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Evaluation of the Sustainability of an Urban Water System in South Africa through Sustainable Development Indicators

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ABSTRACT

This report include two evaluations, the first is to evaluate sustainable development of the urban water system by using sustainable development indicators. The second is to evaluate how the individual SDIs perform since they are taken from a study in a Swedish Town with its general conditions, i.e. climate, demography *etc*, in mind and used for a town in South Africa with other general conditions.

The study was conducted in King William's Town, which is situated in the south-eastern part of South Africa. The urban water system (UWS) of this town has been investigated by using Sustainable Development Indicators (SDIs). In the apartheid era, this was a town for white residence and therefore, a functioning and technically advanced UWS exists. On the fringe of the city, new settlements are being built, consequently adding new connections to the existing system with capacity problems as a result. A set of 19 indicators was taken from a study that was performed on the UWS in a Swedish city, Göteborg. By using this set of SDIs, the sustainability could be evaluated with a focus on the environment. The study area shows signs of water shortage, but interbasin water transfer may solve this problem in the short term. Due to technical problems and an overload of the sewage treatment works, the recipient, the Buffalo River, receives a high load of nitrogen and phosphorus with eutrophication as a result. The problems in both the waterworks and the sewage treatment works are worsening due to technical problems such as malfunctioning dosing equipment. This results in low efficiency and might result in higher costs and environmental detriment. The capacity of the sewage treatment works has been reached for several past years, and due to the governmental programmes that intend to give more people safe drinking water and adequate sanitation, overloads will continue to occur. When comparing the SDIs between Sweden and South Africa, the main difference found was that SDIs involving water consumption and withdrawal have a higher relevance in South Africa than in Sweden, mainly because of the shortage of water. Combined sewers are not applied in South Africa, therefore the possibilities for recycling sludge are higher, but no tests of quality, hygiene or nutritional value, are performed. These are vital before an agricultural usage of sewage sludge. A list of 13 SDIs is, in the end of this report, presented for future works in the study area and South Africa for changing the current unsustainable trend towards a more sustainable development for the UWSs.

KUNGL TEKNISKA HÖGSKOLAN
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This study has been carried out within the framework of the Minor Field Studies (MFS) Scholarship Programme, which is funded by the Swedish International Development Cooperation Agency, Sida.

The MFS Scholarship Programme offers Swedish university students an opportunity to carry out two months' field work in a Third World country resulting in a Master's dissertation or a similar in-depth study. These studies are primarily conducted within areas that are important for development and in a country supported by the Swedish programme for international development assistance.

The main purpose of the MFS programme is to increase interest in developing countries and to enhance Swedish university students' knowledge and understanding of these countries and their problems. An MFS should provide the student with initial experience of conditions in such a country. A further purpose is to widen the Swedish personnel resources for recruitment into international cooperation.

The Centre for International Environmental Studies, CIES, at the Royal Institute of Technology, KTH, Stockholm, administers the MFS programme for all faculties of engineering and natural sciences in Sweden.

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PREFACE BY THE AUTHOR

To do the final work of my M.Sc. degree in a developing country has been a dream for me ever since the beginning of my studies. As Professor Greg Morrison at Water Environment Transport, Chalmers University of Technology, had personal contact with Professor Olalekan Fatoki at University of Hare in South Africa, I naturally considered arranging a project with the base at Fort Hare. The work has been carried out at the University of Fort Hare, Alice, South Africa and partly at the Sanitation Department of Chalmers University of Technology, Göteborg, Sweden. The research studies in South Africa were conducted together with Mr Eric Zinn, also a student at Chalmers University of Technology. I would hereby like to thank the following persons and institutions for assisting me in the compilation of this Master's thesis report.

In South Africa, my supervisor Prof. O. S. Fatoki, of the Department of Chemistry at the University of Fort Hare, arranged for my arrival and well being while in country. His comments have been very useful and his help in establishing local contacts was vital.

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GLOSSARY

The following list of abbreviations and expressions used in the report may be of help when reading the report:

BOD & COD	Biological & chemical oxygen demand
DWAF	Department of Water Affairs
EPA	Environmental protection agency
EU	European Union
KWT	King William's Town
MFS	Minor Field Studies, supported by SIDA
OECD	Organisation for economic co-operation and development
R	South African Rand ≈ 1.40 Skr, 2000
RDP	Reconstruction and Development Programme
SD	Sustainable Development: Defined in the Brundtland report as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".
SDI	Sustainable Development Indicators: Pieces of information that aim to measure assess progress towards SD
SDI-WWS	SDI for Water- and Wastewater Systems
Setplan	A private company in East London, mainly producing reports for municipalities
SIDA	Swedish International Development Co-operation Agency
Strong Sustainability	The existing stock of natural capital must be maintained and enhanced because the functions it performs cannot be duplicated by manufactured capital.
STW	Sewage Treatment Works
TLC	Transition Local Council
UN	United Nations
UNCSD	Untied nations commission on sustainable development
UWS	Water- and Wastewater System
Weak Sustainability	Manufactured capital of equal value can take the place of natural capital.
WPW	Water Treatment Works

1. INTRODUCTION

This report is the final part of the Master's program in Applied Environmental Measurement Techniques at Chalmers University of Technology, Göteborg, Sweden. The work consists of two major tasks, the first is an evaluation of the sustainability of an urban water system (UWS) in King William's Town (KWT), South Africa (SA). The tools for this evaluation are 19 Sustainable Development Indicators (SDIs) that were taken from a study by Margareta Lundin (Lundin, 1997). These SDIs have been used for describing the situation in a larger Swedish town, Göteborg. The second task is an evaluation of these indicators, since the general conditions, such as economic, technical and climate, between SA and Sweden are very different.

1.1 Background

In 1987, the Brundtland report initiated a new way to measure and assess progress towards Sustainable Development (SD) (WCED, 1987). This initiative was further endorsed by the writing of the Agenda 21 document. There are many ways to measure SD, and one way is to use SDIs. When using SDIs, different approaches are possible. One way of producing a list of SDIs is to derive them from criteria. These criteria describe sustainability and point out necessary key features. These criteria can then be used to formulate a SDI. An appropriate SDI should be able to answer the question: *Are we moving towards sustainability or not?* (Lundin *et al.*, 1997)

Even if SA is considered to be the most developed country on the African continent, 16 million people have no operating water distribution, with distances to water sources averaging 1 km away (African water page, 2000). The concern for the environment has also grown ever since the country's emergence from apartheid, and the new constitution has included SD as an article among other important features, such as freedom of speech.

1.2 Project scope and goals

The overall scope of this report is to evaluate the environmental sustainability of the urban water system of King William's Town, South Africa by using Sustainable Development Indicators. The individual goals of this project are:

- to collect data of sufficient amount and quality for the different indicators from appropriate authorities and companies.
- to evaluate the environmental situation using the proposed 19 SDIs, and predict future problems and possibilities.
- to evaluate the relevance of the individual SDI and the awareness of the environmental and social problems related to the individual SDI both in Sweden and SA.

1.3 Project description

This project can be divided into four main steps. The first includes a literature survey on SA, SD and SDIs. The second step was the fieldwork that was conducted in SA, which was mainly data collection, see appendices 8.5 and 8.6. The third step includes the evaluation of the fieldwork and this was mainly performed in SA. The fourth and last step was to produce this report, which was done in Sweden. The steps, with which the goals of this project have been achieved, are visualised in Figure 1.

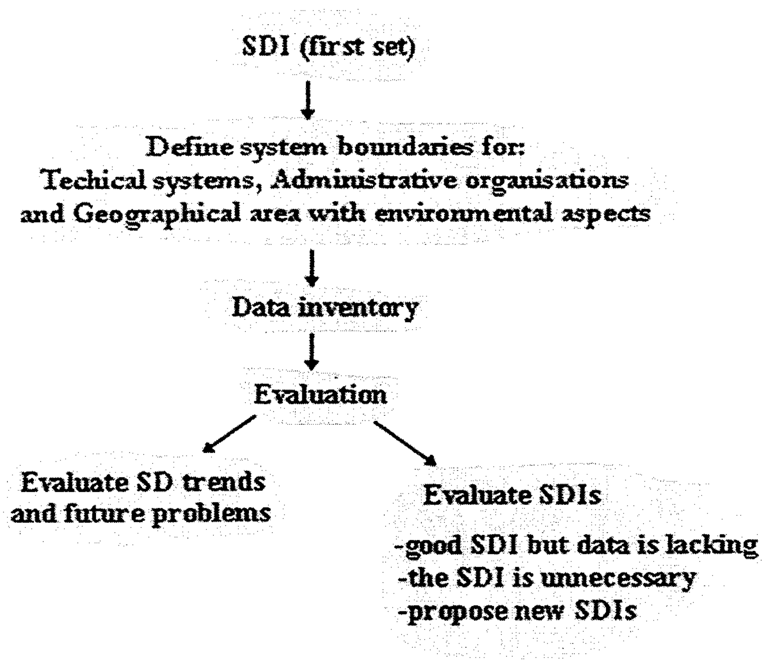


Figure 1. Project methodology

1.4 Methodology of the fieldwork

The fieldwork in SA was performed during two months, between October – December 1999. The first step was to obtain data from different authorities. The most important source for the collection of data was the Schornville Sewage Treatment Works (STW), as the logbooks for the Schornville and Breidbach STWs and the KWT Water Purification Works were stored here. Data has also been obtained from different authorities on municipality, provincial and national levels. Examples of data sources on these levels are; Department of water affairs and forestry (DWAF) in East London and KWT, Setplan in East London, the civic centre in KWT and in Bisho. The characteristics of the obtained data are temporal as they cover varying time spans (2-40 years). The raw data was transformed and re-calculated to fit the applied indicators. This can, for example, be done by using raw data for water production per month at the purification work and divide this by the population, which gives the water consumption per month and capita. This is thoroughly described in the report. When all of the 19 indicators were calculated, diagrams were drawn for each one of them. Evaluation of the work is thereafter separated into two different tasks. The first is to give a survey idea of the situation of the UWS in KWT over time, and also to evaluate the system, if it is moving towards or away from SD. The second task focuses on the differences of the general conditions between Sweden and SA. For example, water scarcity in SA is a big issue, but this is not as significant in Sweden. Therefore, a list of the indicators with respect to their relevance and awareness will be different, depending whether they are considered from a Swedish or South African point-of-view.

1.5 System boundaries

The indicators used in this report look at the performance, efficiency and effectiveness of the technical systems and the management of natural resources. Geographically, the UWS begins with the raw water sources: the Maden and Rooikrans Dams, see Figure 6, includes the KWT water purification work (WPW), see Figure 2 and the pipe network connecting the City Centre of KWT as well as parts of Ginsberg, Schornville and Breidbach to the WPW and the two STWs in Schornville and Breidbach. The system ends with the effluent from Schornville STW, with loads of chlorine and nutrients to the recipient, Buffalo River. The Breidbach STW is not included, as effluent is not intended to enter the river, but instead be irrigated onto sportsfields or evaporate from the ponds.

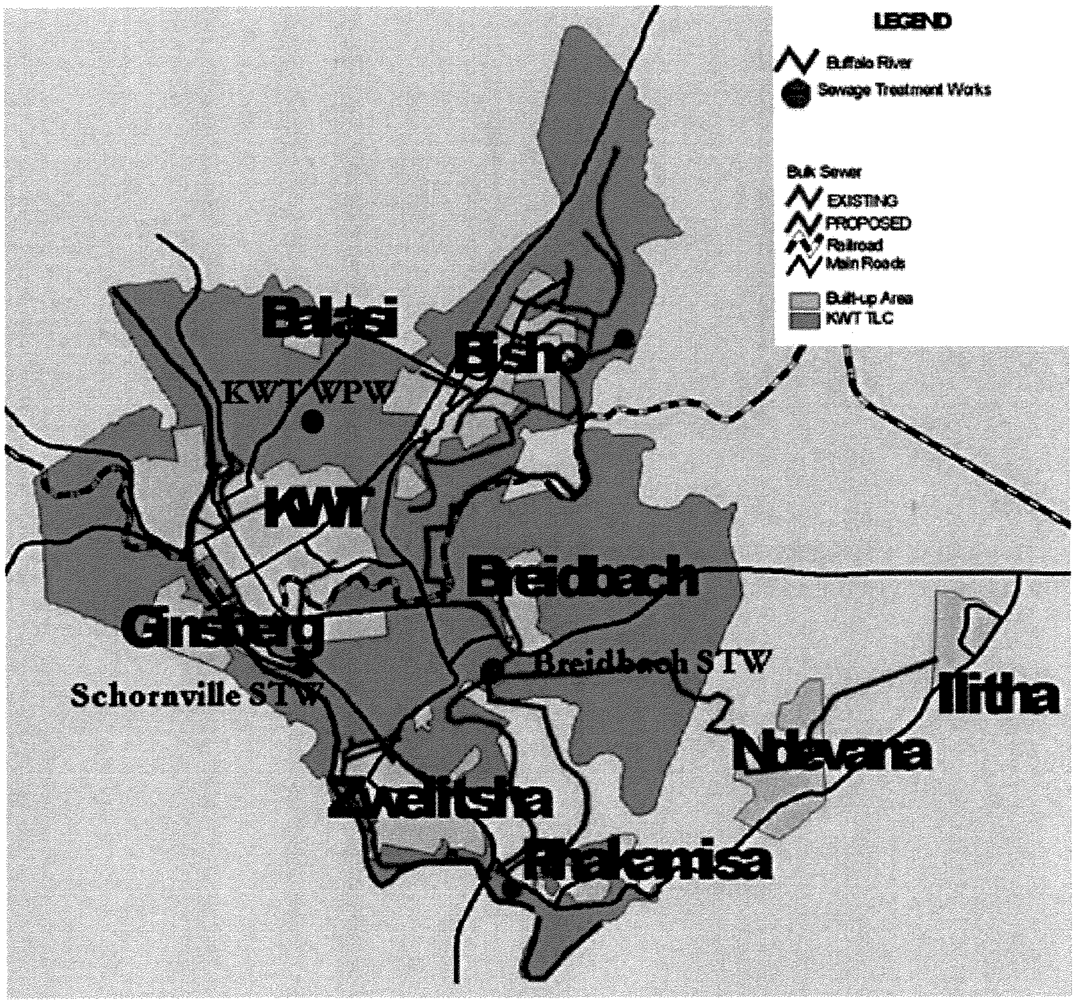


Figure2. The urban water network in KWT TLC (Setplan, 1997)

This UWS was chosen as it was introduced to use at an early stage of the fieldwork. Although this is not the system with the most environmental and operational problems in the area, it was believed to be the system with the most accessible and qualitative data.

2. SUSTAINABLE DEVELOPMENT

There have been discussions about Sustainable Development (SD) for more than a decade and there are probably as many definitions of SD as there are people working with this complex issue. The Brundtland commission states one of the most common definitions on SD as: *"A development is sustainable, if it meets the needs of the present without compromising the ability of future generations to meet their own needs."* (WCED, 1987). Another definition defines SD as: *"improving the quality of life while living within the carrying capacity of supporting ecosystems"*, where this definition has environmental degradation as an approach (IUCN/UNEP/WWF, 1991).

2.1 Water sanitation and sustainable development

The global water consumption over the past century has increased, due to population increases and also due to higher usage per capita. One third of the world's population now lives in countries that show signs of water shortage or stress. This present or upcoming water shortage stands in the way for development, which is vital for the developing countries. Development also has detrimental effects. Following an economic growth and increased food production comes increased pollution and often an over-consumption of water (Lundin, 1999). The construction of a sewage system may also be an obstacle in moving towards a more sustainable society. The reason for this is that large quantities of raw water are removed from a source and polluted in urban societies. The water is also diluted with storm water from impermeable surfaces, which contaminate and pollute the water with e.g. heavy metals. In the different processes of an UWS, energy and natural resources are used. Chemicals are added to purify drinking water and to remove nutrients from the sewage water and electricity is used to power pumps and machines. Because of the heavy metal content in the sewage sludge, recycling of nutrients is difficult in many places. Therefore, large quantities of commercial fertilisers are used in agriculture, instead of recycling the sewage sludge. The production of fertiliser uses large amounts of energy and mined phosphorus, which is expected to last for another 200 years with today's use (Fuggle, 1996).

2.2 South Africa and sustainable development

The discussions concerning development in SA during the 1960's and 1970's was focused on modernisation, under-development and dependency theories. During the 1980's when the oppression in SA escalated, the spotlight of the debate was moved towards the escalating struggle and the increased oppression that it produced. Then, in the 1990's many events happened simultaneously, both inside SA with the release of political prisoners and globally, with the Socialistic collapse and the Rio Conference with its offspring, Agenda 21. The spotlight of the debate was now towards negotiated transitions, and slowly the development debate began to emerge once again (FitzGerald *et al.*, 1995).

