Evaluating water consumption in a national electricity provider

VB Mokoena

orcid.org/0000-0002-9015-0007

Mini-dissertation submitted in partial fulfilment of the requirements for the degree *Master of Business Administration* at the North-West University

Supervisor: Mr MJ Botha Prof: Christo Bisschoff

Graduation May 2018

Student number: 25678949

ACKNOWLEDGEMENTS

Firstly, let me take this opportunity to give praise and thanks to the mighty Lord for giving me the courage and strength to complete this mini-dissertation. I did not do it because I'm wise or clever; I did it because of the will from the mighty lord.

I would also like to thank the following individuals who gave me their physical, emotional and spiritual support through the journey of MBA.

- My Parents Lydia and Lucas Mokoena, you have been a pillar of my strength and you have supported me throughout my studies from primary school until I'm able to stand on my own. I want you to be proud of me.

- To my loving kids Herold, Kay, Tumi and Tidi, thank you for your support and understanding when I had to spend most of my time away from home for the past three years while busy working on my MBA studies.

- My greatest appreciation goes to Mr Martin Botha, my study leader for his support and guidance to ensure that I produce a report of the high quality standard. I really appreciate working with you.

- To my syndicate group, Sedibeng MBA (Shadrack Mkhari, Tarisai Mutasa, Marks Nkele and Sinclair Kaudani) thank you so much for an amazing three years which I have spent with you. You became part of my family and thanked you for the encouragement and support.

- To my friend Sechaba Motselebane thanks your support and encouragement throughout the whole journey for the past three difficult years.

- Mrs Antoinette Bisschoff for the language, technical and typographical editing of this mini-dissertation.

- Mrs Wilma Breytenbach for the statistical analysis for my questionnaire.

- To my employer and sponsor Mr Thomas Conradie thanks for your support and encouragement.

- To Mokgele Leie I like to thank you for ensuring that my textbooks and my account are paid and the follow up thereof.

- Lastly to my wife Motsoka Maimane for the support, courage and prayers you gave me and sacrificed your precious time looking after our kids while I was away from home busy working on my MBA studies.

ABSTRACT

Water resources in South Africa comprise the following three sources in the order of magnitude: surface water (77%), dams and rivers return flows (14%), rain and groundwater. There is 98% assurance level which suggests that any peaks in future demand will result in demand exceeding supply and this is a source of vulnerability that needs to be addressed.

The fact that only three coal-fired power stations are within the water usage targets provides the reason for investigating the problem. Eskom is under pressure to utilise the 2-3% of South African water which is allocated to them for power generation wisely and effectively. During these times of water constraints, it is important that the power stations are operational without violating their water use license agreements. The South African Electricity Supply Industry (ESI) remains dominated by the state-owned and vertically integrated utility provider Eskom. It ranks seventh in the world regarding size and electricity sales. It generates about 95% of South Africa's electricity and another 40% for the African continent. Eskom owns and controls the high voltage transmission grid and supplies about 60% of its electricity directly to customers. The remainder of the electricity distribution is undertaken by 177 local authorities that buy bulk-supplies of electricity from Eskom, while some also municipalities do generate small amounts of electricity themselves which they sell in their areas of jurisdiction. Eskom has 28 power stations of which 14 are large coal-fired stations. The majority of coal-fired power stations are situated near the coal mines in the North-East of the country. All the coal-fired power stations are dependent on two main raw material inputs to function; this is coal and water. Authorisation to use water is dependent on a water licence, and each of the power stations has a water use licence. The water use licence is a binding document which outlines the maximum amount of water which the power station can extract from the water source.

Keywords: Eskom, Litres per unit sent out, zero liquid effluent discharge, water management, water consumption, National energy regulator of South Africa

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LIST OF ABBREVIATIONS

L/USO	Liters per unit sent out
ZLED	Zero liquid effluent discharge
ML	Mega liter
WAF	Water accounting framework
ESI	Electricity supply industry
NERSA	National energy regulator of South Africa
L/USO	Liters per unit sent out
ZLED	Zero liquid effluent discharge
ML	Mega liter
WAF	Water accounting framework
ESI	Electricity supply industry
NERSA	National energy regulator of South Africa
MW	Megawatt
UN	United nations
CEO	Chief executive officer
WMTT	Water management task team
MSA	Measure of sample adequacy
WC/WDM	Water control/water demand management

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CHAPTER 1

1. INTRODUCTION

1.1 BACKGROUND

The South African Electricity Supply Industry (ESI) remains dominated by the state-owned and vertically integrated utility provider Eskom. It ranks seventh in the world regarding size and electricity sales (Eskom, 2000:35). It generates about 95% of South Africa’s electricity, and another 40% for African continent (Eskom, 2000:35). Eskom owns and controls the high voltage transmission grid and supplies about 60% of its electricity directly to customers. The remainder of the electricity distribution is undertaken by 177 local authorities that buy bulk-supplies of electricity from Eskom, while some also municipalities do generate small amounts of electricity themselves which they sell in their areas of jurisdiction (NERSA, 2015:78). Eskom has 28 power stations of which 14 are large coal-fired stations. The majority of coal-fired power stations are situated near the coal mines in the North-East of the country (Eskom, 2000:21). All the coal-fired power stations are dependent on two main raw material inputs to function; this is coal and water. Authorisation to use water is dependent on a water licence, and each of the power stations has a water use licence. The water use licence is a binding document which outlines the maximum amount of water which the power station can extract from the water source. It also outlines the qualities and quantities of the effluent which the station can release to the environment (Eskom, 2013:7).

Each power station has its water consumption targets, depending on the design and the technology used by the power station.

L/USO determines the amount of water in litres which was used for the electricity production such as for turning the turbine, ash dust suppression, ash transportation and effluent disposal. This is divided by the megawatt (MW) sent out to the grid. When the power station is producing electricity but utilised it for internal electricity production processes such as electric feed pumps instead of steam feed pumps, the power station gets penalised. The reason being that the megawatts which were supposed to be sent out to the grid are used internally by the very same power station, for example. The denominator (total MW sent out) will be low (Eskom, 2016:11).

For the 2015/16 financial year, the total water consumption in Eskom was 1.65 litres of water per unit (MW) sent out to the grid. This is above the target of 1.45 litres of water per unit (MW) sent out to the grid (Eskom, 2016:8). Out of fourteen coal-fired power stations, there are only three coal-fired power stations which are within the limit. This sends a strong message that Eskom is not in control of the water usage or consumption and measures and actions need to be taken to bring this situation under control (Eskom, 2016:8). Table 1.1 below is comparing the annual water targets against the actual water consumptions of all fourteen coal-fired power stations in the 2015/2016 financial year (Eskom, 2016:8).

Table 1.1: Power stations water targets and water consumption for 2015/16 financial year.

Power Stations	Annual Target (L/USO)	Year-end Actual
Arnot Power Station	2.2	2.53
Camden Power Station	2.3	2.34
Duvha Power Station	2.14	2.33
Kriel Power Station	2.19	2.33
Komati Power Station	2.42	2.75
Kendal Power Station	0.14	0.19
Matla Power Station	2.03	2.31
Matimba Power Station	0.13	0.13
Majuba Power Station	0.99	1.22
Medupi Power Station	0.55	0.15
Hendrina Power Station	2.4	2.55
Grootvlei Power Station	1.77	1.91
Tutuka Power Station	2.00	2.28
Lethabo Power Station	1.90	1.97
Eskom	**1.45**	**1.65**

Source: (Eskom, 2016:8)

All the coal-fired power stations are committed to zero liquid effluent discharge (ZLED). The idea behind the ZLED is that all the power stations must not release any effluent water (by-product) to the environment.

Therefore, the effluent water must be re-used for the production processes, for example, to use the effluent water for ash transport or dust suppression or recover the water back into the cooling water system (Eskom, 2013:11). The research intends to identify the causes of this high water usage.

1.2. MOTIVATION OF THE TOPIC

South Africa is currently experiencing a serious drought (Ewn, 2016:1). There are some restrictions implemented in many parts of the country regarding water usage. The aim is to conserve the available water so that all the stakeholders can have access to the water. Electricity generation in coal-fired power stations is highly dependent on access to water. Currently, the water consumption in Eskom is 1.65L\USO (litres per unit sent out) against the target of 1.45 L\USO Therefore it is important to identify the areas and reasons which are responsible for the excessive water consumption in Eskom (Eskom, 2016:8).

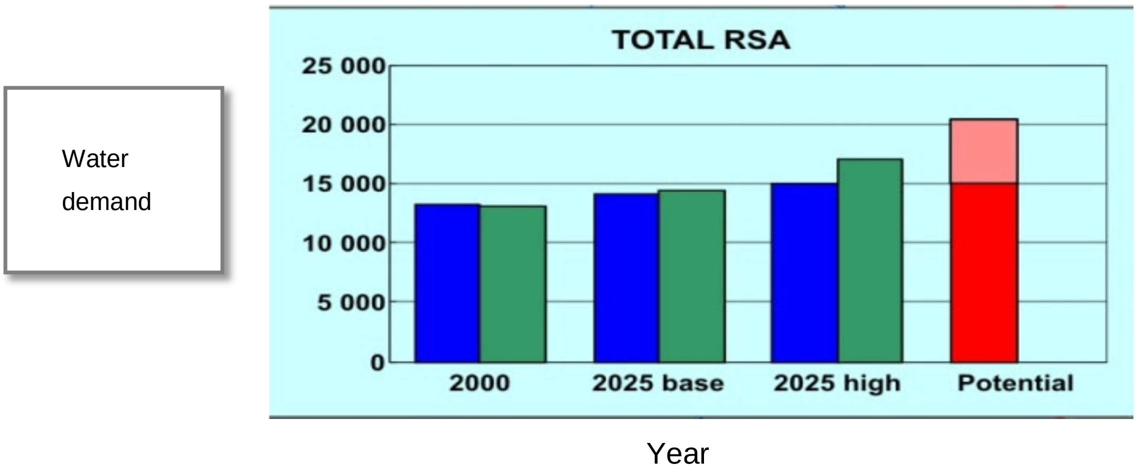
1.3 PROBLEM STATEMENT

Water resources in South Africa comprise the following three sources in the order of magnitude: surface water (77%), dams and rivers return flows (14%), rain and groundwater (9%) (DWAF, 2010:4). There is 98% assurance level which suggests that any peaks in future demand will result in demand exceeding supply and this is a source of vulnerability that needs to be addressed (DWAF, 2010:4).

The fact that only three coal-fired power stations are within the water usage targets provides the reason for investigating the problem. Eskom is under pressure to utilise the 2-3% of South African water which is allocated to them for power generation wisely and effectively (Eskom, 2016:3). During these times of water constraints, it is important that the power stations are operational without violating their water use license agreements.

Figure 1.2 shows that it is evident that in 2025 the water demand will exceed the water availability due to infrastructure development in South Africa. Water availability (blue bars), water use (Green bars) and water development potential – future demand (red bars) (DWAF; 2010:5).

Figure: 1.2: Water availability, water use and water development potential – future demand.



Source: (DWAF; 2010:5)

1.4 OBJECTIVES OF THE STUDY

1.4.1 Main objective

The main objective of this study is to investigate water consumption at coal-fired power stations**.**

1.4.2 Primary objectives

The following primary objectives are set to reach the main objective:

- Investigate the factors contributing to high water usage in the coal-fired power stations;
- To identify whether all the coal-fired power stations are complying with Eskom water management policy;
- Investigate the key plant processes which contribute to high water usage;
- Investigate the prioritisation process and projects which are consistently applied to the power stations to ensure that the water consumption is within the target;

- Investigate the management practices that are applied to ensure minimal use of water in the power station;
- To identify the key performance measurement systems for the reporting and management of water consumption in the coal-fired powered stations; and
- To identify the key performance indicators which are reported and managed for water consumption.

