Community perceptions on Water Resource Management: A case study of the Roodeplaat Dam, South Africa.

Karabo Maruapula

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Supervisor: Dr L.S. Modley

Co-supervisor: Dr K. Yessoufou

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Abstract

The Roodeplaat Dam (RD) is located in Pretoria, South Africa, and has three major tributaries (Pienaars, Edendalespruit and Hartbeesspruit Rivers) flowing into the dam. The Catchment Area of the RD has a variety of land uses and recreational activities. The eutrophication levels of the RD have been a cause for concern since the early 1980s as its level of eutrophication has increased due to cyanobacteria, algae and water hyacinths. The water quality of the three rivers flowing into the RD contribute to the eutrophication within the dam. In order to manage this eutrophication, an integrated approach, involving local communities in the management of water resources is necessary. Therefore, the aim of the present study was to understand community perspectives of the function and management of the RD and its tributaries.

The communities perspectives showed that highly educated people tend to qualify the quality of water as very bad and their perceptions on the potential effects of poor water quality were correlated to gender. People's satisfaction level of the current management plan was negatively correlated to employment status. Surprisingly, the communities involvement in the management and use of water resources in the Roodeplaat Catchment Area were correlated to their ethnicity. On the basis of these findings, a few recommendations were proposed towards the effective management of the RD and its inflowing rivers.

Key words: *Water quality, water management, LULLC, community perceptions*

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Abbreviations

Catchment Management Forum	CMF
Chloride Ion	Cl
Community-Based Natural Resource Management	CBNRM
Department of Water Affairs and Forestry	DWAF
Department of Water and Sanitation	DWS
Electrical Conductivity	EC
Escherichia coli	*E. coli*
Integrated Development Plan	IDP
Integrated Water Resources Management	IWRM
Land Use and Land Cover Change	LULCC
National Water Act	NWA
Nitrogen	N
Phosphorus	P
Roodeplaat Dam	RD
Statistics South Africa	STATS SA
Sulphate	SO_4
Target Water Quality Range	TWQR
United Nation Conference on Environment and Development	UNCED
Water Quality Guidelines	WQGs
Wastewater Treatment Plant	WWTP

Chapter 1 Introduction

1.1 Background

South Africa is a water-stressed country with an average annual rainfall of 450 mm, which is approximately 60% of the world average (CSIR, 2010; CSIR, 2013; DWS, 2015). Most parts of the interior and the western part of the country are arid or semi-arid and are prone to variable rainfall, droughts and floods (CSIR, 2010; CSIR, 2013; DWS, 2015). The country's freshwater water resources, including dams, rivers and groundwater, are under increasing pressure due to rising population, land cover changes and climate change (Oelofse and Strydom 2010; Mwangi, 2014; Peterson et al., 2017; Donnenfeld et al., 2018; Mutambam, 2019).

Moreover, several water resources in the country are exposed to pollutants and contaminants from the mining, industrial, agricultural and domestic water production industries (Nare et al., 2011; Oberholster, 2013; Musingafi and Tom, 2014). This pollution from various sources has resulted in an increased salination and eutrophication of several rivers and dams across the country (van Ginkel, 2005; Oberholster and Ashton, 2008; van Ginkel, 2011; Ally, 2013; Dabrowski and de Klerk, 2013; Mbiza, 2014). The majority of water quality concerns that affect South Africa are faecal pollution, urban runoff, acid mine drainage, and eutrophication (DWAF, 2009; DWS, 2017).

1.2 Eutrophication

Eutrophication is a process driven by nutrient enrichment in aquatic ecosystem, from nitrogen and phosphorus (Matthews and Bernard, 2015; Bhagowati and Ahamad, 2019; Vincon-Leite and Casenave, 2019). Based on the eutrophication level, a waterbody may be classified as oligotrophic, mesotrophic, eutrophic or hypertrophic (Walmsley, 2000; Esfandi et al., 2018). An oligotrophic system is characterised by low productivity and species diversity while mesotrophic systems have moderate productivity and high species diversity (Liao et al., 2017). Eutrophic lakes have a high productivity and high species abundance, but low species diversity (van Ginkel et al., 2002). An extreme eutrophic condition is often referred to as being hyper-trophic (van Ginkel et al., 2002; Liao et al., 2017; Vincon-Leite and Casenave, 2019). Eutrophication can lead to the deterioration of water quality, algal toxin production, oxygen depletion and degradation of recreational activities (van Ginkel, 2002; DWA, 2003; Dodds et al., 2009).

Water is one of the most mismanaged natural resource in South Africa (Reddy, 2002). It is therefore important that this resource is monitored and managed effectively (Oelofse and Strydom, 2010; WWF South Africa and CSIR, 2013). Jonch-Claussen (2004) defines water management *as 'a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems'*. This is linked to not only the quality, but also to the quantity of available water (Berjak, 2003; Biswas and Tortojada, 2011; Cosgrove and Loucks, 2015; Durán-Sánchez, 2018).

1.3 Integrated Water Resource Management

The increased competition and demand between different water uses has motivated for finding new and innovative approached towards managing water resources (Rodda et al., 2016, Muste et al., 2017). An integrated approach is therefore required different sectors to achieve future action on water and sustainable development (Rahaman et al., 2004; Koc, 2010). The IWRM process depends on the collaboration of all interested and affected parties (I&APS) in water resource management (Jonch-Clausen and Fugl, 2001). Implementing IWRM requires the shift from single-sector, management, to sector-integrated, locally focused management, incorporating stakeholder interests which incorporates the interests of diverse stakeholders (Phiri, 2011). The importance of involving communities in conservation projects has been widely accepted and their role in water management is (Cook and Smith, 2005; Warner, 2006; Fleming and Fleming, 2009; Mirumanchi and van Wyk, 2010; Megdal et al., 2017; Jiménez et al., 2019). recognised as an important component of delivering water- related outcomes).

1.4 Problem Statement

The RD is located within a nature reserve (Jones & Lee, 1984; Swanepoel, 1997; Marchand et al., 2012), approximately 24 km north-east of the City of Tshwane, in the Gauteng Province. The dam was originally constructed to supply water for irrigation purposes (Marchand et al., 2009). However, the original irrigation purpose has been supplemented with a recreational service that the dam is increasingly providing to the local communities and beyond (van Ginkel et al., 2007). The Rietvlei, Vaal and Hartbeespoort Dams are amongst South African dams which have been supplemented with recreation services (Toerien and Walmsley, 1979; Thornton and McMillan, 1989; du Plessis, 2017). Consequently, the biophysical integrity of the dam has deteriorated over time with an additional high level of eutrophication due to cyanobacteria, algae and water hyacinths (van Ginkel et al., 2000; Marchand et al., 2012).

General sources of pollution of the RD are well known. These include two Wastewater Treatment Plants (WWTPs) namely Zeekoegat and Baviaanspoort, which discharges the residues of water treatment into three rivers that are referred to, in this document, as the tributaries of the dam: Hartbeesspruit, Pienaars and Edendalespruit (Swanepoel, 1997; Marchand, 2009). The main pollutants sources of pollution in the dam and its tributaries, include domestic and industrial soaps/detergents which contribute to the orthophosphate load (Marchand et al., 2012). Additionally, pollutants emanating from industrialization, housing and agricultural activities at the upstream of the nature reserve, contribute to the dam's eutrophication (Swanepoel, 1997). As a result, the RD has been identified as one of the dams ranked requiring priority eutrophication management in South Africa (van Ginkel, 2005; Marchand, 2009).

1.5 Justification

In the face of these environmental problems, several studies have been investigating the pollution state of the dam as well as its causes (Walmsley and Toerien, 1978; Hohls and van Ginkel, 2004; Lomberg, 2010), and some of these have even proposed some management plans (DWAF, 2008). However, very little research has been done to understand the perceptions and roles of the communities surrounding the RD and its inflowing rivers in water resource management. Therefore, an important question remains: What are the perspectives and contributions of local human communities to the management of the dam and its tributaries? This question needs to be investigated so that an integrated management plan that incorporates a community-based perspective can be possible. However, prior to the investigation of these community perspectives, it was necessary to first understand the levels of pollution of the system as well as the contributing factors to the pollution. This was the motivation for the present study.

1.6 Aim and Objectives

The aim of the study was to understand communities' perspectives of the function and management of the RD and its tributaries. To achieve this, there is first a need to understand the factors contributing to the deterioration of water quality of the system.
As such the following objectives are set:

i) To compare the quality of water between the dam and its tributaries,
ii) To test the relationships between land use and land cover change (LULCC) and water quality,
iii) To understand community perspectives on water resource management in the study area by the surrounding communities.

1.7 Research Outline

The following section provides an outline of the minor dissertation, which is comprised of six chapters. The focus of each chapter can be summarised as follow:

Chapter 1*: Introduction*- This chapter first introduces the concepts of eutrophication and integrated water resource management (IWRM). The chapter also highlights the problem statement and justification of the present study and further presents the layout of the minor dissertation.

Chapter 2*: Literature review*- This chapter provides a review of literature pertaining to the topic of the study. This section also identifies specific areas of paucity in the literature. Key concepts and related case studies are presented in this chapter.

Chapter 3*: Research materials and methods*- This chapter presents the description of the study area. It also provides details on the nature of the research, the research approach and research methodologies employed in this study.

Chapter 4*: Results*- This chapter provides the results of the research. The material presented in this chapter draws from the both primary and secondary data collection.

Chapter 5*: Discussion*- This chapter reports the interpretations of all the results in light with existing knowledge in the literature.

Chapter 6*: Conclusion*- This chapter provides a comprehensive synthesis and conclusion to the study aims and objectives.

Chapter 2 Literature Review

2.1 Water Quality Problems

Globally, unsustainable anthropogenic activities have resulted in the deterioration of river water quality (Peterson et al., 2017; Strokal et al., 2019; Bashir et al., 2020). Rivers have been identified as the most intensively influenced ecosystems in the world (Sibanda et al., 2014; Ding et al., 2015; Sabater et al., 2018) as they are mostly targeted for human settlement and exploitation for water supplies, irrigation, electricity generation and waste disposal (Bagalwa, 2006; Roux and Oelofse, 2010).

Water quality problems are commonly associated with chemical and nutrient loadings into aquatic systems as a result of point and non-point sources of pollution (Brown et al., 2005; Chen, 2015; Gyawali et al., 2015). Point sources of pollution occur at fixed places, which generate pollutants that enter into the stream system through specific points (Tombo, 2010; Hossain, 2017). These points include drainpipes, ditches, and factory outfalls releasing organic loads, heavy loads or nutrients (Tombo, 2010). These sources are relatively easy to identify and regulateas compared to non-point sources of pollution (Tombo, 2010; Matthews and Bernard, 2015; Gyawali et al., 2015).

Non-point sources of pollution, also called diffuse sources, are those with a multitude of locations or places from which pollutants are generated (Tombo, 2010; Wang et al., 2019; Shen et al., 2020). These pollutants often reach the system through agricultural runoff, urban runoff and animal or human waste (Matthews and Bernard; 2015; Cheng et al., 2018). Pollution sources including nutrient runoff from crop and livestock farming, sewage and domestic waste from industrial activities and salts leaching from concrete and soils are illustrated in Figure 2.1 (Zia et al., 2013).

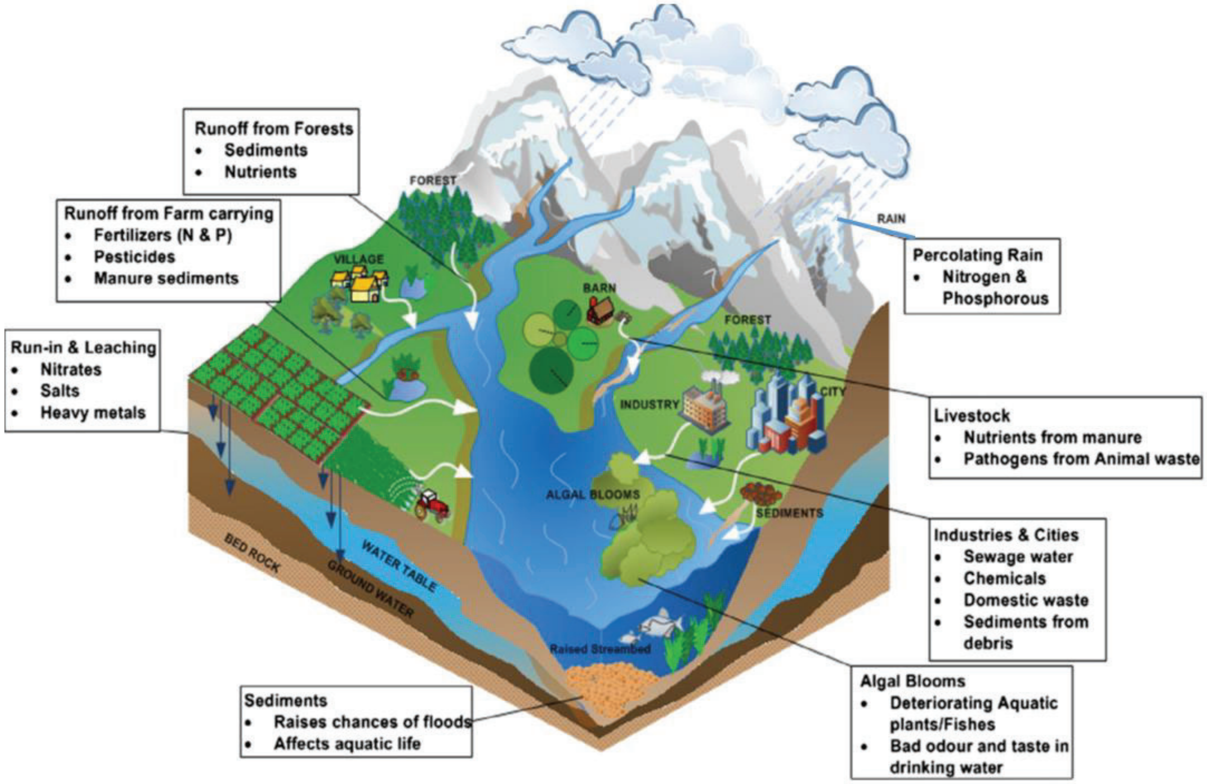

Figure 2.1: Illustration of the water contamination activities within a catchment (Zia et al., 2013).