Making development sustainable means moving beyond a narrow, albeit important, concern with economic growth. That is, ensuring that people's basic needs are being met, that the resource base is conserved, that there is a sustainable population level, that environment and cross-sectoral concerns are integrated into decision-making processes, and that communities are empowered (IUCN/UNEP/WWF, 1991). Mustafa Tolba, the African, former head of the United Nations Environment Programme, sees sustainable development as, necessitating help to the poorest, because otherwise they are left with no option but to destroy the environment. SD also implies self-reliant and cost-effective development, facilitating access to health, shelter, clean water and food. Finally, it implies the need for people-centred initiatives (FitzGerald *et al.*, 1995).

3. SUSTAINABLE DEVELOPMENT INDICATORS

In general, an indicator is a piece of information, which has a wider significance than its immediate meaning (Bakkes *et al.*, 1994). A good example of an indicator is your body temperature that is just not giving you a number, but "behind" this number you can tell if you are sick and to what extent you are sick.

3.1 Definitions and functions

SDIs can be derived from criteria that are trying to describe sustainability and point out necessary key features. These criteria can then be used to formulate indicators. SDIs should be able to answer the question: *Are we moving towards sustainability or not?* (Lundin *et al.*, 1997) An indicator that is related to a criterion, an objective or a target is referred to a performance indicator. A number of indicators that are combined are called an index, while a number of indicators that represents a larger issue are referred to as a set (Bakkes *et al.*, 1994). Indicators are very good in visualising a phenomena of interest, simplifying or summarising important properties, quantifying, measuring and communicating relevant information. These are all qualities that are helpful in a decision-making process. One of the most essential functions of an indicator is to quantify, while further relevant functions are (Gallopín, 1997):

- to assess conditions and trends
- to provide information for spatial comparisons
- to provide early warning information
- to anticipate future conditions and trends

SDIs are currently being developed all over the globe, for the purpose of describing in which direction and at what pace society is maintaining, or recovering, its balance with nature. Two of the better known SDI programs are Sustainable Seattle[1], where the citizens of Seattle, Washington, USA, participate in the development of SDIs. The second is the United Nations Commission on Sustainable Development[2] (UNCSD) which is currently involving 16 nations, one is SA, in their development program, with the goal of having these available for decision-makers by the year 2001. Indicators are not only used for evaluating the state of the environment. Both social (e.g. literacy rate) and economic (e.g. Gross National Product or GNP) indicators are and have been in use for years, proving their informative value. The GNP has, for example, been used universally since 1950 (Lundin, 1999).

3.2 Frameworks and methodologies

Depending on the view of sustainability of the person that proposes indicators, the approach will be different. For example, an economist will probably use a model that has it roots in economics, while an environmentalist will perhaps use a model that is

[1] For more information on 'Sustainable Seattle', see http://www.scn.org/sustainable/susthome.html
[2] For more information on the UNCSDs ISD program, see http://www.un.org/esa/sustdev/isd.htm

based on pressure or effects on the environment. Four different approaches to develop a method will be presented in this paper. The approaches are divided after

- economic origin
- environmental origin
- describing a linkage between societal activities with the environment
- a balanced list of the three dimensions; social, economic and environmental

A presentation of the four different approaches with some method under each approach follows. The indicators used in this report are based on some of the presented methods, but not all of them.

3.2.1 Models with roots in economics

Some of the oldest indicators that are still used are these measuring the Gross Domestic Product (GDP). This has more recently been refined to measure the Genuine Progress Indicator (GPI), while the Human Development Index (HDI) has been developed to concern more social issues. Both the GPI and the HDI include parameters that the GDP neglect, such as ozone depletion and cost of unemployment. One problem with both HDI and GDP is that, since they assume that the natural capital and manufactured capital are close substitutes, measure weak sustainability. Environmental accounting and Sustainable Development Records are two other methods, which are less aggregated than HDI and GDP, and can determine the environmental performance in monetary and physical units (Lundin, 1999).

Environmental Accounting

Environmental Accounting is a method that is based on environmental statistics and is preferably used together with economic statistics (Asheim, 1997). It is used to evaluate a nation's use of natural resources, or it can be used as a business management tool (USEPA, 1995). The objective of using Environmental Accounting is to have a system that visualises the links between the environment and economy, which enables a "greening of the GDP" (Lundin, 1999). As it is difficult to value certain natural resources, such as aquifers or healthy ecosystems, Environmental Accounting can not deal with this and these values are therefore not taken into account (Lundin, 1999).

Sustainable Development Records

Several Swedish municipalities and companies have used Sustainable Development Records (SDR) for evaluating their economical and environmental performance. The SDR model measures the flow of resources used for a certain service that has been performed. This system of flow is divided into four parts: the operation (the studied organisation), the delivering system (purpose of the organisation), throughputs (flows of resources) and resource base. This division results in three different types of SDR indicators (Nilsson *et al*, 1995):

- Effectiveness ratio (service/operation)

- Thrift ratio (operation/throughput)
- Margin ratio (throughput/resource base

This is believed to be more of a bookkeeping system of resources used in the form of materials or energy, and is criticised by Carlsson (1997). It tends to focus on the direction of the sustainability for an operation. Furthermore, many of the indicators are difficult to categorise and overlap each other, resulting in that some indicators are measuring similar parameters (Lundin, 1999).

3.2.2 Models with roots in environmental sciences

As one can expect there are many environmental models to describe environmental trends. The Pressure-State-Response model, the DPSIR model and the media approach are common frameworks that are used by several organisations and countries. The advantage with these models is that they are developed for companies and therefore widely used (Lundin, 1999).

Pressure-State-Response model

The Pressure-State-Response model (PSR) was developed by different organisations including the OECD and are used e.g. by the UN, EU, and USEPA. This model is separated into three different parts (OECD, 1998):

- Pressure describes the environmental pressure on the environment caused by human activities. Emissions and usage of natural resources are examples that can cause a pressure.
- State describes the overall situation of the environment. This can be measured as the state of the environment and the quantity and quality of natural resources.
- Response describes the societal actions on feedback in terms of environmental changes and concerns. This can also be visualised, see Figure 3.

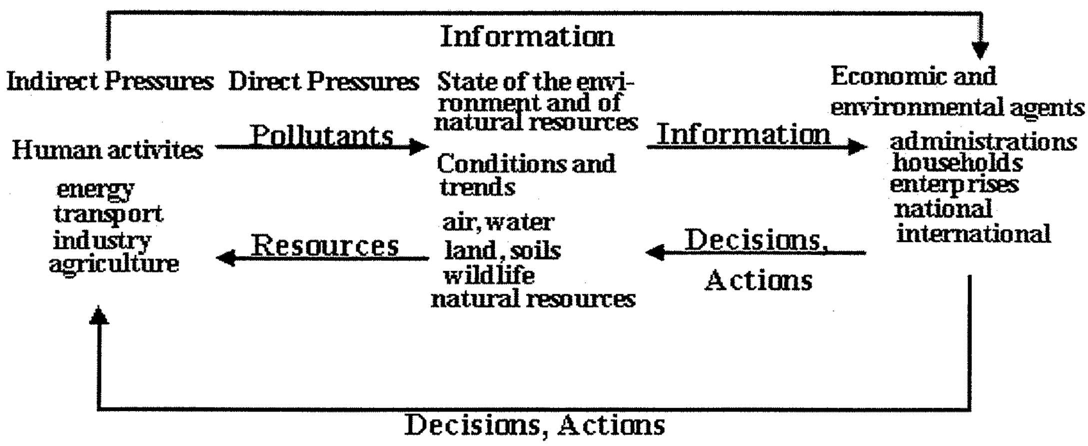


Figure 3. The PSR model (OECD, 1998)

The countries of the OECD have agreed to use the PSR model, measure and publish PSR indicators and identify and define them in a common way. This work has resulted in approximately 40 environmental indicators that covers issues, such as climate change, ozone depletion, air quality, waste, water quality, water resources, forest and fish resources and biodiversity (OECD, 1998).

DPSIR model

The DPSIR model is an extension of the PSR model and is used by the European Environmental Agency. Two more types of indicators have been added to the Pressure, State and Response of the PSR model. The five types of indicators for DPSIR are (Eurostat, 1997):

- Driving forces, includes economic development, population, education and life style
- Pressure, includes emissions, physical impact and use of natural resources
- State, includes concentrations of pollutants, natural resources and biodiversity
- Impact, includes health-related aspects and biological effects
- Response, includes environmental policies, taxes and regulations and technical improvements

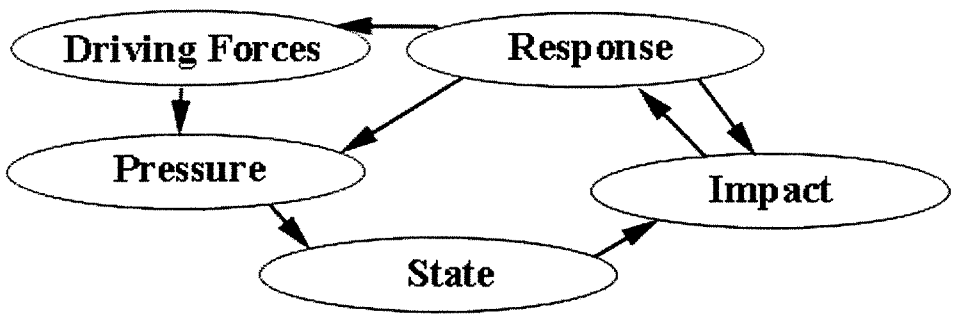


Figure 4. The DPSIR model used by the EEA, (Eurostat, 1997)

The DPSIR model is more complicated than the PSR model, but on the other hand more flexible and different actors, such as Eurostat and the Swedish EPA, currently use it. The model used by the European Environmental Agency and the links between the five different types can be seen in Figure 4. The Swedish EPA is using the DPSIR model to follow up the 15 national environmental objectives, which have the vision to create an ecologically sustainable society (SEPA, 1999). This model is also used to evaluate the toxicity of different substances (Lundin, 1999).

Media approach

The US Office of Water uses this approach to inform the public, in an accessible way, about water resources, drinking water quality and the state of aquatic ecosystems. The media approach measures the well being of an ecosystem and how different human activities stress the system (USEPA, 1999). It is more useful for setting targets and restrictions on a watershed basis and are of less use for specific organisations (Lundin, 1999).

3.2.3 Models that link societal activities and the environment

Both Socio-Ecological Indicators and Ecological Footprints focus on what physical influences society has on nature and tries to connect human activities to the environment (Lundin, 1999).

Socio-Ecological Indicators

The purpose of Socio-Ecological Indicators is to serve as a tool for planning and decision-making processes in society and at different administrative levels. Since they are organised after different socio-ecological principles, they are pedagogical. They also focus on an early stage in the casual chain, which gives them operational status in a policy situation (Holmberg, 1995). There have been attempts to develop indicators for urban water systems, but they have ended up with indicators that can only be used for large geographical areas, such as nations, due to the difficulties in locating adequate data for the types of indicators for municipalities (Lundin, 1999).

Ecological Footprints and Sustainable Process Index

Both the Ecological Footprints and the Sustainable Process Index are indices that are area-based. The Ecological Footprint is a method that measures sustainability by calculating the amount of land a person or a country needs for fulfilling its needs. The needs are calculated in five different categories; food, housing, transportation, consumer goods and services (Wackernagel *et al*, 1999).

The Sustainable Process Index measures the sustainability by calculating the amount of land that is occupied for producing raw materials, processing energy, providing installations and the area required for the staff and the accumulation of products and by-products (Narodoslawsky, 1995). Both models include many simplifications that are not always realistic, but it may be necessary to use them to achieve a single number (Lundin, 1999).

3.2.4 Balanced lists or three dimensions

A "Balanced List" is a framework that usually takes into account social, economic and environmental dimensions. Additionally, institutional and cultural aspects may also be included. This framework is mostly used by different political organisations, the United Nations and Sustainable Seattle have both used this approach.

Commission on Sustainable Development Indicators Program

The approach the United Nations Commission on Sustainable Development (UNCSD) Indicator Program uses is a modified PSR model, which is expanded to include not only environmental issues but also social, economic and institutional issues. The UNCSD has produced a list of 130 indicators, which are used for countries in their decision-making process and to make international comparisons of indicators possible. Of the 130 indicators, approximately 20 indicators deal with water and wastewater issues (UNCSD, 1996).

3.3 The proposed SDIs for urban water systems

The SDIs for UWS used in this report have been proposed in order to aid decision-makers in the progress towards SD (Lundin, 1999). Margareta Lundin tested the indicators in a larger city in Sweden (Lundin *et al.*, 1997). Table 1 includes a list of the SDIs used in this study, as well as some of their characteristics and suggested reference values.

Table 1. List of applied SDI-WWS's. (Lundin, 1999)

SDI - WWS	Type of indicator	Suggested Reference Value
Withdrawal	Pressure	<100 %
Raw Water Quality	State	All water should be drinkable
Protection	Response	All sources should be protected
Water Consumption	Driving Force	WHO recommendations
Drinking Water Quality	State	WHO or National Standards
Chemical and energy use for drinking water treatment	Efficiency	As efficient as possible/ increasing efficiency
Leakage	Efficiency	Low
Reuse	Efficiency	High
Wastewater Production	Pressure	Within treatment capacity
Combined Sewers	Effectiveness	Less than 10 % should be storm water
Treatment Performance	Effectiveness	At least according to regulation
Loads to receiving waters	Pressure	Below critical load
Chemical and energy use for wastewater treatment	Efficiency	As efficient as possible
Resource use per removal of nutrients	Efficiency	As efficient as possible
Recycling of Nutrients	Effectiveness	100%
Quality of Sludge, mg Cd/ g P	State	Below requirements
Energy recovery	Efficiency	As efficient as possible
Access to clean drinking water	State	100% and at least 50 L/day*cap
Access to adequate sanitation	State	100% and water-borne in urban areas

The following chapters include more in-depth explanations and are divided into the technical and socio-economical subgroups: Freshwater Resources, Drinking Water, Wastewater, Recovery of Nutrients and Energy, and Social and Economic Development. The columns in Table 1 are to be interpreted in the following way. TYPE is either based on DPSIR, showing the SDI's place in the casual chain, or as the technical performance of the system in terms of effectiveness/efficiency. The SUGGESTED REFERENCE VALUE shows the targets of the SDI-WWSs.

3.3.1 Freshwater resources

The freshwater resources within the catchment area of the studied area should be assessed and quantified. Three SDI-WWS's can assist in indicating the sustainability of the system on this point.

Withdrawal (%)

The withdrawal indicator is calculated by dividing the annual freshwater withdrawal by the annual available amount. It shows whether or not the withdrawal is at an acceptable level, and if future water shortages are to be expected. Therefore, it is a sensitive SDI-WWS and should indicate an early warning. Data is usually easy to attain on withdrawal volumes for drinking water purposes, as a water works measures these, but needs to be complemented with data from other consumers, e.g. irrigated agriculture and industries. Only estimations are possible for the available volumes of surface and groundwater. Depending on the area, climate, population, economic development and seasonal variations varies. The withdrawal indicator also relates to population and population growth, the future demands of agriculture and industry, and ecosystem health.

Raw water quality (Concentration of pesticides, N, BOD and/or Coliforms)

This parameter is essential for the sustainable future of freshwater ecosystems, as well as for human health. Polluted raw water can stand in the way for a SD, as large amounts of chemicals and energy for cleaning the water are used. In agricultural areas, pesticides and nitrate may pose a threat, while insufficiently or untreated sewage might affect the concentrations of BOD and Coliforms. At larger supplies of raw water, the quality is usually measured on a routinely basis, and this information can often be found at other authorities and organisations as well. This indicator give information on other activities that might affect the raw water source, e.g. point sources of municipal discharges, industrial discharges and waste facilities and non-point sources such as agricultural and urban runoff and landfills. It also indicates the amount of treatment necessary, which cost energy and resources.

Protection (Degree of protected sources)

A high degree of protected water sources ensures the present and future freshwater quality. The existence of a contingency plan indicates how prepared a community is for accidents. A lack of protected water sources and a contingency plan increases the risk that the raw water quality will be affected by potential hazards. The hazards can be agricultural runoff containing pesticides, nitrate and phosphate; landfills, municipal and industrial wastewater discharges containing bacteria and virus; traffic leaving heavy metals, petrol and oil or accidents occurring involving these or other chemicals. As legislation to prevent hazards is up to politicians, it also shows how decision-makers deal with this side of environmental protection and human health issues.

3.3.2 Drinking water

The usage, treatment and distribution of drinking water are of interest when investigating the system's sustainability, partly due to the use of natural resources and energy.