1.4.3 Secondary objectives

Investigate the primary contributing factors to high water consumption in generation;

- Investigate if the water consumption is accurately monitored and accounted for;
- Investigate if reporting structures are in place for effective management of water consumption; and
- Investigate the variables which could be the causes of high water consumption such as workforce, finances, machines, measurements, material, method and environment.

1.5 RESEARCH METHODOLOGY

1.5.1 Literature study

In the literature study the Eskom procedures and policies, research articles, Eskom reports, internet articles and Eskom intranet were used to understand the theory.

1.5.2 Empirical research

The population identified for this study includes all 14 the coal-fired power stations. This constitutes a population of 140 participants. Employees targeted by the survey include managers, supervisors, artisans, technicians, engineers, operators and subject experts. Questionnaires, interviews and observations were utilised to collect the data where after statistical analysis were performed to obtain the results.

1.5.3 Scope of the study

The study focuses on all coal-fired power stations and various departments within such as engineering, maintenance, operating, production, human resources and finance.

1.6 SUMMARY

The first chapter introduced and provided the background of water performance in Eskom coal-fired power stations.The chapter presented the problem statement and highlighted the set objectives to address the problem statement.The problem statement which is the scarcity of water in South Africa and the over-consumption of water by the coal-fired power stations.The research methodology for this study was discussed.

CHAPTER 2 LITERATURE STUDY

2.1 INTRODUCTION

The main aim of this chapter is to investigate the literature applicable to the concepts covered in the study. It further focusses on the literature and techniques which are available in managing and monitoring water consumption in coal-fired power stations. The literature study is aimed at improving the understanding of water consumption of the coal-fired power stations. According to WWF (2014:12), South Africa produces nearly 86% of its electricity through coal-fired power stations, with a heavy reliance on water-intensive, wet-cooled coal power stations. In 2010, wet-cooled coal power stations represented approximately 78% of the country's power generation, while consuming 98% of the water requirements of the power generation utility Eskom. Moreover, although the majority of existing power stations have been built in water catchment areas, certain areas are water scarce and therefore necessitate the need for interbasin water transfers. This requires the use of water pipelines, pumping stations and various other components all of which in turn requires energy to operate (Gulati, M. 2014:12).

Water is a strategic primary energy source which plays a significant role in electricity generation. Eskom power stations constantly operate to supply more than 95% of South Africa's electrical energy and more than half of electricity used on the African continent (Eskom, 2013:40). Without water, this output would not be possible. Eskom is a key stakeholder in the water sector using approximately 320 million cubic metres of water nationally (Eskom, 2013: 40). Eskom is committed and determined to support the drive to improve the management of South Africa's scarce water resources by implementing some innovative and effective water conservation and management strategies, policies and practices (Eskom, 2013:40).

2.2 TECHNICAL ASPECTS

The electric power industry is a large water user and is dependent upon reliable water supplies. Adopting new water-conserving technologies for power production can help alleviate the impact of future water shortages. Several water use reduction technologies are available each with different benefits (Power, 2012:54).

Figure 2.1: Formula Used to Calculate Total Water Usage (l/USO)

$$L/USO = \frac{Raw \quad water_{inlet} - Water \quad To \quad Third \quad parties}{Total \quad MW \quad Sent \quad Out}$$

Figure 2.1 indicates the calculation of the total water consumption in litres per unit sent out. This means the amount of water used in litres to produce and sent out one megawatt of electricity to the grid. If the power stations produced electricity but used it on the other component of the plant for its operations, the power station gets penalised because instead of sending the electricity to the grid, the power station will be using the produced electricity for its operations. The power station is designed with two types of feed water pumps to feed water circulations, which are steam feed pumps and electric feed pumps. During normal operations, the power station will be using the steam feed pump to circulate the water to the boiler. This is the cost-effective way of circulating water because the steam feed pump is using exhaust steam from the boiler. The electric feed pump is using electricity which is generated by the power station and was supposed to be sent to the grid. The other factors negatively affecting water consumption according to the calculations in figure 2.1 are:

- Introducing cold demineralised water to replace the already boiled demineralised water which gets lost from the feed water circulation as a result of passing valves and water leaks;
- Operating all the redundancy pumps due to plant ageing or pumps not delivering the flow as per their design; and
- Poor cooling water performance due to lack of maintenance. The cooling does not extract enough heat from the cooling water which was used to condense the steam from the turbine in the condenser water box (Eskom, 2013:8).

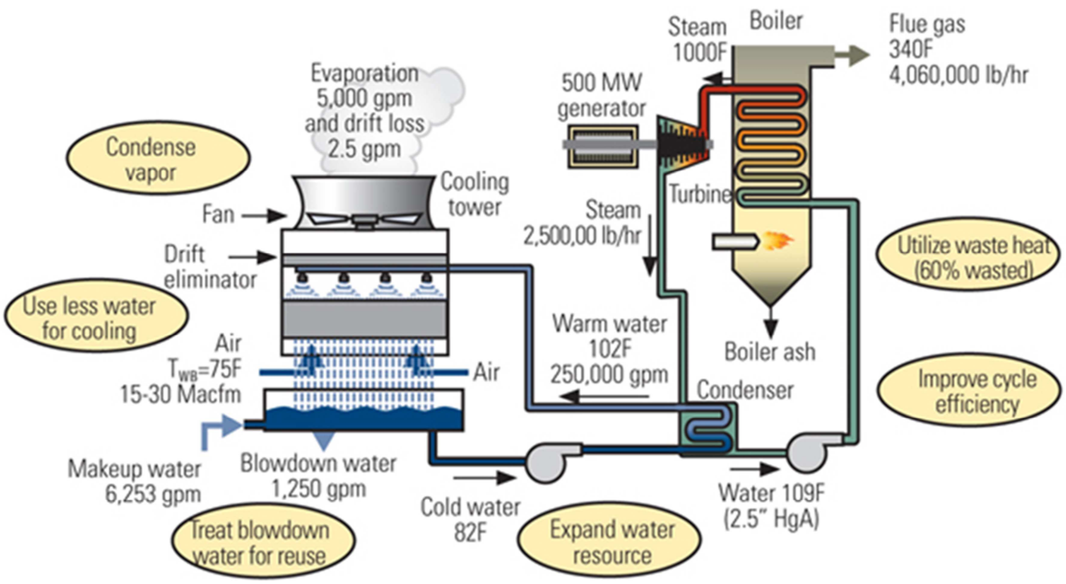
2.2.1 Essential elements

Most of the water is used for cooling systems within electricity generation, and Eskom has three types of cooling systems at its power stations. Wet cooling is the most common, but direct and indirect dry cooling systems are also used (Zammit, 2012: 157).

Although the expense involved in dry cooling systems is greater than in conventional wet cooling systems, limited available water resources may override economic considerations in determining the choice between these technologies (Eskom, 2013: 41).

Figure 2.2 below indicates a schematic presentation of water use in a typical 500-MW thermal plant with a wet cooling tower. The cooling tower in this example requires 23.67m³/min of freshwater when running at full load. The makeup water (water to be added into the water-steam cycle) is required to replace the water lost to evaporation, drift (the water droplets of the process flow allowed to escape in the cooling tower discharge), and cooling tower blowdown.

Figure 2.2: The power regeneration plant water and steam cycle

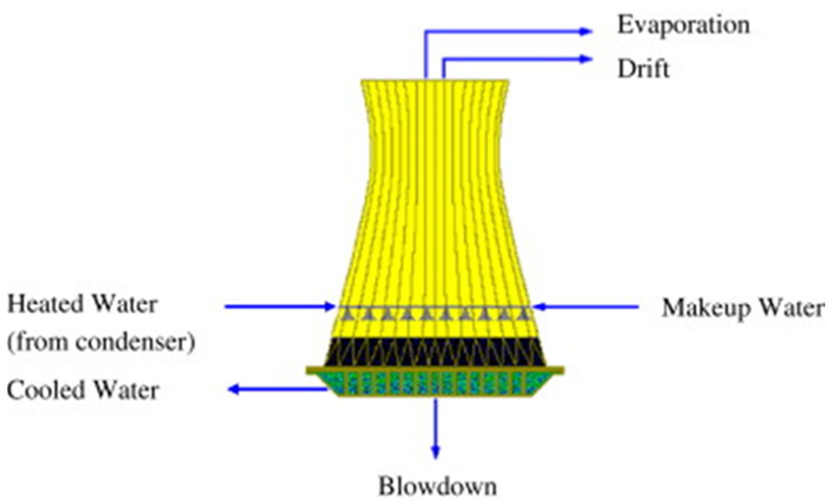


Source: Zammit (2012:143)

Wet cooling is the most commonly used system internationally and locally, but the company has also been phasing in dry cooling systems (Eskom, 2013: 41). The largest use of water in power generation is for condenser cooling. Thermal power plants require a large amount of cooling water to condense the steam turbine exhaust steam. The lower the condensing temperature, the lower the backpressure on the steam turbine, which increases plant thermal efficiency. The most effective method of rejecting this heat is through the use of cooling water (EPRI, 2012: 43).

Wet cooling and indirect dry cooling systems both use condensers, cooling water and cooling towers. In both these systems, the cooling water flows through thousands of condenser tubes, with the steam on the outside. Condensation is achieved as a result of the temperature difference between the cooling water and steam (Eskom, 2013: 41). The warmed cooling water flows to a cooling tower where an upward draft of air removes the heat from the water. After cooling, this water returns to the condenser. Unfortunately, during wet cooling, the upward movement of air means that a substantial amount of water is lost through evaporation, as the water to be cooled is in direct contact with the air. The white plume seen on top of cooling towers at most thermal stations is pure water vapour. The make-up water is added to replace evaporation losses. River water is used for cooling (Energy policy, 2010:5654).

Figure 2.3: Schematic diagram of a wet recirculating cooling tower system.



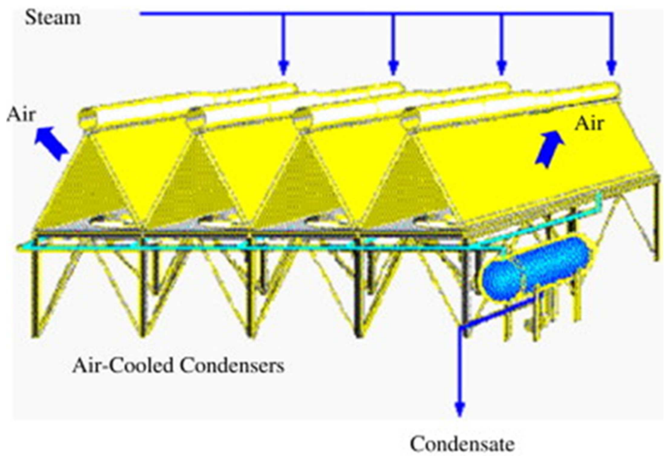
Source: Energy policy (2010:5654)

Eskom has therefore started using dry cooling systems in its effort to conserve South Africa's limited water supplies. Although the expense involved in dry cooling systems is greater than in conventional wet cooling systems, the limited available water resources override economic considerations in determining the choice between the two technologies (Eskom, 2013: 41).

The indirect dry cooling system also uses a cooling tower and water. Here, however, the operating principle is similar to that used in car radiators. Heat is conducted from the water using A-frame bundles of cooling elements arranged in concentric rings inside the tower. Cooling water (clean water) flowing through these elements cools down as the cold air passes over them and returns to the condenser. This is referred to as a closed system as there is no loss of water due to evaporation. In the direct dry cooling system, steam from the last stage turbine blades is channelled directly into radiator-type heat exchangers, with no cooling towers. The heat is conducted from the steam to the metal of the heat exchanger. Air passing through the exchanger is supplied by a number of electrically driven fans. The air removes the heat, thus condensing the steam back into water which will be used once again to produce steam in the boiler (Eskom, 2017:1).

Dry-cooled systems can decrease total power plant water consumption by more than 90% (Eskom, 2017:8). There are however trade-offs to these water savings, namely, high capital costs and lower thermal efficiencies. In power plants with lower thermal efficiencies, more fuel is needed per unit of electricity produced, which can lead to higher air pollution and environmental impacts from mining processing and transport fuel (Eskom, 2014:8).

