Power Outages and their Impact on South Africa's Water and Wastewater Sectors

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Report to the
Water Research Commission

by

Frost & Sullivan

based on a

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DISCLAIMER

EXECUTIVE SUMMARY

Introduction

Strategic decision makers are all too aware of the challenges presented by the energy: water nexus. Without water energy cannot be produced and without energy water cannot be transported or treated.

Despite being Africa's largest economy, South Africa has been constrained by electricity generation capacity shortfalls, which resulted in rolling blackouts across the region. In light of the interdependence between energy and water, the Water Research Commission (WRC) tasked international growth consultancy company, Frost & Sullivan, to help understand the potential impact that current energy supply challenges are having on South Africa's water and wastewater services.

The aim of this project was to provide the WRC and other stakeholders in the South African water and wastewater treatment sectors with an objective and logical evaluation of the current and expected impact and consequences of power outages on water and wastewater treatment services.

Energy Challenges in South Africa

From a time of overcapacity in the 1980s, the last three years have been difficult for South Africa's power sector in terms of generation, transmission and distribution capacity. When demand has outstripped supply there has been a need for load shedding. In particular, power outages were experienced between November 2007 and January 2008.

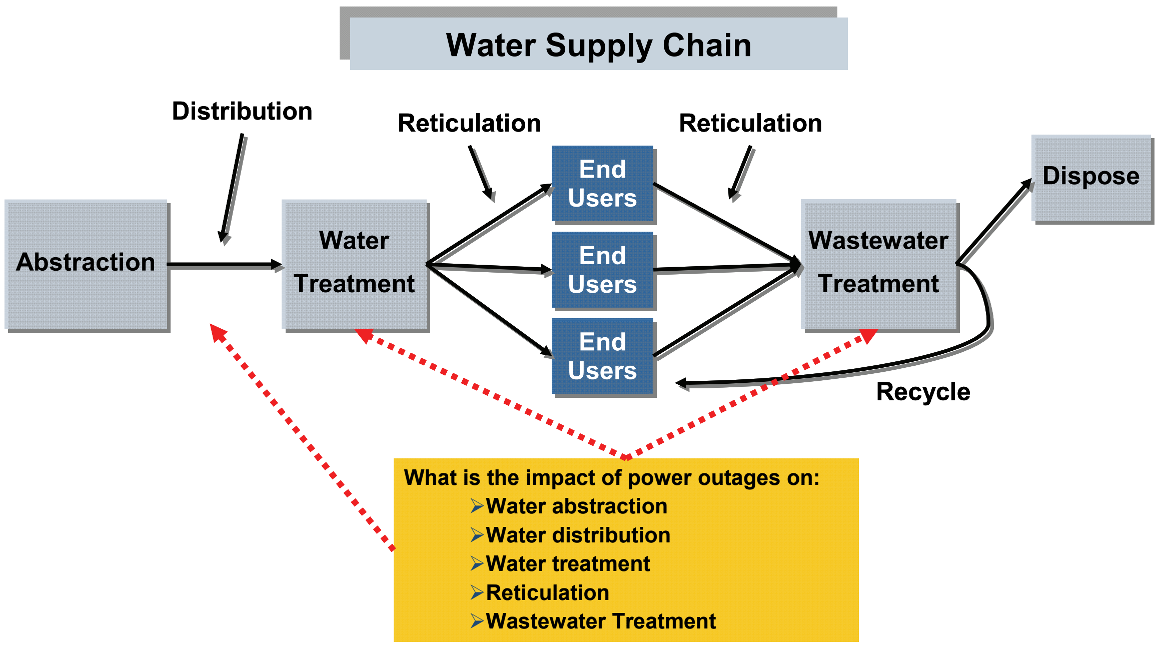
There are ambitious plans to bolster South Africa's generation, transmission and distribution capabilities, however long project lead times places South Africa in a precarious position until these projects are commissioned.

South Africa's Water and Wastewater Sectors

South Africa has one of the most advanced water and wastewater sectors on the continent. Understanding the complexity of South Africa's water supply chain is a critical component of analysing the impact of power outages on this sector.

From water abstraction, treatment, distribution through to wastewater reticulation and treatment, energy plays a vital role.

South African Water Supply Chain



There are numerous factors that influence the amount of energy utilised in the water supply chain including the stage of the water supply chain, technology utilised, the use of pump or gravity feeds and the quality of the water being treated. The figure below illustrates the energy consumption range for each water supply chain stage in South Africa.

Energy consumption range for the South African water supply chain

	kWh / ML	
Process	Min	Max
Abstraction	0	100
Distribution	0	350
Water Treatment	150	650
Reticulation	0	350
Wastewater Treatment	200	1800

The above figure depicts the significant range that can be recorded within specific treatment processes along the supply chain. These variances can be attributed to the energy consumption influencing factors highlighted above.

Power Outage Impact Assessment

The power outage impact assessment phase of this project firstly focused on analysing the impact of power outage events on each stage of the water supply chain. These impacts were reviewed in light of their potential impact on economic, social, health and environmental aspects of South Africa society.

Secondly, a regional comparative impact analysis was completed in terms of water demand levels across the region focused specifically on economic and social water requirements.

Due to the complexity of energy consumption rates and related influences along the water supply chain it is not possible to model power consumption levels and potential impacts from power outages accurately without reviewing specific details of the entire supply chain.

Water supply chain analysis

Based on comprehensive secondary and primary research with water supply chain stakeholders the following potential impacts were highlighted.

Power outage impacts on the water supply chain

Abstraction

Impacts on pumps, equipment and telemetry devices
Water can not be abstracted
Users of small-scale abstraction schemes (boreholes) may be negatively impacted because they need to source alternative water

Water Treatment

Impact on equipment, pumps, telemetry devices and dosing apparatus
Water can not be transported and treatment processes cease to function
Water quality decreases
Revenue loss to water treatment facility, reduced operational capacity, increased labour costs, water wastage, increased pump start-up costs
Chemical dosing may have to be conducted manually as opposed to mechanical dosing
Possible back-up generator costs

Water Distribution / Reticulation

Pumps and telemetry equipment can not operate
Water and wastewater can not be distributed
Costs to purchase back-up generators and portable water storage tanks for local communities.
Costs to purchase portable sewage spill bins and sewage spill clean-up costs

Wastewater treatment

Pumps and telemetry devices can not operate
Treatment stops and sewage flows can not be controlled
Equipment damage costs, possible back-up generator costs, portable sewage spill bin costs, increased labour costs, increased pump start-up costs

The impacts highlighted above are generally direct impacts on the supply chain that result from a power outage. In addition there are also numerous indirect impacts that have economic, social, health and environmental consequences.

Regional water demand analysis

The regional water demand impact analysis reviewed key population and econometric data to compare levels of water demand from a social and economic perspective. Key findings are highlighted in the figure below.

Summary of regional economic and social water requirements

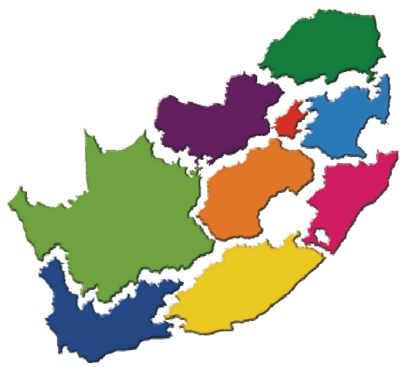
Economic Risk Parameters	
Low Risk	GDP contribution < 15%
Medium Risk	GDP contribution > / = 15%
High Risk	GDP contribution > 30%

Region	Economic	Social
North West	Mining (24%) Manufacturing (3%) Electricity & Water (3%)	Population: 7%
Northern Cape	Mining (7%) Manufacturing (0%) Electricity & Water (2%)	Population: 2%
Western Cape	Mining (0%) Manufacturing (15%), Electricity & Water (10%)	Population: 11%
Eastern Cape	Mining (0%) Manufacturing (8%) Electricity & Water (4%)	Population: 14%
Limpopo	Mining (23%), Manufacturing (1%) Electricity & Water (8%)	Population: 11%
Mpumalanga	Mining (19%), Manufacturing (7%) Electricity & Water (15%)	Population: 7%
Gauteng	Mining (14%), Manufacturing (40%), Electricity & Water (33%)	Population: 21%
KwaZulu Natal	Mining (4%) Manufacturing (21%), Electricity & Water (17%)	Population: 21%
Free State	Mining (9%) Manufacturing (4%) Electricity & Water (7%)	Population: 6%

Mining, manufacturing, electricity and water services were highlighted as key economic sectors that require high levels of water security. Limited or a lack of access to water for these sectors, as a result of a power outage, could have a significant impact on South Africa's GDP.

Summary of regional economic and social water requirements

Region	Economic risk potential	Social risk potential	Prevalence of power outages
North West	Medium	Low	Low
Limpopo	Medium		
Mpumalanga	Medium	Low	Low
Northern Cape	Low	Low	Low
Gauteng	High	High	Low
Western Cape	Medium	Medium	Low
KwaZulu Natal	Medium	Medium	Low
Eastern Cape	Low	Low	Low
Free State	Low	Low	Low



Based on the above parameters Gauteng was identified as the highest risk area in terms of the potential impact of a lack of water services resulting from a power outage event. The high concentration of high water consumption economic activities and a large concentration of South Africa's population afforded it this status. The Western Cape and KwaZulu-Natal have medium level economic and social risks, while North West, Limpopo and Mpumalanga possess medium level economic risk.

Conclusions

Until South Africa's power sector commission additional base load power stations there is the risk that load shedding may remain a reality. The softening of commodity prices and the world economic slowdown have provided some respite for the energy sector, however economic growth and related power demand are anticipated to continue their aggressive growth path from 2010.

The water supply chain is impacted to varying degrees in the event of a power outage. The extent of the impact is dependent on the characteristics of the plant and the availability of back-up power. Pumping is the most vulnerable activity in the water supply chain, but the use of gravity feeds can reduce this impact in many cases. Water security for end users is directly influenced by power outages on abstraction, distribution or water treatment points of the supply chain, however WSAs and Water Boards generally have sufficient back-up water supply to mitigate power outages. Wastewater treatment is very energy intensive, and hence vulnerable to power outage events. Again, plant characteristics dictate impact levels; plants with back-up power supply and overflow dams are generally not impacted by power outages, but less prepared facilities can experience significant environmental, economic, health and social impacts.

A comparison of regional water demand levels highlights key areas that cannot afford energy or water shortages. Manufacturing and mining are examples of two economic sectors that would not be able to operate without a consistent supply of water. Overall, Gauteng, KwaZulu-Natal and the Western Cape emerged as priority areas from both an economic and social perspective.

Several examples of power outage events impacting South Africa's water supply chain have been identified. The Cedarberg Municipality has been plagued with power outages, which directly impacted water and wastewater service delivery. Besides the impact on the local community there is a real financial cost to providing back-up services. A case in the Ugu district revealed a direct impact on a commercial business, which resulted in a loss of revenue and salaries for casual labour. Other cases include health impacts in Howick, KwaZulu-Natal, environmental impacts at Zandvlei in the Western Cape and economic impacts for the City of Cape Town who have installed back-up power supplies. All of these examples can be attributed to power outage events that have impacted the water supply chain.

There is no doubt that power outages have had a direct impact on water and wastewater service delivery in South Africa. Only a handful of cases have been highlighted in this project, which exposed distinct economic, environmental, social and health costs, but with certainty there are other similar cases. Unless the power sector can guarantee that power outages are a theme of the past, water decision makers and managers will need to take appropriate mitigatory steps to ensure that the impacts highlighted in this report are stopped or at least reduced. Failure to do so will have costly economic, environmental, social and health consequences.

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1. Introduction

Water Challenges

Globally, never before have decision-makers been challenged by energy and water issues that are plaguing both developed and emerging economies today. Dependence on diminishing non-renewable sources of energy and the effective management of water are the Achilles heel of economic growth in the 21st century.

South Africa, the economic powerhouse of the African continent, is the epitome of these challenges. The state-owned power supplier, Eskom, is plagued with generation capacity problems, while South Africa's water scarce nature is an ongoing test for water managers.

Energy supply and water management may appear to be mutually exclusive, but in fact they are inextricably linked.

Energy and Water

The energy - water nexus is quite clear; energy cannot be created without water and water cannot be distributed or treated without energy. South Africa's energy sector is entirely dependent on the 2% of total water demand that it consumes; without water no energy can be produced and without energy no water or wastewater can be distributed, treated or supplied to end users.

In light of South Africa's current energy challenges, this raises the question, what will happen in the event that South Africa's water sector is without energy?

The water sector uses significant quantities of energy to extract, treat and distribute water and finally treat and dispose of wastewater. The water sector is heavily reliant on a consistent supply of energy, hence it is important that the impacts of power outages on the water sector are fully understood.

Water Research Commission

The Water Research Commission (hereafter referred to as WRC) is a statutory organisation established in 1971 by an Act of parliament. The WRC represents a dynamic hub for water-centred knowledge, innovation and intellectual capital. It provides leadership for water-related research and development through the support of knowledge creation, transfer and application.

As a leader in water-related research in South Africa, the WRC would like to understand the potential impact that current energy supply challenges are having on South Africa's water and wastewater services, but they have limited capacity to conduct such evaluations. Hence, Frost & Sullivan was commissioned to support the WRC on this project.

This report is organised into four sections:

- **Chapter 2** outlines the current energy challenges in South Africa.
- **Chapter 3** provides an overview of South Africa's water and wastewater sectors in terms of current energy requirements
- **Chapter 4** summarises the impact that power outages will have on South Africa's water and wastewater sectors
- **Chapter 5** includes case studies of specific power outage examples within the water and wastewater sectors

1.1 Project Aim and Objectives

Specific aims and objectives were outlined for this project:

The aim of this project is to provide the WRC and other stakeholders in the South African water and wastewater treatment sectors with an objective and logical evaluation of the current and expected impact and consequences of power outages on water and wastewater treatment services.

- **To develop an objective consensus of opinion of relevant stakeholders around the current and expected impact of power outages on municipal water and wastewater treatment processing.**
- **To outline the phases / and critical points within water and wastewater treatment processing which can be adversely affected by power outages.**
- **To determine the extent to which power outages can damage infrastructure within water and wastewater treatment processing.**
- **To determine the possible impacts of power outages on water and wastewater processing in the context of other variables such as environmental contamination, regional economies and the health of the South African public / industry workers.**
- **To examine the possible consequences of the identified impacts of power outages**
- **To develop an understanding of the issues and impacts of power outages in the context of specific water and wastewater treatment plants through the development of several selected case studies.**
- **To quantify the identified impacts, wherever possible, in an appropriate measure (e.g. time, loss of income, reduced efficiency, increased costs, depreciation of capital equipment, etc.)**

1.2 Research Approach and Methodology

For consulting projects, Frost & Sullivan utilises tried and tested marketing techniques to provide structure to the research and its results, which allows the effective analysis, review and comparison against industry benchmarks.

The project was carried out using primary research (telephone or face-to-face interviews) and secondary (published and online material) research as the principle methods of data gathering.

Frost & Sullivan interacted with the following respondent groups and stakeholders:

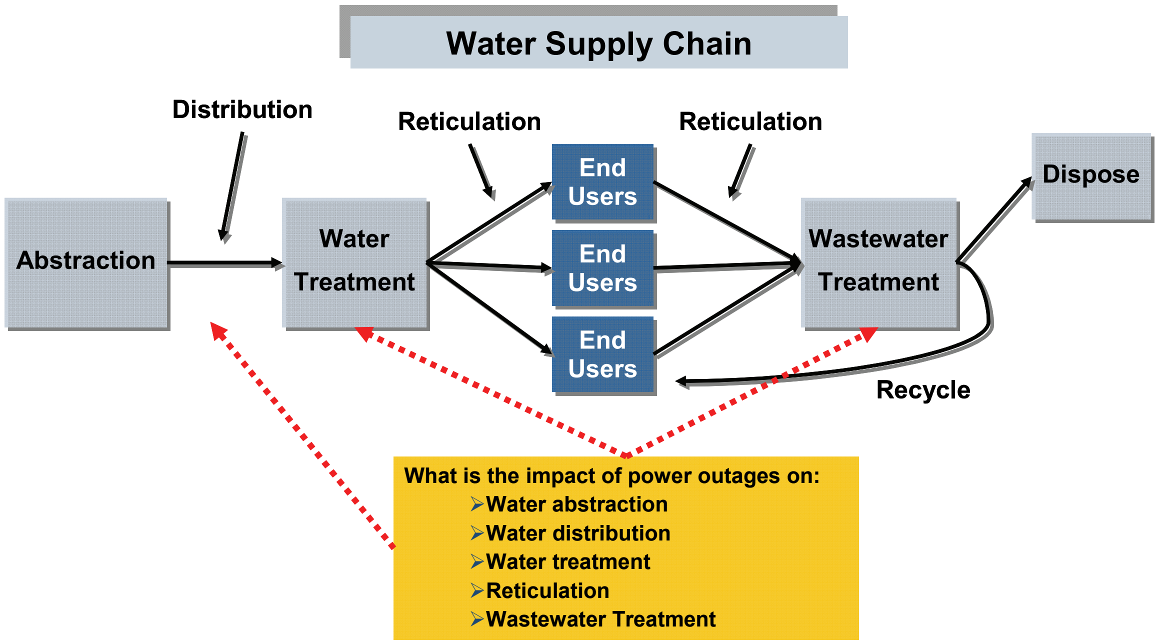
Organisation Type	Target Designations	Type of Information
Water Research Commission	Project Managers, Research managers, Programme leaders	Water and wastewater plant research Relevant statistics
Research Institutes (Universities / Consultants)	Project Leaders and Researchers	Water and wastewater plant research Relevant statistics Impact assessment of power outages
Water Industry Contractors, Municipalities & Water Boards	Managing Directors, Plant Managers, Heads of Water & Wastewater treatment	Water and wastewater plant research Relevant statistics Impact assessment of power outages
Government Departments	Policy Directors, Water Management Directors, Department Heads	Water and wastewater plant research Relevant statistics Impact assessment of power outages
NGO's	Programme Managers	Water and wastewater plant research Relevant statistics Impact assessment of power outages
Associations / Other	Industry Specialists, Consultants, Associations	Relevant statistics Technical information Impact assessment of power outages

1.3 Project Scope and Definitions

PROJECT SCOPE:

This project focuses on the impacts of power outages on South Africa's water and wastewater sectors (hereafter referred to as the water sector). This includes an analysis of each of the identified impact areas and a specific case study analysis to quantify and support these findings.

The assessment of power outage impacts is not limited to the water or wastewater plants alone, but includes all resultant or 'knock-on' impacts and consequences. This project evaluates the potential impacts of power outages on the entire water supply chain as illustrated below:



Source: Frost & Sullivan, 2008

Figure 1: South Africa's water supply chain

PROJECT DEFINITIONS:

For the purposes of this project the following definitions were adopted:

Water treatment is defined as the physical and chemical processes involved in the removal of contaminants from untreated water (ground and surface water) to produce drinking water that is pure enough for its intended use, most commonly human consumption. Substances that are removed during the process of drinking water treatment typically include bacteria, algae, viruses, fungi, minerals such as iron and sulphur, and man-made chemical pollutants.