*Water consumption (L/cap*day)*

As population increases and development progresses, increasing volumes of water will be used for domestic and industrial purposes. It is therefore important that water not be unnecessarily wasted. At the same time, sufficient volumes of water must also be supplied to the users for development to proceed. Data on this is available from the local water works, and the distribution to different sectors (e.g. agriculture, industry, and leakage) is of interest. For households and industries with individual supplies, such as wells, relevant data may be difficult obtain for this indicator, for which estimations may be necessary. As the consumption of drinking water effects the use of energy and resources it is well linked to the general idea of sustainability.

Drinking water quality (% tests within regulations)

In order to protect human health, the quality of drinking water is of the utmost importance. It should have, at the most, tolerable levels of bacteria and chemicals (e.g. Nitrate, lead, herbicides). Drinking water quality is measured in larger supply systems, at the treatment works, but this may deteriorate before arriving to the consumer due to corrosion or contamination. Therefore, the drinking water quality may be difficult to assess at tap. Also, the quality of water in individual wells may be less well known. Health reasons requires the quality to be equal or above legislation or recommendation. Such factors as leakage may indicate a difference between measured drinking water quality at treatment plant and actual quality at tap.

Chemical and energy use for drinking water treatment (mg/l, kWh/l)

The sustainable usage of chemicals and energy requires water treatment to use a minimal amount of these, but not at the cost of drinking water quality. Decreased usage also means decreased cost for the treatment works. Uncontaminated groundwater requires little or no treatment, while surface water and contaminated reserves usually require at least some treatment. On the other hand, a groundwater supply usually requires more money and energy due to pumping. The raw water quality, the protection of water sources and efficient use of chemicals and energy. All this effects the quality of drinking water and also the cost.

Leakage (% of produced water)

Leakage occurs in great volumes in decaying pipes, and leads to increased pumping costs, loss of water (and revenue), loss of pressure, increased risks of contamination by bacteria and corrosion products (e.g. copper, iron and zinc). Rainwater and leaked drinking water may also enter the sewage pipes, diluting the sewage and decreasing the efficiency of the treatment process. Data on leakage is relatively easy to attain in areas where water meters have been installed in households. Otherwise, the municipality or other actors may have made estimations. Decreasing leakage not only decreases costs and increases revenue, it may also prove to be a vital way of decreasing the water demand in 'dry' regions and the need to increase the withdrawal from scarce water sources. This indicator has an effect on the production of wastewater.

Reuse (% reused water compared to total use)

In areas approaching the limits of their freshwater resources, even wastewater must be seen upon as a resource. Therefore, reusing it becomes important in terms of sustainability. Industries can reuse their wastewater, if necessary after treatment. Households can do the same by using grey water and treated wastewater for nonpotable uses. By reusing, not only water is reused - also nutrients, but health problems such as bacteria and viruses must be considered.

3.3.3 Wastewater

The treatment and fate of wastewater components may have the largest impact on the environment. It is therefore vital that volumes, concentrations of chemicals and the usage of non-renewable resources for treatment be monitored.

*Wastewater production (L/cap*day)*

Increased water usage or increased leakage of infiltration water and storm water can cause increased production of wastewater. This may have a number of detrimental effects: untreated water may be released into the environment due to combined sewage overflows, decreased efficiency of sewage treatment, increased use of chemicals and energy for sewage treatment, *etc.* Minimisation of wastewater is therefore important for environmental sustainability. Large flows may be due to storm water in combined systems, and to change the pipe system is an expensive task, but this may prove important when choosing a system (separate or combined) for new connections.

Combined sewers (%)

Using a combined sewage system, where storm water from impervious areas is carried to a STW increases the volumes received during rains. It dilutes the sewage, making the treatment process less efficient, causes combined sewer overflows, and pollutes the sewage sludge, decreasing the possibility of recycling nutrients.

Treatment performance (% removal of nutrients)

The vital function of a STW is to collect and treat the wastewater to levels the environment can handle. For the goal of SD, a high removal is preferable. This data is readily available for larger systems, and is commonly used within the sanitation sector. Yet, this indicator says nothing about the sensitivity of the ecosystem, the cost or resource use for treatment, nor of the fate of removed nutrients.

Loads to receiving waters (kg BOD, P and N)

The release of COD (or BOD), P, N and bacteria into the environment needs to be lowered to acceptable levels. The total load should include agriculture and other non-point sources as well as STW, individual sewage septic systems and combined sewage overflows. Data for this indicator is easy to find for larger systems, although for non-point sources (e.g. agriculture) data can be more difficult to find. This indicator serves as an early warning signal as increasing emissions of nutrients or oxygen demanding substances will affect receiving waters at some point. The load of nutrients from one person during one day are approximately; 70 g BOD, 14 g tot-N and 3 g P (Viessman *et al*, 1998).

Chemical and energy use for wastewater treatment (mg/l, kWh/l)

As with drinking water treatment, the treatment of wastewater should be done with the highest efficiency of non-renewable resources and energy possible, but not at the cost of high effluent concentrations of nutrients, BOD or COD, *etc.* To obtain a balance between removal of nutrients and chemical usage in the treatment process is difficult.

Resource use per removal of nutrients (kg FeCl / kg P)

Measuring the efficiency of energy use and natural resources used in the treatment process is important, as the efficiency should be continuously improved as technology makes it possible. Data exists on the energy and chemicals used in the treatment process at most STWs.

3.3.4 Recovery of nutrients and energy

Sustainable Development demands a minimum usage of non-renewable resources and energy, which in return requires a recovery and reuse of the nutrients in the wastewater sludge, and a recovery of energy in the wastewater treatment process.

Recycling of nutrients (%)

The recycling of resources is a pillar in sustainable development and this naturally applies to UWS as well. The recycling of sludge as fertiliser decreases the need for commercial fertiliser, which requires large amounts of mined phosphorus and substantial amounts of energy are used for the production of nitrogen. The land needed for disposal of dried sludge can also minimised.

Quality of sludge (g Cd/ kg P)

To insure the reuse of sludge as fertiliser, it must fulfil the public and legislative requirements. There are many aspects of interest when considering the quality of sewage sludge as fertiliser, but the main subject of debate and possibly a main reason for reservations to its use is the heavy metal content in sludge, at least in Western Europe. The goal of this indicator may be a bit unclear though. One definition can be that Cadmium should not accumulate in agricultural land, which means that, input equal to output.

Energy recovery (kWh/ month)

Substantial amounts of energy are used for the collection and treatment of wastewater, recovering some of it is in line with SD. This can be done via e.g. digestion of sludge to biogas or by using heat pumps to use the heat in the effluent and produce electricity. The amounts of energy recovered by a plant should be recorded and available, wherever this practice is performed.

3.3.5 Socio - Economic development

The previous SDIs have been developed with the urban systems of Europe and the US in mind. In the area of this case study, other parameters must also been considered, in order to evaluate the full spectrum of the sustainability of water and wastewater system. The following SDIs have been proposed by the UN Commission on Sustainable Development in their CSD Working List of Sustainable Development Indicators. (UN, 1999)

Access to clean drinking water & adequate sanitation

One of the basic human rights is access to sufficient amounts of clean drinking water and adequate (water-borne) sanitation, and this is also a requirement for development. The WHO recommends a total of 50 L/day*cap: 5L for drinking, 15L for bathing, 10L for food preparation and 20L for sanitation. The percentage of people that have access to safe water supply and adequate sanitation in SA can be seen in Table 2.

Table 2. Water and Sanitation situation in South Africa in 1994, (FitzGerald *et al.*, 1995)

	Lacking safe water supply (%)	Lacking adequate sanitation (%)
Urban	33	31
Rural	70	63
World	31	44

As can be seen in Table 2, the situation in SA is severe if compared to other countries, referred as the "World" in Table 2. One reason for this is SA's definition on adequate, which in this sense means water tap inside the house and waterborne sanitation. Kenya on the other hand defines a pit latrine as adequate sanitation and therefore Kenya has a high percentage of people with adequate sanitation. (FitzGerald *et al.*, 1995) The situation is severe in SA, but it is slowly improving with new development of domestic areas in the RDP.

4. BACKGROUND ABOUT THE STUDY AREA

SA is a large country, approximately three times the size of Sweden. It is situated on the southern tip of the African continent. The neighbouring countries and the site for the study, King William's Town, can be seen in Figure 5. To the west, south and east, SA borders the Atlantic and Indian Ocean. In north-west it borders Namibia and in north Botswana, in north-east Zimbabwe, Mozambique and Swaziland. Lesotho is entirely surrounded by SA and is situated in the eastern part of SA.

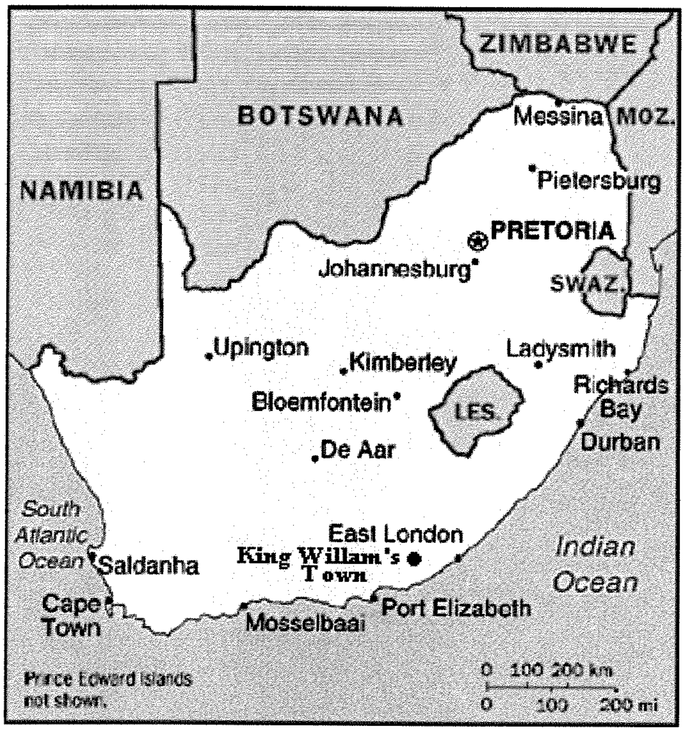


Figure5. Map over southern Africa and the site of the study

4.1 South Africa and the Eastern Cape

The diversity in such a large country is naturally extraordinary with large national parks in the north, mountain ranges all over the country and unspoilt beaches all along the coastline. The climate is kind but very changeable both over the day and also dependent on the location in the country.

The Eastern Cape is one of SA's nine provinces. It has a long coastline facing the Indian Ocean on the south-east side of SA and a hinterland that borders the Western Cape and Northern Cape provinces. It also shares borders with the independent Lesotho and the provinces the Orange Free State and Kwazulu-Natal and it includes the former homelands of Ciskei and Transkei. It is the traditional home of the Xhosa people. The capital of the Eastern Cape Province is Bisho, and other major cities in the province includes Port Elizabeth and East London, both major ports exporting a wide variety of agricultural and manufactured products such as fruit, wool, textiles, steel products, and cars. Uitenhagen, a suburb to Port Elizabeth, is the principal South African centre of car production.

4.2 King William's Town

King William's Town (KWT) is the former capital of the Eastern Cape Province. The town itself has a population of approximately 30 000, but this figure rises when surrounding areas are included. The town is located 60 km from East London and 5km from Bisho, the capital of the former Ciskei. The KWT Transitional Local Council (KWT TLC) was established in 1994. This is a transitional form of local government that is found all over SA, in order to bridge the gap between past and future municipality constructions. The main towns and villages in the region can be seen in Figure 6. The KWT TLC includes the previous independent municipalities KWT, Bisho and Ginsberg together with the four towns Zwelitsha, Phakamisa, Ilitha and Dimbaza. Breidbach and Schornville are the previous areas for coloured people in the old KWT municipality. The rural village of Tyutyu has been part of the KWT TLC since 1995, while other rural villages within the area have elected not to be included. (Davidson *et al*, 1996) The study area of the KWT TLC is quite different than it's surroundings, as it was previously a part of the old SA, almost encircled by the 'independent' homeland of Ciskei. The differences in these areas can be seen to this day, as the study area's level of sanitation (and other aspects) is considerably higher than the surrounding rural and township areas. The UWS of the study area does, to a more or less extent, work, but has deteriorated over the past years, due to a number of reasons, e.g. economic restraints and overloads due to new connections with RDP areas.

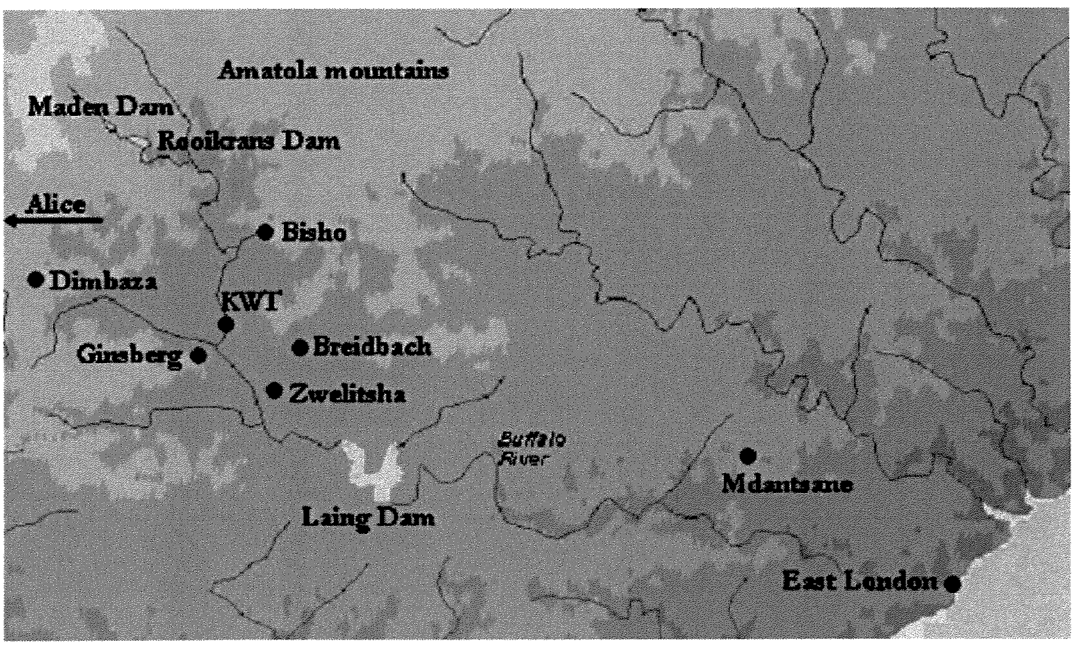


Figure6. Buffalo River Catchment (Microsoft, 1999)

The estimated population of the TLC was 150,000 for 1997 and the population for each area can be seen in Table 3. The TLC includes 27,525 households in 1997. These households include 10,730 backyard shacks either informally on formal sites, or on informal sites. As it is more interesting for the service provider to know the number of sites that are to be provided for, and not the actual number of households, the presence of backyard shacks is the main reason for the large discrepancy between these two figures (Palmer Development Group, 1998).

Table3. Population, sites and households in 1997 (Palmer Development Group, 1998)

		Site		Households			
Area	Population	Informally occupied	Average population	On formal sites	In packyard shacks	Total	Average size
Bisho	5840		4.0	1465	-	1465	4.0
Breidbach	6490	150	5.9	955	-	1105	5.9
Dimbaza	39150	1448	8.0	3438	1500	6386	6.1
Ginsberg	5860	136	4.0	1337	150	1623	3.6
Ilitha	9210	428	5.1	1394	-	1822	5.1
KWT/ Schornville	23120		7.7	3018	-	3018	7.7
Phakamisha	8920	211	6.8	1105	-	1316	6.8
Tyutyu	6920		15.1	459	706	1165	5.9
Zwelitsha	40560	1112	9.2	3291	4888	9291	4.4
Sweetwaters				344		344	
Total	147070	3485	7.2	16806		27525	5.3

Almost 60 % of the households in the TLC earn less than R 1500 per month and the population growth is at 3.2 %, which is considered to be fairly high. The economic turnover in the area is relatively low and the annual expected growth for the coming ten years is in order of 2 %. This together with the increased population gives a slowly worsening economical situation for the households in the TLC (Palmer Development Group, 1998).

4.3 Buffalo River

The rivers of SA are, in general, variable in flow. Many of them are dry most of the year; consequently, they are of little use for navigation or hydroelectric power. They are, however, of some use for irrigation. The amount of irrigation in the Buffalo River is quite low, compared to similar rivers in SA. The catchment of the Buffalo River is one of the most populous areas in southern Africa. 310,000 people are at the moment dependent on the water from the Buffalo River and that number is increasing. The area of the catchment is 1230 km^2 (O´Keeffe *et al.*, 1990). The source of the Buffalo River is high up in the Amatola mountain range and the river flows 140 km to the south-east towards East-London at the sea, Figure 6.

