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EVALUATION OF DRINKING WATER QUALITY IN LAKE MZINGAZI IN RICHARDS BAY

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EVALUATION OF DRINKING WATER QUALITY IN LAKE MZINGAZI IN RICHARDS BAY

By

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SUMMARY

Introduction

Lake Mzingazi is the only suitable source of domestic water supply for the Richards Bay community. Rapid industrialisation in the city of uMhlathuze, accompanied by an influx of people, has resulted in informal settlement occurring around the lake. The uncontrolled activities of this development threaten to pollute the water source. Previous studies in1979 conducted by Council of Scientific & Industrial Research indicated that Lake Mzingazi water was still within acceptable limits in terms of the Department of Water Affairs & Forestry guidelines. The lake water quality was that of a Class I water resource, which is excellent for domestic use.

Pollution of the lake can result from diffuse sources of pollution due to settlement of communities around it. Water purification costs could escalate thus forcing an increase in water tariffs. If pollution resulted in the lake being unable to be utilized, the Richards Bay community will be seriously affected, as it would necessitate the importing of water from distant regions. Either way, the expense of acquiring water would increase. All living organisms rely on adequate water for their survival. Worse still are human beings for their water should not only be adequate but should be of good quality to prevent health risks and even death. It is in view of these possibilities that the study was undertaken.

Aim

The aim of the study is to assess the extent of physical, chemical and biological pollution in Lake Mzingazi due to non-point sources and to recommend necessary protection measures that need to be implemented to prevent any negative health impact on surrounding communities. At present there are no restrictions and no protection of the lake from pollution except that no recreation is allowed into the lake at present.

Methods

Several objectives were set in order to focus on specific issues. One of the objectives was to inform the communities around the lake about the study. Sampling of the lake

water was conducted monthly from June to November 2006 (using a boat). Pictures of areas around the lake were also taken for further analysis. At each sampling run, 36 samples were taken and delivered to a laboratory accredited by the South African National Accreditation Standards for analyses. Six sampling runs were completed.

Secondary data for the period of 1998 to 2005 were obtained from uMhlathuze Municipality in order to establish pollution trends and for comparison purposes with the Department of Water Affairs and Forestry guidelines.

Results

The findings of the study revealed that the quality of the lake water is still within acceptable limits when compared with the Department of Water Affairs & Forestry guidelines; however, informal settlement threatens the future of the lake by encroaching into the lake banks.

Discussion

There is definitely a risk of pollution to Lake Mzingazi as long as there are no pollution prevention plans in place.

Recommendations

All data should be stored in a centralized information system to avoid losing valuable information.

The Water Services Authority must develop and maintain a water quality-monitoring programme that will capture all changes occurring in the lake.

DECLARATION

I. Cleopas Mzondeni Mathenjwa declare that

(i)The research reported in this dissertation, except where otherwise indicated, is my original research.

(ii)This dissertation has not been submitted for any degree or examination at any other university.

(iii)This dissertation does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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Signed:

DEDICATION

I dedicate this work to my wife, my partner and inspiration. For the support and encouragement you have given me, forsaking all wonderful times and pleasures, I praise you. Those cups of tea meant a lot. I thank you greatly. To my youngest daughter, Thobile for understanding and losing her time with me, I am grateful. This wonderful work would have been difficult without your moral support. May the Almighty bless you.

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ACRONYMS AND ABBREVIATIONS

DAEA- Department of Agriculture & Environmental Affairs

DEAT – Department of Environmental Affairs & Tourism

DWAF - Department of Water Affairs & Forestry

GPS - Global Positioning System

NEMA - National Environmental Management Act of 1998

NWA - National Water Act of 1998

SD - Standard Deviation

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1 CHAPTER 1: INTRODUCTION

1.1 BACKGROUND INFORMATION

Richards Bay in Northern KwaZulu-Natal ranks among the fastest growing cities in South Africa, due to rapid industrial development. As a result it has become an environmental ‘’hot spot”. It is located in an ecologically sensitive area where there exists great potential for pollution due to the uncontrolled settlement of people close to natural water resources. Therefore, strict pollution control measures and mitigation efforts are constantly being emphasized and directed to the business fraternity by uMhlathuze Municipality. In response to the ongoing pollution threat, the uMhlathuze Municipality has established an Internal Environmental Work Group, which is responsible for dealing with assessing environmental impact of new developments scheduled to take place in the area. The control of pollution by rural communities’ and due to immigrant activities in the area is still lacking.

Industries have played only a minor role in the pollution of Lake Mzingazi because they are located next to the Port of Richards Bay, situated far south of the lake. Despite this, sustainable development must continue to be enforced and Environmental Impact Assessments (EIAs) performed before any new proposed development. An assessment forms part of the National Environmental Management Act requirements in South Africa (Department of Environmental Affairs & Tourism, 1998).

Lake Mzingazi is situated in the town of Richards Bay in northern KwaZulu-Natal. Five residential areas surround it, namely, Arboretum suburb on the southern side, Mandlazini agri-village on the northwestern side, Meerensee on the eastern side, Mzingazi on the northeastern side and Birdswood on the western side of Mandlazini. The lake is the only source of domestic water supply for all these areas (Appendix G). An estimated 88 650 people depend on the lake for domestic water at the moment. Recreational activities on the lake were discontinued in the 1980s by the municipality and the KwaZulu-Natal Wild Life, to mitigate the effect of pollution of the lake due to this activity.

Northern KwaZulu-Natal is at risk for epidemic water-borne infectious diseases such as cholera since most communities have no access to purified water and adequate sanitation. Therefore, Lake Mzingazi has been targeted by the uMhlathuze Municipality and the Uthungulu District as the main water source for all rural areas under its jurisdiction. Therefore, this calls for adequate monitoring and control of the resource to ensure it remains a good water source, which can improve the health status of the communities.

An influx of people from surrounding tribal rural areas as well as from neighbouring countries such as Mozambique, Zimbabwe Swaziland and other Southern African Development Community (SADEC) countries has occurred. The uMhlathuze Municipality has entered into a contract with a private security company known as Risk Control Group, which is responsible for patrolling these areas, checking and removing informal settlements of unregistered people discovered hiding or living in the bushes.

The uncontrolled influx and immigration has resulted in an unplanned settlement of people in search of employment. The Mandlazini area on the western side of the lake has in particular been affected due to felling of natural trees and removal of grass by illegal and informal settlers. Damage to the environment occurs as the bare soil is eroded by wind and rainfall which could aggravate silting of the lake. The municipality had set up a buffer zone between the lake and the prescribed residential areas; however, the tribal councilors disregarded that arrangement and have allocated homesteads in the buffer zone. The natural vegetation, which serves as a filter that protects the lake from pollution by retaining it, has been compromised.

Wherever a rapid increase in human population density eventuates, large volumes of waste products are produced, which if indiscriminately dumped are allowed to litter the bush and pollute water resources. Human waste production causes land and water pollution if proper control and management such as regular collection and proper disposal of the waste is not instituted. Pollution arises from both domestic and human waste including ground water contamination from sewerage overflows and seepage from pit latrines and other on site sewerage and sanitation systems. The natural receiving environment, both land and water, possesses a limited carrying capacity to absorb this human waste. When the capacity is exceeded, it results in possible pollution of the lake water by seepage and run-off. Further to this, Mandlazini is an agri-village and keeping of livestock is permitted. Livestock are allowed to drink directly from the lake. Dung and urine is likely to enter the water due to this practice. There are no other dams or watering points dedicated for watering livestock.

Not all job seekers succeed in finding employment in the city and often resort to other means of livelihood including land cultivation, which can lead to further degradation of the environment due to felling of trees, removal of soil covering vegetation, accumulation of chemical substances in soil and soil erosion. The threat of pollution by human activities remains very high, especially as people prefer to live in close proximity to Lake Mzingazi, the only substantial water source for the City of uMhlathuze.

It is essential that Lake Mzingazi be protected and a continuous monitoring of water quality be conducted to ensure its sustainability. Contamination of the lake could therefore be a real problem for the community, as this constitutes the only source of domestic water available.

Potential sources of water pollution need to be identified, which include human practices such as livestock farming, land cultivation with poor farming methods, inadequate sanitation systems, feed lots and any other human activity that could impact negatively on the ecosystem of the lake. Humans tend to live under the false impression that natural resources are infinite until disaster strikes, a misleading perception that needs to be reversed. A positive attitude and disposition towards environmental awareness needs to be developed by all communities. The Water Services Authority (WSA) of the City of uMhlathuze and the communities will benefit from being appropriately informed when decisions and planning development need to be made for the area.

The sampling and analysis of the lake water conducted by this study will assist in determination of its physical, chemical and biological quality. The Water Services Authority requires information in order to allocate funds for research and to implement recommendations for the protection of the Lake. Data obtained through this study is important in that it will determine the condition of the water and enable it to be compared to the Department of Water Affairs & Forestry's guidelines. Such knowledge will benefit all role players involved. The study's findings are expected to promote environmental awareness in the communities and they will be advised of the approach they should adopt to ensure environmental sustainability. The necessary co-operation with the Water Service Authority will also be improved. Success in the protection of water resources requires the involvement of relevant communities in making decisions that affect them.

1.2 CURRENT UNDERSTANDING OF THE QUESTION IN THE STUDY

The excessive encroachment of human beings into the lake environment continues. The buffer zone initially established between the lake and the residential area has disappeared and its protective role has been marginalised by the informal settlement of people. The buffer zone was established to clearly separate the residential area from the lake ecosystem and to ensure that there is adequate protection of the lake from pollution by human activities. Misunderstanding caused by newly appointed Indunas and tribal councilors has resulted in people being settled as close as 3 meters from the lake edge. Pit latrines have been observed as close as 2 meters from the lake's banks at the Mandlazini and Mzingazi agri-villages, pose a threat of lake pollution through either seepage or overflowing sewerage from full pits. Studies from other developing countries in sub-Saharan Africa and even developed countries have shown that uncontrolled sewerage overflowing into the environment can result in water resource pollution.

During previous planned settlement, each household was provided with a 2x 4 cubic meter heavy-duty polyvinyl chloride (PVC) conservancy tanks for sewage purposes.

UMhlathuze Municipality suction tankers (super suckers) then emptied these tanks when called out by the Mandlazini agri-village community, thus preventing lake pollution. Recently, newcomers have come to decide on the sanitation system they are to use since no access to a waterborne sewer system exists. Concerns have arisen regarding this practice as the measures that were put in place for better control of pollution are now lacking. The municipality has many reasons to support this study in order to ascertain the present status of the Lake Mzingazi water resource.

1.3 STATEMENT OF THE PROBLEM

Informal habitation has encroached on the catchments of Lake Mzingazi in Richards Bay. The quality of the water is therefore threatened with deterioration deriving from human waste and activities. Worsening water pollution could constitute a public health problem in the near future if no action is taken. It is believed that Lake Mzingazi is being polluted both directly and indirectly by human activities and by waste being deposited in the lake's drainage and catchment area.

Pollution means direct or indirect alteration of the physical, chemical or biological properties of a water resource so as to render it less fit for any beneficial purpose for which it may reasonably be expected to be used (Department of Water Affairs & Forestry, 1998).

1.4 PURPOSE OF THE RESEARCH

The purpose of the study is to assess the extent of physical, chemical and biological pollution in Lake Mzingazi and to recommend the necessary protection and mitigation measures required in order to maintain good water quality and thereby prevent any negative health impact on people living in the surrounding communities.

1.5 THE STUDY AREA

The study will cover areas in the immediate vicinity of Lake Mzingazi and the surrounding suburbs of Richards Bay in Northern KwaZulu-Natal.

1.6 SPECIFIC OBJECTIVES OF THE RESEARCH

The specific objectives include:

- To assess the extent of physical, chemical and biological pollution in Lake Mzingazi;
- To identify possible sources of pollution around the lake through a survey of the area;
- To compare the change in the quality of water between the period 1998 to 2005 and 2006 in order to establish if there is any pollution trend;
- To ascertain the level of pollution as compared with the parameters of the South African National Standard 241:2006 for Domestic Water Supply and with the guidelines of the Department of Water Affairs & Forestry of 1998; and
- To propose recommendations to be undertaken by both communities and the municipality, thus ensuring proper Lake Mzingazi management.

1.7 ASSUMPTIONS UNDERLYING THE STUDY

- All pollution sources of the lake will be clearly identified.
- The impact that pollution has on water quality can be evaluated using available equipment and facilities.
- Recommendations to protect the lake will be identified, accepted, implemented and maintained by the community.
- Alternate living for people can be organised by the political leaders in agreement with the affected people in order to prevent them from using ecologically sensitive areas close to the lake.

1.8 OPERATIONAL DEFINITIONS USED IN THE RESEARCH

- **Water resource quality** – includes the health of all parts of a water resource which together make up the ecosystem, including plants and animal communities and their habitats.
- **Environmental sustainability –** maintaining a balance in resource use by incorporating protection measures to ensure that the resource is not irrevocably damaged.

- **Pollution** – direct or indirect alteration of the physical, chemical or biological properties of a water resource so as to render it less fit for any beneficial purpose for which it may reasonably be expected to be used (Department of Water Affairs & Forestry, 1998).
- **Duty of care -** all people should be responsible for the consequences of their actions and have the duty to act with care in order to avoid damage to the environment (Department of Environmental Affairs & Tourism, 1992).
- **Environmental epidemiology –** an important tool for investigation of the distribution and determinants of environmental diseases in a human population sample. (Katzenellenbogen *et al*., 1997).

1.9 ORGANIZATION OF THE REPORT

The report consists of an introduction, literature review, method, results, discussion, conclusion and a recommendation sections. The introduction provides the background information, purpose, objectives and location of the study. The literature review section assessed the state of current available knowledge, especially the Council for Scientific & Industrial Research (CSIR) reports of previous studies of the lake. The objectives are to ascertain what studies need to be undertaken for the purposes of addressing the problem. The results of the study report the data as found during investigation. The discussion chapter attempts to illustrate whether the results obtained have any relationship with the objectives and whether they are statistically significant. The conclusion sums up the results and the findings of the study. Recommendations will be based on the findings of the study, suggesting what action could be undertaken to improve the situation or avert the problem of human pollution in Lake Mzingazi.

1.10 SUMMARY

The chapter has identified the area of the study, the description of the water resource of interest, background information and the purpose of the study. It has clearly stipulated the specific objectives necessary to deal with the problem statement as observed. It finally furnished the manner whereby the report would be organised.

2 CHAPTER 2: LITERATURE REVIEW

2.1 PURPOSE OF LITERATURE REVIEW

The purpose of the literature review is to present the available information and literature that documents the relationship between physical, chemical and microbiological pollution of domestic water sources and how this impacts on public health. The review focused on Lake Mzingazi and other water resources of a similar nature in South Africa and those in countries outside this continent.

The literature review includes the causes of pollution in other similar areas and the measures taken to rectify or prevent water pollution. In addition it was necessary to examine strategic plans that might be taken to prevent pollution of Lake Mzingazi, as rehabilitation of the environment is costly and no guarantees exist that such measures would restore the resource to its original condition. Information obtained and application from other areas revealed that, through the education of communities and provision of appropriate legislation, pollution can be prevented and intolerable situations reversed. In all events, humans were found in these studies to be the major role players in causing environmental pollution.

2.2 LITERATURE REVIEWED

Books written by both local and international authors dealing with environmental management issues were consulted. Information dealing with lake ecosystems pollution was obtained electronically from the Internet. Earlier reports produced by the Council for Scientific & Industrial Research (CSIR) in KwaZulu-Natal for uMhlathuze Municipality were also considered for this literature review.

2.3 THE AREA OF INVESTIGATION

Richards Bay on the North Coast of KwaZulu-Natal is a town undergoing rapid industrialization and an almost uncontrolled influx of individuals from rural communities into the city in search of both jobs and a livelihood. In particular, development of informal residential areas has resulted in encroachment into eco-sensitive areas such as Lake Mzingazi.

Figure 1: Aerial photo of Lake Mzingazi in 2006 Showing Human Settlement and Sampling Point Positions

Urbanization has been accompanied by extensive stretches of hardened surfaces with storm water drainage systems. Urban runoff is a major source of impaired water quality in estuaries and lakes (United States Environmental Protection Agency, 1993). The removal of vegetation in order to settle people minimizes the natural biological filtration system and, as a consequence thereof, more impurities accumulate in rivers, lakes and, finally the sea.

Mdibi River passes through Sabokwe community, Khondweni Stream traverse Mzingazi agri-village community, Phayeni Stream flows through the area inhabited by the Mzingazi Tribal community while Mzingazi and Nkoninga Rivers traverse the Mandlazini agri-village and Veldenvlei. Predominantly poor communities live in these areas and survive through subsistence farming (Appendix E).

Lake Mzingazi forms part of the Usuthu to uMhlathuze catchment area. Several other lakes besides Lake Mzingazi are also part of this system. These include lakes St. Lucia, Sibaya, Nhlabane, Insezi, Mengezi and Cubhu. The nearby Lake Insezi is already infested with water hyacinths (*Eichhornia crassipes*) that are proving to be difficult to control. Lake St. Lucia is presently under threat of over- exploitation by communities living nearby. Lake Mzingazi does not exhibit growth of hyacinths, although water lettuces (*Pistia stratiotes*) have recently been observed in certain parts of the lake. Aquatic plants such as *Ficus hippopotami and Cyperus papyrus* are common in most parts of the lake as a result of silt deposition associated with soil erosion. Lakes with drainage from denuded land that have silt deposits are prone to such problems.

2.4 THE EFFECTS OF URBANISATION ON WETLAND ECOSYSTEMS IN SOUTHERN AFRICA

Present indications are that approximately 50% of wetlands in South Africa have already been destroyed by urbanization, agricultural and other related practices. The poor management of lakes and wetlands will influence their future sustainability and result in the degradation of water resources. Pollution influences the air we breathe, the water we drink and enjoy, and the soil we use for agricultural or cultivation purposes. Jacques Cousteau has been quoted saying, “Water and air, the two elements on which all life depends, have become global garbage cans.” (Grinning Planet, 2005). Pollution manifests itself more broadly by being present in such concentrations or amounts whereby the physical, chemical and/or biological properties of natural resources are adversely altered or affected, thus influencing their intended use (United States Environmental Protection Agency, 1993; Fuggle & Rabie, 1999).

The Constitution of the Republic of South Africa states clearly in the Bill of Rights that:

> “Everyone has the right – (a) to an environment that is not harmful to their health or well-being; and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislation and other measures that- (i) prevent pollution and ecological destruction; (ii) promote conservation; and (iii) secure the ecologically sustainable development and use of natural resources while promoting justifiable economic and social development” (Constitution of the Republic of South Africa, 1996).

However, this is not happening due to the previous forced removal of people undertaken during the apartheid era. Land demands by people who were victims of previous forced removals have resulted in the unplanned resettlement of people by certain political leaders. This has, in some wetlands, resulted in the deforestation of natural forests and the denuding of the soil. Part of the Dukuduku forest in St. Lucia constitutes an example of such human exploitation of nature. The absence of job opportunities has resulted in some people resorting to wood sculpture for a livelihood. In these circumstances, trees are felled in order to obtain tree stumps to carve sculptures, which are sold for minimal financial reward. Authorities are striving earnestly to curb the problem but, if people possess no alternative means of earning a livelihood, the problem will continue. On the other hand, St. Lucia has witnessed much environmental exploitation due to "mass fishing", where gillnets and other non-sustainable means of fishing are used. Fish obtained in this way can be used either for sale or may simply be eaten at homes. This practice has led to greatly reduced species diversity (Radio Khozi News, 2006).

According to John Yeld, in his book entitled "Caring for the Earth South Africa", 90% of the original wetland has been destroyed in the Tugela basin in KwaZulu-Natal, greatly reducing its biodiversity (Yeld, 1997).

Furthermore, the literature reveals that 58% of the wetland area of the uMfolozi catchment area has already been lost through erosion. Communities living in such surroundings have resorted to subsistence farming, thereby degrading the wetland. The sensitive ecosystem of the uMfolozi has been damaged as a result. South Africa is part of a semi-arid region, and it has been projected that, by 2040, even worse drought conditions will inevitably occur, partly because of the damage and degradation occurring in the wetlands (Yeld, 1997).

Urbanisation is reported to be doubling every 14 years, resulting in the overpopulation of cities. The imbalance between economic development in both the rural areas and the cities is the major causal factor. More than 50% of the population resides in large cities and it is estimated that 80% of South Africa's population will soon be urbanized (Yeld, 1997). The effects thereof are already being experienced with the resettlement of communities in both wetlands and floodplains, which have already witnessed disaster in certain regions of the country.

2.5 POLLUTION OF WATER RESOURCES

2.5.1 NON-POINT SOURCE POLLUTION

The main source of pollution in human settlement areas is non-point source pollution. This type of pollution cannot be traced to any one source. It arises and is diffused from a variety of sources. Some of the sources include water from rainfall, which flows over the landscape, gathering pollutants along the way, which then accumulate in water resources. The known primary activities that generate non-point source pollution are new development, construction, farming, grazing of livestock; manure production, pesticide and fertilizer use (United States Protection Agency, 2000).

Developed countries such as the United States realized as early as 1972 after their Congress passed the Clean Water Act that concentrating only on point source pollution was a grave mistake. Since then the United States has considered non-point source pollution as the primary cause of water quality problems (United States Protection Agency, 2000).

Programmes to control non-point source pollution were initiated and implemented in 1987, which include altering fertilizer and pesticide application methods and storing and properly managing manure from confined animal facilities. The control of urban runoff is achieved through a number of interventions including digging trenches, creating detention ponds at construction sites in order to hold, settle and retain suspended solids and associated pollutants (United States Protection Agency, 2000).

Managing non-point source pollution is an international challenge, as the practices and certain behaviours characteristic of the human race tend to be similar in many respects.

2.6 EFFECTS OF NON-POINT SOURCE POLLUTION GLOBALLY

Globally water pollution has become a serious concern owing to the fact that it affects the total ecosystem, animals, plants and humans. Humans are supposed to be the beneficiaries from the ecosystem but globally nations have realized that human activities are rebounding, thereby affecting the environment. In many countries individuals and communities are now facing the disastrous consequences of such activities. The following effects are common to all water polluters, as discussed in the Grinning Planet (2006).

- **Water related infectious diseases.**

In developing countries especially it has been found that water related diseases are most frequent because of either inadequate sanitation or its non-existence. Diseases including typhoid, cholera, intestinal parasites (amoebiasis, giardiasis, ascariasis and hookworm), enteric and diarrhoeal diseases caused by bacteria and viruses have occurred. Other diseases, though not directly caused by water contamination, have resulted in high mortality. These include bilharzia (schistosomiasis). It has been estimated that 200 million people have been affected by these waterborne and water related infections in 70 countries (Grinning Planet, 2006). Malaria, caused by the *Anopheles* mosquitoes that breed in stagnant waters, is also a huge problem. A number of other water related vector diseases exist, such as dengue fever problems, due to the fact that insects that cause them breed or feed near water. Therefore water pollution does not only reduce the water quality but can also result in serious diseases in humans.

- **Nutrient pollution**

A discharge of raw sewage from underdeveloped towns into water contains high concentrations of nitrates and phosphates that become plant nutrients to aquatic plants. The resultant algal bloom that occurs in the water is a serious problem. It causes death of certain plants that decompose in the water, and in the process, eutrophication takes place. The terrible side effect of eutrophication is that the quality of water is badly affected in that water may taste like mud or even have a musty/grassy smell. In addition to this, water may have colour, which is aesthetically bad. In some countries polluted waters have become unusable due to toxins produced by blue-green algae dying in water (Grinning Planet, 2006).

Similarly, activities such as agriculture, coastal development, stock farming and farm ranches have resulted in large quantities of nitrates and phosphorous compounds being discharged into water bodies thus providing plant nutrients.

A further consequence is that nutrient pollution in water has been found to trigger unusual outbreaks of fish diseases. Microorganisms known as *Pfiesteria* thrive in nutrient-polluted waters and are associated with large fish kills. Countries using fishing as an economic resource may lose their valuable income. It is important that raw sewerage is prevented from flowing into rivers and streams. It is necessary that blocked sewers should be acted upon as a matter of urgency, both to contain and remove pollutants thus preventing damage to water resources (Grinning Planet, 2006).

- **Chemical contamination**

Farming and industrial activities have been identified as major contributors to chemical pollution, either directly into the water bodies or through seepage as a result of the indiscriminate dumping of chemicals. Pesticide runoff from agriculture and homeowners' lawns has been washed into rivers and lakes by rain. Mercury discharged with effluent waste from industries occasions mercury poisoning in humans. Studies have revealed that mercury accumulates in aquatic animals, especially in fish. Humans contract mercury poisoning when they eat contaminated fish. Various other effects of pesticides have been documented. These include damage to the nervous system, liver damage and damage to DNA, contributing to a variety of cancers, damage to the reproductive and endocrine systems (Grinning Planet, 2006)

In the following sub-section a selected account of countries that have witnessed the effects of water pollution is provided.

2.7 UNITED STATES OF AMERICA

It is estimated that approximately 40% of lakes and streams in the United States are so heavily polluted that they cannot be used for either fishing or swimming. (Salt Lake Watershed, 2002). Amongst these pollutants are phosphates, nitrates and silt arising from agricultural activities. These pollutants utilise oxygen from the water, thus killing aquatic life. Sewerage overflows into rivers, carrying with it ammonia, bacteria and parasites from human waste and ending up in lakes. These may cause illness and death if this water is used as drinking water and if not purified.

A further account of lake pollution has been observed in the United States at the Onondaga Lake, downstream of Onondanga River in New York. The lake is regarded as amongst the most heavily polluted, due to non-point source pollution (Onondaga Lake Partnership, 1999). Serious pollution problems in Onondaga Lake developed primarily as a result of sewerage disposal and industrial discharges related to population growth and industrialisation. Efforts were initiated during the 1970's to restore the health of this lake and which remain ongoing. Such a solution has been possible and financially viable for the United States but not for South Africa or other underdeveloped countries. Restoration of Onondanga Lake is still ongoing and is successful.

Lake Erie, Huron, Michigan, Ontario and Superior form the Great Lakes in America. There are eight states bordering the Great Lakes: Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin. The Great Lakes provide 90% of the United States of America's supply of fresh water, which constitutes 18% of the world's water (Michigan in Brief, 2002). However, in the 1960's it was observed that these lakes were becoming polluted by industrial effluents and through non-point source pollution, which were accompanied by large quantities of phosphorous compounds and nitrates. These nutrients encourage the growth of aquatic plants including different types of algae.

