EXECUTIVE SUMMARY

The Olifants River is one of South Africa's major river systems and is an important tributary to the Limpopo River and is recognized as one of the "hardest working rivers" in South Africa. The demands for water for industry, mining, power generation, agriculture and domestic use have increased steadily over the years, exceeding the rate of population growth, and have been accompanied by large increases in the quantity of effluents that are discharged to the river system and its tributaries. The seasonal and inter-annual extremes of river flow, combined with the steady decline in water quality have increased the vulnerability of all the aquatic ecosystems in the catchment, while also increasing the vulnerability of the people who rely on the water resources of this river system for their lives and livelihoods.

The discharge of treated, partly treated and untreated effluents from mines, industries and sewage treatment plants, combined with seepage of acidic mine drainage from several active and abandoned coal mines in the upper reaches, contribute nutrients, salts and metal ions and microbial contaminants to the river system. Steadily rising nutrient concentrations indicate that water storage reservoirs are becoming increasingly eutrophied, and increased concentrations of aluminium and iron are often above those suggested in national water quality guidelines. Blooms of the toxic cyanobacterium *Microcystis aeruginosa* in Lake Loskop are thought to be responsible for recent fish kills and human users of water from this reservoir also face risks to health. The water quality situation in the lower Olifants River recently received considerable public attention when over 170 crocodiles were reported dead inside the KNP and the crocodile population in the upper reaches of the catchment has also declined.

The need for this study arose during discussions between the Water Research Commission and CSIR's Natural Resources and the Environment business unit. It was clear that while a lot of information was available on water quality issues across the Olifants River catchment, much of this information was contained in a variety of confidential project-specific documents, consultancy reports, theses and published papers. An important additional consideration was the need to evaluate the implications of so-called "emerging pollutants", including organic compounds, pharmaceuticals, endocrine disrupting compounds and even nano-sized materials, as potential health risks to humans, livestock and aquatic biota. This study provides an overview of our existing knowledge on the water quality in the Olifants River catchment and the likely sources of poor water quality, outlines the potential risks that these substances pose to all water users and the aquatic ecosystems, and highlights the need for targeted research and urgent remedial actions.

This study collated and evaluated the available water quality data as a basis for an overview of water quality across the entire Olifants River catchment and has also identified many of the likely sources or causes of poor water quality. This will enable water resource decisionmakers in central, provincial and local government, industry and agriculture to define those areas that require priority attention and urgent remediation. In addition, the information also provides a scientifically defensible rationale for developing and implementing measures to improve land use practices across the catchment, as well as a basis for working with counterpart authorities in Mozambique. The ultimate beneficiaries of the recommendations presented in this study will be the aquatic ecosystems within the Olifants River catchment, as well as every person in the catchment that relies on good quality water for their lives and livelihoods.

This study focussed on the quality characteristics of the surface waters present in the Olifants catchment and has compiled a wealth of detail on the seasonal and inter-annual variations in water quality and the trends of change in water quality. There has been a progressive decline in water quality along the main stem of the Olifants River and in several important tributaries over the last twenty years. While the water quality data and indices

provide clear indications as to the type of land-use activity that has contributed to this poor water quality, it is important to emphasize that the available data are not sufficient to allow a precise determination to be made as to the specific source of a particular contaminant.

Therefore, it is important to understand the implications of the wording in the ***Caveat*** presented below.
Our evaluation of the water quality data collected by the DWA routine water quality monitoring programme for the Olifants River system revealed several short-comings of this programme. In particular, the relatively high proportion of samples with unreliable analyses represents a significant waste of scarce time, money and human resources. A related issue was the finding that the elapsed time between sequential samples was often very long with almost half of the DWA sampling sites having a sampling interval of 50 days or more. This makes it difficult to properly interpret changes in water quality and hampers the formulation and implementation of remedial actions.

While the DWA routine water quality monitoring programme has been structured to provide a balance between effective evaluation of water quality and the costs of collecting, analyzing and processing the data, relatively few water quality variables are measured routinely. These few variables are not sufficient to provide a clear and unambiguous 'picture' of all the changes in water quality. The routine water quality monitoring programme needs to be expanded to include trace metals, pesticides, organic compounds, microbial contaminants and suspended sediments to ensure that these can provide a more accurate assessment of the potential health risks associated with poor water quality.