Figure 2.4: Schematic diagram of a dry cooling system



Source: Energy policy (2010:5654)

Currently in Eskom the following power stations namely Matimba, Kendal, and Majuba which are using the dry cooling system to minimise the use of water for cooling purposes. Majuba operates with half the stations on dry and the other half on wet cooling systems (Eskom, 2013: 41).

Figure 2.5: An aerial view of Matimba Power Station which is one of Eskom's dry-cooling power stations.

Source: Eskom (2014:38).

At Koeberg Power Station, Africa's only nuclear power plant, a different cooling system is used. At Koeberg power plant, sea water is used to condense the spent steam to turn it into liquid form. The water which was used for the condensation at higher temperature is discharged back into the ocean (Eskom, 2014:38).

The turbines at coal-fired power stations are steam driven. Steam is produced using highly purified demineralised water. This water needs to be recovered, both to save water and because of the high costs involved in its production. Spent steam leaves the turbine at a very low pressure and high volume. The temperature is approximately 40℃. Steam cannot be compressed, and the only way to recover the spent steam is through condensation, or changing the vapour into a liquid (Eskom, 2014:2).

2.2.2 Containing consumption

Several factors contribute to higher-than-necessary water usage at coal-fired power plants in the country. These include the age and thermal efficiency of existing plants, declining coal quality, which requires burning more coal to produce the same amount of electricity, and declining raw water quality supplied to plants, which means that more clean water is needed to dilute the extra salt (WWF, 2014:13). Decades ago Eskom recognised that the organisation would need to find ways of decreasing water consumption and contribute to sustainable water usage. Hence it has a welldocumented commitment to support the drive to improve water management within its operations (Eskom, 2013:41). Over the past two decades, Eskom has introduced some innovative technologies to save and protect water resources. These include dry cooling, sea-water cooling, desalination of polluted mine water and technical improvements in treatment regimes to maximise productivity (Eskom, 2013:41).

2.2.3 Plant consumptive water

Water is used in almost all areas/ facilities of thermal power stations in one way or the other. A typical list of plant systems/ applications requiring consumptive water is indicated as below: (CEA, 2012:3).

- Cooling Water System;
- Ash Handling System;
- Power Cycle Make-up;
- Coal Dust Suppression;
- Evaporation from Raw Water Reservoir; and
- Minimising Effluent Discharge (CEA, 2012:7).

The technical aspects in coal-fired power stations discussed in the proceeding paragraphs need to be closely managed and monitored to ensure that there is no or less water wastage (CEA, 2012:7).

2.3 WATER MANAGEMENT ASPECTS

Whether the water crisis deepens and intensifies or whether key trends can be bent towards sustainable management of water resources depends on many interacting trends in a complex system. Real solutions require an integrated approach to water resource management. Crucial issues that may provide levers for very different futures include:

- Limiting the expansion of irrigated agriculture;
- Increasing the productivity of water;
- Increasing storage;
- Reforming water resource management institutions;
- Increasing cooperation in international institutions;
- Valuing ecosystem functions; and

- Supporting innovation (Cosgrove & Rijsberman, 2000:156).

The water crisis the world community faces today is largely a governance crisis. Securing water for all, especially for vulnerable populations is often not only a question of hydrology (water quantity, quality, supply, demand) and financing but equally a matter of good governance. Managing water scarcity and water-related risks (such as floods or natural disasters) require resilient institutions collaborative efforts and sound capacity at all levels (WWF, 2012:5).

2.3.1 Risk management for water

Risk management is important in the water and wastewater utility sector because the opportunities to intervene and minimise the consequences of failure are limited. One example of preventative risk management is the adoption of drinking water safety plans aimed at identifying and managing the critical control points in the drinking water supply chain from the catchment to tap (Pollard & Stephenson, 2016:158).

Risks are dynamic because they are determined by space and time, they are continually changing. Thus, company risk profiles and the risk status of individual treatment works is in continual flux. Organisations that can manage their risk information and convert snapshots of risk into meaningful dynamic risk profiles can verify and validate the value of their risk management activity (Pollard & Stephenson, 2016:158).

This business environment is complex and difficult. It requires an organisational capacity to:

- Anticipate and assess risk at the strategic, programme and project/operational scales (from issues as diverse as skills retention, to water safety planning and maintenance scheduling);
- Meaningfully compare and prioritise risks of widely varying characteristics;
- Distinguish between simple risk tools and more sophisticated methods;
- Manage risk reduction without unduly compromising business competitiveness;
- Set in place practical mechanisms for risk identification and management;
- Prioritize issues for immediate action and develop contingency procedure and above all; and to
- Develop a risk-aware culture of proactive risk management rather than risk avoidance (Pollard & Stephenson, 2016:134).

2.3.2 Assurance and compliance

Measures instituted by the government to ensure that the provisions of its regulations are being met, Eskom will:

- Ensure that operations have relevant water permits/licences to comply with the relevant legislation;
- Ensure that operations comply with their water permits/licences conditions;
- Continuously undertake due diligence in the form of water management reviews/inspections/audits throughout its value chain to fully understand the extent of water usage and impacts on water resources;
- Ensure that audits are conducted at appropriate time intervals by permits/water use license/waste licences, Eskom policies, standards and procedures as required for assurance and compliance purposes; and
- Devise and implement contingency and adaptation plans to reduce or minimise impacts on water resources (Eskom, 2013:7).

2.3.3 Training and development

Training and development aim to improve current or future employee performance by increasing an employee's ability to perform through learning, usually by changing the employee's attitude or increasing his or her skills and knowledge.

Eskom will:

- Ensure that employees are suitably trained, qualified and experienced staff is deployed to support this policy; and
- Ensure that relevant personnel receive required training and development on water management aspects (Eskom, 2013:8).

Operating training with the assistance of engineering needs to retrain the operators on the operation philosophy of the water-air ejector system. The relevant employees will be trained and assessed on the plant processes which affect water consumption. They will also be trained on the company policies and procedures and also stakeholder legal requirements (Eskom, 2013:8). Training aims to close the identified gaps and ensure compliance (Eskom, 2013:11).

2.3.4 Water management skills

Water managers must be familiar with a wide range of applicable disciplines and be able to interact with a variety of professionals, stakeholders and users. Managers and their agencies should have sufficient technical, economic, social, financial, and environmental skills to be able to engage in dialogue with professionals and affected stakeholders in the regions where improved water management is needed. They should have the capacity to interact with politicians and inform them about the science behind any impact predictions. They need to understand policymakers' short-term political commitments and be able to facilitate the conciliation of politicians' initiatives with long-term sustainable water resource policies. Obtaining new skills requires improved access to information, sharing capacity (example, as when trainees become trainers) and its application. Information materials, training materials, knowledgeable capacity builders and experts are part of the inputs (WRR, 2014:4836).

2.3.5 Policy principles or rules

Policy principles or rules refer to the fundamental norms, rules, or values that represent what is desirable and positive for the organisation in determining the correctness of its actions. The following are the guiding principles for this water policy:

- To facilitate the integration of the water-related legislation into Eskom’s business;
- To support the objectives of the National Water Act Act No 36 of 1998, National Environmental Management Biodiversity Act and Waste Act No 10 of 2004, National Water Resource Strategy 2012, Water Services Act No 108 of 1997and Integrated Coastal Management Act No 24 of 2008;
- To give effect to the principles of the UN CEO water mandate, Eskom, DWA water conservation and water demand management memorandum of understanding;
- To promote and encourage the effective and efficient use of water and conservation and protection of water resources; and
- To foster a culture of compliance with the legislative requirements and to give effect to the Eskom’s ZLED philosophy (Eskom, 2013:8).

2.3.6 Roles and responsibilities

The roles and responsibilities refer to the specific tasks or duties that members are expected to complete as a function of their roles. There are specific activities or obligations for which they are held accountable. The following bullets are duties of each within the organisation at a different level or position.

- The Chief Executive has the overall accountability for ensuring that this policy is implemented;
- Group Executives, Divisional Executives and Senior General Managers shall be accountable for ensuring the development and implementation of effective management systems, and provision of the required resources to ensure that the objectives of this policy are achieved;
- Power stations managers and supervisors shall be responsible for water issues at work;
- Power stations managers shall ensure that all employees are trained in water management tools and procedures that are relevant to their respective functions;
- All the coal-fired power stations shall ensure compliance to ZLED; and
- Each power station shall identify Water Conservation and Water Demand Management initiatives within their respective work area to promote water efficiency (Eskom, 2013:12).

2.3.7 Process monitoring

Accurate water use monitoring, management, accounting and reporting is considered to be an integral and fundamental water management tool available to power stations. All power stations are required to comply with the minimum requirements to ensure that sound and effective water accounting, monitoring, management and water use reporting to ensure consequent water management is achieved (Eskom,2016:4).

The following processes are an assessment of the process or intervention to ensure that water consumption is accounted for:

- Eskom shall develop suitable targets to monitor the implementation of this policy and power stations shall report on their targets as per the agreed reporting timeframes;

- Eskom will undertake water management reviews/audits at the reasonable frequency the power stations to assess compliance with the strategies and understand the extent of water usage in producing electricity;
- Eskom will conduct internal audits and monitor and report on performance by an agreed audit programme and established business performance reporting procedures;
- The stations shall have flow metering devices on all major streams;
- The stations shall have level measurement on all major storage facilities;
- All stations shall conduct an operational risk assessment to effect a credible water balance and shall ensure that all streams that impact water balance be metered or accounted for; and
- All stations shall ensure that all major processes are balanced such as potable water, demineralised water, main and auxiliary cooling water, effluent and ash systems (Eskom, 2016:4).

2.3.8 Communication

In terms of communication the water management sub-committee is responsible to:

- Communicate key water messages internally and externally with key stakeholders to promote awareness of water sustainability issues and afford timeously and informed decisions;
- Encourage practices that promote water resources pollution prevention and comply with ZLED policy through employees' awareness;
- Ensure that water management information systems are in place and up to date to provide Eskom management and other stakeholders with timely and appropriate water performance information; and
- The power station's water management officer shall plot and communicate to the entire power station the weekly\monthly trend water performance on the major stream such as raw water, potable water used, demineralised water used, recovery to the cooling system and cooling water (Eskom, 2013:7).

2.3.9 Water management task team

The water management task team is a sub-committee of the environmental strategic committee and has been established to discuss weekly water use performance and any variations from the norm and put in place a detailed action plan to address deviations. The team shall exercise its delegated authority as determined by the strategic environmental committee, by the delegation of authority framework approved by the board. The members and officials shall, in exercising their duties, apply the principles and practices set out in King III (Eskom, 2015:3).

The legislative and executive authority that the council derives from the consultation and other legislation gives it dominium over the taxes and collected from those who reside within the borders of the municipality for the supply of electricity, water, sanitation, refuse removal and other services.

The Water Management Task Team (WMTT) comprising of chemistry, engineering, maintenance and operating personnel was established at each coal-fired power station in the last quarter of 2012. The WMTT has five key focus areas, which will be discussed below:

- **Reduction of raw water consumption**

Most coal-fired power stations performed poorly when compared to their water use targets. The poor water performance was as a result of poor condenser performance, high demineralised water consumption and steam leaks. The factors mentioned above resulted in power stations using more water when compared to their targets (Eskom, 2016:14).

- **Reduction of demineralised consumption**

The power stations experienced high demineralised water usage due to demineralised water leaks in the plant. Some of the demineralised water consumption issues require outages of at least seven days to execute the tasks such as replacing the valves, especially demineralised water-related steam valves. Therefore the maintenance work can only be done when the plant is not in operation. Some of the valves and pipelines are normally under pressure and experience high temperatures when the plant is in operation. This means that maintenance employees cannot perform work under these conditions due to unsafe conditions (Eskom, 2016:14).

