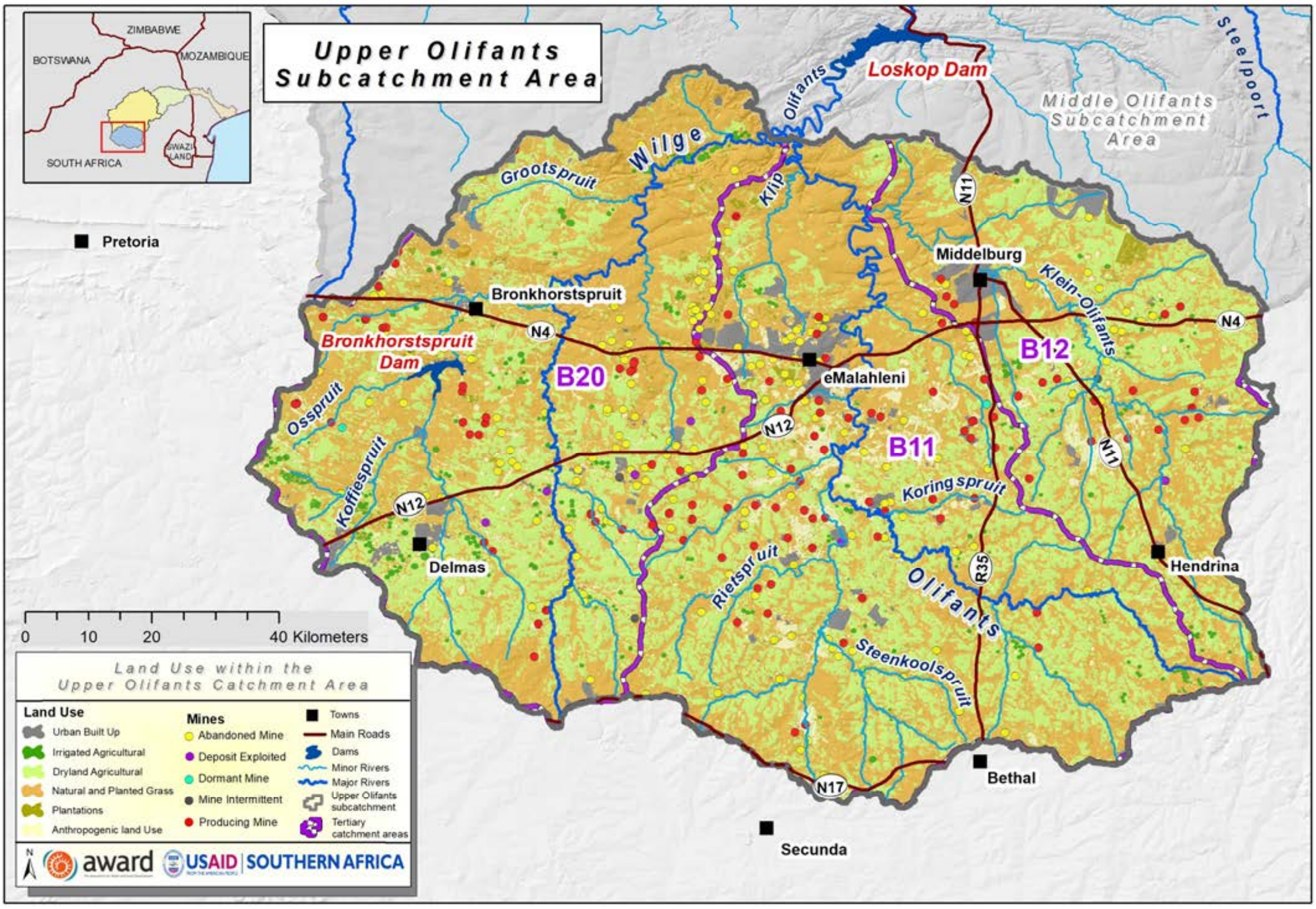

Figure 3: Land use in the upper Olifants River Catchment

Load & Concentration

Water quality can be measured in two ways - by (pollutant) concentration or load.

Concentration refers to the mass of a pollutant in a defined volume of water - as a ratio (e.g. milligrams of sulphate per liter, or PPM).

Load is the amount (mass) of a pollutant that is discharged into a water body during a period of time (e.g. mg of sulphate per hour). If one is managing for concentration then one needs to manage the load that enters the system.

Imagine mixing a teaspoon of salt into a glass of water. The load would be one teaspoon of salt, the concentration would be the ratio of the salt load to the volume of the glass of water. The process of loading the system with salt changes the concentration and can be termed 'salinizing' the glass of water.

According to a CSIR study in the upper catchment, even if the residents do not use the water from the river, "there is a significant chance of accidental infection when walking through the river, or handling and consuming vegetables watered with water from the Brugspruit" ("River water from Olifants River catchment poses high risk of infection" 2011; Dabrowski).

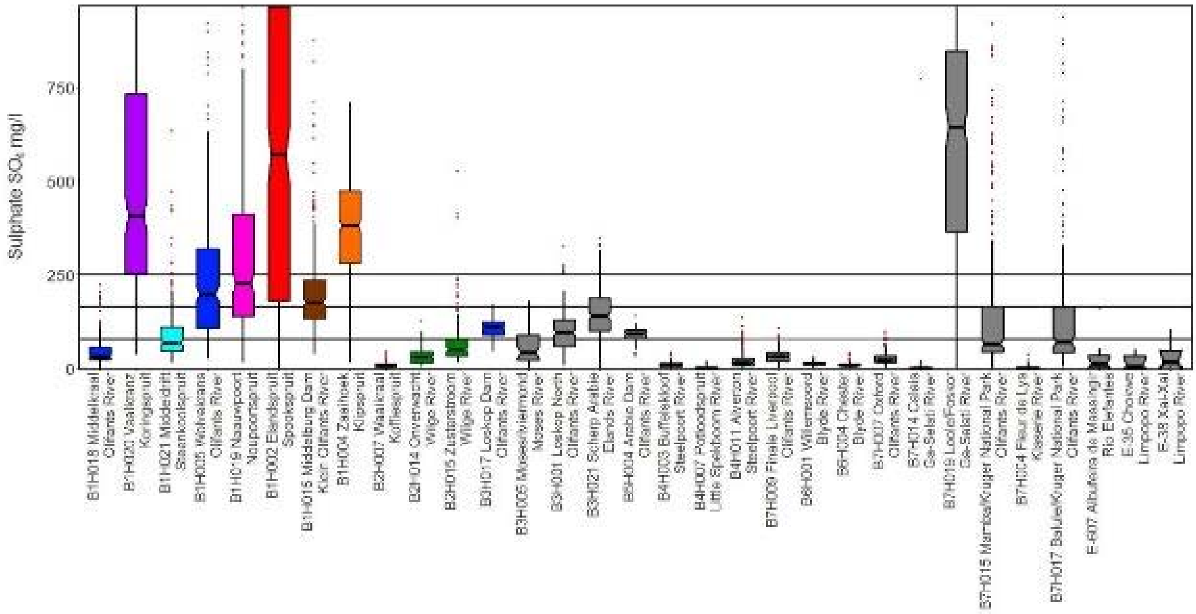

Figure 4: Box and whisker plots of sulphate levels at sites in the Olifants River Catchment. Boxes show the interquartile range, with medians indicated. Whiskers show levels within 1.5 times the interquartile range, and dots show outliers. The upper 2% of data are not plotted. Sites are roughly ordered along the axis by distance from upstream, with those higher in the catchment to the left. Horizontal lines show upper limits of DWS generic Resource Quality Objectives for South Africa. (DWA 2011a)