Lake Erie pollution resulted in algal bloom that altered the water quality. The poor aesthetic quality thereof, such as odours in drinking water and the death of aquatic life, resulted from the lowered oxygen concentration in water. It was also discovered that domestic detergents used by laundries contained high concentrations of phosphorous that were finding their way into the water resources. In 1972 the State of Michigan imposed a phosphorous content restriction on laundry detergents sold in the state to prevent further pollution of the lake. During this period, the lake was declared dead and rehabilitation measures had to be taken to reverse the situation (Michigan In Brief, 2002). For rich countries such a programme is easy and feasible, but for developing countries such as those in the South African Economic Development Country region it is unaffordable.

The seriousness of water pollution has led to consideration of prosecution of those people who continue to pollute water resources against the environmental legislations enacted to protect the environment. In Latin America (Mexico City) a panel of eight legal and water experts prosecuted water polluters charged with polluting rivers and lakes (Cevallos, 2006). In 1992 a tribunal was set up in Amsterdam, Netherlands, which tried cases of water resource pollution in Africa, the Americas, Asia and Oceania. This reveals the commitment of some countries to fight water pollution.

Another example of commitment to a sustainable environment has been shown in Chicago, Illinois by the Joyce Foundation by protecting and restoring the water quality of Maumee River and its tributaries. This constitutes the largest river that enters Lake Erie and carries large quantities of pollutants (The Nature Conservancy, 2007).

2.7.1 BRITISH COLUMBIA, CANADA

Reinforcing the need to protect her water resources, the Government of British Columbia is attempting to tackle non-point source pollution through her Ministry of Environment (Environmental Protection Division, 1999). The government of British Columbia has enacted both legislation and regulations whereunder a Non-Point

Source Pollution Action Plan has been devised. It is noteworthy that Canada, of which British Columbia is a province, is regarded as a country where the quality of water is generally good. This report states "Non-point source water pollution is subtle and gradual, caused by the release of pollutants from many different and diffuse sources, largely unregulated, and associated with urbanization, agriculture, and other forms of land development".

Williams Lake in the Cariboo (British Columbia) was also polluted through cattle ranching in the area. An article published in the November 30, 2001 edition of 'Issue of the Envirozine' entitled" Great Lakes Portraits- Protecting a National Treasure", reported that overuse, neglect and population pressure have led to a decline in the health of certain lakes. As was observed, a growing population created serious pollution problems by destroying a vital wildlife habitat, thereby stressing the ecosystem even further. The experience of eutrophication in Lake Erie during the 1970s can be construed as a necessary alarm for both scientists and other role players (EnviroZOne, 2001).

It must be assumed that uMhlathuze Municipality is presently undergoing similar changes and may therefore be able to learn from this experience since two agri-villages have been established already.

2.8 AFRICAN STATES

2.8.1 LAKE VICTORIA IN NAIROBI, KENYA

Kenya has experienced serious problems as a result of non-point source pollution. According to the Associated Press Thursday, Nov. 4, 1999, Lake Victoria was being polluted by nutrients deposited in water from agricultural activities. In identifying the problem, the research team under Director General Pedro Sanchez needed to employ the use of a sophisticated satellite remote sensing device. The satellite was used to study soil types around the lake. In so doing the research team was able to identify a flow of nutrient rich sediments feeding into the lake. This plume of nitrogen-and –phosphorus –rich sediments acted as a feed to water hyacinth (Associated Press, 1999).

Approximately 30 million people were believed to be dependent on this resource for their livelihood. The hyacinth had caused water to stagnate in certain areas, resulting in the breeding of malaria-bearing mosquitoes and snails that host bilharzia parasites (Associated Press, 1999). Maureen Ongwae reported in the 'Business Daily' that hyacinth is presently choking boat business in Lake Victoria. Members of the community previously benefited from tourists who enjoyed navigating the lake by boats. However, due to infestation of the lake by hyacinth, normal navigation is no longer possible. Certain aquatic weeds such as hippo grass have also appeared, thereby accentuating the problem. Tourists can no longer cross from one side of the lake to the other to appreciate environmental diversity (Business Daily, 2008). Therefore, besides losing income from fishing and tourism, the community is now exposed to diseases such as malaria and bilharzia.

Another account documented in 'Africa Environment Outlook' concerned incidents where large numbers of flamingos died due to heavy metal poisoning in Lake Nakuru and Lake Bogoria. These originated from industrial effluents and agrochemicals deriving from poor agricultural practices producing chemical pollutants that ultimately flowed into the lakes. Wanyama wa Chebusiri of the BBC News reported on the 4th October 2006 that, "Kenya's Lake Nakuru is in danger of losing its famous pink shores due to environmental degradation and pollution" (BBC News, 2006). This account proved disturbing to the community as the lake provided a major source of income to the hotel industry as tourists used to visit the area to watch the birds. John Njoroge, manager of Sarova tourist resort even said, " Once you have less flamingos, or none at all, it will mean visitors will cancel their bookings and we will suffer" (BBC News, 2006).

However, the government incurred heavy criticism from politicians when it evicted informal settlements that were adjacent to the lake. Boyce Rensberger remarks as follows concerning Lake Nakuru, "Lake Nakuru is nowhere near Lake Erie and

Kenya's cities are environmental paradises compared with New York. But American style pollution is creeping up on Kenya and many other growing African countries almost faster, it seems, than the benefits of industrialization." Lake Nakuru is the major recipient of water pollution arising from the fast growing cities (Rensberger, 1973). The writer further projected that by the year 1990 the concentration of organochlorine would have increased tenfold in the lake. This scenario has indeed transpired with the consequence of multiple flamingo deaths, as witnessed in Kenya.

A fact -finding mission conducted in Lake Elementetia in Kenya revealed that the following factors have greatly affected the lake:
(1) Natural forests and woodlands had vanished due to deforestation, cultivation and animal grazing.
(2) Overuse of the lake through excessive abstraction of water from the tributaries of the lake also resulted in less recharge of the lake.
(3) The usual urban effluent discharge into streams flowing into the lake has contributed greatly to compounding the problem of lake pollution.

Lake Elementetia was once rated 5th wetland of international importance in 2005 as it provides refuge to threatened, vulnerable and endangered species of birds. Therefore, the team recommended, *inter alia*, that the wetland management plan for Lake Elementetia be finalized and implemented to minimize further environmental degradation (East African Wild Life Society, 2006).

2.8.2 LAKE VOLTA IN KUMASI, GHANA.

Kumasi is referred to as the Garden City of Africa according to Enoch Darfar Frimpong. The metropolis is presently growing at an alarming rate with the result that suburbs are materialising in previously uninhabited areas. Pollution control in such circumstances becomes a particularly difficult factor to monitor and enforce. Environmentalists have observed pollution of water resources from human waste and materials used in building. Attempts at creating awareness among communities have proved futile. Dumping and littering continues unabated (Frimpong, 2007).

Lack of access to waterborne sewerage has resulted in most raw sewerage being dumped directly into rivers. This constitutes a health risk as the same rivers are used for domestic purposes. At the present rate of pollution, Ghana is at risk of developing into yet another water stressed country on the African continent in the next few years (Frimpong, 2007). This would be disastrous for the Ghanaians, as water would have to be imported from other countries at high cost.

2.8.2 LAKE CHIVERO IN HARARE, ZIMBABWE

Water hyacinth has been identified as the most serious problem threatening Harare's main water supply, namely Lake Chivero. Studies have observed the weed to be one meter tall in certain parts of the lake. This spreading weed is soaking up oxygen and it prevents the rays of the sun from reaching the water surface. This has resulted in fish kills and the loss of other aquatic lives. The community has thus lost a source of food as well as income obtained through selling fish. As might be expected, the quality of water has dropped tremendously. Also, hyacinth has a high transpiration rate and this has resulted in the loss of high volumes of water from the lake (Science in Africa, 2005).

Environmentalists are seriously alarmed, attributing blame to industries for disposing trade effluent into water bodies. These effluents carry phosphates and nitrates amongst other pollutants, which consequently promotes the growth of hyacinth. Though an Environmental Management Act was enacted in March 2003, implementation thereof has not been successful due to the associated political upheavals in Zimbabwe. In 2005, when this report was issued, 40% of the lake had already been covered by hyacinth. This constitutes yet a further pollution statistic and can be extrapolated to be occurring on a global scale (Science in Africa, 2005). It may seem exaggerated, but the fact is that lakes and rivers are somehow linked. Therefore, the unwanted hyacinth can be carried over to another country by merely flowing in water. It is only necessary for one or two plants to multiply excessively as long as there are adequate nutrients in water.

2.8.3 LAKE KIVU IN EASTERN DEMOCRATIC REPUBLIC OF CONGO

Lake Kivu forms one of the largest lakes in Africa, lying on the border of the Democratic Republic of Congo and Rwanda. It supplies both water and fish to two million people and provides a link between the ports of Goma and neighbouring states. It has been discovered that the lake contains large deposits of methane gas and the fishing economy has now been greatly affected due to methane poisoning. Estimates by the United Nations Environmental Programme (UNEP) projected that the lake contains sufficient methane to power the United States for one month. This is definitely a large quantity of gas considering that sheer geographical size of the United States of America is. Scientists are conjecturing whether an explosion risk to the area might exist. Alternatively, the methane might be employed as a source of energy. Thus the expression, "Lake Kivu- A Time Bomb or Source of Energy" has been formulated. In fact, Lake Kivu, Lake Nyos and Lake Monoun have been termed Africa's Killer Lakes by United Nations Environmental Programme (Global Envision, 2007). These lakes cannot support aquatic life anymore due to pollution.

2.8.4 WATER POLLUTION IN SOUTHERN AFRICA IN GENERAL

Various studies by different researchers have identified similar pollution problems encountered in the Southern African Development Community region. The pollution trend is the same. The pollution of rivers, lakes and other water bodies from domestic and industrial wastes as well as run-off from agricultural activities all pose a potential threat to water resources in the southern region. Countries are yet to find ways to manage the population influx that result from urbanisation and the rapid development of cities if water resources have to be protected (Gibbs Magazine, 2007).

Water pollution results in negative effects on water quality, which indirectly or directly impacts on public health. Sifelani Tsiho cited polluted Lake Chivero in Harare in Zimbabwe, Lake Victoria in Kenya, Lake Tanganyika, Zambian lakes, and other water resources in other African states as constituting a cause for concern as the region is largely semi-arid (Gibbs Magazine, 2007) and, therefore, pollution of water resources further reduces the quantity of water available for use by people.

A lesson could be learnt from the information gathered from our neighbours as well as from abroad that pollution of Lake Mzingazi in South Africa may not only result in a serious water shortage, but could also stimulate the development of those dire circumstances witnessed by other Southern African Development Community countries. Thus, quicker action than anticipated is imperative. Any further extension of malaria risk areas in northern KwaZulu –Natal cannot be permitted, because it will only exacerbate the present prevailing problems where the burden of disease during epidemics is great.

2.9 SOUTH AFRICA

Pollution incidents have occurred in South Africa as well. The Hartebeespoort dam experienced a massive problem due to algal bloom. Despite a cleanup being conducted, a large financial injection was necessary to obtain a bioactive reducer to eliminate blue-green algae (Knoll, 2001). This proved to be expensive. In KwaZulu - Natal and specifically Richards Bay, Lake Nsezi still has unending problems due to hyacinth infestation demonstrating the existence of pollution in water. The Department of Water Affairs & Forestry has been striving to restrict this unwanted growth through chemical spraying, but it has nevertheless proved to be difficult to control.

Any observation of Lake Mzingazi indicates a surprising phenomenon. The water hyacinth which is a serious problem experienced nationwide has not yet infiltrated the lake.[1]

Mzingazi agri-village and Mandlazini agri-village settlement are located on the east and northwest boundaries of Lake Mzingazi. This raises various concerns because of the increasing numbers of livestock, which are accentuating the problem of soil erosion. Both phosphates and nitrate pollutants arising from agricultural and household waste further aggravate the situation. These contaminants usually increase the nutrients in water and the final result could be eutrophication. These settlements

1 Maharaj, N. 2006. Personal Interview.

were declared agri-villages to enable people to keep livestock. Though this was not suitable for the area surrounding the lake, political pressure compelled the municipality to allow residents of these villages to retain a limited number of livestock. It is a difficult process to monitor a sustainable number of livestock that the community may maintain. Therefore, there is a great need to create environmental awareness in the community in order to curb the pollution problem and arrest further escalation thereof. [2]

The 1997/1998 Status Report entitled 'Protection of Lake Mzingazi from Pollution' (Archibald, 1998) provided a means of graphically illustrating the potential pollution issues involved to the relevant authorities. The report did not constitute a product of scientific research,(section 8, page 16). Therefore, in order to inform policy makers, this study was undertaken to provide relevant data and information to inform policy and practice. The report further urges the municipality to engage in a process of identifying significant environmental factors that could result in lake pollution. It is further suggested in this report that it is necessary that the water quality status of the lake be constantly monitored.

In Mpumalanga Province environmentalists have discovered that Lake Chrissie or Chrissiesmeer as it is more commonly known as, is experiencing a similar pollution problem of raw sewage flowing into it from adjacent residential areas. Recent tests on water have exhibited high levels of *E. coli, Vibrio cholerae* and the presence of bilharzia parasite. Despite reports having been produced highlighting these issues, the Msakaligwa Municipality have not responded to the plea of the environmentalists. It is further asserted that this type of pollution has been occurring for eight years, with the result that the situation has reached environmentally disastrous proportions (News 24, 2005).

During September 2005, pollution in Lake Chrissie deteriorated so severely that the Mpumalanga health department had to cut off water supplies to three towns in the region in order to protect local residents from potential health hazards arising from a

[2] Bukhosini, R. 2006. Personal Interview.

pollution threat created by the nearby Chrissiesmeer Abattoir. The local municipality failed to control waste disposal which was being dumped into an adjacent reservoir. Residents in the region are also condemning the establishment of mines around the lake and the wetland. The feeling is that a further serious pollution threat might yet materialise from these mines, a development which will simply aggravate an already serious situation. Tour operators undertook legal action against the Msakaligwa municipality in terms of the National Environmental Management Act 107 of 1998, which states that anyone who fails to prevent the environment from being polluted may be charged with a crime. Only after such legal action was taken was Msakaligwa municipality compelled to ensure that funds were allocated for necessary water and sewage projects that will reduce further damage to the Chrissiesmeer ecosystem. During the 2007/08 capital budgets, the equivalent of 4.1 million US dollars was set aside for environmental projects. This constitutes a sizeable sum of money, which could potentially have been used to improve the lives of the people of Mpumalanga, but it is simply dissipated by poor maintenance and control on the local municipality's behalf (Lang, 2005).

Khulani Mavundla focused on yet another phenomenon occurring in Chrissiesmeer: The Matotoland (frog land) Eco-tourism Association conducts an annual frog hunt in the lake. This occurs on sequential weekends in November each year. People are taught how to catch frogs, identify and release them into the water. The importance of frogs to the environment has been stressed to the communities. The representative of the Matotoland Eco-tourism Association declared to the people during the frog hunt: "Abnormalities in frogs are the first signs of a polluted environment (News 24, 2005). Environmental awareness in communities is crucial so that they can participate in all activities meant to protect the ecosystem. An informed community is easy to work with because they have learnt to appreciate their habitat, thereby taking ownership of the problem themselves.

Another study has been conducted in the Western Cape Province at the Zeekoevlei, which is the largest fresh water lake in South Africa. The area is recognised as being an important regional recreational venue. Due to the fact that the lake forms part of the low-lying region, it is prone to pollution due to nutrient loading from its upstream watershed. Phosphorous compounds and nitrates have caused serious eutrophication due to algal growth in the lake. This has resulted in a complete change in species diversity. Since 1990 the Cape Town City Council has been seriously examining management plans that will assist in the rehabilitation of the lake (Harding, 1991).

Thus a review of the literature reveals that no doubt can exist relating to the phenomenon of water pollution particularly through non-point sources constituting a wide spread problem across many countries. As previously emphasized, South Africa's water resources are limited due to the fact that South Africa is classified as a semi-arid country. Southern Africa is therefore vulnerable to environmental changes due to this water resource limitation. Marty Matlock argued that in Southern Africa poverty is widespread, with large numbers of its people living on less than "a dollar a day", HIV/AIDS is a serious and a growing problem in many of the countries and its population is largely rural and heavily dependent on agriculture. (Encyclopedia of Earth, 2007).

This has been a general observation in all developing countries. Successive reports have demonstrated that the sustainable management of Africa's natural resources is one of the key factors in overcoming poverty. Achim Steiner writes, "The 20th century was an industrial age, the 21st century is becoming a biological one" (Africa Focus Bulletin, 2006). If nations are to survive in this world, they need to take the environment's ecosystems seriously. Therefore it is essential that the City of uMhlathuze undertake pollution prevention measures immediately as we have seen in other countries the effects of not taking timeous actions. It is this factor, which has led to the commissioning of this study.

2.10 SOUTH AFRICAN LEGISLATION DEALING WITH WATER QUALITY

2.10.1 CONSTITUTION OF SOUTH AFRICA

The importance of an individual's right of access to potable water is entrenched in the Constitution of South Africa Act 106 (1996). The Bill of Rights (1996) states that, "every person is entitled to a clean and adequate water supply". As a result, municipalities have a duty to ensure that water resources in areas of their jurisdiction are protected from pollution. Water needs to be both adequate and, crucially, life sustaining. Therefore, water pollution control forms a major function of the Water Services Authority in ensuring good quality water supply to the community of uMhlathuze.

2.10.2 NATIONAL ENVIRONMENTAL MANAGEMENT ACT

In terms of the National Environmental Management Act (NEMA) 107 of 1998 (Department of Environmental Affairs & Tourism, 1998), every individual should act responsibly and should be accountable according to the principle of "Duty of Care". In terms of section 28 of Chapter 7 of the Act, any person who has the inclination to pollute the environment has a duty to control such activities, which can lead to pollution or otherwise, undertake all measures possible to prevent pollution. This section places great emphasis on the duty of care and remediation of environmental damage. On occasions, individuals and communities may not deliberately pollute the environment but, it nevertheless does occur. The National Environmental Management Act incorporated section 30 to address such cases in order to prevent further environmental damage. This deals with all emergency incidents. The National Environmental Management Act 107 (1998) does therefore enable protection of water resources since they obviously form part of the environment. The act further clarifies the duties and responsibilities of all affected persons, whether authorities, industries or organs of state.

The National Environmental Management Act also permits any individual who realizes that environmental pollution is taking place as a result of ignorance or deliberate act, to take such person or organisation to court for causing damage to the environment. This means that even municipalities are not exempted from being prosecuted. It is therefore the duty of the Water Service Authority of uMhlathuze

Municipality to be proactive enough in order to eliminate pollution risks to the environment, which could result in huge environmental liability. To ensure this happens, Water Service Authority has established a new section in its organisational structure known as Pollution & Environment Section to manage this situation.

2.10.3 NATIONAL WATER ACT

The nation's water resources trusteeship falls under the Department of Water Affairs & Forestry Ministry. The National Water Act 36 (1998) is the enabling legislation of the Department of Water Affairs & Forestry. At present, both the National Environmental Management Act and the National Water Act apply the "polluter pays" principle in solving problems of environmental pollution. If an individual or organisation has caused environmental pollution, such a polluter must take reasonable measures to clean up and rehabilitate the affected area. These activities can result in huge financial expense. A polluter may become bankrupt if found guilty. However, in the case of rural areas, it may prove difficult to identify the polluter precisely. Therefore, the expenses incurred become the burden of the local municipality. The Pollution & Environmental Section undertakes policing to ensure that the relevant national environmental legislations to protect natural resources are enforced. Part 4 of Chapter 3 supports the National Environmental Management Act by stating the steps needed to be taken in the prevention and remedying of the effects of pollution of water resources as well as dealing with emergency incidents. Therefore, it is apparent that both pieces of legislation reinforce one another.

2.11 PREVIOUS STUDIES RELATED TO LAKE MZINGAZI.

In 1978 the Council for Scientific and Industrial Research first measured Lake Mzingazi water quality (Archibald, & Miller, 1979). This study was conducted because of a concern that rapid development due to industrialisation could impact negatively on the lake. However, the status report produced was not utilised nor were the recommendations of the report ever implemented. The data therefore remained as baseline information.

Approximately 30 years have elapsed since the report was compiled and development around the lake increases resulting in large numbers of people settling either formally or informally around the lake. In the light of these previous circumstances, an investigation should be undertaken to determine the present status of the lake. Though one does not know the condition of the lake at present, but it can be assumed from previous experiences, both locally and internationally, precisely what could materialise if proper planning to ensure pollution prevention in Lake Mzingazi is not undertaken urgently. This study needs to identify and verify any issues that could lead to possible pollution of the lake.

2.12 THE DUTY OF THE SOUTH AFRICAN GOVERNMENT

It is the responsibility of the national government to ensure that national water resources are protected from pollution and degradation. The Department of Water Affairs & Forestry is entrusted with overall responsibility for all national water resources by the South African government. The National Water Act constitutes the main legislation enforced by the Department of Water Affairs & Forestry. One of the major functions of this legislation is the prevention of water pollution and the making of recommendations in cases of any emergency (Chapter 3, Part IV), (Department of Water Affairs & Forestry, 1998).

The Department of Water Affairs & Forestry is unable to perform its pollution prevention duties satisfactorily without the proper monitoring of resources. In this manner, national water quality is established through The National Microbiological Monitoring Programme wherein all provinces are involved in the testing of water resources in their various areas of jurisdiction (Department of Water Affairs & Forestry, 1998).

However, such water should not only be of an acceptable quality, but furthermore an adequate quantity is also imperative. Section 5 of Chapter 2 of the National Water Act requires the establishment of a National Water Resource Strategy in which clarity is furnished as to how water resources will be protected, utilized and how society is to be involved in this process.

It is in the interest of the whole South African community that the principles of 'sustainability and equity' be firmly entrenched nation-wide. This is vital because water availability cannot be increased, as water resources are finite. It is necessary that, while we are utilising water resources for our benefit, we must be so diligent that our activities do not result in their damage. In this way a good legacy would have been left for future generations in that water resources would have remained usable, thus sustaining human lives. Similarly we would have left posterity their equitable share of the environment required for their survival. These two central guiding principles should be observed. There should be a balance between present human activities and the environment to ensure sustainable development in our communities is practiced at all times for the benefit of our progeny.

Furthermore, South Africa is a signatory to the Rio De Janeiro Declaration of 1992 wherein the international community made a commitment to take care jointly of "mother" earth, (Department of Environmental Affairs & Tourism, 1998). South Africa, through her Department of Environmental Affairs & Tourism managed to compile her first Environmental legislation, (The National Environmental Management Act of 1998) as a measure towards ensuring a cleaner environment.

It is still difficult in some areas to achieve the goals of the National Environmental Management Act, the reasons being that most old industries were built prior to the passing of this act. Such industries either need to change outdated processes and structures even before newer and state of the art new technologies are applied. The second problem encountered is the attitude of certain process managers. They feel their industries have used old technology in operation without complaints. Thus, their argument revolves around why they need now to undergo the expenses of changing technology. Their goal is high production with minimum expenses. Environmental consideration and protection is not in their vocabulary.

While there is a strong need to enforce legislation, the law enforcement officer is faced with tough decisions to make. Does he/she close non-complying industries or allow them time to steadily adapt and change? Municipalities throughout the country receive income through levies, taxes and rates from these industries. Similarly, a large proportion of the population in these communities benefit from employment derived from the same industries. Yes, change is happening but it will take time before all industries comply. However, our National Government has introduced an Environmental Management System for industries through the international standard known as International Standard Organisation (ISO- 14001) for the protection of the environment. In terms of this standard, all organisations should establish and implement management systems that will enable them to reduce and minimize waste production in their processes. They are, of necessity, required to show commitment as to how they are going to maintain continuous improvement of the environment. This presents a major undertaking, which should be supported by top management, as it usually requires a large financial input to rectify and rehabilitate negatively impacted areas.

2.13 RESEARCH FINDINGS ALREADY IN USE

In 1979, certain studies were conducted by Archibald *et al*., (1979) wherein they documented Lake Mzingazi water quality characteristics. However, there was no subsequent follow up of these studies and their recommendations were not implemented. The investigation method and the sampling positions established at the time of the original study will again be used in this study. The sampling points were chosen in such a way that all rivers and streams entering the lake were considered. This was and remains important because these rivers pass through human residences and settlements. In addition pollutants emanating from this source could wash off and flow into the lake. Data is available from the previous study although it could not prove anything specific at the time. However, it may still be used as baseline information to compare the results of the current study. In this way, any possible variations can be identified and an investigation can be conducted if circumstances warrant it.

In 1985 the Mzingazi Water Purification Plant, situated at the southern side of the lake, experienced difficulties with its water filters. The filters were experiencing regular blockages and required to be replaced frequently. This constituted an unusual occurrence in their operation. An investigation discovered that vegetable growths were blocking the sand pores in the filters. Samples taken from the lake verified the fact that a sudden growth of algae on the water surface had occurred. This phenomenon is known as algal bloom. These will normally arise where a water resource receives large quantities of phosphates and nitrates. No evidence of any pollution source was identified. However, it is suspected that mainline sewerage manholes especially from residential suburbs such as Birdswood on the western side of the lake, Arboretum on south western side and Meerensee on the eastern side could have overflowed, resulting in large volumes of raw sewage polluting the lake, before repairs could be made. The main problem with the sewerage system is that it depends more on gravitational flow and, as a result, manholes are found upstream and close to rivers. Unless preventative measures are undertaken, there is nothing that can stop a reoccurrence of algal bloom. [3]

Fishing activities by the local communities, namely Mzingazi and Mandlazini, have been observed during the sampling of the lake. Since the boats used are of substandard quality, the likelihood always exists that certain of these crafts might become damaged and consequently disintegrate in water. The possibility that they might rot resulting in pollution of water exists. Human agricultural practices have resulted in deforestation and removal of natural vegetation thereby disabling the wetland's filtration system. Bare soil is further eroded during rainfall, pushing silt into the rivers and the lake. This is bad for the lake because it then promotes aquatic plant growth on the water surface. As has been mentioned previously, this may result in eutrophication in water. When this occurs, water purification operations may be in jeopardy due to filter blockages. As a result of this, water may have a bad smell and/or bad taste. Though this may not constitute a health problem *per se* it causes doubt as to the purity of the drinking water. It is a warning however, to those monitoring the water quality that toxin producing blue-green algae could emerge. Toxins cannot be removed by normal purification method and therefore pass on into the reticulation system. Poisoning of the people drinking such contaminated water could occur, thus seriously affecting their health. The integrity of the service provider, namely the Water Service Authority, could then be badly tarnished and may suffer damages due to claims by affected individuals.