The degradation of water quality is a direct effect of development and land use change (Bateni et al., 2013). It has been predicted that the demand for water in South Africa will increase by 32% (to 17 700 million m^3) by 2030 due to growing population, climate change and increased human activities (CSIR, 2013). Therefore, it is important to understand the link between water quality and land cover/land use so that water resources can be used sustainably and managed effectively for future generations.

2.2 Parameters defining water quality

Water quality is defined as a variable that evaluates the usage of water for different purposes using various parameters such as physical, chemical and biological (NWA, 1998; Shukla et al., 2018). It is changed and affected by both natural processes and human activities (Khatri and Tyagi, 2014). The degradation of water in dams and rivers increases algal bloom and phytoplankton biomass and further degrades the taste and odour (Swanepoel et al., 2017). The National Water Act of South Africa (Act 36 of 1998) states that water resource management was formulated to achieve the sustainable use of water for the benefit of all users (NWA, 1998). Therefore, it is important to monitor the physico-chemical and biological parameters of water for an effective management of water pollution for the benefits of human health and aquatic ecosystems. The following parameters are the most commonly used variables to define water quality.

2.2.1. pH

pH is described as the value that is used to measure the concentration of hydrogen ion in water (DWAF, 1996a). At $pH<7$, water is said to be acidic, while a $pH>7$ implies that the system alkaline. pH varies seasonally due to the hydrological cycle, whereby concentrations of organic acids are relatively lower during the rainy months. Industrial activities such as mine drainage and acid precipitation are known to cause acidification of freshwater systems, while higher pH values are known to be caused by increased biological activities mainly found within eutrophic systems. The pH is thus affected by the temperature, biological activity and concentration of organic and inorganic ions (DWAF, 1996a).

2.2.2. Electrical conductivity (EC)

Electrical conductivity (EC) can be defined as the ability of water to conduct an electrical current (DWAF, 1996c). The conductivity may be due to the presence of salts in water, all of which carry an electrical charge. High EC in water may be due to the magnesium, calcium, potassium, chloride and sulphate (DWAF, 1996c).

2.2.3. Chloride ion (Cl)

Chloride is an anion (negatively charged ion) Cl^- of the element chlorine, which does not occur in nature (DWAF, 1996a). Chloride salts such as sodium, potassium, calcium and magnesium are all highly soluble in water. Elevated concentrations of chloride in domestic water may result in a salty taste to water thus accelerating the rate of corrosion in metals (DWAF, 1996c).

2.2.4. Nitrogen (N)

Nitrogen is a nutrient, which in excess can lead to the pollution of waterbodies. It exists in a variety of organic and inorganic forms and must undergo many transformations in the ecosystem to be used by organisms (DWAF, 1996d, e). Inorganic nitrogen is a term used to describe nitrogen components including ammonia (NH_3), ammonium (NH_4), nitrogen dioxide (NO_2) and nitrate (NO_3) present in water (DWAF, 1996d, e). The major sources of nitrogen entering aquatic ecosystems includes, the discharge of effluent streams containing human and animal waste, agricultural fertilizers and organic industrial wastes (DWAF, 1996d, e).

2.2.5. Phosphorus (P)

Phosphorus is the nutrient controlling the degree of eutrophication within the aquatic ecosystem (DWAF, 1996a; van Ginkel, 2002). This nutrient occurs in both organic and inorganic forms and is found in water as dissolved and particulate species. Phosphorus is seldom present in high concentrations in clean water surfaces as it is mainly taken up by plants.

2.2.6. Sulphate (SO_4)

Sulphate is the termed used to describe the oxy- anion of Sulphur in the VI oxidation state (DWAF, 1996a, b, d). It usually forms salts with various cations such as potassium, sodium, calcium, magnesium, barium, lead and ammonium (DWAF, 1996a, b, d). Sulphate is usually released from acid mine wastes and many other industrial processes such as tanneries, textile mills and processes using sulphuric acid or sulphate (DWAF, 1996c).

2.2.7. Escherichia coli (E. coli)

Escherichia coli (*E. coli*) is an indicator of faecal (bacterial) pollution which originates from the humans and animals. It is used to assess the quality of wastewater effluents, river water, sea water at beaches, and raw water for drinking supply, treated drinking water, water used for irrigation and aquaculture and recreational water (DWAF, 1996b).

A variety of diseases such as gastroenteritis, cholera, and salmonellosis are particularly associated with the consumption of faecal polluted water, which is fatal (especially in infants) (DWAF, 1996b, d). According to DWAF (1996d), the risk of infection correlates with the level of contamination to the waterbody and the amount of water consumed by the individual.

Recently, researchers (Ahmad et al., 2016; Yusuf et. al., 2017; Hashmin et al., 2018) have assessed the quality of water on river basins and watershed levels. Ahmed et al. (2016) conducted a study with the aim of identifying water quality parameters and contamination sources of the River Bashgal in Pakistan. The results showed that water quality parameters were within the required levels, which was safe human consumption and aquatic ecosystems (Ahmed et al., 2016). Yusuf et al. (2017) to assess the water quality and heavy metal load of the Saba River in Osogbo, Nigeria. Most of the physico-chemical parameters measured were within the set limits with the exception of some oxygen parameters (DO, BOD and COD) (Yusuf et. al., 2017). Hashim et al. (2018) carried out an assessment on water quality and microbial contamination along the Langat River in Malaysia. The pH values were within acceptable limits and no statistical difference was observed among sampling points. A positive relationship was revealed between sampling point 20 and *E. coli*. This was due to effluents discharged from domestic sewage and a wastewater treatment plant in the surrounding area (Hashim et al., 2018).

2.3 The South African Water Quality Guidelines

The South African Water Quality Guidelines (WQGs) are divided into categories for the specific water uses. The document consists of guidelines for domestic, recreational, industrial and agricultural water uses. The guidelines are used by the DWS to prevent water pollution and to protect the quality of water resources in South Africa. The document also provides information on the acceptable limits for water for uses or target water quality range (TWQR).

For the purpose of this study, the South African WQGs for domestic, recreational, industrial, agricultural: irrigation and aquatic ecosystems (Table 2.1) were used to assess the water quality status of the Roodeplaat Catchment Area (DWAF, 1996 a, b, c, d, e). By doing so the, the physico-chemical and biological results of the rivers flowing into the dam will be compared to the WQGs set by DWAF in order to measure the level of pollution in the Roodeplaat Catchment Area.

Table 2.1: South African Water Quality Guidelines (DWAF, 1996a, b, c, d, e)

	Unit	Domestic volume 1	Recreational Use volume 2	Industrial Use volume 3	Agricultural Irrigation volume 4	Aquatic Ecosystems volume 5
pH	mg/L	6-9	6.5-8.5	Category 1: 7-8	6.5-8.4	pH values should not be allowed to vary from the range of the background pH values for a specific site and time of day, by > 0.5 of a pH unit, or by > 5
	mg/L			Category 2: 6.5-8		
	mg/L			Category 3: 5-10		
Electrical Conductivity	mg/L	>450	N/A	Category 1: 0-70	>40	N/A
	mg/L			Category 2:70-120		
	mg/L			Category 3:120-250		
	mg/L			Category 4: >250		
Nitrogen	mg/L	N/A	N/A	N/A	>0.5	< 0.5 Oligotrophic 0.5-2.5 Mesotrophic 2.5-10 Eutrophic >10 Hypertrophic
Phosphorus	mg/L	0-100	N/A	N/A	0.1	< 5 Oligotrophic 5-25 Mesotrophic 25-250 Eutrophic >250 Hypertrophic
Chloride Ion	mg/L	0-100	N/A	Category 1: 0-20	0.1	N/A
	mg/L			Category 2: 20-40		
	mg/L			Category 3: 40-100		

	Unit	Domestic volume 1	Recreational Use volume 2	Industrial Use volume 3	Agricultural Irrigation volume 4	Aquatic Ecosystems volume 5
	mg/L			Category 4: 0-500		
Sulphate	mg/L	0-200	0-200	N/A	>20	N/A
E. coli	mg/L	N/A	>400	N/A	>50 000	N/A

2.4 Understanding the relationship between land use and land cover change (LULCC) and water quality

Land cover refers to the physical and biological cover over the surface of land, including water vegetation, bare soil and/ or artificial structures (Hau, 2017). However, land cover represents the spatial distribution of the different land cover classes on the earth's surface and can be estimated qualitatively and quantitatively with the use of Remote Sensing (Roy and Roy, 2010). On the other hand, land use refers to the way in which land has been used by humans and their habitats (agriculture, settlements, industry and fishing) (Kaul and Sopan, 2012). The influence of land use on water quality has been a concern since the 1970s (Bu et al., 2004; Tu, 2011; Xie et al., 2012; Haung et al., 2013; Matano et al., 2015; Razali et al., 2018; Camara et al., 2019). Since then, watershed management and catchment scale studies have become increasingly important for determining the impact of human activities on water quality (Ahearn et al., 2005; Ding et al., 2015; McCarthy et al., 2018;).

Several studies (Walmsley and Toerien, 1978; Swanepoel, 1997; Lomberg, 2010; Kiberna et al., 2014; Haung et al., 2015; Gyawali et al., 2015; Pullanikkatil et al., 2015; Ding et al., 2015) have been conducted across the world to understand the link between water quality and LULCC. Haung et al. (2015) conducted a study to examine the effect of land use patterns on stream water quality in the Three Gorges Reservoir Area (TGRA), China (Haung et al., 2015). The results show that both forest land and grassland are negatively correlated to Total Nitrogen (TP) and Total Nitrogen (TN). This shows that both land covers play a role in reducing nitrogen and phosphorus concentrations, thus stabilizing the quality of water. However, built-up area was positively correlated to TP and TN, indicating that an increase in impervious surfaces and built-up area degrades water quality.

A similar study was conducted in China by Ding et al. (2015) with the aim of determining the influences of land use patterns on water quality of the Dongjiang River Basin. Ding et al. (2015) found a positive relationship between urban land use and TN and ammonia nitrogen (NH_3-N) and a negative relationship between agricultural land and water quality

(Ding et al., 2015). Gyawali et al. (2015) examined the changes of land use on water quality. The results of the study highlighted the negative impact of urbanisation on river water quality, which is influenced by point sources from urban areas. Agricultural land correlated negatively with water quality, which was agreement to the results obtained by (Ding et al., 2015).).

In Zimbabwe, a study was conducted to analyse the changes in land use and land cover on the quality of water in Upper Manyame River catchment (Kiberna et al., 2014). The results indicated bareland, grassland and forested land were converted to for agricultural and industrial activities between the years 1984 and 2011 (Kiberna et al., 2014). A study conducted in Malawi by Pullanikkatil et al. (2015) assessed the impact of land use on water quality in the Likangala catchment. The quality of water and ecosystems integrity declined from 1984 to 2013 due to the surrounding land uses. The results show forested land declined, while built-up land increased significantly during the study period, which is similar to findings obtained in the study conducted by Kiberna et al. (2014). Pollutants from a nearby WWTP, residential area and agricultural land were identified during site visits. During the focus group discussions, community members reported that the water in the Likangala catchment was unfit for human consumption.