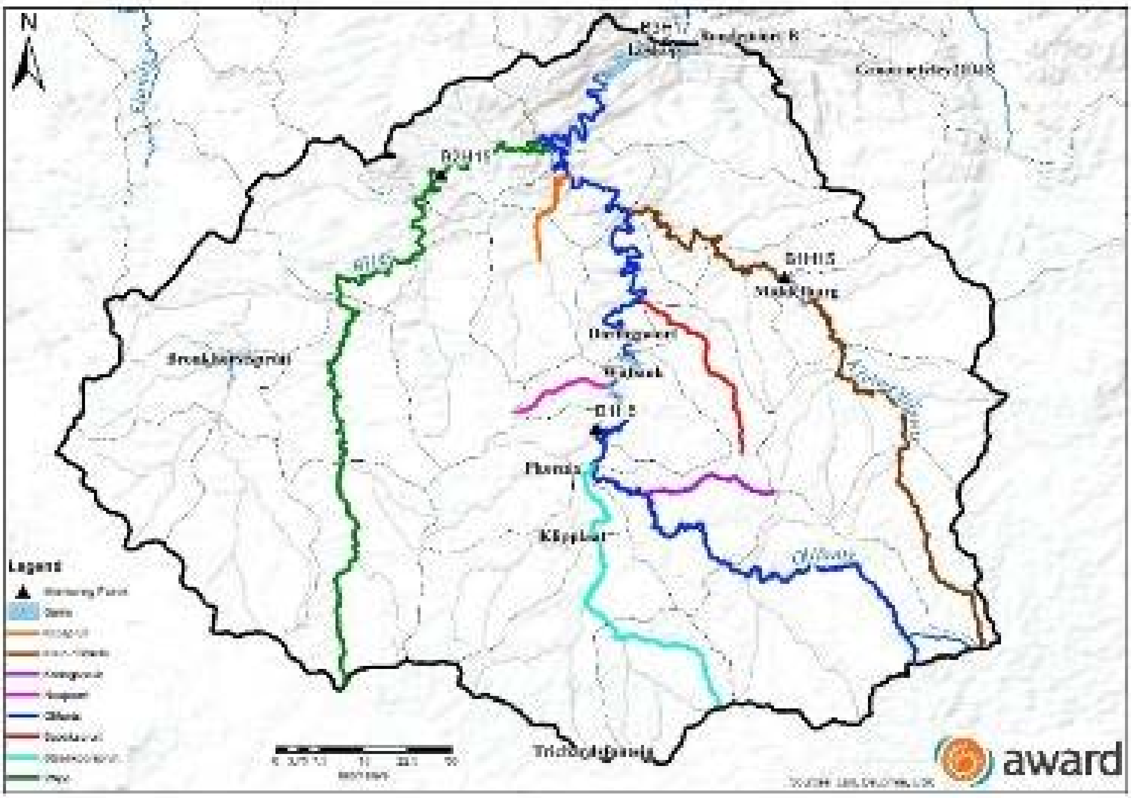

Figure 5: Map of the upper Olifants River Catchment. Tributaries are colour-coded to correspond to results for sulphate concentrations shown in Figure 4

Middle Olifants River Catchment (including Blyde)

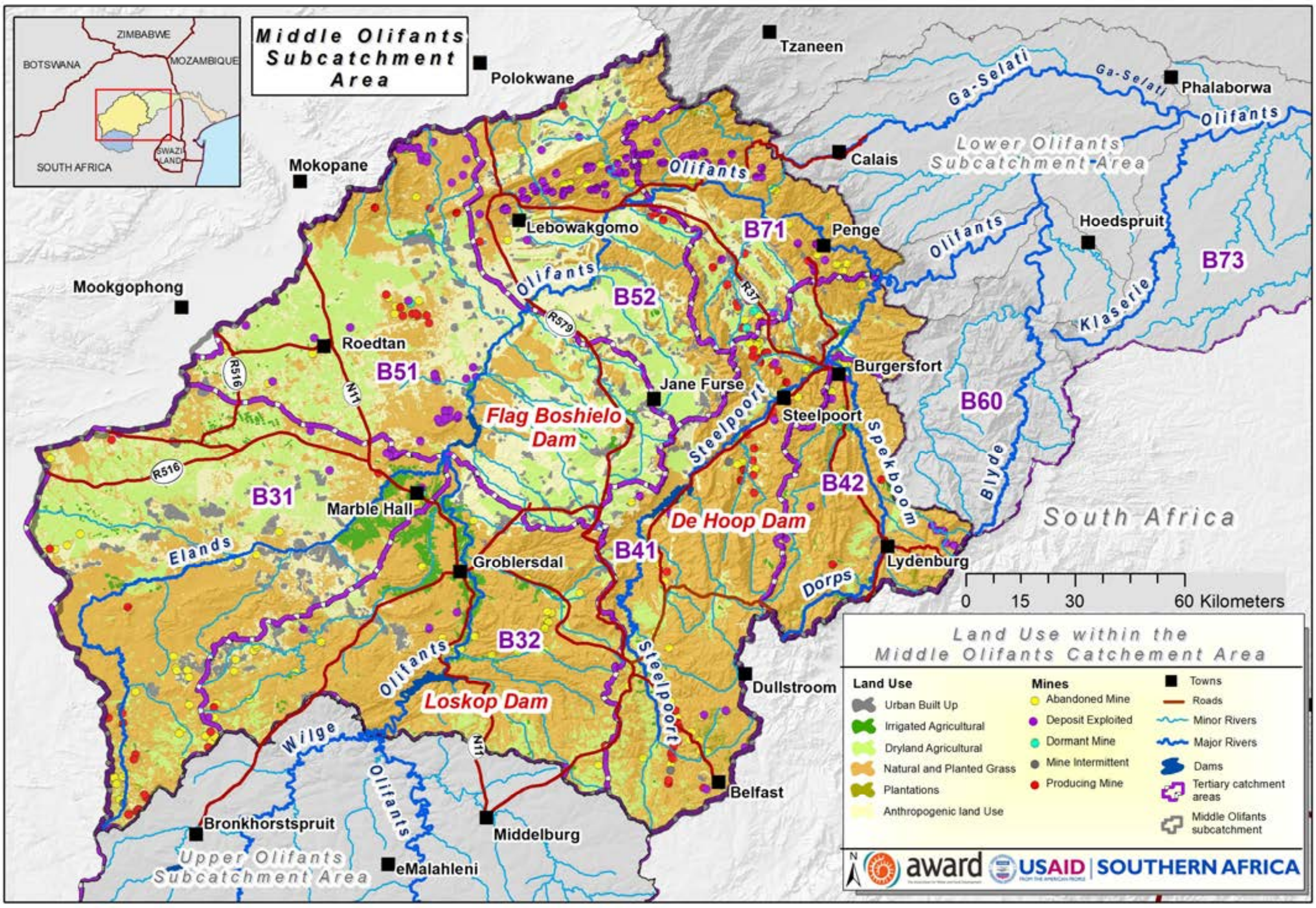

Figure 6: Land use map of the middle Olifants River Catchment

There are very few data for water quality parameters in the middle Olifants due to the lack of a comprehensive monitoring network (see Figure 1). What data there are, are derived from the few sites as seen in Figure 2 and our own site-specific sampling (Table 1). The middle catchment as used here refers to the stretch from Loskop Dam to just past the Olifants and Steelpoort confluence near Penge (Figure 6). A key issue, and one detailed by other studies[2], is that Loskop Dam is shifting towards being meta-eutrophic as nutrient levels increase (P. Oberholzer and J. Dabrowski, pers. comm. June 2014). Also salts and sulphate levels are increasing in the dam with time. Certain metals are retained in the dam, and worryingly high levels of several others, including mercury, were found (Dabrowski et al. 2013). The dam supplies water to the Loskop irrigation scheme and further downstream. This area shows signs of secondary salinization owing to irrigation return flows, and high levels of pesticides have been reported from water resources in the area (Grobler 1994, Bollmohr et al. 2008). The area below the dam has been implicated in further secondary salinization due to extensive dryland agriculture, and sediment export from degraded land.

[2] *By the CSIR for the Olifants River Forum*

The Steelpoort and Blyde River catchments add relatively unpolluted[3] water to the Olifants River and reduce the salt load in this region. However, even in these catchments, phosphate levels were often high. Otherwise water quality in these rivers was generally good in the reporting period, even in the Steelpoort River catchment where several mines are present (Ashton and Dabrowski 2011). However, worryingly high levels of several toxic metals like arsenic were found sporadically in both catchments.

Impacts of poor water quality on health: Case study from the Burgersfort area

A number of concerned civil society organisations raised the alarm around cattle deaths and the suspected link to mine discharge emanating from the Twickenham and Hakney mine shafts which were flowing into the Mhotsi river, an ephemeral tributary of the Olifants, this discharge had now turned the river into a perennial tributary. Samples taken by AWARD were sent for spectrophotometric analysis. The Mhotsi River was used as a reference site as it was upstream of both discharges emanating from the mine shafts.

The results (Table 1) revealed severe water quality problems. The most notable constituent concentrations were Lead (Pb), Cadmium (Cd) and Copper (Cu), with Lead exceeding 2000 times the limit specified by the Department of Water Affairs (see Table 1). More concerning were the levels of Lead and Cadmium measured in the canal which was being used by the Moroke community to irrigate crops. Both of these may cause anaemia, kidney, lung and brain damage. Clearly such impacts have major implications for the right to a health environment as espoused in the Constitution. To date no regulatory action has been taken.