- **Drive implementation of zero liquid effluent discharge**

This is an area of great concern as none of the planned projects have been implemented mainly due to a lack of funds and the projects prioritised as a low priority. The non-implementation of these projects is exposing the organisation to the risks of non-compliance with water use licenses and the National Water Act No 36 of 1998. Therefore power stations are not complying with zero liquid effluent discharge policy which resulted in power stations committed the environmental legal contravention by allowing the contaminated water to be released to the environment (Eskom, 2016:14).

- **Implementation of water accounting framework**

The working group on the WAF has revised the WAF to make it a policy instead of a directive (Eskom, 2016:15).The WMTT is seen as an appropriate vehicle to drive the reduction of raw water and demineralised water consumption. The multi-disciplinary nature of the WMTT allows for effective interventions in addressing identified water management deficiencies. It is important for the coal-fired power stations to re-establish their WMTT and make them function in the best interest of the power stations (Eskom, 2016:15). Eskom power stations have a water accounting framework policy. Its objective is to prescribe the minimum requirements for the monitoring, accounting and reporting of water use at Eskom's power stations to facilitate sound water and effluent management (Eskom, 2016:5).

2.4 THE WATER ACCOUNTING POLICY STATEMENT

The demand for water remains on the increase while the supply is constrained. The department of water and sanitation is committed to water conservation and water demand management initiatives that will promote the efficient use of water throughout the various sectors of the country. Eskom as a strategic user is committed to continuous improvement of the water management tools (such as water management and monitoring policies) and initiatives used within the organisation, as well as the introduction of new tools that minimise and optimise the water use in support of the policy (Eskom, 2016:4).

All Eskom's coal-fired stations are directed as follows:

- The stations shall have flow metering devices on all the major streams as identified. The stations are given three years to install operation flow meters on the major streams; and
- The stations shall report weekly and monthly on water use performance. The reporting format shall be adopted by all the coal-fired stations for this directive (Eskom, 2016:5).

The purpose of this directive is to establish:

- Minimum requirements for metering of water streams within the power station boundaries; and
- Water monitoring, accounting and reporting framework that will provide the necessary information that will assist in defining and driving WC/WDM strategies (Eskom, 2016:5).

2.5 LEADERSHIP AND ORGANISATIONAL CULTURE

Culture is collective motives, values, beliefs, identities and interpretations or implications for important occasions that result from the collective experience of the members of a collective that are transferred through generations (Ruth & Niglas, 2008:165). McShane and Von Glinow (2010:211) support this definition stating that it consists of the values and assumptions shared within an organisation.

Organisational culture can impact the way people establish individual and professional objectives, execute work and manage assets to accomplish them (Nwibere, 2013:367). It also influences the manner in which employees and managers cognitively and subconsciously think, decide and influence their perceptions, feelings and actions (Yukl, 2013:144). Corporate culture has both direct and indirect relationships with organisational effectiveness (Cummings & Worley, 2009:189).

Here Xirasagar (2008:338) states that corporate culture is directly correlated with the managerial leadership style of managers in the organisation as summarised below:

- Managers working in organisations with a competitive organisational culture are more inclined to adopt a transformational style of leadership as opposed to laissez-faire style. This is because competitive culture organisations highlight principles of challenging goals, competitive benefit, advertising dominance, and high earning;

- Managers working for organisations with the organisational culture of a bureaucratic nature are more likely to practice transactional leadership style. This is because values depicted by bureaucratic cultures are formalisation, instructions, standard operating procedures and hierarchical co-ordination (Cummings and Worley, 2009:222); and

- Managers working for companies adopting consensual corporate culture are more likely to practice all leadership styles as mentioned above. This is because consensual culture depicts elements of the institution, allegiance, individual obligation, wide-ranging socialisation, collaboration, self-management, and communal inspiration (Cummings and Worley, 2009:222).

The organisational management culture that is sustaining and continues to learn and improve in the face of the inevitable peaks and troughs of organisation requires:

- Leadership;
- Procedures;
- An appetite for conservative decision-making where safety is put first even under pressure;
- A culture of sharing reporting;
- Good communication at the appropriate level;
- An open, learning organisational culture open to benchmarking against the best in class;
- Systematic competency checking;
- Effective management of organisational change; and
- The ability to prioritise (Pollard and Stephenson: 2016, 175).

2.5.1 The influence of leadership on organisational performance

Individuals are motivated by their requirements to satisfy (Maslow's) hierarchy of needs (Adair, 2004:198). A good leader provides the right climate, and the opportunities for these needs to be met on an individual basis (Adair, 2004:213). According to Adair (2004:222) identify five characteristics of what they call exemplary leaders:

- Challenge the process: leaders search for opportunities. They experiment and take risks, constantly challenging other people to exceed their limitations;

- Inspire a shared vision: leaders envision an enabling future and enlist people to join in that new direction;

- Enable others to act: leaders strengthen others and foster collaboration;

- Model the way: leaders set the example for people by their leadership behaviour, and they plan small wins to get the process moving and;

- Encourage the heart: leaders regard and recognise individual contributions, and they celebrate team successes (Adair, 2004:269).

2.6 FUTURE CHALLENGES

Population growth and climate change are external factors that drive the demand for water. Climate change can affect water supply from reduced and more variable precipitation and increase water demand due to an increase in temperature. Increased population means increased water and its associated energy use. Even though centralised water systems are more extensively used in current urban systems, alternative water systems like rainwater tanks, stormwater harvesting and greywater recycling are gaining importance due to growing water scarcity. Also, decentralised water systems are particularly useful in serving areas difficult to reach by centralised systems due to topographic or economic reasons (Burn et al., 2012). Increasingly, decentralised water systems are gradually being integrated with centralised water systems (Naira, 2014:7).

South Africa is currently experiencing a serious drought. Therefore there are some restrictions implemented in some parts of the country regarding water usage. The aim is to conserve the available water so that all the stakeholders can have access to the water. Each power station has a water use licence which is a binding document that outlines the maximum amount of water which the power station can extract from the water source.

CHAPTER 3 RESEARCH MODEL AND METHODOLOGY

3.1 INTRODUCTION.

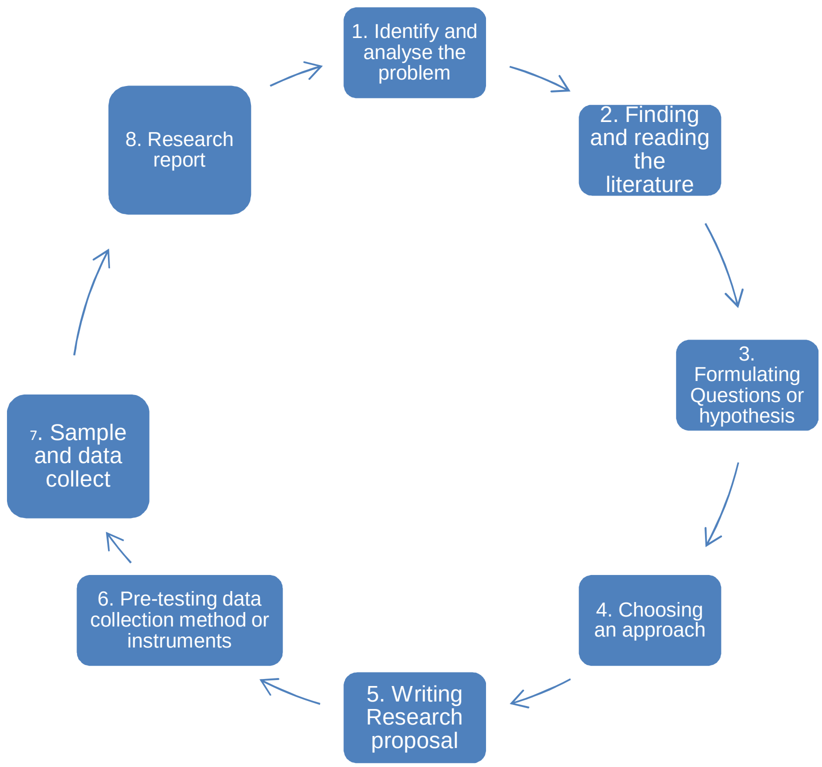
The primary objective of this study was to investigate the water consumption in all Eskom's coal-fired power stations. To address the primary objective of the study, it is of essential to analyse the current or the existing water consumption processes in the coal-fired power stations. In the previous chapter, a literature study was performed on the subject of water management and consumption. The aim is to identify and addressing the main objective of the research. The information gathered in the literature paved the way to execute the secondary objectives of the study.

Business research does not exist in a vacuum. It is shaped by what is going on in the real world of business and management and by intellectual traditions and philosophical ideas that shape the social science. Research in the field of management and business needs to be contextualised in broader social science disciplines (Bryman & Bell, 2014:4). Research can be described as the phenomena of using specialised techniques and processes whereby researchers focus on achieving study objectives using systematic and formalised techniques (Thomas, 2004:14). The researcher should also plan and anticipate a proper research design to ensure that the results of the study are valid (Cooper & Schindler, 2014:36). Nevertheless, it is significant that the research methodology is discussed and different views are considered and analysed in the study.

3.2 RESEARCH PROCESS

According to Du Plooy-Cilliers (2014:10), research is a 'recursive process' because it starts with a question, goes through the process of finding answers, returns to answer the initial question which then leads to further questions. The author defines the start of the research process being the identification and analysis of the problem and ending with a research report.

Figure 3.1 below illustrates a formal research process with steps that the researcher will follow when undertaking research.



Source: (Du Plooy & Cilliers, 2014:14)

3.3 RESEARCH METHODOLOGY

There seems to be little to the quantitative/qualitative distinction other than the fact that that quantitative researchers employ measurement and qualitative do not. However, the distinction between quantitative and qualitative research is useful for classifying different business research methods, strategies or approaches (Bryman & Bell, 2014:30).

Quantitative research approaches tent to:

- Emphasize quantification in the collection and analysis of data;
- Adopt deductive approach to the relationship between theory and research in which the emphasis is placed on the testing of theories;

- Incorporate the practices and norms of the model of the natural sciences and positivism in particular; and
- Embody a view of social reality as an external objective reality (Bryman & Bell, 2014:31).

By contrast, qualitative research approaches:

- Usually, emphasise words rather than quantification in the collection and analysis of data;
- Predominantly emphasise an inductive approach to the relationship between theory and research in which the emphasis is placed on generating rather proving theories;
- Reject the practices and norms of the natural scientific model and positivism in particular, in preference for an emphasis on how individuals interpret their social world; and
- View social reality as both constantly shifting and emergent as interpreted by individuals (Bryman & Bell, 2014:31).

Quantitative research as the objective evaluation of the data which consist of numbers, trying to exclude bias from the researcher's point of view using questionnaires as the instruments and always involves the numerical analysis of data gathered (Vosloo 2014:334). This study will utilise a quantitative approach.

3.3.1 Research design

The research design refers to a logical sequence that connects the empirical data to a study's initial research questions and its conclusions (Yin, 2003:20). As stated by Welman *et al*. (2010:52) research design is the plan according to how the researcher obtains research participants and collects information from them. In this, the researcher describes what they are going to do with the participants, to research conclusions about the research problem.

This type of design is adopted in the case where the study is descriptive, and variables are measured at a specific time, and also, no influence is involved on those variables. (Fouché *et al.,* 2011:155). It, therefore, renders a research design as an ultimate structure for which a potential research sample is selected as well as the selection of the suitable data collection method (Vosloo, 2014:316).

To achieve the set research goal, a self-administered/individually administered questionnaire was utilised to collect data. The validity of the questionnaire will be tested by employing exploratory factors analysis to confirm that the questions formulated do measure each of the constructs or variables. The questions used to measure each influence are tested using their reliability (Somekh & Lewin, 2004:9).

The researcher will make use the questionnaires to explore the research question and objectives given the nature of events within the organisation. As employees have a different background, education level and management level, the survey will adapt the formulation of the questions to fit respondents.