Wastewater treatment is defined as the process of removing contaminants from wastewater, both runoff (effluents) and domestic. It includes physical, chemical and biological processes to remove physical, chemical and biological contaminants.

Wastewater treatment produces a waste stream (or treated effluent) and a solid waste or sludge which is suitable for discharge or reuse back into the environment.

Power outages, also commonly called power cuts or power failures, refer to a loss in the supply of power. These events typically last for a short period of time only, but there are examples that have lasted days. Power outages refer to both planned (load shedding) and un-planned losses in the supply of power. Unplanned power outages refer to power outages which arise due to equipment failure or generation and distribution problems. Load shedding is the planned cut-off of power supply along certain lines when the demand for power exceeds the supply.

Water distribution refers to the transfer of water from water boards to local municipal reservoirs.

Water reticulation refers to the distribution of water from local municipalities to end users.

Wastewater reticulation refers to the distribution of wastewater to wastewater treatment facilities.

Water abstraction refers to the processes of abstracting raw water from various sources such as dams, rivers and boreholes. This forms the first stage of the water cycle.

The kilowatt-hour (kWh) is a unit of energy equivalent to one kilowatt (1 kW) of power expended for one hour (1 h) of time. The kilowatt-hour is not a standard unit in any formal system, but it is commonly used in electrical applications.

2. Energy Challenges in South Africa: an overview

2.1 Overview of South Africa's Energy Sector

South Africa's electricity supply industry is dominated by the state owned enterprise Eskom. The utility is the only national transmitter and system operator and generates 92% of electricity in South Africa. The remaining 8% consists of power imports (4.5%,) private generators (3%) and electricity produced by municipalities (0.5%.) The principal energy used for electricity generation in South Africa consists of coal, gas, nuclear, diesel, water and heavy oil.

***Coal dependant electricity**: There are a number of coal mines specifically dedicated to the supply of coal to Eskom base-load power stations. These include Rand Mines, Ingwe Coal Corporation and Coal SA. Eskom receives 80% of its coal from dedicated suppliers and sources the remaining 20% through short-term contacts with other coal suppliers. Coal is the most abundant source of energy in South Africa as most of the coal is low quality with a low heat value and high ash content. This makes it suitable for cheap power generation and Eskom produces approximately 90% of its electricity through coal fired power stations. Eskom uses over 90 million tons of coal per annum and approximately 325 million cubic meters of water per annum to produce this energy.*

Source: Eskom, 2008

2.2 Current and Future Energy Challenges

The power sector in South Africa has been struggling to deliver a reliable and sufficient supply of electricity. The measure of secure and sufficient power supply is the ability to consistently balance the supply of power (generation) and the demand for power (load.) The supply/demand balance must be maintained at a frequency of 50Hz. If the load exceeds the power generation, then the entire system will slow down and Eskom will instruct available power plants to increase their power generation. When there is insufficient generation capacity, the system will slow down and eventually crash if the load is not reduced. This may then lead to manual load shedding.

Power outages were experienced between November 2007 and January 2008. There were five load shedding events in November and four in December 2007 due to generation capacity shortages. January 2008 experienced fourteen power outage events due to increased demand after the December holiday period, generation capacity shortages and unplanned outages.

The following table outlines the current power situation in South Africa and future plans to deal with this crisis:

Table 1: Current power situation and future plans

	Current situation	Future plans
Generation	• Installed capacity is approximately 42,000 MW • Record power production is only 36,500 MW • Peak demand levels sometimes exceed power production and load shedding occurs • Reserve margins are currently between 8 and 10 per cent which is below the industry standard of 15 per cent	• $28.3 billion allocated to developing Eskom's generation capacity • Moth-balled power stations to be brought back to service – Cameden, Grootvlei and Komati
Transmission	• The necessity to transfer power from the eastern part of South Africa to the Western Cape (as a result of issues at Koeberg nuclear power plant) highlighted insufficient	• Eskom allocated $2.2 billion to upgrade transmission lines • This will improve transmission network in areas which need upgrading – including the

	transmission capabilities and line failures	Western and Eastern Cape
Distribution	• Under-investment in municipal infrastructure and necessary skills	• Eskom has committed approximately $3.5 billion to upgrade distribution infrastructure • Municipalities are also implementing infrastructure improvement programmes

Source: Frost & Sullivan, 2008

There are certain issues causing a delay in Eskom's recovery approach to the electricity crisis in South Africa.

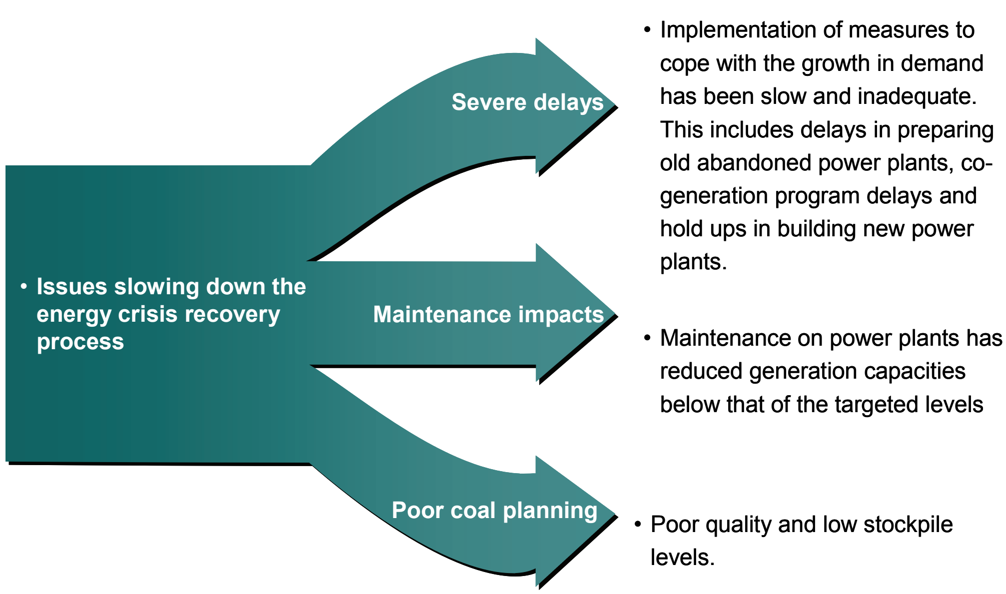
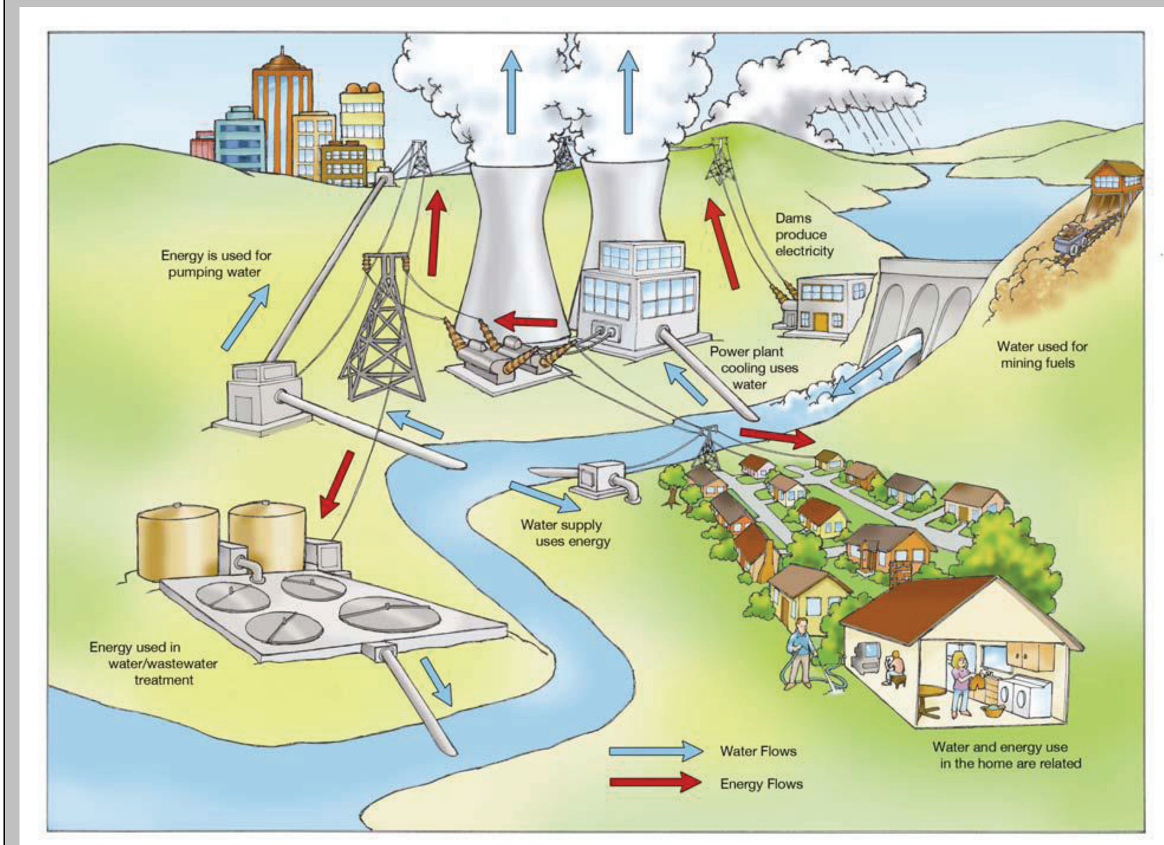


Figure 2: Issues slowing the energy crisis recovery process

Source: NERSA, Inquiry into the national electricity supply shortage and load shedding, 2008

The rectification of the power crisis in South Africa is expected to be a long and complicated process which will take a number of years to achieve. There is a distinct possibility that further power outages will occur during this time.

ENERGY AND WATER: THE INEXTRICABLE LINK.

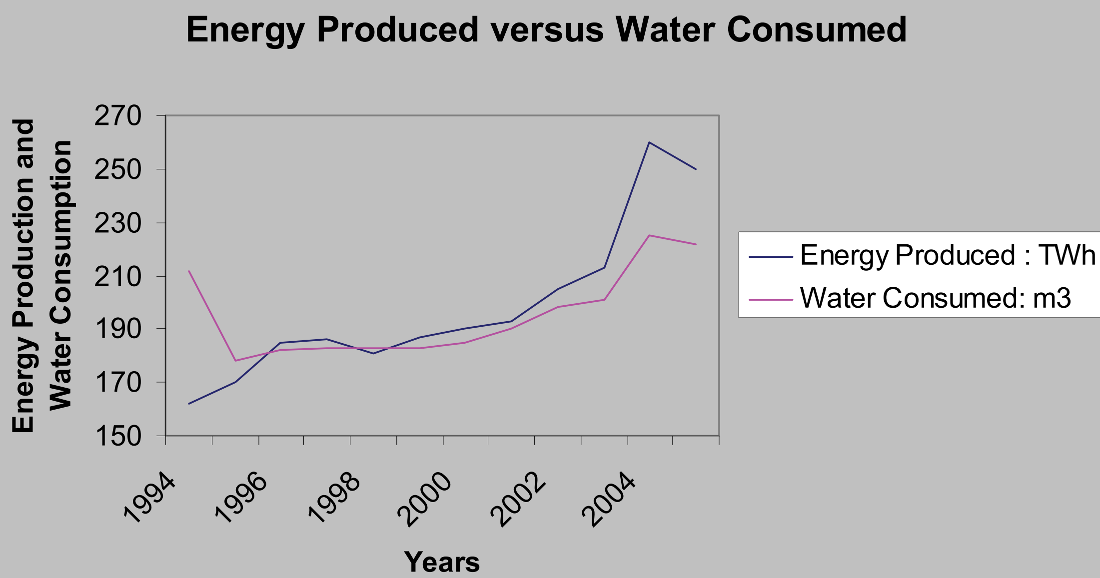


Source: American Water (2008)

In South Africa thermal energy is used to generate the majority of the electricity needed. Coal is used to heat water and convert it into steam which is released to turn large turbines to create power. Eskom uses approximately 325 million cubic meters of water per annum to produce this energy (Eskom, 2008).

Without water Eskom would not be able to produce the countries power supply. Eskom uses raw water which is rigorously treated before entering into the production process. The majority of power stations were built in water catchment areas; however certain areas are water scarce which necessitates the need for inter-basin water transfers. This requires the use of pipelines, pumping stations and various other components, all of which require energy to operate.

Further, South Africa's water sector is heavily reliant on a constant supply of energy to ensure that water and wastewater treatment facilities are able to safely and efficiently treat and ultimately distribute potable water to our cities and towns.



The above graph shows the relationship between the water consumed and the energy produced by Eskom from 1994 to 2005. Eskom has implemented various measures to conserve the use of water, however the graph clearly depicts the co-dependency that exists between water and electricity production.

Source: Eskom, 2008

3. South Africa’s Water and Wastewater Sectors: an overview

3.1 Introduction

South Africa is a water scarce country, however raw water resources are of a high quality in comparison to more developed nations. Developed nations water treatment processes are complex and involve advanced treatment technologies, but South Africa is able to apply relatively simple treatment techniques. No other Sub-Saharan African country can match South Africa’s track record with regard to water quality. In fact, globally, in only a small number of countries, South Africa included, is it safe to drink water directly from the tap.

A challenge for South African water authorities is the distribution of water. For example, the Gauteng region’s water supply is supplemented by a complex water transfer scheme from Lesotho. However, Gauteng’s large mining and industrial based local economy has driven the development and adoption of advanced wastewater treatment techniques, which has placed South Africa at the forefront of wastewater treatment on the African continent.

Before one can effectively review the impact of power outages on South Africa’s water sector it is important to have a clear understanding of how the sector operates and what the current energy demands are.

The aim of this chapter is to provide an overview of South Africa’s water sector and outline particular energy requirements within each portion of the water value chain as outlined below:

- Abstraction
- Water treatment
- Water end users
- Water and wastewater reticulation and water distribution
- Wastewater treatment

3.1.1 Abstraction

Overview

The abstraction of South Africa's water is largely managed by the Department of Water Affairs and Forestry (DWAF).

The total net abstraction of water from surface-water resources amounts to approximately 10, 2 million ML per year for South Africa, after allowing for the re-use of return flows. This represents approximately 20% of the total mean annual run-off of 49, 2 ML per year. A further 8% is estimated to be lost through evaporation from storage and conveyance along rivers, and 6% through land-use activities. As a national average, approximately 66% of the natural river flow (mean annual run-off) therefore still remains in the country's rivers (GCIS, Pocket Guide to South Africa 2006/2007 - Energy and Water).

South African Abstraction Volumes per Annum		
Total mean annual run-off	49, 2 million ML	100%
Net abstraction	10, 2 million ML	20%
Evaporation loss	3, 9 million ML	8%
Land-use loss	2, 9 million ML	6%
Remaining river flow	32, 4 million ML	66%

Source: GCIS, Pocket Guide to South Africa 2006/2007 - Energy and Water

Figure 3: South African abstraction volumes

Water is also abstracted from ground water sources and in a small number of cases seawater is desalinated for localized usage. South Africa's raw water is collected in approximately 400 dams located in 47 different primary catchment areas across the country. The amount of abstraction that occurs per region is dependent on the amount of surface and ground water available and as well as the demand levels.

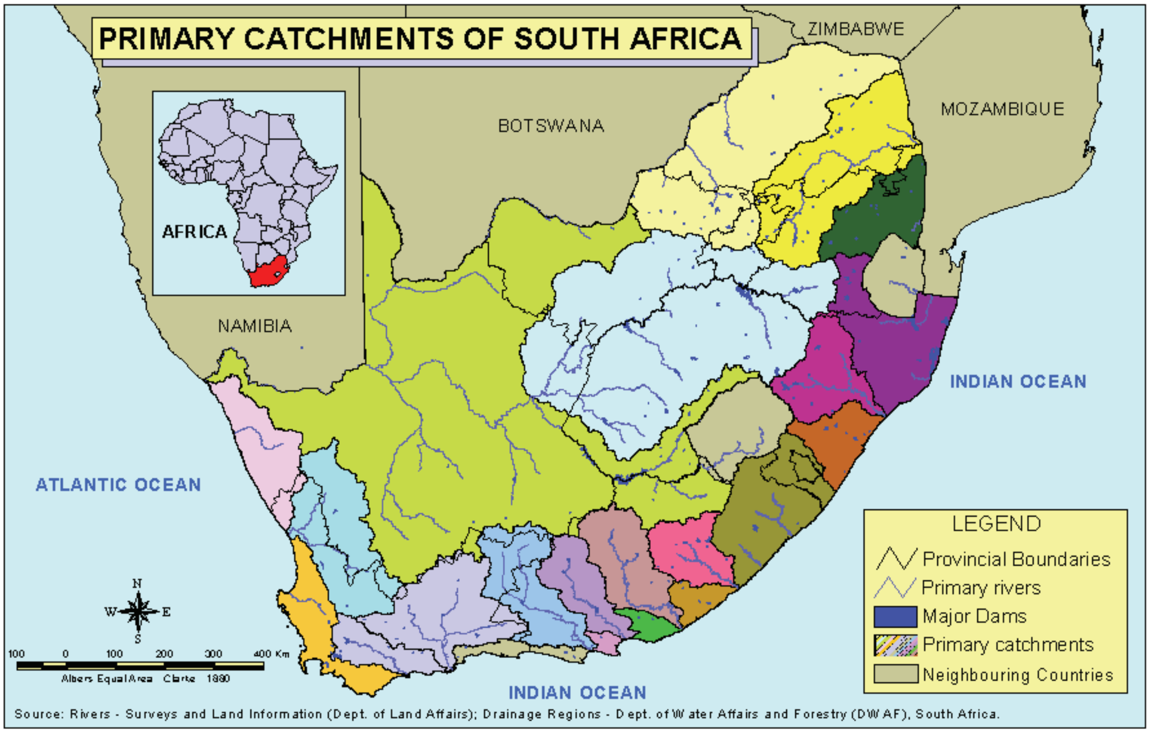


Figure 4: South African catchment areas and major dams

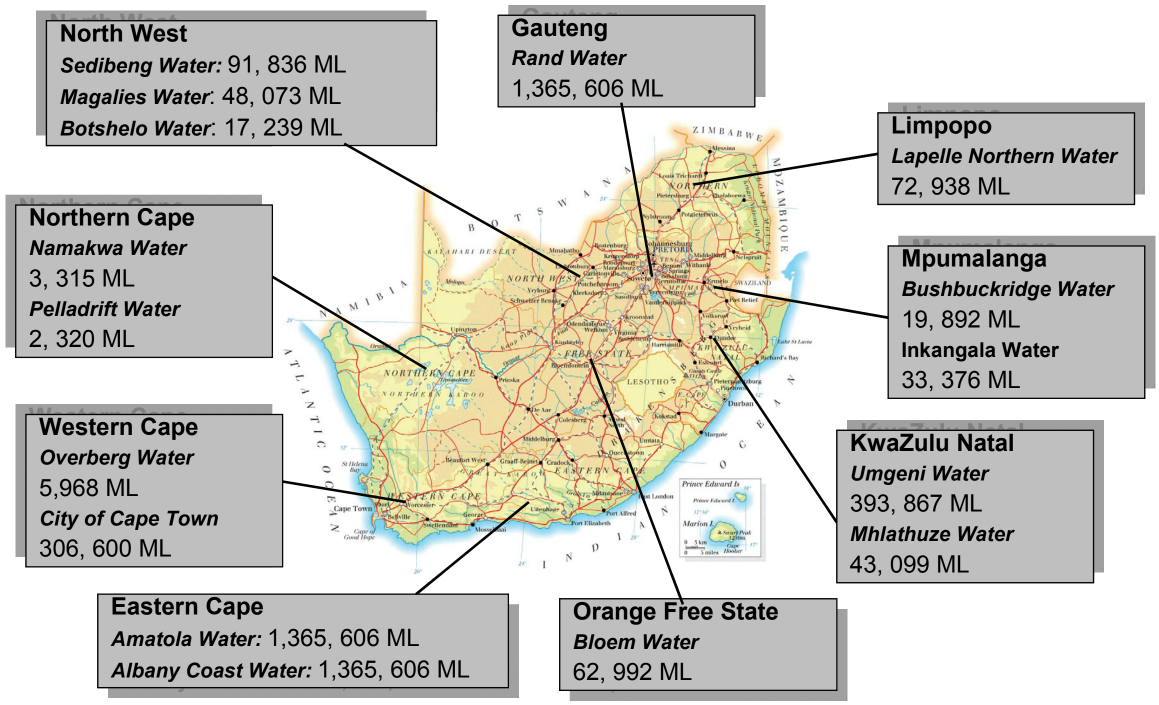
Abstraction Energy Requirements

Energy usage within the abstraction phase of the water value chain is limited to pumping activities. Water catchment schemes use gravity to move water, but when there are topographical limitations, high lift and booster pumps are used to lift the water to a point where gravity can be used.