TABLE 1: SPECTROPHOTOMETRIC RESULTS FOR WATER SAMPLES TAKEN IN THE BURGERSFORT AREA IN AND AROUND MOROKE VILLAGE

Sample Site	Date	Pb (ppm)	Limit (ppm)	Cd (ppm)	Limit (ppm)	Cu (ppm)	Limit (ppm)
Site A: Discharge Twickenham Mine	21/05/2018	>20	0.01	0.23	0.005	0.2	1
Site B: Discharge Hakney Mine	21/05/2018	>20	0.01	19	0.005	4.21	1
Site C: Canal next to Mhotsi River	21/05/2018	0.43	0.01	0.23	0.005	<0.01	1
Site D: Mhotsi River	21/05/2018	<0.01	0.01	<0.01	0.005	0.1	1

[3] *While at the time of analysis this was true for both the Blyde and Steelpoort, new data suggests that the increase in mining activities, especially chrome mining, is affecting water quality trends.*

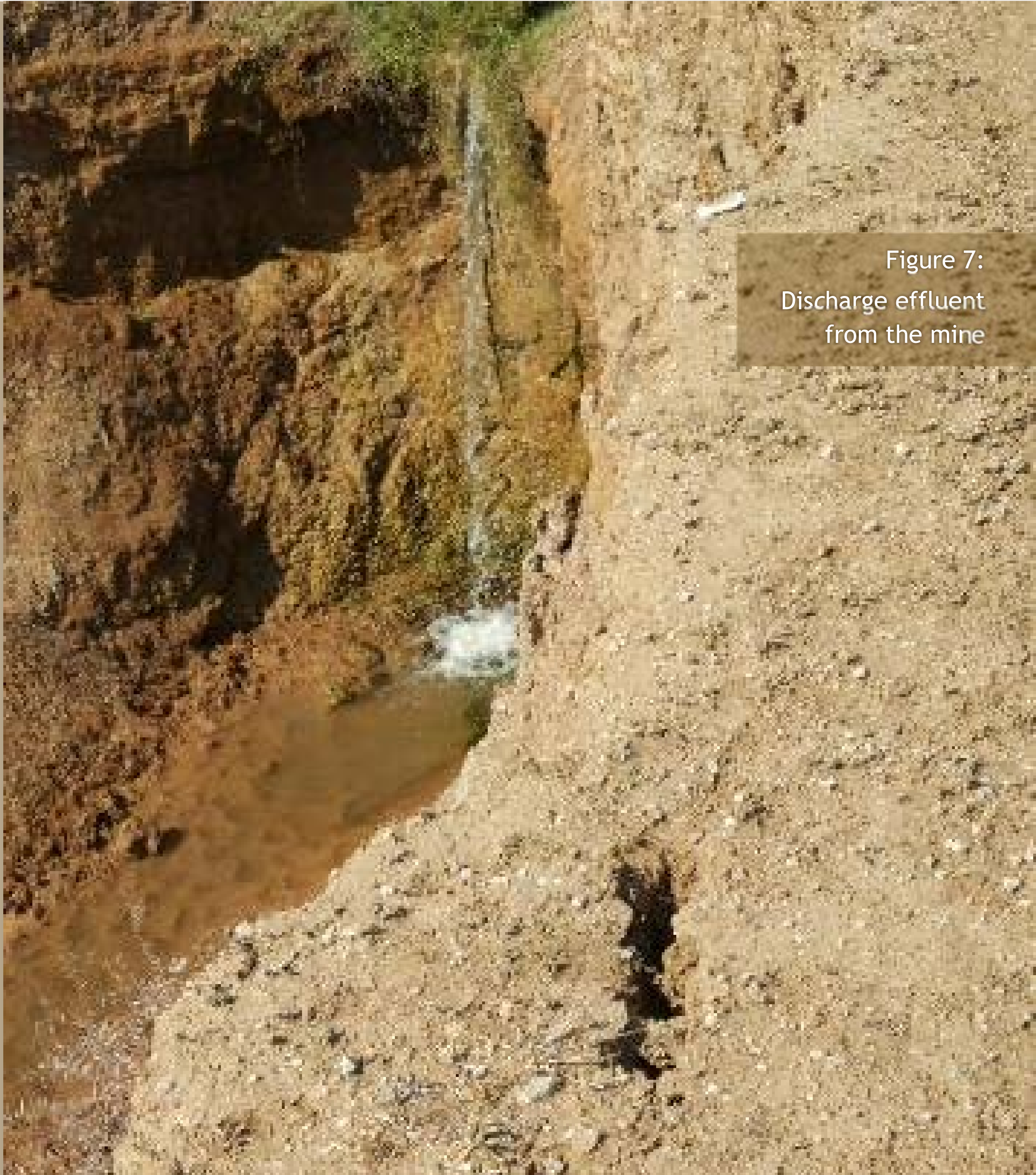

Figure 7:
Discharge effluent from the mine

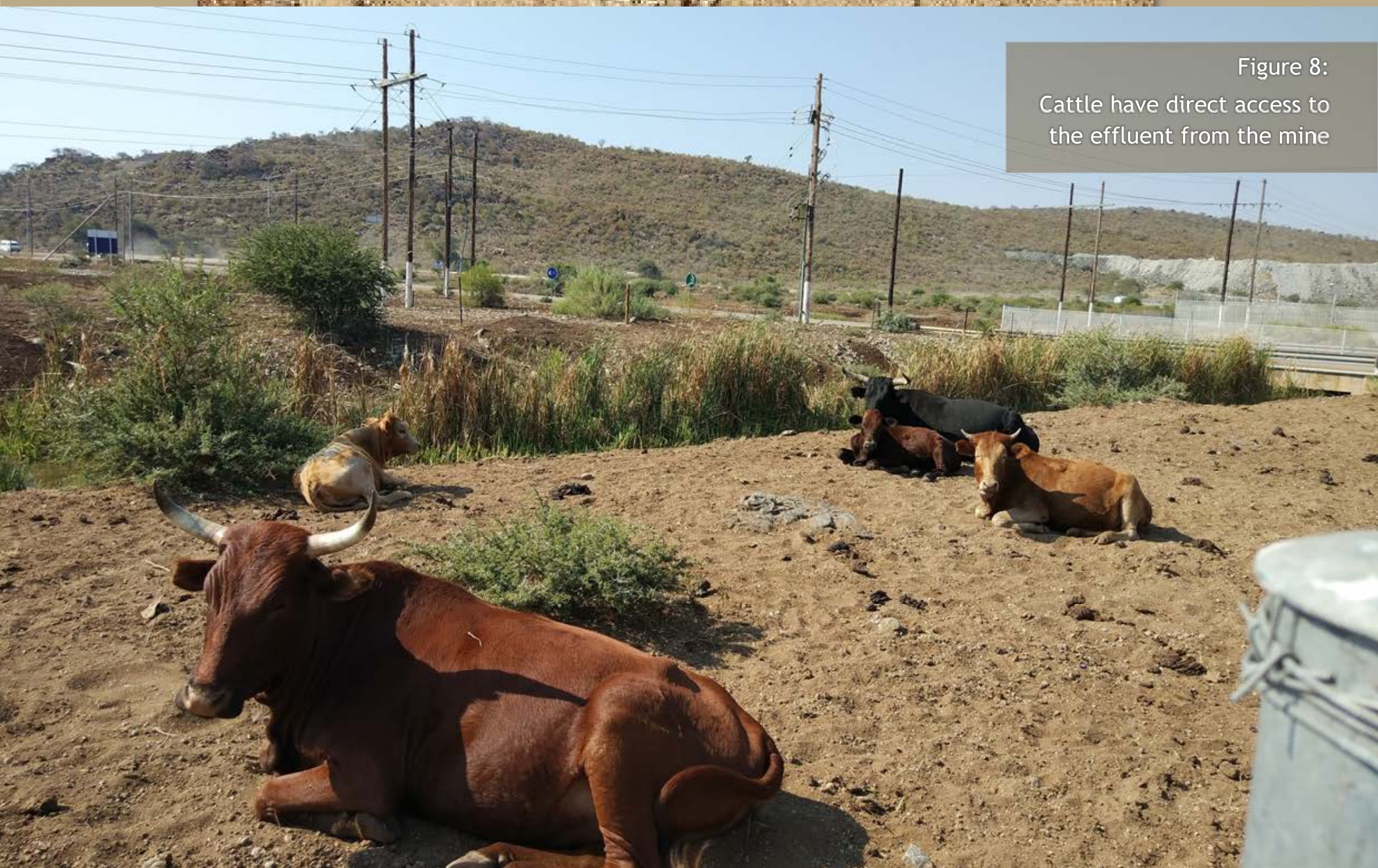

Figure 8:
Cattle have direct access to the effluent from the mine

Lower Olifants River Catchment

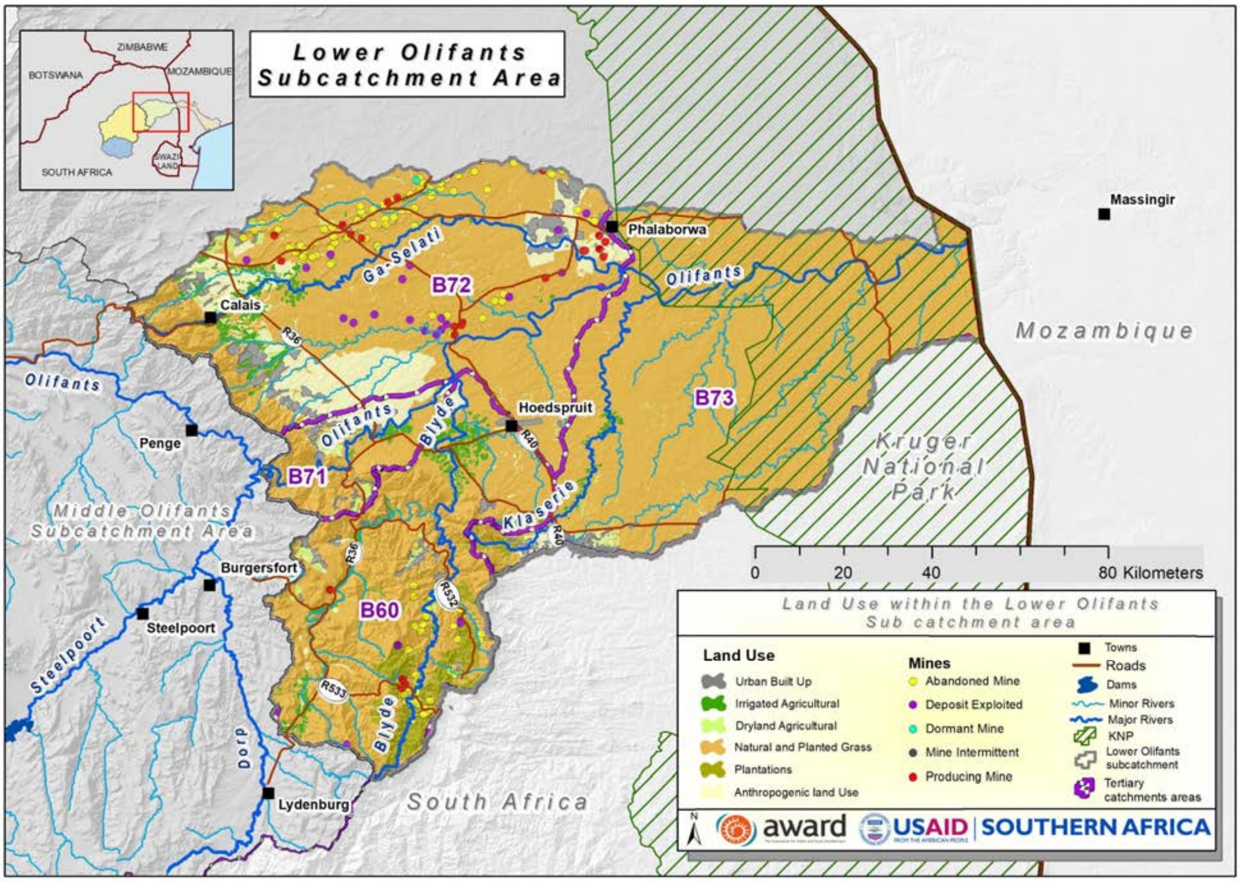

Figure 9: Landuse map of the lower Olifants River Catchment

Again, water quality data for the lower Olifants are limited as seen in Figure 2, the lower South African catchment has few identified impacts (salinization, eutrophication etc), There are two main drivers of water quality changes near Phalaborwa: mining and Waste-Water Treatment Works. These contribute salts, metals, nutrients and E. coli respectively. but the most significant threat in this region is the impact of the Phalaborwa mining-industrial centre, the worst point impact in the entire catchment (see Figure 9). Phalaborwa is situated on the lower Ga-Selati