[3] Maharaj, 2003. Personal interview in July 2003: uMhlathuze Municipality Laboratory, Richards Bay

2.14 SUMMARY

The chapter has reviewed certain particular available literature relevant to the topic in question. The purpose, therefore, was to identify suitable information that could support and assist in conducting the study. Books written by both local and international authors were consulted. Research reports previously produced in this field, particularly relating to Lake Mzingazi, were scrutinised in order to identify any gaps needing further study.

Highlights of both local and neighbouring countries and international incidents of pollution were described. Documented information identified uncontrolled and unplanned human activities as being crucially responsible for pollution of water resources. Richards Bay is at present experiencing a similar trend in industrial development off course accompanied by population influx and migration. Similar effects were observed in the literature review in other countries. It is, therefore, extremely necessary that a study be conducted in Lake Mzingazi in order to determine to what an extent the water quality has been affected. If not contaminated, what are the pollution threats we are faced with? Are there any requirements that should be addressed to prevent pollution from occurring? This can only be known if the study is undertaken.

As mentioned previously, the 1997/98 report of the Council for Scientific & Industrial Research indicated that a scientific study should be undertaken by the uMhlathuze Municipality to ensure that suitable action is taken to protect the quality Lake Mzingazi water quality. Due to continuous development and settlement of communities in eco-sensitive areas around the lake, it calls for urgent action to be taken.

Issues of livestock farming should be addressed, as there is no control of the numbers that should be kept by each homestead especially in the so-called agri-villages. It is only a matter of time before the carrying capacity of the land would be exceeded. Such an investigation cannot be performed in this study due to time constraints. This would require establishing a forum of all interested and affected parties to handle such matters.

3 CHAPTER 3: RESEARCH METHODS

3.1 INTRODUCTION

The study aims to evaluate the drinking water quality in Lake Mzingazi by determining both the physico-chemical composition and bacteriological status of the water.

3.2 TYPE OF RESEARCH

The research is classified as ***environmental epidemiology*** as it endeavors to determine the environmental factors that could result in a negative health impact on the community due to drinking of polluted water from the lake. (Katzenellenbogen *et al*., 1997). By being aware of these factors, such as water resource pollution and its health effects, preventative measures can be implemented to protect the community from waterborne diseases such as cholera, gastroenteritis and typhoid (Benenson, 1990).

3.3 METHODS

3.3.1 STUDY DESIGN

An observational descriptive and cross sectional study design was used with the purpose of quantifying pollutants in the water. The study involves a secondary analysis of data obtained during the period 1998 to 2005 and comparing it to primary data collected in 2006 to ascertain if there are any noticeable trends in water pollution. All data measured were then compared to the Quality of Domestic Water Supplies Assessment Guide (Department of Water Affairs & Forestry, 2002). Analysis of such data was in terms of set allowable limits of these guidelines, which specify the allowable level for each variable in order for a water resource to be suitable for domestic water use.

Environmental surveys were conducted in Mandlazini agri-village and Mzingazi agri village in order to observe and identify human practices in and around Lake Mzingazi, which could pose a pollution threat.

3.4 SAMPLING

3.4.1 SAMPLING STRATEGY

Sampling of the lake was planned in such a manner that it would cover both the rainy season and the dry winter season of the year. The strategy conceived was to ensure that any physico-chemical and biological changes occurring in the lake during different seasons of the year were captured. It would be expected, for example, that rain would wash more pollutants into the lake during the summer.

3.4.2 SAMPLE SIZE

A representative sample was obtained with sampling points being taken from the perimeter of the lake and in relation to the tributary rivers that enter it. Sample points were then allocated to each river entry point in order to capture pollutants at its source. Seven rivers were identified that flow into the lake. These were Phayeni River, Khondweni River, Mdibi River, Mandlazini River, Nkoninga River, Golf Course Stream and Mzingazi River. Three more sample points were taken at different depths in the centre of the lake - surface water, at 4m, and 9m. A further sampling point was at the lake outflow. A total of 12 sampling points were used for the study. Three specimens were taken at each sampling point at different distances from the shoreline. Specimens were collected from all 12 points monthly, starting from June 2006 to November 2006. Samples taken during 1998 to 2005 were not taken regularly due to the fact that the boat navigators were members of the Fire and Rescue crew and were not available at some schedule times, as they had to attend to emergency situations.

Table 1: Twelve sample point positions in Lake Mzingazi located using Global Positioning System.

Old Sample ID	New Sample ID	Location	GPS Coordinates X	GPS Coordinates Y
MZ1	SWLM01	Lake Mzingazi-Mzingazi River	S28.76778	E32.08339
MZ2	SWLM02	Lake Mzingazi-Golf course fairway14	S28.77312	E32.09144
MZ3	SWLM03	Lake Mzingazi-G.C. fairway 1	S28.76893	E32.1013
MZ4	SWLM04	Lake Mzingazi-Phayeni stream	S28.76775	E32.10389
MZ5	SWLM05	Lake Mzingazi-End of Mzingazi	S28.75288	E32.1234
MZ6	SWLM06	Lake Mzingazi-Mdibi inlet	S28.72751	E32.14286
MZ7	SWLM07	Lake Mzingazi_ Mandlazini 01	S28.73206	E32.12733
MZ8	SWLM08	Lake Mzingazi-Mandlanzini 02	S28.74343	E32.11469
MZ9	SWLM09	Lake Mzingazi-Centre1-4Metres	S28.74959	E32.11664
MZ10	SWLM10	Lake Mzingazi-Centre2-12Metres	S28.75849	E32.10878
MZ11	SWLM11	Lake Mzingazi-Red Bank	S28.75047	E32.09782
MZ12	SWLM12	Lake Mzingazi-Nkoninga stream	S28.75474	E32.07711

* SWLM = Surface Water Lake Mzingazi

3.4.3 COMMUNITY FACILITATION

To facilitate community involvement, it was necessary to conduct explanatory meetings with the councillors and Indunas of the tribal area. Mandlazini and Mzingazi agri-villages were included as the lake is located on their land. The communities would not have been pleased to witness outsiders coming in and out of their area without their knowledge and awareness as to what was happening. This consideration was therefore important for the safety of both the researcher and his team. The information-sharing meeting explained the purpose of the research and why it was important to prevent pollution of the lake. Community leaders informed the research team that the reasons supplied were satisfactory and that the community was willing to give the research its full support. The second issue was that of community participation. Such involvement would arise where measures needed to be taken to mitigate situations where possible pollution was noted. Therefore, it was important that proper groundwork should be done in order to gain the trust and support of the communities.

Following consultation with the community leaders, site visits were undertaken to the various sample points around the lake to check accessibility by boat. The most recent report (1997/98) was studied and evaluated in order to identify relevant issues of concern such as risks and the safety of the research team (Archibald, 1997).

3.5 DATA SOURCES

3.5.1 DATA COLLECTION

The study measured the quality of the lake water by quantifying the relevant water quality parameters set by the South African National Standard (SANS 241: 2006). The information obtained from the study will assist the Water Service Authority in providing a better service to the community and enables it to function as a more effective regulatory body. The data used in this study is numerically continuous data. Primary and secondary data were employed for comparative purposes.

3.5.2 PRIMARY DATA

A motorized small boat was used to access the sampling sites since it was difficult to reach the feeder streams via the banks due to vegetation overgrowth and the presence of hippos in the lake, which made it unsafe. The boat launch site is situated on the southwestern bank of the lake adjacent to the Mzingazi Water Purification Plant. The Fire and Rescue team boat-crew ensured the safety of both the researcher and the sampling team. Suitable specimen bottles were used to collect samples of water from each site. During each sample run, 36 samples were taken. Twelve were for biological analysis and the rest (24) were for physico-chemical analysis. These were delivered to UMhlathuze Water Board Laboratory for analysis immediately after having been collected. Six Sample runs were conducted monthly, starting from June 2006 to November 2006. UMhlathuze Water Laboratory was chosen since it has an ISO-17025 accreditation by the South African National Accreditation Standards (SANAS).

3.5.3 SECONDARY DATA

Secondary data for the period 1998 to 2005 was obtained from the municipality of uMhlathuze Engineering Department. Contacts were made with the City Engineer requesting the use of this data for this study. The request was granted and the necessary documents were issued to the researcher. No restrictions were imposed, as it was strongly believed that the study could benefit both the municipality and the communities around the Lake. The 1998 to 2005 data had been collected from the similar 12-sample points used for primary data collection in 2006. During this period, the lake was supposed to be sampled bimonthly. [4] However, it was difficult to schedule regular sampling as the boat-crew; (firemen) may be engaged in emergencies. Secondly entering the lake would depend on suitable weather conditions. In 2003 sampling was not done because of a boat breakdown. Therefore, only available data was used.

3.5.4 ENVIRONMENTAL SURVEYS IN AND AROUND THE LAKE

It was also necessary to conduct surveys around the lake to identify any potential conditions that could result in pollution of the lake. Photographs representing different areas were taken to verify any degradation around the lake that was used as evidence of what was taking place. Where obvious sources of pollution were identified, investigations were conducted immediately to identify their origin.

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[4] Maharaj, N, 2006 – personal communication.

The environmental surveys also served to identify human activities either in the lake or on the wetland draining into the lake. Humans are usually responsible for water resource pollution because of their practices in and around lakes, such as stock farming, crop cultivation, and the resettlement of homesteads close to the waters edge.

3.6 RELIABILITY OF MEASUREMENT INSTRUMENTS

Measurement instruments in the laboratory were calibrated as per manufacturer's method to ensure reliability and repeatability of measurements.

3.6.1 MEASURES TO ENSURE VALIDITY

The laboratory assistants were trained and supervised by the laboratory technician, which ensured that the analytical methods followed were those prescribed by the South African Bureau of Standards. Freshly prepared analytical reagent solutions were used and modern efficient instruments were employed during analysis.

3.6.2 REDUCTION OF BIAS

- **MEASUREMENT BIAS**

All instruments used in the laboratory and in the field were calibrated as per the manufacturer's instructions and the laboratory analysts were supervised to ensure that correct methods were adhered to.

- **SELECTION BIAS**

Selection bias was minimized, as three specimens from each of the 12 sample points were used from selected areas around the lake and monthly sampling ensured that seasonal bias did not occur. All sample points were allocated Global Positioning System coordinates for ease of identification, thus ensuring that a similar spot was used each month.

3.7 DWAF STANDARDS AND WATER GUIDELINES

Both primary and secondary data processed were compared to the Department of Water Affairs & Forestry Guidelines: Quality of Domestic Water Supplies Assessment Guide, 2002. This guide uses certain variables that determine the water class and, therefore its assessment for human use. The variables can supply information that categorises whether the water would be suitable for drinking, cooking, the washing of clothes, irrigation or bathing.

Therefore, without directly testing the health of people exposed to the water, the guide is able to determine the risk of what health effects one could expect under certain circumstances.

3.8 VARIABLES

The Quality of Domestic Water Supplies Assessment Guide (Department of Water Affairs & Forestry, 2002) was used to select the variables measured in this study. The variables provide numerically continuous data. They serve to quantify the selected physico-chemical and microbiological constituents in water. Through these variables, the study was able assess and identify whether the water quality in Lake Mzingazi is polluted and whether it is suitable for human consumption. In order to ascertain the source of pollution, environmental surveys around the lake were performed.

3.8.1 PHYSICAL ANALYSIS

- Water pH (pH units)
- Suspended Solids (mg/l)
- Turbidity (NTU)
- Conductivity (mS/m)

3.8.2 CHEMICAL ANALYSIS

- Fluorides (mg/l)
- Nitrates (mg/l)
- Total Phosphates (mg/l)
- Chlorides (mg/l)
- Chlorophyll a (ug/l)

3.8.3 MICROBIOLOGICAL ANALYSIS

Faecal coliforms (count per 100 ml)

Analytical testing methods recommended by SANS 241: 2006 were used for all variables.

3.9 DATA HANDLING

3.9.1 DATA PROCESSING

The raw data acquired from the uMhlathuze Municipal Engineers Department (secondary data) were grouped in terms of sample points for each variable. The values for each variable at each sample point were summed and averages were calculated. The averages were then used to determine summary statistics for the entire lake for each variable. The summary statistics depict the mean, the standard deviation and the median for each variable for the lake water quality during the period from 1998 to 2005.

The values for the primary data obtained during 2006 were processed in a similar manner to the existing data. The two sets of processed data were then compared point by point to the Department of Water Affairs & Forestry Guidelines in order to obtain a meaningful comparison and interpretation of the physico-chemical quality as well as the microbiological content of the lake water.

3.10 STATISTICAL METHODS

All data was summarised and presented graphically where appropriate.

- The t-tests for the means of the variables were calculated and were then used to find p-values from the statistical tables.
- 95% Confidence intervals (CI) were also determined to check significance of the results.
- Graphical presentation of means of variables against time (years) from 1998 to 2006 was also undertaken.
- Difference between two means was used to calculate p- values where the threshold value of p was set at 0.05 for the two sets of results obtained: 1998 to 2005 and 2006.

3.10.1 LIST OF POSSIBLE CONFOUNDERS

It was necessary to consider the influence of the weather on the data.

3.11 ETHICS AND PERMISSION

The research project was registered for partial fulfillment of the Master of Public Health degree. Ethical approval for the study was obtained from the University of KwaZulu-Natal Biomedical Research Ethics Committee.

Permission to conduct the study in the lake was obtained from community leaders (democratically elected councilors and rural tribal Izinduna) as well as from the uMhlathuze Local Authority. Permission to utilize secondary data was also obtained from the uMhlathuze Local Authority.

3.12 SUMMARY

In this chapter, the aims of the study and details of the methods used to achieve the research goals of the study were described. The type of research undertaken as well as the study design is described. Data sources are identified and the types of variables selected that are relevant to the study are described.

Therefore, the study stands on its own and will prove to be valuable to both the Council of uMhlathuze Municipality and the communities. Further studies would be necessary to look at the projected trend in pollution and the time it would take to reach the Department of Water Affairs & Forestry limits. The uMhlathuze Municipality should also commission a study that will come up with the plan to manage the water resource.

4 CHAPTER 4: RESULTS

4.1 INTRODUCTION

The results of the study are presented in this chapter with the help of tables as well as photographs that were taken during the environmental survey carried out on the lake. The water quality data were summarised in frequency distribution table and measures of central tendency used. The photographs represent the different types, areas and sources of pollution.

4.2 WATER QUALITY IN LAKE MZINGAZI BETWEEN 1998 to 2005 AND 2006

The quality of the lake water is summarised using the overall means obtained from all sample points for each variable during the period of 1998 to 2005 (Table 2) using secondary data and also for the study year 2006 (Table 3) for which primary data was collected.

The data from these two periods is combined and compared in Table 4.

Table 2: Overall Water Quality of all 12 Sample Points from Lake Mzingazi for the period 1998 to 2005.

	pH	Suspended Solids mg/l	Conduc-tivity mS/m	Turbidity NTU	Chlorides mg/l	NO_3 mg/l	Fluoride mg/l	Total Phosphate mg/l	Chloro-phyll a ug/l	Faecal Coli /100ml
Mean	7.75	16.21	43.46	3.65	79.1	1.83	0.23	0.52	1.09	3.00
Std. Error	0.03	0.89	0.36	0.11	0.1	0.05	0.00	0.02	0.13	1.00
Median	7.77	15.86	43.39	3.55	79.0	1.81	0.22	0.50	1.08	3.00
Std. Deviation	0.09	3.10	1.24	0.39	0.3	0.19	0.02	0.06	0.44	2.00
Range	0.36	10.01	3.89	1.20	1.2	0.60	0.05	0.21	1.18	7.00
Minimum	7.55	12.53	42.01	3.15	78.4	1.57	0.21	0.45	0.42	1.00
Maximum	7.91	22.54	45.90	4.35	79.6	2.17	0.26	0.66	1.60	7.00

Table 3: Water Quality of all 12 Sampling Points from Lake Mzingazi in 2006

	pH	Suspended Solids mg/l	Conduc-tivity mS/m	Turbidity NTU	Chlorides mg/l	NO_3 mg/l	Fluoride mg/l	Total Phosphate mg/l	Chloro-phyll a ug/l	Faecal Coli /100ml
Mean	7.84	6.79	44.79	2.55	90.03	0.48	0.22	0.19	2.65	6.00
Std. Error	0.01	0.68	0.44	0.16	0.11	0.03	0.02	0.07	0.11	1.00
Median	7.84	6.50	45.23	2.34	90.00	0.46	0.23	0.08	2.77	5.00
Std. Deviation	0.04	2.35	1.54	0.54	0.39	0.12	0.05	0.26	0.38	4.00
Range	0.12	7.83	5.50	1.63	1.33	0.34	0.14	0.79	1.33	14.00
Minimum	7.78	3.83	39.92	1.98	89.33	0.34	0.14	0.04	1.97	2.00
Maximum	7.90	11.67	45.42	3.62	90.67	0.67	0.29	0.83	3.30	16.00

Table 4: Water Quality Status Averaged from all 12 Sample Points for Lake Mzingazi for 1998 to 2005 (A) and 2006 (B).

	pH		Suspended Solids (mg/l)		Conductivity (mS/m)		Turbidity (NTU)		Chlorides (mg/l)		Nitrates (mg/)		Fluorides (mg/l)		Total Phosphates (mg/l)		Chlorophyll a (ug/l)		Faecal Coliforms /100 ml)	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Mean	7.75	7.84	16.21	6.79	43.46	44.79	3.65	2.55	79.1	90.0	1.83	0.48	0.23	0.22	0.52	0.19	1.09	2.65	3.00	6.00
Std Error	0.03	0.01	0.89	0.68	0.36	0.44	0.11	0.16	0.10	0.11	0.05	0.03	0.0	0.02	0.02	0.07	0.13	0.11	1.00	1.00
Median	7.77	7.84	15.86	6.50	43.39	45.23	3.55	2.34	79.0	90.0	1.81	0.46	0.22	0.23	0.50	0.08	1.08	2.77	3.00	5.00
Std Deviation	0.09	0.04	3.10	2.35	1.24	1.54	0.39	0.55	0.30	0.39	0.19	0.12	0.02	0.05	0.06	0.26	0.44	0.38	2.00	4.00
Range	0.36	0.12	10.01	7.83	3.89	5.50	1.20	1.63	1.20	1.33	0.60	0.34	0.05	0.14	0.21	0.79	1.18	1.33	7.00	14.00
Minimum	7.55	7.78	12.53	3.83	42.01	39.92	3.15	1.98	78.4	89.3	1.57	0.34	0.21	0.14	0.45	0.04	0.42	1.97	1.00	2.00
Maximum	7.91	7.90	22.54	11.67	45.90	45.42	4.35	3.62	79.6	90.7	2.17	0.67	0.26	0.29	0.66	0.83	1.60	3.30	7.00	16.00
Limits	**5.0 - 9.5**		**0 - 25**		**0 - 150**		**0 - 5**		**0 -200**		**0 --- 10**		**0 - 1. 0**		**0—0.25**		**0 - 5**		**0 - 10**	
t test	-3.1655		8.3885		2.3302		5.7206		-70.3443		20.8103		0.6433		4.2841		-9.2952		2.5095	
p-value	0.01>p>0.001		p< 0.001		0.05>p>0.02		p<0.001		p<0.001		p< 0.001		p > 0.5		p< 0.001		p< 0.001		0.02>p>0.05	

* Limits from SANS 241:2006

4.3 COMPARISON OF THE QUALITY OF WATER IN LAKE MZINGAZI FOR THE PERIOD 1998 to 2005 AND 2006.

Table 3 presents all the means for the period 1998 to 2005 and 2006. The Difference between Means t-test was used in order to determine whether the difference between these periods were significant statistically.[5]

- pH: .There was a significant change in pH during the two periods ($0.01 > p > 0.001$)
- Suspended Solids: There was a statistically significant ($p < 0.001$) sharp drop in suspended solids in the lake water between the period 1998 to 2005 and a 2006.
- Conductivity: There was a statistically significant ($0.05 > p > 0.02$) change observed in conductivity of the water between the values for the period 1998 to 2005) and the values for 2006.
- Turbidity: $p < 0.001$. The difference is statistically significant. Turbidity shows a decrease from the period of 1998 to 2005 and 2006.
- Chlorides: There is a noticeable and statistically significant ($p < 0.001$) increase in chlorites from the period of 1998 to 2005 and 2006.
- Nitrates: The difference was statistically significant ($p < 0.001$) decrease in nitrates observed from the period 1998 to 2005 and 2006.
- Fluorides: $p > 0.5$. The difference and fluoride concentration was not statistically significant between the mean for the period 1998 to 2005 and 2006.

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5 $$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{SD^2}{n_1} + \frac{SD^2}{n_2}}}$$

(Swinscow, 1983).

where x_1 represents the means for (1998 to 2005), x_2 the means for 2006;

SD_1 and SD_2 are the standard deviations for the samples respectively

n_1 and n_2 are the number of sample points.

The p values were determined from calculated t-tests.

- Total Phosphates: There is a statistically significant ($p < 0.001$) decrease in total phosphates from the period 1998 to 2005 and 2006.
- Chlorophyll: There was a noticeable and statistically significant ($p < 0.001$) increase in the value of chlorophyll a for the period 1998 to 2005 and 2006.
- Faecal coliforms: The difference is statistically significant. There was a statistically significant ($0.02 > p < 0.01$) decrease in the value of faecal coliforms from the period 1998 to 2005 and 2006.

Except for fluoride all the values of water quality measurements were significantly different between the average value for 1998 to 2005 and the survey year 2006.

4.4 ENVIRONMENTAL SURVEY RESULTS

The following photographs demonstrate the condition of the lake shoreline taken from the boat at different places around it during 2006, and typified the various lakeside environmental conditions. They highlight areas that need special attention, as they could constitute a potential pollution problem in the future. The photographs showed human practices and activities in and around the lake. Each photograph presents evidence of what was observed and is accompanied by a short explanation.

Figure 2: Illegal Water Abstraction from Lake Mzingazi in 2006

It was discovered that the golf course estate was illegally extracting water from the lake. The problem herewith lies with pollution that may be introduced into water during pump repairs when pump failure occurs.

The Water Services Authority has been tasked by the Department of Water Affairs & Forestry to be responsible for all water resources under the area of its jurisdiction. Therefore such abstraction undermines this responsibility and as a result part of water usage would be unaccounted for. Illegal water extraction would result in a loss of income to the municipality since this water use is not metered and therefore no charge is made for it.

Figure 3: Removal of Vegetation at the Banks of Lake Mzingazi in 2006

The maintenance of the banks of the lake by the Meerensee Golf Estate was very poorly undertaken. Natural vegetation such as grass and shrubs had been removed, thus promoting soil erosion. The silt from soil erosion provides good nutrition to aquatic plants. As evidence of this, *Phragmites, Typha and Cyperus species* were observed all along the banks of the lake. It was also observed that opposite the entry point of the Khondweni River on the eastern bank large quantities of soil and silt had been transferred into the lake. Silting has allowed aquatic plants to grow from the eastern bank encroaching on the lake. Similarly, on the western bank at about same position, plants of a similar type are growing towards the centre of the lake due to soil deposition which as a result of erosion along the Mandlazini River. These two sand spits are about to meet which will then divide the lake into two and make boat navigation difficult if not impossible.

Figure 4: Improper Land use Along the Banks of Lake Mzingazi in 2006

Along the Mzingazi agri-village, communities had planted large gum tree plantations on the banks of the lake. These may not constitute pollution *per se*; but it nevertheless may attract people to use the area for toilet purposes as it was observed that a lack of sanitation facilities already exists. Eucalyptus trees have a very high water usage and therefore their planting along the lake causes depletion of the fragile water resource. The growth of aquatic and terrestrial plants along the banks of the lake is an indication that the lake is shrinking in size.

Figure 5: Improper Allocation of Residential Stands and Agricultural Land in Close vicinity To Lake Mzingazi in 2006

Improper settlement of communities in close proximity to the lake constituted a major pollution threat. Human settlements were found less than 3 meters from the lakeshore in some places. The buffer zone initially set between the lake and the residential area by Mandlazini Trust in 1997 had been drastically reduced and, therefore, increased the pollution risk to the lake. In most of the homesteads, sub-standard pit latrines were observed. Pit latrines are unsuitable in such an eco-sensitive area as seepage of the contents could occur into the lake. As a minimum, it might be expected that at least conservancy tanks be used and be emptied when full in order to prevent groundwater seepage and sewerage overflow into the lake.

No suitable road infrastructure for waste removal trucks existed and, as a result, domestic waste was found dumped next to the banks of the lake. It was left to nature to play a role in ensuring either the degradation of waste or allowing the rain to wash off some or all of it into the lake water. Either way this would have negative impact on the water resource. Pollution may occur and that will not only be to the detriment of the people who have caused it but to everyone who ought to benefit from the lake.

Agricultural activities were observed along the banks of the tributary rivers of Lake Mzingazi and at some instances on the banks of the lake itself. As observed, vegetation had been removed and soil erosion was occurring, with a possibility of water pollution. Where crop cultivation is taking place, people are inclined to use fertilizers to promote or improve the yield. While this may be suitable for the farmer and crop, it also promotes and accelerates aquatic plant growth if washed by rain into a water resource.

Figure 6: Pollution by Water Lettuce from Golf Course in Lake Mzingazi, 2006

Water lettuce (*Pistia stratiotes*) is observed in this photograph on the western side of the lake. However, investigation suggested that these could have originated from the eastern side, namely from the golf course. Ponds at this public facility were found to contain this type of the plant. It is possible that its source could also have been the Meerensee suburb that is close to the golf course. Some of these plants could have possibly been washed into the lake by storm-water. Water lettuce constitutes a water surface growth, which could have potentially disastrous consequences. These plants can produce geosmin, which is a complex compound responsible for bad odours and bad taste in water.

Figure 7: Soil Erosion on the banks of Lake Mzingazi, 2006.

The effects of stock farming were observed on the banks of the lake adjacent to Mandlazini agri-village. Livestock are allowed to drink directly from the lake. In such areas, increasing amounts of faecal coliforms contamination of the water is likely due to pollution with livestock faeces. Besides, water contaminated with cow dung and urine smells bad and is unpleasant to drink. Secondly, soil erosion caused by livestock convey into the lake silt that is rich in plant nutrients.