The catchment area of Buffalo River can be divided into three parts; upper, middle and lower. There are two dams in the upper part, downstream of the Amatola, Maden and Rooikrans, which is followed by agricultural land, and eventually KWT. The agricultural land is divided by forestry, 90 ha and irrigated agricultural land, 31 ha. The middle part begins upstream of KWT and Zwelitsha, comprising of urban/industrial complexes. Laing Dam and some agricultural land downstream is the end of the middle part. Bridle Drift Dam and the East London's harbour forms the lower part of Buffalo River's catchment area (O'Keeffe *et al*, 1996). The four dams, Maden, Rooikrans, Laing and Bridle Drift, see Figure 6, are all raw water supplies for towns in the area. Maden is meant to supply KWT and Rooikrans was mainly meant to supply Zwelitsha together with Laing Dam. Bridle Drift Dam supplies Mdantsane and East London (O'Keeffe *et al*, 1996).

Due to stolen raw water pipes, seen as four empty rings in the bridge in Figure 7, from Maden Dam to KWT, the town is supplied by water from Rooikrans. This has been the fact for the past two years (Personal communication with Mr Braweni, KWT WPW). Today, the water from Maden Dam is simply flowing over the brim and via a small stream to the Rooikrans Dam, see Figure 7.

Figure7. Stolen water pipes at Maden Dam

The catchment area for Maden is 31 km^2 and 48 km^2 for Rooikrans. The full supply level is 0.32 resp. 4.91 $*10^6$ m^3. Mean annual rainfall over the whole catchment area is 736 mm. Since the mountains receives between 1500-2000 annually it provides 40 % of the runoff for the whole catchment (O'Keeffe *et al.*, 1996).

Median flow is less than 1 m^3/s in all parts of the river. The mainstream flows permanently upstream Maden Dam. Downstream it can be reduced to pools during droughts. A typical pool can be seen in Figure 8. Return flows from STWs and industries in KWT ensure the flow into Laing Dam (O'Keeffe *et al.*, 1996).

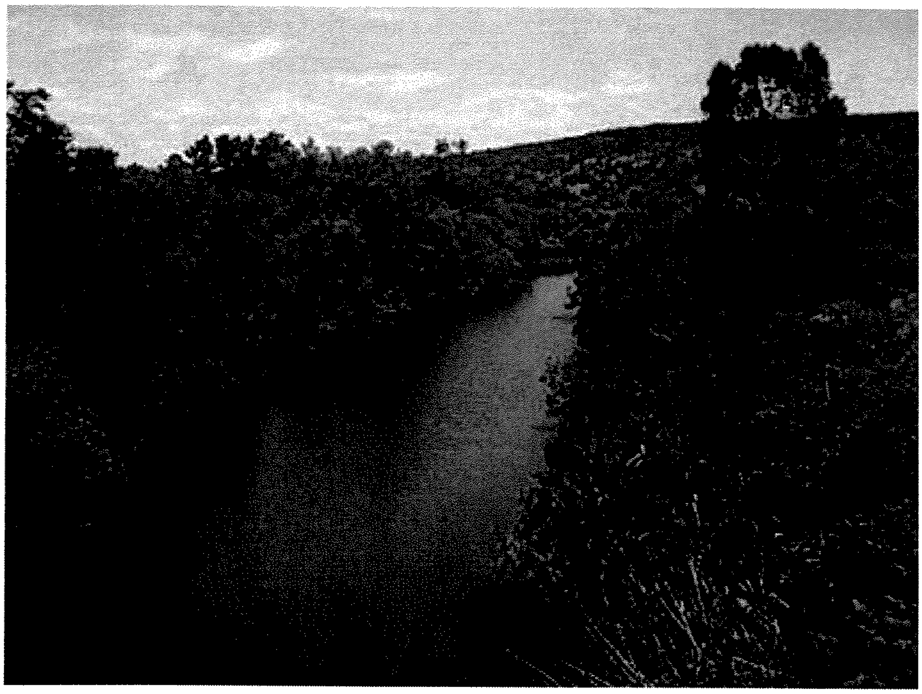


Figure8. Drought pool in Buffalo River

4.4 A technical description of the UWS

There are five STWs in KWT TLC and they are located in Bisho, Breidbach, KWT (Schornville), Zwelitsha and Ilitha, and can be seen as purple dots in Figure 2. Some of these are small, overloaded or not working at all resulting in overflows of raw sewage into the Buffalo River (GIBB AFRICA, 1999).

4.4.1 An overview of the water/wastewater system of KWT TLC

The main water users in the catchment in 1996 were (O'Keeffe *et al.*, 1996):

- KWT 47000 m3/month
- East London 80000m3/month
- Ciskei Public Works 607000 m3/month (The former homeland of Ciskei does not any more exist)
- Da Gama Textiles 3660 m3/month

The major sources of return flows in the catchment area in 1996 were (O'Keeffe *et al.*, 1996):

- From King William's Town via the STW or industrial irrigation schemes
- From Zwelitsha via the STW and industrial irrigation schemes

- Wastewater from Mdantsane accidentally reaching Bridle Drift Dam from broken sewers
- A small amount of irrigation return flow from the upper/middle catchment

There are also three dumpsites situated on or near the riverbanks, which are suspected of polluting the river through seepage (O'Keeffe *et al.*, 1996). Two industries, Da Gama Textiles and King Tanning leather tannery, use irrigation schemes to dispose of their effluents. They are estimated to contribute 88 % of the artificial salinity load in the river. The artificial load is 35 % of the total salinity load into the river (O'Keeffe *et al.*, 1996).

The on-site connections in the KWT TLC are equipped with meters, where consumers are charged according to the consumed water in Bisho, Breidbach, KWT and Schornville. Other areas are charged after a flat rate (Setplan, 1997).

4.4.2 Detailed descriptions of the different works of the KWT TLC

The plants that are included in this paper are the KWT WPW, and the Schornville and Breidbach STWs.

KWT Water Purification Works

The KWT WPW receives raw water from the Maden and Rooikrans Dams and supplies King William's Town, Breidbach and Ginsberg. The raw water is purified with lime, chlorine and aluminium sulphate. The WPW reached 88% of its design capacity in March 1994, and peak water demands push the works into overload mode (Setplan, 1997).

Schornville STW

The Schornville STW serves KWT and is located in the residential area of Schornville, south-west of the city core on the east bank of the Buffalo River. This is the larger of the two STWs located within KWT proper. It was built in the 1960's, when it initially only applied mechanical and biological treatment, referred to the old plant. In the 1980's the STW was updated with a separate activated sludge step, referred to the new plant. For the different steps see Figure 9.

The sewage that enters the work is predominately domestic, but with a 10 % share of industrial origin. When it enters the work, the sewage first passes a mechanical screen, thereafter running through three channels for sedimentation of larger particles. This is followed by a flow counter and the addition of hydrated lime. Here the flow is diverted either to the newer activated sludge step (60%) or the old biofiltration unit (40%). The activated sludge step includes three zones: anaerobic, anoxic and aerobic. Ferric chloride is added for phosphate removal and two clarifiers follow this. Before the effluent is discharged, chlorine is added. The biofiltration unit, starts with two parallel sedimentation tanks, which lead to a biological treatment step. A humus tank follows and three parallel sand filters are also used. It is then chlorinated and discharged to the Buffalo River. All sludge is dried in large basins and given for free to local farmers. A large portion is also deposited on landfills. The sludge is not tested (GIBB AFRICA; 1999).

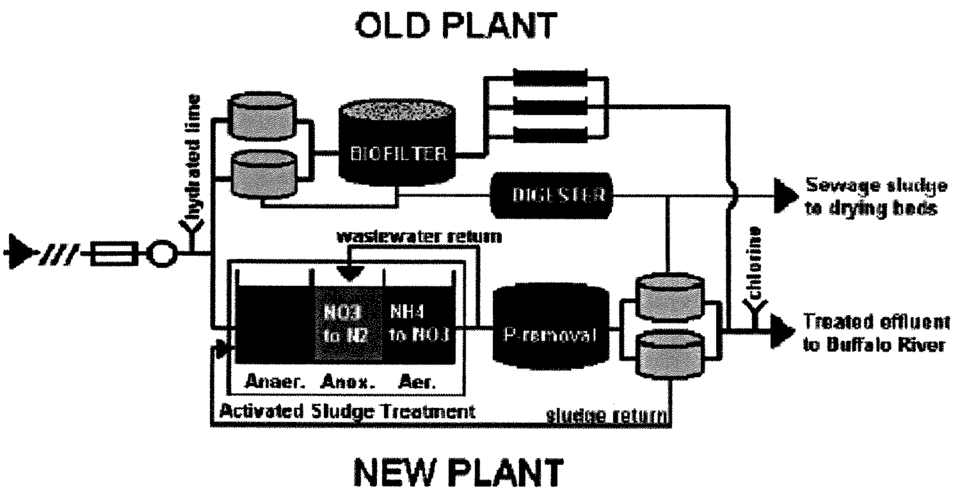


Figure9. Technical description of the Schornville STW (Zinn, 2000)

Twenty percent of the incoming wastewater is used for irrigation at King Tanning Industry and at the KWT Golf Course. This is not treated for phosphate removal or chlorinated. The maximum capacity of the plant is 4800 m^3 per day and this volume was estimated to be reached in 1998 (GIBB AFRICA; 1999).

Breidbach STW

The Breidbach town is served by a waterborne sanitation system and the sewage is entirely domestic. The Breidbach STW, which consists of oxidation ponds, is located on the east banks of the Yellowwoods River, a tributary to the Buffalo River. The capacity of the STW is 800 m^3 per day and this is estimated to be sufficient until 2005 (GIBB AFRICA; 1999). The works consists of two sets of oxidation ponds, two primary ponds and four secondary ponds. Final effluent does not comply with the general phosphate standards and is used to irrigate sportsfields. In 1993, the average sewage flow was 543 m^3 per day. Periodical discharges have taken place, due to seepage from ponds and run-off from irrigated land (GIBB AFRICA; 1999).

4.4.3 Comments on non-working steps

Even if there are many sites included in this study, in situ inspections have only been done at KWT WPW and Schornville STW.

Schornville STW

Many of the problems that occur at the Schornville STW have their origin in economical problems. Long time takes before broken or malfunctioning steps or machines are repaired. During the different visits these steps were malfunctioning:

- The mechanical self-cleaning equipment on the inflow bars has been malfunctioning several times, therefore bars was installed which has to be cleaned manually
- The sludge digester was out of order

- The sludge from the clarifier that usually was taken to the digester was instead sent to the activated sludge step
- One clarifier was out of order
- The anoxic zone in the activated sludge part was out of order

(Mr Cornelius, 2nd manager at Schornville STW in KWT TLC).

KWT Water Purification Works

The problems at KWT WPW are not as severe as the problems at Schornville STW. There were one major issue that concerned Mr Mhambi, manager at KWT WPW, and that was the difficulties in the dosaging of chemicals. This was done manually, with the result that the clarifiers were clogged if the dosages were too high.

4.5 Water, a scarce resource in South Africa

SA has practically no freshwater lakes. Their water supply is therefore confined to rivers, artificial lakes behind dams and ground water (Fuggle *et al* 1996). The mean annual precipitation in SA is 500 mm per year and the mean annual runoff is 30 mm per year. This is due to a very high degree of evaporation. Sweden has slightly more precipitation, but the annual runoff is much higher, around 400 mm per year, Figure 10.

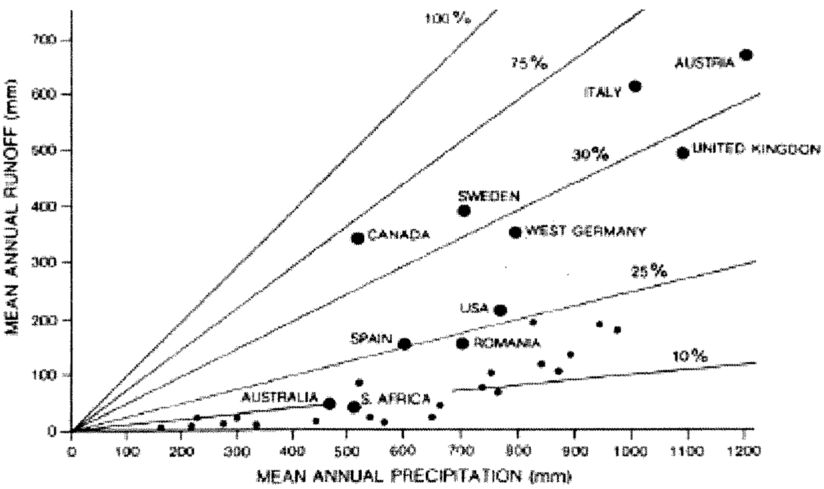


Figure10. Annual precipitation runoff in different countries (Fuggle el., 1996)

Therefore, Sweden has a very good opportunity to collect water for drinking purposes, while SA has much harder conditions to face. That is the reason why almost all of the South African river basins are connected to an interbasin water transfer and that almost all catchments have dams (Fuggle *et al* 1996). SA has 519 dams that together collect more than 50 % of the mean annual flow from the rivers. The prevailing attitude is that water flowing into the sea is wasted. This has, of course, a large impact on the biological life in the South African rivers (O'Keeffe *et* *al.*, 1990). As can be seen in Table 4, the total water usage is expected to increase from 19,043 m^3 in 1990 to 25,888 m^3 in 2010. The major user of water in SA is agriculture, which takes 67 % of the directly used water and more than half of all the water used. The estimated shares in the year 2010 indicate that the domestic and the industrial shares will increase from 12 % and 7.6 % respectively in 1990 to 17.3 % and 11.4 % respectively in the year 2010. One reason for this is the huge RDP program, which emphasises an increase of the connections of water and wastewater to households (Fuggle *et al.*, 1996).

Table 4. Water-use by different sectors in South Africa (estimated in 1986), and predicted changes in the next 20 years (Fuggle *et al.*, 1996)

Demand sector	1990 (10^6 m^3 y^{-1})	%	2010 (10^6 m^3 y^{-1})	%
Direct use				
Municipal & domestic	2281	12	4477	17,3
Industrial	1448	7,6	2961	11,4
Mining	511	2,7	649	2,5
Power generation	444	2,3	900	3,5
Irrigation	9695	50,9	11885	45,9
Stock watering	288	1,5	358	1,4
Nature conservation	182	1	191	0,7
Indirect use				
Forestry runoff reduction	1427	7,5	1700	6,6
Ecological use, estauries and lakes	2767	14,5	2767	10,7
Total	19043	100	25888	100

4.6 Environmental situation

The general conditions for the Buffalo River are that the river is turbid, alkaline, warm in temperature and has a natural high saline content (O´Keeffe *et al*, 1990). Although the quality of water in this study area is quite good, the reservoir downstream of KWT, the Laing Dam, shows increasingly more apparent signs of pollution of salinity and eutrophication. Therefore, the sustainability of the study area is of direct importance for downstream consumers, i.e. Zwelitsha, East London, *etc.* The environmental problems along the Buffalo River are mainly due to over-population and over-development in a relatively small catchment with inadequate water resources (O'Keeffe *et al.*, 1996).

There has been, particularly in the middle and lower parts, concern for many years about the water quality in the river. Since dams like the Laing Dam are situated downstream of KWT and Zwelitsha, it receives treated domestic and industrial effluents. The Bridle Drift Dam receives domestic effluents from Mdantsane through four small tributaries. The middle and lower parts of the Buffalo River are subjected to high salinity concentrations and eutrophication (O'Keeffe *et al.*, 1996).

The phosphorus concentrations reaches its maximum downstream of KWT with levels of 15 mg/l. Faecal bacterial counts in Bridle Drift also reach unacceptably high levels, as high as 15 000 cells/dl (O'Keeffe *et al.*, 1996).

4.7 Sources of pollution

There are both non-point sources and point sources in the Buffalo River catchment. The non-point sources are mainly land use (agricultural and forestry), urban run-off and natural sources (degradation of bedrock). The point sources are STWs, three dumpsites and the two industries, Da Gama Textiles and the King Tanning leather tannery.

As mentioned earlier, the largest concerns are eutrophication and high salinity in the dams. The main source of phosphate loads entering the Buffalo River are the STWs, which stand for as much as 70% of the total load. Another large source for phosphate is urban runoff, mainly during heavily rainfall. In the middle reaches, diffuse urban runoff contributes to a very large portion of the total phosphate load in this section of the river. This is where all the old townships, as well as the newer RDP areas, are situated. The main reason for the large contribution from townships is that a high numbers of animals are held as stock (O'Keeffe *et al.*, 1996).