A number of studies (Walmsley and Toerien, 1978; Swanepoel, 1997; Lomberg, 2010; Marchand et al., 2012; Modley et al., 2020) have investigated the pollution and eutrophication state of the RD as well as its causes, and some of these have even proposed management plans (DWAF, 2008). Walmsley and Toerien (1978) conducted a study with the aim of assessing the water quality of the three rivers flowing into the RD. This study focused mainly on the chemical parameters for analysis. The results showed that the Pienaars River contributed the most pollution (dissolved minerals) to the dam, as it discharged the most water into the dam as compared to the other two rivers (Walmsley and Toerien, 1978).

A study conducted by Swanepoel (1997) analysed the effect of LULCC on the water quality of the Roodeplaat Catchment Area (Swanepoel, 1997). The results from the study indicated there has been drastic LULCC in the area due to increasing anthropogenic activities along the catchment area. It was also reported that grassland and vegetated land have been converted to industrial, domestic and agricultural land. In addition, Swanepoel (1997) found that the general sources of pollution in the RD can be attributed to the Baviaanspoort and Zeekoegat WWTPs, which directly discharge wastewater effluents into the dams tributaries (Hartbeesspruit and Pienaars River).

A more comprehensive study was conducted by Lomberg (2010), which assessed the focused on the effects of seasonal changes on the water quality of the RD, from 2006 to 2009 (Lomberg, 2010). Water quality and rainfall data were analysed over a ten-year period (1999-2009). The results identified an inverse relationship between the quality of water and rainfall data. The results also indicated that the Baviaansport and Zeekoegat WWTPs were amongst other land cover changes that altered the quality of water in the RD (Lomberg, 2010).

More recently, Modley et al. (2020) assessed and compared the biotic integrity of the rivers) flowing into the RD. The results showed that all the rivers were highly polluted by nutrients and faecal coliform. These results also confirmed the hypertrophic status of the RD. The Pienaars River was more polluted than the other rivers, due the land uses (Baviaanspoort WWTP, informal and low-cost housing and, and agricultural activities) surrounding the river (Modley et al., 2020).

2.5 Water resource management in South Africa

The management of water resources in South Africa has evolved over time and the Department of Water and Sanitation (DWS) has been working towards an Integrated Water Quality Management (IWQM) (Pollard and du Toit, 2008; DWAF, 2015). Initially management was based on a pollution control approach (DWS, 2015). However, Agenda 21 calls for a paradigm shift towards the development of integrated methods and strategies towards the management of water resources (Wilkinson et al., 2015).

Integrated Water Resources Management is designed to change the traditional methods of water management with a more sustainable and holistic approach (Rolston et al., 2017). Given the complex nature of aquatic systems, such integrated approach is necessary. For example, at catchment scale, both human and bio-physical factors interact in an integrated fashion. Therefore, making catchments a complex system whose management requires, the consideration of perceptions of all stakeholders involved in the use of the resource (Alam & Quevauviller, 2014).

A critically important element of IWRM is the integration of various sectoral views and interests in the development and implementation of the IWRM framework (see Figure 2.2) . The implementation of an IWRM process consists of three pillars: the enabling environment, the institutional framework and the management instruments (Alam and Quevauviller, 2014; Wilkinson et al., 2015).

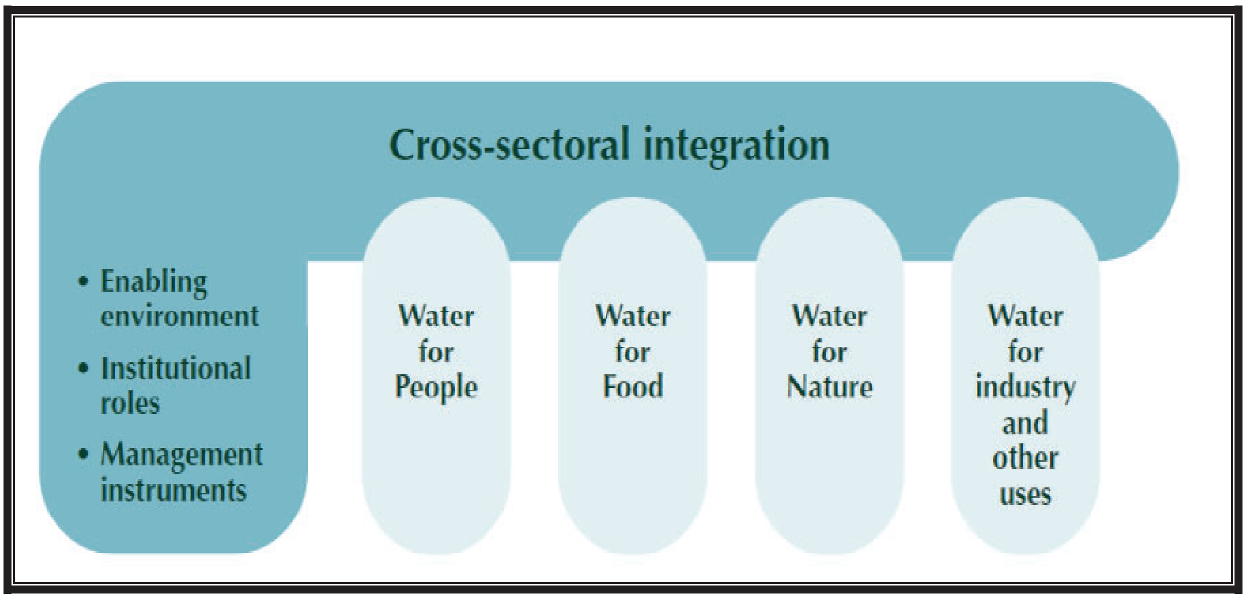

Figure 2.2: Cross- sectoral aspects of Integrated Water Resource Management (IWRM) (Alam and Quevauviller, 2014).

2.5.1 Legal framework and call for public participation in the sector of water resource management

In terms of legal framework or policy, early documents include the White Paper on Water Supply and Sanitation (1994) and the White Paper on a National Water Policy for South Africa (1997), which aimed to address rural poverty and past inequities (RSA, 1994; 1997). The two policies are supported by the National Water Act (NWA) (Act No.

36 of 1998), which aims to protect the quality of water resources and to ensure equity in water allocations (Pollard and du Toit, 2008).

In addition, further legal documents regulating water usage in South Africa includes the South African Constitution (Act 108 of 1996), the National Water Policy White Paper of 1997, the National Water Act (Act 36 of 1998), and the National Water Services Act (Act 108 of 1997). These Acts are complementary and provide a framework for sustainable water resource management to enable an improved and broadened service delivery (NWA, 1998). For example, South Africa's highly acclaimed National Water Act (Act 36 of 1998) provides the foundation for a new and fundamentally different way of managing water resources in the country. Together with the White Paper for National Water Policy (which sets out 28 principles; DWAF 1997), it challenges the policies and values of the past by framing water resource management within the context of two fundamental principles: equity and sustainability (RSA, 1997).

The NWA, in particular, called for the creation of a Catchment Management Agency (CMA) (NWA, 1998). Catchment Management Areas are participatory corporate bodies to which management authority is delegated in their respective water management areas. As management is regarded as something of national importance, and rivers often cross provincial boundaries, the CMAs are placed directly under the Minister of the Department of Water and Sanitation (previously known as DWAF). All these policies emphasise the need for public participation in the process of water resources management. All CMAs should have community representatives including racial and gender structures participating in the management of water resources, therefore, ensuring that their water related needs and expectations are considered (NWA, 1998). Although a management plan has been proposed for the RD (DWAF, 2008), the perspectives of local communities on the dam and its tributaries are not fully integrated into the management of the catchment area.

2.6 Community participation in water quality monitoring and management

Community-based natural resource management (CBNRM) is a strategy that encompasses the principles of participation of individuals, households and communities in aspects that directly and indirectly affects the resources of present and future generations (Dewan et al., 2014; Mountjoy et al., 2016; Tantoh and Simatele, 2017; Addison et al., 2019). Through this approach, the government plays the role of the facilitator of processes to support and develop the capacity of the community to manage its own water system (Lammerink et al., 1999). In this process communities become active participants in the protection of natural resources and are held accountable for their own actions (Lammerink et al., 1999; Ananga, 2015).

In the context of water resource management, participation, also known as stakeholder engagement, is an approach which allows stakeholders to participate in monitoring and management of water resources and including the in any decion-making process. This would include their participation from planning phase to the final evaluation phase of a project or programme (Waithaka, 2013; Thoradeniya and Maheshwari, 2017; Rolston et al., 2017; Galvez and Rojas, 2019). It is an approach that empowers people with knowledge, skills, knowledge and experience in the functioning and management of the resources at hand (Rolston et al., 2017) (in our case RD and its tributaries).

Participation in water resources management has gained increasing momentum over the last few years (Chifamba, 2013; Behnke et al., 2017; Mashazi et al., 2019). A study conducted by Chifamba (2013) assessed the level of community participation in IWRM in the Save Catchment. Behnke et al. (2017) identified mechanisms for a community-based management system for rural communities, using Ghana, Kenya, and Zambia as case studies. In South Africa, Mashazi et al (2019) evaluated the perceptions and participation towards water resource management of the local community along the Kaalspruit River in Tembisa.

Stakeholder engagement aims to include all interested and affected water users to voice out their opinions on the management of water resources, (Manyatsi and Brown, 2009). It will be crucial to identify who and how the various stakeholders will be engaged to ensure that there is robust debate that can lead to the design of a comprehensive management plan (Polland and du Toit, 2008). A number of studies have been conducted to across the world to understand community perceptions, opinions and their involvement in the management of water resources (Heyd and Neef, 2004; DWAF, 2008; Nkonjera, 2008; Nare et al., 2011; Boakye and Akpor, 2012; Noga and Wolbring, 2013).

A study was conducted by Heyd and Neef (2004) on the participation of local people in water management in Thailand. The study was focused on the communities strategies used to transform participatory methods at municipal level (Heyd and Neef, 2004). The community expressed their dissatisfaction and lack of trust towards the government. The community also highlighted that the government does not involve them in participatory projects as stated in the policies. It was concluded that local community members should be given the opportunity to participate in water resource management as it is a constitutional right (Heyd and Neef, 2004). Noga and Wolbring (2013) conducted a study in Canada on perceptions of water ownership, water management and the responsibility of providing clean water (Noga and Wolbring, 2013). The results of the survey showed that some perceptions may influence certain beliefs, however, many other beliefs were not correlated to any specific perception. It was also indicated that further education and public understanding of water related issues important for governments and policy makers (Noga and Wolbring, 2013). Nkonjera (2008) investigated the participation of local communities in the domestic water development projects in Mbeya district, Tanzania. The results of this study indicated that the level of community engagement in water resource management was associated with gender, income status and age (Nkonjera, 2008).

In South Africa, Nare et al. (2011) developed a framework towards effective stakeholder engagement in water quality management in the Luvuvhu Catchment (Nare et al., 2011). The results showed that 90% of the respondents acknowledged that the water in their community was monitored.Fifty-one (51%) of the respondents identified the government being responsible for monitoring and management of water resources (Nare et al., 2011). The study concluded that the state of mindset from communities can lead to the dependency syndrome, where communities expect the government to play the leading role in the management of the system (Nare et al., 2011). Similarly, Boakye and Akpor (2012) assessed the involvement of communities in water resource management in the Msunduzi river catchment, KwaZulu Natal. The results highlighted that the communities had found their participation to be meaningless as their opinions on the status of the catchment were not considered.

For RD in particular, a study conducted by Vela VKE Consulting Engineers (2008) (DWAF, 2008) on behalf of the Department the of Water and Sanitation (DWS), formerly known as the Department of Water Affairs and Forestry (DWF), proposed a Resource Management Plan (RMP) for the RD. The RMP aimed to meet the objectives of the NWA and to provide the operational guidelines and responsibilities (DWAF, 2008). The plan was developed based on sustainability development and aspects relating to public participation. The RMP took into consideration the inputs of all interested and affected stakeholders and addressed four key Performance Areas (KPAs) that align with the National Water Act (Act No. 36 of 1998) as illustrated in Figure 2.3 (DWAF, 2008).