3.1.2 Water Treatment

Overview

There are 15 Water Boards in South Africa who are responsible for the treatment, storage and supply of bulk water to local municipalities. In areas where a Water Board is not active, for example the City of Cape Town, a Water Service Authority (WSA) is responsible for this function. Water Boards typically purchase raw water from DWAF, treat the water and then distribute it to end users. The 15 water boards and their estimated volume of water sold in 2007 are illustrated below:



Source: Water Board Annual Reports

Figure 5: South Africa's water board 2007 sales volumes

From the above diagram it is evident that the bulk of South Africa's Water Boards' potable water is sold and distributed by Rand Water, which highlights the importance of water treatment in the densely populated and urbanised Gauteng region. Other regions where significant amounts of water are treated are the Western Cape (Cape Town) and KwaZulu-Natal (Durban), two densely populated and economically active areas of South Africa. .

Comparison of the above potable water sales figures illustrates that there is a correlation between the population density and economic activity levels of a region and the amount of water treated.

There are 166 WSAs across South Africa that treat and provide water to end users. Research by DWAF has revealed that the amount of water treated by each WSA varies; Table 2 below outlines the findings from this study.

Table 2: Water Service Authorities Water Treatment Levels

	Total of WSAs	Percentage of WSAs treating all water supplied	Percentage of WSAs not treating 1 – 10% of water supplied	Percentage of WSAs not treating 11 – 20% of water supplied	Percentage of WSAs not treating 21 – 30% of water supplied	Percentage of WSAs not treating >30% of water supplied
EC	17	59%	12%	6%	0%	18%
FS	20	90%	5%	5%	0%	0%
GP	12	83%	8%	0%	0%	0%
KZN	14	79%	7%	7%	7%	0%
LP	11	55%	18%	0%	0%	18%
MP	18	83%	11%	6%	0%	0%
NC	32	66%	0%	0%	0%	19%
NW	12	92%	0%	0%	0%	0%
WC	30	80%	7%	0%	0%	0%
National	**166**	**76%**	**7%**	**2%**	**1%**	**7%**

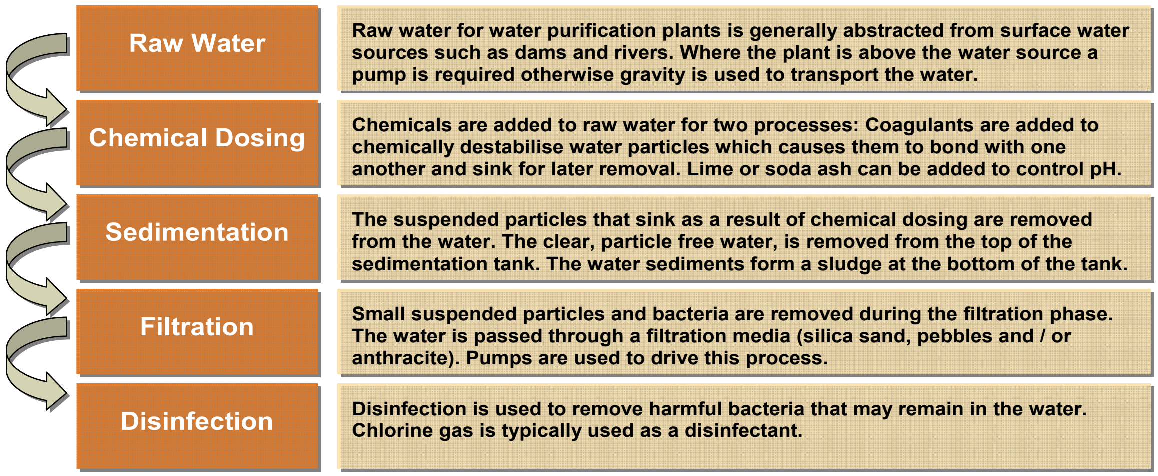
DWAF, Drinking Water Quality Survey, November 2007

Key findings reveal that only 76% of WSAs treat all of the water they supply to end users. The amount of treatment amongst the remaining WSAs varies significantly:

- WSAs not treating 1-10% of water: 7%
- WSAs not treating 11-20% of water: 2%
- WSAs not treating 21-30 % of water: 1%
- WSAs not treating > 30% of water: 7%

These findings indicate that there is significant variation in the levels of treatment between WSAs, which will directly influence the amount of energy consumed at each plant.

South Africa's raw water resources, in comparison to more developed nations, are typically of a high quality and do not require extensive treatment. The South African water treatment cycle typically follows the processes outlined in figure 6.



Source: eWISA and various secondary sources, 2008

Figure 6: Water treatment phases

Water Treatment Energy Requirements

Energy usage in the water treatment sector is dominated by pumping activities, however there are other important processes that require energy. Approximately 85 – 99 per cent of water treatment plant energy consumption can be attributed to pumping, but chemical dosing and remote telemetry control systems also require energy.

Typical pumping procedures within a water treatment plant include:

- Raw water and well pumps
- High service pumps
- Filter backwash pumps
- Distribution system booster pumps

Energy usage in water treatment facilities varies greatly depending on the location of the plant and the amount of pumping required.

Table 3: Water treatment energy consumption

Water Board / Treatment Works	Average Energy Consumption (kWh / ML)
Rand Water	**662**
Bloem Water	**562**
Amatola Water	**824**
Sedibeng Water	**1154**
Wiggins Water Treatment Works	**57**

Source: Water Board Annual Reports

The amount of electricity consumed to treat water in South Africa depends on various plant attributes; however one can draw inferences from key examples. Rand Water is South Africa's largest supplier of potable water, supplying approximately 20 million people. In 2007 Rand water consumed approximately 1.7 billion kWh's of electricity, which equated to approximately 662 kWh per ML of water treated.

	Rand Water	Sedibeng Water
Total Electricity Consumed (2007)	1,7 billion kWh	69, 1 million kWh
Electricity Consumed / ML (2007)	662 kWh / ML	1154 kWh / ML
	Gravitational feeds	Pumped feeds

Source: Water Board Annual Reports

Figure 7: Comparison of Rand Water and Sedibeng Water energy consumption

Sedibeng Water, supplying water in the Orange Free State and Northern Cape, consumed approximately 69.1 million kWh of electricity, which equated to approximately 1154 kWh per ML of water treated. Sedibeng Water's energy figures include other operation costs, but the significantly higher kWh / ML, compared to Rand Water, is because they do not utilise gravitational feeds. The majority of water treated is pumped and lifted approximately 200 m over a distance of 100 km to end users. Wikkins water treatment works is another example where low electricity consumption is recorded due to the high utilization of gravity fed water.

What these examples illustrate is that energy consumption in the water treatment sector varies considerably depending on the location of the plant.

Current challenges within South Africa's water treatment sector

Within the realms of this project an important issue is whether existing infrastructure, operations and maintenance processes are able to provide a sustainable, reliable and safe supply of potable water despite the additional challenges presented by power outages. It is thus important to have a clear understanding of the conditions, capacities, capabilities and general status of South Africa's water treatment sector.

Water Supply under Threat

The current electricity supply crisis has come about largely due to governments' lack of urgency to act on warning signs which arose more than ten years ago. There are certain issues that are currently contributing to the vulnerability of a number of South Africa's water treatment plants, which include:

- *Old and badly maintained water treatment plants (this includes the pipes which are used to distribute water to towns and cities)*
- *Poor management and lack of skills among municipal staff*
- *Poor maintenance practices*
- *Lack of funding*
- *Lack of emergency preparedness and limited technical support (especially in the case of small, remote water treatment plants)*
- *Lack of monitoring equipment – this includes equipment to monitor flow, turbidity, pH and chlorine levels*
- *Subsequent lack of monitoring – including flow rate monitoring and lack of chemical dosage monitoring*

In a number of cases water treatment plant personnel (especially small and remote sites), are only able to cope with the basic operation of the plant; any complex maintenance or management issues are not addressed. It is apparent that water treatment facilities in South Africa are under strain and are not in a good position to deal with further pressures.

3.1.3 Water End Users

Overview

Water is utilised in varying quantities by different end users. As illustrated below, by far the largest consumer of water in South Africa is the agricultural sector, followed by urban areas, mining and bulk industrial and finally rural and afforestation.

The importance of a secure water supply and the impact of power outages cannot be judged by the volumes consumed, but rather an analysis of the water requirements of each end-user group.

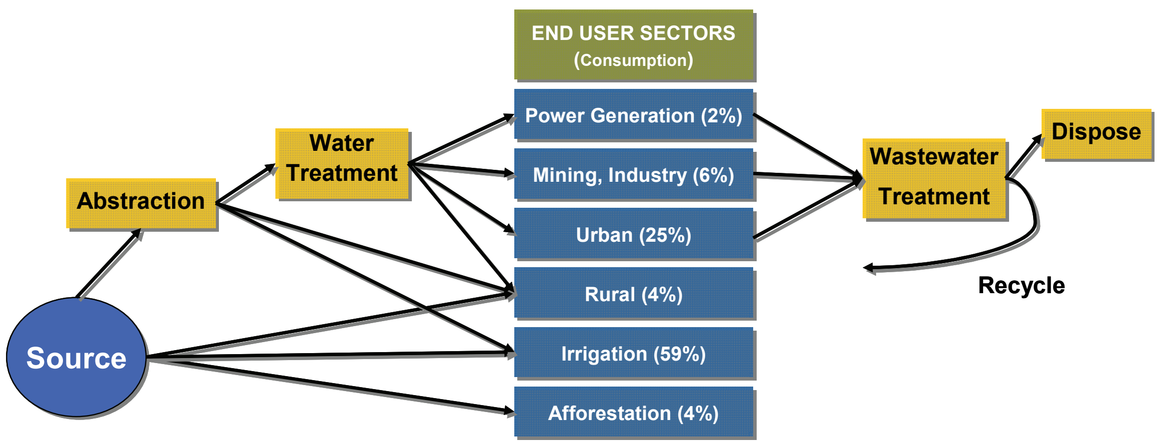


Figure 8: South African end user water consumption breakdown

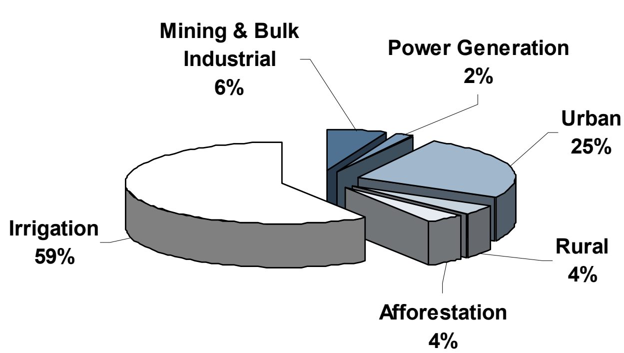


Chart 1: South African end user water consumption breakdown

Mining & Bulk Industrial

In the bulk industrial sector water is utilised for purposes such as processing, cleaning, dilution, and cooling. Major water-using industries include steel, chemical, paper, and petroleum refining. Use of water in the mining sector includes the extraction of naturally occurring mineral solids such as coal and ores; liquids, such as crude petroleum; and gases, such as natural gas.

Mining and bulk industrial activities are the cornerstone of South Africa's economy and without water they would seize to function. Water is critical to the functioning of this end-user group and any limitation in supply due to a power outage would result in significant negative impacts.

Power Generation

Eskom is South Africa's single largest user of water, consuming approximately 2 per cent of total demand. Eskom has a high dependence on wet-cooled power stations, which currently comprise approximately 64 per cent of total power output. Wet-cooled power stations use significantly more water than dry-cooled plants.

Without a secure supply of water Eskom would seize to function effectively, further exacerbating the current energy supply crisis.

Irrigation

The importance of irrigation is illustrated by the large amount of water that is used by the agricultural sector. Irrigation water is applied to farm, orchard and horticultural crops, as well as water used to irrigate grazing land. Other uses in the agricultural sector include chemical application, crop cooling, harvesting and for the leaching of salts from the crop root zone. A diverse range of produce is grown for local and international consumer markets.

Despite the importance of the agricultural sector and the large volumes of water consumed, the bulk of irrigation water utilised is untreated, therefore once abstracted it bypasses the traditional water supply chain because it is released directly back into the environment when utilised. Hence, the agricultural sector has largely been excluded from the scope of this study.

Urban

Domestic water use is largely attributed to household activities such as drinking, food preparation, bathing, washing and toilet flushing. The majority of water and wastewater service demand stems from South Africa's densely populated urban areas, and at current urbanisation rates there is going to be increasing pressure on the water supply chain.

Commercial activities within urban areas are also responsible for water consumption and without a secure supply these business activities would be negatively impacted.

Rural

Relative to urban areas, the water consumption figure for rural areas is significantly lower. A challenge in rural areas is access to safe drinking water. Certain rural communities do not have a secure and safe supply of potable water; water is abstracted from untreated sources or great distances are traveled to access a safe supply.

3.1.4 Water distribution and water / wastewater reticulation

Overview

Water distribution refers to the delivery of water from water boards to local municipalities. Water and wastewater reticulation refers to the water supply and sewerage service or storm water systems, operated by local municipalities.

A significant challenge for water managers is ensuring that water is available at the point of demand, which often requires moving it hundreds of kilometers.

Water and wastewater reticulation involves the use of complex pipeline networks and pumping stations to transport water or wastewater to the end user or treatment facility, respectively.

All of South Africa's large urban areas have extensive water and wastewater distribution systems as detailed in the table below.

Table 4: Outline of major cities wastewater and water reticulation networks

City	Reticulation / Distribution Infrastructure
City of Cape Town	**Wastewater** • 8600 km wastewater reticulation pipelines • 376 wastewater pump stations • 29 storm water pump stations **Water** • 9058 km's of water distribution pipelines • 103 water pump stations
Johannesburg	**Wastewater** • 10, 058 km wastewater reticulation pipelines • 38 sewer pumping stations **Water** • 10, 957 km's of distribution pipelines • 87 pump stations • 33 water towers
Durban	**Wastewater** • 5500 km wastewater reticulation pipelines • 265 wastewater pump stations
Port Elizabeth	**Wastewater** • 3000 km wastewater reticulation pipelines • 69 pump stations **Water** • 3000 km of distribution pipelines • 5 pump stations

Source: Municipal Reports and Municipal Websites

Water and Wastewater Distribution and Reticulation Energy Requirements

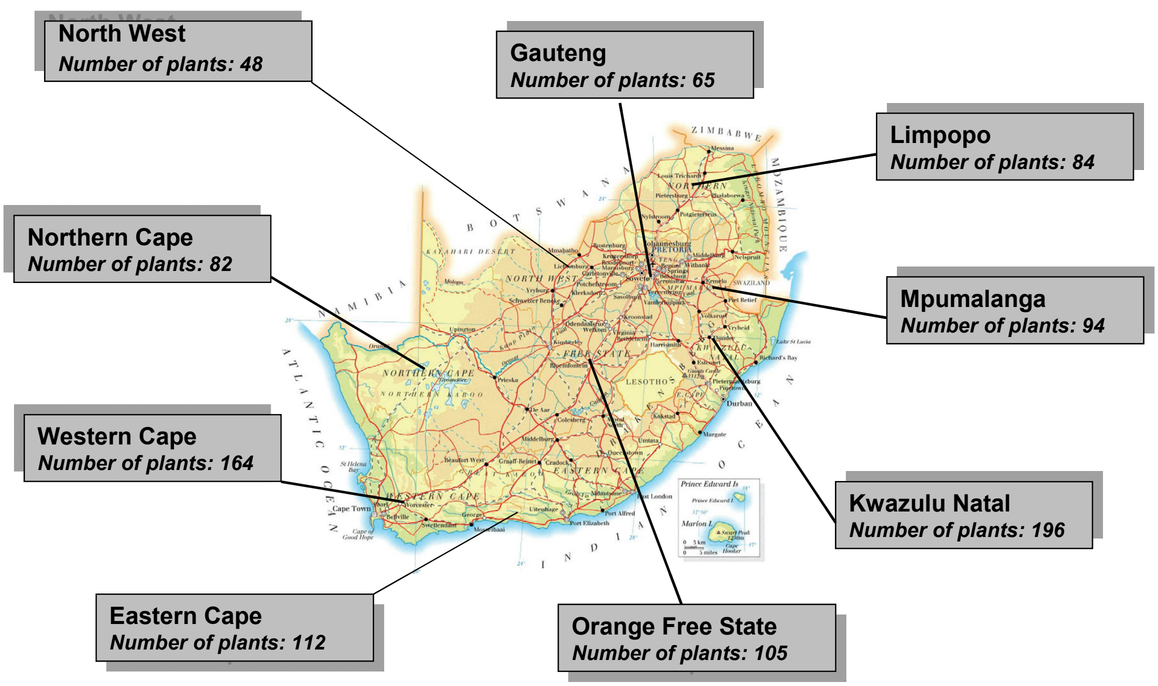
Energy usage for the reticulation of water and wastewater is very similar to that of water distribution. Pumping is the largest energy consuming component, with telemetry control systems also requiring consistent power.

The quantity of energy used is determined by the level of pumping required; in areas where gravity is utilised significantly less energy is consumed.

3.1.5 Wastewater Treatment

Overview

South Africa is at the forefront of wastewater treatment on the African continent. The majority of nations south of the Sahara have poorly developed wastewater treatment sectors, but South Africa boasts approximately 950 individual wastewater treatment works (WWTW).



Source: eWISA, 2008

Figure 9: South Africa's wastewater treatment plant distribution

The majority (51%) of South Africa's wastewater treatment plants are classified as micro plants (< 0.5 ML / day), however at least 21 per cent process between two and ten megalitres of wastewater per day. There are approximately 70 plants that process in excess of 25 megalitres of wastewater per day.