4.8 Previous research

Research on the Buffalo River has been performed for decades with the Water Research Commission as the main actor. The Freshwater Institute at Rhodes University, Grahamstown, and other actors, such as the Palmer Development Group, have also conducted a number of research projects. Many of the published articles concerning the Buffalo River have been focused on biological issues, but environmental issues have also been included.

5. CASE STUDY

The evaluation is divided into two tasks. First, an evaluation of the sustainability of the UWS of the study area is done by using the proposed 19 SDIs and thereafter an evaluation of the SDIs' usefulness in Sweden and South Africa.

5.1 Results of the proposed SDIs from the study area

An evaluation on the sustainability of the UWS in the study area includes all the indicators proposed by doctoral student Margareta Lundin, ESA, Chalmers University of Technology, Göteborg, Sweden. Two additional indicators that include the access to safe drinking water and adequate sanitation have also been used.

5.1.1 Freshwater resources

Withdrawal

Estimations[3] of the annual available volume of raw water in the Maden and Rooikrans Dams is a total of 3.1 million cubic metres (GIBB AFRICA, 1999). Previously, water was taken from both dams, but in 1996 the pipes from Maden Dam were stolen, see Figure 7, and have not yet been replaced.

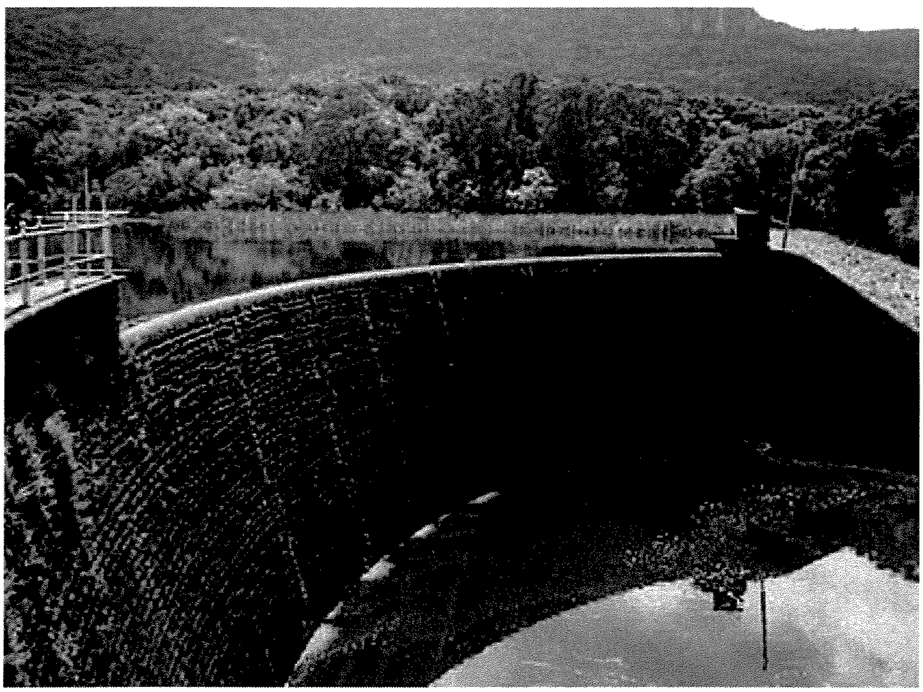
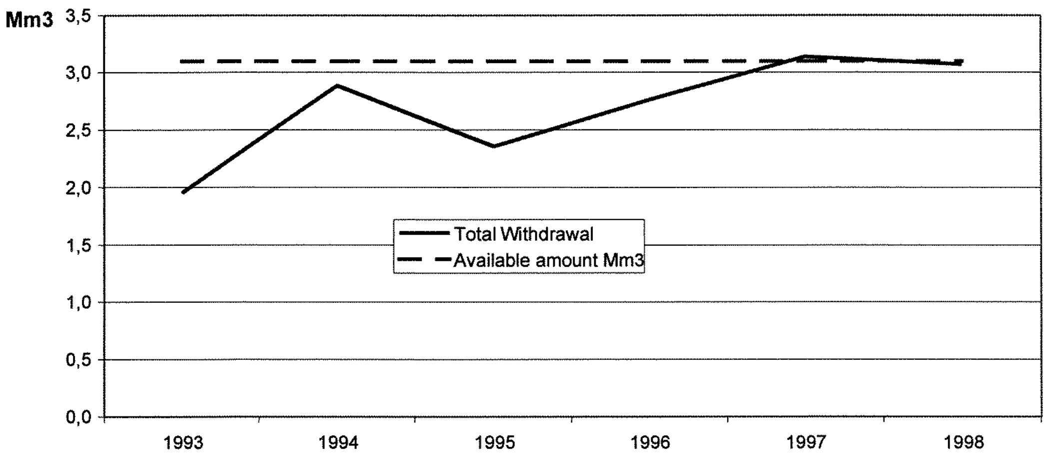


Figure11. Overflow at Maden Dam

[3] Personal communication with Mr. S. Russeau, Amatola Water Board on 991110

Fortunately, the Maden Dam is situated upstream of the Rooikrans, and the overflow from the former is collected by the latter before being piped to the KWT Purification Works, see Figure 11. As these two dams are now working in series, the total withdrawal volume has been used. The collected data shows that the withdrawal volume increased by 50% between 1993 ($2x10^6$ m^3) and 1998 ($3x10^6$ m^3) see Figure 12. The 1998 withdrawal equals approximately 100% of the total annual available volume. Additional water is also taken from the dam to the Rooikrans WPW, which supplies some small villages with clean drinking water, and "wet" industry Da Gama Textiles (near Zwelitsha) and the small Pirie Trout Farm, downstream of the Rooikrans Dam. Although the increased withdrawal is clearly apparent, the Engineering Section of the TLC is not excessively worried about future water shortages, as it considers the problem to be a lack of pipes. Future plans include a further interconnection of dams, as well as connecting the large Wiggleswade Dam north of Bisho. This is believed to cover the future raw water needs of the TLC. The Engineering Section is, though, also aware that future increases in withdrawal will meet a limit.[4]



Source data: Monthly values of the inflow of raw water to the KWT Purification Works, taken from Maden and Rooikrants Dam. Available amount is an estimation by Mr S Russeau of the Amatola Water Board.

Figure12. Withdrawal from Rooikrans and Maden Dam

Raw water quality (Concentration of pesticides, N, BOD and/or Coliforms)

Despite a lack of numerical data on this indicator, professionals working with are knowledgeable about the water quality at the Maden and Rooikrans Dams have assured us of its sufficient quality, which has even been described as "pristine". This opinion is shared by J. O'Keeffe's who states, "the upper reach of the Buffalo River is near-pristine" (O'Keffee *et al.*, 1990). Data beginning in 1960 has been collected for Nitrogen, Sulphur and Phosphorus in Rooikrans Dam and can be seen in appendix 8.1.

[4] Personal communication with Mr. Hetem, Civil Engineering Section, KWT TLC (Bisho) on 991112

Protection (Degree of protected sources)

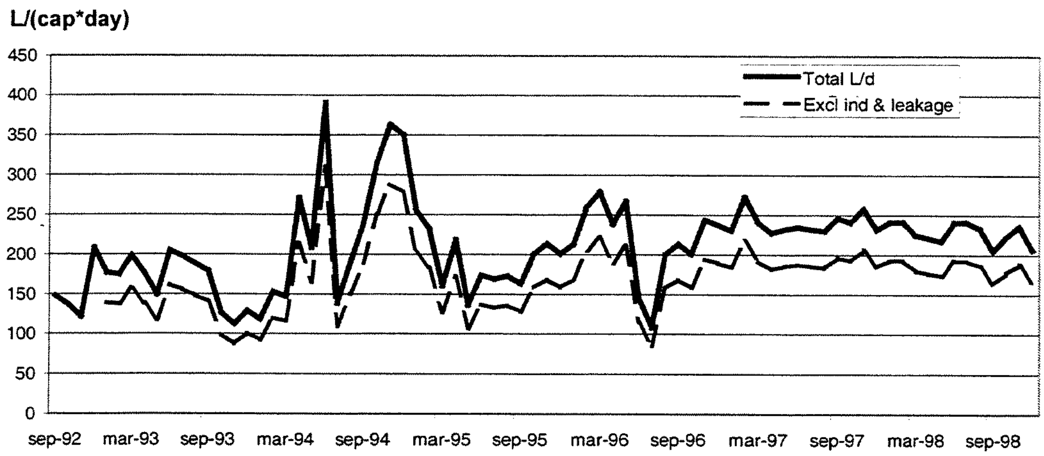
Both the Rooikrans and Maden Dams are located approximately 20 km from the main urban area of KWT, of which almost 10 km is gravel road, i.e. this is a remote area. No further development of the area is planned[5], and the Maden Dam is currently also used for trout fishing, while sailing is allowed on the Rooikrans. Their further non-development is therefore in the interest of the public, and those who enjoy these "pristine" environments would not welcome future alterations.

To our knowledge, no contingency plan exists for the eventuality of an accident that would pollute these sources beyond usage, although water is already drawn from the Laing Dam in periods of drought, and can also be used as a substitute reservoir.

5.1.2 Drinking water

*Water consumption (L/cap*day)*

Due to the history of the region, population estimations have been educated guesses at best, and usually underestimated. The TLC's Framework Plan (Setplan, 1997) includes the latest population estimation and is assumed to be close to accurate. The population of KWT (incl. Schornville, Ginsberg and Breidbach) served by the KWT Purification Works in 1997 was estimated at 35 500, increasing annually by more than 3% (Setplan, 1997).



Source data: Inflow of raw water to the KWT Purification Works (PW). Population served by PW, estimation by Setplan (1997). Flow to King Tanning taken from WRC Report No. 405/1/96. Leakage estimated at 20 %, various sources.

Figure 13. Water consumption for KWT TLC

Consumption was calculated by dividing inflow values at the KWT Purification Works by the population estimation (Setplan, 1997), which was adjusted according to projected population increases. The water consumption per capita and day (incl. industries and leakage) has increased from approx. 175 l/cap*d (mid-1993) to the peak of 1995 at over 250 l/cap*d and now seems to be stabilising at around 230-240 l/cap*d, see Figure 13. Deduction of the largest 'wet' industry receiving water from

[5] Personal communication with Mr Kooverji, DWAF, East London on 991105.

the Purification Works, King Tanning (2109 m^3/month, from O'Keeffe *et al.*, 1996), and leakage (20%) results in a domestic consumption of just under 200 l/cap*d. The withdrawal from King Tanning equals less than 1% of the total water use.

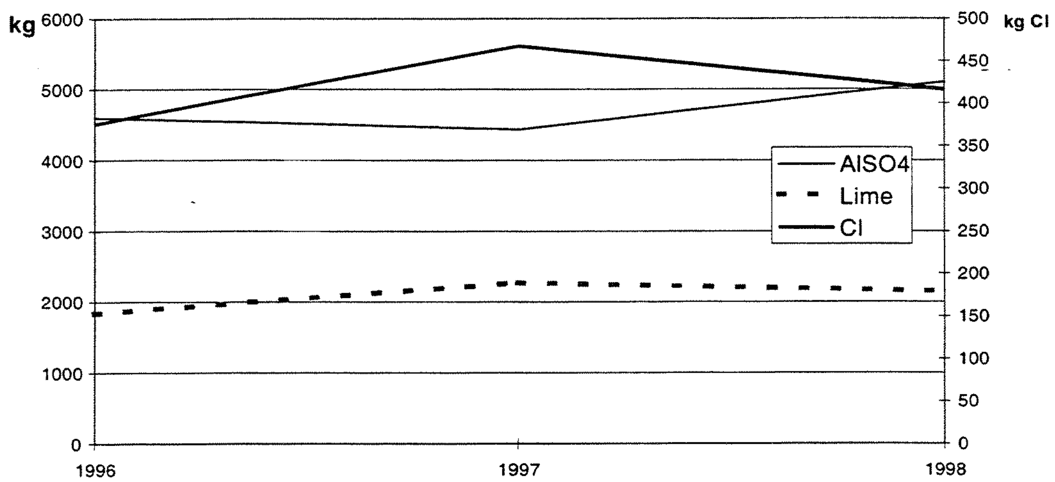
Drinking water quality (% tests within regulations)

As with the previous indicator, there is a lack of acquired numerical data for this indicator, but professionals[6] spoken with assured us of the good quality of the drinking water.

Chemical and energy use for drinking water treatment (mg/l, kWh/l)

As the Maden & Rooikrans Dams are located in areas void of industries and large-scale agriculture, the raw water being tapped by the KWT Purification Works is of such high quality that little treatment is necessary.

Data on the usage of chemicals at the KWT Purification Works has been obtained for the period Nov '96 to Dec '98. During this period, the withdrawal of raw water has been stable at around 3.1×10^6 m^3/y, or 225 L/cap*d. The dosage of Chlorine and lime has been relatively stable (2 mg/l and 8 mg/l resp.) during this period, while the dosage of aluminium sulphate has increased from approximately 16 to 19 mg/l. The total amount of chemicals used in 1997 was for $AlSO_4$ 53 tons, increasing to 61 tons in 1998; for lime from 27 to 26; and for Chlorine from 5.6 to 5. This is presented in Figure 14.



Source data: Chemical usage at the KWT Purification Works, obtained as monthly

Figure 14. Chemical usage at KWT Purification Work

Future efficiency improvements are to be expected, as the dosing equipment at the KWT Purification Works is imprecise, making it difficult to optimise dosing after need[7], but new equipment is hoped to be installed in the near future[8].

[6] This includes Wayne Selkirk (991118) at Pollution Control Technologies, which the TLC employs to do the actual water quality measurements.
[7] Personal communication with Mr Braweni of the KWT Purification Works 991102.
[8] Personal communication with Mr Hetem 991112.

Leakage (% of produced water)

The leakage in the water/wastewater system has been estimated at 20%.[9] This means that one fifth of the total produced drinking water is wasted, including the energy and resources used for its production. Also, substantial amounts of untreated sewage leak into the environment, and infiltrated rainwater dilutes the sewage that does reach the STW. In Sweden, 20 % leakage is normal. (Lundin, 1997)

In addition to the leakage, during rainfalls, water is entering the sewage system through backyards wells, see Figure 15 (see also Combined sewers). [10]

Reuse (% reused water compared to total use)

No domestic reuse of water could be found. However, King Tanning receives treated wastewater from the Schornville STW, and after usage and certain treatment in treatment ponds, the water is again discharged into the Buffalo River. KWT Golf Course receives treated wastewater from Schornville STW for irrigation on green areas. Both received just under $0.2*10^6$ m^3/year, for the years 1993-1996, since then, the meters have been malfunctioning.

Breidbach STW uses all the effluent for irrigation on sportsfields. There are no measurements performed on the quality of the water used for irrigation.

5.1.3 Wastewater

*Wastewater production (L/cap*day)*

The wastewater production, received at the Schornville STW, has been fluctuating for the past six years with an extraordinary peak in 1996, see Figure 15. For annual volumes, see Appendix 8.3. The rainfall curve correlates with the curve for wastewater production. This is proof of a leakage of rainwater into the UWS. In 1996, the inflow volume to Schornville STW was $2,55*10^6$ m^3, equalling 250 l/cap*day. This volume decreased in 1998 to just under $1,5*10^6$ m^3 or 135 l/cap*day.

The much smaller Breidbach STW, which uses a pond system, received during the period 95-97 approximately $0.2x10^6$ m^3/y, equalling 90 L/ day and person connected. The reason for the lower volumes per capita for Breidbach can be that this STW is connected to households that in average are poorer than households connected to Schornville STW, and thereby the usage is lower.

[9] Based on personal communication with Mr Hetem, Mr Kooverji and a report by the Dept of Public Works (1994).