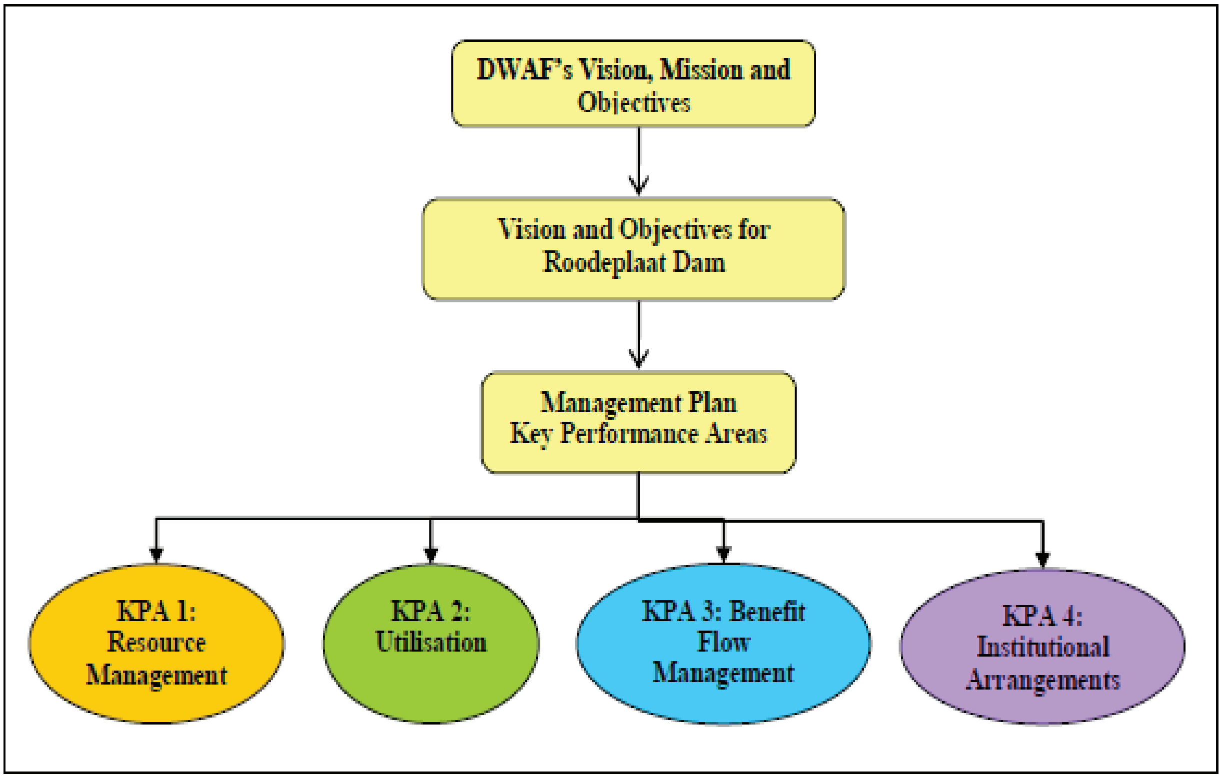

Figure 2.3: Management Framework implemented in the RMP (DWAF, 2008).

The abovementioned plan was designed to include all I&APs to participate in the protection and management of resources at the RD. However, the local community was not engaged effectively nor was it given the opportunity to get involved in this process. The perceptions and roles of community of communities along the dam-river system have not been adequately investigated. Therefore, the present study assessed the perspectives and contributions of the local communities to the management of the dam and its tributaries. The study also provided achievable recommendations for the improvement of the existing management plan.

Chapter 3 Materials and Methods

3.1 Study Site

3.1.1 Geographic location

The RD is located approximately 25 km north-east of the City of Tshwane, South Africa (Figure 3.1). The dam falls within the Crocodile West Marico Water Management Area, with a catchment area of 690 km^2 and a surface area of 3.97 km^2 (Pieterse and Toerien 1978; van Ginkel et al., 2007). The dam's reservoir has a net capacity of 41.9×10^6 m^3 and covers an area of 396 ha at full capacity, with a mean depth of 10.6 m and a maximum depth of 43 m (Steyn et al., 1976; van Ginkel et al., 2002). The major tributaries flowing into the dam are the Hartbeesspruit (west of the catchment), the Pienaars River (located in the center of the catchment) and the Edendalespruit (east of the catchment) (Figure 3.1).

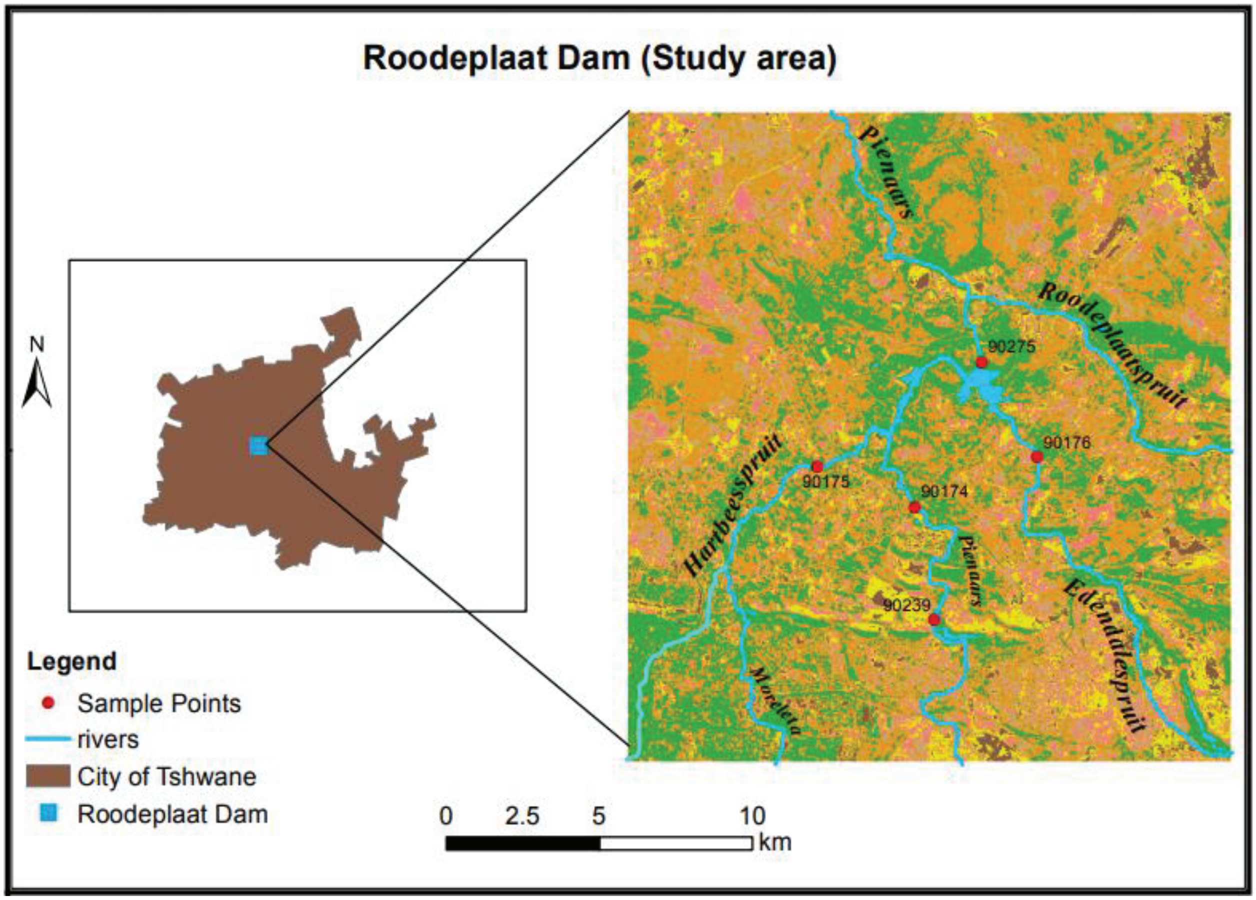

Figure 3.1: Location of Roodeplaat dam within the Tshwane Municipality (left) and a zoom-in image of the dam and its tributaries (right).

3.1.2 Climate and geology

Tshwane has a mean summer rainfall of 537 mm per annum and an annual precipitation of 600-800 mm and is characterized by moderate dry to sub-tropical climate with mean annual temperatures ranging from 16 to 20ºC (Mulders, 2015). Geologically, the area is comprised of shale and quartzite of the Magaliesberg Stage, overlain by shale, siltstone and minor quartzite bands belonging to the Smelterskop Stage of the Pretoria Series (Walmsley and Toerien, 1978). The terrain is underlain by three geological units: the Rayton Formation of the Pretoria Group within the Transvaal Supergroup, the Pienaars River Complex, with the Alkaline complexes and the Rashoop Granophrye Suite of the Bushveld Complex (DWAF, 2008).

3.1.3 Ecology

The RD is surrounded by the Marikana Thornvels, which is characterized by open *Acacia karroo* woodland with dense shrub areas along the drainage lines, including termitaria on rocky outcrops (DWAF, 2008). The dam is predominantly surrounded by tree species which include *Vachellia karro (formerly known as Acarcia Karro)*, *Acacia gerrardi*, *Acacia karroo*, *Rhus lancea* and *Ziziphus mucronata*. The dam is home to a variety of animal species, and some of these have been classified as threatened or endangered even though sensitive biological features are already protected in the Roodeplaat Nature Reserve which is situated south of the dam (DWAF, 2008).

3.1.4 Social Baseline

3.1.4.1 Population and Gender Groups

The City of Tshwane (CoT) is one of five district municipalities in the Gauteng Province, South Africa. It is the largest municipality in Gauteng, with an area of 4.173 km^2 (IDP, 2017). The municipality has a population of 3.31 million, with an annual growth rate of 2.92% (IDP, 2019). Of the total population, 79.11% are black African, 17.45 % are white, 1.82 % are coloured, with other population groups making up the remaining 1.62% (Figure 3.2) (Stats SA, 2016).

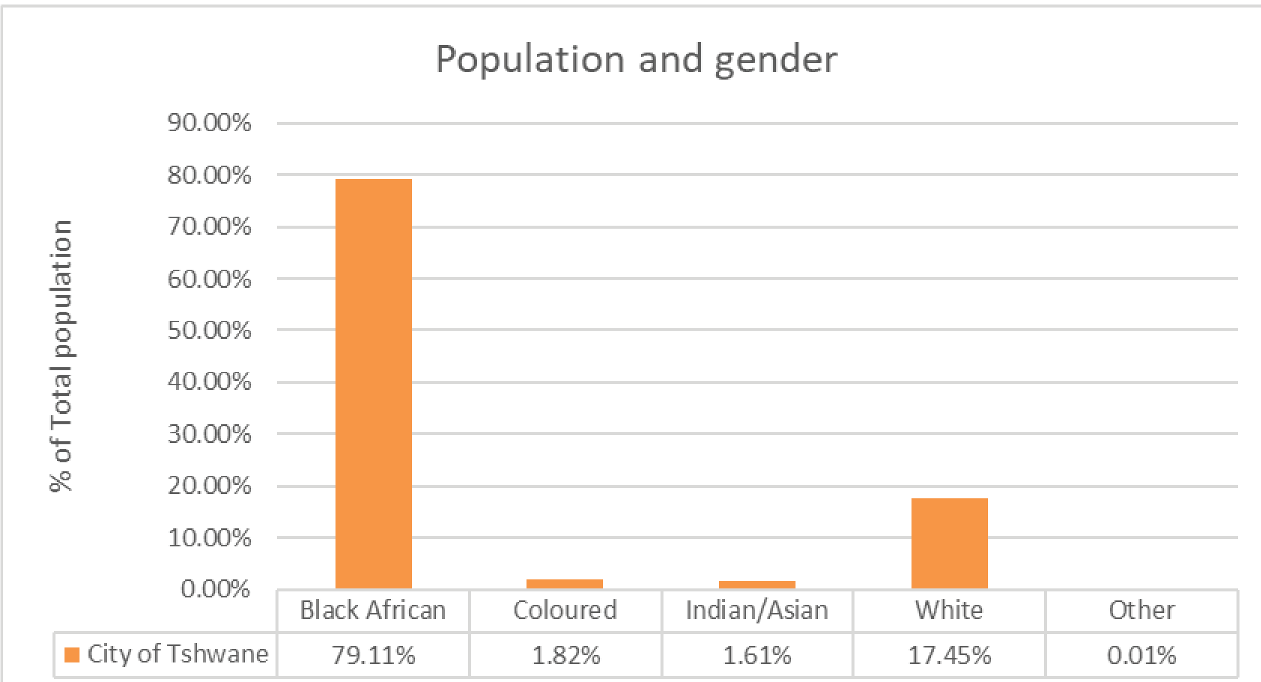

Figure 3.2: City of Tshwane's total population according to race (Stats SA, 2016).

3.1.4.2 Age Structure

Approximately 60% of Tshwane's population is younger than 35. The youth accounts for 35.15% and senior residents (65+ age group) only account for approximately 8.42% of Tshwane's total population (Figure 3.3) (Stats SA, 2016).