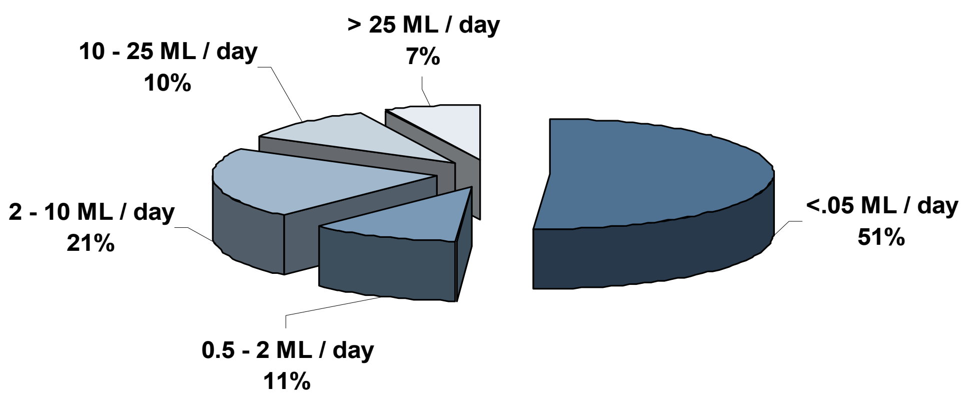


Chart 2: Wastewater treatment plant capacities

Approximately 29 million people are connected to waterborne sewage systems in South Africa. Each person is estimated to produce approximately 200 liters of wastewater / day, which equates to a total of approximately 5800 ML of wastewater per day. Including the commercial sector, heavy industry and mining this figure is anticipated to total approximately 7600 ML of wastewater per day.

Population growth is placing increased pressure on water authorities to manage wastewater more effectively. Apart from the increase in sewage treatment loads caused by population increases many wastewater treatment plants are old, badly maintained and operate beyond their capacity limits and are thus under increasing pressure to maintain an effective and efficient level of operation.

The wastewater treatment cycle (as illustrated below) follows the flow of raw wastewater from its source, through the wastewater treatment facility, until the treated effluent and sludge are released back into the environment or distributed for reuse.

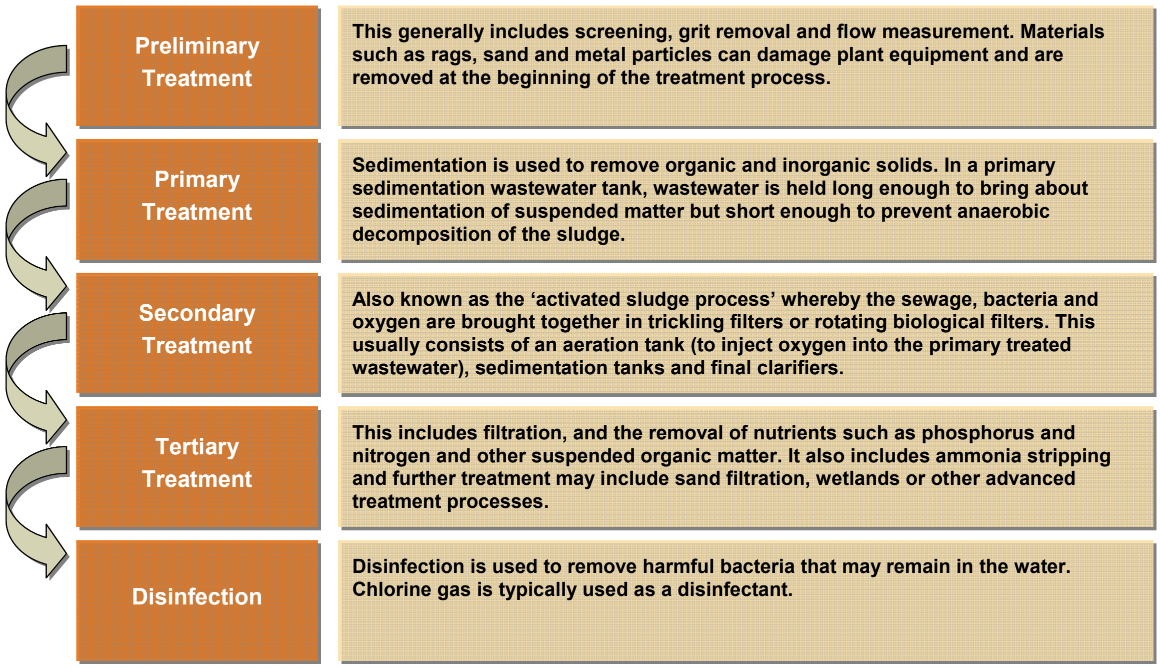


Figure 10: Wastewater treatment cycle

Wastewater Sector Energy Requirements

Like water treatment, wastewater treatment plants can vary significantly in terms of the amount of energy consumed.

Table 5: Examples of energy consumption at WWTW in South Africa

Water Board / Treatment Works	Average Energy Consumption (kWh / ML)
Athlone WWTW	220 – 630
Wildevoëlvlei WWTW	450 – 1450
Wiggins WWTW	706
Howick WWTW	950
Darvill WWTW	400

Source: Relevant Municipalities and Treatment Works Managers

The reason for these energy consumption variations is due to a number of factors. Larger plants are typically more efficient; Darvill wastewater treatment works (70 ML / day) consumes significantly less energy than Howick (5 ML / day).

	Athlone WWTW	Wildevoelvlei WWTW
Average value (kWh / ML received)	388	874
Maximum value (kWh / ML received)	630 (February)	1450 (February)
Minimum value (kWh / ML received)	220 (August)	450 (August)
	Gravitational feeds	Pumped feeds

Source: City of Cape Town, 2008

Figure 11: Energy consumption comparison: Athlone versus Wildevoëlvlei WWTW

In the above figure energy consumed differs between the two WWTW as well as seasonally within each works. Athlone WWTW utilises gravitational feeds, which is reflected in the lower kWh / ML figure, while Wildevoëlvlei WWTW relies on pumping. In the winter months (August) additional rain water enters the wastewater system, hence the amount of energy consumed per ML is reduced, but overall energy consumption remains constant.

In the event of a power outage Wildevoëlvlei will be more significantly impacted because of their reliance on pumped feed processes.

Critical process points within wastewater treatment systems

Wastewater treatment plants utilise significant amounts of energy. The bulk of the energy consumed, as detailed in the graph below, results from aeration processes.

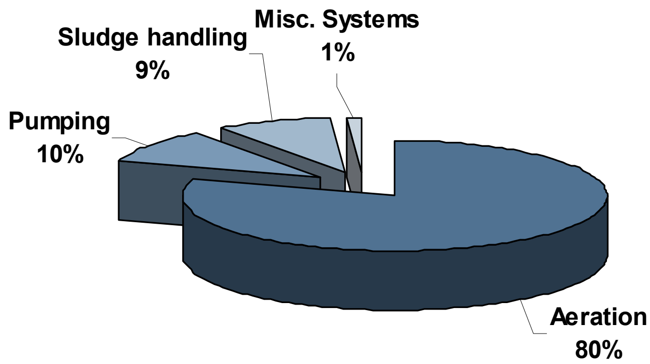


Chart 3: Wastewater treatment plant energy consumption

Aeration within a WWTW is an important process, however in the event of a power outage pumping, which only consumes 10% of total energy, and the treatment monitoring systems (Misc. Systems – 1% of total consumption) are also important in terms of ensuring that wastewater does not pollute the surrounding environment.

Current challenges within South Africa's wastewater treatment sector

Within the context of this report the understanding of the current state, management and operation of wastewater treatment infrastructure in South Africa is important.

Wastewater treatment plants need to function as they were designed in terms of their usage and capabilities.

Recent research by the Department of Water Affairs and Forestry (2008) revealed the following results:

Key Attributes of South African Wastewater Treatment Works:

- *The majority of wastewater treatment plants do not operate within their design capacity. This important factor will impact heavily on the possible consequences of power outages on the wastewater treatment industry in South Africa.*
- *It is estimated that 40% of wastewater treatment plants do not monitor their volume of discharge. Without sufficient monitoring, wastewater plants are unable to accurately establish if they are operating within their designed capacity. A lack of crucial information will mask the need for the upgrading and expansion of treatment plants.*
- *Almost a third of Water Service Authorities (WSA) say that they do not monitor treated effluent quality on at least a monthly basis.*
- *A large proportion of WSA (who manage 83% of the treatment plants) do not have an appropriate permit for their treatment facilities.*
- *Furthermore, only 25% of those licensed wastewater treatment works are said to adhere to their specified license. This impacts quality standards, capacity usage, monitoring, safety, and most critically the upgrading of facilities.*

The majority of wastewater treatment plants in South Africa are 30 – 50 years old and from the above results it is apparent that the majority of them are poorly managed.

Source: DWAF: Wastewater Assessment of Water Services Authorities in South Africa, 2007

3.2 Summary of energy usage in the water cycle

Water and wastewater treatment processes utilise significant amounts of energy. In the state of California 19% of energy consumed is attributed to water and wastewater treatment. Further, it is estimated that approximately 7% of global electricity consumption is utilised by the water and wastewater treatment sectors (American Water, 2008).

It is not possible to calculate how much electricity is needed, on average, to treat a megalitre of water or wastewater. Various factors influence the amount of energy consumed in these treatment processes, which include:

<u>Location of treatment plant:</u>
Treatment plants that can use gravity to distribute water or wastewater will save significant amounts of energy because pumps are not required.

<u>Quality of water / wastewater:</u>
The quality or water or wastewater influences the amount of electricity consumed. In wastewater treatment, the more concentrated the effluent (higher COD 'Chemical oxygen demand'), the more efficient your treatment becomes. Even though your effluent may be more concentrated, the treatment process would use less energy to treat the same volume of solids, when compared to a diluted effluent mix.

<u>Treatment technology utilised:</u>
Certain treatment technologies consume more energy than others. For example, reverse osmosis membranes use significantly more energy than other filtration techniques.

Energy Consumption Breakdown
With so many variable factors contributing to the amount of energy consumed in the water value chain it is difficult to quantify exactly how much energy is being consumed in total. However, it is possible to breakdown the water supply chain in terms of the energy consumed by each process over a range. The figure below provides a relative energy consumption breakdown across the water value chain.

Process	kWh / ML Min	Max
Abstraction	0	100
Distribution	0	350
Water Treatment	150	650
Reticulation	0	350
Wastewater Treatment	200	1800

Source: These figures are based on examples from the South African water value chain.

Figure 12: Energy consumption breakdown

Wastewater treatment is by far the largest consumer of energy with a range of 200 – 1800 kWh / ML treated. Water treatment typically reflects lower energy consumption figures at 150 – 650 kWh / ML treated. Abstraction, distribution and reticulation vary depending on whether gravitational feeds are utilised or not.

3.3 International benchmarks

International benchmarks: New York's water and wastewater sector energy consumption rates

The municipal water and wastewater sectors in New York State are energy intensive. Energy costs to pump, treat, deliver and collect water can comprise up to one-third of a municipalities energy bill. The table below shows the estimated energy consumption across New York's water and wastewater sectors.

Table: 6: New York's water and wastewater sector energy consumption levels

	Wastewater sector	Water sector
Energy consumption	2 billion kWh / year	1 billion kWh / year

Two thirds of the energy consumed is within the wastewater sector. To put the magnitude of the sectors consumption into perspective, the 7.1 million households in New York consumed a total of 42.3 billion kWh in 2001, or 5,974 kWh / household. The table below compares New York's energy consumption (per megalitre of treated effluent), with the national average.

Table 7: Comparison between New York and national average energy consumption

	New York	National average
Wastewater treatment (kWh/ML)	390.50	316.62
Water Treatment (kWh/ML)	153	369.3

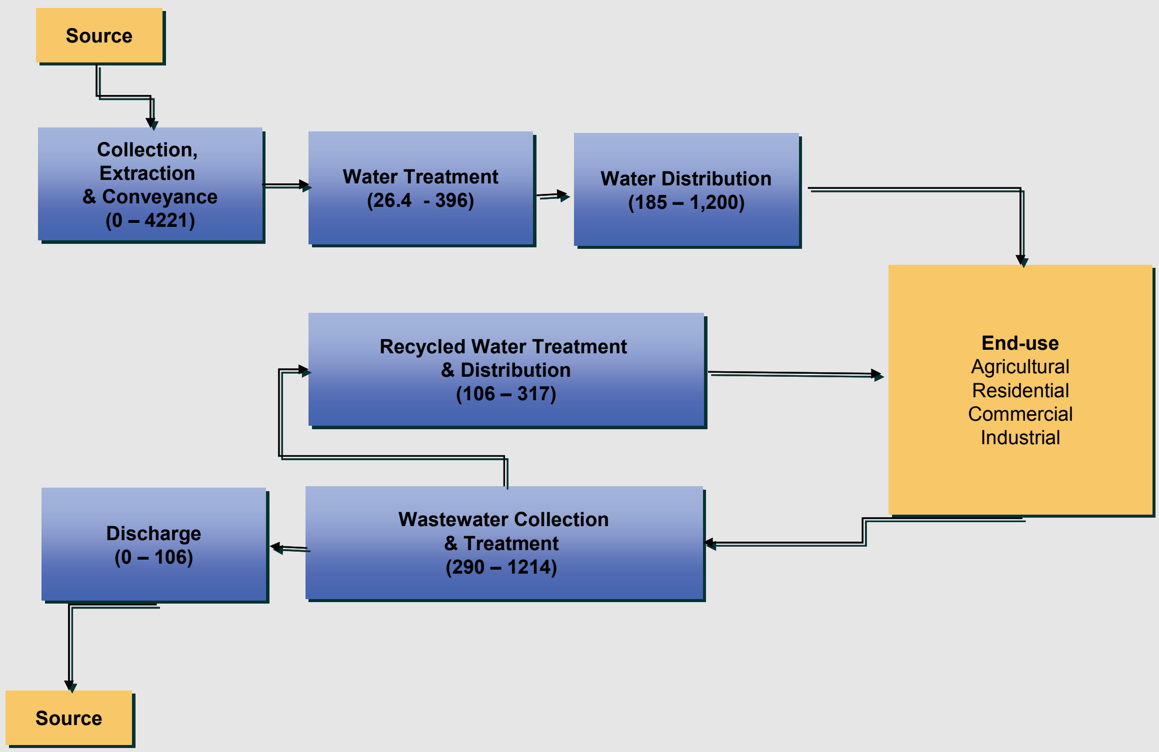
New York's energy consumption in the wastewater treatment sector is above that of the national average due to the widespread use of activated sludge (energy intensive secondary treatment process) and the compliance with stringent effluent limits, which require tertiary or advanced treatment.

The bulk of energy consumption in the water sector is consumed through processing (treatment) and distribution (pumping). However, energy use in New York's largest water supply systems (serving over 100,000 people) is extremely low.

Nearly 50 percent of the state's population is served by two drinking water systems that are operating under Filtration Avoidance Determinations issued by the US Environmental Protection Agency so that conventional treatment is not required for their source surface waters. In addition, many facilities incorporate gravity distribution systems for at least a portion of their service area, significantly reducing energy consumption and costs attributed to pumping. In New York State, small to mid-sized communities (serving 3,300 to 50,000 people) account for the greatest proportion of energy use. Excluding the systems that operate under Filtration Avoidance Determinations, New York's drinking water sector consumes an average of 153 kWh/ML, which is nearly 70 percent less energy than the national average of 390.5 kWh/ML.

Source: PG&E New Construction Energy Management Program, Municipal Wastewater Treatment Plant baseline Study, 2003

Water Cycle Energy Usage: California (kWh/ML)



<u>Preliminary total = 501 to 6,253</u>

Source: California Energy Commission, Water-Energy Paper, 2005

Ageing infrastructure and energy usage

Ageing infrastructure, both at treatment facilities and within collection and distribution systems, has the potential to significantly influence energy use within the water and wastewater sectors. Outdated treatment processes, obsolete controls and end-of-life equipment can result in greater than necessary energy consumption. Inflow, infiltration and combined sewers results in greater pumping both within the collection system and wastewater treatment works. Leaking distribution systems and lost water forces utilities to produce a greater volume of treated water, affecting energy consumption for abstraction, treatment and distribution.

4. Power Outage Impact Assessment

4.1 Introduction

This section of the report provides a systematic breakdown of the impact of power outages on each stage of the water cycle. This is followed by a regional analysis, which compares impact levels across South Africa's provinces from an economic and social perspective.

Included in the impact analysis of each water supply chain process is:

- outline of critical energy-requiring equipment;
- outline of specific scenarios that may arise for that water cycle process;
- a power outage impact assessment ranking;
- an overview of all impacts on economic, environmental, social and health aspects of society.

Scenario analysis

Due to significant variations in the capacity, infrastructure type, location and other variables within South Africa's water supply chain, it is not possible to state exactly what the impact of a power outage will be on, for example, all wastewater treatment plants in South Africa. It is not possible to say that a 2 hour power outage will cause all wastewater treatment plants to discharge raw sewage into the environment.
The impact on each individual wastewater treatment plant will be determined by the specific characteristics of the plant in question.

Due to this, a scenario analysis approach has been adopted. Within each portion of the water supply chain, where relevant, more than one scenario has been outlined if varying plant characteristics will result in different impacts.

Power outage impact assessment ranking

The scenario analysis provides a high-level breakdown of the impact that power outages have on each stage of the water cycle. It utilises a ranking system to determine the impact level of a power outage.

The impact levels are organised into 4 categories: no impact, low impact, medium impact and high impact. The impact level is determined according to direct impact and indirect impacts (knock-on effects).

- Direct impacts are classified as impacts that stem from a power outage and that influence the functioning of a specific process within the water supply chain. For example a power outage will result in the aeration process of a wastewater treatment plant to cease functioning.
- Indirect impacts are those that result because a key process within the water supply chain has ceased to function. For example, if a wastewater reticulation system fails the wastewater may overflow into a wetland causing environmental pollution.

Table 8: Impact level categories

No impact	**Direct impact:** none **Indirect impact:** none
Low impact	**Direct impact**: Yes **Indirect impact**: None
Medium impact	**Direct impact**: Yes **Indirect impact**: Yes Impact lasts for the duration of the power outage
High impact	**Direct impact**: Yes **Indirect impact**: Yes Impact lasts for a time period longer than the duration of the power outage

4.2 Abstraction

Energy requirements

Pumping consumes the bulk of electricity usage, but other critical points include telemetry devices.

Energy consumption
Pumps
Telemetry Equipment

Scenario analysis

SCENARIO	IMPACT
Gravitational feed abstraction	No impact
Pumped abstraction	Medium impact

Table 9: Abstraction impact overview

IMPACTS	
ECONOMIC	Raw water cannot be abstracted
SOCIAL	Users of small-scale abstraction schemes (boreholes) may be negatively impacted because water must be sourced from elsewhere

Discussion

In scenario one, a power outage will have no impact on gravitational abstraction (this process does not require the use of electricity). In scenario two, a power outage will have a direct impact on pumped abstraction. The pumping and telemetry equipment used to abstract water from its source will not be able to function without power. The resultant indirect impact is that raw water cannot be abstracted during the power outage event. The impact in scenario two is thus considered to be medium - operations will continue as per normal as soon as the supply of power is restored.