[10] Based on Personal communication with Mr Hetem

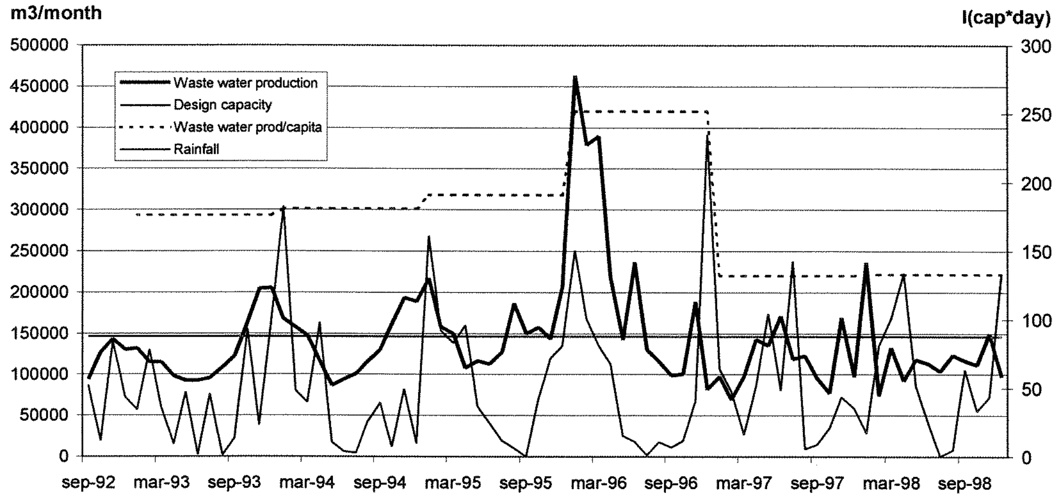


Figure15. Wastewater production and design capacity for Schornville STW compared with rainfall data for KWT

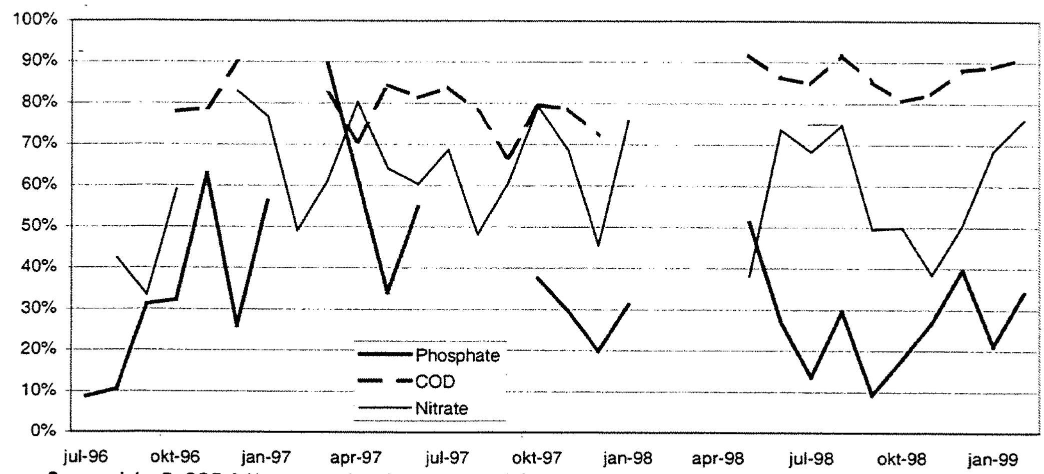
Combined sewers (%)

The standard in SA is separate systems, with one set of pipes for the domestic and industrial sewage, and another for the surface runoff. KWT is no exception. One problem is that backyard tap drains, which are built so that no rainwater can enter, have been sabotaged. This results in large volumes of rainwater entering the sewage system during heavy rains, see Figure 15.

Treatment performance for Schornville STW (% removal of nutrients)

For results, see Figure 16. The levels for Phosphorus removal were 50 % in 1996 and 1997, but dropped to 30 % in 1998 and the first two months in 1999. COD has on the other hand improved from slightly above 80 % in 1996 to 90 % in 1999. The treatment performance for Nitrogen, which was conservatively estimated as the transformation of Ammonia to Nitrate, was in 1996 70 % and dropped to 50 % in the beginning of 1998 and 1999.

The overall treatment performance is better in the newer activated sludge plant, as compared to the older biofilter plant. One explanation for this can be that the activated sludge plant was built at a latter stage.



Source data: P, COD & N concentrations in raw sewage influent and treated water effluent. Assumed 60/40 distribution between New and Old plants.

Figure 16. Treatment performance at Schornville STW for N, COD and P

The treatment performance has, as mentioned above, improved for COD between 1996 and the beginning of 1999, while decreased for Nitrogen and Phosphorus. The chemical removal of Phosphorus is done by applying Ferric Chloride, which may explain the decreased performance for Phosphorus. The decreased usage of Ferric Chloride has affected the P removal. The process of removing Nitrogen has apparently been a problem, which was seen during in situ inspection at Schornville STW, see also chapter 4.4.3 Comments on non-working steps, page 25.

Loads to receiving waters (kg COD, P and N)

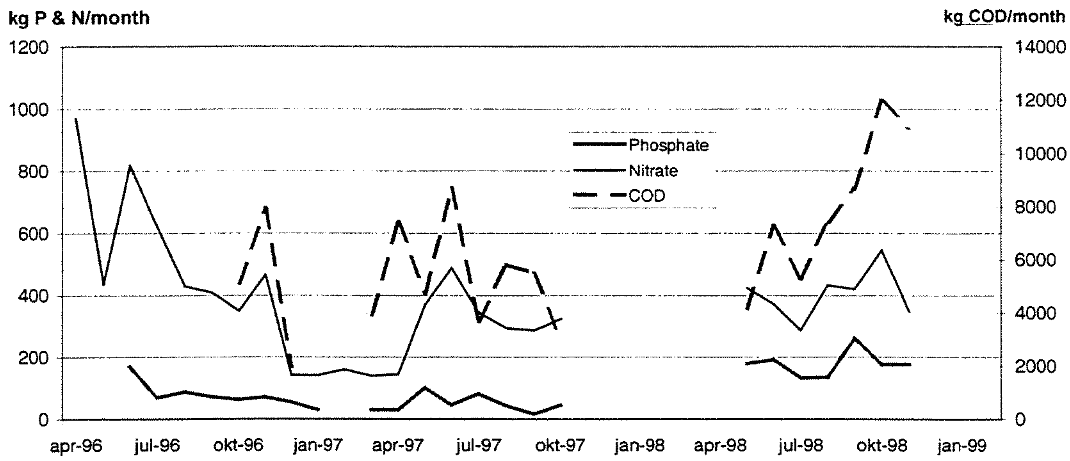
Effluent levels of Nitrate are exceeding acceptable levels[11] for the years 1996 through 1999. The highest annual average of the period was in 1998, when it was as high as 4.5 mg/l. Loads are presented in Figure 17.

Approximately 400 kg of Nitrate is entering the Buffalo River every month from the Schornville STW, and this trend increased slightly in 1998. The total Nitrogen load has increased as well. Through 1996 and 1997 the load was oscillating around 1100 kg, while this increased in 1998 to approximately 2500 kg per month. Phosphorus effluent levels were at acceptable levels[12] during 1996 and 1997, but these levels shot up above regulation in 1998 to around 1.6 mg/l and were increasing during the first two months of 1999 to around 2.3 mg/l. This also applies to the total loads of P. In 1996 and 1997 this added up to approximately 70 kg/month, and jumped to around 200 kg/month in 1998. The effluent levels of COD have been above the Special Standard Limits of 30 mg/l for the years 1996-1999. In 1996 and 1997 the average effluent contained 6 tons of COD per month and this increased to a maximum in

[11] For sensitive areas like the Buffalo River, the South African Water Act, No 54, 1956, specifies the application of the Special Standards limits. For Nitrate this is less than 1.5 mg/l.

[12] For sensitive areas like the Buffalo River, the South African Water Act, No 54, 1956, specifies the application of the Special Standards limits. For orthophosohate this is less than 1.0 mg/l.

October 1998 to 15 tons. This peak correlates with the peaks for Nitrogen and Phosphate.



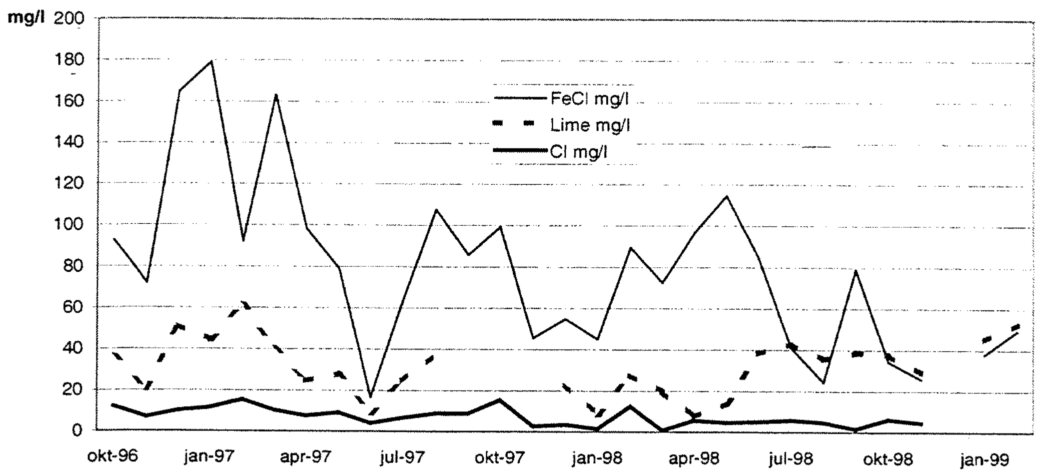
Source data: COD measurements on the raw sewage influent and the effluent from the New and Old plants. Effluent volumes from the Schornville STW to the Buffalo River.

Figure 17. Loads of N, COD and P to Buffalo River

Information on the loads derived from agriculture was not obtained, but these were assumed to be small due to the lack of large-scale farming schemes. The loads from King Tanning were not assessed either, due to a lack of acquired data. This high – salinity effluent is irrigated to a farm, which is situated on one of the banks to the Buffalo River. The seepage from the farm contributes mainly to the salinity of the Buffalo River.

Chemical and energy use for wastewater treatment (mg/ l, kWh/ l)

The use of chemicals has decreased considerably over the last few years. Ferric Chloride has decreased from 73 tons (1996) to 44 tons (1998), lime from 47 (1996) to 39 tons (1998) and Chlorine from 11 (1996) to 5 tons (1998). See appendix 8.4. Considering the usage per volume of treated wastewater see Figure 18, the trends are the same. The use of FeCl has decreased from 650 to just under 400 mg/l, lime has decreased from just under 400 to under 300 mg/l, and chlorine has decreased from 100 to around 50 mg/l.



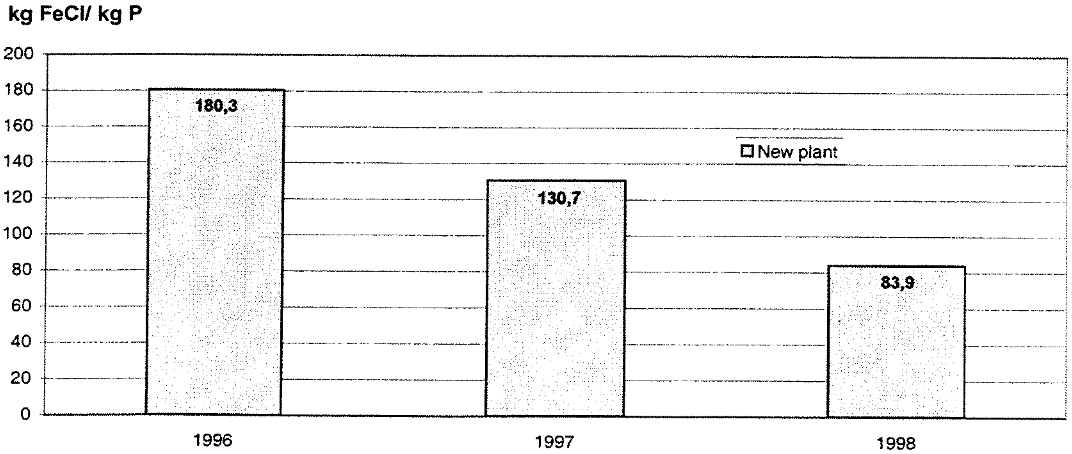
Source data: Daily and monthly values of chemical used at the Schornville STW. Inflow volumes to the Schornville STW.

Figure 18. Chemical usage at Schornville STW

Resource use per removal of nutrients (kg FeCl/ kg P)

Ferric Chloride is added to the Activated Sludge Step of the STW. The efficiency of this removal has varied considerably every year: 180 kg FeCl/ kg P in 1996, 131 kg FeCl/ kg P in 1997 and 84 kg FeCl/ kg P in 1998, see Figure 19. These large fluctuations must be viewed in the light that the decreased usage of Ferric Chloride also has occurred in a period of increased influent and effluent levels of Phosphate. One reservation to the previous calculations is that some of the P removed occurred in previous sedimentation steps.

The theoretical use ratio of Ferric Chloride for Phosphorus removal is 5.2:1. (Viessman *et al.*, 1998)



Source data: Ferric Chloride use at the Schornville STW. Influent and New plant effluent concentrations of P. New plant inluent volumes and New plant effluent volumes to Buffalo River.

Figure 19. FeCl usage per P removal

5.1.4 Recovery of nutrients and energy

Recycling of nutrients (%)

Dried sludge is given away to any farmers who are willing and able to collect it themselves from the Schornville STW. This ends up with a very erratic pattern of usage, as few have the possibility of transporting any considerable amounts. The percentage of sludge used for agricultural purposes was estimated at between 30-50%[13], with the remainder being deposited at landfills. Recycling of sludge with adequate quality should be promoted.

Quality of sludge (g Cd/kg P)

There are at the moment no measurements performed on the sludge to ensure the quality, which is unacceptable. Since the sewage system does not include surface runoff from city streets the quality is assumed to be sufficient.

Energy recovery (kWh/month)

There are no such facilities at the Schornville STW.

5.1.5 Socio - Economic development

Access to clean drinking water & adequate sanitation

As the studied areas were not included in the Republic of Ciskei, they have attained a higher level of development equal to those of the larger cities of SA. The access in the study area is assumed to be 100 %. The consumed water per capita is well in excess of the WHO minimum of 50 liters per day and capita.[14]

The situation is slightly different if one look on the KWT TLC, see in Table 5. The percentage of individuals lacking adequate service is as high as 27 %.

Table 5. Service levels in 1998 for KWT TLC (Setplan, 1997)

	Inadequate	Standpipes	Yard taps (on-site sanitation	Yard taps (w/borne sanitaion)	In-house
(%)	27	4	0	8	61

Sanitation is water born and assumed to accommodate 100 % of the population in the study area.[15]

[13] Through personal communication with Daria Dolley and Cornelius Mhambi of the Sch STW
[14] Estimation by Daria Dolley.
[15] Estimation by Daria Dolley.

5.2 Evaluation of the utilised SDIs in there different contexts

The majority of the 19 proposed indicators were developed for use in Sweden and therefore with Swedish or at least Western European conditions in mind. Since this study was conducted in SA some of this basic conditions are different. An evaluation of the relevance and importance of each one of the indicators is therefore of interest. With this follows also the awareness for each one of the different SDIs. The evaluation is presented as a discussion and figures and background are taken both from the study area and from SA as a whole. This part of the evaluation is the personal view of the author.

5.2.1 Freshwater resources

Withdrawal (%)

Withdrawal, as a SDI, has a high relevance for both Sweden and SA, but this driving force differs in magnitude. The driving force in Sweden is to save water, but this is geographically limited to some islands and coastal areas. In SA, the driving force is also to save water, since the demand of water is high and water is scarce. This applies to the country in whole. The awareness of problems related to a high withdrawal is also known in both countries. In SA, this SDI can predict a coming water shortage.

Raw water quality (Concentration of pesticides, N, BOD and/or Coliforms)

The relevance for this SDI is higher in SA, since most of the municipalities are dependent on a single water source, while in Sweden, a municipality often has multiple choices or, at least, it can be arranged. The awareness of this SDI is higher in Sweden than in SA. As mentioned earlier, the quality of the raw water sources of KWT is adequate, but further downstream the problems are more severe. The reasons for this are leaking landfills on the riverbanks and untreated effluents entering the river. In Sweden almost all effluents entering a recipient are treated, therefore would not the water further downstream be so effected as in SA. The authorities controlling the raw water in SA are both on provincial and municipality levels, depending on the owner of the water reservoir. The municipality, for example, administrates the Maden Dam, while the Rooikrans Dam is administrated by DWAF.

Protection (Degree of protected sources)

In Sweden, all water is a public resource, while this is not the case is SA, where water is divided into public and private water. A private owner has unrestricted rights of use and enjoyments of the water occurring on his property and can even impound the watercourse (Fuggle *et al.*, 1996). In Sweden, all watercourses are to some extent protected by laws. The awareness that a majority of the water in SA that is useful for drinking purposes has its origins in mountain areas is high, and therefore the protection of these watercourses is an ongoing process.