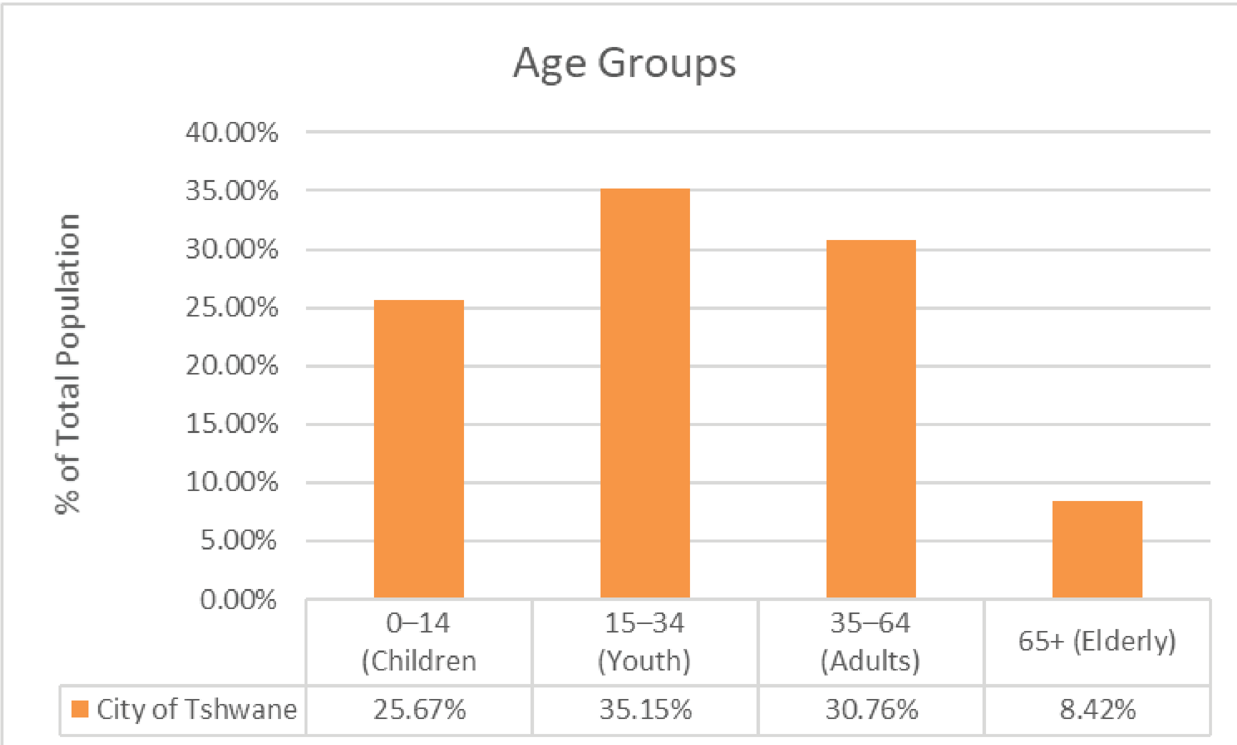

Figure 3.3: Broad age groups per population of the Tshwane Municipality

3.1.4.3 Residential Status

Figure 3.4 indicates that most households living within the CoT, (74.01%) reside within a formal house (concrete block structure). According to data obtained from the Community Survey (Stats SA, 2016), 9.05% of households within the municipality reside in an informal dwelling (shack not in backyard) and 4.45% of the population lives in a flat or apartment (Stats SA, 2016).

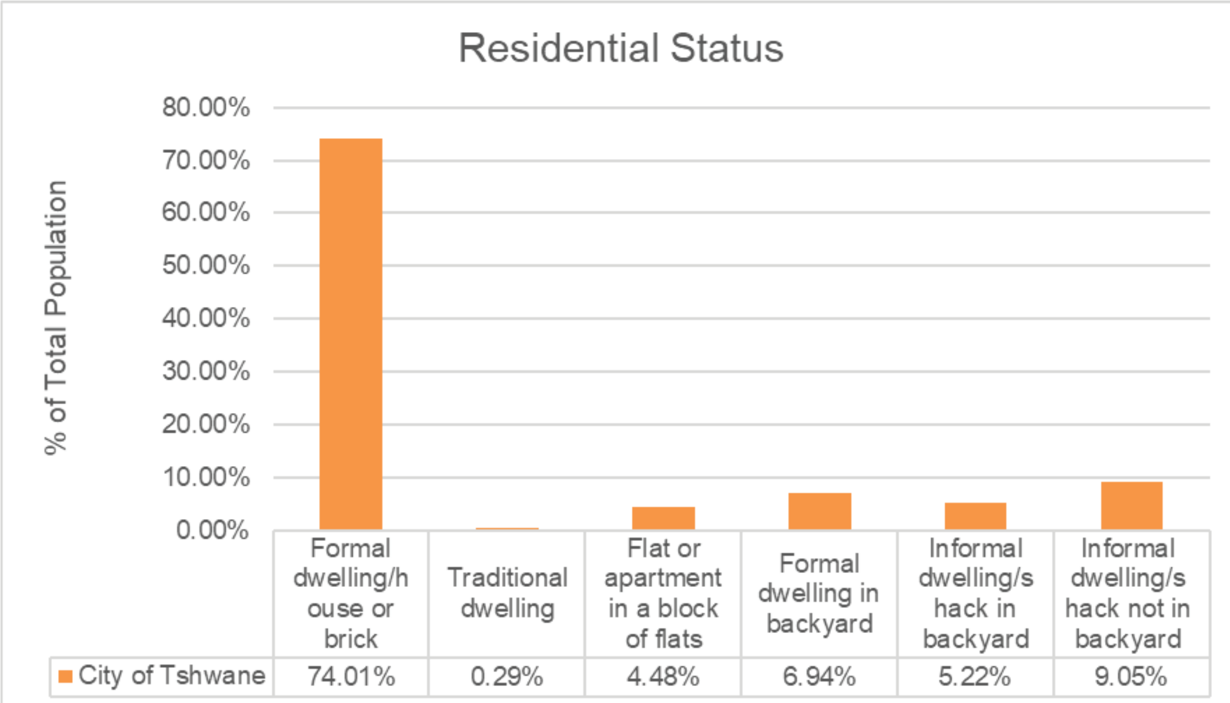

Figure 3.4: Residential status of the residents in the City of Tshwane (Stats SA, 2016).

3.1.4.4 Education

Of the total population, 24.2% have no formal schooling, with only 8.11% having Grade 9/ Standard 7 as illustrated in Figure 3.5. The education level of the residents in the CoT is high, with 49.64% of the population having completed Grade 12/matric (Stats SA, 2016). The total number of people with matric has increased by an average annual rate of 4.35% from 2007 to 2017 (IDP, 2017). Of the total population, only 8.6% have a tertiary education.

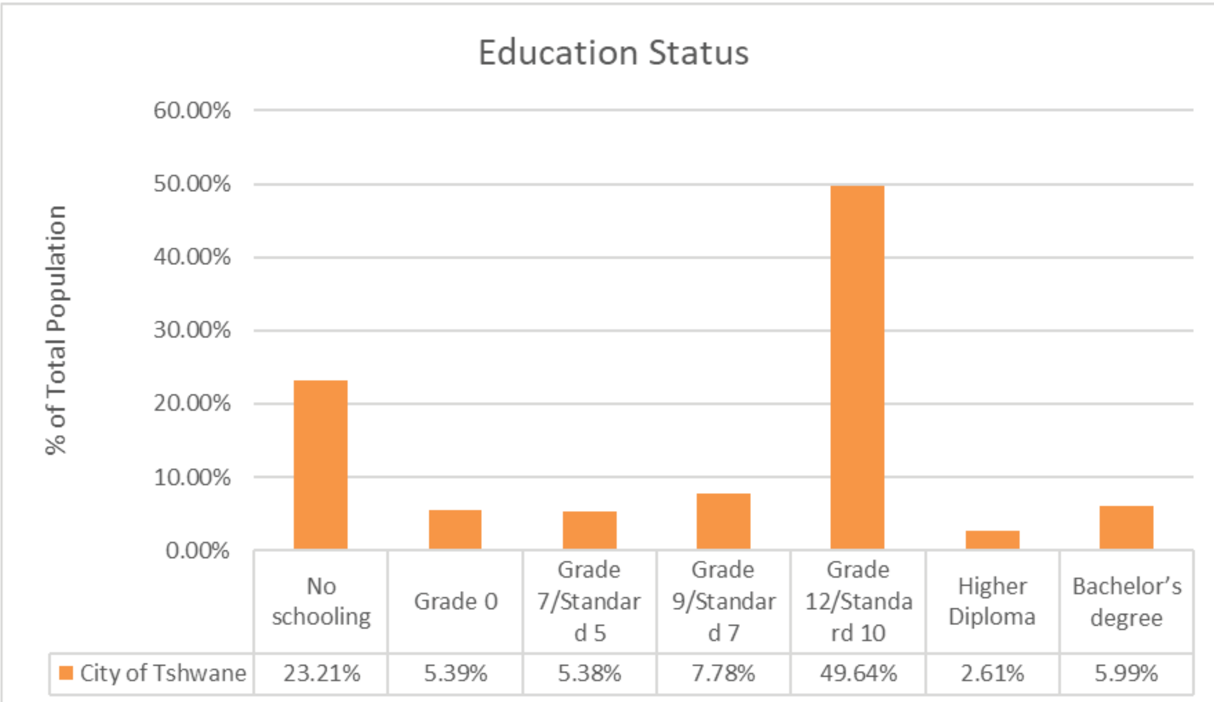

Figure 3.5: Educational status within the Tshwane Municipality (Stats SA, 2016).

3.1.4.5 Employment

The CoT is currently facing high levels of unemployment, with only 34.82% of the population having employment. Of the 34.82%, 86.97% are working in the formal industry while only 13.02% are working in the informal sector. City of Tshwane employs most of its workers in community services, finance and trade industries (IDP, 2017).

3.1.5 Land use and land cover surrounding the rivers flowing into the Roodeplaat Dam

Edendalespruit is surrounded by small farms and residential dwellings. To the west of the river is Mamelodi Township, a residential area with low-cost housing dominated by informal settlements (Figure 3.6 A). Agricultural areas also dominate the surrounding areas (Lomberg, 2010). Hartbeesspruit is pre-dominantly surrounded by residential holdings, from Pretoria East to Pretoria South and Mamelodi. The residential houses range from low-cost to middle- and high-cost (Figure 3.6 B, C and D).

Figure 3.6: Informal settlement found to the west of the Edendalespruit in (A); low- cost housing of Mamelodi Township (B) along the Pienaars River; Middle and High- cost housing found to the east of Hartbeesspruit (C and D).

The northern side of Hartbeesspruit is surrounded by the Zeekoegat Water Treatment Plant (WWTP) (Figure 3.7), small farms and a nature conservation area, while the south of the river (upstream) is encircled by industries such as brick manufacturers (Swanepoel, 1997). The Pienaars River forms the catchment basin for Mamelodi Township. This management area is dominated by mixed bushveld vegetation, varying from dense, short bushveld to more open tree savannah. The Baviaanspoort Wastewater Treatment Plant (WWTP) (Figure 3.7) is the main land use activity surrounding the Pienaars River (Marchand, 2009; Lomberg, 2010).

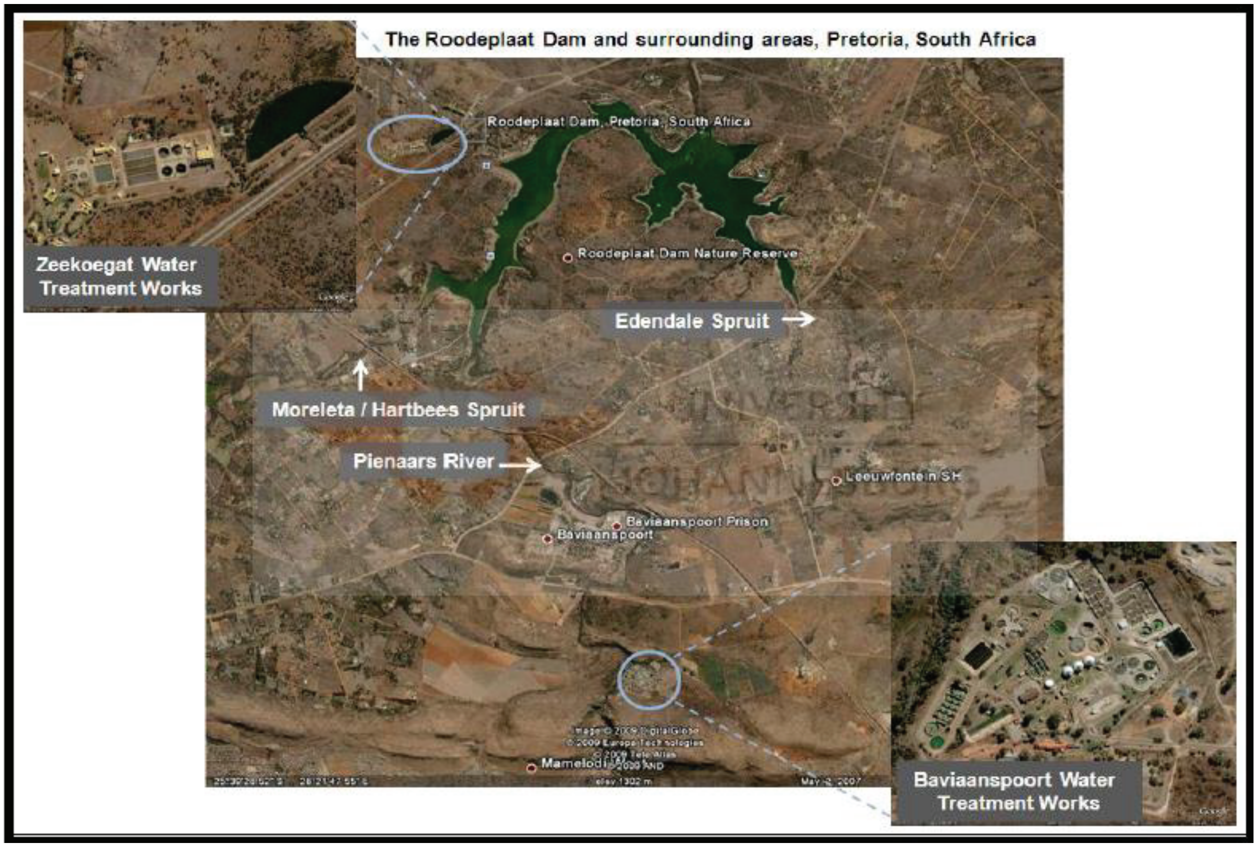

Figure 3.7: A digital overview of the Roodeplaat Catchment Area and its surrounding areas (Marchand, 2009).