River just upstream of its confluence with the Olifants River (Figure 9). Samples from the lower Ga-Selati River have, overall, the highest levels of phosphate, sulphate and salinity in the lower catchment. Levels of sulphate and salinity are slowly decreasing with time, but phosphate levels, which have increased since the start of the data record around 1990, are still increasing (in contrast to the recent improvement noted at many sites in the catchment). Although acid events have been reported from the site, pH data show the pH to be good, although rather alkaline, and to have changed with time. A number of toxic elements such as metals, pesticides and herbicides have been found in water and sediments in the region. The impacts of water entering the Olifants River from the Ga-Selati River can be found throughout the Kruger National Park and into Mozambique, although levels are lower after dilution of Ga-Selati River water with Olifants River water (see box plots downstream of Ga-Selati in Red in Figure 10).

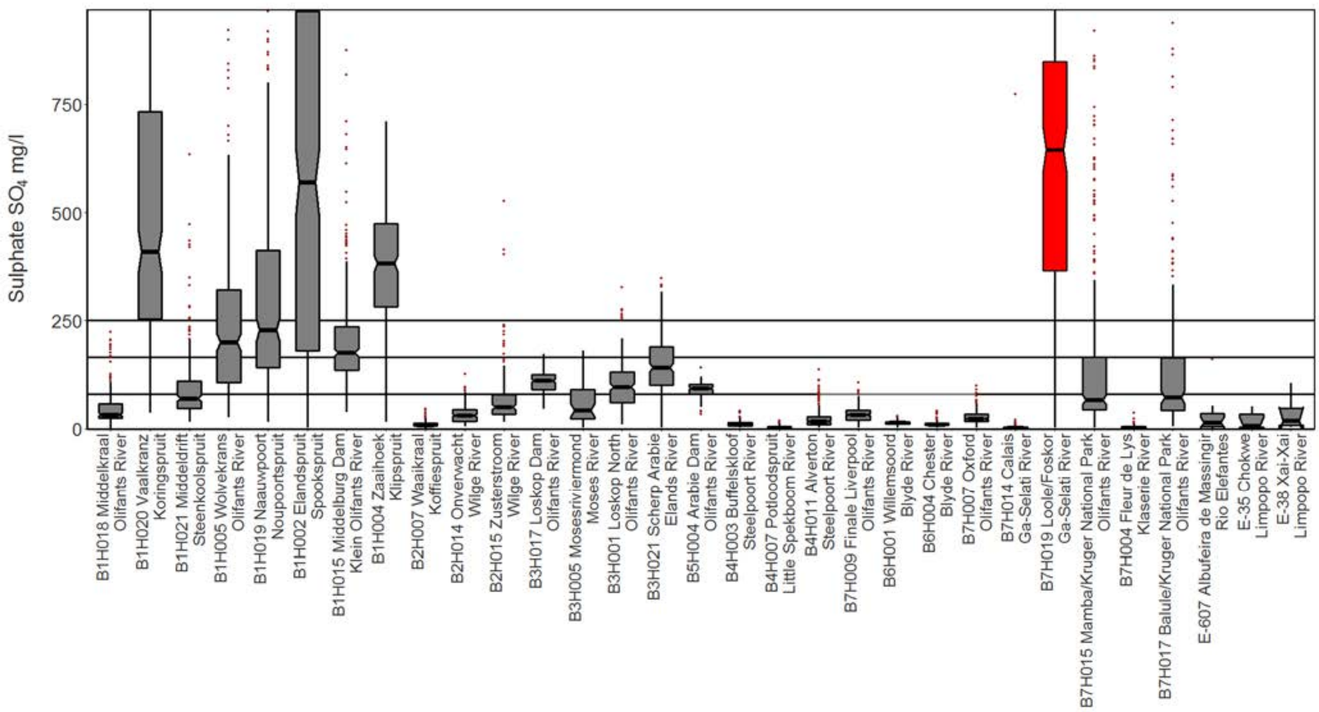

Figure 10: Box and whisker plots of sulphate levels at sites in the Olifants River Catchment. Boxes show the interquartile range, with medians indicated. Whiskers show levels within 1.5 times the interquartile range, and dots show outliers. The upper 2% of data are not plotted. Sites are roughly ordered along the axis by distance upstream, with those higher in the catchment to the left. Horizontal lines show upper limits of DWAS generic Resource Quality Objectives for South Africa. (DWA 2011a)