5.2.2 Drinking water

*Water consumption (L/cap*day)*

Since the water consumption SDI includes population increases, the differences between SA and Sweden are apparent. Sweden has a low population increase, while the increase in the study area exceed 3 % (Setplan, 1997). The consumption in SA is also very unfair, with a small portion of the population, farmers, consuming a large quantity of the available water for irrigation purposes, see Table 4. The relevance for this indicator is high in SA. The acknowledgement of an increasing population and the current unfair distribution of this resource has set new goals in order to achieve a guaranteed supply of water to all, so that development can proceed. The awareness of this SDI is high in SA, with new connection for water and sewage built every day and campaigns for saving water saying, "Water is your right, to save it is your responsibility". It is very easy to obtain data for this SDI in Sweden, since all users connected to a bulk network has water meters. In SA, it is becoming more and more common to pay a flat rate, making data harder to obtain.

Drinking water quality (% tests within regulations)

Since no regular measurements are performed on the drinking water quality, data has been difficult to obtain. It is therefore impossible to make comparisons between Sweden and SA.

Chemical and energy use for drinking water treatment (mg/l, kWh/l)

The awareness of the chemical and energy use at the WPW is lower in SA than in Sweden. In SA, economical concerns control how much and which chemicals are used. In Sweden, in addition to the economical issues, there are other concerns present, such as environmental problems. A good example of this was that the dosage was done manually and adjusted just a couple of times each day, and not after quantity of water entering the plant. The relevance of this indicator is greater in SA than in Sweden. By presenting this SDI for decision-makers, both money and the environment can be saved.

Leakage (% of produced water)

Little was known about the leakage in the system, only estimation were available. Leakage as a SDI has relevance both in SA and Sweden, but to what extent is difficult to evaluate. The awareness of problems related to this SDI is high in both countries, but little is done because of the need of large investments for repairing or replacing leaking water pipes.

Reuse (% reused water compared to total use)

Both the relevance and awareness of reuse as a SDI is higher in SA than in Sweden. A good example of this is that wastewater from the STWs in the study area is used to irrigate sportsfields and a golf course, or sent to the industries. By increasing the reuse of water, a decrease of the effluent to recipients and a decrease of the withdrawal is achieved, in addition to fertilising the sportsfields with nutrients. The indicator lacks a great relevance to Swedish conditions.

5.2.3 Wastewater

- *Wastewater production (L/ cap*day)*

The awareness of this SDI, related to wastewater production in the study area, is high since the capacity of the existing STWs has already been exceeded for a number of years and the planing of a new, larger-scale STW for the whole TLC is in progress. The relevance is higher in SA than in Sweden, due to the population increase and new household connections through the extensive RDP programme.

Combined sewers (%)

Combined sewers are a considerate problem in Sweden, since almost all UWS built before 1960 are built as combined. This is not the case in SA, as separate systems are the norm, and therefore the relevance is larger in Sweden. The advantages of using a system with separate sewers are less water and pollution to the STW, and higher concentrations of nutrients in the incoming water, thereby making a more efficient process possible.

Treatment performance for Schornville STW (% removal of nutrients)

The awareness of the STW's treatment performance was not especially apparent in the study area. When diagrams showing the performance at Schornville STW were presented to the staff, few knew why the trend for phosphorus was declining for example. The relevance for this SDI is high in both countries, since a higher treatment performance is preferable for the environment. Many South African rivers have, for example, a tendency towards eutrophication, (Setplan, 1997) a problem well known in Sweden for decades.

Loads to receiving waters (kg BOD, P and N)

The relevance of the SDI for loads to receiving waters is greater in the study area compared to Sweden. One of many reasons for this is that new houses are connected to the existing bulk network almost every day. The capacities of the STWs in the study area have already been exceeded. Therefore, a higher load to the Buffalo River can be expected (GIBB AFRICA, 1999). The awareness of this SDI is high, both in SA and Sweden, since signs of a high loads in the environment are apparent as e.g. eutrophication.

Chemical and energy use for wastewater treatment (mg/ l, kWh/ l)

Since the dosage of chemicals at the Schornville STW is done manually, efficiency might be low. Chlorine is added to the effluent for disinfection. This may have severe effects on the recipient, but it is also necessary since water is used for drinking purposes downstream. The awareness of using a SDI for chemical and energy use is low in SA, and the relevance is moderate.

Resource use per removal nutrients (kg FeCl / kg P)

The awareness of resource use per nutrients removed was low in the study area. For example, the dosing was done manually. In a country like SA, were liquid capital is low, a SDI for this issue would be relevant for the purpose to save money, and at the same time protect the environment. The awareness of this issue is high in Sweden.

5.2.4 Recovery of nutrients and energy

Recycling of nutrients (%)

A recycling of nutrients was done to a small extent in the study area. The awareness of the importance of recycling nutrients was low. One reason for this may be that SA is a large producer of commercial fertilisers. The relevance and importance of using a SDI in this field is high in both countries, since phosphate from rocks is a limited resource. Sludge from the STW is now deposited on local dumpsites and leakage may occur, which may also reach recipients.

Quality of sludge (g Cd/kg P)

The relevance and importance of the sludge quality, as a SDI, is higher in Sweden than in SA, because of the use of combined sewers in Sweden and Western Europe and more traffic in these parts of the world. This results in heavy metal concentrations in the sludge. The awareness of this is low in the study area. No quality testing of the sludge was performed before the sludge was given away to farmers or deposited.

Energy recovery (kWh/month)

There were now facilities for energy recovery in the study area, and the awareness should therefore be low.

5.2.5 Socio - Economic development

Access to clean drinking water & adequate sanitation

The access to clean drinking water & adequate sanitation is greatly different between Sweden and SA. The relevance of use for this SDI is very low in Sweden, since it is too imprecise, while in SA it is extremely important. The awareness of problems associated with a low access to both clean drinking water and sanitation is very high in Sweden and SA.

5.3 Data availability and assurance for the proposed SDIs

Data that have been measured by different actors in the study area has been available, with no restrictions. But, there was an exception, the drinking water quality tap test was conducted by a private company, which refused to provide use with these data. The assurance of the data can be regarded to be low especially from the Schornville STW, mainly due to failure in measuring equipment such as flow meters. This has been taken into considerations and some data has been excluded in the results part.

5.4 Summary of relevance and awareness for the different SDIs

A summary of the indicators' importance in the context of Sustainable Development is rated in the RELEVANCE column in Table 6. If data on the indicator is readily available at e.g. local treatment plants or municipal offices, it scores a high rating on DATA AVAILABILITY. The scoring for DATA AVAILABILITY does only take the study area into consideration and not SA as whole.

Table 6. List of relevance, data availability and awareness for the proposed SDI-WWS's (Lundin, 1999)

SDI - WWS	Type of indicator	Relevance		Data availability		Awareness	
		Sweden	SA	Sweden	SA	Sweden	SA
Withdrawal	Pressure	***	***	***	***	***	***
Raw Water Quality	State	***	***	***	***	***	**
Protection	Response	***	***	*	*	***	**
Water Consumption	Driving Force	***	***	***	**	***	***
Drinking Water Quality	State	***	***	**	*	***	**
Chemical and energy use for drinking water treatment	Efficiency	**	**	***	***	***	**
Leakage	Efficiency	**	***	**	**	***	***
Reuse	Efficiency	**	***	**	**	**	***
Wastewater Production	Pressure	***	***	***	***	***	***
Combined Sewers	Effectiveness	***	*	***	***	***	***
Treatment Performance	Effectiveness	***	***	***	**	***	*
Loads to receiving waters	Pressure	***	***	**	**	***	***
Chemical and energy use for wastewater treatment	Efficiency	**	**	***	***	**	*
Resource use per removal of nutrients	Efficiency	**	**	***	**	***	*
Recycling of Nutrients	Effectiveness	***	***	**	*	***	*
Quality of Sludge, mg Cd/ g P	State	***	**	**	*	***	**
Energy recovery	Efficiency	**	***	***	-	***	**
Access to clean drinking water	State	**	***	**	**	**	***
Access to adequate sanitation	State	**	***	**	**	**	***

***	High important
**	Moderate importance
*	Low importance
-	no such facilities

The individual SDIs in Table 6, has variable grading for relevance, data availability and awareness when compared between Sweden and SA. A new list, see Table 7, of SDIs is therefore proposed. This list includes SDIs that are more relevant for the general conditions in study area and SA in general, and for future work in the study area. A short description follows why the individual SDI has been chosen.

Withdrawal has a high importance for all the three columns in Table 6, and is therefore valuable to be used as a SDI in the study area. Raw water quality is also of high importance and is therefore recommended for future use in SA.

In the next category of SDIs, water consumption is believed to be useful, this SDI has also grading in the columns concerning SA. The SDI for chemical and energy use for drinking water treatment is included even if the grading shows moderate importance. By using this SDI balance between economic and environmental concerns can be found. This is extra important in country like SA, where the economic situation is harsh. Reuse is included in list. Mainly because of the large advantageous of reusing water and also that this should be promoted even further. Domestic reuse is for example a big opportunity for the study area to save water.

Wastewater production is the first SDI in the third category of SDIs, to be included in the list. This SDI has a high importance for all columns. Loads to receiving waters and treatment performance are included in new list as SDIs. Both are very important in verifying the performance of the STW and the environmental impact of the recipient, which are detrimental aspects for moving towards a more sustainable development. Chemical and energy use has a moderate importance in the columns in Table 6, but as mentioned for the similar SDI for the WPW, this is a good SDI for both environmental economic concerns.

In the last and fourth category, recycling of nutrients and quality of sludge has been included. These are very useful in promoting reuse of sludge of high quality, in terms of pollution, for agricultural fertilisers. The two last SDIs that has been suggested are access to safe drinking water & adequate sanitation. These two are not so very important for the study area itself but very important for other areas in SA and in the vicinity. With the grading in the three columns in Table 6 in mind a list, see Table 7, is proposed for future work with SDIs and UWSs in SA and the study area.

Table 7. Proposed list of SDIs for future work

SDI-WWS	Comments
Withdrawal	*
Raw Water Quality	*
Water Consumption	*
Chemical and energy use for drinking water treatment	*
Reuse	
Wastewater Production	*
Treatment performance	*
Loads to receiving waters	*
Chemical and energy use for wastewater treatment	*
Recycling of Nutrients	*
Quality of sludge	*
Access to clean drinking water	
Access to adequate sanitation	

* Proposed by Margareta Lundin in Lundin, 1999

Table 7 includes also if the proposed SDI is suggested in (Lundin, 1999) for future studies. As can be seen there are only three SDIs that has not been suggested by Lundin, and this SDIs does not have any relevance in Sweden. Reuse has some relevance for small areas in Sweden such as islands and coastal areas. The two last SDIs does not have any relevance at all for Sweden, since the access both to sanitation and safe drinking water is 100 %.

6. SUMMARY

The summary describes thoroughly the situation in the study area with the SDIs in mind. It also intends to give an overall view of the environmental situation in the study area and to describe some technical limitations in the works and dams in the study area. It ends with a short summary of the evaluation of the used SDIs in their different contexts.

The annual withdrawal has approached the estimated available volume for the past six years and even exceeded this limit in 1997. Severe water shortages are still not expected, as future plans include the further interconnection of local dams, as well as including the large Wiggleswade Dam.

The chemical usage at the KWT WPW was fairly stable for the period Nov 1996 to Dec 1998, except for an increased use of $AlSO_4$. As the raw water in the Maden and Rooikrans dams is of excellent quality, it is unsure if this increased dosage was necessary. A future study into the required dosing at KWT Purification Works and new equipment might allow for future decreases in the chemical usage at this plant, saving both money and resources.

Although the raw water withdrawal has increased, the wastewater production has been erratic over the same years. This may be due to leakage in the wastewater system, which would explain the peak in the summer of 95/96, which was extraordinarily wet.

The chemical usage at the Schornville STW has decreased considerably for all three chemicals used. The decreased usage of Ferric Chloride has been-unfortunate, as the concentrations of Phosphorus (as well as Nitrogen and COD) in the raw water has increased. The consequence being increased effluent concentrations and total loads to the Buffalo River between 1996 and 1999, in some cases up to six times!

The treatment performance for Nitrogen and COD has actually increased during the observed period, while the removal of Phosphorus has simultaneously declined, most probably due to the decreased usage of Ferric Chloride.

To ensure the future use of sewage sludge as agricultural fertiliser, measurements of the heavy metal content present in the sludge should be conducted on a regular basis, in order to guarantee the public health. Also, the distribution of the sludge to local farmers should be encouraged, thereby decreasing the volumes of potential fertiliser being deposited and thereby "wasted".

Even if the access to clean drinking water & adequate sanitation was high in KWT, many areas in the vicinity of the KWT TLC are lacking this. One of the effects of the RDP programme will be a higher percentage of the population having a proper connection, resulting in a higher percentage of the population having access to safe drinking water and adequate sanitation, which is a necessity for further economical and social development.

The proposed SDIs from the paper (Lundin, 1999) are all relevant in their original context, while in SA some might have a lower degree of relevance. But the majority of the proposed SDIs have showed relevance in SA, the main reason for this being that a majority of municipalities in SA are dependent on a single water source and thereby very vulnerable. By using the proposed SDIs for the study area and SA in general UWSs can be effectively monitored by decision-makers, public, technical staff and others. When this communication between the different actors is established, the current directions of sustainability will be changed and the UWSs will be more sustainable.

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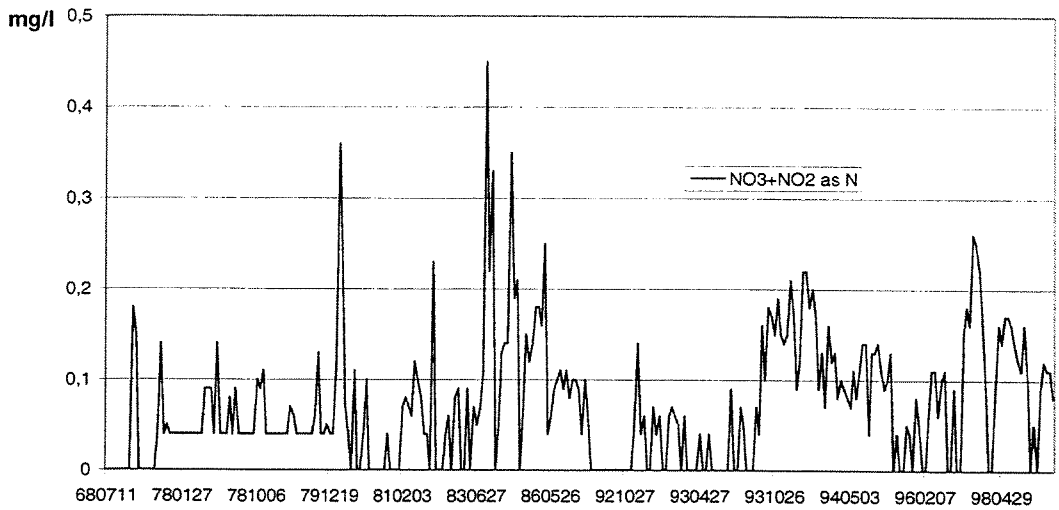
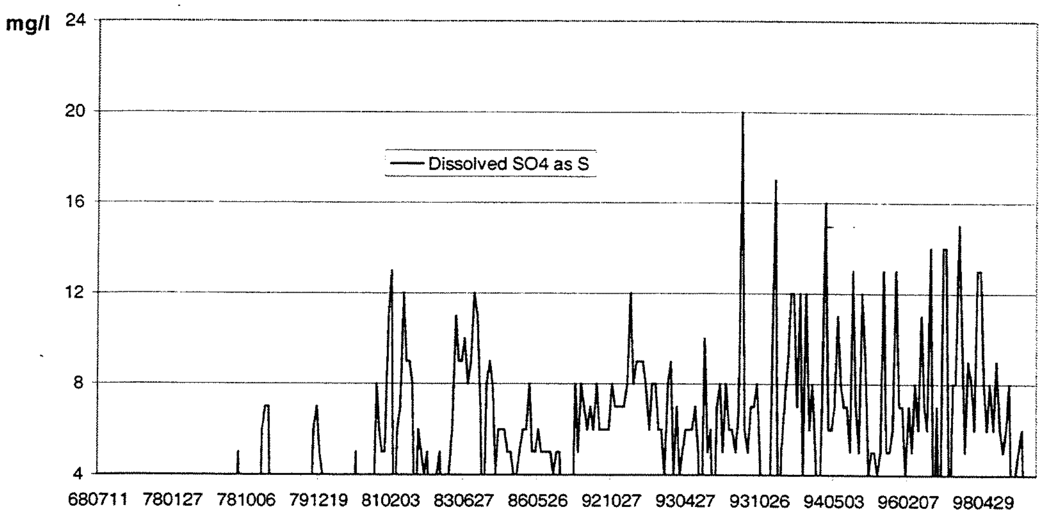
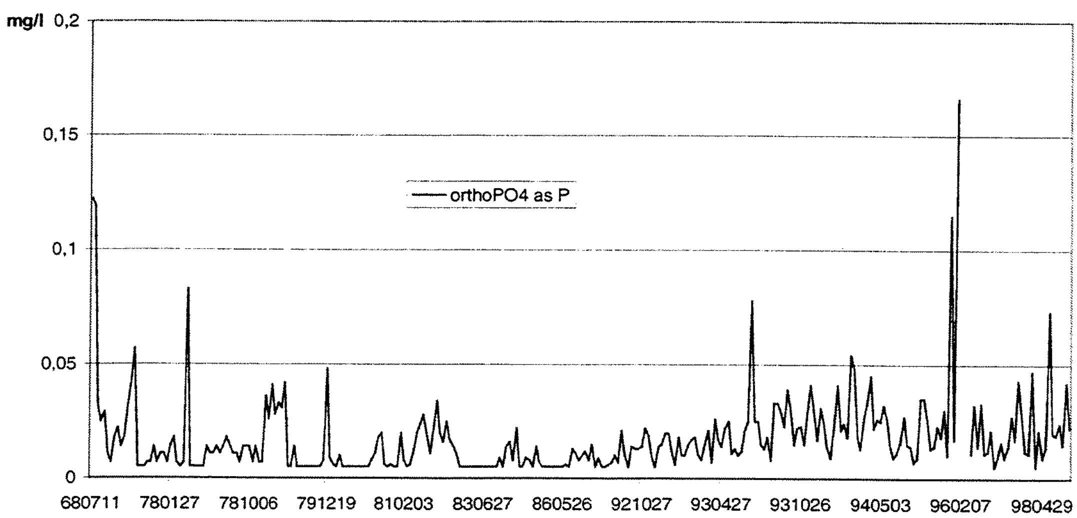
8. APPENDICES