3.2 Data collection

3.2.1 Water quality

The water quality data required to conduct the study was obtained from the Department DWS. Department of Water and Sanitation collects water samples from the RD and its tributaries every month and performs selected physico-chemical and biological analyses. Water quality data were collected from five (5) sampling sites on the Pienaars River, Hartbeesspruit, Edendalespruit and inlet to the Roodeplaat Dam (Table 3.1). Sampling sites were selected based on near-stream land use activities as well as to match the sampling sites selected by DWS for water quality monitoring. The analyses focused mainly on pH, electrical conductivity (EC), chloride ion (Cl), nitrogen (N), phosphorus (P), sulphate (SO_4) and *Escherichia coli* (*E. coli*). Furthermore, the results are compared to the DWAF water quality guidelines (WQG) (where available) for domestic use, recreational use, industrial use, agricultural: irrigation and aquatic ecosystems (DWAF, 1996a, b, c, d, e).

Table 3.1: Sample sites chosen from the data obtained from Department of water and Sanitation (DWS).

Sample Site	Description	Geographic Coordinates
1.90275	Roodeplaat Dam on the Pienaars River near the Dam Wall.	Longitude: 28.373
		Latitude: -25.622
2.90176	Leeuwfontein on Edendalespruit	Longitude: 28.39194
		Latitude: -25.6489
3.90174	Pienaars River on Hartbeesspruit	Longitude: 28.35115
		Latitude: -25.6632
4.90239	Pienaars River at Baviaanspoort	Longitude: 28.35861
		Latitude: -25.695
5.90175	Kameeldrift on Hartbeesspruit	Longitude: 28.31944
		Latitude: -25.6508

3.2.2 Land Use and Land Lover Change

Land cover changes were examined to investigate the impact of land use on water quality during the study period. Remote sensing data were collected from United States Geological Survey (USGS) (http://earthexplorer.usgs.gov/) website from the year 2007 to 2017. During the selection of imagery, only cloud-free images were collected for each year. Landsat 7 and 8 images of path 170 and row 078 were selected for both dry and wet season. The imagery was pre-processed in ERDAS imagine for radiometric calibration to convert the image from digital number to radiance. The radiance was pan-sharpened to resample the spatial resolution from 30 to 15 m. The images were also corrected for atmospheric irregularities and converted to reflectance. After radiometric correction, the separate bands were combined using the composite tool in ArcMap 10.5 software. Unsupervised classification and the Iso Cluster algorithm was used to detect land cover types from 2007 to 2017. Land cover classes were categorized into seven groups: waterbodies, sparse vegetation, dense vegetation, built-up land, agricultural land, bareland and grassland. Then, the size (m^2) of each land cover was determined for each year using ArcMap 10.5. Finally, the change in land cover was measured as the change in the size of each land cover type over time.

All the land cover data collected over 2007-2017 period and analysed in this study are presented as Appendix B.

3.2.3 Level of community engagement

Residential areas and local communities were targeted to collect data pertaining to their perceptions on water resource management. Site selection was driven by the communities proximity to the dam-river system. Random sampling method was employed to interview the people in the local communities. This included approaching people randomly in the streets and asking for their permission to participate in an interview after having explained the purpose of the study.

Community perspectives were measured in three ways: i) the perceptions of the communities, ii) their level of participation in the management of the dam-river, and iii) their level of satisfaction on the existing management plan of the dam.

3.2.3.1 Community perceptions of functional values of the dam-river systems

The functional value here is defined as the ecological roles as well as the ecosystem goods and services that the dam-river system provides to the surrounding communities. These functional values were firstly documented, and then the communities perceptions and awareness levels of these values were recorded. All these data on functional values, perceptions and awareness level of communities were obtained through semi-structured interviews, site visits, group discussions and online surveys (Appendix C and Appendix D). Data on perceptions were recorded as a binary YES-or-NO response to the following question: do you perceive the dam-river system as a useful resource for the environment and human community?

3.2.3.2 Communities level of participation in the management of the dam-river system

Community members were asked to rank their level of participation to the management of the dam-river system using three levels of ranking: Poor < Good < Excellent (poor =1, good = 2, excellent = 3). This data was collected through the online questionnaire and face-to-face interviews.

3.2.3.3 Communities level of satisfaction with the existing management plan of the dam-river system

During the questionnaire survey, community was also asked to rank their level of satisfaction towards the existing management plan. This was done using the following rank: Very dissatisfied < dissatisfied < Satisfied <Neutral < Very satisfied.

3.3 Data Analysis

All quantitative analyses were done in R 3.5 (R Development Core Team 2018).

3.3.1 Comparison of water quality in the river-dam system

This comparison of water quality was done in two ways, firstly among all water bodies, and secondly, between the dam and the combination of all rivers. These comparisons were done using the simple ANOVA ($\alpha = 0.05$).

3.3.2 Testing relationships between LULCC and water quality

To assess the relationships between the change (in term of size) in each land cover type and each water quality parameter, the generalized linear model (glm) was fitted, using water quality as response and LULCC as predictor variables, and the significant level was set at $\alpha = 0.10$.

3.3.3 Understanding community perspectives on water use management in the study area

Community perspectives were measured in different ways: community perceptions on water quality, community perception of potential effects of water quality on community, community satisfaction levels of water management, community involvement in the management as well as community utilization of the dam-river system.

Community perceptions were defined as a rank variable with three levels: very bad < bad < good. To identify the determinants of community perceptions, the cumulative link model was fitted using the R function *clm* implemented in the library Ordinal (Christensen, 2013) using the rank variable as response and community demographic data as predictors. Because the respondents to the questionnaire are not independent data points (since some belong to the same community), the cumulative link mixed effect model (CLMM) was also fitted to the data to correct for this non-independence, using residential area as random effect. This was done using the R function *clmm* also implemented in the library Ordinal. The CLMM model is preferred to the machine-learning methods based on a number of advantages that the CLMM provides (Luiz et al., 2016). In summary, CLMM is a better approach as it does not require that the ranked categorical variable (used as response variables; here quality of water) be converted into numerical values. In so doing, the CLMM has the advantage of preserving the variance structure of the original ordinal ranks of the categorical response variables, and thus prevents the loss of information generally observed when categorical variables are, either converted into numerical values, or grouped into binomial classifications. The CLMM also prevents an unnecessary elevated type I error generally observed when ranked variables are converted into numerical values in which, differences between consecutive rank levels are assumed to be equal. While fitting the CLMM model, cultural group will be used as a random effect to account for potential effects of shared cultural groups between residents.

On community satisfaction level, this was also measured as a rank variable: very dissatisfied<dissatisfied<satisfied. Consequently, the same cumulative link model was

also fitted to test for the determinants of community satisfaction levels by fitting the R functions *clm* and *clmm*; the first (*clm*) without correcting for community non-independence in relation to the residential areas they belong to, and the second (*clmm*) to correct for this non-independence.

In contrast to the perception and satisfaction levels, community involvement into the dam-river management was measured as a binary variable, that is, poor vs. good involvement. To test for the determinants of the community involvement levels, a *glm* model was fitted to the data with a binomial error structure. Similarly, to the analyses above, the non-independence of the community was corrected for by fitting this time the generalized mixed effect model using the R function *glmer* in the library lme4 (Bates et al. 2015) with residential area used as random effect. The same *glm* and *glmer* were also fitted to test the determinants of the perceptions of potential effects of water quality on community, given that these perceptions were here measured as a binary variable, that is, Yes/No to the question does the water quality of the RD and its inflowing rivers affect the surrounding community? If so, how? Finally, similar analyses were too done to test for the determinant of the community utilization of the dam-river system, which is also a binary variable, i.e., Yes/No to the question *do you use the dam-river system for anything*?

The significant level was tested at $\alpha = 0.05$. The R scripts used for all these analyses are presented as Appendix E.

Chapter 4 Results

4.1 Comparison of water quality in the dam-river system

All the water quality data collected over 2007-2017 period and analysed in this study are presented as Appendix A. There was no significant difference in pH (df=3, P=0.68), *E. coli* (df= 3, P=0.06) and P (df=3, P=0.19) among water bodies. Even when water quality was combined for all rivers and compared with water quality of the dam, the same pattern was found: pH (df= 1, P=0.41), *E. coli* (df=1, P=0.28), and P (df=1, P=0.22) (Table 4.1). However, there were significant differences in EC (df = 3, P<0.001), N (df = 3, P=0.0006) and SO_4 (df=3, P<0.001), but only when water bodies are compared individually (Figure 10). In addition, Cl showed significant differences in both scenarios: comparison of individual waterbody (df = 3, P=0.0002); all rivers combined vs. dam (df = 1, P=0.04) (Table 4.1) Moreover, Figure 4.1 illustrates box and whisker plots of the physico-chemical parameters having a significant difference.

Table 4.1: Path coefficients of model 1 tested in this study. See R scripts (Appendix E) for the details of the models**.**

	Waterbodies					All rivers vs Dam				
Water quality parameter	Df	Sum Sq	Mean Sq	F.value	p.value	Df	Sum Sq	Mean Sq	F.value	p.value
pH	3	97	32.46	0.505	0.68	1	44	43.79	0.689	0.408
E. coli	3	9.393e+12	3.131e+12	2.621	0.0558.	1	1.470e+12	1.470e+12	1.17	0.282
P	3	169	56.35	1.598	0.195	1	54	53.90	1.509	0.222
EC	3	6646	2215.3	22.31	<0.001 ***	1	25	24.73	0.156	0.694
Cl	3	3485	1161.6	7.068	0.000224 ***	1	744	744.1	3.986	0.0484 *
N	3	1378	459.4	6.337	0.000601 ***	1	8	8.20	0.096	0.758
SO_4	3	7016	2338.6	18.69	<0.001***	1	329	329.0	1.781	0.185