The improper human practices that were observed around the lake could result in degradation of water resources, similar to what has occurred elsewhere and which required vast sums of money to rehabilitate. South Africa is presently in the process of improving the lives of her people by making potable water available for everyone. South Africa overall is a semi-arid country due to insufficient rain precipitation. It is simple common sense, therefore, that available water resources must be preserved.

This study was implemented at a very opportune time not only to evaluate the water quality in Lake Mzingazi but also to warn people to prevent an irreversible situation from occurring both to themselves and future generations.

The following activities were observed from the communities around the lake:

- Land cultivation along banks of rivers that enter Lake Mzingazi.
- The use of fertilizers by the communities.
- Livestock farming in Mandlazini and Mzingazi.
- Watering of livestock directly in the lake.
- Overflowing conservancy tanks from Mandlazini schools.
- Development taking place at the Meerensee Golf Estate.
- Illegal fishing by communities using substandard boats.
- Rain wash-offs from roads.
- Livestock kraals in Mandlazini and Mzingazi.
- Pit-latrines from homesteads situated in close proximity to the lake.

These activities could cause a negative impact to the health of the ecosystem if they are not properly managed.

4.5 TRENDS IN MEAN ANNUAL WATER QUALITY VARIABLES IN LAKE MZINGAZI 1998 TO 2006

The aim of this section is to determine whether there were trends in pollution occurring during the period 1998 to 2006. The annual mean value of each variable was plotted against time.

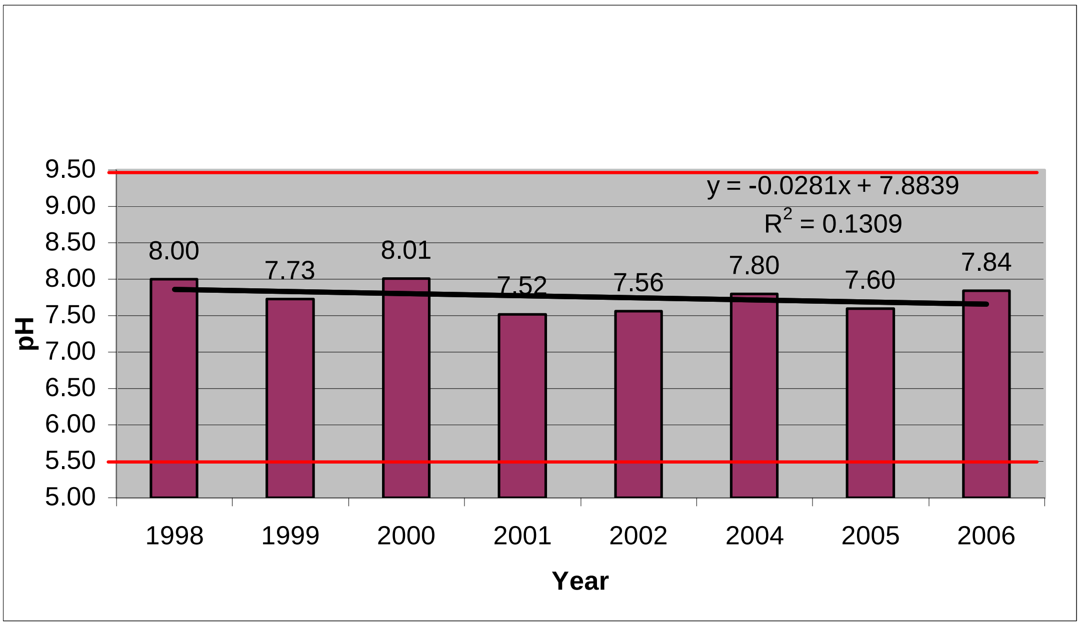

Figure 8: Average pH values (and linear trend line) in Lake Mzingazi from 1998 to 2006 (Red line = maximum and minimum allowable limits)

pH

The pH of the lake water indicated minor year-to-year changes. All mean values, however, lie within allowable limits (5.5 to 9.5) in terms of the Department of Water Affairs guidelines. The trend line shows a steady decline in pH from 1998 to 2006.

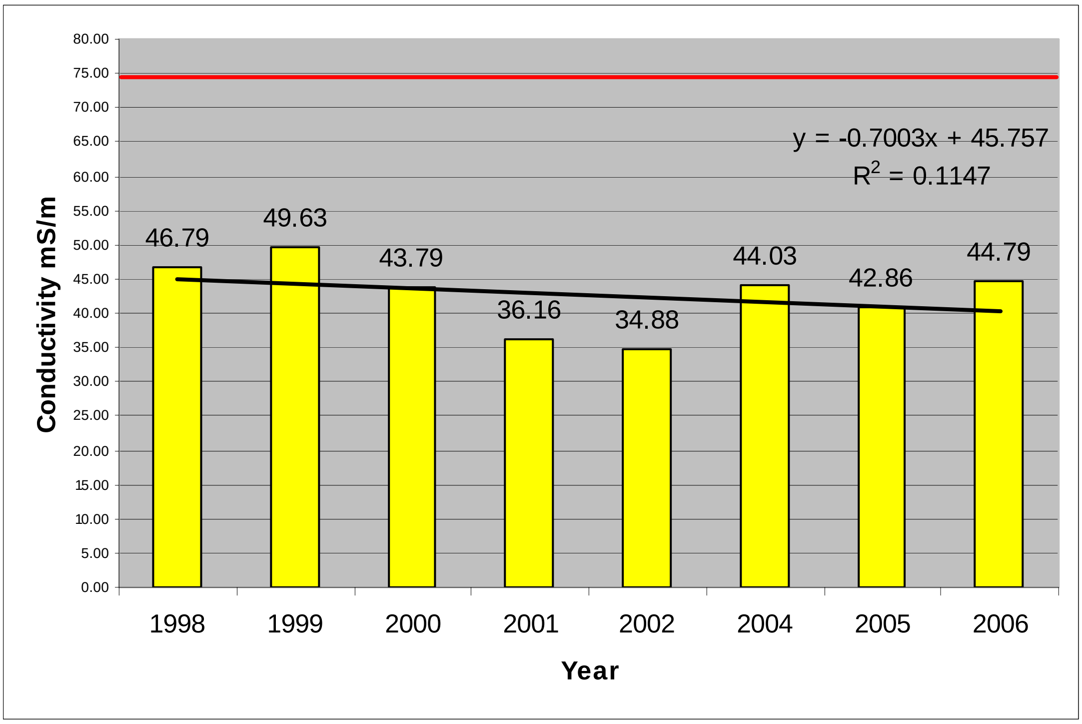

Figure 9: Average Conductivity mS/m (and linear trend line) in Lake Mzingazi from 1998 to 2006 (Red line = maximum allowable value).

Conductivity

The year- to- year variations show a decrease in conductivity up to 2002 and a slight increase from 2004 to 2006. All values still lie below the maximum allowable limit (75 mS/m).

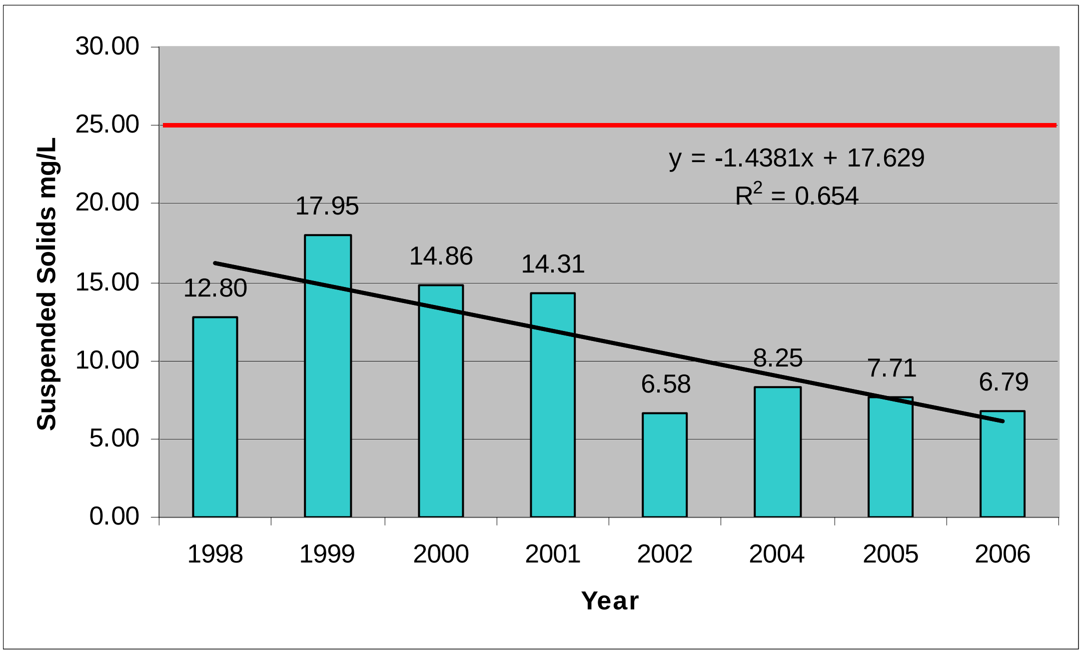

Figure 10: Average Suspended Solids mg/l (and linear trend line) in Lake Mzingazi from 1998 to 2006 (Red line = maximum allowable value).

Suspended Solids

There has been a progressive decrease in suspended solids from 1998 to 2006. All measurements were found to be far below the maximum allowable limit of 25mg/l.

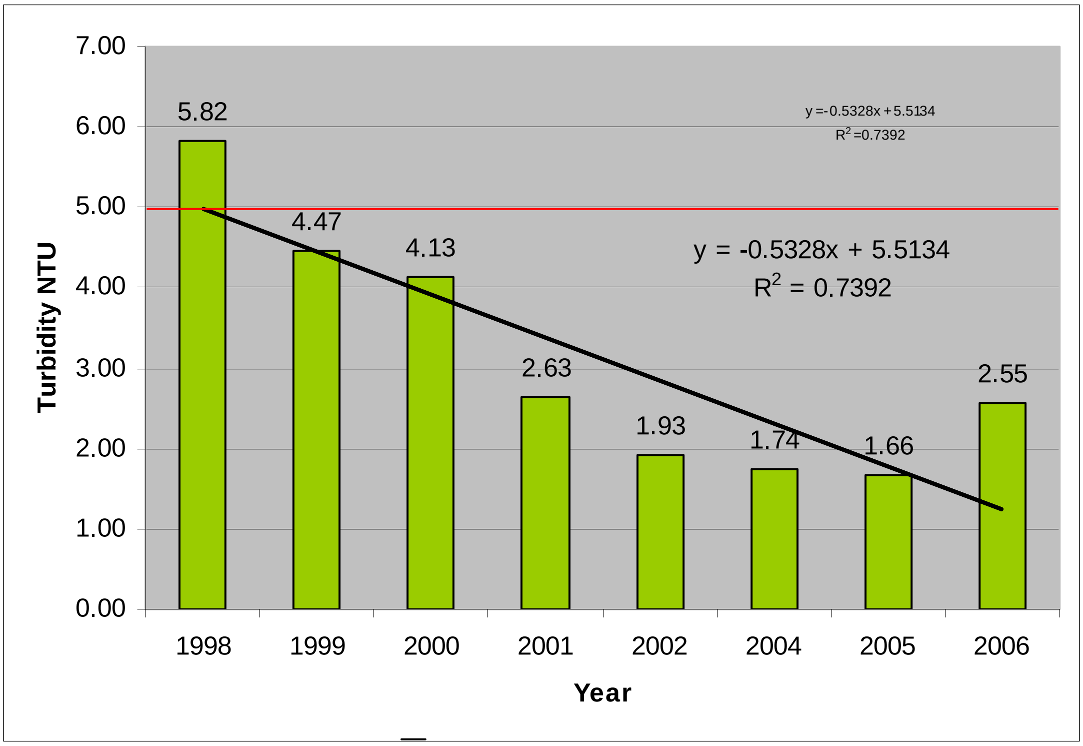

Figure 11: Average Turbidity NTU mg/l (and linear trend line) in Lake Mzingazi from 1998 to 2006 (Red line = maximum allowable value).

Turbidity

Turbidity is related to suspended solids because it is also associated with suspended matter in water. Turbidity is a measure of the ability of water to scatter light proportional to the concentration of suspended solids. Turbidity can also be a measure of settleable matter in water. It has no direct health effect except that it may shield disease-causing microorganisms where water is used directly from the source for drinking purposes. Purified water may still transmit pathogenic organisms to humans where turbidity is very high since it has the effect of shielding microorganisms from the disinfecting agents such as free chlorine.

Turbidity in Lake Mzingazi water has shown a steady decrease in trend from 1998 to 2006 and then a slight increase for 2006. This could be attributed to the Meerensee Golf Estates development on the eastern side of the lake during 2006. Dust emissions and silt from earth moving machines could have been washed off into the lake, thus increasing turbidity. The mean for 2006 is still within allowable limits and chances are that the concentration would drop even further when the development is completed.

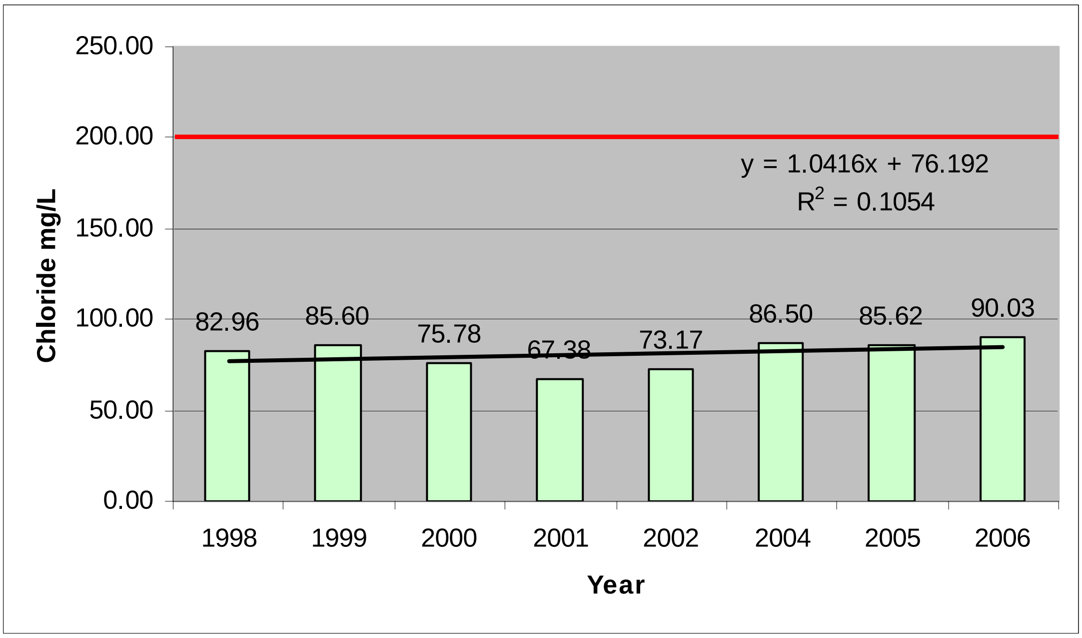

Figure 11: Average Chlorides mg/l (and linear trend line) in Lake Mzingazi from 1998 to 2006 (Red line = maximum allowable value).

Chlorides

These originate from dissolved salts of chlorides in water resources. Chlorides impart a salty taste to drinking water if present in high concentrations. Such water fails to quench thirst especially when the concentration exceeds 200 mg per liter. In a susceptible individual nausea, diarrhoea and vomiting may be experienced. It is difficult and expensive to purify water with a high salt content and specialised methods may be necessary.

Chlorides have generally demonstrated an increase in concentration. However, the values are still far below the maximum allowable limit of 200mg/l. The trend line confirms the increase from 1998 to 2006. The increase could be explained by communities farming near the lake especially if they are using fertilisers.

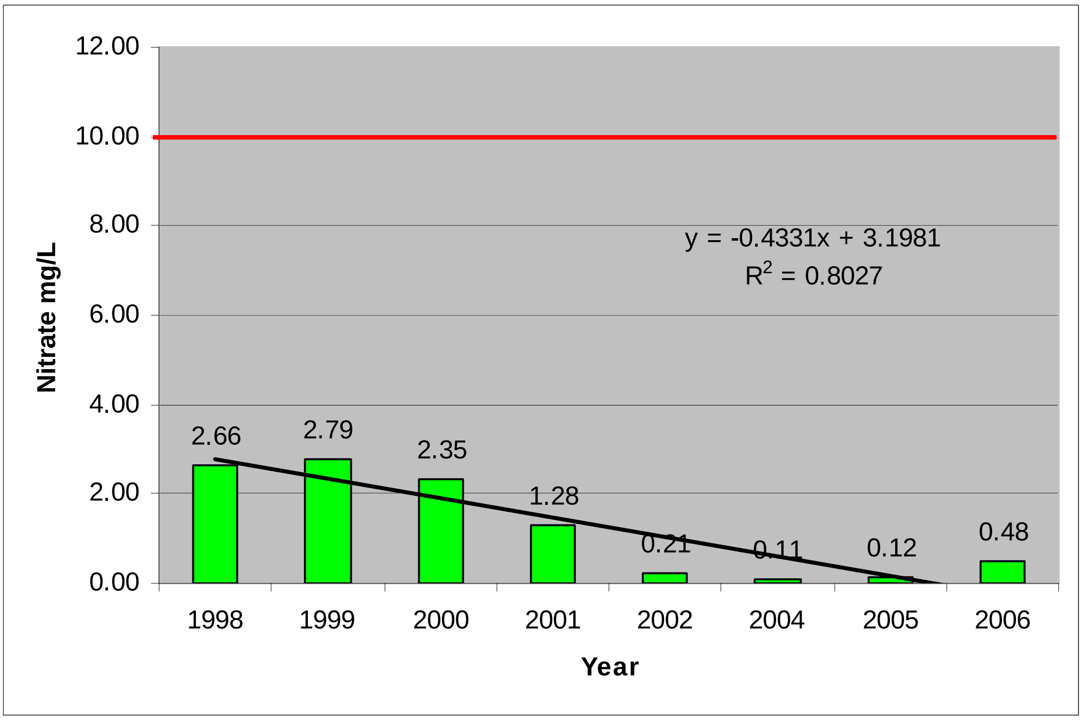

Figure 12: Average Nitrates mg/l (and linear trend line) in Lake Mzingazi from 1998 to 2006 (Red line = maximum allowable value).

Nitrates

Elevated concentrations of nitrates in water may indicate the presence of contamination due either to raw sewage or fertilizers from neighbouring agricultural activities or farm ranches in the vicinity of a water resource. Nitrates in drinking water have a direct effect on humans in that they may form nitrites in the gastrointestinal tract due to bacterial activity. Nitrites combine easily with haemoglobin, forming methaemoglobin. This combination is dangerous to infants under 3 months of age.

In Lake Mzingazi, nitrates have shown a progressive reduction over time.

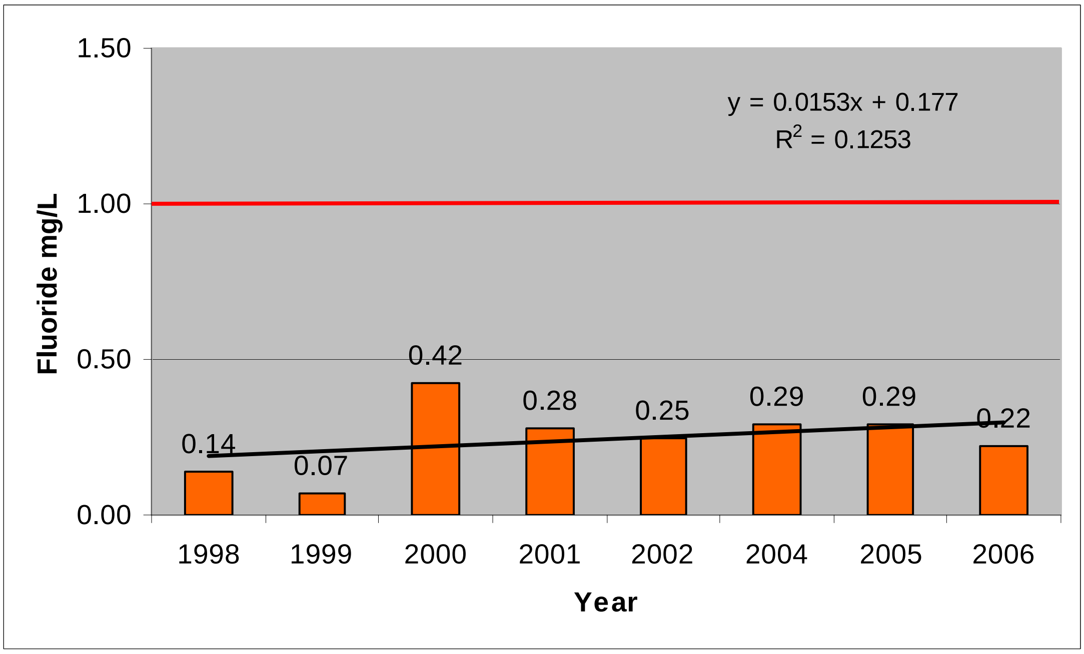

Figure 13: Average Fluorides mg/l (and linear trend line) in Lake Mzingazi from 1998 to 2006 (Red line = maximum allowable value).

Fluorides

The presence of this element is important in domestic water for it prevents dental caries by hardening dental enamel. However, at concentrations above 2 mg per litre it may result in discolouration and mottling of teeth. Children under the age of 7 are mostly affected.

All values lie within the allowable limit of 1 mg/l. In the year 2000, the mean value of fluorides increased and then dropped again in 2001 and has since then stabilised around 0.28 mg/l. There was no cause for concern as the increased concentration was still below the allowable limit.

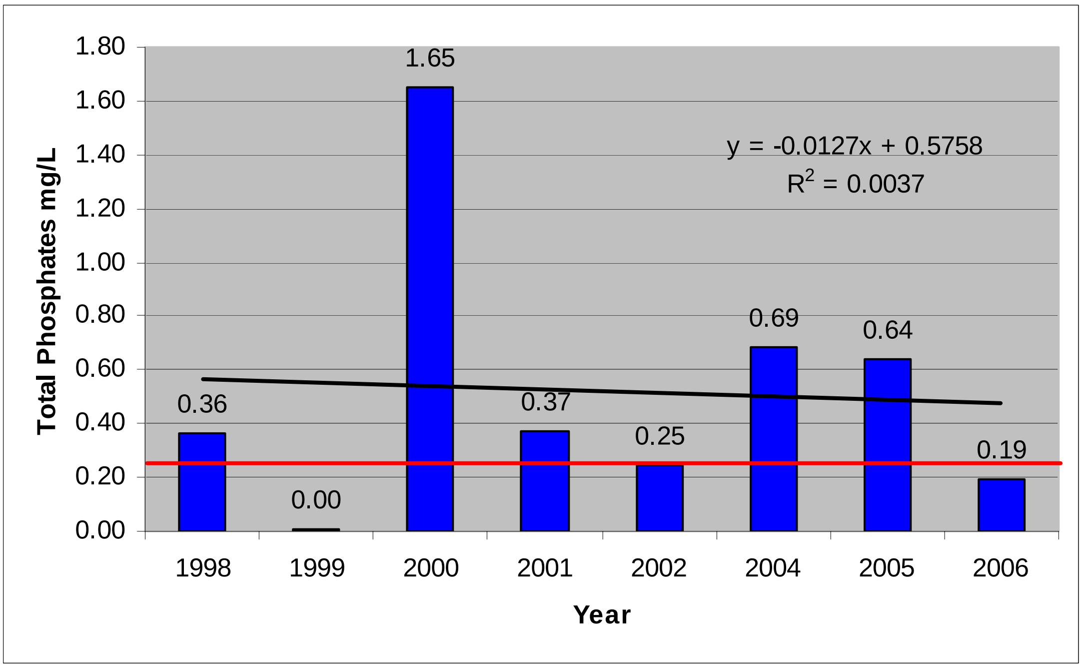

Figure 14: Average Total Phosphates mg/l (and linear trend line) in Lake Mzingazi from 1998 to 2006 (Red line = maximum allowable value).

Total Phosphates

Phosphates found in natural water may provide nutrition that promotes surface growth. It is an essential compound for aquatic plant growth in combination with nitrates. However, elevated concentrations may be indicative of sewerage contamination in water. Algal bloom may then occur which in turn may result in eutrophication of water resources. Bad tastes and odours in drinking water may be a sign of the early stages of eutrophication.

The total phosphates average values were higher than the allowable limit of 0.25 mg/l during the period of 1998 to 2005, except for 1999 and 2002 when the values were within the specified limit. The values came down once more in 2006. It would appear that there were sources contributing to the increase in phosphate concentration in the lake. Human activities such as land farming, development of the Golf Estates, animal husbandry, might have contributed a lot to this problem.

In 2000 alone, the mean value of phosphates was very high. This could be attributed to raw sewerage injection as a result of overflowing sewerage from either Arboretum, Veldenvlei or Birdswood.