4.3 Water treatment

Energy requirements

Energy usage in the water treatment sector is dominated by pumping activities. Approximately 85% – 99% of water treatment plant energy consumption can be attributed to pumping (American Water, 2008). Common pumping procedures within a water treatment system include raw water and well pumps, high service pumps, filter backwash pumps and distribution system booster pumps. Other important water treatment processes that require energy include chemical dosing systems and remote telemetry control systems.

Energy consumption
Pumps
Telemetry equipment
Dosing equipment

Scenario analysis

SCENARIO	IMPACT
Rand Water: • 480 ML water processed / day • 8 chlorine dosing stations • 100 dosing pumps • Extensive PLC control and monitoring system • Back-up generators	**Low impact**
Johannesburg Water: • 87 pump stations • 33 water towers • No generator back-up facilities	**High impact**

Table 10: Water treatment impact overview

IMPACTS	
ECONOMIC	Water cannot be transported (pumped facilities) and treatment procedures cease to function Loss of revenue to WT facility – reduced operations, and increased labour costs End users may be impacted by reduced water supply and low quality water
SOCIAL	Lower quality drinking water Possible 'knock –on' effect resulting in water reticulation delays for local communities
HEALTH	Sub-standard quality drinking water can have health impacts
ENVIRONMENTAL	Water wastage on plant re-start

Discussion

Scenario one is considered to have a low impact because the back-up generator capacity at Rand Water is sufficient to maintain the desired level of operation. In this case, a power outage will cause operations to stop for a short period of time before the back-up power supply is activated. The indirect impacts are considered minor due to the short change over period between electricity supplied by Eskom to electricity produced by the back-up generators.

Scenario two will incur both direct and indirect impacts should a power outage occur. Operations will cease to function, and as a result water will not be treated. These impacts extend beyond the period of the power outage due to the numerous possible knock-on impacts.

Without power, pumping systems and telemetry devices in a water treatment plant are unable to function. Water cannot be distributed, dosing apparatus and other treatment procedures cease to function (unless the treatment plant has a source of back-up power).

As a result of these direct impacts the quality of the treated water deteriorates as time passes.

There are a number of indirect economic impacts associated with the impact of power outages on water treatment facilities. These include a loss of revenue to the organization responsible for the water treatment – due to increased costs associated with re-starting pumps, increased labour costs, loss/wastage of water and loss of production time. Further, in the case where a power outage or series of power outages has an ongoing impact on a specific water treatment plant this could indirectly impact water reticulation to the end user.

Indirect social impacts include the possible distribution of lower quality water from the treatment plant to the end user. This could also have indirect health implications should the end user consume untreated water.

Case Study: Impact of Load Shedding on Water Boards

This case study examines the impact of load shedding on Johannesburg Water and Magalies Water. Johannesburg Water experienced 262 power outage events in 2008, adding up to a total power outage duration of 10 hours and 44 minutes. These outages have had a number of negative impacts on both of the mentioned water boards, including: loss of revenues, increased labour costs, reduced water quality and water wastage. Financial losses to Magalies Water have been significant: for example, for every 3 hour power failure at Bospoort WTP alone, R1728 is lost; for every 2 hour power cut at Vaalkop, R1482 is lost. This has totaled to over R730, 000 for these two plants in the 07/08 financial year.

For further detail refer to the case studies in section 5.

4.4 Water distribution and water / wastewater reticulation

Energy requirements

Pumping consumes the greatest portion of energy and is the most critical element in ensuring that a water distribution network operates smoothly. Pumps are used to drive the water (or wastewater) through the pipe network. Other critical equipment includes telemetry systems which are used to monitor pumping activities.

Energy consumption
Pumps
Telemetry equipment

Scenario analysis

SCENARIO	IMPACT
Pump operated distribution / reticulation	High impact
Gravity-fed distribution / reticulation	No impact

Table 11: Distribution / reticulation impact overview

IMPACTS	
ECONOMIC	Water and wastewater cannot be distributed Loss of revenue to commercial end users when water supply is disrupted or due to sewage contaminations/pollution Loss of revenue to water board or local municipality due to 'pump start-up' costs, increased labour costs, loss of potential revenues. Municipal costs to fix damaged infrastructure and supply drinking water storage tanks for local communities

	Cost to clean up sewage spills **Expenses incurred by local communities who need to travel to water distribution facilities** **Possible knock-on impact on property values (where sewage spills contaminate land/water in close proximity to property)**
SOCIAL	**Water supply disruptions – local communities may not have access to potable water. This can impact on time, as local residents may have to travel to collect safe drinking water.** **Possible implications for recreational activities (due to contaminated water)** **Aesthetically displeasing sewage spills**
HEALTH	**Raw sewage spills create health hazards as the effluent often contains dangerously high levels of *E. coli* and other diseases**
ENVIRONMENTAL	**Sewage spills and low quality effluent can enter into the environment causing pollution and toxicity with numerous possible knock-on effects** **Long term impacts include eutrophication and high toxicity levels causing river, vlei systems to fail.** **Fish and fauna impacted**

Discussion

There is no impact on a distribution or reticulation system (or a section of this system), that uses gravity. Operations will continue as normal regardless of the power outage. A power outage will have no impact in scenario two.

However, this is not the case in scenario one. A distribution or reticulation system (or part thereof) that uses pumping as the main source to drive flow will be directly impacted by a loss in power, and this may have undesirable indirect impacts. These impacts will extend beyond the period of a power outage, and may include a number of the impacts discussed below.

A power outage results in the inability to distribute water or reticulate wastewater (in all cases where pumps drive these operations). Economic impacts may comprise the loss of revenue for water distributors during the outage event and higher labour costs as increased personnel are required for plant start-up.

Other economic impacts could include ensuring that local communities have access to potable water. The cost to provide portable water storage tanks and portable sewage storage tanks is significant. Other costs would be travel and labour expenses involved in setting up these storage facilities, and the expense related to cleaning up any resultant sewage spills.

Commercial end users who rely on a secure and consistent supply of water for their operations can be adversely affected by water reticulation problems. They may experience loss of operating time and revenue losses. This could have a further knock-on impact for casual employees in terms of salary payments.

Social impacts are focused on local communities who will not have access to water. The loss of time and money to travel to new water points is significant for poor communities. A loss in water supply will also have minor impacts on recreational activities which involve water supply.

Aesthetically displeasing sewage spills are a significant health hazard and damaging to the environment. When pumps do not operate the flow of sewage cannot be controlled, which results in sewage spills. Raw sewage carries disease and high levels of *E. coli*, and is considered dangerous for human contact.

Sewage spills can be highly detrimental to the environment causing nutrient overload and eutrophication. With consistent spillage into aquatic environments oxygen levels, overall water quality and aquatic biota are negatively impacted.

Case Study: Infrastructure Impact

Power outages have had a noticeable impact on the Cederberg Municipalities water services infrastructure. Not only have power outages caused damage to existing equipment, but they have also necessitated the purchase of further equipment (namely, water storage tanks and sewage storage tanks). The associated costs are large considering the Cederberg Municipality serves an estimated population of only 40,000 – 45,000 people, which is less than one percent of the total population in South Africa.

For further detail refer to the case studies in section 5.

Case Study: Environmental Impact Assessment

This case study examines the impact of millions of liters of raw sewage flowing directly into Zandvlei, the last remaining estuary in the False Bay coast line of Cape Town. Experts believe that this, and other sewage spills, will have a notable detrimental impact on the long term ecological condition of the vlei. The immediate 'knock-on' effects impacted recreational users and local residents. Many local property owners express their concern regarding the impact on property prices, including the long-term impact should the water quality at Zandvlei continue to deteriorate.

For further detail refer to the case studies in section 5.

4.5 End users

Water security is vital for the functioning of South Africa's economy. Without a secure supply of water important contributors to South Africa's GDP will not be able to function effectively. The power sector is the single largest consumer of water in South Africa and it also forms the backbone of South Africa's energy-intensive mining and heavy industrial activities.

This section of the report reviews each of South Africa's largest water consumers in terms of their water security and whether power outages have or could have an impact on their water and wastewater management functions.

Power sector

Eskom's reliance on a secure supply of water is well documented. Without a reliable source of water Eskom's wet-cooled power plants will not be able to function, hence Eskom works closely with DWAF to ensure adequate supply. Recent water security initiatives that Eskom has worked on include developing a memorandum of understanding (MOU) regarding the supply and management of water in the energy sector.

<u>MOU Aims</u>

- Negotiating a memorandum of understanding with DWAF on water conservation and water demand management for five years.
- Develop a strategic partnership with DWAF to foster water conservation and demand management in the power generating sector.

<u>MOU Objectives</u>

- Share, inform and guide regulatory initiatives on water management within the power generation sector;
- Exchange information regarding policies, strategies and developments in the field of water use and conservation and climate change;
- Joint research, co-operation and agreement in the areas of best water management practice and water use performance improvement;
- Promote, encourage and support good water management practices;
- Develop benchmarks for the power generation sector and implement plans to meet set targets;

- Explore synergies between Eskom's Energy Efficiency and Electricity DSM Programme and DWAF's WCWDM Programme.

Reference: Eskom, Energy and Water Conservation, 2007

<u>Power sector end user impact analysis</u>

No examples of load shedding events impacting the supply of water to the power sector could be identified. This is likely a result of Eskom's close working relationship with DWAF in terms of water usage within the power sector specifically focused on demand-side management and water security.

Mining & bulk industrial

South Africa's mining and heavy industrial sectors are all too aware of the impact that power outages can have on their business processes. Mines and energy-intensive industries have had to scale back production levels significantly as a result of a power shortages.

<u>Mining & bulk industrial end user impact analysis</u>

Within the mining sector impacts related to the management of water and wastewater within mines were identified.

Anglo Gold Ashanti, Mining Engineer

"Load shedding had an immediate impact when it happened but since then we have put management systems in place to cope with it. Initially when there was an abrupt power cut there was no pumping of the water that was flooding the mines so water just kept on flowing in – so we have established a relationship with Eskom where load shedding is now done in an organised fashion."

Beeshoek Iron Ore Mine, Engineer

"Load shedding has had a significant impact on us. We are currently commissioning 11 generators, 1125 KW per generator – though we haven't had load shedding since last year in February in terms of production losses. Plants had to be shut down with production losses of 600 tonnes per hour. We are currently in a process of negotiating with Eskom to negotiate how we will save the 10% on load shedding. "

Petrochemical: Sasol, Environmental Adviser (Water and Cleaner Production)
"I am not aware that our water supply to Sasol factories had been affected by load shedding. I am aware that for example Rand Water is looking at demand management so they need to pump less water and use less energy. Sasol is also looking at implementing alternative more energy efficient waste water treatment technologies to improve efficiencies, supported by Eskom's DSM programme. We continue to engage with DWAF on water security, assurance of supply and so on but are more focused on assurance of supply. Water supplemented to the Vaal is coming from Lesotho in preference to Sterkfontein, one of the reasons being the additional pumping costs associated with bringing water up from Sterkfontein – it is an issue."

Mittal Steel, Water Engineer
"Mittal is a very large consumer of electricity; we buy our electricity in bulk and distribute internally as and where we need it. For example we can prioritise certain areas if need be. We have critical treatment areas that require prioritisation and if Eskom cannot supply electricity they have back-up supply on site – generators – to cover for such events."

No examples of power outages impacting the water security of mining or large industrial companies were identified. Large users of water who manage their water and wastewater internally typically either install generators as back-up supply or they prioritise these functions over less important processes.

Urban

Urban areas account for a significant portion of South Africa's water consumption. Water is not only consumed by households, but commercial businesses also fall within this category.

<u>Urban end user impact assessment</u>

A short-term lack of water and wastewater services to households, as a result of power outages, within urban areas is an inconvenience. A lack of water supply to the commercial sector within urban areas is more significant. Businesses stand to lose money because operations cannot function, and alternative knock-on effects can impact the livelihoods of staff.

Further, commercial businesses, in comparison to the large mines and industrial end users are less likely to have back-energy supply or alternative ways to source water or wastewater services.

Food and Beverage: Distell, Stellenbosch, Water Manager
"Distell have no contingencies in place for power outages in terms of their water management. We obtain our water from the municipality and have never had issues with regard to supply. We also have boreholes on site. Wastewater is treated onsite, and if we are without electricity the plant will not function – the pumps and aerators will not work. If we are without electricity for a few days we would be in trouble because pollution could occur."

Case Study: End User Impact Assessment

This case study examines the economic knock-on impact of a municipal water reticulation issue, which lead to the temporary closure of a small seafood processing plant in the UGU District, in September 2008. The case study also examines costs incurred by the local municipality surmounting to over R200,000, when some regions went without water reticulation services for a 2 week period. *For further detail refer to the case studies in section 5.*

Case Study: Health Impact Assessment

This case study examines the influence of power outages on the recent sewage spill outbreak occurring in the vicinity of the Howick Siphumele/Thokoza low cost housing and informal settlements, which have resulted in dangerously high levels of *E. coli* and total phosphate levels downstream from the township. Apart from the immediate health hazards, the sewage spills resulted in *approximately one million liters of raw sewage* entering into the already fragile Umgeni River, thus impacting on the long-term environmental health of the river and ecological system. The cumulative sewage spill problems in the Siphumele/Thokoza informal area resulted in a high number of fish kills in the Umgeni River, which further illustrated the extent of the problem. *For further detail refer to the case studies in section 5.*

4.6 Wastewater treatment

Energy requirements

Wastewater treatment plants use significantly more energy than water treatment plants. The majority of energy is used for aeration, however, pumping is considered to be the most critically impacted point during power outages.

Energy consumed
Aeration (80%)
Pumps (10%)
Sludge handling (9%)
Misc. systems (1%)

Scenario analysis

Table 12: Impact of power outages on Cape Town wastewater treatment works

Wastewater treatment works	Percentage pumped	Impact of power outage	Short term mitigating strategy	Time for impact	Impact level
Cape Flats Average flow: 130 ML/day	90% gravity	Partial treatment can take place	Divert raw sewage into isolated maturation pond then blend good quality effluent with poor quality effluent	7 days	**Low impact**
Camps Bay Average flow: 2 ML/day	100% gravity	Overflows to surf zone	Has standby generator for screens	1 day	**Medium impact**
Scottsdene Average flow: 9 ML/day	30% gravity, then lifted at inlet	Raw wastewater overflows into the emergency pond and spills into the river after about 6 hours	Has an emergency pond for temporary storage	6 hours	**High impact**

Source: City of Cape Town, 2008

Table 13: Wastewater treatment impact overview

IMPACTS	
ECONOMIC	Treatment plant and treatment processes cease operation Equipment damage costs Sewage spill cleanup costs Cost for backup generators and portable spill bins Increased labour costs Pollution can impact property values
SOCIAL	Recreational activities can be impacted by sewage spills/contaminated bodies of water Aesthetically displeasing raw sewage spills
HEALTH	Sewage spills pose significant health risks for individuals who come into contact with untreated effluent. Raw sewage carries many diseases and usually contains high levels of *E. coli* which can cause illness
ENVIRONMENTAL	Pollution of environment Long term impacts include eutrophication and high toxicity levels causing river, vlei systems to fail. Fish and wildlife impacted

Discussion:

In the event of the WWTW's outlined in table 8 experiencing a 24 hour period of power outage the following would occur:

The Cape Flats WWTW is only impacted directly and has no resultant indirect impacts. Operations will experience little disruption during the power outage and will return to full capacity when the power is returned. The impact is thus considered to be low.

A power outage at Camps Bay WWTW will have both direct and indirect impacts. Operations will stop and wastewater will not be treated. These impacts are not expected to extend beyond the power outage duration because sewage will only be released into the sea after 24 hours (which is the duration of the stated power outage). In this case, the power outage will have a medium impact.

Scottsdene WWTW is the most significantly impacted as its emergency pond will overflow after six hours. The direct and indirect impacts from a 24 hour power outage at Scottsdene WWTW will extend far beyond the period of power outage. The impact is thus considered to be high.

Wastewater treatment plants are considered to be the most vulnerable and highly impacted portion of the water supply chain in terms of power outages. Power outages can have a number of economic implications, such as equipment damage costs, possible health costs, sewage spill cleanup costs, costs to purchase generators, costs to purchase portable 'spill bins', increased labour costs and revenue loss to private individuals (property value depreciation).

Sewage spills are aesthetically displeasing and can impact recreational activities at public dams and rivers. They also pose great health risks, especially when sewage leaks into highly populated areas. Diseases can be transmitted by the pathogenic organisms in the wastewater, which can impact human, animal and plant life. The short term impacts of raw sewage contamination are clear. Dead plant, fish and bird-life is a common occurrence; however, it is the long term impact of continuous sewage contamination that many experts consider to be most critical impact. Eutrophication and high toxicity levels can cause river, wetland and vlei systems to collapse.

Refer to Appendix 1 and 2 for additional scenario analysis of power outage impacts on wastewater treatment processes.

Case Study: City of Cape Town – Generator Back-up Costs

This case study examines the power outage impact assessment and mitigation strategies, which was drafted by the Cape Town Municipality in 2006, for a sample of Cape Town's WWTWs. It highlights the short and long term mitigation strategies and resultant impacts of power outages over a period of time. The cost to provide back-up generators for only 4 of Cape Town's wastewater treatment plants amounts to just under R5 million (2006 costs), which highlights the significant potential cost to provide power supply back up for all 956 WWTW in South Africa. *For further detail refer to the case studies in section 5.*

4.7 Regional water demand impact analysis

Analysing the impact of power outages on South Africa's water sector at a city or town level, without analysing specific water or wastewater treatment facilities in detail, is not feasible. To understand the exact impact of a power outage on an area will require analysing the entire water system in that region with a specific focus on:

- Location of the water and wastewater treatment plants
- Quality of water or wastewater being treated
- Use of pumped or gravity fed distribution / reticulation systems
- Number and capacity of pumping stations utilised
- Treatment technology utilised
- Level of back-up power supply utilisation

Only once each of these particular attributes has been accounted for can one confidently assess the impact of a power outage on a specific site.

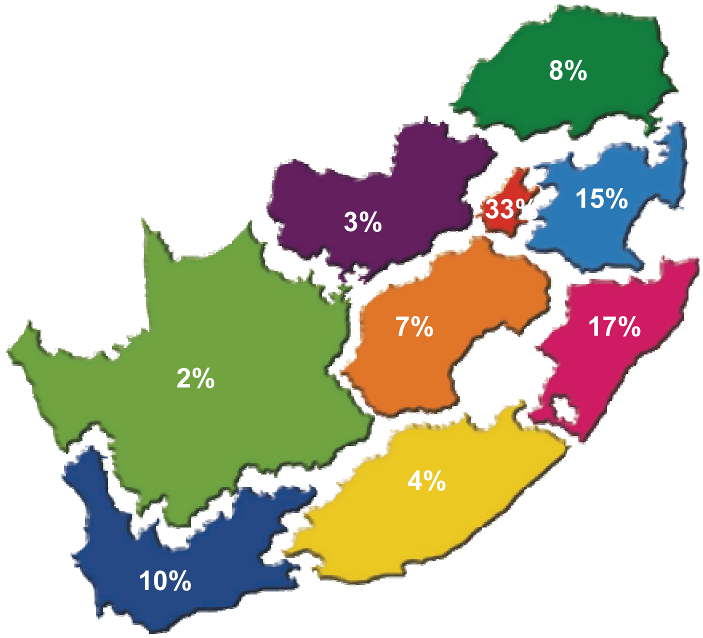
However, the relative impact, at a regional level, of no or limited water services can be estimated by ascertaining the importance of water in specific regions. Water requirements, within the context of this project, can be divided into social and economic. Societies' water needs are driven by population dynamics; economic requirements are influenced by water intensive economic activities.