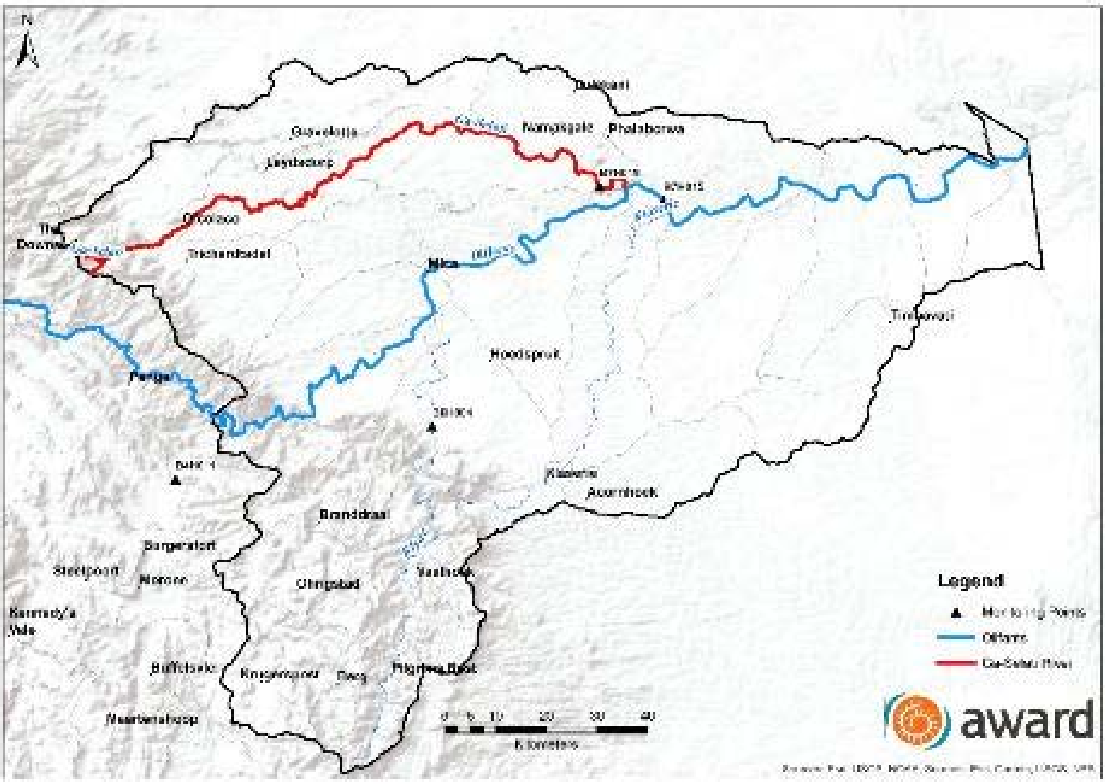

Figure 11: Map of the lower Olifants River Catchment. Ga-Selati is colour-coded to correspond to results for sulphate concentrations shown in Figure 10.

Case study: potential

Whilst water quality data is limited, a health assessment study of water quality (heavy metals and pathogens) from 2009 to 2011 revealed much about water quality and the potential health risks. The team sampled drinking water and crops irrigated by water from the Olifants River at two villages in South Africa and one in Mozambique.

The results indicated alarming levels of heavy metals, microbes (Norovirus) and immune disruptors (Genthe et al., 2013). They concluded that communities living along the Olifants River and reliant on the river water for domestic use are potentially at higher health risks and infections due to poor water quality and presence of microbial pathogens from waste water treatment effluents, heavy metals as a result of mining (Figure 13), and endocrine disrupting chemicals as a result of agricultural runoff as well as pharmaceutical waste.

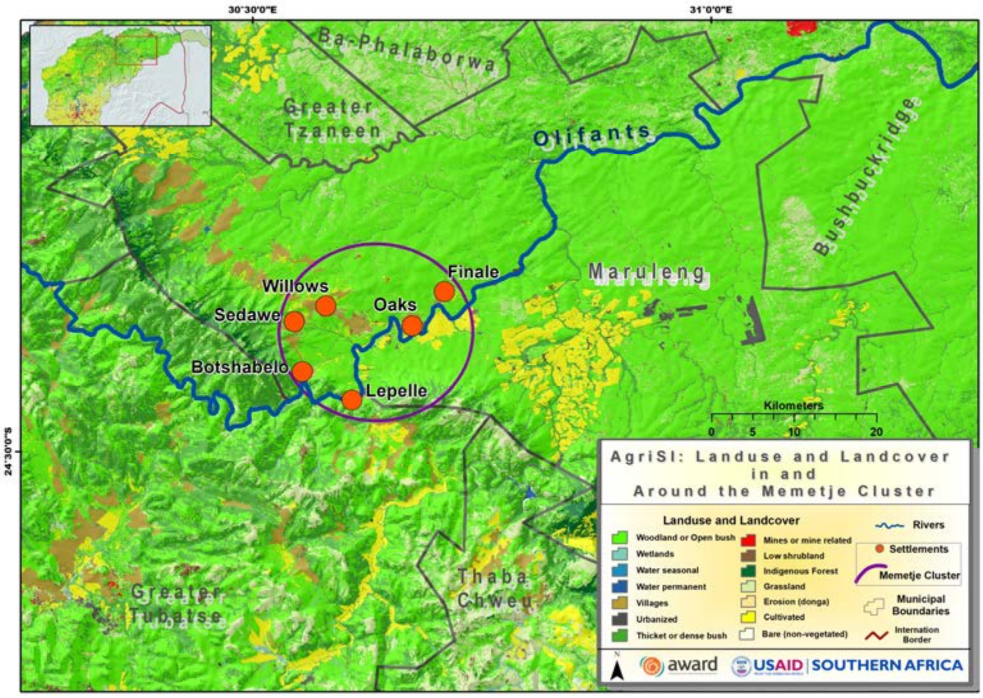

Figure 12: Site of the villages sampled

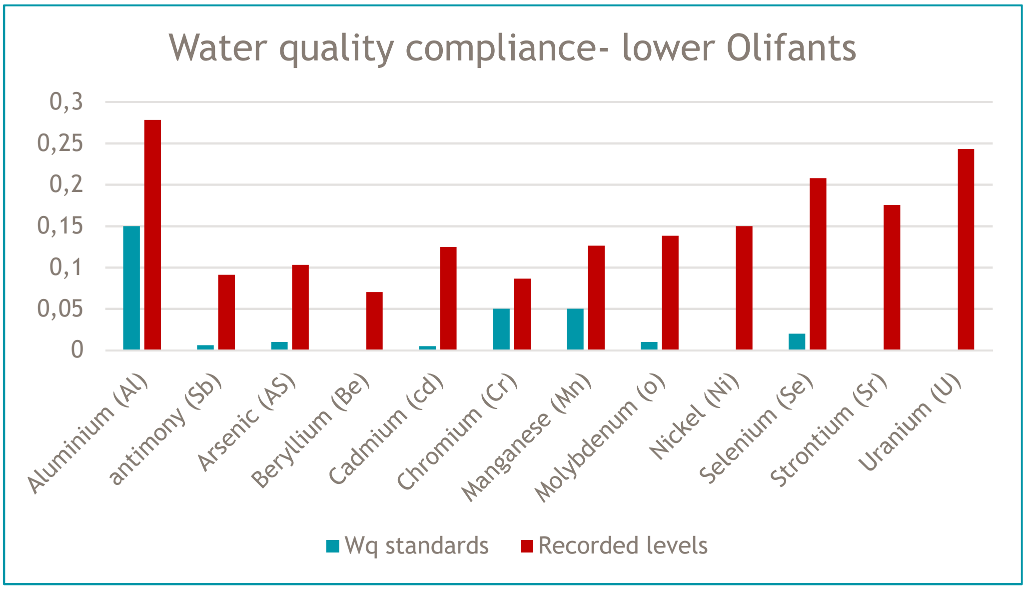

Figure 13: Summary of the results of water quality data collected by the health assessment in the Botshabelo and Lepelle villages on the lower Olifants (mg/l)