3.4 POPULATION

The study population is focused on the technical employees (engineering, maintenance, operating and Production) and managerial employees in all the Eskom's coal-fired power stations.

The population which is identified for this research study includes all the Eskom's fourteen coal-fired power stations with a total of 300 participants for all the coal power stations. Employees to be covered during the survey include senior management, middle management, line management, supervisors and other positions. The questionnaires were used for collecting data, and statistical analysis will be performed on the results obtained. Each employee irrespective of gender, age, and job position will have an equal chance to participate in the survey.

3.5 THE SAMPLE

Probability sampling can determine the probability that any element or member of the population will be included in the sampling. The advantage of probability sampling is that it enables the researcher to indicate the probability with which samples results deviate in differing degrees from the corresponding population values (Welman, Kruger, Mitchell, 2005:58).
Each member of the population had the same chance of being included in the sample. The participants in this study included senior management, middle management, line management, supervisors, any other positions, both males and females and different ages at all Eskom's coal-fired power stations.

3.6 GATHERING OF DATA

Data were collected by using questionnaires, and the respondents were targeted during working hours when most were attending their daily production meetings when they were in the workshops and offices. The researcher explained to the participants that these questionnaires would be used for academic purposes only. They were requested to complete the questionnaires. The self-administered questionnaires were developed to complete the survey of the study.

The questionnaire comprised Likert-scale questions to obtain the necessary information for the study. The questionnaire provided the respondents with four options to choose from when answering each of the asked questions on the questionnaire. The questionnaire comprised three sections namely, section A: biographical and general information, section B: technical aspects and section C: management aspects.

3.7 DATA ANALYSIS

3.7.1 Data analysis techniques

The self-administered questionnaires were espoused as the data collection instrument. The reliability of the questionnaires was endorsed by the research supervisor from the North-West University. The instrument allowed for participants to give their perceptions of the water management in the system in the coal-fired power stations. The study population comprised individuals from various positions in the power stations and this were done in an attempt to diversify the study to get various responses and perceptions.

The research study employed the quantitative method. This method was used because it allowed for the use of the selected tool for data collection.

The researcher collected the completed questionnaires; the results of the questions were captured on a Microsoft Excel spreadsheet, to be statistically analysed. The captured data was presented in a manner that allowed easy importing for statistical analysis.

3.7.2 Statistical analysis

The collected data from participants in all the Eskom's coal-fired power stations will be analysed using the different types of the statistical analysis.

3.8 SUMMARY

In this chapter, the research methodology and process was analysed for relevance. The questionnaires used in this study were developed from the literature study about the objective of this study. The data collection tool was verified for reliability and validity. The targeted study population and sampling were identified and selected according to their relevance to the research study. Only the questionnaire will be used for this study. The completed questionnaire will be analysed and interpreted using the statistical analysis results which will be conducted by the North-West University's statistical consultation services at the Potchefstroom campus.

CHAPTER 4: RESULTS, ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

This chapter focuses on the opinions of employees as the target population identified to participate in the survey to determine the factors affecting water consumption in Eskom's coal-fired power stations as part of the current research study. The perceptions of these participants regarding the technical knowledge and water management effectiveness are also presented in this chapter.

The empirical study was conducted using a questionnaire administered to various employees occupying technical (engineering, maintenance, operating and management) positions in the coal-fired power stations. The questionnaire was constructed, and the reliability thereof was calculated with the assistance of the North-West university statistical consulting services and the research supervisor.

4.2 STATISTICAL ANALYSIS OF DATA

Data captured through the questionnaire was analysed by the North-West University's Statistical Consultation Services at the Potchefstroom Campus using the Statistical Analysis System (SAS Institute Inc., 2005). Frequency tables were drawn to describe the socio-biographic variables of the study population. Reliability coefficients were computed for each measuring instrument's subtest, and confirmatory factor analyses were done to confirm construct validity of subtests.

To determine whether a factor analysis may be appropriate, Kaiser's measure of sample adequacy (MSA), which indicates the intercorrelations among variables, should be computed (Tabachnick & Fidell, 2001). The index ranges from 0 to 1, reaching 1 when each variable is perfectly predicted by the other variables (Hair *et al.*,1998:730).

4.3 RESPONSES TO THE SURVEY

The target population for the study became the study population as random sampling was not performed. According to the study population, the total number of respondents was 270 from all the 14 coal-fired power stations. Majority of the correspondence came from Mpumalanga, as most of the Eskom's coal-fired power stations are situated there. A total of 300 questionnaires were sent to employees in different coal-fired power stations via email through their supervisors, researcher's former colleagues and managers while somewhere hand delivered. A total of 270 questionnaires were returned via email and hard copies in four weeks, indicating a response rate of 90%.

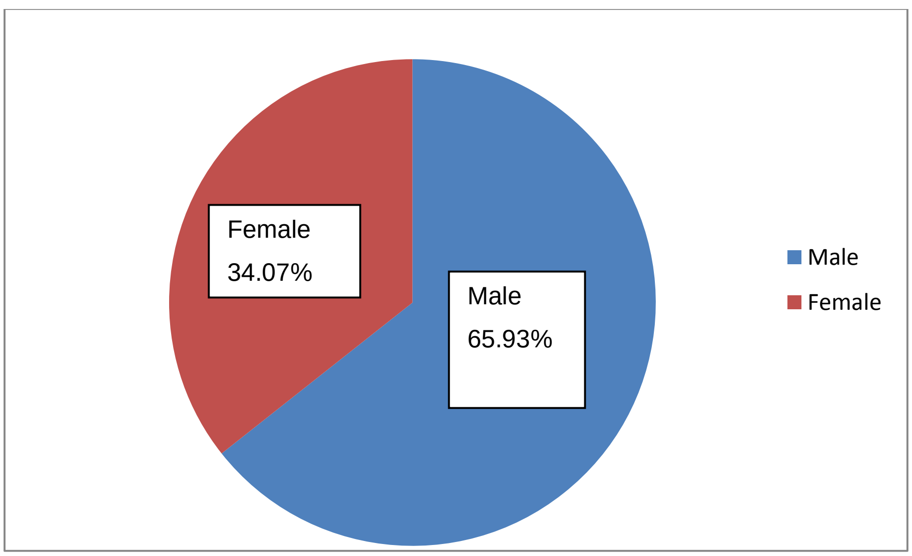
4.4 DEMOGRAPHICS OF THE RESPONDENTS

In this section, the researcher aimed at gathering information relating to the biographical aspects of the respondents. These included gender, age group, highest qualification, position and the name of the power station.

4.4.1 Gender

The study sample was heterogeneous as it was made up of both males and females. Figure 4.1 below indicates the gender composition of the respondents.

Figure 4.1: Gender percentage breakdown



As can be seen in figure 4.1, the sample was made up of 64.34% males and 35.66% females. This was required to understand the gender composition of the respondents.

4.4.2 Age group

Respondents were also asked to indicate their age groups. This ensured that the different age groups of the respondents involved were identified. The findings are indicated in figure 4.2 below.

Figure 4.2: Age group breakdown

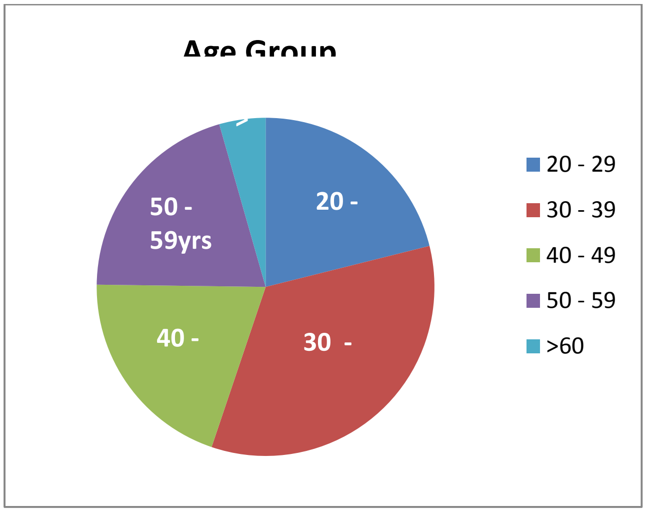
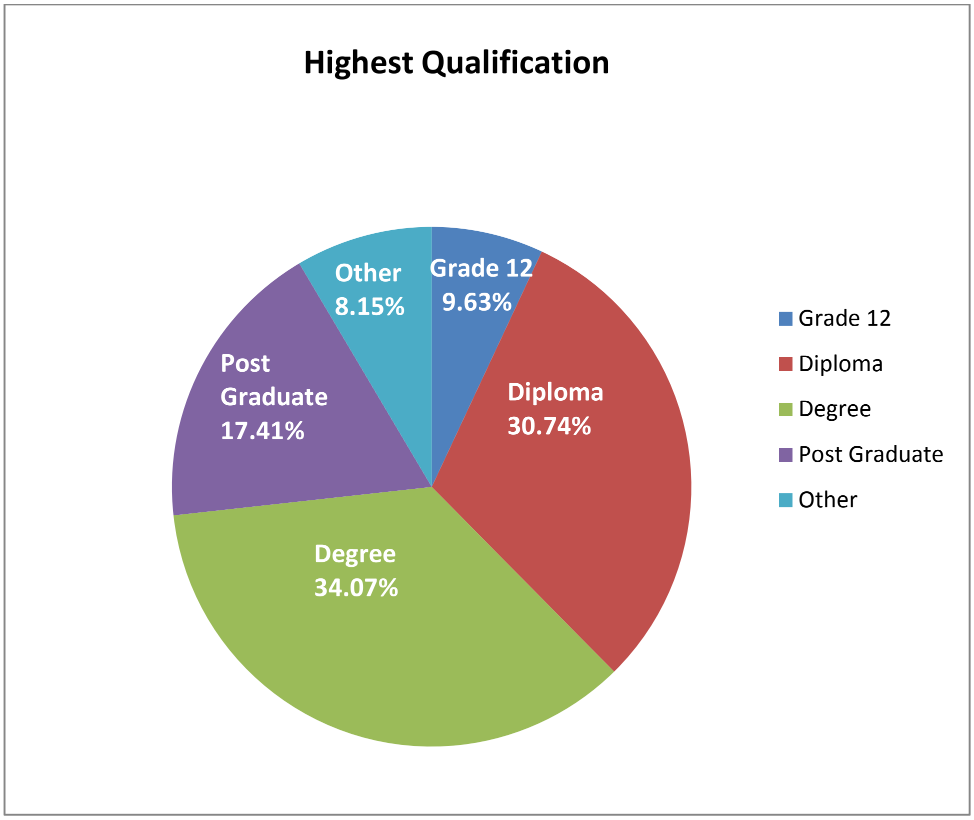


Figure 4.2 above indicates the different age groups amongst the respondents. Respondents between the ages of 20 – 29 years old were found to contribute 21.11%, 30 – 39 years contributed 34.07%, 40 – 49 years contributed 20%, 50 – 59 years contributed 20.37% and above 60 years contributed to 4.44% of the respondents.

4.4.3 Qualifications of respondents

Respondents were requested to indicate their highest level of academic qualifications. Five qualification levels were available for selection, namely: grade 12, diploma, degree, postgraduate and other. The qualifications results are presented in figure 4.3 below.