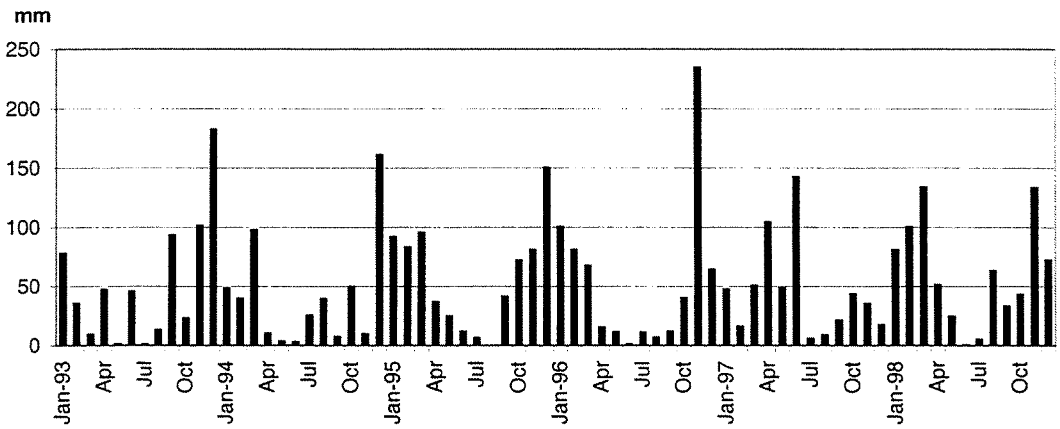
8.1 Raw water quality for N, S and P in Rooikrans dam





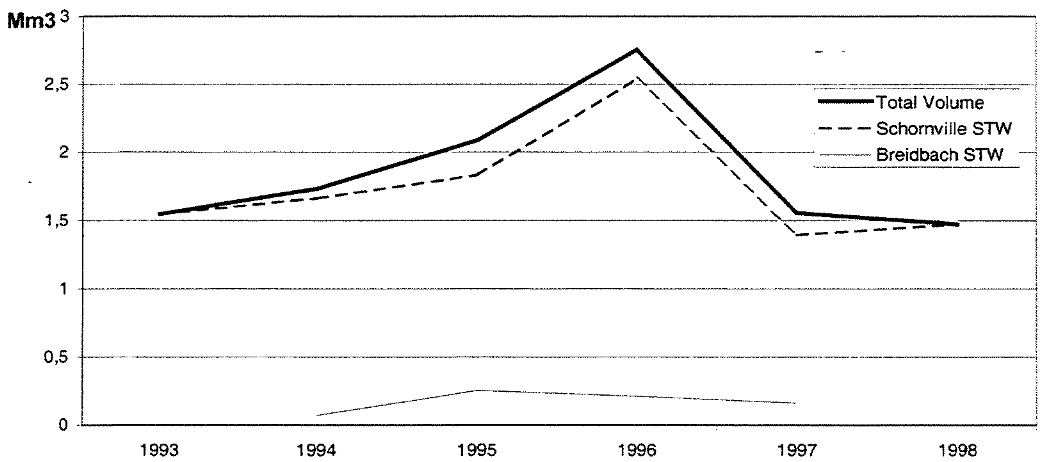


8.2 Rainfall data for KWT



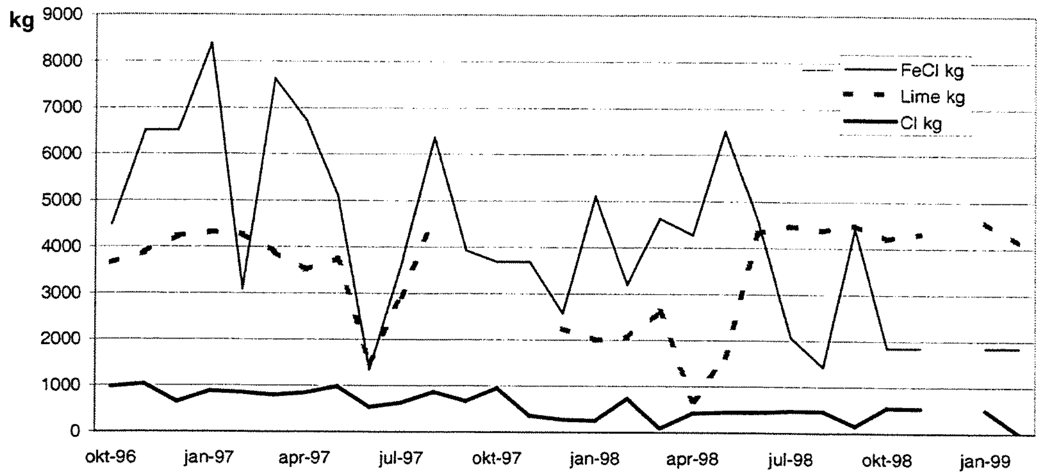
Source data: Rainfall data obtained from the Weather Bureau in Pretoria, the cordinates for the measurement point are: 0079712 X LAT: 3252 LON: 2724 H: and 400 m absl.

8.3 Wastewater production



Source data: Wastewater inflows to Schornville & Breidbach STWs. Only data from Schornville STW for 1993 & 1998. Population estimations according to Setplan (1997).

8.4 Total chemical usage at Schornville STW



Source data: Daily and monthly values of chemical used at the Schornville STW.

8.5 Raw data I

	-		Schornville STW		KWT WPW			Schornville STW		
	Withdrawal	Population	Wastewater	Effluent	AlSO4	Lime	Cl	FeCl	Lime	Cl
	m3/month		m3/month	m3/month	kg/mon	kg/mon	kg/mon	kg/mon	kg/mon	kg/mon
jan-92		17368								
feb-92		17368								
mar-92		17368								
apr-92		17368								
maj-92		17368								
jun-92		17368								
jul-92		17368								
aug-92		17368								
sep-92	137951	17368	93960							
okt-92	133014	17368	127320							
nov-92	114659	17368	143010							
dec-92	202734	17368	130350							
jan-93	172842	17976	131880							
feb-93	154526	17976	114930							
mar-93	194713	17976	114930							
apr-93	167175	17976	97980							
maj-93	147135	17976	92430							
jun-93	195729	17976	92430							
jul-93	195581	17976	95340							
aug-93	186583	17976	108900							
sep-93	172406	17976	122490							
okt-93	126521	17976	163620							
nov-93	108628	17976	204750							
dec-93	129754	17976	205020							
jan-94	119298	18605	167670							
feb-94	139226	18605	157380							
mar-94	148850	18605	147090							
apr-94	265628	18605	116790							
maj-94	211674	18605	86520							
jun-94	384815	18605	93840							
jul-94	141693	18605	101160							
aug-94	194501	18605	115950							
sep-94	236580	18605	130740							
okt-94	324028	18605	162180							
nov-94	361957	18605	193650							
dec-94	361957	18605	188974							
jan-95	264502	18927	216959							
feb-95	218271	18927	158272							
mar-95	167066	18927	149788							
apr-95	220899	18927	107998							
maj-95	142495	18927	116725							
jun-95	176511	18927	112840							
jul-95	177719	18927	127586							
aug-95	182261	18927	186310							
sep-95	166741	18927	150039							
okt-95	212429	18927	157778							
nov-95	220046	18927	143337							
dec-95	213579	18927	206853							
jan-96	227543	19589	463004							
feb-96	250448	19589	378889							
mar-96	299332	19589	389228							
apr-96	248350	19589	217635	199278						
maj-96	287916	19589	142431	77491						
jun-96	153165	19589	236250	73590						
jul-96	117877	19589	130137	67352						
aug-96	216807	19589	115808	69203				6880	3850	1120
sep-96	225241	19589	98964	60421						
okt-96	219108	19589	100965	80985				4490	3650	971
nov-96	257944	19589	188446	161946	4500	2025	376	6507	3875	1033
dec-96	260502	19589	82305	99703	4700	1650	376	6507	4225	655
jan-97	253364	20275	97509	92641	4530	1700	413	8378	4325	886
feb-97	271498	20275	69697	77865	3950	1550	435	3088	4275	858
mar-97	266172	20275	97437	88797	3750	1850	493	7634	3900	800
apr-97	243967	20275	142628	131032	4350	2375	446	6733	3500	848
maj-97	257702	20275	135193	93949	5000	2200	355	5115	3750	983
jun-97	253184	20275	170749	151130	4950	2025	542	1353	1508	540
jul-97	258803	20275	118636	94701	4450	1875	612	3619	2919	634
aug-97	257160	20275	123173	110531	4400	2800	541	6361	4650	866
sep-97	267477	20275	95601	77411	4250	2875	422	3937		670
okt-97	270514	20275	77334	91744	4100	2500	434	3686		947
nov-97	281418	20275	168778	80306	5350	3075	498	3686		358
dec-97	261593	20275	97509	68646	4150	2425	424	2570	2250	278
jan-98	273342	20985	236286	79492	4900	2625	403	5115	2000	256
feb-98	248061	20985	74389	90491	4300	2275	320	3198	2050	735
mar-98	256477	20985	133001	131942	6550	2350	460	4622	2625	90
apr-98	243977	20985	92253	85205	6050	2275	305	4273	688	420
maj-98	248807	20985	118349	99008	5900	2325	415	6512	1650	438
jun-98	267044	20985	112875	92226	4850	2075	391	4579	4325	443
jul-98	277050	20985	103941	74767	4250	1850	435,9	2066	4475	479
aug-98	268727	20985	123570	102947	3850	2500	404	1436	4375	468
sep-98	229583	20985	116751	104049	5700	2350	658	4419	4500	154
okt-98	257646	20985	111396	109481	5850	1700	397	1847	4200	548
nov-98	265017	20985	149677	138546	5800	1975	380	1847	4325	542
dec-98	240000	20985	97509		3200	1450	424			
jan-99	220730	21719						1847	4575	503

8.6 Raw data II

	Ammonia NH3N			Nitrate NO3N			NO3N+NH3N				Phosphate			COD		
	Raw	N.Final	O.Final	Raw	N.Final	O.Final	Raw	O.Final	N.Final	Final	Raw	N.Final	O.Final	Raw	N.Final	O.Final
jan-96																
feb-96																
mar-96																
apr-96	1,50	4,33	7,43	19,84	0,81	2,05	21,34	9,48	5,14	6,87	4,63	0,45	0,41			
maj-96	1,40	3,86	3,76	2,71	2,41	2,78	4,11	6,54	6,27	6,38	0,00	0,04	0,00			
jun-96	1,37	4,97	3,40	2,75	2,75	2,75	4,12	6,15	7,72	7,09	0,90	0,90	0,90			
jul-96	1,40	4,06	8,80	3,50	4,68	0,00	4,90	8,80	8,74	8,76	0,74	0,66	0,70			
aug-96	1,58	4,25	5,23	15,85	2,65	9,53	17,43	14,75	6,90	10,04	0,97	0,80	1,18			
sep-96	1,38	3,54	7,60	25,40	14,00	10,68	26,78	18,28	17,54	17,83	1,34	0,59	1,42			
okt-96	1,44	3,60	5,43	28,73	7,53	8,77	30,17	14,19	11,13	12,35	1,16	0,46	1,28	286,00	35,00	105,50
nov-96	2,08	2,80	3,53	1,36	0,33	1,40	3,44	4,93	3,13	3,85	1,27	0,36	0,64	248,50	37,50	75,50
dec-96	1,77	1,33	3,35	13,05	0,46	0,32	14,82	3,67	1,79	2,54	1,13	0,63	1,15	297,00		75,00
jan-97	1,85	1,43	2,40	29,10	6,30	4,00	30,95	6,40	7,73	7,20	0,90	0,23	0,63			
feb-97	1,73	4,80	0,00	16,33	10,53	0,00	18,07	0,00	15,33	9,20						
mar-97	2,06	2,98	0,00	23,90	13,88	0,00	25,96	0,00	16,86	10,11	3,68	0,63	0,00	284,50	34,00	75,00
apr-97	1,33	1,63	0,74	16,03	1,85	2,58	17,35	3,32	3,47	3,41	0,70	0,24	0,31	223,00	70,00	58,00
maj-97	1,40	3,85	2,77	31,25	4,30	14,33	32,65	17,10	8,15	11,73	1,42	0,63	1,40	282,00	73,00	
jun-97	1,64	3,12	4,26	23,88	5,08	8,72	25,52	12,98	8,20	10,11	0,73	0,41	0,21	340,50	51,50	82,00
jul-97	1,86	3,10	4,42	15,12	0,61	3,24	16,98	7,66	3,71	5,29	0,63	0,18	1,90	242,00	20,67	66,00
aug-97	1,68	2,78	3,28	22,72	11,06	7,58	24,40	10,86	13,84	12,65	0,69	0,51	0,35	270,00	49,20	74,00
sep-97	1,56	3,50	4,12	19,08	2,95	6,62	20,64	10,74	6,45	8,17	0,16	0,16	0,29	216,80	51,00	103,20
okt-97	1,18	4,44	6,44	49,20	0,37	12,44	50,38	18,88	4,81	10,44	1,16	0,37	1,25	235,75	40,25	60,33
nov-97	3,50	1,40	3,53	26,40	3,39	12,78	29,90	16,30	4,79	9,39	1,18	0,58	1,20	271,00	32,60	95,00
dec-97	1,58	0,94	5,84	28,00	17,20	7,24	29,58	13,08	18,14	16,12	1,10	0,72	1,12	243,00	45,00	101,25
jan-98	1,78	5,64	6,26	34,00	0,73	5,78	35,78	12,04	6,37	8,64	1,06	0,47	1,12		28,60	53,80
feb-98	2,74	3,84	3,50								0,61	1,52	0,39	311,33	32,67	74,50
mar-98																
apr-98																
maj-98	3,20	4,53	4,43	41,50	16,75	32,80	44,70	37,23	21,28	27,66	3,90	1,55	2,43	546,00	35,00	58,00
jun-98		4,18	4,01	57,50	6,57	17,69	57,50	21,70	10,76	15,13	2,91	1,83	2,57	593,80	62,80	107,60
jul-98		3,21	3,81	45,09	9,31	13,20	45,09	17,01	12,52	14,32	1,85	1,54	1,67	420,00	46,82	88,90
aug-98		3,62	5,49	56,56	8,46	12,07	56,56	17,56	12,09	14,27	1,96	1,25	1,58	923,56	55,99	103,83
sep-98		2,97	6,77	42,64	18,84	14,32	42,64	21,09	21,81	21,52	3,09	2,71	2,95	638,22	98,60	84,00
okt-98	3,75	6,73	5,18	43,83	20,95	12,92	47,58	18,10	27,68	23,85	2,41	2,10	1,81	697,50	160,20	95,50
nov-98		2,24	3,90	32,59	20,31	12,51	32,59	16,41	22,55	20,10	2,03	1,31	1,74	519,33	90,00	94,22
dec-98		3,12	4,47	15,62	4,44	3,48	15,62	7,94	7,56	7,72	2,30	1,18	1,70	439,63	48,00	58,00
jan-99		3,96	4,46	27,52	2,87	6,96	27,52	11,42	6,84	8,67	2,55	1,92	2,15	508,33	36,60	86,25