CAVEAT

It is important to stress a ***Caveat*** to readers of this report in relation to the interpretation of general statements that attribute the causes of poor water quality to past and / or current mining activities in the different portions of the Olifants catchment. The numerous mines in the catchment range from large to small operations – of different ages – and employ a range of different mining techniques, while their respective operating companies have widely differing economic resources at their disposal. Many of the older mines – particularly coal mines in the upper portion of the Olifants catchment – have been worked out and abandoned; custodial responsibility for these mines now rests with the National Government. All mines that are still operating with valid mining permits and water use licences are responsible for controlling their water use and for the quality of any effluent that may seep out of or be discharged from their properties. Several mines are known to operate highly effective pollution control systems and it is likely that these mines would contribute very little in the way of "problematic" water quality constituents. In contrast, some other mines - including abandoned mines - appear not to have effective pollution control measures in place. Therefore, while it is definitely possible to link instances of certain water quality variables (*e.g.* low pH values or high concentrations of sulphate, total dissolved salts and some metal ions) to the broad category of causes that are labelled "mining activities", we do not have the fine-scale, more detailed data that would allow us to indicate which specific mines or mining operations are responsible for specific cases of water quality problems in particular rivers. This issue can only be resolved by obtaining a much more detailed data set from those rivers where mining activities appear to be responsible for water quality problems. These data would allow a clear distinction to be made between the mines and mining operations that are effectively managed from those where additional or more stringent management efforts and interventions are required.

It is equally important to stress that the broad-scale of the analysis conducted in this study could not provide information at a sufficiently fine scale of resolution that would allow definition of the specific industries, wastewater treatment works or areas and types of farming operations that are responsible for specific water quality constituents or for specific water quality problems. This finer level of detail will require more detailed studies in specific sub-catchments to determine which specific land-use activities are responsible for particular types of water quality problems. This information can then be used to design customized solutions to each specific problem.

The practice of reporting or relying on mean or median values as a measure of the water quality status at a particular site should be discontinued as soon as possible, because these values on their own are meaningless. All water quality monitoring reports should include the percentile analysis of the data and a comparison of the percentile data with specific limits for each water quality variable. In addition, time series analyses should be used to illustrate trends of change and times of the year when water quality worsens.

Every local authority, industry, institution or commercial farming operation that has been granted a water use licence and an effluent discharge licence by the Department of Water Affairs (DWA) is required to submit regular reports to DWA on the quantity of water used and quantity and quality of effluent discharged. These reports and their associated monitoring and audit data are often considered to be 'confidential' or 'commercial in confidence' and the information in these reports was not available for examination. These data would have helped to provide a much clearer 'picture' of the water quality status in the catchment and would also have enabled specific effluent dischargers to be identified and prioritized for actions designed to improve the treatment of their effluents.

Very few data are available on the concentrations of trace metals that are present in the Olifants system. Many of these metal ions pose important health risks to humans, livestock and aquatic biota. It is therefore important to determine the precise sources of these metals and the quantities involved so that appropriate management actions can be taken to improve water quality across the catchment. In this regard, it is important that the Department of Water Affairs review and revise the existing sets of water quality guidelines so that these provide more useful guidance to regulators.

While the primary source area for a large proportion of the suspended sediments that enter the Olifants River has been known for several years, no corrective actions have been taken to date. Given the likelihood that the suspended sediments are likely to be linked to fish kills and crocodile deaths in the lower Olifants River, it is essential that suitable actions are taken to reduce the entry of these sediments into the river system.

Some independent studies have revealed the presence of unacceptably high numbers of faecal bacteria and pathogenic organisms in some of the tributary rivers in the upper Olifants catchment. These data indicate clearly that at least some of the wastewater treatment works are not functioning properly and need to be rehabilitated. Rural communities and single households that may draw their water directly from the river seldom have access to sufficient resources to allow them to treat the water before use, and are therefore at greatest risk from these contaminants. The Department of Water Affairs needs urgently to work with the local authorities and institutions that are responsible for operating wastewater treatment works and bring all these works back to full operational efficiency.

The few data available on the chemistry of rainwater samples collected in the upper Olifants catchment reveal that most rainwater samples are sufficiently acidic to be classed as 'acid rain'. This acidic rainfall has the definite potential to acidify soils and also to influence the productivity of croplands in areas where this rain falls. There is an urgent need to understand the full extent and implications of the acidic deposition across the upper Olifants catchment and to work with those institutions responsible for the source emissions to find cost-effective ways to reduce these emissions. In addition, the Departments of Agriculture and Water Affairs need to work closely with the farming community to devise and apply the most costeffective solutions to counter increased soil acidity.