Figure 4.3: Highest qualification breakdown

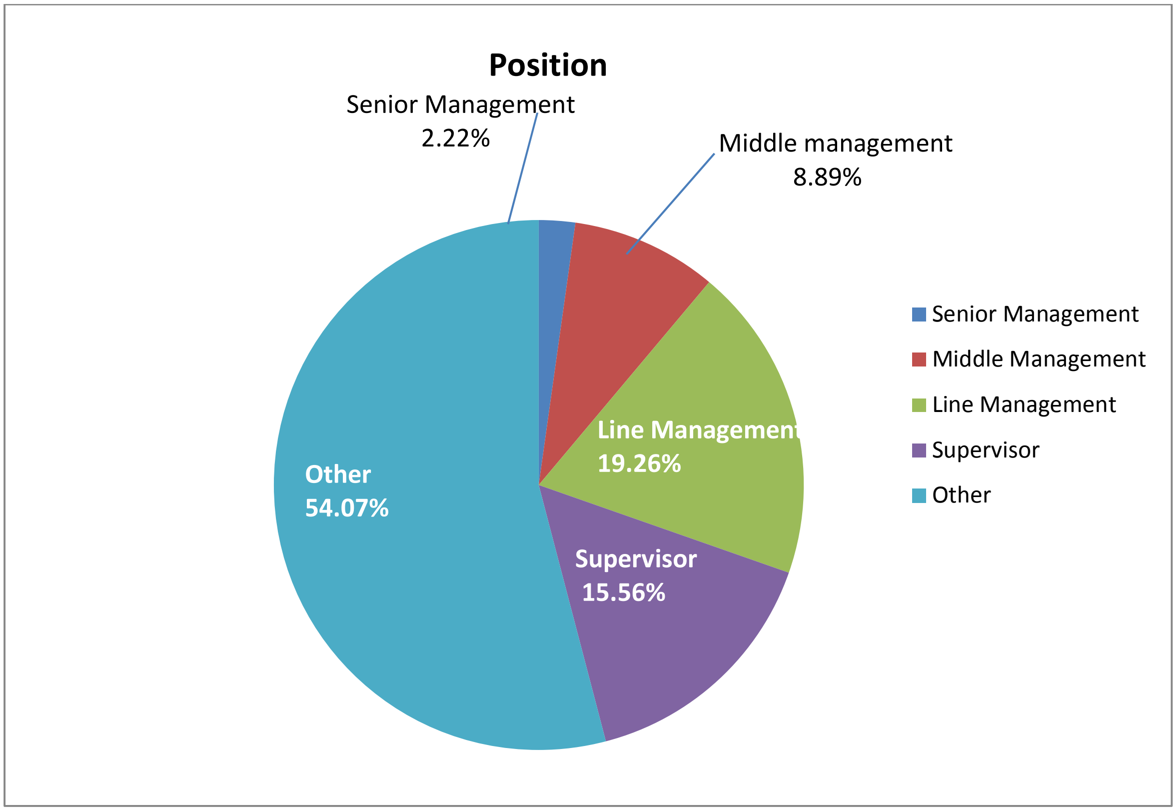


The majority of respondents indicated degrees as their highest qualification as 34.07% while 30.74% indicated diploma as their highest qualifications. 17.41% have postgraduate qualifications, while 9.63% indicated grade 12 as their highest qualification.

4.4.4 Distribution of position domain of the respondents

The respondents were requested to indicate the domain of their position within the coal-fired power station. In figure 4.4 below the results are presented.

Figure 4.4: Job position analysis

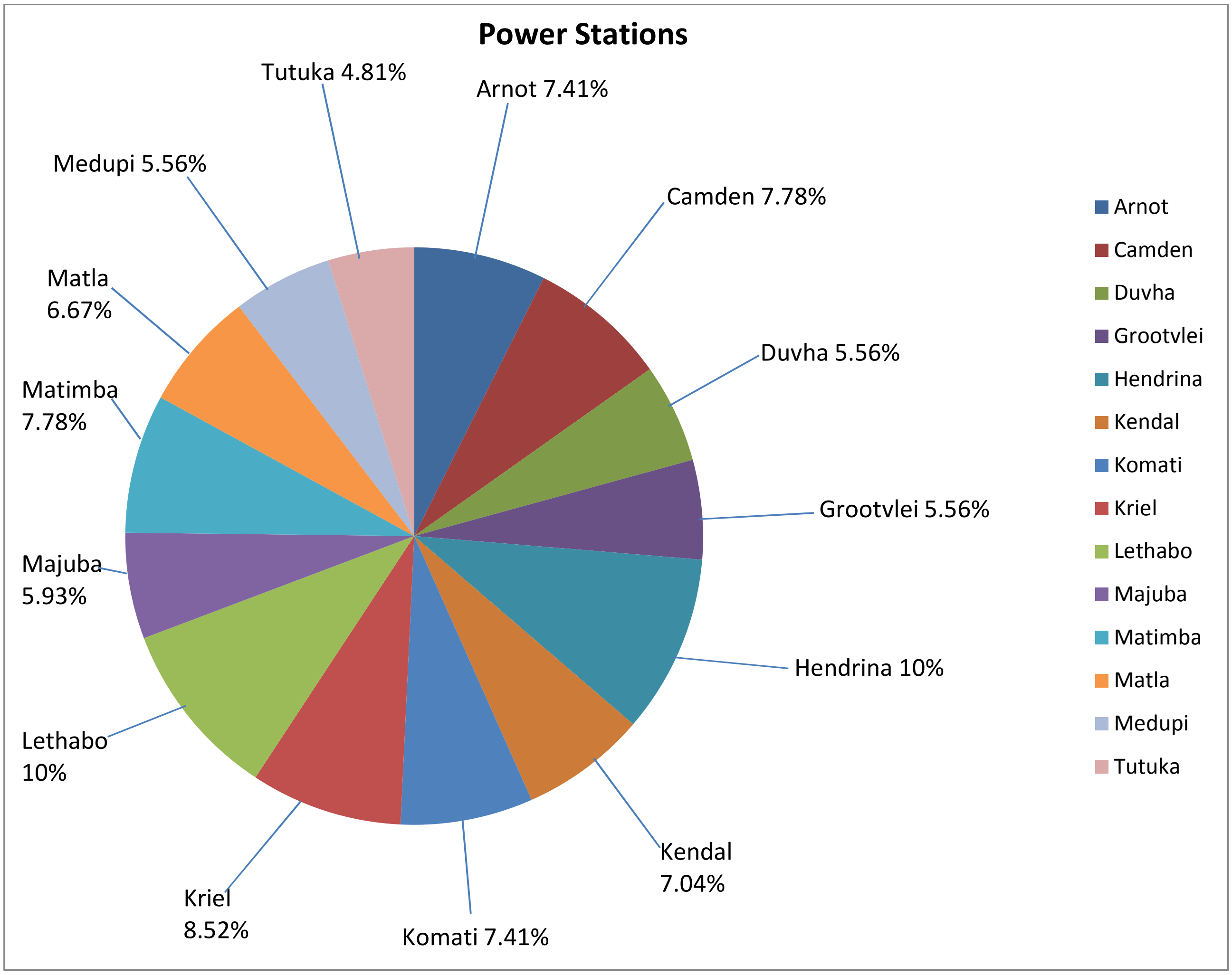


The highest number of respondents was from the other positions at 54.07% followed by line management at 19.26%, then supervisor at 15.56% and senior management and middle management at 11.11%.

4.4.5 Power stations name

Below are the results in a percentage of all Eskom's coal-fired power stations which the questionnaires were sent to for survey.

Figure 4.5: Power stations breakdown



The percentage participants can be seen in figure 4.5 above with the lowest response from Duvha power station at 5.56%, and the highest from Lethabo and Hendrina power stations at 10% each.

4.5 QUANTITATIVE ANALYSIS

4.5.1 Kaiser's measure of sample adequacy (MSA)

The MSA is done to determine whether factors are appropriate. Kaiser's measure of sample adequacy which indicates the intercorrelations among variables should be computed (Tabachnick & Fidell, 2001). This index ranges from 0 to 1, reaching 1 when each variable is perfectly predicted by the other variables. The MSA for this study was 0.72.

The measure can be interpreted with the following guidelines as illustrated in table 4.1 below.

Table 4.1: Kaiser's measure of sample adequacy

MSA value	description
≥ 0.80	Meritorious
0.70	Middling
0.60	Mediocre
0.50	Miserable
< 0.50	Unacceptable

Source (Hair *et al*., 1998:730)

The questionnaires which were used in the study were divided into two categories: technical aspects and management aspects. The main aim was to identify if the participants have the technical knowledge and how the management is conducted.

4.5.2 Technical aspects

Factor 1 and 2: Technical Aspects of awareness and understanding

Table 4.2: Below show the results of factor analysis on B1 (technical awareness and understanding).

Number of factors retained	Number of correspondents	Percentage variance explained	MSA	Communalities vary between
2	270	48	0.70	0.29 and 0.69

Two factors will be retained by the mineigen criterion.

The results of the above table consist of two factors: Factor 1 technical awareness and factor 2 is technical understanding.

Factor 1 is loaded with four statements which are: (B 1-1, B1-2, B 1-3, B1-6). All the above statements relate to the technical awareness to the all the technical employees at the coal-fired power station. This factor aims to test the technical knowledge of the participants mentioned above.

Factor 2 is loaded with two statements which are: (B1-4, B 1-7). The statements relate to the technical understanding. This is to test if the participants understand which technical aspect of the power station is affecting the water consumption either positively or negatively.

Both factors 1 and 2 results have an MSA value of 0.70 which means the results can be trusted. The communalities for both factor 1 and 2 vary between 0.29 and 0.69.

Factor 3: Technical aspects of targets and measures

Table 4.3: Below show the results of factor analysis on B2 (water consumption targets and measures).

Number of factors retained	Number of correspondents	Percentage variance explained	MSA	Communalities vary between
1	270	37	0.70	0.20 and 0.87

The results of the above table consist of one factor: Factor 3 is water targets and measures.

Factor 3 is loaded with six statements which are: (B 2-1, B2-2, B 2-3, B2-4, B2-5, B2-6). All the above statements relate to water consumption targets and measure at the coal-fired power station. This statement is meant to verify if the technical employees and management are aware of their power stations water consumption targets and measures. This factor has an MSA of 0.70 which implies that the results can be trusted. The lowest and highest loading factor is 0.20 and 0.87 respectively.

4.5.3 Management aspects

Factor 4 and 5 management aspects of awareness and risk management

Table 4.4: below show the results of factor analysis on C1 (management awareness).

Number of factors retained	Number of correspondents	Percentage variance explained	MSA	Communalities vary between
2	270	68	0.70	0.43 and 0.71

Two factors will be retained by the mineigen criterion.

The results of the above table consist of two factors: Factor 4 is management awareness and factor 5 risk management.

Factor 4 is loaded with four statements which are: (C 1-1, C1-2, C 1-3, C1-6). All the above statements relate to the management awareness of the all the technical employees at the coal-fired power station. The main aim of this factor is to test if the relevant employees have sufficient knowledge regarding the water management awareness in the power stations.

Factor 5 is loaded with two statements which are: (C1-4, C 1-5). The statements relate to the water management risk in the power station. This is to test if the participants are aware if their power stations are well equipped to deal with any risk which might affect the electricity production due to water unavailability.

Both Factors 4 and 5 results have an MSA value of 0.70 which means the results can be trusted. The communalities for both factor 4 and 5 vary between 0.43 and 0.71.

Factor 6: Communication

Table 4.5: below show the results of factor analysis on C2 (Communication on water management).

Number of factors retained	Number of correspondents	Percentage variance explained	MSA	Communalities vary between
1	270	56	0.80	0.41 and 0.63

Two factors will be retained by the mineigen criterion.

The results of the above table consist of one factor: Factor 6 is Communication on water management.

Factor 6 is loaded with six statements which are: (C 2-1, C2-2, C2-3, C2-4, C2-5, C2-6). All the above statements relate to the communication of water management at the coal-fired power station. This statement is meant to test if water management is communicated to the employees at the power stations by management. This factor has an MSA of 0.80 which implies that the results can be trusted because the MSA is interpreted as Meritorious. The lowest and highest loading factor is 0.41 and 0.63 respectively.

Factor 7: Responsibility and skills in water management)

Table 4.6: below show the results of factor analysis on C3 (Responsibility and skills in water management).

Number of factors retained	Number of correspondents	Percentage variance explained	MSA	Communalities vary between
1	270	61	0.70	0.50 and 0.70

The results of the above table consist of one factor: Factor 7 is responsibility and skills in water management.