Mozambique – lower Limpopo

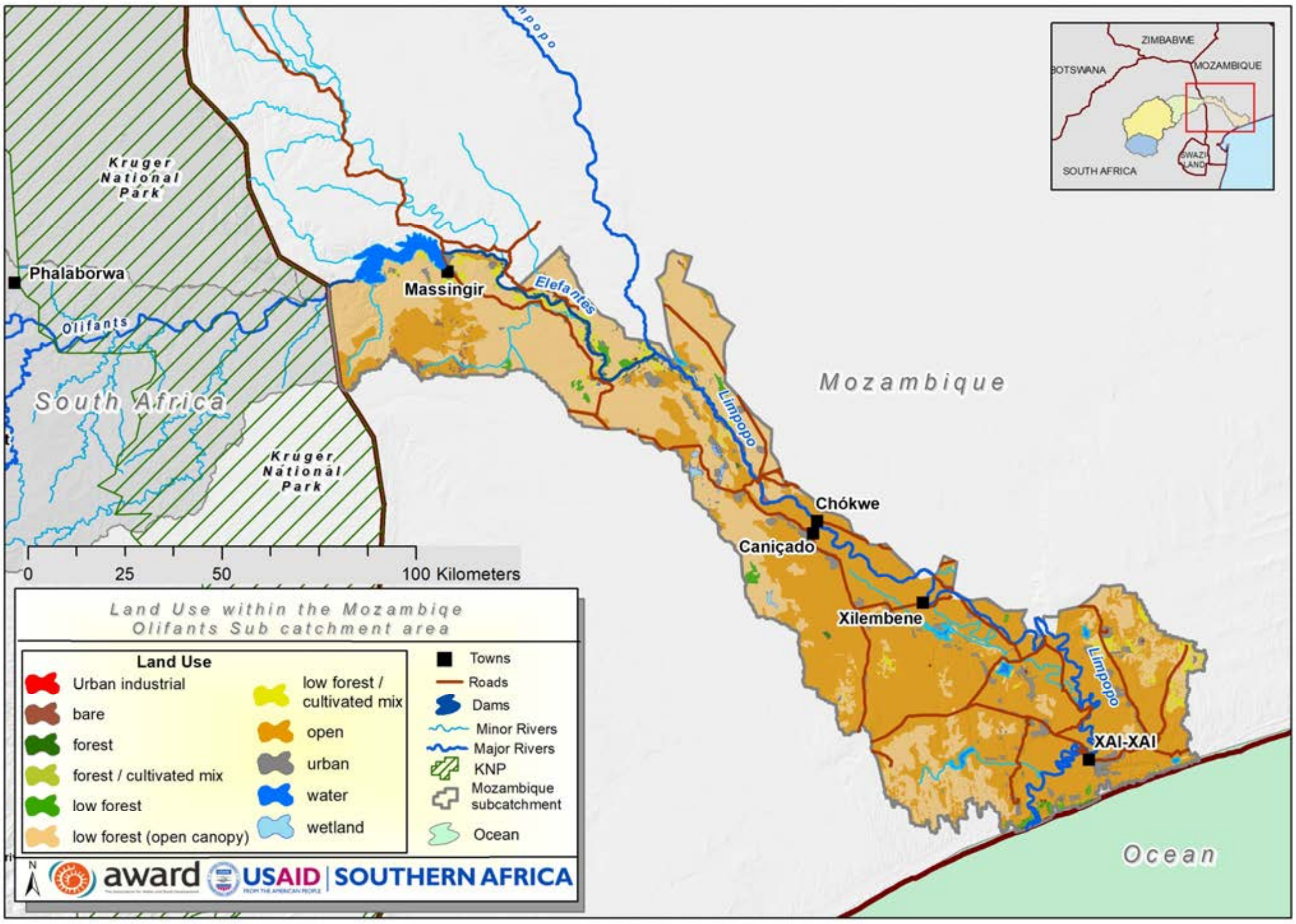

Figure 14: Landuse map of the lower Limpopo in Mozambique showing the confluence of the Olifants and Limpopo rivers

There are few data from the Mozambique Rio Elefantes and Limpopo River. The pH and sulphate levels are generally good, and salinity remains unchanged until the river nears the coast at Xai-Xai. Although phosphate data were not available, total phosphorous data suggest that Massingir Dam is becoming eutrophic, which accords with other published information (Mussagy 2008). No data were available on potential toxins in the area.

Understanding the water quality problems

High phosphate levels in freshwater in South Africa have been identified as a threat because of their tendency to cause eutrophication. Eutrophication leads to uncontrolled plant and algal growth, which in turn may kill fish, cause toxic algal blooms, and increase problems in treating water for use. Phosphate levels all over the catchment have showed a long-term tendency to increase with time, often driving levels above the accepted guidelines. However, recent data from many sites shows a sudden and dramatic improvement in phosphate levels at many sites in the Olifants River catchment.

With the exception of a few rivers in the upper catchment, a few sites showed clear evidence of acidification of water as a result of AMD. In general, rivers in the catchment tended to be fairly alkaline, although less so in their headwaters. An overall increase in pH levels was observed at sites across the catchment until around 1995. The reason for this shift is not known.

Sulphate pollution of water in the upper catchment and at Phalaborwa is substantial. This problem is particularly associated with coal mining and mining at Phalaborwa. Other mines operate in the catchment without showing these impacts. At impacted sites, sulphate levels drive increased salinities, making the water less suitable for use. Particularly worrying is a tendency towards increasing sulphate pollution in the upper catchment. This needs to stabilize or reduce future impacts will be severe.

Salinity levels in the Olifants River have been identified by many as a management challenge. The causes include mining, industry, power generation, irrigation return flows, urban runoff, wastewater treatment waste disposal sites and land use and degradation. In the Olifants River, salinity changes are particularly associated with mining in the upper catchment and at Phalaborwa, irrigation, and land-use and land degradation. Salinization results in decreased utility for all users, and the potential for land salinization when water is used for irrigation. Salinization associated with irrigation and land-use patterns is particularly worrying because increased sodium can lead to a collapse in soil structure when saline water is used for irrigation.

Worrying levels of toxic metals and inorganic compounds have been documented in the catchment by a number of other researchers, and our assessment supports their conclusions. Acidified rivers in the upper catchment commonly had high levels of aluminium, iron and manganese. However, the majority of rivers in the upper catchment were not acidified, although the sulphate loads indicate that they contained neutralized mine effluent. Rivers across large parts of the catchment often had high loads of aluminium, cadmium, copper and zinc. Certain localities might have other toxic metals present but due to the lack of data it can only be assumed based on the surrounding activities. Some metals were only monitored with tests that were insufficiently sensitive to detect whether guideline levels had been exceeded, and so little is known of the true threat posed. Some toxins were not monitored at all, despite their being found to bioaccumulate in fish to levels that would threaten a regular human consumer. Finally, no data were available for levels of these compounds in Mozambique.

Hardly anything is known about levels of pesticides and herbicides in the catchment. Surveys have reported elevated DDT at several sites in the catchment, with other pesticides being found in the irrigated zone below Loskop Dam (Ashton & Dabrowski 2011, Griffin *et al.* in press). Bioaccumulation of pesticides has also been detected. The absence of information on these compounds is problematic.

Levels of microbial pollution are also not well understood. Recent studies have found the levels of *E. coli* generally exceed guidelines, severely so in places. Sources of this contamination are generally due to badly operated wastewater treatment works, unsewered settlements, and feedlots. Surveys that looked at pathogenic bacteria found several potential disease risks associated with microbial pollution (DWA 2011a, Griffin et al. in press). Some of the bacteria sampled were found to be antibiotic-resistant. The unacceptable *E. coli* levels in the Olifants River catchment is a feature shared with many other catchments in the country.

Sediment loading of the river has also been found to be an issue. Sediments largely originate in degraded lands in the middle catchment. Sediments alter the water quality, and have several impacts on rivers. Sediment is deposited in reservoirs reducing water storage capacity. This has happened at the Phalaborwa Barrage. While this barrage is flushable, the sediment load that was released when it was flushed in 2019 caused serious environmental damage in the Kruger National Park downstream. Sediments may adsorb metals and toxins and remove them from solution. This can reduce the concentration of these compounds in the water, but concentrates them in deposited sediments where they are available to benthic biota. They may be released from the sediment by disturbance or physico-chemical change.