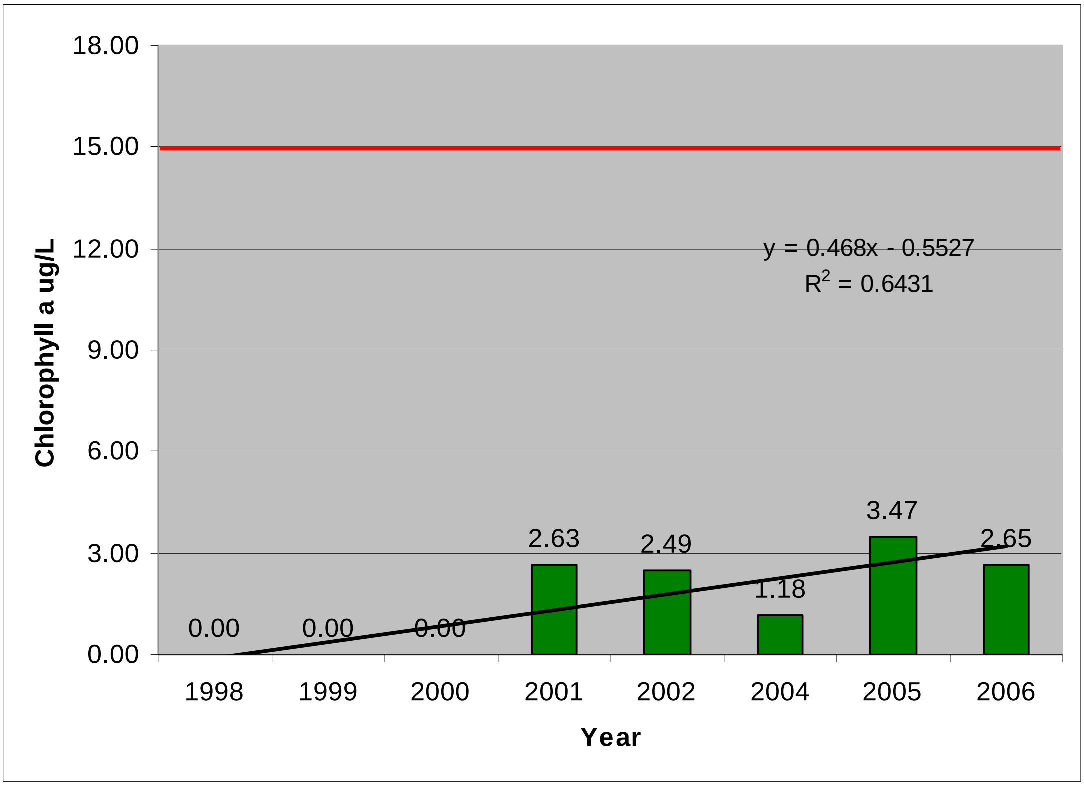

Figure 15: Average Chlorophyll a µg/l (and linear trend line) in Lake Mzingazi from 1998 to 2006 (Red line = maximum allowable value).

Chlorophyll a

Chlorophyll is usually present in minute quantities due to algal growth in water. However, a raised concentration may indicate the presence of nitrates and phosphates as a result of either sewerage pollution or farming activities in the vicinity of a water resource. Increased chlorophyll should be investigated and the source eliminated in order to prevent algal bloom.

The values for chlorophyll a have shown a steady increase from 1998 to 2006. Though the concentration is well below the allowable limits of 15µg/l, there is a noticeable trend for the concentration to be increasing. Surface growth usually takes place when there are adequate nutrients in water. The phenomenon is a cause for concern because, at certain concentrations, this could suddenly turn into an algal bloom, which has shown to be problematic for water purification plants.

In 2002, the Mzingazi water purification plant received numerous complaints relating to odour and bad taste in drinking water. Tests performed on water samples picked up geosmin and 2-methylisorboneol. These are the major organic pollutants produced by *Anabaena laxa* and *Actinomycetes* species of algae that grow on water surface. A water resource may become unusable for human consumption if this type of pollutant increases substantially.

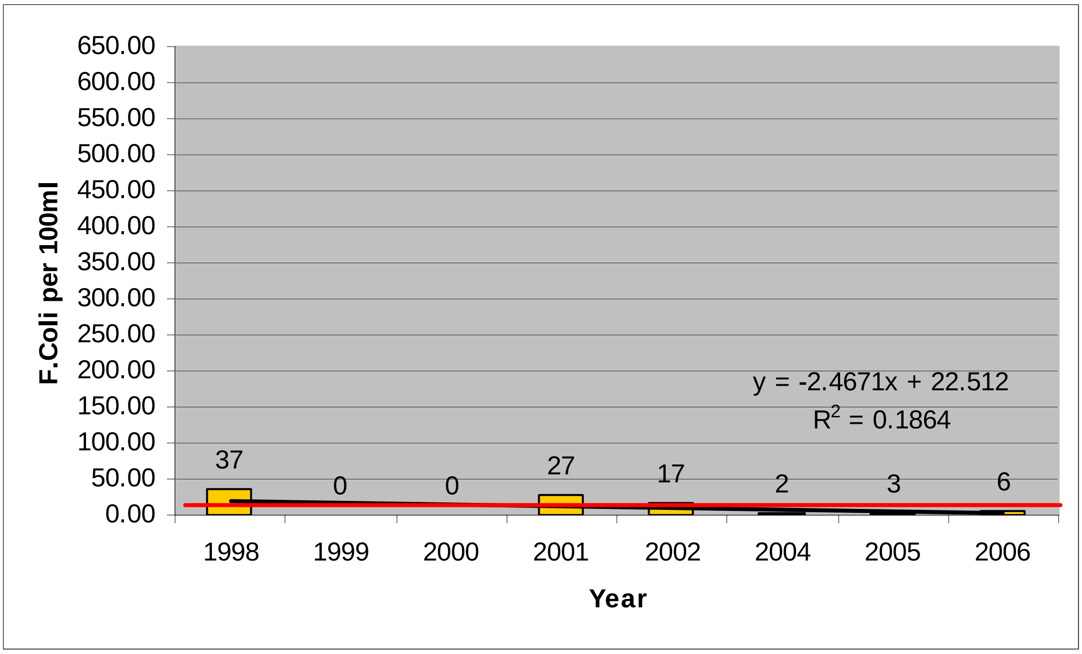

Figure 16: Average Faecal coliforms per 100 ml (and linear trend line) in Lake Mzingazi from 1998 to 2006 (Red line = maximum allowable value).

Faecal Coliforms

Faecal coliforms are used as indicator microorganisms warning of possible faecal contamination in water. If *Escherichia coli* (*E. coli*) are found in the water it may then also contain other pathogens such as *Salmonella* sp., *Vibrio cholerae*, *Campylobacter,* other pathogenic *E. coli* as well as gastrointestinal viruses. *E. coli* usually arise from faeces of warm-blooded animals. They are also ubiquitous in nature. An elevated count of organisms per 100 ml may require a specific test for human pathogenicity, such as for faecal *Streptococci* determination. This test is specific in that it will only detect faecal coliforms of human origin.

Waterborne diseases such as cholera, salmonellosis, typhoid fever, dysentery and gastroenteritis may occur in humans due to ingestion of poorly treated water. Suitable culture media are used to grow faecal coliforms from the sample. The culture media are then incubated for adequate periods at favourable temperatures; thereafter counting of organisms is done under a light microscope. The results are given in counts of microorganisms per 100 ml of a sample (Department of Water Affairs & Forestry, 1996).

There has been a decreasing trend in faecal coliforms from 1998 to 2006, as indicated by the trend line. Such a feature is an indication that there has been a better control of the sewerage overflow into the environment since 1998. The establishment of the Pollution Control Division in the Department of Community Services/ Health in the City of uMhlathuze has assisted in minimizing pollution incidents due to sewer overflows. Sewer manholes at the Golf Course Estates used to overflow for days without being attended to. Therefore the pressure from this division ensured that urgent steps were immediately taken. An increase occurred in 2001 and, thereafter, a decrease in the trend is detectable to 2004. A further increase was observed between 2005 and 2006.

However, there is no impending crisis, as the faecal count has remained under control. The problem with high counts of microorganisms in water is that a large dosing of chlorine has to be undertaken in the water purification process to kill all organisms. Such dosing usually develops taste and odours in water that smells like '*jik*'. Continuous intake of drinking water with high contents of free chlorine is thought possibly to damage peoples health.

4.6 CORRELATION BETWEEN MEAN ANNUAL VALUES OF WATER QUALITY VARIABLES AND ANNUAL RAINFALL IN LAKE MZINGAZI.

The intention of this section is to determine the strength of the relationship between the measured data obtained and one of the environmental factors, namely the average rainfall of each year under consideration. Rainfall figures were obtained from the Engineers Department weather station situated at the Mzingazi Water Purification Plant. Plant operators record weather readings daily. It is expected that the tributaries of Lake Mzingazi should convey greater quantities of pollutants with heavy down pours associated with increased rainfall.

Whether this has an influence or not on the variables used will be demonstrated by using the Correlation Coefficient, which will be calculated from the values here below. Rainfall was chosen, as it is the critical factor in dispersing pollutants from the surrounding environment into the lake.

Table 5: Average Annual Rainfall versus Average of each Measured Variable from 1998 to 2006 from 12-samples points in Lake Mzingazi

Variable	1998	1999	2000	2001	2002	2004	2005	2006	Correlation	Description
pH	8.00	7.73	8.01	7.52	7.56	7.80	7.60	7.84	0.2870	$0 < r < 1$
Suspended Solids	27.99	19.00	14.86	14.31	6.58	8.25	7.71	6.79	0.0820	$0 < r < 1$
Turbidity	5.82	4.47	4.13	2.63	1.93	1.74	1.66	2.55	0.1530	$0 < r < 1$
Conductivity	46.79	49.63	43.79	36.16	34.88	44.03	40.78	44.79	0.0336	$0 < r < 1$
Fluorides	0.14	0.07	0.42	0.28	0.25	0.29	0.29	0.22	0.2552	$0 < r < 1$
Nitrates	2.66	2.79	2.35	1.28	0.21	0.11	0.12	0.48	0.2616	$0 < r < 1$
Total Phosphates	0.36	0.0	1.65	0.37	0.25	0.69	0.64	0.19	0.9931	$0 < r < 1$
Chlorides	82.96	85.60	75.78	67.38	73.17	86.50	85.62	90.03	0.1445	$0 < r < 1$
Chlorophyll a	0.0	0.0	0.0	2.63	2.49	1.18	3.47	2.65	- 0.0864	$r < 0$
Faecal coliforms	37.00	0.0	0.0	27.00	17.00	2.00	3.00	6.00	- 0.3624	$r < 0$
Annual Rainfall (mm)	87.1	105.5	176.7	99.4	104.2	62.6	113.5	132.3		

The results showed that there was a relationship between rain and the variables. The pH, conductivity, turbidity, chlorides, suspended solids, fluorides and nitrates exhibited very weak positive correlation. On the other hand total phosphates and annual rainfall showed a strong positive relationship. Faecal coliforms and chlorophyll a had a weak negative correlation with annual rainfall.

4.7 INTERPRETATION OF THE CALCULATED COEFFICIENTS

In all of the calculated coefficients the dependent variables matched against the average rainfall in the vicinity of Lake Mzingazi showed evidence that the rainfall has an influence on water quality. However, the relation in most of the variables is a weak one since the values of a coefficient are far less than 1.

Many factors can lead to this, such as the natural filtration around the lake, availability of pollutants, human activities and the assimilation capacity of the lake itself, which could be preventing a more noticeable negative impact. The fact that sampling of the feeder streams is done at the entry point to the lake could diminish the actual concentrations due to mixing. Having said that, the threat of pollution of the lake cannot be dispelled by only looking at the correlation coefficients. There is a strong need for continuous monitoring of the activities around it, with the aim of minimizing pollutants entering the lake via the tributaries.

The buffer zones originally established by the Mandlazini Trust and the Richards Bay Transitional Local Council should have been adhered to by both parties. The purpose of the buffer zones was to ensure that settling of people around Lake Mzingazi wetland did not encroach into the sensitive ecosystem. However, Mandlazini Community leaders have violated the agreement.

In summary, the coefficients indicate that a relationship between the rainfall and the variables exists. The relationships have thus far been shown to be weak. However, it may be expected that rainfall could impact negatively on the water quality. However, for the past 8 years, little or no negative influence of rain has been observed. The assimilative capacity of the lake could be the strongest factor nullifying the effect of rainfall on the variables used to assess quality of the water. Future studies will need to consider sampling the feeder streams before they enter the lake so as to identify which feeder streams are bringing high concentrations of pollutants, which may be better correlated. The closeness of the homesteads to the lake's banks is posing a serious concern since waste collection and disposal is lacking. Increasing waste produced by humans would eventually reach and enter the lake, which would impact negatively on the assimilative properties of Lake Mzingazi and, therefore, the quality of water.

4.8 GRAPHICAL REPRESENTATION COMPARING THE 12 SAMPLE POINTS IN TERMS OF NITRATES, PHOSPHATES AND CHLOROPHYLL a DURING THE PERIOD OF 1998 – 2006.

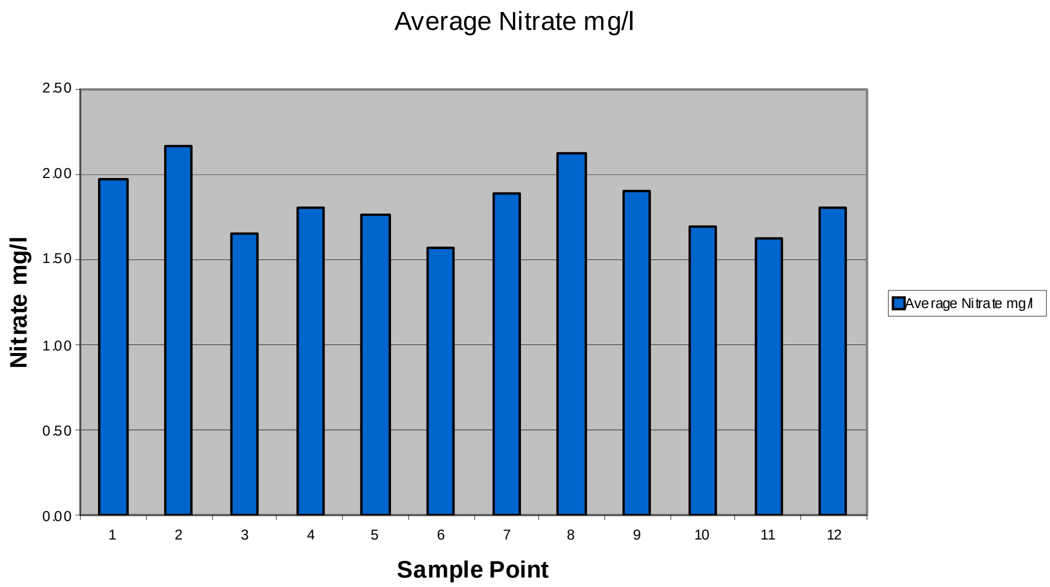

Figure 17: Average Nitrate level for the period 1998 to 2006 for each Sampling Point in Lake Mzingazi.

The above bar graph shows the average values of nitrates for each sample point during the period of 1998 – 2006. Although the values are below the allowable limit of 10mg/l, however each point shows its uniqueness. Sample point 2 is taken from the Golf Estates stream entering the lake. The value is higher than all sample points and could be indicative of fertilizer use in the greens. Sample point 8 on the other hand is on the Mandlazini side and possibly reflects farming activities are taking place in this agri-village. All other sample points show an average lying between 1.5

mg/l and 2 mg/l. Except for sample point 9 and 10 sample points represent influence of human activities.

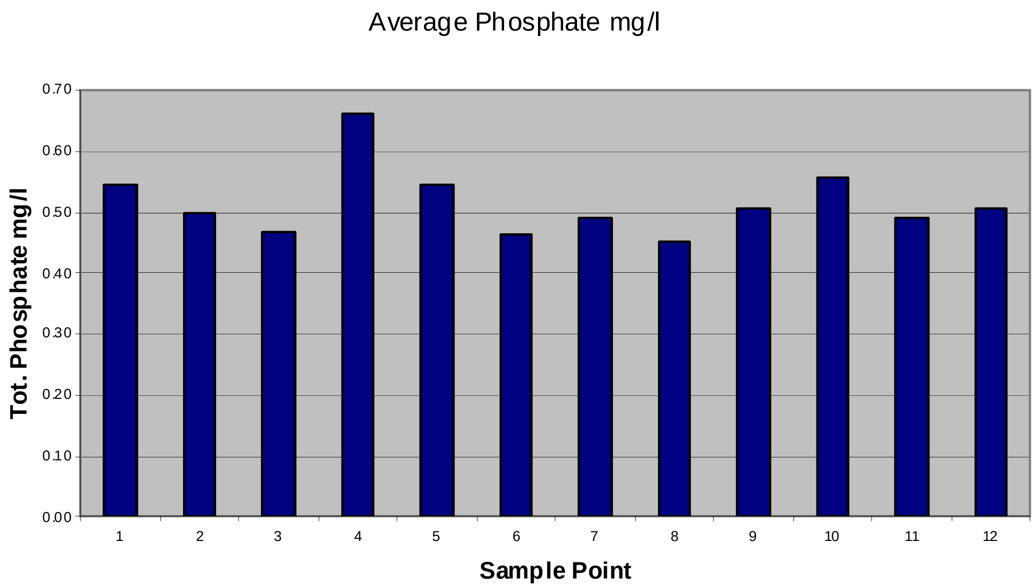

Figure 18: Figure 17: Average Phosphate level for the period 1998 to 2006 for each Sampling Point in Lake Mzingazi.

The phosphates values are far higher than the acceptable limit of 0.25 mg/l. Most of the values are around 0.5 mg/l while sample 4 is the highest at 0.65 mg/l. This sample point is taken from Lake Mzingazi on the side where Mzingazi Agri-villages is located and could be associated with fertilizer being used by the communities in the vicinity of the lake.

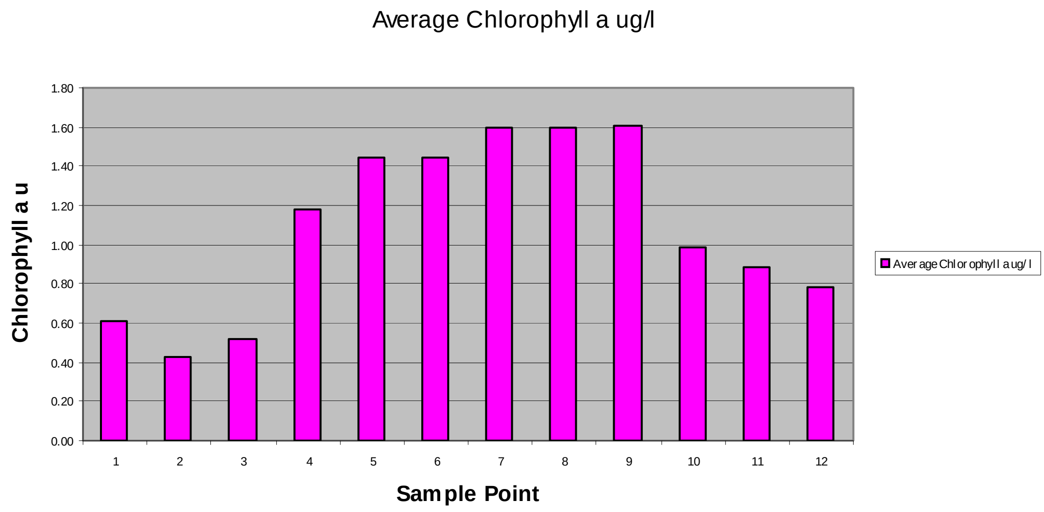

Figure 19: Figure 17: Average Chlorophyll a level for the period 1998 to 2006 for each Sampling Point in Lake Mzingazi.

The average values of chlorophyll a have remained lower than the acceptable limit of 15µg/l. However, points 4, 5, 6, 7, 8 showed more than twice the values of other sample points. Sample point 9 in the middle of the lake could have been affected by the values at the affected lake edge points that had raised values. All sample points are associated with the use of phosphates and nitrates due to the fact that rivers entering the lake flow through the farming communities of Mzingazi and Mandlazini Agrivillage. Nitrates and phosphates may promote surface growth of various algae in the lake. They have shown high values along the farming communuities as well. Therefore, it seems chlorophyll a is confirming the presence of the pollutants.

4.9 SUMMARY

This chapter presented results obtained during the study in various forms with an attempt undertaken to identify any possible pollution trends that could be detected during the past eight years. Statistics were applied to the results in order to find and show any significance of the results.

Because of poor settlement planning, especially in Mandlazini and Mzingazi agri-villages and the fact that both these agri-villages lie in Lake Mzingazi catchment's area, increasing waste production from households would eventually impact negatively on the lake. The lake surveys conducted also suggested that the current human practices could lead to the degradation of the lake ecosystem.

Studies have shown that urbanization in southern African countries has resulted in water resource pollution due to poor basic utilities such as a solid waste disposal system and adequate sewerage treatment and disposal, which fail to keep pace with rapid growth and development. Therefore Richards Bay communities need to learn from these neighbours and undertake the necessary steps in order to succeed in conserving or preserving this valuable water source.

5 CHAPTER 5: DISCUSSION

5.1 INTRODUCTION

The discussion of the results will be based on the guidelines of the Quality of Domestic water supplies, Volume 1: Assessment Guide (2002) and the South African National Standard (SANS 241: 2006). These guides furnish the minimum number of physical, chemical and microbiological variables necessary to determine whether a water source will be suitable for domestic water use or not. Interpretation will be conducted in accordance with these guides and the national standards.

Secondly the environmental survey results observed during the study will assist in identifying potential threats to the lake water quality. Here, reference will be made to the human activities around the lake as well as the manner whereby homesteads are settled.

The results obtained during 1998 to 2005 and during 2006 show that in general, all of the results fall within the acceptable limits of both guidelines. Analysis of previous results obtained during 1977/78 by the Council for Scientific and Industrial Research of the same lake allows for historical comparisons to be made. After a period of 30 years since the first analyses, the lake water quality seems to have resisted negative changes. The lake is well situated and it enjoys good aeration due to the prevailing North Easterly winds blowing over it. The southern end of the lake has a constant discharge (outflow) of water into Mzingazi River serving as a cleansing mechanism for the lake as well.

However, certain points must be noted concerning the data. Sample points 4,5,6,7,8,11 and 12 have exhibited higher values than the overall average on certain variables. These variables are indicative of the human activities associated with these sample points and in particular the farming activities that are taking place in these communities. It is obvious that a certain negative influence is being experienced from these areas. However, although the effects remain minimal at this stage, this provides no guarantee that the status quo will remain as further encroachment into sensitive wetland continues to occur.

In the data set some results appear as outliers, widening the standard deviation (SD). These extreme values may be caused by the prevailing environmental conditions, which occurred during sampling. For instance, turbulence will increase turbidity and suspended solids values at that particular point. Such a factor cannot be taken as an outlier since it represented a measured value at the time. However, extreme results occurring under these conditions do not reflect the general lake water quality.

Though the standard deviation appears wide, all the values still fall within the acceptable limits of the guidelines.

5.2 ROLE OF THE DEPARTMENT OF WATER AFFAIRS & FORESTRY GUIDELINES

The intention of this study was to evaluate the water quality of the lake in terms of the physico-chemical and microbiological pollution. The results obtained would then be compared to the Quality of Domestic Water Supplies Assessment Guide (Department of Water Affairs & Forestry, 2002). Applying the guidelines to the data obtained would also indirectly suggest if the quality of water would be a risk to human health, without the necessity of conducting a community or user survey. This approach was considered appropriate in terms of the available resources and the limited time available for the study. The results would invariably determine whether there would be any need to conduct further study in the community depending on the final quality of the water in the lake.

Surveys conducted in the vicinity of the lake revealed that water from the lake is sometimes used in its original setting for recreational purposes such as fishing, but also for crop irrigation, washing of clothes and watering of livestock. Purified and reticulated water is supplied to Mandlazini Agri-village and Mzingazi Agri-village for domestic use by the uMhlathuze Municipality. As a result there is minimal risk to communities surrounding the lake as all water supplied for human consumption is purified. Conventional water purification however has its limitations. Water can be safely and easily purified provided the water quality of the source water is either Class I or Class II. It is for this reason that the water quality of Lake Mzingazi is being evaluated. The purpose of the study is to ensure that a state is not reached where the lake, which provides the only source of water supply, would become unusable to the communities of uMhlathuze Municipality.

In conclusion, it would be an appropriate action for the Water Service Authority to ensure that the water quality of the lake remains sustained at its present satisfactory and acceptable status so that it would also continue to serve as a life sustaining water resource for both present and future generations.

5.3 WATER RESOURCE QUALITY AND PUBLIC HEALTH

The Department of Water Affairs & Forestry is the national custodian of all water resources in the Republic of South Africa. Realising that the quantity and quality of water resources are strongly linked, it was important, however, to note that quality is a significant and direct factor in relation to the health of the general public. Therefore, in deciding whether a water resource can be used, it is necessary to be aware of certain guidelines that specify variables used to evaluate the quality of water. The World Health Organization (WHO) has stringent guidelines on water classification. According to the World Health Organisation the ideal water class for human use is Class 0 (Department of Water Affairs & Forestry, 2002), which has no negative health impact on humans. As a result of human activities globally, such a pristine water resource is entirely unattainable.

Since the provision of a regular daily need for water by the people is of paramount importance, the Department of Water Affairs & Forestry has water classes that could be purified for domestic use. Four classes of water source are recognized depending on certain variables, which include physical, chemical and microbiological constituents of the water. Special attention in the development of this guide was devoted to those chemicals and microbiological substances, which pose a significant risk to health. The guide is entitled: Quality of Domestic Water Supplies Assessment Guide (Department of Water Affairs & Forestry, 2002).

In terms of the guide, water suppliers can easily determine the class of a water resource by using the set criteria. The classes were colour coded in terms of how good or bad the quality is assessed and categorised (Department of Water Affairs &

Forestry, 2002). At a glance, therefore, an expert can ascertain the suitability of a resource. The guidelines have proven to be both a success and an invaluable tool in the planning of water supplies.

Each variable was examined in order to determine any overall trend. The average values for each sample point was scrutinised properly for any noticeable changes. The overall water quality will be examined in terms of the summary statistics.

5.4 ANALYSIS OF DATA

The variables were treated individually in terms of the guidelines to ascertain whether they fell within the acceptable limits or not. The reasons for deviations were discussed in terms of the activities and land use around sample points.

5.5 VARIABLES OF CHOICE

5.5.1 PH

The pH of a solution is a characteristic that determines whether a solution is acidic or alkaline. Natural waters have a neutral pH of 7. Any pH less than 7 is considered acidic while pH values above 7 are alkaline. The pH does not have a direct negative health impact per se except at extremes when water may taste soapy due to alkalinity or bitter as a result of its acidity. However, an abnormal pH may allow heavy metals such as lead, zinc or copper to dissolve in water causing it to be toxic to both humans and aquatic animals. The pH can result in water proving to be corrosive to the reticulation pipes and household utensils such as kettles when it is either on the acidic or basic side.

The pH of the lake water indicated minor year-to-year changes. All mean values, however, lie within allowable limits (5.5 to 9.5) in terms of the Department of Water Affairs & Forestry Guidelines (Quality of Domestic Water Supplies Volume 1: Assessment Guide, 2002). Although pH showed a steady decline from 1998 to 2006, the changes are no cause for concern as the normal pH for unpolluted water is 7 and most values were around 7.

The maximum value for pH taken from Appendix 7.1 is 8.96 and the minimum value is 6.80. Both values lie within the acceptable limit of SANS 241: 2006. Therefore no acute or chronic infection is expected as far as public health is concerned.