Factor 7 is loaded with five statements which are: (C 3-1, C3-2, C 3-3, C3-4, C 3-5). All the above statements relate to the responsibility and skills needed at the power stations to manage water consumption. These statements are to test if the coal-fired power stations have adequate skilled employees to manage water consumption and also that there are clear roles and responsibility for the relevant employees. This factor has an MSA of 0.70 which implies that the results can be trusted. The lowest and highest loading factor is 0.50 and 0.70.

Factor 8: Leadership and organisational culture

Table 4.7: below show the results of factor analysis on C4 (Leadership and organisational culture).

Number of factors retained	Number of correspondents	Percentage variance explained	MSA	Communalities vary between
2	270	68	0.70	0.60 and 0.75

The results of the above table consist of one factor: Factor 8 is Leadership and organisational culture.

Factor 8 is loaded with three statements which are: (C4-1, C4-2, C4-3). The above statements relate to how the leadership and organisational culture affect the water management in the power stations. These statements are to test how the power station leadership and culture affects the water management. This factor has an MSA of 0.70 which implies that the results can be relied upon. The lowest and highest loading factor is 0.60 and 0.75.

4.6 VALIDITY AND RELIABILITY OF THE QUESTIONNAIRE

The reliability of a test refers to the consistency of scores obtained by the same persons when they are re-examined with the same test on different occasions, or with different sets of equivalent items, or under other variable examining conditions (Anastasi & Urbina, 1997: 84). The validity of a test concerns what the test measures and how well it does so (Anastasi & Urbina, 1997: 113). If valid, it measures then what it is supposed to measure. Because “reliability is a characteristic of data” (Eason, 1991: 84) researchers must attend to the influence that the participants themselves have on score quality in every study. As Thompson (1994: 839) explained because total score variance is an important aspect of reliability, the participants involved in the study will themselves affect score reliability: “the same measure, when administered to more heterogeneous or more homogeneous sets of subjects, will yield scores with differing reliability”.

The Cronbach alpha coefficient is used to determine the level of reliability and internal consistency of the data. Table 4.7 below describes the significance level of the Cronbach alpha coefficients.

Table Error! No text of specified style in document.**.8: Cronbach alpha coefficients**

Cronbach’s Alpha Coefficient	**Internal Consistency**
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$\alpha < 0.5$	Unacceptable

Source: (Tavakol & Dennick, 2011:54)

Table 4.9: below show the Cronbach alpha for the complete data set of 0.62.

Construct	N	Coefficient Alpha
Technical awareness	270	0.66
Technical understanding	270	0.08
Target and measures	270	0.79
Management awareness	270	0.59
Risk management	270	0.54
Communication	270	0.84
Responsibility and skills	270	0.69
Leadership and organisational culture	270	0.78

Table 4.9 above it is clear that some calculated Cronbach alpha values for the factors are below the satisfactory reliability coefficients. When studying the Cronbach alpha, one must take into consideration that the increasing value of Cronbach alpha is partially reliant on the number of items represented in the scale. The low-reliability coefficients in the study indicate that if the study is repeated in a different setting, these low factors will most probably not represent themselves.

Analysis of the mean of the factors identified.

The questionnaire used to determine water management in Eskom's coal-fired power station was designed on a four-point Likert scale. The four-point scale gives the respondents four different choices to select from for each statement.

- Strongly disagree: 1
- Disagree: 2
- Agree 3
- Strongly agree: 4

The mean values from the Likert scale for the eight factors were calculated.

Table 4.10 below is the number of participants, mean and standard deviation of the factors which were analysed. This is to test if the participants agree or disagree with the questionnaires.

Table 4.10: Mean and constructs

Construct	N	Mean	Standard deviation
Technical awareness	270	3.11	0.51
Technical understanding(indirect cooling systems)	270	2.86	0.91
Technical understanding(monitoring water consumption)	270	3.85	0.35
Target and measures	270	3.08	0.66
Management awareness	270	2.94	0.52
Risk management	270	3.51	0.47
Communication	270	2.84	0.67
Responsibility and skills	270	2.82	0.59
Leadership and organisational culture	270	3.00	0.60

From the table 4.10 above it is clear that both managerial and non-managerial agrees with the factors which were analysed. The mean of all the factors is above the value of 2.5 which is the medium of the values 1 to 4. However, there are other statements from the different factors which the participants do not agree with them. Some of the statements have 50% agree, and 50% disagree.

The participants disagree with the following statements: table 4.11 below are the mean results to confirm the above statement.

Table 4.11 Mean results of disagree and neutral

	Statement	mean
B1-2	That electric feed pumps can negatively affect water consumption	2.5
B2-3	How to calculate the water consumption	2.58
C1-6	Rewards for reporting water leaks	1.84
C2-2	Participation in the water-related forums	2.54
C2-4	That water consumption get discussed in their daily toolbox talk meetings	2.50
C3-4	There is training for employees to improve water management	2.39

4.7 EFFECT SIZE

An advantage of drawing a sample is that it enables the researcher to study the properties of a population. In such cases, the statistical significance tests (example. t-test) are used to show that the results (example difference between two means) are significant. The *p*-value is a criterion of this, giving the probability that the obtained value (or more extreme) could be obtained under the assumption that the null hypothesis is true. A small *p*-value (example Smaller than 0.05) is considered as sufficient evidence that the result is statistically significant.

Cohen (1998) gives the following guidelines for the interpretation of the effect size in the current case:

- Small effect: $d = 0.2$;
- Medium effect: $d = 0.5$; and
- Large effect $d \geq 0.8$

They consider data with $d \geq 0.8$ as practically significant, since it is the results of a difference having a large effect.

The table below is the descriptive and effect sizes on the constructs of water consumption for the two differences groups: Group 1 managerial and group 2 non-managerial.

Table 4.12: Effect size

Construct	Group	N	Mean	Standard deviation	*p*-value	d-value
Water management technical awareness	1	82	3.33	0.37	<0.0001	0.61
	2	188	3.02	0.53		
Technical understanding(indirect cooling systems)	1	82	2.98	0.93	0.16	0.19
	2	188	2.80	0.91		
Technical understanding(monitoring water consumption)	1	82	3.94	0.24	0.0022	0.31
	2	188	3.82	0.39		
Water consumption target and measures	1	82	3.30	0.49	<0.0001	0.50
	2	188	2.98	0.70		
Water management awareness	1	82	3.11	0.40	<0.0001	0.44
	2	188	2.87	0.55		
Water management risks	1	82	3.58	0.41	0.0851	0.20
	2	188	3.48	0.50		
Communication on water management	1	82	3.13	0.45	<0.0001	0.58
	2	188	2.71	0.71		
Water management responsibility and skills	1	82	2.96	0.47	0.0049	0.32
	2	188	2.76	0.62		
Leadership and organisational culture	1	82	3.17	0.48	0.0007	0.38
	2	188	2.93	0.64		

As can be seen from Table 4.12 above that there are three areas of concerns were managerial employees (group 1) differs in opinion with non-managerial employees (group 2) with a medium effect in practice (d = 0.61) on technical awareness. The managerial employees (group 1) have a mean value = 3.33 agree more on technical awareness than non-managerial employees (group 2) with a mean value = 3.02 with a medium practical effect *d* = 0.61.

There also a difference between the managerial employees (group 1) and the non-managerial employees (group 2) with a medium effect in practice. Meaning that group 1 have a mean of 3.30 agree more on target and measures than group 2 with a mean = 2.98 and with a medium practical effect *d* =0.50.

Lastly was a difference between the managerial employees (group 1) and the non-managerial employees (group 2) with a medium effect in practice. Meaning that group 1 have a mean of 3.1 which shows that they agree more on communication than group 2 with a mean = 2.71 and with a medium practical effect d = 0.58. The rest of the other constructs there is little or no difference between the managerial employees (group 1) and non-managerial managerial employees (group 2). Which means both groups perceived the construct in the same way and the d value is less than 0.5.

4.8 CONCLUSIONS

To evaluate the water consumption in an electricity provider, a set of questionnaire was used for data collection. The questionnaire consisted of three sections, which are: section a participant's biographical information, section b technical aspects and management aspects with related to water consumption.

The target population was technical employees (maintenance, operations, engineering and production) and employees at managerial positions in the coal-fired power stations. The study population consisted of 270 employees from all the Eskom’s fourteen coal-fired power stations.

The respondents from both managerial and non-managerial tend to agree on most of the factors. The constructs in table 4.12 show that there are only three contracts out of a total of nine constructs which have a medium effect d-value ($d > 0.5$) between the two groups (managerial and non-managerial).

The internal consistency and reliability of the questionnaire were assessed by calculating Cronbach Alpha Coefficients. The results have indicated to have an acceptable internal consistency and reliability because most of the constructs have Cronbach Alpha Coefficient above 0.7.

In next chapter, the conclusions which were drawn from this study will be presented. Also, the recommendations arising from the findings of this chapter 4 will be outlined in the next chapter.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

In the previous chapter, the interpretation of the empirical findings obtained through a quantitative study was presented. This chapter seeks to determine whether or not the goals and objectives set out in chapter one were met. This discussion will then be followed by the conclusion of the chapter thereby highlighting the important aspects of the findings. Recommendations will be outlined, which will provide an outline on how to improve the water consumption in the coal-fired power stations. The chapter concludes with highlighting aspects of future research. The chapter will be concluded with limitations of the study and future fields of study which can be beneficiary to this topic.

5.2 RESEARCH OBJECTIVES

The main objective of this study was to investigate water consumption at all the Eskom's coal-fired power stations. The study was done because Eskom's coal-fired power stations were not achieving their set water consumption targets. This study will assist Eskom's coal-fired power stations managers to able to manage the water consumption better and accurately. The outcome of all the objectives is discussed below:

5.2.1 Research objective 1: Investigate the factors contributing to high water usage in the coal-fired power stations.

From the literature study, it was revealed that there are factors which directly contributing negatively or positively to water consumption at the coal-fired power stations. Some of the factors include the dry cooling systems, wet cooling systems and electric feed pump operation. In the literature, it was said that wet cooling system uses more water compared to dry cooling system. The results of questionnaire B1 (technical awareness and understanding) the participants confirmed that they are not aware that the electric feed pump is negatively affecting the water consumption. However, the results show that the participants are aware that most of the Eskom's fired power stations are using the wet cooling system.

5.2.2 Research objective 2: To identify whether all the coal-fired power stations are complying with Eskom water management policy.

As seen in the literature study that there are policies and procedures in Eskom's coal-fired power stations for the management of water consumption. The above-mentioned objective was discussed in questionnaire C1 (water management and risk management) were the results of the analysis showed that the participants aware that there are policies and procedures which are used to govern the water consumption. And that the stations have risk management in place to deal with any water crisis. However, employees are discouraged from reporting any water leaks because they are not rewarded.

5.2.3 Research objective 3: Investigate the management practices that are applied to ensure minimal use of water in the power station.

It was said in the literature that Eskom is committed to zero liquid effluent discharge from the water management policies and water licences. The purpose of this is to ensure that the power stations recover all the used water back into the power for electricity production. From the questionnaire C2 (communication on water management) it is clear from the analysis that the participants agree that they have access to water reports. However, they do not participate in the water-related forums. The water consumption is not discussed in their sections toolbox talk meetings.

5.2.4 Research objective 4: To identify the key performance measurement systems for the reporting and management of water consumption in the coal-fired powered stations.

The coal-fired power stations are expected to accurately measure the water consumption and report the monthly performance to the power station managers. The results of the survey for participants on questionnaire C2-6 under the communication on water management confirmed that the water consumption targets are not shared with the workforce.

5.2.5 Research objective 5: To identify the key performance indicators which are reported and managed for water consumption.

Each power station has a task to compile weekly and monthly reports for water consumption. In the reports, the power stations must highlight their challenges on water consumption. The participants do not know how to calculate the water consumption performance. This means the employees are not aware of what to be included in the calculation of the water consumption.