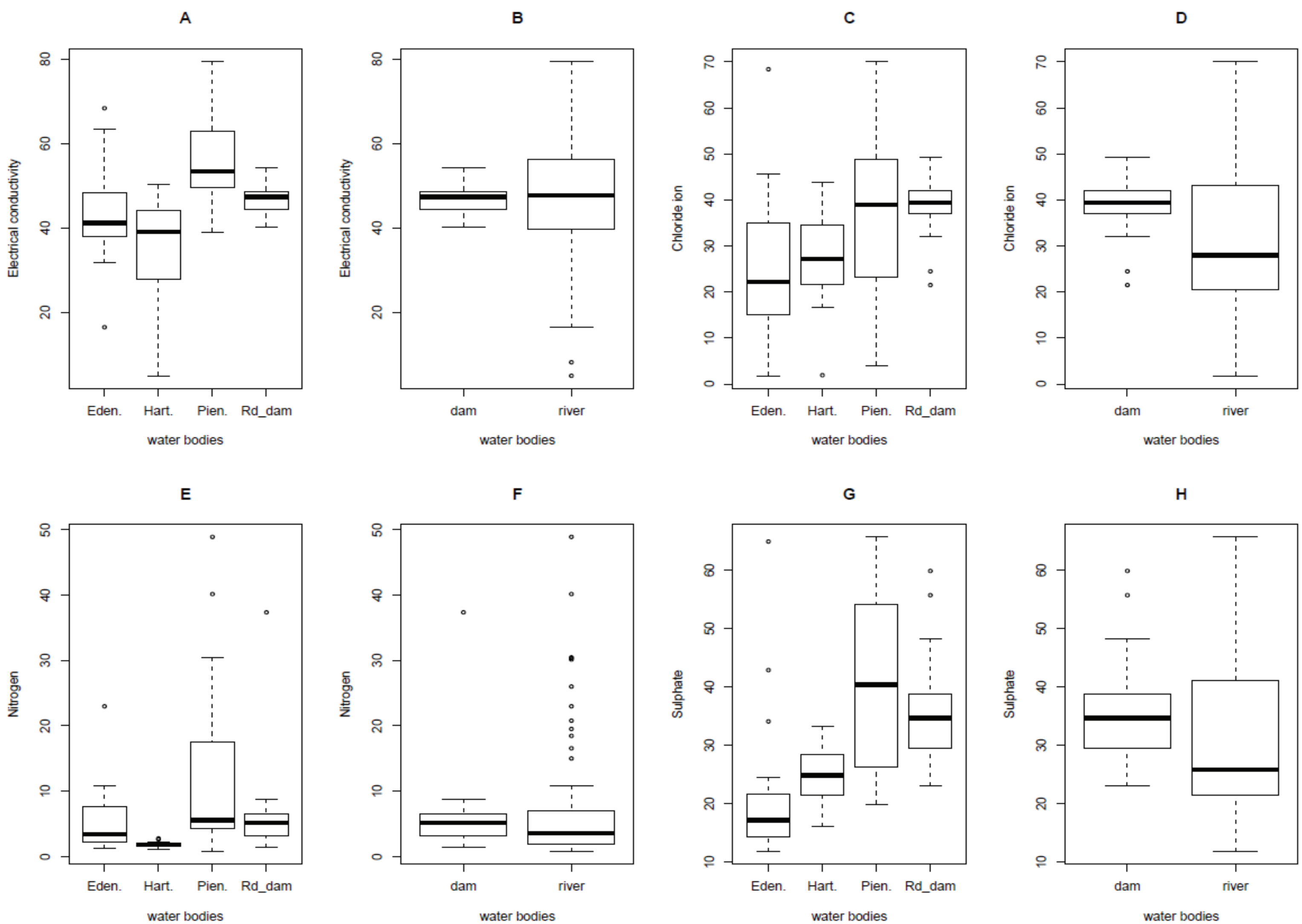

Figure 4.1A, B, C, D, E, F, G and H: Box and whisker plots of the physico-chemical parameters having a significant difference.

4.2 Testing relationships between LULCC and water quality

All land cover types and changes over the 2007-2017 period are presented as Appendix B. Illustrations for 2007 and 2017 are shown (Figure 4.2 and Figure 4.3). The changes in land cover size (area and percentage) are also illustrated in Table 4.2. Among the different land cover types, only sparse vegetation did not show any correlation with all water quality parameters analysed. However, the analyses showed that the changes in agricultural land correlate negatively with Cl (β=-0.17, P=0.09) and N (β=-0.15, P=0.05). Also, the increases in built-up area correlate positively with N (β=0.08, P=0.01) and SO_4 (β=0.13, P=0.004) (Table 4.3). Furthermore, the increases in bareland correlate negatively with electrical conductivity (β=-0.11, P=0.08) and N (β=-0.09, P=0.09). Finally, the changes in grassland and dense vegetation also correlate significantly with Cl (positive correlation, β=0.09, P=0.09) and electrical conductivity (negatively, β=-0.07, P=0.07), respectively. The details of all these results are in Table 4.3.

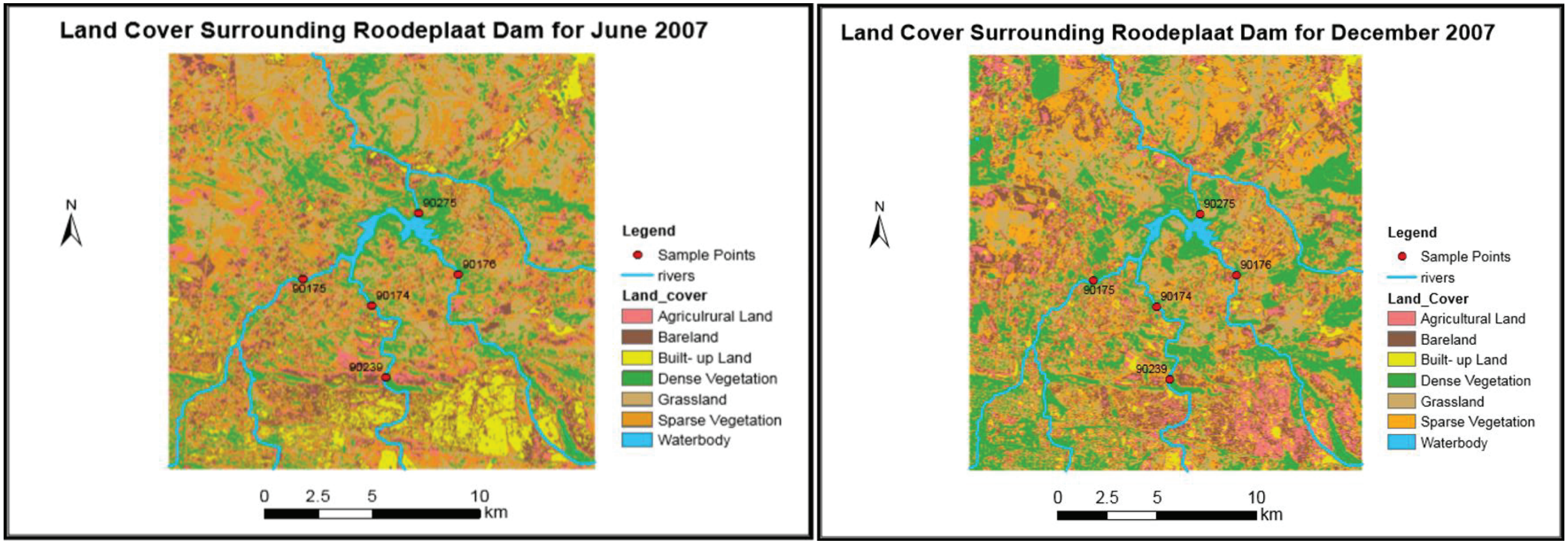

Figure 4.2: Land Cover surrounding the Roodeplaat Catchment Area for June 2007 and December 2007

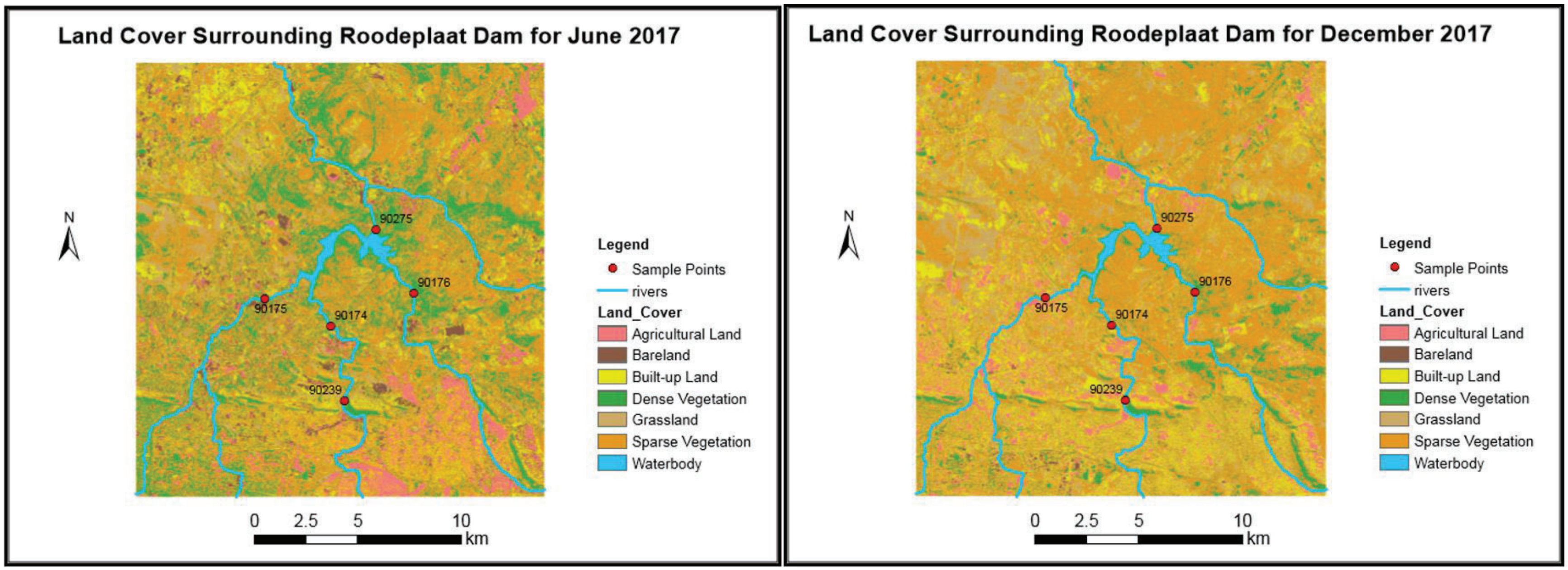

Figure 4.3: Land Cover surrounding the Roodeplaat Catchment Area for June 2017 and December 2017

Table 4.2: Size (area and percentage) of land cover change from 2007 to 2017

Classification	2007 Area (km^2)	Percentage (%)	2017 Area (km^2)	Percentage (%)
Waterbody	4.0	0.90	4.0	0.90
Dense Vegetation	91.4	22.0	50.3	13.5
Sparse Vegetation	85.3	21.5	141.5	34.2
Agricultural Land	31.9	7.7	38.3	9.2
Built-up Area	11.8	2.84	71.9	17.3
Bareland	58.3	14.0	13.2	1.7
Grassland	132.3	31.9	95.8	23.2
Total	415	100	415	100

Table 4.3: Summary of the path coefficients of model 2 tested in this study. See R scripts (Appendix F) for the details of the model.

Land Cover	Water quality parameter	estimate (β)	Std.error	T.value	p.value
Sparse vegetation	EC	-0.0070	0.047	-0.147	0.883
	Cl	-0.0316	0.052	-0.604	0.547
	N	-0.034	0.036	-0.956	0.341
	SO_4	0.0195	0.051	0.377	0.707
Dense vegetation	EC	-0.0722	0.040	-1.804	0.074•
	Cl	-0.0119	0.044	-0.266	0.799
	N	-0.0012	0.032	-0.040	0.968
	SO_4	-0.0218	0.044	-0.496	0.621
Grassland	EC	0.0357	0.053	0.666	0.507
	Cl	0.0982	0.058	1.677	0.096•
	N	-0.0455	0.041	-1.107	0.271
	SO_4	0.0070	0.058	0.121	0.904
Bareland	EC	-0.1174	0.068	-1.716	0.089•
	Cl	-0.1184	0.075	-1.563	0.089
	N	-0.0933	0.055	-1.696	0.093•
	SO_4	-0.1145	0.074	-1.535	0.128
Agricultural Land	EC	-0.0433	0.095	-0.454	0.651
	Cl	-0.1752	0.104	-1.681	0.095•

Land Cover	Water quality parameter	estimate (β)	Std.error	T.value	p.value
	N	-0.1554	0.0788	-1.972	0.051•
	SO_4	-0.1582	0.1028	-1.539	0.127
Built-up Area	EC	0.0430	0.0451	0.955	0.342
	Cl	0.0513	0.0497	1.033	0.304
	N	0.0879	0.0341	2.578	0.011 *
	SO_4	0.1380	0.0473	2.913	0.004**

4.3 Understanding community perspectives on water use management in the study area

To understand the perspectives of communities, a number of questions were investigated. First, how can people's perceptions of water quality in the dam-river system be explained? Among all the demographic variables tested (gender, age, education level, ethnic group and employment status), there was a negative but significant correlation between people's perception and only education level (Table 4.4), irrespective of whether we corrected for residential area (β=-4.64, P=0.08) or not (β=-2.40, P=0.003) (Table 4.4). This means that highly educated people tend to qualify the quality of water as very bad.

Table 4.4: Path coefficients of people's perceptions on water quality as tested in the study See R scripts (Appendix F) for the details of the model.

predictor	Not corrected for residential area			Corrected for residential area		
	estimate (β)	Std.error	p.value	estimate (β)	Std.error	p.value
Gender	-1.04542	0.84165	0.2142	-0.32399	1.03201	0.7536
Age	-0.01150	0.02865	0.6880	-0.00259	0.03441	0.9399
Education-Level	-2.40972	0.83496	0.0039 **	-4.64045	2.65316	0.0803 •
Ethnic_group	-0.00056	0.40526	0.9989	-1.16770	2.34272	0.6182
Employment	-0.00058	0.44289	0.9989	-0.16992	0.54580	0.7556

Second, how can people's satisfaction level of the dam-river management be explained? The analyses revealed that only employment status matters, as it is the only variable that correlates significantly but in a negative way with people's satisfaction level (Table 4.5), meaning that employed people tend to be very dissatisfied with the current management of the dam-river system. Again, this finding holds irrespective of whether residential origin of the respondent is corrected for (β=-0.92, P=0.05) or not (β=-0.76, P=0.06) (Table 4.5).