5.5.2 SUSPENDED SOLIDS

Suspended solids are particulate matter found in water as a result of inorganic and/or organic debris suspended as solids. Such water may be unpleasant aesthetically if the concentration is high. At times settled solids may cause objectionable odours in water. High concentrations may encourage microbial growth in water, which may result in negative health effects in people drinking the contaminated water. The higher this level is, the greater the probability that the water may contain microorganisms that may cause illness. The filtration costs may be high where such water is purified for domestic use.

There has been a progressive decrease in suspended solids from 1998 to 2006. All measurements were found to be far below the maximum allowable limit of 25mg/l. KwaZulu-Natal Wildlife was instrumental in prohibiting recreational activities such as boating and fishing in the lake. It is disturbing nevertheless that many human settlements are less than 3 metres from the lake edge and a possibility exists that more human waste could be introduced into the water.

There is a noticeable decrease in sample points 5, 6, 7, 8 and 9 for the 2006 mean values. Such a phenomenon can be observed in the mean values for the period 1998 to 2005. These mean values are twice as high as those of 2006. A marked improvement in suspended solids for 2006 appears to be detectable. Attention must be drawn, however to the fact that such points are associated with human farming practices. Rivers passing those areas convey dirt created through farming activities such as stock farming, cutting down of trees to open land for agriculture and cultivation of land.

In Appendix 7.1 the maximum value is 60mg/l and the minimum is 4mg/l for the period 1998 to 2005. No specification is given by SANS 241:2006, however the General Standard for Effluent has been used as a reference point for the sake of illustration. Taking 25mg/l as the acceptable limit there was a couple of values that were higher than 25mg/l in some of the sample points in 1998. Due to good mixing in the lake aesthetic conditions were normalized. Therefore the lakes suspended solids were generally lower than 25mg/l indicating no health effects.

5.5.3 CONDUCTIVITY

Conductivity normally gives the concentration of anions as a result of dissolved salts in water. Water with a high concentration of salts is not able to quench thirst.
Such a property determines the amounts of dissolved salts in water. Water with an increased salt content will conduct electricity due to the availability of ions in water. High salt content renders the water undrinkable and will thus not quench thirst. Increased salt content in water may result in serious health effects on infants under 1 year old and certain heart patients.

The mean values for the period 2006 are higher than those of the period of 1998 to 2005. This may indicate that farmers are using fertilizer and, during rainy days, soil erosion carries salts into the lake. It may also be that the lake water level decreased due to less rain and the concentration seems to be high whereas in fact this is not the cause. It is difficult to supply a reason for these observed changes particularly because they are so slight. Under normal circumstances, this will provide no cause for concern since the means remains within allowable limits.

In terms of Appendix 7.1 the minimum value is 30.5mS/m and that of the maximum value is 79.9mS/m. Taking the acceptable limit to be 75mS/m there was a slight increase in conductivity in sample point 2. However its effect is rectified by good mixing in the lake. No health effects are expected to occur.

5.5.4 TURBIDITY

Turbidity will affect the appearance of water and therefore its aesthetic acceptability. Pollution due to farming, recreation or boating activities and fishing methods may increase turbidity. Succinctly stated, turbidity is a measure of cloudiness or muddiness of water.

An indirect health effect prevails where water has a high turbidity value. Such a consequence occurs because microorganisms may adhere to the dirt particles and thereby form colonies of bacteria that may cause diseases. The mean values for both (1998 to 2005) and 2006 fall within the allowable limits but the 2006 values are generally lower than those of 1998 to 2005. This could be attributed to the fact that greater human activities and exploration occurred during early stages of settlement.

The maximum value of turbidity in Appendix 7.1 is 9.5NTU for the period of 1998 to 2005 which was picked up at sample point 3. On average this type of water fall in Class II in terms of Appendix C. As mentioned previously the prevailing winds over the lake makes water mixing to be good and therefore diluting the effects of high turbidity. No health effects can occur as there is no masking of microorganisms present in water.

5.5.5 CHLORIDES

These refer to negative ions resulting from dissolved sodium chloride (table salt) and other fertilizer salts. They impart a salty taste in water when present in high concentration. This may also induce nausea and vomiting in people. Again, a marked increase in concentration in the 2006 averages is observable when compared to the previous period of 1998 to 2005. Despite these values remaining within the allowable limits, it is nevertheless obvious that an injection of these salts derives from fertilizers, either from farming or swimming pools being illegally emptied into the storm water system from the residential area of Meerensee and Arboretum, situated on the east and west side of the lake respectively.

The position of the lake adjacent to the sea is another possible source of salt- water infiltration into the lake. A serious drop in lake levels may result in differential pressures between the lake and the sea, thus causing water movement towards the lake. Such development could pose very serious implications if allowed to continue to climb because treatment of such water for domestic purposes would require a specialised treatment (Reverse Osmosis) over and above the conventional method used for water purification. Such water treatment contains its own inherent price and, therefore would result in an increase in water tariffs, which could be expensive for an average individual.

The maximum value of the chlorides in Appendix A is 90mg/l during the period of 1998 to 2005 and 94mg/l in 2006.Both these values are far below the allowable limit of 200mg/l as specified in SANS 241:2006. Therefore no health effects are expected to occur.

5.5.6NITRATES

The nitrate concentrations are somewhat lower in the mean values for the year 2006. Nitrates may originate from fertilizers or from raw sewerage pollution. For both the 1998 to 2005 period and that of 2006, the concentrations were assessed as being far below the allowable limits.

It is important that nitrates are maintained at a low level in water to avoid health problems. In high concentrations nitrates may induce cyanosis in infants less than 1 year old. Nitrates possess the tendency to cause tiredness and a failure to thrive in people.

Nitrates salts form part of plant nutrient in water or soil. An increased concentration of nitrates in rivers and lakes usually promotes plant growth on the water surface. This could result in a serious situation where algal bloom may take place. Water purification may be interrupted due to clogging of the filters by these minute plants. Another family of the algae plant, namely the blue-green algae, produces toxic substances that are poisonous to aquatic animals and humans. No purification method can remove these toxins from water since they completely dissolve in water. Eutrophication of water may also occur with increased vegetation on the water surface. Such an outcome is also undesirable because it may render the whole water resource unusable.

The maximum value in terms of Appendix 7.1 is 5.72mg/l which was a once off peak in sample point 8 during the period of 1998 to 2005. SANS 241:2006 give 6mg/l as the allowable limit. There are no health effects expected to occur.

5.5.7 FLUORIDES

The mean values for fluorides were found to be within allowable limits for both periods and a comparison. Fluorides cause stained teeth and damage to the skeletal system of aquatic animals if present in high concentrations in water. Fluorides may originate from the ground as a natural element found in soil or from atmospheric fall out from industries where raw materials used contain fluorides.

The allowable limit in terms of SANS 241:2006 is 1mg/l. Both maximum values for the period of 1998 to 2005 and that of the year 2006 are 0.55mg/l and 0.67mg/l respectively which are within the acceptable limit. Therefore this water presents no health effects to the community.

5.5.8 TOTAL PHOSPHATES.

Phosphates form part of plant nutrients that promote growth. Substantial amounts of these may arise from raw sewerage and fertilizers used in farming. Rain causes erosion in fields, transporting phosphate-contaminated storm water into rivers and lakes. Such a development may increase concentrations in water resources. Similar to the nitrates, phosphates at certain concentrations may promote algal bloom. The mean values were found to be higher when compared to the allowable limits during the period of (1998 to 2005) and were within limits in 2006.

The allowable limit for Total Phosphates is not specified in SANS 241:2006, as a result DWAF guidelines for surface water has been used as a reference point. The summer limit value is 0.25mg/l, which is the critical concentration capable of promoting algal bloom. The occurrence of algal bloom may be accompanied by toxin causing algae. There is no water purification method that can remove these toxins. Most of the values were higher than 0.25mg/l and the highest concentration reached was 2.90mg/l during 1998 to 2005 and 4.52mg/l in 2006. Though no health effects have been experienced, numerous public complaints regarding bad odour and taste were received. Therefore sensitive people could have experienced minor health effects.

5.5.9 CHLOROPHYLL a

This particular test is used to determine the amount of vegetation on water surface, especially the algae family. An increase in the concentration of chlorophyll a is an indication of plant nutrients' increase. The mean values for both periods in question being compared were found to lie below the allowable limit. However, the 2006 values were found to be higher than those of the period of 1998 to 2005. An increase in human activities occurred due to the development of the Meerensee Golf Estate during 2006. Herein could exist the reason for such an increase in chlorophyll a, resulting from increasing plant nutrients in water. This factor is a cause for concern as the municipality received complaints from the community regarding odours and bad taste in drinking water. This incidence occurred early in the year 2006 during the hot summer months, especially between January and February. Alarm bells are already sounding and calls for urgent steps to be undertaken in order to prevent deterioration of the water quality in the lake.

The maximum value in terms of Appendix 7.1 is 16.76µg/l which is slightly higher than 15µg/l which is the allowable limit in SANS 241:2006. However this was a once off peak in 2001 at sample point 8. This supports that there were nutrients in water as reflected by phosphates. The presence of high concentrations of chlorophyll a may cause odour and taste in water. Only complaints have been received and no noticeable health effects at present.

5.5.10 FAECAL COLIFORMS

This serves as an indicator for faecal pollution in water. An increase in coliforms count in water could indicate that disease- causing organisms (pathogens) are present. Water contaminated with faecal matter, especially from humans, can cause waterborne diseases such as cholera, gastro-enteritis and various forms of water-borne I diseases. The use of this water for drinking purposes, watering of vegetables or even bathing has resulted in fatalities in regions where access to purified water is scarce. Even where water is purified the presence of large quantities of faecal coliforms may necessitate an increase in chlorine used for disinfecting water. But chlorine use in large quantities also has negative effects such as producing an odour in water and this may affect susceptible individuals. High chlorine dosing in domestic water may result in the formation of trihalomethanes, which are the disinfection byproducts. These may cause cancer in prolong exposure to such water.

The results obtained for both periods under study were found to be very low and lie within the allowable limits. It is observed that sample points 2, 5, 6, 7, 8 and 12 provided higher values in 2006 especially. These sample points receive water from rivers passing through farming communities. Observation of these areas indicated that there was an inadequate availability of toilet facilities. These were either poorly designed in most cases or even completely absent. The consequence was that bushes were being used as toilets and therefore faecal matter was flushed by rain into the lake.

The SANS 241:2006 is 10 Counts per 100ml. Higher counts were recorded at sample points 5 and 7 to the value of 183 and 175 respectively during the period 1998 to 2005. The highest value recorded in 2006 was 50 Counts per 100ml in sample point 6. However due to good mixing in the lake the means were lower than the allowable limit. No cases of waterborne diseases have been reported.

5.5.11 COMPARISON OF THE WATER QUALITY BETWEEN 1978/1979, THE PERIOD 1998 TO 2005 AND 2006

Comparison of the water quality during the study of 1978/79 (Table 9) and the results for 2006 using mean values show some noticeable changes. The pH of the lake gave a mean of 7.43 in 1979 while it went up to 7.84 in 2006. The value for the period of 1998 – 2005 shows a mean of 7.75. This indicates an increasing trend. Therefore, the development around the lake has an impact.

The suspended solids for 1979 had a mean of 5mg/l and increased to 16.21mg/l for the period of 1998 to 2005. However, it seemed to have dropped to 6.79 mg/l in 2006. This still shows an increase in the variable. Conductivity mean was 33.9 Ms/m before developments. It went up to 43.46mS/m during the period of 1998- 2005. It further went up to 44.79 mS/m in 2006. An increasing trend. Nitrates measured in 1979 gave a mean of 6.9 µg/l and it was 1.83 mg/l for the period 1998 to 2005. It measured 0.48 mg/l. There is a slight drop between the last two periods. However, it shows an increase as well. The chlorophyll a had a mean of 2.9 mg/m^3 during the study in 1979 and 1.09 mg/l for the period of 1998 – 2005 and a value of 2.65 mg/l during 2006. Again an increasing trend is being observed. Therefore, the trend is indicative of changes in the physico-chemical characteristics of the surface water quality of Lake Mzingazi. Though the quality of this resource is still within the parameters laid down in the South African National Standard (SANS 241: 2006) for domestic water supply, there is nevertheless a reason for concern as to how long it will take for it to exceed acceptable limits of the Department of Water Affairs & Forestry.

Table 6: Physico-chemical characteristics of the surface waters of Lake Mzingazi (Archibald et al 1979)

Water Quality Variable	Northern Lake (Open Water)					Central Lake (Open Water)					Main Lake (Open Water)				
	Max	Min	Mean	SD	CV%	Max	Min	Mean	SD	CV%	Max	Min	Mean	SD	CV%
Secchi Disc (cms)	173	107	139	25		187	91	134	28	21	123	80	101	15	15
Temperature° C	28,1	17,8	22,8	3,6	16	28,5	17,0	22,7	3,8	17	27,1	16,5	21,9	3,6	16
pH Value	8.87	7,00	7,43	0,5	7	9,55	7,30	7,79	0,6	7	8,90	7,30	7,64	0,4	5
Suspended Solids (mgℓ$^{-1}$)	2	2	5	1,7	34	9	2	6	2,4	40	10	4	8	1,7	21
Conductivity mS/m	35,6	30,2	33,9	1,6	5	34,7	28,7	32,4	1,9	6	31,2	25,3	29,0	1,9	7
Silicon ng SI ℓ$^{-1}$	6,8	5,2	5,8	0,6	10	6,8	5,2	5,9	0,6	10	7,0	5,6	6,1	0,4	7
Total Soluble Phosphorus µg Pℓ$^{-1}$	10	4	6	1,7	28	9	3	6	1,8	30	21	3	7	5,1	73
Nitrate-N µgN ℓ$^{-1}$	25	1	6	6,9	115	8	1	3	2,2	73	7	1	3	2,2	73
Ammonia-N µgN ℓ$^{-1}$	22	3	9	5,5	61	23	5	11	5,0	45	20	5	9	4,8	53
Dissolved Oxygen mgℓ$^{-1}$	9,1	7,5	8,3	0,6	7	9,7	7,7	9,0	0,6	6	9,4	7,4	8,7	0,6	7
Chlorophyll mg/ m³	12,0	4,0	2,9	2,4	30	11,1	2,6	7,9	2,6	33	23,0	10,1	16,1	3,9	24

5.6 ENVIRONMENTAL SURVEYS.

Various photographs of certain areas taken around Lake Mzingazi revealed that potential pollution threats exist. On the Golf Course side, it was observed that vegetation had been removed from the banks of the lake. Already signs of erosion were visible. Should this remain bare it could raise the turbidity of water due to debris and silt flowing into the lake on rainy days. The second problem was that of exotic plants observed on the western side of the lake. These were traced back to the golf course. It was obvious that they originated from the Meerensee suburb situated on the eastern side of the lake. These plants are a nuisance to the environmental especially when allowed to grow on water resources since they are capable of covering the whole surface like the water hyacinth. When this occurs, dissolved oxygen on the water surface is drastically reduced and that may result in death of aquatic life. Secondly, sunrays are prevented from penetrating the water and this may result in a change in temperature thus affects aquatic life. The worse case scenario that can happen is the occurrence of eutrophication, which could render the water source unfit for human use.

The main human activity around the lake and especially along the tributaries of the lake was found to be land cultivation. In most areas vegetation and natural forests had been removed to open way for land cultivation. There is also animal husbandry taking place on the Mandlazini side of the lake and that has caused serious soil erosion due to livestock tracks when driven there for watering. Besides silt deposition during soil erosion into the lake, there is also a possibility of increasing contamination of faecal coliforms due to cow dung and urine, as mentioned previously.

The unplanned human settlement in close proximity to the lake poses serious future pollution implications. Homesteads in this area have no access to any waterborne sewerage facility and as a result thereof the pit latrine system is in use. There is a potential for seepage from these structures, which could have negative impacts in the lake, thus resulting in major deterioration of the water quality due to human faecal contamination. Such an outcome will be a disaster since human faeces may also contain pathogenic microorganisms. The second problem with improper settlement on the banks of the lake is the dumping of domestic waste. As previously alluded to, road infrastructure is seriously lacking and, therefore there is no collection of domestic waste for proper disposal. The lake thus remains at risk of being polluted by various wastes produced by humans.

On the Mzingazi agri-village side, blue gum tree plantations were observed. These trees are known to have a high water usage, which may result in a decrease in the lake water level causing it to shrink. Such a development should not be allowed since many people depend on the lake for basic water needs.

Boat launch areas were observed where substandard boats were used for fishing purposes. Fishermen were seen on most occasions of lake sampling and survey.
All of the above observations need to be considered and borne in mind when proposing recommendations for the lake protection plan.

5.7 SUMMARY

This chapter has discussed the results obtained during the study. Each variable had been discussed and paying particular attention to the Department of Water Affairs & Forestry guidelines. The importance of the guidelines to the study and the relationship to public health has been illustrated.

Though the results proved acceptable during this study, it would be crucial for the municipality of uMhlathuze to maintain a closer eye to those changes that were observed. Looking at the development around the lake, there is no doubt that pollution risk exists due to proximity to the lake. At present the water quality of Lake Mzingazi falls within Class 1 and Class 2 in terms of the findings. It still remains a good source for the provision of domestic water via the water purification plant.

Comparison of the water quality during the study of 1978/79 and the results for 2006 using mean values show some noticeable changes. The pH of the lake gave a mean of 7.43 in 1979 while it went up to 7.84 in 2006. The value for the period of 1998 – 2005 shows a mean of 7.75. This indicates an increasing trend. Therefore, the development around the lake has an impact.

The suspended solids for 1979 had a mean of 5mg/l and increased to 16.21mg/l for the period of 1998 to 2005. However, it seemed to have dropped to 6.79 mg/l in 2006. This still shows an increase in the variable. Conductivity mean was 33.9 Ms/m before developments. It went up to 43.46mS/m during the period of 1998- 2005. It further went up to 44.79 mS/m in 2006. An increasing trend. Nitrates measured in 1979 gave a mean of 6.9 µg/l and it was 1.83 mg/l for the period 1998 to 2005. It measured 0.48 mg/l. There is a slight drop between the last two periods. However, it still shows an increase as well. The chlorophyll a had a mean of 2.9 mg/m^3 during the study in 1979 and 1.09 mg/l for the period of 1998 – 2005 and a value of 2.65 mg/l during 2006. Again an increasing trend is being observed. Therefore, the trend is indicative of changes in the physico-chemical characteristics of the surface water quality of Lake Mzingazi. Though the quality of this resource is still within the parameters laid down in the South African National Standard (SANS 241: 2006) for domestic water supply, there is nevertheless a reason for concern as to how long it will take for it to exceed acceptable limits of the Department of Water Affairs & Forestry.

Remediation measures are already necessary by the uMhlathuze Municipality. Aquatic plants growing along the banks of the lake and particularly in the area located at the entrance of Khondweni River and Mandlazini River are indicative of the shallowness of the lake. Soil and silt washed off by rain is the main cause. Dredging is the only possible way to remove the soil together with unwanted weeds. However, careful planning should be done as dredging may cause turbulence and turbidity increase in water. As might be anticipated, such measures would require a financial injection from the municipality. Biological treatment of invasive plants such as the water lettuce should be employed to avoid further multiplication of the weed, thereby preventing eutrophication from taking place in future. Other pollution problems can be addressed through the creation of environmental awareness amongst people in the area.

6 CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The study has successfully dealt with the specific objectives in the following manner: The active co-operation of the community was regarded as the most essential step in undertaking the study. The researcher developed a good understanding and respect with the leaders in the communities, especially those in the agri-villages, namely Mzingazi, Mandlazini and Sabokwe. These communities have both assisted and co-operated satisfactorily with the research team and, furthermore, undertook to continue in this manner. Herewith lies an important achievement since they constitute a valuable constituency whose co-operation is necessary in the implementation of any protection measures on Lake Mzingazi.

Data was collected for the year 2006 and was used as primary data while the secondary data obtains for the period of 1998 to 2005 was successfully acquired from the local municipality. Both sets of data were processed to provide information regarding the water quality in the lake. The results were then compared to identify any changes in the water quality. The results of the previous studies during 1978/79 and the results of this study indicated that the lake water quality fell within allowable limits, as stipulated in terms of the Department of Water Affairs & Forestry guidelines and the South African National Standard.

The evaluation of the current results of the study confirms the water quality in Lake Mzingazi as ranging between Class I and Class II. Such water is satisfactory and may be used for human consumption after the conventional water purification process. At present no negative effects can be anticipated in relation to public health, as the quality of the resource does not pose a health risk in terms of the Department of Water Affairs & Forestry guidelines.

It is a disturbing factor however, that currently the development of homesteads was found to occur very close to the banks of the lake. Absolutely no barrier separates human settlements from the lake. This is a cause for concern as human waste has been discovered near the lake, having been dumped owing to lack of collection.

Organic substances can be washed into the lake thereby causing pollution. Land cultivation situated close to the lake retains the potential to further increase silting as a result of soil erosion. The increase in chlorophyll a is a serious warning that the lake is receiving nutrients that, in turn, is promoting aquatic plant growth on water surface. Odours and bad taste have been experienced during hot summer months as a result. This is an indication that pollution is creeping into the lake and potentially disastrous consequences are possible as algal bloom could occur.

The lake survey and investigations made it possible to identify existing and future potential pollution threats to Lake Mzingazi through human practices. The destruction of wetland forests and removal of natural vegetation will ultimately affect the natural filtration capacity of the wetland, thus allowing most pollutants to enter the lake in future. It is mandatory that that the Water Service Authority obtains the people's willing co-operation in order to prevent further environmental degradation that could lead to serious environmental implications for the community of Richards Bay. Every person in the municipality should be made aware that water is a basic right and, therefore all residents have a role to play in enhancing its value and the protection of river ecosystems and wetlands.

6.2 RECOMMENDATIONS

The purpose of this section is to inform and advise the Water Service Authority as the lead agent in the uMhlathuze local authority's water conservation, of measures that can be undertaken to protect the lake ecosystem. However, an informed decision-making will require the involvement of the communities in the vicinity of the lake in order to achieve maximum co-operation from all role players.
The recommendations based on the findings of the study consist of the following:

The Water Service Authority should develop Lake Mzingazi management policy that will be linked to the municipality's developing ISO-14001. An appropriate example is that utilised by the government of Swaziland to protect Lake Matsamo. (Department of Water Affairs & Forestry/ Swaziland Ministry for Natural Resources & Energy/ Komati Basin Water Authority. Management Plan for Sustainable Development & Utilisation of Lake Matsamo and Surrounds: Swaziland. February

2004). The policy should necessarily indicates precisely how water usage from the lake is to be acquired in order to avoid direct extraction from the lake, as is presently the situation prevailing with the Meerensee Golf Estate. Irrigation of the golf greens should be done via a metered pipe system from the municipality's reticulated water system. The Water Services Authority should account for all water usage under its control.

- There is an urgent need to form a lake management forum, which will include community representatives from the agri-villages, Meerensee, Arboretum, industries and forest companies (Mondi Forests, Safcol). The purpose of the forum is to discuss issues pertaining to human activities around Lake Mzingazi. It is through communication and education that communities will understand the impact of their activities on the environment. The Department of Water Affairs & Forestry should be invited to the meetings for guidance and support.

- Water Services Authority must develop and maintain a water quality-monitoring programme that will capture all changes occurring in the lake and which will act as an early warning tool should changes in water quality occur in the lake. This will provide ample time to act in order to prevent any further damage to the ecosystem of the lake.

- Mandlazini agri-village and Mzingazi agri-village should set aside an area where a properly built watering facility for livestock can be located. In this manner soil erosion and pollution by livestock can be avoided.

- Homesteads in the vicinity of the lake should be advised to utilize conservancy tanks for sewerage collection. The conservancy storage tanks should be emptied when 75% full in order to avoid the contents potentially overflowing into the environment.

- Eucalyptus plantations around the lake should be discouraged to ensure that the lake is not unnecessarily deprived of any more water.

- A life cycle study for Lake Mzingazi should be undertaken in order to determine the sustainability of the lake for future generation.

- No fishing should be allowed in Lake Mzingazi. People found trespassing should be arrested. This will serve as a deterrent as regards people using the lake. The sea remains easily accessible and located nearby and people should therefore be encouraged to use it for fishing purposes instead.

- Homesteads located in close vicinity to the lake should be relocated in order to prevent further lake pollution.

6.3 SUMMARY

The lake has demonstrated resilience to pollution deriving from human activities. The reason herefore lies in its assimilation capacity. However, limits exist which when exceeded, occasion the occurrence of negative impacts. Therefore, the community should undertake only positive actions in ensuring that the environment receives the appropriate and necessary respect and consideration in order to sustain its human population.

Recommendations have been made and are based on the findings of this study. The community will benefit provided they take heed of the latter and work in collaboration with the Water Services Authority of uMhlathuze Municipality in protecting Lake Mzingazi.

A rapid positive response from the people of Richards Bay will greatly facilitate the satisfactory condition of this resource for themselves and their progeny. The time to act is now! While the problems around the lake are not unique and may seem to not have obtained the level of severity as in other parts of the country, they nevertheless remain serious.