Water quantity: Catchment overview

Summary of the Olifants' current and future water balances

Water balance

A water balance, describes water availability and demand, based on the flow of water in and out of a catchment. Water flows into a catchment through precipitation, run-off and groundwater inflow and out of a catchment through evapo-transpiration, river flow and other human and industrial uses. The annual water balance compares the water available to the demand, to identify sub-catchments which are in water surplus, balance or deficit.

The Reserve or Ecological Water Requirements [EWRs]

The EWR is simply the quantity, quality and seasonal pattern of water needed to maintain aquatic ecosystems within a particular ecological condition and it is afforded 100 % assurance in the National Water Act (Act 56 of 1998) (DWA 2006). It is not considered to be a water use, since this is water that must remain in the river.

The Olifants Basin is highly developed and water stressed due to the intense utilisation of limited water resources by various sectors (IWR Water Resources 2014).

The intense water utilisation in the basin consequently affects both water quantity and quality negatively, thereby affecting catchment water security (Schreiner et al. 2009; Pollard & du Toit 2011); *(see Resource 1: Keeping the Olifants River flowing)*. Water security is the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies (Cook & Bakker 2012).

The water requirements in the Olifants Basin have increased substantially over the last few years due to diverse activities including mining, urban development, improved service delivery to rural communities, irrigation, power generation and the need to provide the Reserve or Ecological Water Requirements (EWRs).

Water for power generation at Arnot, Hendrina, Kendal, Kriel, Komati, and Matla power stations within the Olifants Basin is imported from either the upper Komati or the Vaal Systems, which are outside the basin. However, potential future demand for water from the mining sector as well as rural communities is large, which led to the construction of the De Hoop Dam, completed in 2013, as a supply-oriented strategy (approximate capacity 348 million m^3). There are plans to increase the quantity of water being transferred out of the catchment for Polokwane and mining. There has also been an expansion in undocumented agricultural water use; for example, 400 ha in the lower Olifants between 2013 and 2019 *(see Resource 1: Keeping the Olifants River flowing)*.

Approach to water balance

The main water users in the lower Olifants are domestic supply, irrigation and mining. To understand where water shortages are likely to occur during droughts, currently and in the future, the Olifants Basin was divided into sub-catchments. The water balance of each of these sub-catchments for 2014 is shown in Figure 15. Current (2014) water balance was based on observed flows, while future water balance was based on streamflows from the Water Resources Yield Model (DWA 2010). Flows from the Letaba and Shingwedzi Rivers (outside the Olifants catchment) were taken into account when determining the water balance of Olifants River within Mozambique (IWR 2014). The current (2014) water balance shows that of the fifteen sub-catchments, five are in balance, five are in surplus, while the other five are in deficit.

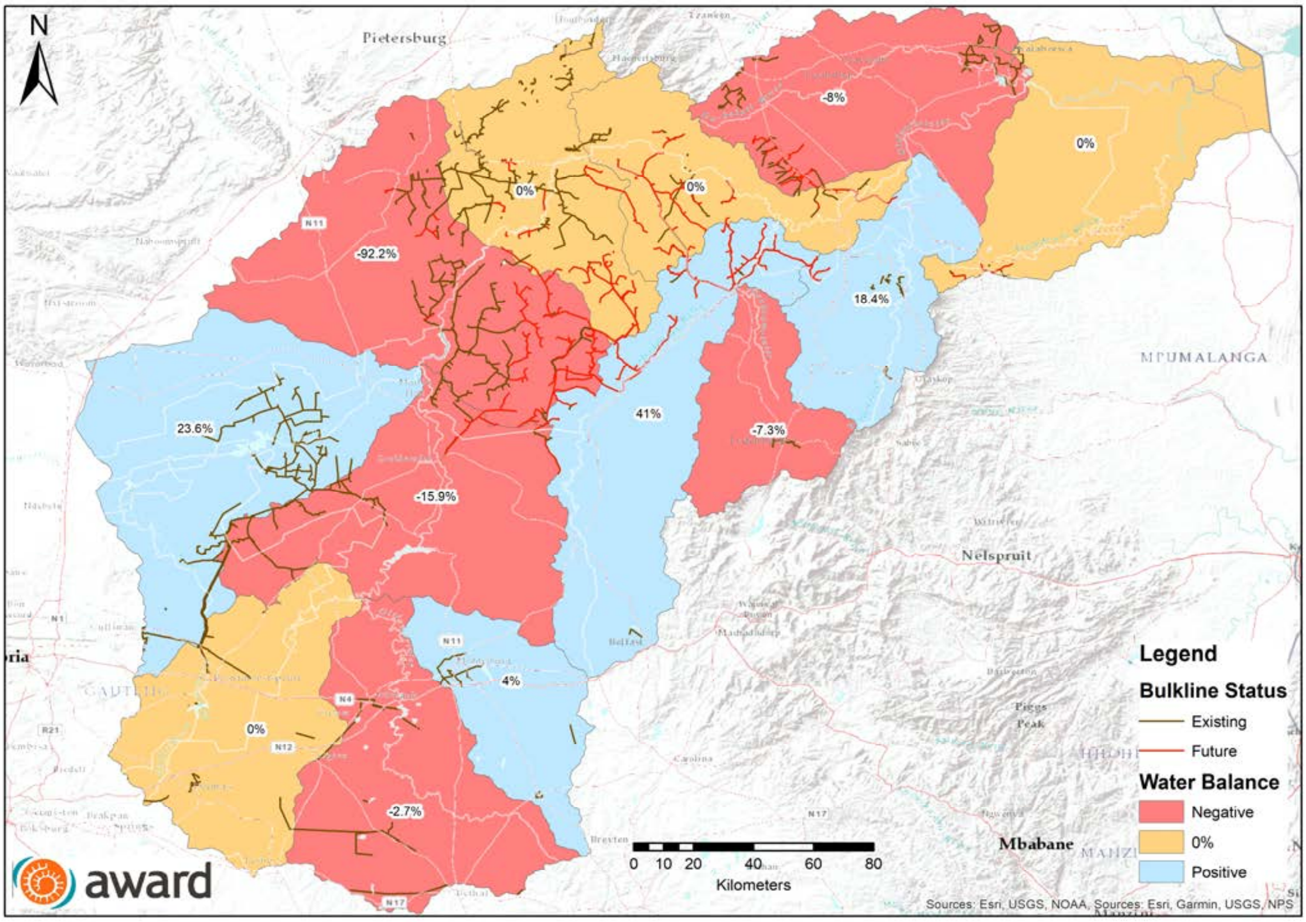

Figure 15: Water balance for sub-catchments in the Olifants Basin in 2014

Hydrological alteration

The different parts of the flow regime play different roles in sculpting and maintaining the river ecosystem: for example, the onset of flow seasons, which may affect breeding cycles of biota; or the magnitude of the annual flood, which may inundate a floodplain. Removal of part or all of a particular element of the flow regime will affect the riverine ecosystem differently.

A preliminary analysis indicates that some areas of the Olifants River Catchment have undergone major hydrological alterations of greater than 68% (see Figure 6).