5.2.6 Research objective 6: Investigate if the water consumption is accurately monitored and accounted for.

From the literature study, it was mentioned that Eskom has processes to monitor the water consumption accurately. It is clear from the questionnaire B2 (targets and measures) that the participants agree that they are familiar with the water targets of their respective power stations. They also confirmed that they are aware of the actual water consumption for their power stations. However they do not know how to calculate the water consumption.

5.2.7 Research objective 7: Investigate if reporting structures are in place for effective management of water consumption.

Eskom formed the water management task team to all the coal-fired power stations. This task team aims to drive the water-related issues. All the technical departments (operating, maintenance, engineering and production) have a representative on this task team. This task team is responsible for escalating issues to top management. The participants in the questionnaire C3 (responsibility and skills) confirmed that the coal-fired power stations have water management task team at their respective power stations.

5.3 CONCLUSIONS

The study was conducted within 14 Eskom's coal-fired power stations. To retrieve usable and accurate results the employees at technical departments (engineering, operations, maintenance and production) and management were targeted during the study. The analysis was done comparing the non-managerial employees and managerial employees. The aim was to understand if water management is the responsibility of every employee in the power station. The data was collected using a questionnaire distributed through email and hand delivery. Completed questionnaires were collected and analysed through a statistical analysis methods.The data were tested for reliability using Cronbach alpha, and it was found to be relevant and reliable. The results indicated that there is not much difference between the managerial and non-managerial employees, even though there are other areas were they two groups were not in agreement.

5.4 RECOMMENDATIONS

To provide the recommendations, it is important to take note that there is small variance between the two groups (managerial group and non-managerial group) from the questionnaire survey. From the research conducted it is highly recommended that Eskom's coal-fired power stations managers to focus on the following factors at the management level. The questionnaire used to determine water management in Eskom's coal-fired power station was designed on a four-point Likert scale (1 – 4), with the midpoint of 2,5.

5.4.1 Technical aspects

Technical awareness

Both the managerial and non-managerial have sufficient knowledge of technical awareness. However, there is an area of concerns which must be addressed. There is a need to conduct an awareness session with all the employees to discuss all the factors which contribute to high water consumption in the coal-fired power station.

Technical understanding

On the technical understanding, both the managerial and non-managerial have little or lack of knowledge in this field. However, there is an area of concerns which must be addressed. It is clear that there is a need for power station managers to invest to both managerial and non-managerial employees to address their technical knowledge so that they can understand what technical factors are affecting the water consumption in the coal-fired power stations.

Targets and measurements

According to the findings on this subject, it is clear that employees at managerial positions know their power stations water targets and measurements as compare to employees at the non-managerial position. From the results of the survey, it is clear that non-managerial employees do not know how to calculate the water consumption. Therefore managers in the coal-fired power stations must ensure that the employees get trained on how to calculate the water consumption. This is to ensure that the employees understand how their day to day activity is the water consumption in the coal-fired power station.

5.4.2 Management aspects

Management awareness

It is also evident from the analysis that employees at managerial positon are more familiar with water management awareness as compared to the employees at non-managerial positions. The non-managerial employees must be taken through a thorough water management training to ensure that they have sufficient knowledge on water management issues. The motivation for non-managerial employees is also needed to to encourage them to report any water-related issues such as water leaks by reward and recognition. This will encourage the employees to take accountability for the water management and familiarise themselves with the water management policies.

Communication

On the issue of communication on water management, it is also evident that employees at managerial positions are aware of this subject than the employees at non-managerial positions. Therefore the employees at non-managerial positions must be encouraged to take part in the water-related forums, where the water consumption and management are discussed. They must also make it a standard agenda point for their daily toolbox talk meetings to discuss the water consumption and management.

Responsibility and skills

The results of the survey show that both the employees at managerial positions and non-managerial positions are not fully convinced that the responsibilities are defined in the coal-fired power station as to who is responsible for managing the water consumption. It is also evident that there is lack of training for employees to deal with the water management in the power stations. The managers at the coal-fired power stations need to clarify the roles and responsibilities of the individuals who are supposed to address the water-related issues at the power station. They also need to invest in providing the training to the affected employees.

Leadership and organisational culture

The leadership and organisational culture play an important role in the employee's behaviour. From the results of the above subject, the employees at non-managerial positions believe that the leadership and organisational culture does not promote the water management. Therefore there is a need for the power stations managers to show commitment and improve a culture of conserving water by communicating their action plan on how are they going to manage and monitor the water consumption closely.

By implementing and monitor the above-mentioned recommendations, the coal-fired power stations water management will get attention from both managerial and non-managerial employees. This will mean that every employee in the power station will take accountability for water management.

5.5 FUTURE RESEARCH AND LIMITATIONS

The results of this research study are limited by the fact that the focus was on all the coal-fired power stations at the same time. Meaning that the results are generic to all the coal-fired power stations. This limitation is an area identified for further research. This research study can, therefore, be expanded to perform each coal-fired power stations independently so that the results cannot be generic rather power station specific. Furthermore, based on the limitations and conclusion of this study, the following future research areas are suggested.

- Further research may be conducted only focusing on other technical aspects of each power station to identify what technical challenges are affecting their water performance.
- Further research can focus on how to improve the water set targets.
- Perform the study for dry-cooled power stations and wet-cooled power stations.

5.6 SUMMARY

This investigation is important because most of the power stations consumed more water in comparison to their set targets. It was deemed to be of paramount importance to determine if there is an effective water management system in Eskom's coal-fired power stations. Eskom is contributing to South Africa's economy because the electricity plays a major role in most of the industries. Therefore it is very important that the coal-fired power station produces electricity within their specified water licences. Even though the participants agreed that there are processes in place to manage water consumption in the coal-fired power stations, there is still need to make sure that those processes are implemented and monitored to ensure that Eskom's water performance is within the specified target.It very important that Eskom develops processes to monitor the water consumption at the power stations. The results of the study revealed that there are other areas of concerns within Eskom's coal-fired power stations which needs attention. By addressing these areas of concerns, Eskom's coal-fired power stations should be in a position to improve the water consumptions. The following areas of concerns should be addressed:

- To improve the technical knowledge regarding the factors which are affecting the water consumption;

- The employees need to be exposed to the process on how to calculate the power station's water consumption;

- Reward and recognition for the employee who goes the extra mile by reporting water leaks;

- The employees must be encouraged to participate in the water-related forums within the power stations; and

- Training to be given to the employees so that they can be able to address all the known water-related challenges.

It is possible for Eskom's coal-fired power stations to meet their water consumption targets by putting in place a proper action plan. Water consumption should be every employee's responsibility.

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ANNEXURE 1: QUESTIONNAIRE

Research Questionnaire is to evaluate the management of water consumption in Eskom's coal fired power stations.

Dear participant

Thank you for sparing your precious time to complete this questionnaire. The questionnaire will assist the researcher in evaluating the management of water consumption in an Eskom's coal-fired power station. It would be greatly appreciated if you kindly complete the following questions as honest as possible. Please note that the information being asked for is purely for academic purposes, and the completed questionnaire will be kept strictly confidential by NWU for a certain period.

Your participation in this survey is highly appreciated.

Should you need any clarification, please feel free to contact my supervisor Mr MJ Botha at Martin.Botha@nwu.ac.za or on 018 285 2500.

Kind Regards

Vusi Mokoena

MBA - Student

072 912 0062

mokoenVB@eskom.co.za

SECTION A: BIOGRAPHICAL AND GENERAL INFORMATION

1: BIOGRAPHICAL INFORMATION (Please mark an **X** in the appropriate box)

Gender	Male	1	Female	2

Age Group	20 – 29	1	30 -39	2	40 -49	3	50 - 59	4	60 - above	5

Highest Qualification	Matric/ Grade12	1	Diploma	2	Degree	3	Post Graduate	4	Other	5

2. IN WHICH DOMAIN IS YOUR POSITION? (Please mark an **X** in the appropriate box)

Senior Management	1
Middle Management	2
Line management	3
Supervisor	4
Other position	5

3. NAME OF THE POWER STATION: (Please mark an **X** in the appropriate box)

Arnot		Camden		Duvha		Grootvlei		Hendrina	
Kendal		Komati		Kriel		Lethabo		Majuba	
Matimba		Matla		Medupi		Tutuka			

SECTION B: TECHNICAL ASPECTS

Please rate the following aspects as follows:

1	Strongly disagree
2	Disagree
3	Agree
4	Strongly agree

1. GENERAL AWARENESS AND UNDERSTANDING OF TECHNICAL ASPECTS
(Please indicate by making an **X** in the relevant column)

		Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
1.1	I am familiar with the cause of high water consumption	1	2	3	4
1.2	The electric feed pump is negatively affecting water consumption	1	2	3	4
1.3	I am familiar with the of ZLED(zero liquid effluent discharge)	1	2	3	4
1.4	Indirect dry cooling system also uses a cooling tower and water	1	2	3	4
1.5	Wet cooling is the most commonly used system	1	2	3	4
1.6	An air-cooled condenser will save water consumption	1	2	3	4
1.7	It is important to have a process to monitor water consumption	1	2	3	4

2. WATER CONSUMPTION TARGETS AND MEASURES (Please indicate by making an **X** in the relevant column)

		Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
2.1	Are you familiar with the current water target for your power station	1	2	3	4
2.2	Are you familiar with actual water consumption in your power station	1	2	3	4
2.3	Are you familiar on how to calculate water consumption	1	2	3	4
2.4	Suitable targets are needed to monitor the implementation of the water management policy	1	2	3	4

SECTION C: MANAGEMENT ASPECTS

1. WATER MANAGEMENT AWARENESS (Please indicate by making an **X** in the relevant column)

		Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
1.1	The power station has a policy to manage water consumption	1	2	3	4
1.2	Water consumption is taken seriously at the power station	1	2	3	4
1.3	Water is a scarce resource in the power station	1	2	3	4
1.4	The risk management of water is important	1	2	3	4
1.5	I report water leaks	1	2	3	4
1.6	I receive rewards for reporting water leaks	1	2	3	4

2. COMMUNICATION ON WATER MANAGEMENT (Please indicate by making an **X** in the relevant column)

		Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
2.1	Do you have access to water reports	1	2	3	4
2.2	Do you participate in the water-related forums	1	2	3	4
2.3	I influence my team to ensure that water consumption is taken care of	1	2	3	4
2.4	Is water consumption discussed during toolbox	1	2	3	4
2.5	Water challenges are communicated	1	2	3	4
2.6	The power station report on the water targets as per the agreed reporting timeframes	1	2	3	4

3. RESPONSIBILITY AND SKILLS IN WATER MANAGEMENT (Please indicate by making an **X** in the relevant column)

		Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
3.1	Water consumption is everyone's responsibility	1	2	3	4
3.2	There are enough skilled employees in the power station to manage water consumption	1	2	3	4
3.3	The water management task team in the power station is active	1	2	3	4
3.4	There is training to improve water management	1	2	3	4

3.5	There are policies to govern water consumption in your power station	1	2	3	4

4. LEADERSHIP AND ORGANISATIONAL CULTURE (Please indicate by making an **X** in the relevant column)

		Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
4.1	Management promotes a culture of conserving water	1	2	3	4
4.2	Employees are motivated by my management to conserve water	1	2	3	4
4.3	There is leadership to manage water effectively in your power station	1	2	3	4

Dynamic Language & Translation Specialists

Antoinette Bisschoff
71 Esselen Street, Potchefstroom
Tel: 018 293 3046
Cell: 082 878 5183
antoinettebisschoff@mweb.co.za
CC No: 1995/017794/23

Monday, 18 December 2017

To whom it may concern,

Re: Letter of confirmation of language editing

The dissertation **Evaluating water consumption in an electricity provider** by **Vusi Bethuel Mokoena (25678949)** was language edited. The referencing and sources were checked as per NWU referencing guidelines. Final corrections remain the responsibility of the author.

Antoinette Bisschoff

Officially approved language editor of the NWU since 1998
Member of SA Translators Institute (no. 100181)

Precision ... to the last letter