This section of the report analyses the potential impact of no or limited water services on a regional level by reviewing both social and economic water demands across South Africa. The following metrics form the basis of this analysis:

- Water and energy GDP contribution per province
- Population breakdown per province
- Economic GDP contribution per province
- GDP contribution per economic sector

Provincial energy and water GDP contribution

The amount of energy and water services provided per province varies significantly. Figure 13 below outlines the provincial GDP contribution for energy and water services across South Africa.



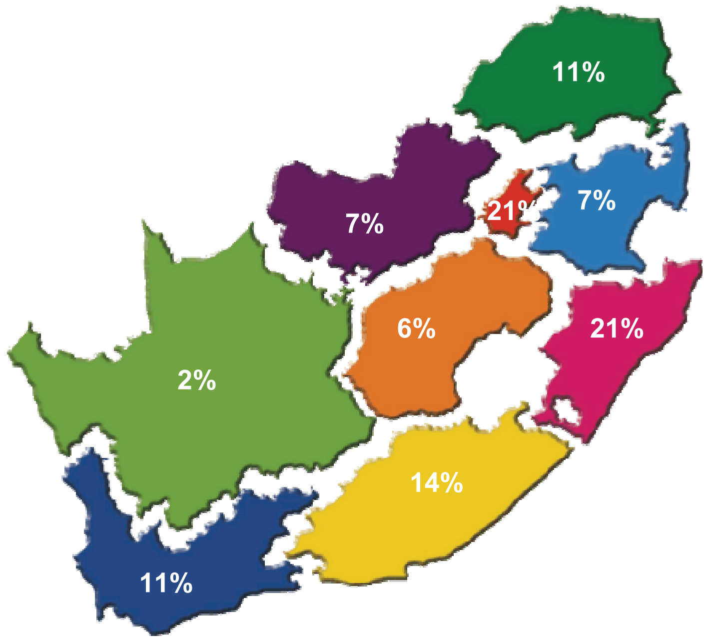
Source: Stats SA, 2009

Figure 13: Energy & water economic activity (GDP contribution) per province

Analysis of this data indicates that energy and water service providers in Gauteng, KwaZulu-Natal, Mpumalanga and the Western Cape are the largest regional energy and water GDP contributors. Demand for energy and water services in these regions are largely driven by economic and social needs.

Population trends

An analysis of South Africa's population metrics indicate that Gauteng, KwaZulu-Natal and the Western Cape are home to a significant proportion of the population, which correlates with the energy and water metrics in figure 13 above.



Source: Stats SA, 2009

Figure 14: Population breakdown per province

Interesting trends revealed from this analysis include:

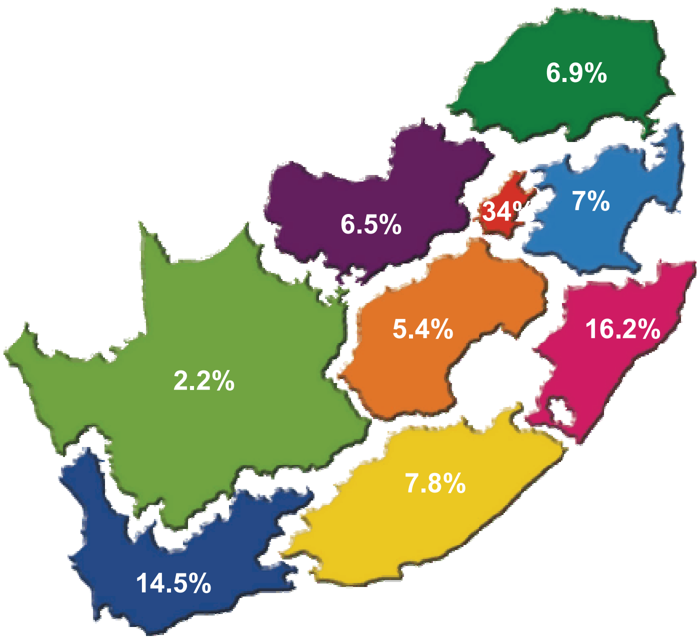
- Despite Gauteng and KwaZulu-Natal having the same population figures, Gauteng has a significantly higher water and energy GDP contribution metric. This is due to the higher levels of economic activity within Gauteng and the largely rural-based population of KwaZulu-Natal.
- The Eastern Cape has a low water and energy GDP contribution metric (4%) despite the relatively large population (14%). As for KwaZulu-Natal, this is explained by the regions largely rural population.
- Areas like the Northern Cape have low water and energy demand (2%), which correlates with the regions low population levels (2%).

Understanding these social water demand trends is important when trying to determine the impact of no or limited water services on a regional basis.

Economic trends

Balancing economic, social and environmental water requirements is becoming increasingly difficult for water authorities who need to take into account varied water demand levels from different economic sectors. Figure 15 below depicts the different GDP contributions from each province.

Figure 15: GDP contribution per province



Source: Stats SA, 2009

Figure 14: Population breakdown per province

Correlated with water and energy GDP contribution levels and population metrics, the largest economic GDP contributions stem from Gauteng, KwaZulu-Natal and the Western Cape. Hence, these regions require priority in terms of economic water allocation and security.

Based on this data, limited or no water services within these three regions would have a significant negative impact on South Africa’s economy. However, economic sectors have different water requirements, thus, as detailed in table 14, one must analyse South Africa’s water demand requirements more carefully to truly understand these trends.

Table 14: Economic sector GDP breakdown per province (water intensive activities and respective regions highlighted in yellow)

Economic Activity	WC	NC	EC	FS	NW	LP	GP	MP	KZN
Agriculture, forestry, fishing	24%	6%	5%	9%	7%	8%	6%	10%	25%
Mining & quarrying	0%	7%	0%	9%	**24%**	**23%**	**14%**	**19%**	4%
Manufacturing	**15%**	0%	8%	4%	3%	1%	**40%**	7%	**21%**
Electricity, gas & water supply	**10%**	2%	4%	7%	3%	8%	**33%**	**15%**	**17%**
Construction	19%	1%	5%	3%	5%	4%	41%	5%	14%
Wholesale & retail trade	18%	2%	8%	5%	5%	6%	34%	5%	17%
Transport, storage & communication	15%	2%	7%	5%	6%	6%	31%	6%	22%
Financial services, real estate services	20%	1%	8%	4%	5%	6%	37%	4%	14%
Personal services	13%	3%	13%	10%	9%	5%	24%	6%	17%
General government services	9%	2%	11%	5%	6%	9%	39%	5%	14%

Stats SA, 2009

Sectors within South Africa's economy have different water requirements. Agriculture consumes the bulk of South Africa's water, however this sector falls outside the scope of this study. Table 15 below outlines South Africa's most water-intensive economic sectors. Failure to deliver water services to any of these sectors, as a result of a power outage, would have a significant impact on South Africa's GDP metrics.

Table 15: Economic activities that utilise significant quantities of water include:

Economic Activity	GPD Contribution (2008)
Mining	5%
Manufacturing	16%
Electricity, gas & water	2%

Statistics South Africa, 2008

It is evident from the above two tables that particular sectors and regions are more important in terms of economic water security levels. For example, one of the most important sectors is manufacturing, which contributed 16 per cent to total GDP in 2008, and is currently dominant in the Gauteng, Western Cape and KwaZulu-Natal provinces. Failure to deliver a secure water service to manufacturing plants in these regions, as a result of power outages, would have significant negative economic impacts.

Although a small GDP contributor, the electricity sector in the Gauteng, Mpumalanga, KwaZulu-Natal and Western Cape Provinces is a critical contributor to other economic sectors, such as manufacturing. The impact of power outages on electricity and water supply services in these regions would be significant.

Summary

The complexity of analysing the impact of power outages at a localized level encouraged a regional, comparative approach that was based on econometric and population data. This method allows for comparison and prioritization to occur between regions.

Economic Risk Parameters	
Low Risk	GDP contribution < 15%
Medium Risk	GDP contribution > / = 15%
High Risk	GDP contribution > 30%

Region	Economic	Social
North West	Mining (24%) Manufacturing (3%) Electricity & Water (3%)	Population: 7%
Northern Cape	Mining (7%) Manufacturing (0%) Electricity & Water (2%)	Population: 2%
Western Cape	Mining (0%) Manufacturing (15%), Electricity & Water (10%)	Population: 11%
Eastern Cape	Mining (0%) Manufacturing (8%) Electricity & Water (4%)	Population: 14%
Limpopo	Mining (23%), Manufacturing (1%) Electricity & Water (8%)	Population: 11%
Mpumalanga	Mining (19%), Manufacturing (7%) Electricity & Water (15%)	Population: 7%
Gauteng	Mining (14%), Manufacturing (40%), Electricity & Water (33%)	Population: 21%
KwaZulu Natal	Mining (4%) Manufacturing (21%), Electricity & Water (17%)	Population: 21%
Free State	Mining (9%) Manufacturing (4%) Electricity & Water (7%)	Population: 6%

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Figure 16: Summary of regional economic and social water requirements

It is important to remember that these impact rankings are based on a comparison of regional economic data. Specific regions may have unique, localised characteristics that influence the impact of power outages on water services, however these have not been considered in this comparative analysis.

Figure 16 and 17 summarise key regions in South Africa that require prioritization in terms of water and power allocation. Failure to deliver energy or water to any of these regions will directly impact the mining, manufacturing, electricity and water sectors, which would have a significant impact on South Africa's GDP.

Two of the regions are considered medium risk in terms of social impacts on resident populations, while Gauteng is a high risk area.

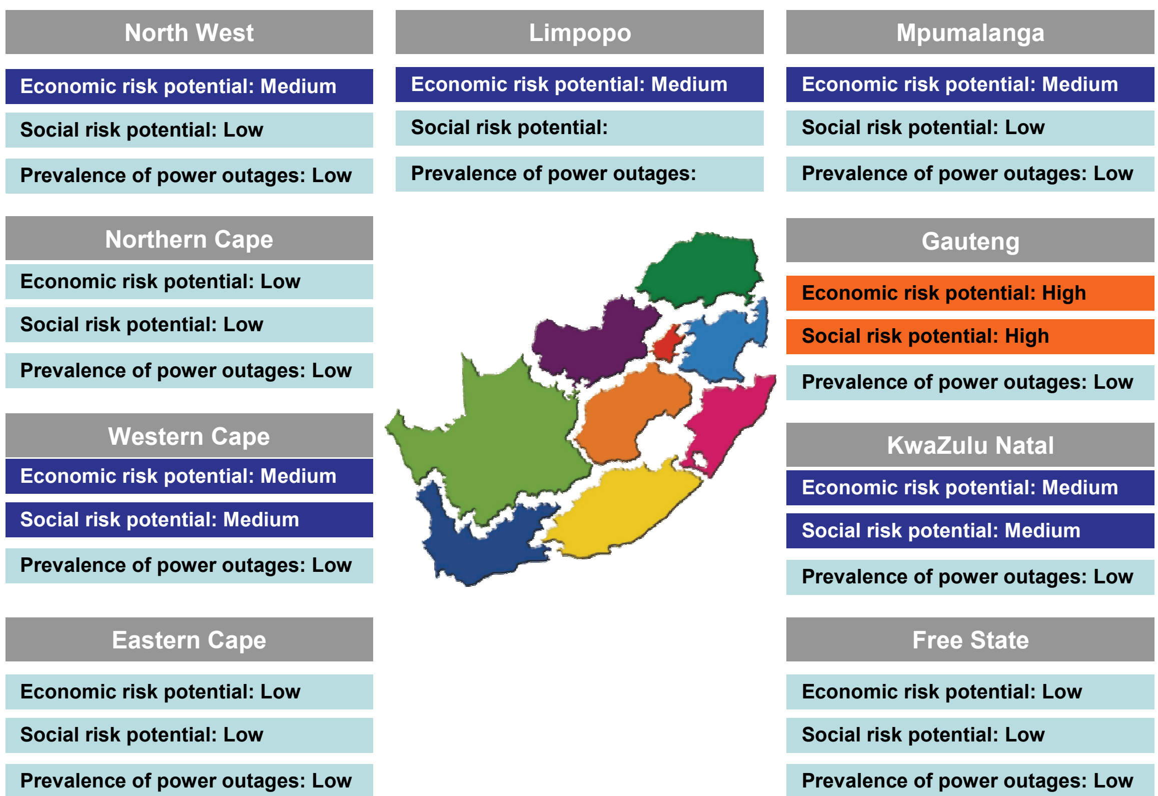


Figure 17: Summary of regional economic and social water requirements

No power outages have been experienced in any regions across South Africa in 2009, hence the prevalence of power outages in each region is considered low.

5. Recommendations

Tacking power supply challenges in the water and wastewater sectors will require a multifaceted approach. No individual mitigatory measure will successfully account for every eventuality that may arise in terms of a power outage.

Key areas that should be addressed include:

Improved communication

The water sector needs to improve levels of communication with the energy sector. If load shedding is required, critical processes along water supply chains need to be prioritised. Large consumers of water (Eskom, Sasol) work closely with water and energy service providers to ensure secure levels of supply, but this needs to be extended to smaller WSAs. Closer working relationships and improved communication between water managers and Eskom or local power distributors will ensure that vulnerable water distribution, treatment and wastewater reticulation and treatment systems are prioritised.

On-site power supply

In the event that power outages cannot be avoided on-site generation capacity is the best solution. This will ensure that critical processes continue to function. The cost of back-up power supply is significant, but this needs to be weighed against the cost of potential impacts resulting from system failure.

Human resource capabilities

Human resources are already stretched in South Africa's water sector. However, it is imperative that personnel are adequately trained and know what mitigatory measures need to be implemented in the event of a power outage.

Contingency plans

Linked to the previous measure, contingency plans need to be put in place so water managers and operational staff know what to do in the event of a power outage. This initiative should be managed and driven by DWAF and rolled out across all WSAs.

6. Conclusions

Until South Africa's power sector commission additional base load power stations there is the risk that load shedding may remain a reality. The softening of commodity prices and the world economic slowdown have provided some respite for the energy sector, however economic growth and related power demand are anticipated to continue their aggressive growth path from 2010.

In addition to the energy sectors' woes, South Africa's water and wastewater sectors have been earmarked as vulnerable due to poorly maintained infrastructure and skill shortages.

A load shedding event has yet to occur in 2009, however the recurring rolling blackouts of 2007 and 2008 made a big enough impression to induce water managers into thinking about the importance of a consistent supply of energy for water services.

South African water and wastewater managers typically do not track energy utilisation in their treatment plants. The variable nature of energy consumption levels across the supply chain makes it difficult to model energy utilisation and power outage impacts at a local or regional level. Modeling impacts at these levels would require analysing specific characteristics of each treatment plant and distribution / reticulation systems over time.

The water supply chain is impacted to varying degrees in the event of a power outage. The extent of the impact is dependent on the characteristics of the plant and the availability of back-up power. Pumping is the most vulnerable activity in the water supply chain, but the use of gravity feeds can reduce this impact in many cases. Water security for end users is directly influenced by power outages on abstraction, distribution or water treatment points of the supply chain, however WSAs and Water Boards generally have sufficient back-up water supply to mitigate power outages. Wastewater treatment is very energy intensive, and hence vulnerable to power outage events. Again, plant characteristics dictate impact levels; plants with back-up power supply and overflow dams are generally not impacted by power outages, but less prepared facilities can experience significant environmental, economic, health and social impacts.

A comparison of regional water demand levels highlights key areas that cannot afford energy or water shortages. Manufacturing and mining are examples of two economic sectors that would not be able to operate without a consistent supply of water. Overall, Gauteng, KwaZulu-Natal and the Western Cape emerged as priority areas from both an economic and social perspective.

Several examples of power outage events impacting South Africa’s water supply chain have been identified. The Cedarberg Municipality has been plagued with power outages, which directly impacted water and wastewater service delivery. Besides the impact on the local community there is a real financial cost to providing back-up services. A case in the Ugu district revealed a direct impact on a commercial business, which resulted in a loss of revenue and salaries for casual labour. Other cases include health impacts in Howick, KwaZulu-Natal, environmental impacts at Zandvlei in the Western Cape and economic impacts for the City of Cape Town who have installed back-up power supplies. All of these examples can be attributed to power outage events that have impacted the water supply chain.

There is no doubt that power outages have had a direct impact on water and wastewater service delivery in South Africa. Only a handful of cases have been highlighted in this project, which exposed distinct economic, environmental, social and health costs, but with certainty there are other similar cases. Unless the power sector can guarantee that power outages are a theme of the past, water decision makers and managers will need to take appropriate mitigatory steps to ensure that the impacts highlighted in this report are stopped or at least reduced. Failure to do so will have costly economic, environmental, social and health consequences.

7. Case Studies

7.1 Infrastructure impact

Case study on infrastructure costs within water and wastewater treatment facilities, and reticulation of water, as a result of power outages

Overview:

This case study outlines the infrastructure costs within the Cederberg Municipality water facilities (including water treatment, wastewater treatment and water delivery to the relevant consumers) that have been attributed to power outages.

> Situated in the West Coast district the Cederberg Municipality serves the following communities: Clanwilliam, Citrusdal, Lamberts Bay, Elands Bay, Graafwater, Leipoldtville, Wupperthal, Elandskloof and Paleisheuwel.

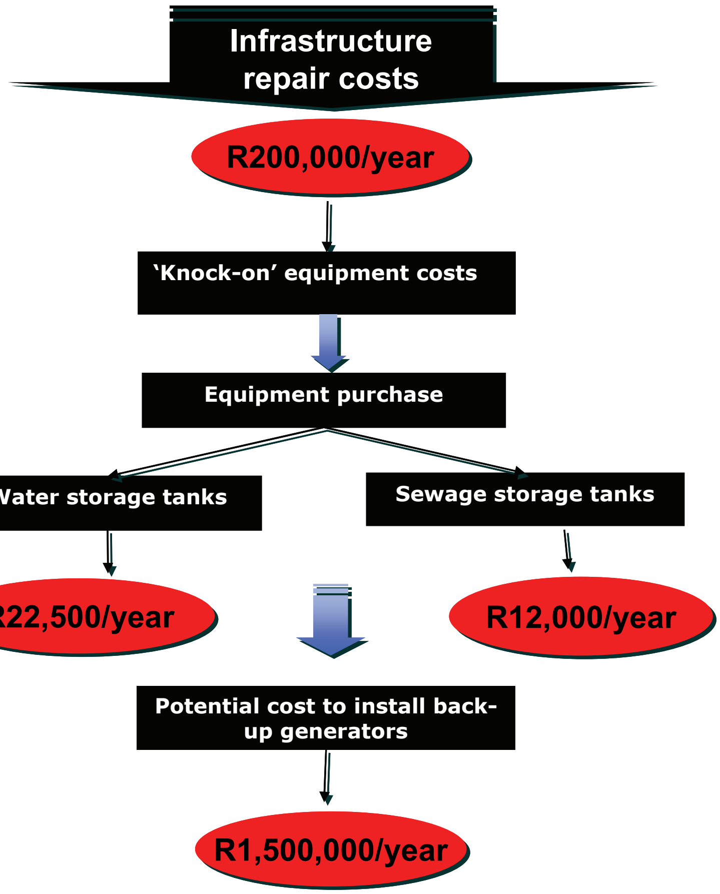
Impact Assessment:

Power outages have caused damage to infrastructure: telemetry equipment (which electronically interlinks the operation of water systems) and motor equipment are often damaged; pumps are sometimes caused to overheat when power outages impact on normal processes within water and wastewater treatment facilities, as well as the distribution of water to end users. The costs associated with the replacement and repair of broken and damaged infrastructure, due to power outages, is estimated to be R200,000 per year for the total Cedarberg community.