The available water quality data indicate that significant acidic mine drainage with its associated low pH values and elevated concentrations of sulphate and other dissolved salts and metal ions has been present in some tributary streams and rivers in the upper reaches of the Olifants catchment for at least the last 25 years. In some instances, there are clear

indications that the situation has worsened in recent years. Remedial management attention should be directed to identifying the specific sources of the contaminants that enter these rivers and then working with the operators of these mining activities and associated industries to rectify the problems. In addition, the presence of elevated concentrations of aluminium in several tributary streams and in Lake Loskop suggests that there is a need to understand the speciation chemistry of aluminium in river and reservoir waters that receive acidic mine drainage so that a fuller assessment can be made of the potential health risks of this aluminium to humans, aquatic biota and livestock, as well as the implications for the design and operation of water and wastewater treatment works.

The precise sources of the elevated nutrient (N and P) concentrations recorded for most of the streams and rivers in the Olifants catchment are not easy to identify. While there is clear evidence that significant proportions of these nutrients are derived from non-functional or improperly operated wastewater treatment works, return flows from irrigated agriculture also contribute nutrients to the river system. The combination of nutrients from wastewater treatment works and agricultural sources has resulted in high to very high nutrient concentrations in every tributary river in the Olifants catchment. This has led to the progressive accumulation of nutrients in reservoirs such as Lake Loskop and has resulted in the development of extensive blooms of potentially toxic cyanobacteria. The toxins produced by these organisms are known to persist in water for relatively long periods of time and are not removed or eliminated in conventional secondary water treatment processes. This situation should not be allowed to continue and the Department of Water Affairs must work with local authorities and agricultural organizations to prevent further eutrophication of the rivers in the catchment, and enforce the existing policies and statutes to ensure that the current situation can be reversed.

Perhaps the most worrying issue related to the water quality data for the Olifants catchment is what appears to be an apparent absence of effective management actions to deal with easily identifiable situations where water quality has been compromised. This suggests that the officials and water resource managers who are responsible for water quality management are not receiving the correct information. If this is true, then it indicates a breakdown of the monitoring process, which includes every aspect from sample collection, analysis and interpretation to remedial management response and checking. This situation suggests that there is a need to review the ways in which water resource managers interpret water quality data and information, and – if necessary – change these processes so that there is a clear and direct link between the appearance of poor water quality and a carefully considered and targeted management response.

The data analyzed in this study revealed that impacts of acidic mine drainage in some tributary rivers has progressively worsened over time. In the case of the Spookspruit and Klein Olifants River, this deterioration has continued unabated since at least 1990. Despite some management attention having been directed towards the Klipspruit in the form of treating a portion of the acidic seepage in this river, the quality of the water in the Klipspruit has continued to decline.

Similar trends of worsening water quality occur in Lakes Witbank and Loskop. In Lake Loskop, the deterioration in water quality has continued unabated since at least 1975. Because water storage reservoirs retain and accumulate a proportion of their inflowing loads of salts, nutrients and sediments, the quality of the water in these reservoirs will continue to deteriorate if there is no improvement to the water quality of their inflowing rivers. However, even if the inflowing water quality is dramatically improved, it will take a period of time equal to approximately 5-7 times the water residence time in the lake for the lake to reach a new equilibrium and for the full benefits of the improvement to be visible. Another important consideration is that while water quality deteriorates during the drier winter months, the coincidence of this worsening water quality with low water temperatures accentuates the

adverse effects on aquatic organisms at this time.

The available data on temporal trends in water quality do not appear to have prompted sufficient meaningful and effective remedial management responses. Praise-worthy smallscale efforts such as the treatment of some acid mine drainage in the Brugspruit are simply too small to deal with the scale of the water quality problems in the catchment. Many of the characteristics of poor water quality are present to varying degrees along the length of the Olifants River – a situation that is shared by several other South African rivers. While there is a gradual improvement in water quality with increasing distance down the Olifants River, tributary inputs of untreated or incompletely treated domestic effluent, as well as industrial and mining effluents, plus return flows from irrigated lands, ensure that the water quality remains poor. In the lower reaches of the Olifants River, the contribution of the Ga- Selati River maintains poor water quality in the lower reaches of the Olifants River.