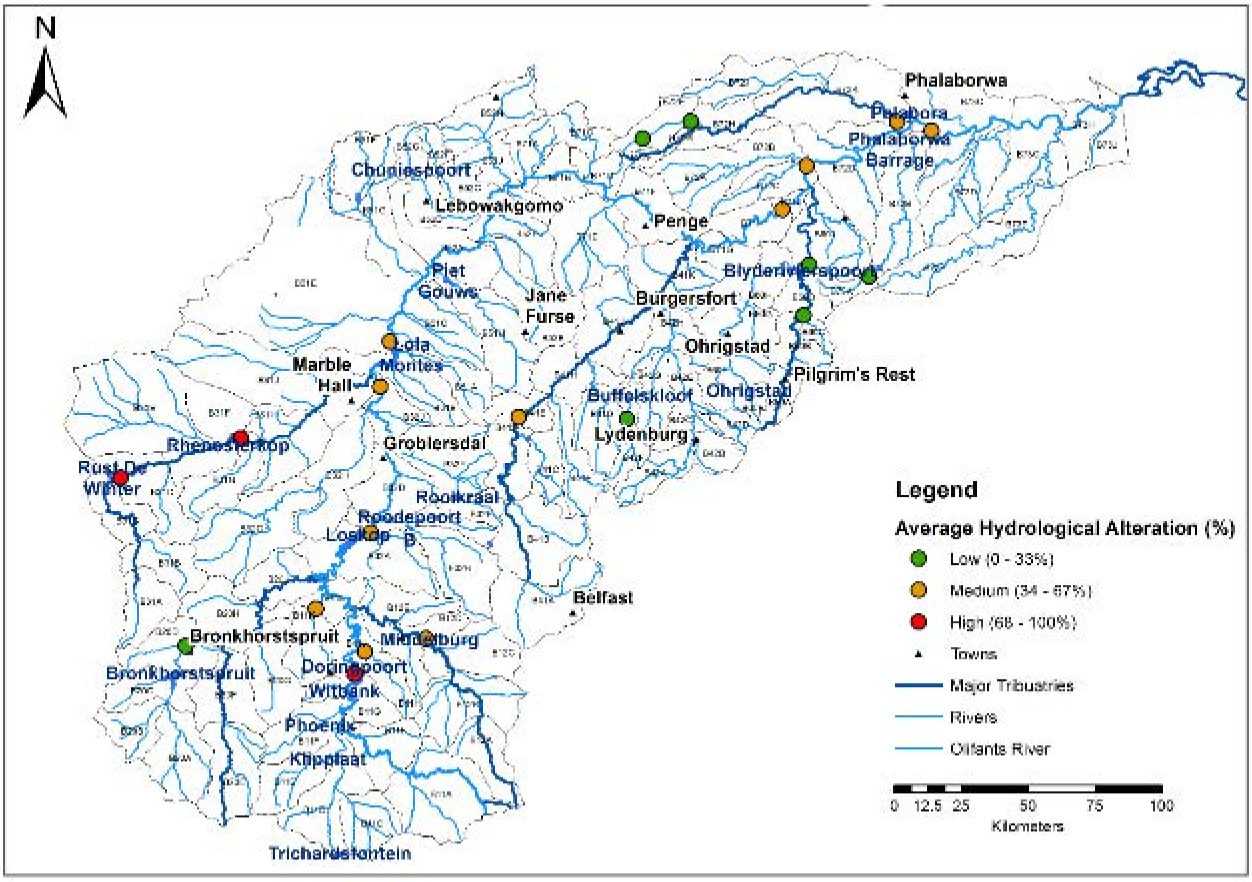

Figure 16: Map of discharge points analysed for hydrological alteration in the Olifants River Catchment pre- and post- 1990 as there were significant increases in irrigated agriculture and mining

Readers are referred to the AWARD resource detailing experiences of maintaining flows during the worst drought on record. *(See Resource 1: Keeping the Olifants River flowing).* This highlights the water security implications of continued increasing demand during times of water stress.

Non-compliance with the Reserve

There are several large dams in the catchment which can meet the large water requirements under the current operating regimes. However, the EWR is not being met, especially during the dry season. Meeting these requirements, which is a legislative requirement under South African law, will result in an increased deficit within the South African part of the Olifants Basin. Our recent analysis of the impacts of climate change on water resources of the ORC indicate significant reductions in water yield and streamflow (up to 60% on the eastern boundary of South Africa). *(See Resource 4: Predicted Impacts of Climate Change on Water Resources of the Olifants River Catchment).*

This deficit can be addressed by using a systemic approach to water resources management (link systems brochure) and greatly improved water governance and management, especially regulation of undocumented water use. Other strategies may include water demand management strategies such as more efficient water use, removal of alien invasive plants, reuse (use of treated mine decant water) and recycling.

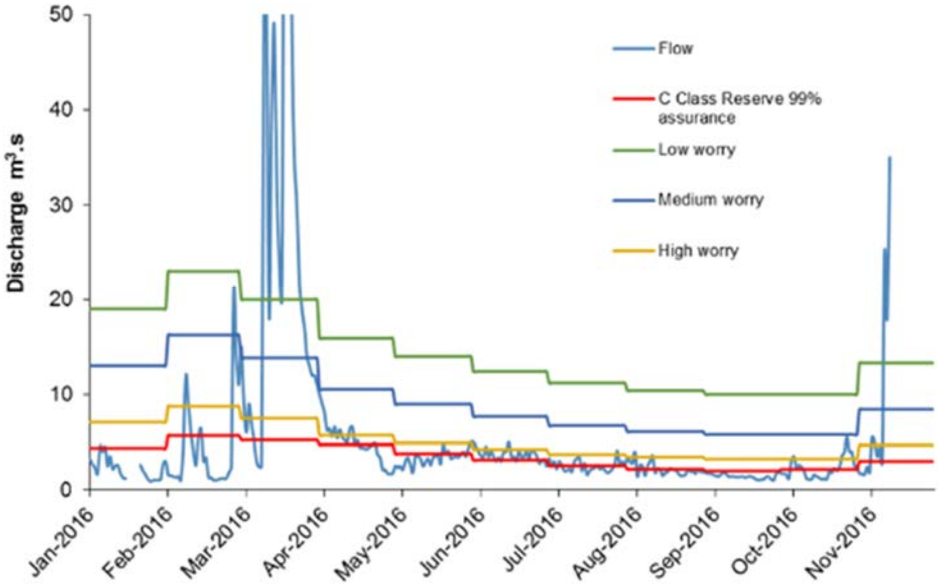

Figure 17: Unverified flows plotted together with the KNP management response thresholds and the Reserve for Mamba Weir (B7H015) in Kruger National Park (Riddell et al. 2016)

Conclusion

Water quality in the Olifants River Catchment is threatened by a number of factors. These have consequences for all water users as well as the environment. Major issues are outlined below.

Coal mining and associated energy generation, industry and development in the upper catchment are a major threat to water quality. The production of acid mine effluent leads to increasing salinities, potential acidification, and has been blamed for increasing toxic metal loads in rivers leaving the area. The associated development and industry also supports some salinization and the potential for microbial contamination of water. As salinities leaving the upper catchment are increasing, it appears the impacts are not being appropriately managed. The potential for a legacy where agricultural output has been permanently curtailed by mining, and ongoing contamination of water affects water users in the area and downstream, is one that needs to be avoided.

Phosphate loading from the upper catchment seems to be the cause of the shift towards eutrophication seen in Loskop Dam. Irrigated farming in the middle catchment is receiving water with steadily increasing salinity from upstream, which threatens the future of continued farming in the area. Increased salinization of water as a result of irrigation further stresses the resource, as does extensive use of pesticides in the area. Management of land use and land condition in the middle catchment would help manage sediment export from the region and would reduce local salinization.

The extent of the impact noted at Phalaborwa is considerable and needs to be addressed. The data suggest that both the municipality and the mines/industry are implicated in this. The decrease in water quality in Kruger National Park and the state of the water entering Mozambique needs to be improved. Although sulphate and salinity levels are improving, phosphate levels show the reverse trend. Trends in metals are not known as too few data are available. The large phosphate load entering the river at this point supports reports that Massingir Dam downstream in Mozambique is becoming eutrophic. The catchment contains a large number of wastewater treatment works. While no clear link can be made on the basis of our analysis, which did not assess the impact of each of these, it seems likely that they are having a major impact on water quality in the catchment. Phosphate levels have been observed to increase in all parts of the catchment, and this is at least partially a function of phosphate release from wastewater treatment works. High microbial loads can also be attributed in many cases to wastewater treatment works operation.

Since the availability of water, either through demand or supply management strategies, is one of the key elements that influences catchment resilience, it is therefore essential to understand the current and future water balances within the Olifants Basin across all user sectors from a systems view point. For instance, the availability of water to various sectors is influenced by upstream water use, and in some cases, downstream priorities of water supply. These water balance results can be used to trigger resilient water management options in the priority sub-catchments (those in deficit and in balance), currently and in the future under climate change. Thus, water balance could be an empowering tool for water resource managers to prepare for and mitigate the effects of regional climate change on their local hydrologic resources. There is no comprehensive water resources analysis of the whole Olifants Basin, including the Letaba tributary, hence there is some uncertainty associated with the Massinger Dam yield, which requires further study.

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AWARD is a non-profit organisation specialising in participatory, research-based project implementation. Their work addresses issues of sustainability, inequity and poverty by building natural-resource management competence and supporting sustainable livelihoods. One of their current projects, supported by USAID, focuses on the Olifants River and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems to sustain livelihoods and resilient economic development in the catchment.

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About USAID: RESILIM-O

USAID: RESILIM-O focuses on the Olifants River Basin and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems that support livelihoods and resilient economic development in the catchment. The 5-year programme, involving the South African and Mozambican portions of the Olifants catchment, is being implemented by the Association for Water and Rural Development (AWARD) and is funded by USAID Southern Africa.

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