Power outages in the Cedarberg region are not only responsible for infrastructure damage but have caused a 'knock–on' effect necessitating the purchase of various storage tanks. Power outages have negatively affected the delivery of potable water to end users, especially in communities that are supplied water that is pumped from boreholes. Pumping is the most critical function in the distribution of water from boreholes and pump stations (used in water/wastewater treatment plants and those used for the reticulation of water) form the most vulnerable and badly affected area of the overall water services system, during periods of power outage.

Fifteen storage tanks (each with a capacity of 5000 liters) have been purchased at a total cost of R22,500. These are placed in strategic locations to ensure that local communities have access to potable water during times when power outages negatively impact the delivery of water. Furthermore, four sewage storage tanks (each with a capacity of 5000 liters) have been purchased at a total cost of R12,000. The portable sewage storage tanks are used during power outage events to ensure that sewage does not overflow into the environment, and thus prevent health and environmental hazards.

The Cedarberg Municipality requires an estimated R1.5 million to purchase power generators to provide back-up for its water services during periods of load-shedding.



Note: the cost to install back-up generators refers to the capital required; this money has not been spent.

Load shedding and water service security – possible 'knock-on' effects

The local water and sewerage facilities in the Cedarberg Municipality have been badly affected by power outages and load shedding events. The current focus of the municipality is to provide low-cost housing for local communities. The Department of Water Affairs, Department of Environmental Affairs and Tourism, Department of Environmental Affairs and Development Planning (DEA&DP) will not allow or approve further development before the municipality is able to secure its bulk services.

The main challenge for the municipality is enhancing and further developing the current bulk service offering. The municipality stated that power outages and load-shedding have had a notable impact on the operational aspect of water services and other bulk services. This has thus impacted on the overall bulk service security and has contributed to a 'slowing down' in the development of low-cost housing in the region.

Conclusion:

Power outages have had a noticeable impact on the Cedarberg Municipalities water services infrastructure. Not only have power outages caused damage to existing equipment, but they have also necessitated the purchase of further equipment (namely, water storage tanks and sewage storage tanks). The associated costs are large considering the Cedarberg Municipality serves an estimated population of 40,000 – 45,000 people, which is less than one percent of the total population in South Africa.

**Source: Primary research, Cedarberg Municipality, 2008*

7.2 End user impact assessment

Case study outlining the impact on commercial end users due to power outages causing poor water service delivery

Overview:

This case study outlines the economic impacts of a municipal water distribution problem, which occurred in the UGU District in September 2008, as a result of power outages. More specifically, the case study identifies the resultant impacts on a local sea food processing plant, located in Margate.

Background and impact assessment:

The UGU District is a coastal region of KwaZulu-Natal and is characterized by rugged terrain and it is thus heavily dependent on the use of pumping facilities to drive the distribution of water to local communities and businesses.

In September 2008, the UGU District experienced a number of power outages which detrimentally impacted water services. At this time, local water facilities were already fragile, as the distribution network had experienced breaks on its system; the frequent and excessive power outages further exacerbated the problem. The water distribution network was hit with an eleven hour power cut in early September followed by cascading power outages the next day. Due to the extreme impact of the power outages, it took 14 days before water services were rectified, and some regions were left without access to piped water for the complete 2 week period.

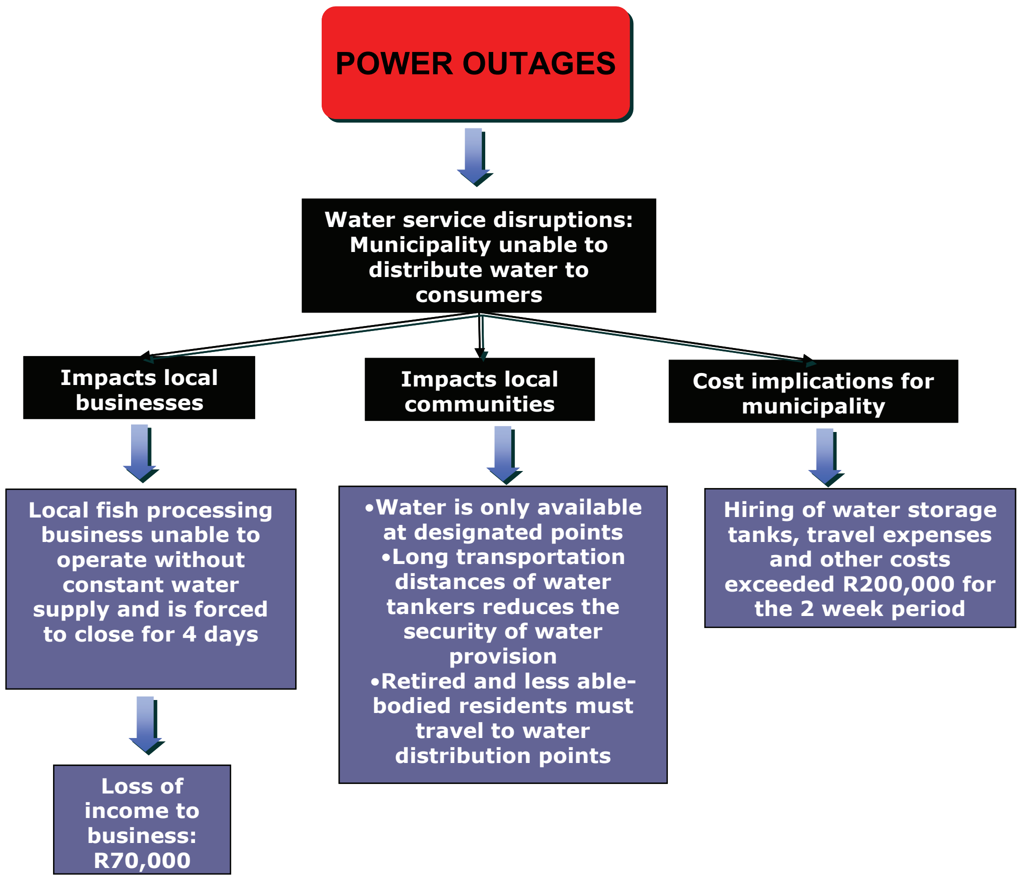
The municipality made use of approximately 20 hired water tankers which were strategically placed to ensure that local communities would have access to potable water. This was not an easy process as the tankers had to be transported over 50 km to various areas. The cost of hiring these tankers and the associated travel expenses exceeded R200,000 for this 2 week period.

During this time it was noted that a number of retired, and less able-bodied persons, experienced problems gaining timely access to the portable water storage tanks. The number of tankers was limited, and due to the long distances which had to be traveled to replenish the storage tanks, this meant that local communities did not have access to a reliable and secure supply of water during this period.

Further, the UGU District has experienced many negative impacts on its wastewater treatment facilities as a result of power outages. The most common and frequent impact is that of sewage spills. These arise when emergency portable sewage collection tanks (which are used to collect/store run-off sewage when power outages cause sewage pumps to shut down) reach their capacity and overflow. A spillage event can cost up to R60,000 to remediate.

Impact on local seafood processing plant

Futurama 135 CC (a local seafood processing business) was forced to close down for 4 days in early September 2008 due to the water delivery stoppage. The processing plant uses high volumes of water and is reliant on a constant supply of water to function affectively. Revenue loss for the 4 day period was in the region of R70,000 and this was coupled with the inconvenience and hassle of processing the necessary insurance claim, which involved obtaining a written letter from the UGU Municipality, authenticating the water supply issues.



Conclusion:

The UGU District has experienced a number of disruptions to its water services as a result of power outages. This has had a direct impact on the availability of water to local communities and businesses. During the 2 week period in which water delivery (by pipe) was disrupted, a local fish processing company was forced to close down its operations for 4 days, at a cost of R70,000. In addition the UGU Municipality spent over R200,000 to provide portable water tanks for the local community.

**Source: UGU District Municipality & Futurama 135 CC, 2008*

7.3 Health impact

Case study: Sewage spills in the Siphumele/Thokoza low cost housing and informal settlements, Howick KwaZulu-Natal

Overview:

This case study examines the influence of power outages on the recent sewage spill outbreak occurring in the vicinity of the Howick Siphumele/Thokoza low cost housing and informal settlements, which have resulted in dangerously high levels of *E. coli* and total phosphate levels downstream from the township.

Siphumele/Thokoza low cost housing and informal settlements are located in Howick, a town in the KwaZulu-Natal Midlands, which is in the heart of the uMngeni Municipal region.

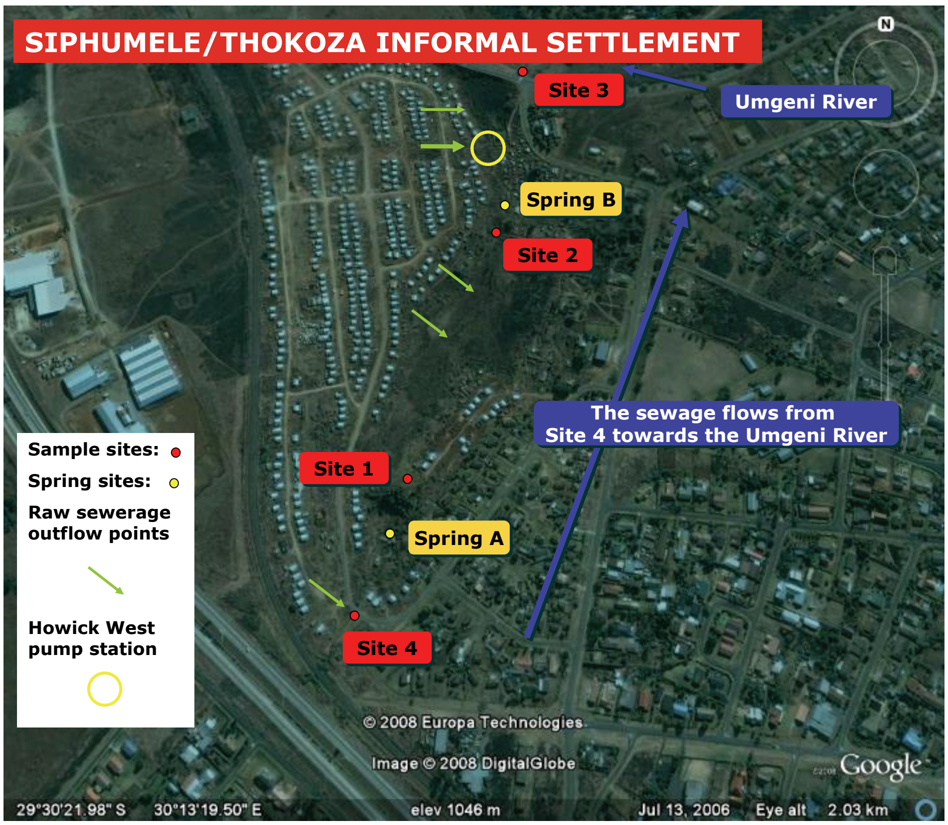
Images courtesy of WESSA, 2008

Impact assessment:

The sewerage contamination issue was first brought to the attention of authorities in August 2008 when a story covering the issue was published in local media. Many residents report that the sewage spills had been a problem since 2007.

From September 2008, when water quality testing began, all results showed high levels of *E. coli.* This sewage feeds directly into the Umgeni River and many people in the community draw water from springs that lie within the drainage path. See map highlighting Springs A & B.

Water testing for *E. coli* was not necessary as it was clear that many of the samples were raw sewerage and the drainage path was thus acting as a sewer. To exacerbate problems the sewerage manhole at site 4 became blocked and as a result added a significant quantity of raw sewerage from Howick West into the drainage system.



* Source: WESSA, 2008

Load-shedding was the direct cause of a number of sewage spills at Howick's local sewage pump stations over this period. During the load-shedding period (from August to October), which on average occurred 4 times a month, there was an average of 20 directly resultant sewage spills per month.

Only 1 of the 7 local pump stations in Howick has a backup generator, and only 1 of the pump stations has sufficient storage capability to store raw sewage during short power outages. The remaining 5 pump stations (including Howick West, which is responsible for ongoing sewage problems in the Siphumele/Thokoza informal settlement) were unable to operate, and as a result, each pump station released raw sewage into the surrounding areas during each of the load-shedding events (which occurred, on average, over a 2 hour period).

Howick West pump station has an estimated daily flow of 1 megalitre and is estimated to have spilt approximately 80 kilolitres during each of the load-shedding events (assuming each power outage lasted on average 2 hours). This amounts to just under 1 million liters of raw sewage being released from Howick West over this period.

A number of sewage infrastructure problems resulted in various sewage outflow points (as highlighted on the above map) which formed the stream leading through the informal settlement towards the Umgeni River. However, load-shedding was the direct cause of most of the sewage problem around the Howick West pump station, in close proximity to 'spring B', from which many local residents draw water.

Samples from site 3 (as shown below) reveal dangerously high levels of *E. coli* which is a major health threat and was the cause of a large number of fish kills in the Umgeni River. *E. coli* measurements above 500 units per 100 ml are considered dangerous for human contact.

Water test results, Howick, KwaZulu-Natal

Effluent quality at site 3, downstream from Howick West Pump Station		
Date	***E. coli*/100 ml**	**Coliforms/100 ml**
2008/08/12	> 4838	
2008/08/19	> 241 900	
2008/08/26	2600	> 24 190
2008/09/02	> 241 900	
2008/09/10	104 600	
2008/09/17	241 900	
2008/09/23	249 000	
2008/09/29	1 300 000	

**Source: WESSA, 2008*

Conclusion:

Load shedding was the direct cause of a number of sewage spills at Howick West pump station and created a significant health risk for the local residents of Siphumele/Thokoza informal settlement. High levels of *E. coli* can cause severe diarrhea and stomach pain and can be extremely dangerous for small children where infection can damage their red blood cells and kidneys.

Apart from the immediate health hazard, the sewage spills resulted in approximately one million liters of raw sewage entering into the already fragile Umgeni River, thus impacting on the environmental integrity of the river. The cumulative sewage spill issues in the Siphumele/Thokoza informal area resulted in a high number of fish kills in the Umgeni River, which further illustrates the extent of the problem.

Source: WESSA & Howick West Pump Station, 2008

7.4 Environmental impact

Case study outlining the potential environmental effect of sewage spills on wetland habitats due to the impact of load-shedding on wastewater treatment plants.

Overview:

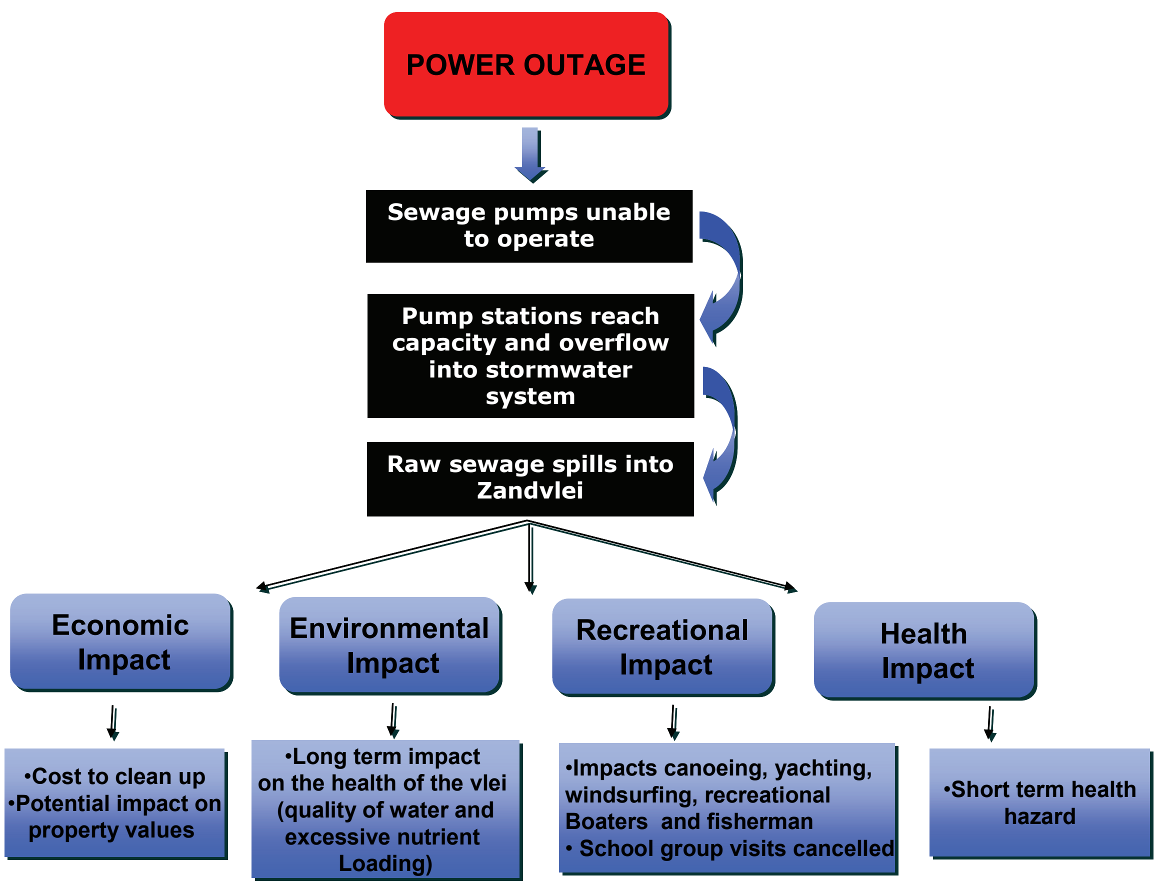
This case study evaluates the environmental impact of raw sewage flowing directly into the Zandvlei wetland, as a direct result of a power cut causing a wastewater treatment plant to overflow.

Zandvlei is a wetland, river system and estuary situated on the False Bay Coast in Cape Town. Many consider this to be the most important freshwater recreational area in the city and it is home to the Peninsula Canoe Club and Imperial Yacht club. Zandvlei is very popular among windsurfers, recreational boaters, fisherman and local residents.

Impact assessment:

In February 2006, Zandvlei was polluted by millions of liters of raw sewage as a result of power outages. Cape Town's 393 sewerage pump stations receive sewage by gravity feed from residential areas which is pumped to sewerage treatment plants. During power outages, these pumps are not able to function and sewage continues to flow to the relevant pump stations. When these stations reach capacity, overflow sewage is diverted into the stormwater system. The stormwater system in turn flows into rivers and vleis (preventing spillages within residential areas).