There is clear evidence that several wastewater treatment works in the upper reaches of the Olifants catchment are either not operating effectively or large volumes of sewage effluent are leaking / being discharged directly into the rivers. The combination of poorly treated or untreated sewage effluent with acidic mine drainage accentuates the poor water quality already present in the Klipspruit, and eventually contributes to the progressively worsening water quality in Lake Loskop. In some tributary rivers, the presence of endocrine disrupting compounds (EDCs) and both pharmaceutical and veterinary antibiotics poses health risks to all users and could promote development of antibiotic resistance in certain microorganisms.

This overview of the changes in water quality along the length of the Olifants River shows that while some of the sampling sites in the lower reaches of the Olifants River had relatively good water quality (compared to upstream sites), these sites also experienced periodic worsening of water quality. The water quality of the Great Letaba and Shingwidzi rivers appear to contribute relatively few salts, nutrients and metal ions to the lower reaches of the Olifants River. The periodic cessation of flow in both of these rivers also reduces the size and importance of their contributions to water quality in the lower Olifants River.

The spatial trends in water quality across the Olifants catchment reveal that numerous sources of different contaminants are contributing to the overall water quality situation. The apparent absence of any meaningful or sustained improvements in water quality across the catchment suggests that whatever management actions may have been taken to date have not been fully effective. The Department of Water Affairs is in the process of completing the compilation and implementation of an integrated water resource management plan for the upper and middle reaches of the Olifants River catchment. This welcome development will need to be fully embraced by all stakeholders in the catchment if it is to succeed.

The continued inflow of poor quality water from the South African portion of the Olifants River into Mozambique would appear to contravene some of the provisions in the revised SADC Water Protocol. While this Protocol does not deal specifically with water quality issues, it requires all signatory Parties to ensure that their water use in a shared river basin does not cause appreciable harm to a neighbouring country. In effect, the provisions of the SADC Water Protocol appear to carry greater weight than, and thereby over-ride, the provisions of earlier bilateral agreements and treaties between countries.

If poor quality water continues to flow into Mozambique from South Africa, and water quality continues to deteriorate further over time, this is likely to contravene to the content and intent of the revised SADC Water Protocol and could give rise to future claims for compensation from Mozambique. While it is clear that this situation should be halted and reversed as quickly as possible, this will require a far greater emphasis on effective water quality management across the entire Olifants catchment. In turn, this will require a far closer association with, and continuous co-operation between, water resource managers, local

authorities, industries and land-owners at all levels. All stakeholders will need to be involved in the process and everyone will need to contribute to solving the many problems linked to or caused by the catchment's poor water quality.

This study has exposed several areas where the available data and information are not sufficient to provide a clear and unambiguous assessment of many of the causes of poor water quality in the Olifants River catchment. A summary of the most important research needs to resolve these problems include investigations aimed at defining the extent and exact sources of critical pollutants and contaminants, followed by their control or remediation.

The suggested research topics include:

- Evaluate the effluent quality data that are currently considered to be 'confidential' or 'commercial in confidence' to determine which industries, institutions, local authorities or landowners need to be prioritized in terms of urgent remedial treatment of their effluents;
- Review and revise the current DWA water quality monitoring programmes so that they include trace metals, bacteria and other microbial organisms, organic compounds and suspended sediment evaluations;
- Develop and enforce effective resource quality objectives (RQOs) for each river reach in the Olifants River catchment;
- Find ways to strengthen and enhance the abilities of water user groups such as the Olifants River Forum (ORF) so that their efforts to improve the water quality situation in the catchment are more likely to succeed;
- Develop and refine ways to streamline some of the management approaches (such as the resource classification system which is presently cumbersome to use and often deters potential applications) so that water quality management approaches can be less time-consuming and more cost-effective;
- Review and if necessary revise the chemical composition conditions of all effluent discharge licences issued to effluent dischargers in the Olifants River catchment;
- Determine the longevity in natural aquatic systems of the microbial contaminants indicative of domestic sewage pollution and the implications of this for water users located downstream of points where these organisms originate;
- Define the types, extent, exact sources and implications of endocrine disrupting compounds (EDCs, including pharmaceutical and veterinary antibiotics) and other new and emerging pollutants such as nano-sized particles;
- Pin-point the sources, followed by determination of their character and extent, of acidic drainage from operating and abandoned mines and devise or compile suitable options to control and minimize these;
- Define the exact sources of pathogenic organisms (especially *Cryptosporidium* and *Giardia*) and the most suitable treatment or preventative processes to stop the input of these organisms to the aquatic systems;
- Accurately quantify the extent to which water storage reservoirs are retaining salts, nutrients and sediments, the conditions under which this happens, the factors that control the rates of retention and transfer between sediments and water, and the implications of the retained loads for water quality in these reservoirs;
- Accurately quantify the extent to which coal-fired power plants and heavy industries are contributing atmospheric emissions that contain potentially acidic materials to the catchment and identify the most appropriate treatment and preventative processes to minimize the impacts of these substances on aquatic systems and cultivated areas;
- Identify which trace metals originate from which type of mining or industrial activity and specify how best to prevent the entry of these trace metals into the aquatic systems;
- Evaluate alternative mining methods for coal mines in the upper catchment that would allow proper exploitation of the available reserves whilst minimizing the generation of acid mine drainage from their associated pyrite deposits;