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7 APPENDICES

7.1 APPENDIX A: SECONDARY DATA FOR THE PERIOD 1998 to 2005

TABLE 6: Water Quality at Sample Point 1, Lake Mzingazi (1998to 2005)

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
15/10/1998	8.04	20.00	45.40	4.48	82.00	1.76	0.00	0.00	0.00	0.00
01/12/1998	7.51	19.17	43.35	4.98	78.83	2.56	0.36	0.96	0.00	5
03/12/1998	8.13	10.00	47.00	5.57	86.00	1.32	0.00	0.00	0.00	0.00
26/02/1999	7.10	15.00	45.80	3.10	84.00	5.28	0.00	0.00	0.00	0.00
10/03/1999	7.10	20.00	46.20	4.30	82.00	2.64	0.00	0.00	0.00	0.00
29/04/1999	6.80	10.00	47.30	3.37	84.00	3.08	0.00	0.00	0.00	0.00
28/07/1999	6.97	45.00	47.90	2.37	88.00	3.08	0.00	0.00	0.00	0.00
11/10/1999	7.01	25.00	52.10	15.80	88.00	3.08	0.45	0.02	0.00	0.00
28/02/2000	8.33	20.00	47.20	7.25	88.00	2.68	0.20	1.50	0.00	0.00
04/07/2000	7.68	15.00	42.80	2.61	70.00	2.64	0.52	1.35	0.00	0.00
06/11/2000	8.06	15.00	36.80	5.67	70.00	2.64	0.47	2.10	0.00	0.00
25/01/2001	7.69	35.00	30.40	1.51	58.00	2.20	0.31	0.38	0.00	7
01/08/2001	7.51	19.17	43.35	4.98	78.83	2.56	0.36	0.96	0.00	5
22/08/2001	7.59	15.00	28.30	1.49	64.00	0.70	0.23	0.11	0.41	2
13/11/2001	7.17	10.00	32.10	1.30	68.00	0.61	0.12	0.26	2.66	0.00
01/08/2002	7.62	8.00	34.30	1.13	72.00	0.31	0.24	0.24	1.94	1
01/12/2004	7.90	9.00	43.70	1.53	86.00	0.10	0.32	1.17	1.46	2.00
06/07/2005	7.40	9.00	42.00	1.39	86.00	0.12	0.27	0.65	1.78	4.00
09/11/2005	7.80	9.00	43.40	1.54	86.00	0.08	0.32	0.68	3.43	0.00
AVERAGE	**7.55**	**17.28**	**42.07**	**3.91**	**78.93**	**1.97**	**0.22**	**0.55**	**0.61**	**1.00**

TABLE 7: Water Quality at Sample Point 2, Lake Mzingazi (1998to 2005)

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
15/10/1998	8.26	60.00	47.40	4.69	84.00	0.44	0.00	0.00	0.00	0.00
01/12/1998	7.84	17.50	43.89	4.08	79.17	3.20	0.32	0.96	0.00	29
03/12/1998	8.32	15.00	47.40	4.80	86.00	3.96	0.00	0.00	0.00	0.00
26/02/1999	8.00	10.00	45.40	3.90	86.00	4.12	0.00	0.00	0.00	0.00
10/03/1999	7.80	20.00	46.00	4.30	84.00	3.08	0.00	0.00	0.00	0.00
29/04/1999	7.51	15.00	47.10	3.47	84.00	2.44	0.00	0.00	0.00	0.00
28/07/1999	7.51	30.00	79.90	4.24	86.00	3.08	0.00	0.00	0.00	0.00
11/10/1999	7.30	25.00	52.40	7.75	88.00	4.84	0.38	0.02	0.00	0.00
28/02/2000	8.49	15.00	47.60	6.23	88.00	3.20	0.20	1.70	0.00	0.00
04/07/2000	7.70	15.00	42.90	1.33	70.00	2.64	0.51	1.12	0.00	0.00
06/11/2000	8.25	10.00	40.00	2.95	70.00	2.64	0.30	2.00	0.00	0.00
25/01/2001	7.55	15.00	29.10	1.21	58.00	2.64	0.31	0.47	0.00	10
01/08/2001	7.84	17.50	43.89	4.08	79.17	3.20	0.32	0.96	0.00	29
22/08/2001	7.52	15.00	32.60	1.99	66.00	0.80	0.23	0.05	0.45	6
13/11/2001	7.00	10.00	33.00	1.32	66.00	0.45	0.21	0.22	2.13	1
01/08/2002	7.61	5.00	34.50	1.38	74.00	0.28	0.30	0.25	1.39	19
01/12/2004	7.80	6.00	43.60	1.67	88.00	0.12	0.29	0.40	0.49	1.00
06/07/2005	7.50	9.00	41.90	1.38	86.00	0.10	0.37	0.61	1.24	21.00
09/11/2005	7.80	6.00	43.20	1.62	88.00	0.10	0.29	0.74	2.37	0.00
AVERAGE	**7.77**	**16.63**	**44.30**	**3.28**	**79.49**	**2.18**	**0.21**	**0.50**	**0.42**	**6.00**

TABLE 8: Water Quality at Sample Point 3, Lake Mzingazi (1998to 2005)

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
15/10/1998	8.28	40.00	47.90	9.51	84.00	0.88	0.00	0.00	0.00	0.00
01/12/1998	7.89	15.17	44.17	4.21	79.83	2.40	0.35	0.90	0.00	6
03/12/1998	8.19	15.00	48.40	5.92	88.00	2.20	0.00	0.00	0.00	0.00
26/02/1999	8.00	5.00	45.60	3.63	86.00	3.20	0.00	0.00	0.00	0.00
10/03/1999	8.00	10.00	45.90	4.40	84.00	2.64	0.00	0.00	0.00	0.00
29/04/1999	7.22	10.00	47.30	3.77	86.00	2.64	0.00	0.00	0.00	0.00
28/07/1999	7.45	30.00	48.10	4.28	86.00	2.20	0.00	0.00	0.00	0.00
11/10/1999	7.86	25.00	52.50	7.60	90.00	2.64	0.39	0.02	0.00	0.00
28/02/2000	8.85	20.00	47.50	5.20	88.00	2.64	0.40	0.80	0.00	0.00
04/07/2000	7.38	15.00	43.00	1.69	70.00	1.76	0.50	1.39	0.00	0.00
06/11/2000	8.56	10.00	39.90	2.96	70.00	2.64	0.27	2.10	0.00	0.00
25/01/2001	7.63	25.00	30.10	2.39	58.00	1.76	0.32	0.56	0.00	7
01/08/2001	7.89	15.17	44.17	4.21	79.83	2.40	0.35	0.90	0.00	6
22/08/2001	7.49	10.00	33.40	1.93	66.00	0.70	0.19	0.09	0.53	5
13/11/2001	7.18	7.00	33.30	1.53	68.00	0.21	0.16	0.22	2.13	16
01/08/2002	7.50	5.00	35.50	1.29	74.00	0.11	0.26	0.21	1.60	49
01/12/2004	7.80	5.00	43.40	1.62	86.00	0.10	0.29	0.37	0.96	2.00
06/07/2005	7.50	8.00	42.20	1.39	84.00	0.18	0.34	0.68	2.22	7.00
09/11/2005	7.70	5.00	43.60	1.60	84.00	0.14	0.29	0.64	2.39	0.00
AVERAGE	**7.81**	**14.49**	**42.94**	**3.64**	**79.56**	**1.65**	**0.22**	**0.47**	**0.52**	**5.00**

TABLE 9: Water Quality at Sample Point 4, Lake Mzingazi (1998to 2005)

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
15/10/1998	7.55	60.00	51.50	20.80	86.00	2.64	0.00	0.00	0.00	0.00
01/12/1998	7.88	16.25	45.01	4.40	79.67	3.03	0.37	0.91	0.00	33
03/12/1998	8.20	10.00	48.60	5.69	88.00	3.52	0.00	0.00	0.00	0.00
26/02/1999	7.60	5.00	45.70	3.95	84.00	3.52	0.00	0.00	0.00	0.00
10/03/1999	7.90	10.00	46.60	4.30	84.00	2.64	0.00	0.00	0.00	0.00
29/04/1999	7.69	10.00	47.70	2.20	84.00	2.20	0.00	0.00	0.00	0.00
28/07/1999	7.74	30.00	49.00	2.89	88.00	2.20	0.00	0.00	0.00	0.00
11/10/1999	7.96	25.00	54.40	7.40	90.00	1.76	0.40	0.03	0.00	0.00
28/02/2000	8.88	20.00	46.70	7.56	86.00	2.20	0.40	1.20	0.00	0.00
04/07/2000	7.40	15.00	43.10	2.30	70.00	2.20	0.48	1.30	0.00	0.00
06/11/2000	8.44	10.00	41.20	3.58	70.00	2.64	0.35	2.30	0.00	0.00
25/01/2001	7.65	25.00	32.20	2.92	60.00	1.32	0.36	0.17	0.00	60
01/08/2001	7.88	16.25	45.01	4.40	79.67	3.03	0.37	0.91	0.00	33
22/08/2001	7.42	5.00	36.10	1.84	64.00	0.70	0.21	0.14	0.45	6
13/11/2001	7.20	13.00	36.70	2.61	68.00	0.31	0.22	0.22	12.50	3
01/08/2002	7.34	6.00	34.10	1.52	72.00	0.18	0.21	0.23	2.36	11
01/12/2004	7.80	7.00	44.40	1.46	86.00	0.10	0.27	3.72	1.24	1.00
06/07/2005	7.50	9.00	42.40	1.42	84.00	0.10	0.31	0.67	2.72	2.00
09/11/2005	7.70	7.00	42.60	1.45	84.00	0.10	0.27	0.77	3.19	0.00
AVERAGE	**7.78**	**15.76**	**43.84**	**4.35**	**79.33**	**1.81**	**0.22**	**0.66**	**1.18**	**8.00**

TABLE 10: Water Quality at Sample Point 5, Lake Mzingazi (1998to 2005)

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
15/10/1998	7.98	20.00	48.20	7.64	82.00	3.96	0.00	0.00	0.00	0.00
01/12/1998	7.88	16.67	44.67	4.48	79.50	2.33	0.40	1.09	0.00	95
03/12/1998	8.15	20.00	48.90	6.74	88.00	2.64	0.00	0.00	0.00	0.00
26/02/1999	7.70	5.00	45.80	3.41	82.00	1.60	0.00	0.00	0.00	0.00
10/03/1999	7.60	20.00	46.70	4.40	82.00	3.08	0.00	0.00	0.00	0.00
29/04/1999	7.86	10.00	48.20	3.35	86.00	2.20	0.00	0.00	0.00	0.00
28/07/1999	7.88	30.00	42.30	3.53	88.00	3.08	0.00	0.00	0.00	0.00
11/10/1999	7.81	25.00	55.30	7.56	88.00	2.20	0.38	0.02	0.00	0.00
28/02/2000	8.71	15.00	46.20	7.52	86.00	1.76	0.50	1.40	0.00	0.00
04/07/2000	7.39	15.00	43.00	2.32	70.00	2.64	0.48	1.16	0.00	0.00
06/11/2000	8.66	15.00	41.50	4.64	70.00	2.20	0.44	2.90	0.00	0.00
25/01/2001	7.60	25.00	32.70	2.63	60.00	1.76	0.36	0.47	0.00	183
01/08/2001	7.88	16.67	44.67	4.48	79.50	2.33	0.40	1.09	0.00	95
22/08/2001	7.44	15.00	36.10	1.90	66.00	0.80	0.26	0.06	0.61	7
13/11/2001	7.22	14.00	33.40	1.84	66.00	0.31	0.21	0.22	16.49	14
01/08/2002	7.33	7.00	35.90	2.34	72.00	0.29	0.22	0.19	2.80	17
01/12/2004	7.70	9.00	44.60	2.48	86.00	0.13	0.27	0.36	1.02	0.00
06/07/2005	7.50	9.00	42.60	1.96	86.00	0.13	0.29	0.65	2.84	3.00
09/11/2005	7.70	7.00	43.60	2.48	84.00	0.13	0.27	0.73	3.60	0.00
AVERAGE	**7.79**	**15.49**	**47.61**	**3.99**	**79.00**	**1.77**	**0.24**	**0.54**	**1.44**	**3.00**

TABLE 11: Water Quality at Sample Point 6, Lake Mzingazi (1998to 2005)

Sample Date	Ph	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
15/10/1998	8.20	14.00	47.90	5.71	82.00	2.20	0.00	0.00	0.00	0.00
01/12/1998	7.61	16.25	48.10	4.79	79.17	2.15	0.37	0.96	0.00	100
03/12/1998	7.86	10.00	48.60	8.81	86.00	2.64	0.00	0.00	0.00	0.00
26/02/1999	7.40	5.00	46.30	3.74	84.00	2.52	0.00	0.00	0.00	0.00
10/03/1999	7.40	15.00	48.00	4.40	82.00	1.76	0.00	0.00	0.00	0.00
29/04/1999	7.58	10.00	57.70	3.41	84.00	2.64	0.00	0.00	0.00	0.00
28/07/1999	7.53	35.00	58.90	3.64	88.00	2.64	0.00	0.00	0.00	0.00
11/10/1999	7.98	20.00	54.50	7.50	88.00	2.20	0.37	0.02	0.00	0.00
28/02/2000	8.55	20.00	46.00	7.90	88.00	2.20	0.50	1.50	0.00	0.00
04/07/2000	7.29	15.00	45.50	2.69	70.00	2.20	0.49	1.05	0.00	0.00
06/11/2000	7.46	10.00	45.70	3.24	70.00	1.76	0.27	2.30	0.00	0.00
25/01/2001	7.59	25.00	37.80	5.95	60.00	1.32	0.32	0.34	0.00	190
01/08/2001	7.61	16.25	48.10	4.79	79.17	2.15	0.37	0.96	0.00	100
22/08/2001	7.48	10.00	37.10	1.91	66.00	0.70	0.28	0.06	0.57	10
13/11/2001	7.41	15.00	33.60	1.96	66.00	0.26	0.21	0.26	14.90	11
01/08/2002	7.37	8.00	36.40	2.93	72.00	0.20	0.22	0.34	3.02	9
01/12/2004	7.70	11.00	45.10	2.10	88.00	0.14	0.26	0.32	1.12	3.00
06/07/2005	7.40	7.00	43.20	1.78	84.00	0.08	0.23	0.58	2.68	3.00
09/11/2005	7.60	8.00	43.60	2.09	86.00	0.14	0.26	0.13	5.12	6.00
AVERAGE	**7.63**	**14.24**	**45.90**	**4.18**	**79.07**	**1.57**	**0.22**	**0.46**	**1.44**	**22**

TABLE 12: Water Quality at Sample Point 7, Lake Mzingazi (1998to 2005)

Sample Date	PH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
15/10/1998	8.27	6.00	47.00	5.38	82.00	3.52	0.00	0.00	0.00	0.00
01/12/1998	7.77	16.25	45.87	4.49	79.33	2.58	0.35	0.99	0.00	175
03/12/1998	8.13	10.00	48.30	6.42	86.00	3.08	0.00	0.00	0.00	0.00
26/02/1999	7.30	10.00	46.00	3.70	82.00	4.40	0.00	0.00	0.00	0.00
10/03/1999	7.70	30.00	47.40	4.20	84.00	2.64	0.00	0.00	0.00	0.00
29/04/1999	7.95	5.00	48.70	2.13	84.00	2.44	0.00	0.00	0.00	0.00
28/07/1999	7.65	25.00	49.80	4.08	86.00	2.20	0.00	0.00	0.00	0.00
11/10/1999	8.04	30.00	54.30	7.40	90.00	2.20	0.30	0.02	0.00	0.00
28/02/2000	8.63	20.00	45.90	7.42	88.00	2.20	0.30	1.60	0.00	0.00
04/07/2000	7.21	10.00	43.40	3.00	70.00	2.64	0.51	1.21	0.00	0.00
06/11/2000	7.98	15.00	42.10	3.31	70.00	2.20	0.43	2.30	0.00	0.00
25/01/2001	7.70	15.00	33.40	3.79	62.00	1.76	0.37	0.34	0.00	26
01/08/2001	7.77	16.25	45.87	4.49	79.33	2.58	0.35	0.99	0.00	175
22/08/2001	7.47	10.00	37.20	1.96	66.00	0.70	0.18	0.06	0.45	9
13/11/2001	7.42	17.00	37.00	2.20	68.00	0.25	0.19	0.22	12.77	2
01/08/2002	7.72	8.00	35.40	2.91	74.00	0.21	0.21	0.33	3.96	9
01/12/2004	7.70	7.00	45.00	1.66	88.00	0.10	0.26	0.13	2.05	2.00
06/07/2005	7.40	9.00	42.50	1.85	84.00	0.10	0.25	0.66	2.96	3.00
09/11/2005	7.70	8.00	43.20	1.64	86.00	0.10	0.26	0.47	8.06	4.00
AVERAGE	**7.77**	**14.08**	**44.12**	**3.79**	**79.40**	**1.89**	**0.21**	**0.49**	**1.59**	**21**

TABLE 13: Water Quality at Sample Point 8, Lake Mzingazi (1998to 2005)

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
15/10/1998	7.53	60.00	45.50	5.41	82.00	2.64	0.00	0.00	0.00	0.00
01/12/1998	7.75	17.50	45.16	3.75	79.36	2.92	0.34	0.84	0.00	13
03/12/1998	8.22	10.00	47.80	5.63	86.00	3.52	0.00	0.00	0.00	0.00
26/02/1999	7.70	10.00	45.80	3.72	82.00	5.72	0.00	0.00	0.00	0.00
10/03/1999	8.00	20.00	46.40	4.30	84.00	1.32	0.00	0.00	0.00	0.00
29/04/1999	7.38	5.00	45.70	2.18	86.00	2.60	0.00	0.00	0.00	0.00
28/07/1999	7.58	40.00	49.30	2.15	88.00	3.08	0.00	0.00	0.00	0.00
11/10/1999	8.21	35.00	54.10	6.80	88.00	2.20	0.31	0.02	0.00	0.00
28/02/2000	8.14	15.00	46.40	5.20	88.00	2.64	0.30	0.90	0.00	0.00
04/07/2000	7.17	15.00	42.40	2.10	70.00	3.20	0.48	1.06	0.00	0.00
06/11/2000	8.22	15.00	41.70	3.44	70.00	2.64	0.36	2.30	0.00	0.00
25/01/2001	7.49	15.00	32.20	2.86	60.00	1.76	0.36	0.21	0.00	18
01/08/2001	7.51	19.17	43.35	4.98	78.83	2.56	0.36	0.96	0.00	5
22/08/2001	7.45	10.00	36.70	1.98	64.00	0.70	0.25	0.08	0.53	8
13/11/2001	7.54	7.00	36.10	1.71	68.00	0.31	0.19	0.26	16.76	1
01/08/2002	7.71	7.00	34.70	1.83	74.00	0.16	0.24	0.22	2.93	20
01/12/2004	7.80	10.00	44.20	1.88	86.00	0.10	0.28	0.63	0.52	2.00
09/11/2005	7.60	8.00	43.40	1.86	88.00	0.10	0.28	0.68	7.99	0.00
AVERAGE	**7.73**	**17.70**	**43.38**	**3.43**	**79.01**	**2.36**	**0.21**	**0.45**	**1.60**	**4.00**

TABLE 14: Water Quality at Sample Point 9, Lake Mzingazi (1998to 2005)

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
01/12/1998	7.89	15.00	46.98	4.03	80.00	2.81	0.39	1.02	0.00	6
03/12/1998	8.27	10.00	47.90	5.53	88.00	3.52	0.00	0.00	0.00	0.00
26/02/1999	7.90	10.00	49.70	3.44	84.00	3.97	0.00	0.00	0.00	0.00
10/03/1999	8.00	10.00	49.10	4.30	84.00	2.20	0.00	0.00	0.00	0.00
29/04/1999	8.27	10.00	49.90	4.10	86.00	1.76	0.00	0.00	0.00	0.00
28/07/1999	8.02	25.00	54.80	3.85	88.00	3.52	0.00	0.00	0.00	0.00
11/10/1999	8.05	25.00	54.40	6.40	90.00	2.64	0.31	0.02	0.00	0.00
28/02/2000	8.73	20.00	46.50	5.23	88.00	2.64	0.40	1.70	0.00	0.00
04/07/2000	7.23	15.00	43.00	1.99	70.00	2.64	0.46	1.15	0.00	0.00
06/11/2000	7.45	15.00	45.00	3.01	70.00	1.86	0.48	2.50	0.00	0.00
25/01/2001	7.56	15.00	37.40	2.76	60.00	3.52	0.41	0.25	0.00	5
22/08/2001	7.45	10.00	36.30	1.96	66.00	0.70	0.31	0.08	0.49	7
13/11/2001	7.35	6.00	36.70	1.34	66.00	0.32	0.18	0.22	11.17	0.00
01/08/2002	7.48	7.00	35.20	1.99	72.00	0.10	0.22	0.19	3.01	15
01/12/2004	7.80	10.00	44.40	1.81	86.00	0.08	0.31	0.18	0.98	0.00
06/07/2005	7.40	8.00	42.50	1.69	86.00	0.13	0.23	0.61	1.97	5.00
09/11/2005	7.70	10.00	44.00	1.80	86.00	0.08	0.31	0.66	9.64	0.00
AVERAGE	**7.80**	**13.00**	**41.99**	**3.25**	**79.41**	**1.91**	**0.24**	**0.50**	**1.60**	**2**

TABLE 15: Water Quality at Sample Point10, Lake Mzingazi (1998to 2005)

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
01/12/1998	8.01	20.42	46.28	4.18	79.33	2.45	0.39	1.10	0.00	2
03/12/1998	8.30	10.00	46.90	5.70	84.00	3.52	0.00	0.00	0.00	0.00
26/02/1999	8.00	10.00	52.70	3.78	84.00	2.64	0.00	0.00	0.00	0.00
10/03/1999	8.00	10.00	54.10	4.40	82.00	2.64	0.00	0.00	0.00	0.00
29/04/1999	8.23	10.00	51.70	3.57	86.00	2.60	0.00	0.00	0.00	0.00
28/07/1999	8.06	70.00	53.50	4.12	88.00	3.08	0.00	0.00	0.00	0.00
11/10/1999	8.18	30.00	52.50	6.60	88.00	1.76	0.35	0.02	0.00	0.00
28/02/2000	8.88	20.00	47.20	6.09	86.00	1.76	0.40	2.20	0.00	0.00
04/07/2000	7.33	10.00	43.30	2.05	70.00	2.20	0.47	1.34	0.00	0.00
06/11/2000	7.89	15.00	42.00	2.62	70.00	1.86	0.46	2.30	0.00	0.00
25/01/2001	7.69	25.00	32.10	3.66	60.00	2.64	0.44	0.21	0.00	0
22/08/2001	7.51	10.00	33.80	1.96	66.00	0.70	0.22	0.13	0.53	4
13/11/2001	7.67	6.00	36.00	1.39	57.00	0.40	0.13	0.22	7.45	0.00
01/08/2002	7.69	6.00	34.20	2.22	74.00	0.19	0.29	0.25	2.73	6
01/12/2004	7.90	7.00	43.50	1.93	86.00	0.09	0.30	0.32	0.99	0.00
06/07/2005	7.50	7.00	42.10	1.34	86.00	0.15	0.32	0.65	2.59	2.00
09/11/2005	7.60	5.00	43.20	1.90	86.00	0.09	0.30	0.71	2.40	0.00
AVERAGE	**7.91**	**15.97**	**44.42**	**3.38**	**73.73**	**1.69**	**0.24**	**0.56**	**0.98**	**1.00**

TABLE 16: Water Quality at Sample Point11, Lake Mzingazi (1998to 2005)

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
01/12/1998	7.90	15.00	44.53	3.98	79.33	2.36	0.38	0.99	0.00	32
03/12/1998	8.25	10.00	46.70	4.60	86.00	2.20	0.00	0.00	0.00	0.00
26/02/1999	8.00	10.00	45.50	3.63	84.00	2.64	0.00	0.00	0.00	0.00
10/03/1999	7.10	15.00	46.00	4.30	82.00	3.08	0.00	0.00	0.00	0.00
29/04/1999	8.16	10.00	46.90	3.12	86.00	2.64	0.00	0.00	0.00	0.00
28/07/1999	8.01	25.00	47.50	3.89	88.00	3.08	0.00	0.00	0.00	0.00
11/10/1999	8.10	20.00	53.10	5.80	88.00	2.20	0.31	0.02	0.00	0.00
28/02/2000	8.96	15.00	47.30	5.23	88.00	2.20	0.40	1.90	0.00	0.00
04/07/2000	7.37	15.00	43.20	1.79	70.00	1.76	0.55	0.95	0.00	0.00
06/11/2000	7.96	10.00	41.00	3.31	70.00	1.76	0.45	2.10	0.00	0.00
25/01/2001	7.63	20.00	30.50	3.87	60.00	2.20	0.39	0.21	0.00	61
22/08/2001	7.40	10.00	34.10	1.94	66.00	0.70	0.21	0.08	0.73	2
13/11/2001	7.43	7.00	33.30	2.40	66.00	0.37	0.13	0.26	6.12	2
01/08/2002	7.72	7.00	34.20	1.51	74.00	0.22	0.30	0.22	1.88	4
01/12/2004	7.90	8.00	43.40	1.38	86.00	0.10	0.31	0.27	1.30	6.00
06/07/2005	7.60	8.00	41.90	1.41	84.00	0.14	0.32	0.65	2.12	0.00
09/11/2005	7.80	8.00	43.20	1.42	86.00	0.09	0.31	0.70	2.86	2.00
AVERAGE	**7.84**	**12.53**	**42.49**	**3.15**	**79.02**	**1.63**	**0.24**	**0.49**	**0.88**	**6**

TABLE 17: Water Quality at Sample Point12, Lake Mzingazi (1998to 2005)

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
01/12/1998	7.72	15.42	44.10	4.38	79.33	2.61	0.41	0.95	0.00	7
03/12/1998	8.26	5.00	47.80	5.40	86.00	3.52	0.00	0.00	0.00	0.0
26/02/1999	7.20	10.00	44.70	3.71	82.00	2.64	0.00	0.00	0.00	0.00
10/03/1999	7.80	10.00	45.80	4.30	82.00	2.64	0.00	0.00	0.00	0.00
29/04/1999	8.14	10.00	46.40	3.37	86.00	2.20	0.00	0.00	0.00	0.00
28/07/1999	7.85	25.00	43.00	3.49	88.00	2.20	0.00	0.00	0.00	0.00
11/10/1999	7.94	35.00	52.50	5.31	88.00	3.96	0.34	0.02	0.00	0.00
28/02/2000	8.11	10.00	46.20	5.69	86.00	2.64	0.40	1.50	0.00	0.00
04/07/2000	7.42	15.00	43.20	1.42	70.00	1.86	0.52	1.10	0.00	0.00
06/11/2000	7.54	15.00	40.00	8.02	70.00	2.64	0.55	2.10	0.00	0.00
25/01/2001	7.44	15.00	30.90	3.96	60.00	2.20	0.40	0.43	0.00	10
22/08/2001	7.24	15.00	33.60	1.94	66.00	0.70	0.24	0.10	0.57	4
13/11/2001	7.48	4.00	34.50	1.81	68.00	0.34	0.25	0.22	3.72	2
01/08/2002	7.69	5.00	34.20	2.11	74.00	0.31	0.29	0.27	2.29	24
01/12/2004	7.80	10.00	43.10	1.33	86.00	0.11	0.33	0.38	2.04	3.00
06/07/2005	7.50	9.00	40.80	1.37	86.00	0.15	0.34	0.86	1.61	5.00
09/11/2005	7.80	5.00	43.40	1.33	86.00	0.10	0.33	0.65	3.04	1.00
AVERAGE	**7.70**	**12.55**	**42.01**	**3.47**	**79.02**	**1.81**	**0.26**	**0.50**	**0.78**	**3.00**

PROCESSED DATA

The results shown here give mean values of processed data and the statistics worked out from the proceeds data.