During the outages in late February, raw sewage flowed directly into the water courses feeding into Zandvlei and its various wetland areas. These include Westlake, Keysers Rivers in the north-west and the Sand and Langevlei rivers in the north-east. The 10 smaller pumps in Marina da Gama also discharged raw sewage directly into Zandvlei.



Cost to clean up: R5000 (3 staff for 3 days) – resulting in intrinsic costs: School groups cancelled, normal functions at the reserve are neglected

Environmental costs: Bioaugmentation (adding naturally occurring microbes) is used as short term solution to aid the breakdown of sewage and prevent short term impacts such as possible health hazards. This is a short term solution and it does not deal with the long term impacts on the environment. Most notably, excessive nutrient loading in Zandvlei has resulted in the system suffering from eutrophication. Excessive nutrient loading will eventually cause the system to crash as the water turns toxic. The long term cumulative impact of excessive and constant raw sewage inflows into Zandvlei will ultimately result in the collapse of the last functioning estuary in Cape Town.

Recreational costs: The local canoe club, yacht club, recreational boaters, windsurfers and fisherman are impacted by reduced water quality.

Residential Impact: Residents of Zandvlei are the most highly impacted end user group. Apart from the impacts associated with general use of the vlei (recreation), sewage spills and the resultant impact on water quality and the general 'health' of the wetland can have further 'knock-on' effects. Many residents consider the impact on property values to be of paramount concern. The wetland is considered to be the main point of attraction for local residents and potential property buyers; the polluted system could impact property values.

Conclusion:

Load-shedding has impacted sewage pump stations in Cape Town and was the cause of a spill that saw millions of liters of raw sewage flowing into Zandvlei, the last remaining estuary in the False bay coast line. Experts believe that this, and other sewage spills, will have a notable detrimental impact on the long term ecological condition of the vlei. The immediate 'knock-on' effects impacted recreational users and local residents. Many local property owners express their concern for the impact on property prices, including the long-term impact should the water quality at Zandvlei continue to deteriorate.

Source: City of Cape Town, Cape Nature, Zandvlei Trust, 2008

7.5 Impact of load shedding on water boards

Johannesburg Water:

Johannesburg Water has experienced a number of impacts on various areas of their operations due to power outages.

> Johannesburg Water is a municipal entity owned by the City of Johannesburg and it provides water and sanitation services to the residents of Johannesburg. The entity supplies some 650 000 domestic, commercial and industrial customers and serves an estimated 3 million people.

The table below shows the high frequency of power outages at Johannesburg Water and the total duration of these events for 2007 & 2008.

	2008		2007	
Month	**No. of outages**	**Total outage duration (minutes)**	**No. of outages**	**Total outage duration (minutes)**
January	38	86.79	20	109.96
February	26	120.22	4	7.73
March	24	45.73	11	9.46
April	36	120.21	2	1.3
May	23	36.89	13	19.05
June	23	29.51	15	16.12
July	13	32.19	14	14.25
August	14	33.15	16	25.58
September	12	21.13	11	11.91
October	16	31.37	36	92.33
November	19	25.57	25	61.04
December	18	61.89	31	39.07
Total	**262**	**644.65**	**198**	**407.8**

Source: Johannesburg Water, 2008

Power outages have impacted on Johannesburg Water in a number of ways including:

- Impacts on Instrumentation and programmable logic controllers (PLCs) which are used for measurement and control purposes
- Requires the use of more ferric chloride for the removal of phosphates instead of using biological removal processes
- Labour costs: overtime costs for employees is dramatically increased
- Water quality deteriorates after 2 hours of power outage, mainly affecting ammonia and orthophosphate levels; after 4 hours ‘what comes in goes out’ and there is thus no purification.
- Treatment facilities do not have back-up generators and Johannesburg Water is looking to use more efficient technologies for the aeration process (which consumes the most electricity).

Magalies Water:

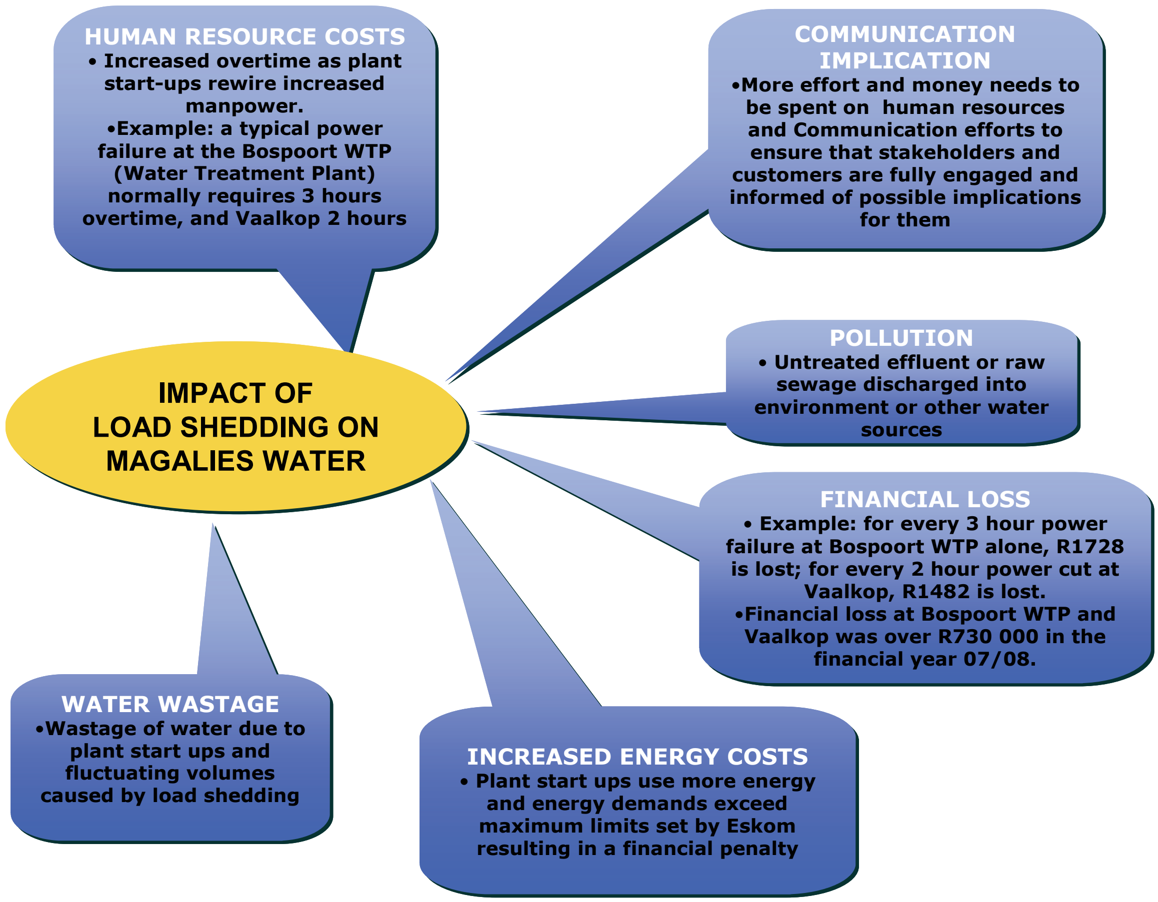
Magalies Water is a state owned Water Board providing a wide range of related water and sanitation services. It operates in four provinces including Gauteng, Limpopo, North West and Mpumalanga covering an operational area of approximately 34 000 square kilometers.

Magalies Water plants rely solely on Eskom to supply a reliable and constant supply of energy. During a power outage, all operations halt at Magalies Water. For every power failure, an extra 2 hours is required for the plant start-up, which results in a ‘double blow’ in terms of operations and the resultant financial impact.

Load shedding impacts on energy demand in two ways:

1. Plant start-up, especially big pumps, requires more energy than if they were running normally.
2. A larger number of pumps will be started to make up for lost time and to ensure that reservoirs are refilled above critical levels. This results in the energy demand exceeding the maximum limits set by Eskom, thereby resulting in an additional financial loss (in the form of a penalty from Eskom).

Impact of load shedding on Magalies Water:



**Source: Tap In, March 2008*

The current power crisis has resulted in significant revenue losses combined with added expenditure costs for Magalies Water, as well as production losses on the part of its major customers such as mines. Magalies Water is looking into alternate energy sources, such as diesel generators, to assist in meeting its energy needs. Added to this Magalies Water is currently consulting with Eskom (as is the case with most water boards) to outline workable options to deal with load shedding challenges.

7.6 City of Cape Town: generator back-up costs

Case study outlining the power outage mitigation strategies drafted by the city of Cape Town for a sample of their wastewater treatment plants, 2006

This following table outlines City of Cape Town's basic assessment of wastewater treatment plants, in terms of the impact of a power outage on their operations, and possible short and long term mitigation strategies. The table represents a sample of Cape Town's WWTW from information collated in 2006.

Wastewater treatment works	Percentage pumped	Impact of power outage	Short term mitigating strategy	Long term strategy	Time for impact
Athlone Average flow: 105 ML/day	All pumped. Langa pumpstation has stand-by generator.	Partial treatment can take place	Divert raw sewage into isolated maturation pond, then blend good quality effluent with poor quality effluent	Add standby generator	2 days
Bellville Average flow: 55 ML/day	Mostly pumped. Gravity flow lifted on site.	Partial treatment can take place	Standby generator to power screens and a pump	Add larger standby generator and build maturation ponds	1 day
Scottsdene Average flow: 9 ML/day	30% gravity, then lifted at inlet	Raw wastewater overflows into the emergency pond and spills into the river after about 6b hours	Has an emergency pond for temporary storage	Add standby generator	6 hours
Camps Bay Average flow: 2 ML/day	100% gravity	Overflows to surf zone	Has standby generator for screens	Add larger standby generator	1 day

Greenpoint Average flow: 30 ML/day	100% gravity	Overflows to surf zone	None	Add standby generator	1 day
Cape Flats Average flow: 130 ML/day	90% gravity	Partial treatment can take place	Divert raw sewage into isolated maturation pond then blend good quality effluent with poor quality effluent	Add standby generator	7 days

**Source: City of Cape Town, 2006*

Note: *The City of Cape Town has invested heavily in a large number of fixed and portable generators to ensure that its wastewater treatment facilities and pump stations are able to operate during power outages. The data used in this case study is from 2006 and many of the 'Long term strategies' (as outlined above) have since been implemented.*

The Table below highlights the costs to purchase generators for a sample of Cape Town's WWTW, 2006

Plant	Generator location	Generator size	MV circuit breaker	LV circuit breaker	Generator enclosure	Total cost
Athlone	Pump station	700 KVA		R4,200	R5,000	
	Blowers	1500 KVA	R200,000	R4,200	R5,000	
	Total cost (2006 estimates)	*R2.5 M (million)*	*R0.2 M*	*R0.0084 M*	*R0.01 M*	*R2.7184 M*
Scottsdene	Inlet works	1500 KVA		R4,200	R5,000	
	Aerators	1500 KVA		R4,200	R5,000	
	Total cost (2006 estimates)	*R1.0 M*		*R0.0084 M*	*R 0.01 M*	*R1.0184 M*

Camps Bay	Inlet works	1500 KVA		R4,200	R5,000	
	Total cost (2006 estimates)	*R0.5 M*		*R0.0042 M*	*R0.005 M*	*R0.5092 M*
Greenpoint	Inlet works	1500 KVA		R4,200	R5,000	
	Total cost (2006 estimates)	*R0.5 M*		*R0.0042 M*	*R0.005 M*	*R0.5092 M*

**Source: City of Cape Town, 2006*

The basic impact assessment table and associated sample expenditure costs for generators clearly illustrates the significant expense involved with the safe-guarding of wastewater treatment facilities from the negative impacts of power outages. The cost to provide backup generators for only 4 of Cape Town's wastewater treatment plants amounts to just under R5 million (2006 costs). This illustrates the potential cost to provide back-up power for all 956 WWTW in South Africa.

Most South African WWTWs purchase their electricity from ESKOM and do not generate their own source of power. Any on-site power generation is only provided for standby power.

8. Appendix 1

WASTEWATER TREATMENT WORKS: Detailed scenario analysis

Take a scenario where a typical WWTW utilises a biological treatment process, chemical dosing to control their pH, phosphorus and pathogenic microorganisms, as well as a SCADA communications system which runs and monitors all the major processes of the plant. In such as case:

An interruption in supply for longer than 6-8 hours will have an immediate impact on the plant. Should this be a once-off occurrence, the plant will be able to buffer and stabilize, and will recover within 2-4 days.

Should such interruptions in electricity supply occur on a more frequent basis (e.g. 2- 3 hours, at 2 times a day), the plant will not be able to carry the process loads, and a backlog in treatment capacity will develop beyond the design capacity of the plant. Untreated effluent will emerge and be discharged from the plant to the environment on a daily basis. WWTW do not have "holding facilities" which can retain wastewater until situations improve for "later treatment‟. Wastewater treatment is a process – and of continuous nature.

- **Computerized control and monitoring systems:** these consist of a distributed control system, using programmable logical controllers (PLC's) strategically placed in the plant. PLC's controls all the drives and systems in its area and also serves as an input/output device to collect data on the status of equipment and process variables. The PLC's are interconnected via an industrial communication network, through which they communicate with each other and the supervisory control and data acquisition system (SADA). SCADA systems functions as the Human Machine Interface (HMI) and all supervisory control is executed from the SCADA system. Shut-down of such system will render all process equipment out of commission, including microprocessor driven equipment, such as field instruments and protection relays.

- **Inlet works:** no screening will be removed, which will block the screens and result in overflow of incoming raw sewage to the environment. Repairs to screen and motors will be inevitable and will have high financial implications, which may reach beyond the approved operations and maintenance (O&M) budget of the treatment works. The lack of degritting will result in grit being transferred and deposited to the primary settling tanks, anaerobic digesters and biological reactor. These structures will later have to be decommissioned and physically cleaned, which is not always possible since no alternative structure exist to take the place of the treatment function of these structures. Damages to aerators, motors and mixers are inevitable as this equipment is not designed to handle gross and hard particles.

- **Primary settling:** Desludging will result in sludge not being wasted and transferred to the sludge thickeners. This will increase the COD loading to the activated sludge plant above its design capacity and will result in carbon, nitrogen and phosphorus discharge to the river. Disinfection will not take place effectively or economically with such high SS in the effluent to the disinfection plants. Anaerobic digesters will be under-utilized at some times and overloaded at times of normal power supply, causing shock loading, acidification, and numerous other process defunctionality in sludge management practices.

- **Activated sludge:** Aeration control will be affected with no oxygen being introduced to the process, return sludges not being recirculated, settling taking place where mixers are not operational, etc. Overall, this will have consequences of poor/no biological phosphate and nitrogen removal, substandard effluent with COD and SS carry-over and failure of the biological nutrient removal system.

- **Waste activated sludge (WAS) and recirculation:** The WAS withdrawal system maintains the sludge age in the biological reactor at a pre-determined level, which assists with the optimization of the biological process. The sludge age ensures that the nutrient removal of nitrogen and phosphorus takes place. Failure to maintain the correct conditions to the nutrient-removing microorganisms will affect their type, age, presence, and performance. Ineffective microbial activity takes many months to recover, and microbes may have to be re-inoculated into the system in case of loss of certain biological activity.

- **Pump Stations:** Flooding, inability to remove the sludge, effluents or to reach their destined land application will result in total plant upset, and non-compliance to effluent discharge standards. Groundwater pollution is a high risk under such conditions.

- **Measuring Systems:** The failure/loss of these systems would not directly lead to failure of the process but would make these systems inoperative. The result would be that the plant operator and manager do not have a basis to operate the plant from.

Source: DWAF, The impact of electricity load shedding on wastewater treatment in South Africa, 2008

9. Appendix 2

WASTEWATER TREATMENT WORKS: Detailed process scenario analysis

The following scenario depicts the main pollutants that are being removed on a daily basis via the wastewater treatment process; the process unit that is responsible for such treatment; whether power outages impact on the process unit; and lastly, the consequence of not removing these pollutants from the wastewater before discharge to the environment:

Impact of a power outage on wastewater treatment processes

Contaminant removal in WWTW	Process responsible for contaminant removal	Impacted by electricity supply	Consequence of non-removal of contaminant
Suspended solids	Sedimentation	Yes	If discharged, untreated sludge deposits and anaerobic and septic conditions will occur in the environment, which will lead to polluted rivers, oxygen depletion, fish deaths, with environmental and public health compromised
	Screening and communication	Yes	
	Filtration	Yes	
	Flotation	Yes	
	Chemical polymer addition/sedimentation	Yes	
	Coagulation	Yes	
Biodegradable organics	Activated sludge variations	Yes	If discharged untreated into the environment, this can lead to the depletion of natural oxygen resources and the development of septic conditions
	Fixed-film: trickling filters	No	
	Fixed-film: rotating biological contractors	Yes	
	Lagoon and ponds variations	No	
	Intermittent sand filtration	Yes	
	Physical-chemical systems	Yes	

Pathogens	Chlorination and hypochlorination	Yes	**This is the most critically impacted point** Diseases can be transmitted by the pathogenic organisms in the water, which can impact human, animal and plant life
	Ultraviolet	Yes	
	Ozonation	Yes	
	Oxidation pond radiation	No	
	Land application	Yes	
Nutrients	**Nitrogen removal**		Nitrogen, phosphorous and carbon are essential nutrients for microbial growth. When discharged into an aquatic environment they will lead to the growth of undesirable aquatic life, such as algae blooms. When discharged in excessive amounts, they can also lead to the pollution of groundwater, (e.g. Roodeplaat dam and Hartbeespoort dam, etc.). Typical consequences are eutrophication with oxygen depletion, fish deaths, algae blooms, etc.
	Suspended-growth nitrification and denitrification	Yes	
	Fixed-film nitrification and denitrification	Yes	
	Amonia stripping, ion exchange, breakpoint chlorination	Yes	
	Land application	Yes	
	Phosphorus removal		
	Metal salt addition/sedimentation	Yes	
	Lime coagulation/sedimentation	Yes	
	Biological-chemical phosphorous removal	Yes	
	Land application	Yes	
Priority pollutants	Various physio-chemical processes	Yes	When discharged in excessive amounts, they will have various impacts as known or suspected carcinogenicity, mutagenicity, or high acute toxicity
	Variety of biological processes	Yes	

Heavy metals	Chemical precipitation	Yes	Heavy metals are added to wastewater from commercial or industrial activities. These can deposit in rivers, etc. High levels will result in fish death, human health deterioration and various illnesses
	Ion exchange	Yes	
	Land treatment	Yes	
Dissolved inorganic salts	Ion exchange	Yes	These constituents are added to domestic water supply as a result of various water use applications. They contribute to the salinity of natural waters with various implications on environmental sustainability of natural species.
	Reverse osmosis	Yes	
	Electrodialysis	Yes	
Refractory organics	Carbon absorption	Yes	These organics resist conventional treatment methods and requires specialized treatment. In excessive amounts these contaminants are toxic to biological systems, animal and human life.
	Tertiary Ozonation	Yes	

Source: DWAF, The impact of electricity load shedding on wastewater treatment in South Africa, 2008