- Implement a monitoring system to conduct routine evaluations of the presence and toxicity of cyanobacteria in reservoirs and selected river sites in the catchment;
- Evaluate simple water treatment systems for small communities and possibly also for single households that would allow individuals to obtain reliable supplies of wholesome water for domestic use and reduce their health risks;
- Gauge the extent to which “Payments for Ecosystem Services” (PES) approaches could be used as a mechanism to improve water quality across the Olifants River catchment and, if found to be economically feasible, how best to implement such approaches;
- Confirm and quantify the exact origins of the suspended sediments present in the Olifants River and determine when and where these sediments are transported and settled out;
- Quantify the extent to which trace metals and other contaminants are associated with suspended sediments and evaluate their implications for water quality, aquatic biota and water treatment processes;
- Review the existing water treaties and agreements between Mozambique and South Africa to determine if there are mechanisms that can be incorporated to strengthen their applicability to water quality management for the benefit of both countries;
- Investigate the most cost-effective technical solution for treating water that contains cyanobacterial toxins so that the water is both affordable to consumers and safe for use;
- Determine those aspects of the speciation chemistry of aluminium associated with waters that receive acidic mine drainage and the implications of this for aquatic biota, human health and the design and operation of water treatment systems;
- Evaluate the full implications of introducing phosphorus-free detergents for domestic use on the effectiveness and efficiency of wastewater treatment works, and the resulting reduction in phosphorus loads entering rivers in the Olifants catchment;
- Determine what remedial techniques and technologies could be deployed to successfully improve water quality in water storage reservoirs;
- Compile a comprehensive water quality management plan for the Olifants River catchment to complement the DWA integrated water resource management plan for the catchment;
- Assess the extent to which passive water treatment systems such as natural and manmade
wetland systems could be used to improve water quality, and evaluate the implications of seasonal changes in climatic factors and inflowing loads on the functioning of these systems;
- Determine the extent to which nutrients derived from livestock are influencing water quality in the Olifants catchment and derive effective land management options to prevent this source of nutrients from entering the river systems;
- Determine the exact water quality conditions and components that are implicated in the pansteatitis incidents amongst fish and crocodiles;
- Determine the most appropriate options for treating acidic mine drainage to a state where it can safely be used over the long-term for alternative uses such as irrigation;
- Develop and implement suitable operating procedures for the Phalaborwa Barrage and other water storage reservoirs to reduce the quantity of sediments released to downstream river sections; and
- Review and revise the existing sets of water quality guidelines, expanding these to include inorganic and organic substances where no guideline exists.

This list of research needs reflects the extent to which our collective knowledge and understanding of the Olifants River system and its water quality are deficient. Clearly, the required research cannot be carried out over-night and it may be several years before all the water quality issues can be dealt with effectively. Nevertheless, it is essential to start a process whereby research funding institutions, academic institutions, local authorities, industries, water user organizations and water quality researchers can examine and prioritize the research needs. This will provide a structured approach that will help to provide

the information that is required to successfully restore the water quality in the Olifants catchment to acceptable levels. In addition, this process will require improvements to be made to the effectiveness of several institutional structures and organizations that share responsibility for managing water resources and water quality in the Olifants River catchment.