TABLE 18: Average Values for Sample Points, Lake Mzingazi (1998 to 2005)

Sample Points	PH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
1	7.55	17.28	42.07	3.91	78.93	1.97	0.22	0.55	0.61	1.00
2	7.77	16.63	42.03	3.28	79.49	2.18	0.21	0.50	0.42	6.00
3	7.81	14.49	42.94	3.64	79.56	1.65	0.22	0.47	0.52	5.00
4	7.78	16.25	43.91	4.35	79.33	1.81	0.22	0.66	1.18	8.00
5	7.79	15.49	47.61	3.99	79.00	1.77	0.24	0.54	1.44	22.00
6	7.63	14.24	45.90	4.18	79.07	1.57	0.22	0.46	1.44	22.00
7	7.77	14.08	44.12	3.79	79.14	1.89	0.21	0.49	1.59	21.00
8	7.72	17.70	43.38	3.43	79.01	2.36	0.21	0.45	1.60	4.00
9	7.80	13.00	41.99	3.25	79.41	1.91	0.24	0.50	1.60	2.00
10	7.91	15.97	44.42	3.38	73.73	1.69	0.24	0.56	0.98	1.00
11	7.84	12.53	42.49	3.15	79.02	1.63	0.24	0.49	0.88	6.00
12	7.70	12.55	42.01	3.47	79.02	1.81	0.26	0.50	0.78	3.00

7.2 APPENDIX B - PRIMARY DATA: 2006

TABLE 19: Water Quality at Sample Point 1, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	8.10	7.00	47.30	1.30	92.00	0.50	0.28	0.06	0.27	6.00
06/062006	7.80	11.00	44.50	1.60	90.00	0.15	0.65	0.05	3.14	5.00
25/07/2006	8.10	6.00	45.20	1.94	90.00	0.16	0.57	0.14	2.25	1.00
19/09/2006	6.80	3.00	46.20	2.60	92.00	0.40	0.06	0.08	4.33	0.00
22/11/2006	8.30	5.00	44.40	2.30	88.00	0.70	0.05	0.03	3.55	1.00
05/12/2006	7.80	3.00	44.90	2.50	90.00	0.00	0.06	0.02	1.71	0.00
AVERAGE	**7.82**	**5.83**	**45.42**	**2.04**	**90.33**	**0.32**	**0.28**	**0.06**	**2.54**	**2.00**

TABLE 20: Water Quality at Sample Point 2, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	8.00	2.00	46.30	1.20	94.00	0.70	0.29	0.05	0.27	3.00
06/062006	7.80	9.00	44.40	1.60	90.00	0.32	0.69	0.05	1.87	15.00
25/07/2006	8.00	7.00	45.40	2.30	90.00	0.31	0.60	0.10	2.44	7.00
19/09/2006	7.00	2.00	46.10	2.30	92.00	0.60	0.05	0.07	4.17	3.00
22/11/2006	8.00	3.00	44.70	2.60	88.00	1.40	0.05	0.03	3.55	2.00
05/12/2006	7.90	3.00	44.70	1.90	90.00	0.00	0.04	0.02	1.15	3.00
AVERAGE	**7.78**	**4.33**	**45.27**	**1.98**	**90.67**	**0.56**	**0.29**	**0.05**	**2.24**	**6.00**

TABLE 21: Water Quality at Sample Point 3, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	8.00	5.00	46.60	1.30	94.00	0.40	0.29	0.05	0.27	3.00
06/062006	7.70	15.00	43.70	2.60	88.00	0.36	0.35	0.05	2.84	8.00
25/07/2006	8.00	4.00	45.50	2.30	90.00	0.35	0.59	0.13	0.84	3.00
19/09/2006	7.10	6.00	46.20	2.20	92.00	0.60	0.06	0.16	3.81	0.00
22/11/2006	8.10	4.00	44.50	2.70	88.00	0.90	0.06	0.03	1.77	4.00
05/12/2006	8.00	4.00	44.80	3.00	90.00	0.00	0.04	0.03	2.29	0.00
AVERAGE	**7.82**	**6.33**	**45.22**	**2.35**	**90.33**	**0.44**	**0.23**	**0.08**	**1.97**	**3.00**

TABLE 22: Water Quality at Sample Point 4, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	7.90	1.00	47.60	1.60	92.00	0.30	0.26	0.05	0.27	5.00
06/062006	7.80	13.00	43.90	2.40	88.00	0.25	0.35	0.05	2.28	8.00
25/07/2006	8.00	5.00	46.30	2.60	90.00	0.25	0.37	0.09	1.11	5.00
19/09/2006	7.40	7.00	47.00	4.40	90.00	0.20	0.04	0.10	7.81	6.00
22/11/2006	8.20	5.00	43.00	3.50	88.00	1.10	0.04	0.02	4.34	2.00
05/12/2006	7.90	9.00	43.70	3.20	88.00	0.00	0.03	0.02	4.01	9.00
AVERAGE	**7.87**	**6.67**	**45.25**	**2.95**	**89.33**	**0.35**	**0.18**	**0.06**	**3.30**	**6.00**

TABLE 23: Water Quality at Sample Point 5, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	7.90	8.00	48.00	1.80	92.00	0.40	0.23	0.07	0.27	8.00
06/062006	7.80	18.00	43.60	2.50	90.00	0.15	0.36	0.05	2.48	8.00
25/07/2006	8.10	6.00	46.40	2.50	90.00	0.15	0.37	0.73	3.02	0.00
19/09/2006	7.30	8.00	47.10	4.00	90.00	0.50	0.05	0.12	4.28	21.00
22/11/2006	8.20	8.00	42.80	4.00	86.00	0.70	0.04	0.02	5.02	4.00
05/12/2006	7.90	14.00	43.60	2.00	90.00	0.00	0.03	0.02	2.29	5.00
AVERAGE	**7.87**	**10.33**	**45.25**	**2.80**	**89.67**	**0.32**	**0.18**	**0.17**	**2.89**	**8.00**

TABLE 24: Water Quality at Sample Point 6, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	7.90	12.00	48.10	1.40	94.00	0.60	0.23	0.16	0.27	12.00
06/062006	7.50	19.00	44.20	2.60	90.00	0.20	0.25	0.05	1.35	50.00
25/07/2006	8.00	5.00	46.30	2.40	90.00	0.21	0.28	0.08	2.64	0.00
19/09/2006	7.40	11.00	47.40	8.00	92.00	1.20	0.04	0.15	2.30	18.00
22/11/2006	8.20	4.00	41.10	3.90	88.00	0.20	0.03	0.03	2.56	12.00
05/12/2006	7.90	19.00	44.00	3.40	88.00	0.00	0.03	0.03	4.01	3.00
AVERAGE	**7.82**	**11.67**	**45.18**	**3.62**	**90.33**	**0.40**	**0.14**	**0.08**	**2.19**	**16.00**

TABLE 25: Water Quality at Sample Point7, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	7.80	3.00	48.30	1.40	94.00	0.60	0.24	0.07	0.27	8.00
06/062006	7.60	10.00	43.70	2.30	90.00	0.53	0.32	0.05	2.40	9.00
25/07/2006	8.00	3.00	15.20	2.50	90.00	0.53	0.30	3.37	1.83	0.00
19/09/2006	7.50	9.00	47.30	6.00	92.00	0.90	0.04	0.23	4.08	1.00
22/11/2006	8.00	6.00	41.40	4.50	86.00	0.80	0.04	0.04	2.96	2.00
05/12/2006	7.90	18.00	43.60	3.30	88.00	0.00	0.04	0.03	5.73	0.00
AVERAGE	**7.80**	**8.17**	**39.92**	**3.33**	**90.00**	**0.56**	**0.16**	**0.63**	**2.88**	**3.00**

TABLE 26: Water Quality at Sample Point 8, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	7.70	3.00	47.90	1.30	94.00	0.40	0.23	0.06	0.27	4.00
06/062006	7.60	17.00	43.90	2.40	90.00	0.45	0.38	0.05	2.23	8.00
25/07/2006	8.00	5.00	46.40	2.90	90.00	0.44	0.38	0.60	2.29	2.00
19/09/2006	7.60	6.00	46.80	4.70	90.00	0.60	0.04	0.11	5.42	2.00
22/11/2006	8.00	4.00	42.50	3.70	86.00	0.80	0.04	0.05	5.52	21.00
05/12/2006	7.90	9.00	43.70	1.80	90.00	0.00	0.03	0.03	2.29	0.00
AVERAGE	**7.80**	**7.33**	**45.20**	**2.80**	**90.00**	**0.45**	**0.18**	**0.15**	**3.00**	**6.00**

TABLE 27: Water Quality at Sample Point 9, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	8.00	4.00	47.80	1.40	92.00	1.20	0.22	0.07	0.27	7.00
06/062006	7.70	14.00	43.70	2.10	88.00	0.45	0.67	0.05	2.08	12.00
25/07/2006	7.90	4.00	46.20	2.60	90.00	0.45	0.38	0.05	2.27	1.00
19/09/2006	7.60	3.00	46.00	2.30	90.00	0.70	0.06	0.00	5.07	0.00
22/11/2006	8.10	7.00	43.20	3.40	88.00	0.30	0.05	0.03	5.52	0.00
05/12/2006	7.90	10.00	43.80	1.70	90.00	0.00	0.03	0.03	1.72	1.00
AVERAGE	**7.87**	**7.00**	**45.12**	**2.25**	**89.67**	**0.52**	**0.23**	**0.04**	**2.82**	**4.00**

TABLE 28: Water Quality at Sample Point10, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	8.00	1.00	46.50	1.60	92.00	0.30	0.27	0.06	0.27	4.00
06/062006	7.70	9.00	44.60	1.80	88.00	0.11	0.56	0.05	1.47	7.00
25/07/2006	8.00	4.00	45.40	1.80	90.00	0.12	0.51	0.05	2.87	1.00
19/09/2006	7.80	2.00	46.10	2.60	90.00	0.70	0.06	0.27	4.51	1.00
22/11/2006	8.00	2.00	44.60	2.70	88.00	0.50	0.07	0.02	5.32	0.00
05/12/2006	7.90	5.00	44.70	2.00	90.00	0.00	0.04	0.03	2.29	0.00
AVERAGE	**7.90**	**3.83**	**45.32**	**2.08**	**89.67**	**0.29**	**0.25**	**0.08**	**2.79**	**2.00**

TABLE 29: Water Quality at Sample Point 11, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	7.90	3.00	46.40	1.60	92.00	0.20	0.28	0.07	0.40	2.00
06/062006	7.60	14.00	44.70	1.50	88.00	0.06	0.65	0.05	1.01	10.00
25/07/2006	8.00	5.00	45.40	1.60	90.00	0.10	0.57	4.52	1.93	14.00
19/09/2006	7.80	1.00	46.20	2.40	92.00	1.00	0.07	0.26	4.36	1.00
22/11/2006	8.20	4.00	44.30	2.20	88.00	0.80	0.08	0.02	4.53	4.00
05/12/2006	7.80	3.00	44.80	4.70	90.00	0.00	0.04	0.03	2.29	0.00
AVERAGE	**7.90**	**5.00**	**45.30**	**2.33**	**90.00**	**0.36**	**0.28**	**0.83**	**2.42**	**5.00**

TABLE 30: Water Quality at Sample Point 12, Lake Mzingazi in 2006

Sample Date	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
26/04/2006	7.90	3.00	46.30	1.40	92.00	0.20	0.27	0.07	0.27	4.00
06/062006	7.60	10.00	43.50	1.60	90.00	0.14	0.65	0.05	1.55	10.00
25/07/2006	7.90	4.00	45.20	2.20	90.00	0.14	0.60	0.16	1.34	12.00
19/09/2006	8.00	5.00	46.00	2.50	92.00	1.00	0.07	0.07	4.33	1.00
22/11/2006	8.10	4.00	44.00	2.40	88.00	0.20	0.08	0.02	6.11	7.00
05/12/2006	7.80	4.00	45.00	2.60	90.00	0.00	0.04	0.02	2.87	8.00
AVERAGE	**7.88**	**5.00**	**45.00**	**2.12**	**90.33**	**0.28**	**0.29**	**0.07**	**2.75**	**7.00**

PROCESSED DATA

TABLE 31: Average Values of Sample Points, Lake Mzingazi in 2006

Points	pH	Suspended Solids mg/l	Conductivity mS/m	Turbidity NTU	Chlorides mg/l	NO3 mg/l	Fluoride mg/l	Total Phosphates mg/l	Chlorophyll a ug/l	Faecal Coli per 100ml
1	7.82	5.83	45.42	2.04	90.33	0.32	0.28	0.06	2.54	2.00
2	7.78	4.33	45.27	1.98	90.67	0.56	0.29	0.05	2.24	6.00
3	7.82	6.33	45.22	2.35	90.33	0.44	0.23	0.08	1.97	3.00
4	7.87	6.67	45.25	2.95	89.33	0.35	0.18	0.06	3.30	6.00
5	7.87	10.33	45.25	2.80	89.67	0.32	0.18	0.17	2.89	8.00
6	7.82	11.67	45.18	3.62	90.33	0.40	0.14	0.08	2.19	16.00
7	7.80	8.17	39.92	3.33	90.00	0.56	0.16	0.63	2.88	3.00
8	7.80	7.33	45.20	2.80	90.00	0.45	0.18	0.15	3.00	6.00
9	7.87	7.00	45.12	2.25	89.67	0.52	0.23	0.04	2.82	4.00
10	7.90	3.83	45.32	2.08	89.67	0.29	0.25	0.08	2.79	2.00
11	7.90	5.00	45.30	2.33	90.00	0.36	0.28	0.83	2.42	5.00
12	7.88	5.00	45.00	2.12	90.33	0.28	0.29	0.07	2.75	7.00

7.3 APPENDIX C: GUIDELINES/STANDARD

Table 7: Colour coded water quality classification system

Class	Colour	Description	Effects
I	Green	Good water quality (Target)	Suitable for use, rare instances of negative effects
II	Yellow	Marginal water quality	Conditionally acceptable. Negative effects may occur in some sensitive groups
III	Red	Poor water quality	Unsuitable for use without treatment. Possible chronic effects.

5.2.1 Surface Water:

- Surface Water (Rural / Urban Suburbs)
- Surface Water (Mzingazi Canal)
- Surface Water (Lakes)

Surface water in the City vicinity is mainly used for contact recreation, i.e. swimming and fishing, as well as a source of raw water for water purification. The quality of the surface water was therefore evaluated against the South African Water Quality Guidelines for Recreational, Aquatic Ecosystems and Domestic Use. A summary of the guideline values used is given in Tables 8.

Table 8: Water quality requirements for surface water as adapted from the South African Water Quality Guidelines for Recreational, Aquatic Ecosystems and Domestic Use

Determinants	Units	Class I	Class II	Class III	Guide
Microbiological Requirement					
E. Coli	Counts / 100ml	0 - 200	200 - 400	> 400	Rec.
F. Coli	Counts / 100ml	0 - 600	600 - 2000	> 2000	Rec.
Chemical Requirement					
pH	pH units	6.0 – 9.0	9.0 - 11	> 11.0	Dom
Chemical Requirements – Macro-determinant					
Chlorophyll a	µ g/L	0 -15	15 -30	> 30	Rec.
Ammonia as N	mg/L	0 - 1	1 - 10	> 10	Dom.
Chemical Oxygen Demand (COD)	mg/L				
Chloride	mg/L	0 - 200	200 - 600	> 600	Dom.
Conductivity	mS/m	70	70 - 150	> 150	Dom.
Dissolved Oxygen	% saturation	80 - 120	> 60	> 40	Aqu. Eco
Fluoride	mg/L	0-1.0	1-1.5	>3.5	Dom.

Nitrate as N	mg/L	0-6	6 - 20	> 20	Dom.
Ortho phosphates	mg/ L				
Potassium	mg/L	0-50	50 - 100	> 100	Dom.
Suspended Solids	mg/L				**
Sodium	mg/L	0-100	100 - 200	> 200	Dom.
Sulphate	mg/L	0-200	200 - 400	> 400	Dom.
Total Dissolved Solids	mg/L	0-450	450 - 1000	> 1000	Dom.
Total Hardness	mg/L	0-50	50 – 100	> 100	Dom.
Turbidity	NTU	0-1	1 - 5	> 5	Dom.
Determinants	**Units**	**Class I**	**Class II**	**Class III**	**Guide**
Chemical Requirements – Micro-determinant					
Aluminium as Al	mg/L	0 - 0.15	0.15 – 0.5	> 0.5	Dom.
Arsenic as As	mg/L	0 - 0.01	0.01 – 0.2	0.2 – 0.3	Dom.
Cadmium	mg/L	0 - 0.005	> 0.005	> 0.005	Dom.
Chromium (VI) as Cr^{6+}	mg/L	0 - 0.005	> 0.005	> 0.005	Dom.
Copper as Cu	mg/L	0 - 1.0	1 - 3	3 - 30	Dom.
Iron as Fe	mg/L	0 - 0.1	0.1 – 0.3	0.3 - 1.0	Dom.
Lead as Pb	mg/L	0 - 0.01	> 0.01	> 0.01	Dom.
Manganese as Mn	mg/L	0 - 0.05	0.05 – 0.1	0.1 – 0.15	Dom.
Mercury as	mg/L	0 - 0.001	> 0.001	> 0.001	Dom.
Selenium as Se	mg/L	0 - 0.02	0.02 – 0.05	0.05 – 0.1	Dom.
Vanadium as V	mg/L	0 - 0.1	> 0.1	> 0.1	Dom.
Zinc as Zn	mg/L	0 - 3	3 - 5	5 - 10	Dom.

**- Cannot change more than 15 %.

Rec. - South African Water Quality Guidelines for Recreational Use

Aqu.Eco - South African Water Quality Guidelines for Aquatic Ecosystems

Dom. - South African Water Quality Guidelines for Domestic Use

7.4 APPENDIX D: STATISTICAL SIGNIFICANCE OF THE RESULTS.

In analytical results it is necessary to specify the level of uncertainty usually due to random error or systematic error in the laboratory. This is normally based on the normal distribution curve that show how far or how close to the mean the results are. The measure of this is known as the Confidence Interval (CI). For this study the CI is 95%. Only 5% is allowed as an error.

CI = $\mu \pm (Z*\sigma)$, where Z is the statistical factor for 95% confidence interval, σ is the population standard deviation and μ is the mean value. Then CI = $\mu \pm \overline{(}1.96*\sigma)$. In this case it means that all at results lie between the mean and ± 2 standard deviations

CONFIDENCE INTERVALS FOR SECONDARY DATA: 1998- 2005

- **pH** mean value was 7.75 giving a CI as 7.75± 0.18. This means that the true value will be found between 7.57 – 7.93 that is within acceptable range.
- **Suspended Solids**: Mean = 15.02mg/l and CI = 15.02mg/l ± 6mg/l. The true value lies between 9.02mg/l and 21.02mg/l. In this case the CI has a wide range, not every sample point was actually affected except where there was turbulence when the sample was taken.
- **Conductivity**: Mean = 43.57mS/m, CI = 43.57mS/m ± 2.43mS/m. The true value will lie between 41.14mS/m – 46.00 Ms/m
- **Turbidity**: Mean = 3.65 NTU, CI = 3.65 NTU ± 0.76 NTU, therefore true value lies between 2.89 NTU – 4.41NTU
- **Chlorides**: Mean = 78.73 mg/l while the CI =78.73mg/l ± 0.59mg/l, meaning the true value lies between 78.14mg/l – 79.32mg/l
- **Nitrates**: Mean = 1.85 mg/l and the CI= 1.85mg/l ± 0.37mg/l and the true value will lie between 1.48mg/l – 2.22 mg/l
- **Fluorides**: Mean = 0.23mg/l and the CI = 0.23mg/l ± 0.04mg/l and the true value lies between 0.19 mg/l – 0.27mg/l
- **Total Phosphates**: Mean = 0.51 mg/l and the CI = 0.51 mg/l ± 0.12 mg/l and the true value lies between 0.39mg/l – 0.63mg/l
- **Chlorophyll a**: Mean = 1.09µg/l and the CI = 1.09µg/l ± 0.86µg/l and the true value lies between 0.23µg/l – 1.95µg/l

- **Faecal Coli**: Mean = 8.00coliforms/100ml, giving a CI = (8.00± 2.00) coliforms/100ml.The wide range being that on initial stages analysis was not done. The true value lies between 8.00coli/100ml and 10.00coliforms/100ml

CONFIDENCE INTERVALS FOR THE PRIMARY DATA: 2006.

- **pH:** Mean = 7.84 and the CI = 7.84 ± 0.08. The true value lies between 7.76 – 7.92
- **Suspended Solids:** Mean = 6.79mg/l and the CI = 6.79mg/l ± 4.61mg/l and the true value lies between 2.18mg/l and 11.4mg/l. This shows a wide range, however, this is to be expected as sample points experienced different turbulence due to prevailing winds on the lake.
- **Conductivity:** Mean = 44.79mS/m and the CI = 44.79mS/m ± 3.02mS/m implying that the true value lies between 41.77mS/m and 47.81mS/m. The value at sample point is an outlier in terms of the CI, however, the value could be correct as the river traverse rural community who do not use fertilizer but manure.
- **Turbidity:** Mean = 2.55 NTU and the CI = 2.55 NTU ± 1.06 NTU. The true value lies between 1.49 NTU and3.61 NTU
- **Chlorides:** Mean = 90.03mg/l and the CI = 90.03 mg/l ± 0.76mg/l and the true value lies between 89.27mg/l and 90.79mg/l
- **Nitrates:** Mean = 0.40mg/l and the CI = 0.40mg/l ± 0.24mg/l. Therefore the true value lies between 0.16mg/l and 0.64mg/l
- **Fluorides:** Mean = 0.22 mg/l and the CI = 0.22mg/l ± 0.10mg/l, therefore the true value lies between 0.12mg/l and 0.32mg/l
- **Total Phosphates:** Mean = 0.19mg/l and the CI = 0.19mg/l ± 0.51mg/l and the true value lies between – 0.32mg/l and 0.71mg/l
- **Chlorophyll a:** Mean = 2.65μg/l and the CI = 2.65μg/l ± 0.74μg/l. Therefore the true value is between 1.91μg/l and 3.39μg/l
- **Faecal Coli:** Mean = 6.00coli /100 ml and the CI = (6.00coli/100ml ± 7.00) coli/100 ml. Therefore the true value lies between –1.00 coli/100 ml and 13.00coli/100 ml

7.5 APPENDIX E: MAIN FEEDER STREAMS OF LAKE MZINGAZI

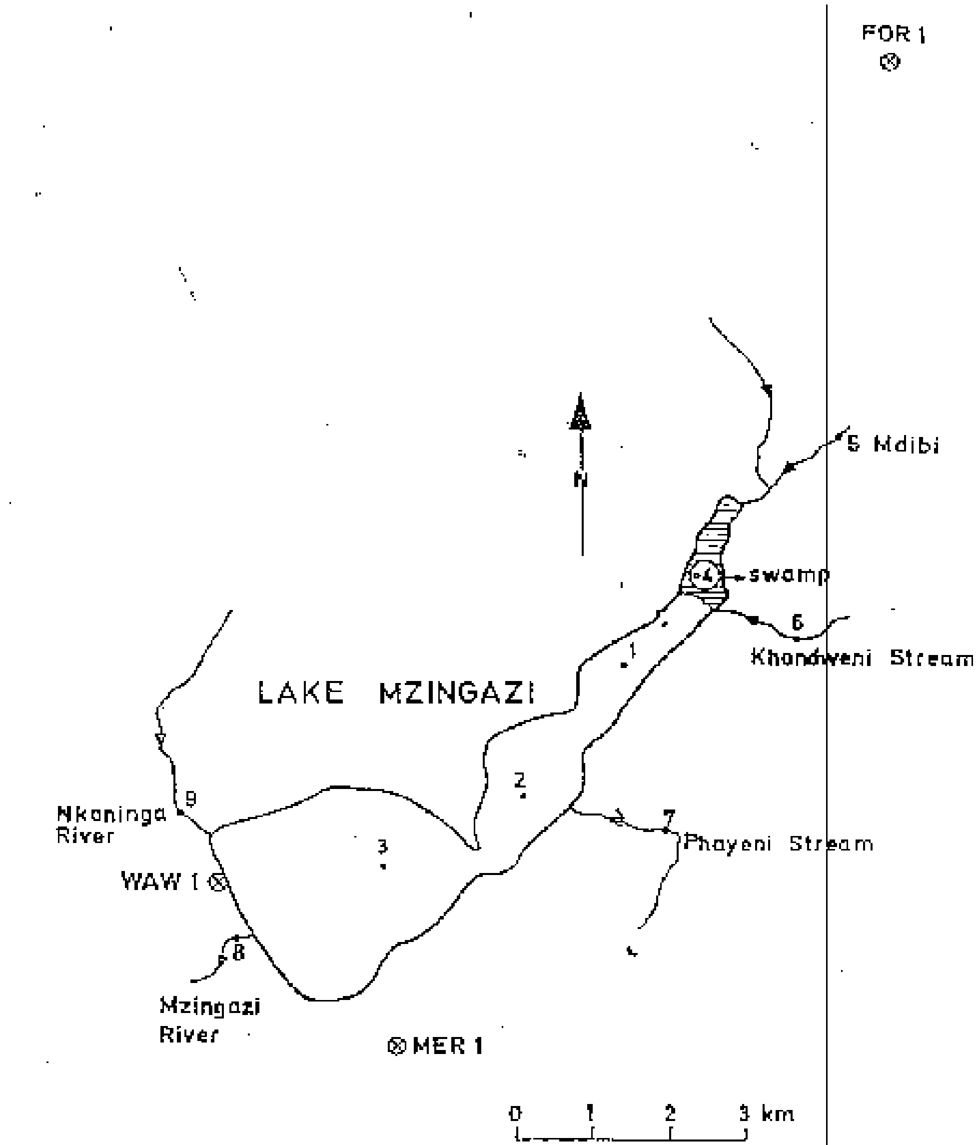

Fig 4 MAIN FEEDER STREAMS OF LAKE MZINGAZI

APPENDIX F: AERIAL MAP OF LAKE MZINGAZI WITH SURROUNDING HUMAN SETTLEMENTS.

7.7 APPENDIX G: AERIAL MAP OF LAKE MZINGAZI WITH POSITION OF MZINGAZI WATER PURIFICATION PLANT