Table 4.5: Path coefficients of people's perception on their level of satisfaction as tested in the study. See R scripts (Appendix F) for the details of the model.

predictor	Not corrected for residential area			Corrected for residential area		
	estimate (β)	Std.error	p.value	estimate (β)	Std.error	p.value
gender	-0.76290	0.67940	0.2615	-0.42404	0.72119	0.5566
age	-0.01057	0.02245	0.6379	-0.01942	0.02428	0.4239
Education_ Level	-0.64198	0.63773	0.3141	-0.81996	0.68170	0.2290
Ethnic_group	0.42927	0.28772	0.1357	0.52524	0.40235	0.1917
employment	-0.7618	0.41075		-0.92585	0.47873	0.0531 •

The next question was: do you think that the water quality may affect communities? The analyses revealed that gender and education levels explain people perceptions of potential effects of water quality on community: males tend to believe that water quality may affect community (β=2.04, P=0.07) but this too depends on education level (β=-1.49, P=0.09). These relationships, however, disappear when residential origin is corrected for (Table 4.6).

Table 4.6: Path coefficients of people's perceptions on the effect of water quality on communities as tested in the study. See R scripts (Appendix F) for the details of the model.

predictor	Not corrected for residential area			corrected for residential area		
	estimate (β)	Std.error	p.value	estimate (β)	Std.error	p.value
gender	2.048155	1.14594	0.0739 •	2.267682	1.44431	0.116
age	-0.007392	0.03015	0.8064	-0.008775	0.03334	0.792
Education_ Level	1.490466	0.89656	0.0964 •	0.449034	1.43938	0.755
Ethnic_group	0.047997	0.42307	0.9097	1.795349	1.5858	0.258
employment	0.168342	0.49532	0.7340	-0.313168	1.58586	0.632

Community members were also asked if they are involved in the management of the system. The results indicate that their involvement depends on ethnic group: white community tends to be more involved in the management of dam-river system than other communities (Figure 4.4), irrespective of whether residential origin was corrected for or not (β=0.52, P=0.06) (Table 4.7).

Table 4.7: Path coefficients of model 6 tested in the study. See R scripts (Appendix F) for the details of the model.

predictor	Not corrected for residential area			corrected for residential area		
	estimate (β)	Std.error	p.value	estimate (β)	Std.error	p.value
gender	-0.691925	0.62237	0.2662	-0.691925	0.62242	0.2663
age	0.001499	0.02057	0.9419	0.001499	0.02057	0.9419
Education_ Level	-0.905152	0.64414	0.1600	-0.905152	0.64419	0.1600
Ethnic_group	0.527569	0.28670	0.0657 •	0.527569	0.28672	0.0658 •
employment	-0.223386	0.36435	0.5398	-0.223386	0.36437	0.5398

Finally, what explains the differences in communities' interactions (utilization) with dam-river system? The analysis showed that only ethnic group matters in this case with white communities tending to show more engagement (β=0.56, P=0.0003) (Figure 4.4). However, again, this relationship disappears when residential origin is corrected for (Table 4.8).

Table 4.8: Path coefficients of model 6 tested in the study. See R scripts (Appendix F) for the details of the model.

predictor	Not corrected for residential area			corrected for residential area		
	estimate (β)	Std.error	p.value	estimate (β)	Std.error	p.value
gender	-0.240983	0.37192	0.5170	-0.112823	0.46185	0.807
age	0.007098	0.01277	0.5783	0.000351	0.01559	0.982
Education_ Level	0.280812	0.37020	0.4481	-0.465391	0.49244	0.345
Ethnic_group	0.560514	0.15513	0.0003***	-0.168734	0.26477	0.524
employment	-0.054391	0.22778	0.8112	-0.224445	0.27200	0.409

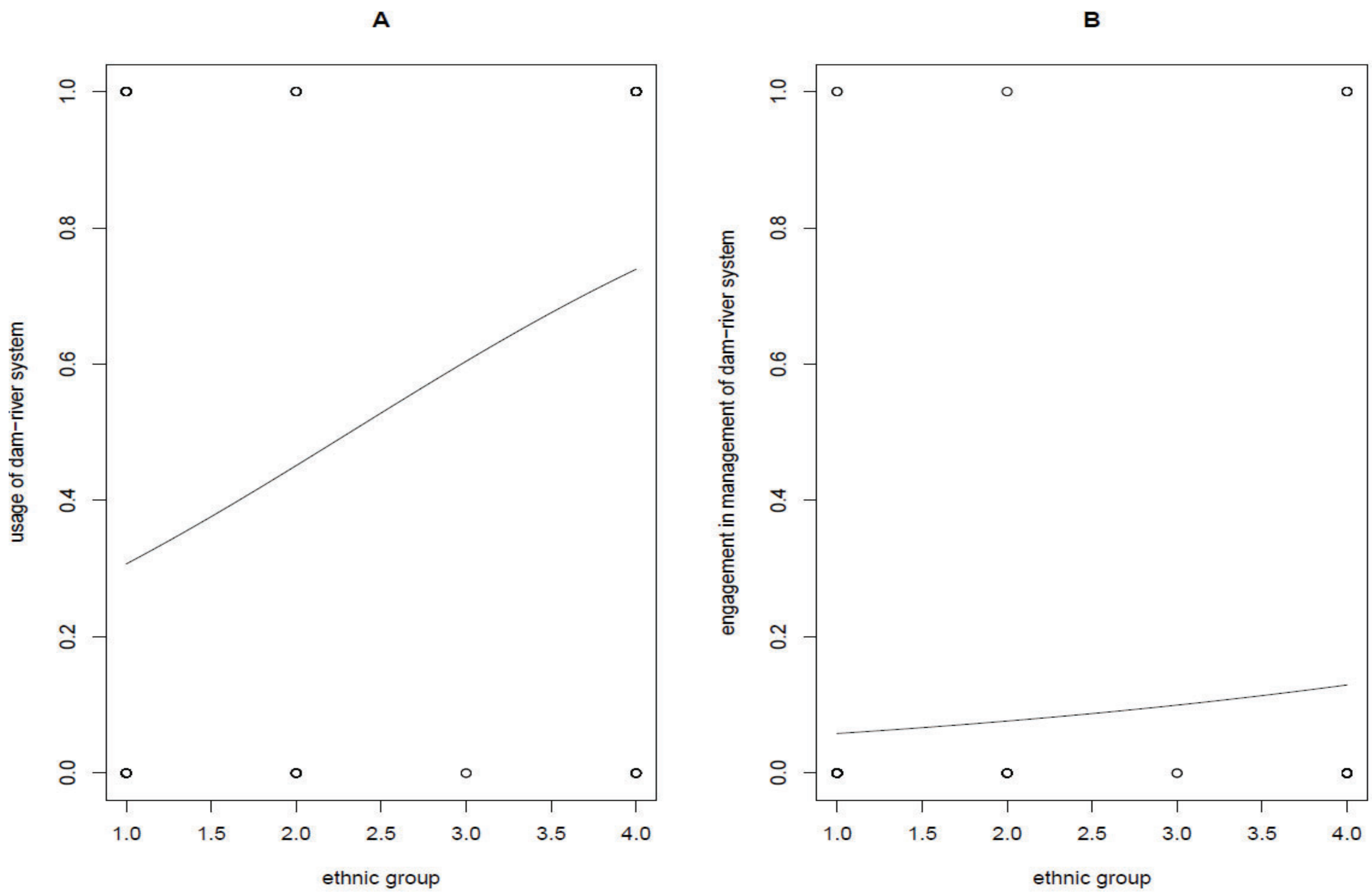

Figure 4.4: Relationship between dam-river usage, engagement in management of the system and ethnic group

Chapter 5 Discussion

5.1 Water Quality

The water quality results showed an interesting range of data along the Pienaars River, Edendalespruit, Hartbeesspruit and Roodeplaat Dam. The results show that land cover uses along the Pienaars River are responsible for polluting the river thus contributing the deteriorating quality of water of the RD.

The results indicate that the pH value ranged from 6.79 to 8.94 during the study period. Pienaars River has the highest pH value (8.94) whereas the lowest pH value (6.79) was found for Edendalespruit (Appendix A). Biologically, the pH ranges found in the present study mean that the Edendalespruit tends to be more acidic whereas the Pienaars River tends to be more alkaline. The high pH values at the Pienaars River result from domestic, industrial and agricultural activities along the river as seen in other studies (Bahar et al., 2008; Ahmad et al., 2016; Hashim et al., 2018). This may be due to the fact that the pH of natural waters is influenced by various factors such as temperature, discharge of effluents and surface runoff (DWAF, 1996a). Interestingly, the pH values over the study period were well within acceptable DWAF guidelines of 6.0 to 9.0, which is deemed suitable for human consumption, recreational activities, industrial use and aquatic ecosystems and industrial (DWAF, 1996a, b, c, e).

The phosphorus values ranged from 1.82 mg/L to 42.8 mg/L during the study period (Appendix A). The highest phosphorus value was observed at the Pienaars River while the lowest value was found at Edendalespruit. Phosphorus values fell well within acceptable limits of 0-100 mg/L for domestic use; however, they were higher than the prescribed acceptable limit of 0.1 mg/L for agricultural use and aquatic ecosystems (DWAF 1996d, e). The high P values at the Pienaars River may be due to domestic, industrial and agricultural activities along the river. This assumption was based on a study conducted by Lomberg (2010) which highlighted that more than two thirds of the P load in the entire catchment were from the Baviaanspoort and Zeekoegat WWTPs. Marchand et al. (2012) found that high P levels in the Roodeplaat Catchment Area were due to effluents discharged from the Baviaanspoort WWTP, agricultural and industrial wastewater. In China, Ding et al. (2015) assessed the impacts of land use activities on surface water of the Dongjiang River Basin. The results of the study showed that municipal wastewater and industrial effluent were the main sources of P along the Dongjiang River Basin, which was in agreement to the present study.

There were significant inconsistencies and gaps in the data provided which could not provide an accurate description of the study area. However, from the data collected it was observed that the Pienaars River had the highest *E. coli* value of 5 720 000 cfu/ 1000mL (Appendix A). According to the DWAF guidelines (1996b, d) *E. coli* should not exceed 1 000 cfu/1000mL. A study conducted by Hau et al (2013) analysed the effect of LULC on the water quality of the Malacca River Watershed in Malaysia. The results showed that sewage from residential and industrial effluents discharged from treatment plants heighten the *E. coli* levels in the river. Similarly, Hashim et al. (2018), found that high *E. coli* levels in the Langat River, were a result of effluents from the wet market, poultry, domestic sewage and poor sanitation may contribute to microbial contamination. It was therefore highly expected that the Baviaanspoort WWTP is responsible for the high *E. coli* values in the Pienaars River (Lomberg, 2010). However, according to the National Water Act Guidelines, the Nitrate should not exceed 15 mg/L, Total Aluminium > 0.03 mg/L, Total Boron <0.5 mg/L, Cadmium >0.0001 mg/L, Copper >0.002 mg/L, Iron >0.3 mg/L, Lead <0.009 mg/L, Mercury <0.001 mg/L, Selenium <0.008 mg/L, Zinc <0.05 mg/L (Republic of South Africa 1998b). The high *E. coli* values at the Pienaars River may be caused by the other surrounding land uses, including informal settlements with inadequate sewage facilities of the Mamelodi Township and small-agricultural holdings, which is agreement to the studies conducted by Hau et al. (2013) and Hashim et al. (2018).

However, from a statistical perspective, these variations in pH, P and *E. coli* did not translate into significant differences, irrespective of whether pH is compared among rivers or between rivers and the dam. The expectation was that there would be differences in pH, P and *E. coli*, among rivers on one hand, and between rivers and dam, on the other. This expectation was grounded on two main reasons. Firstly, previous studies conducted on the Roodeplaat Dam Catchment Area found that the surrounding land uses (agricultural, WWTP, industrial and residential) along the Pienaars River, may result in the discharge of wastewater (from the plant) and domestic waste into the Pienaars River (Walmsley and Toerien, 1978; DWS, 2008; Lomberg 2010; Mulders, 2015). Secondly, all three rivers flow into the dam, potentially heightening the pollution level of the dam. The flow of the rivers might redistribute ions across the system such that significant differences might be difficult to detect as revealed by the statistical analysis.

The water quality results showed that the highest EC value (79.57 mg/L) was found at the Pienaars River and the lowest EC value (4.92 mg/L) was found at Hartbeesspruit (Figure 4.1). Conductivity is significantly higher in the river (all rivers combined) versus the dam (Figure 4.1). Conductivity values fell within acceptable DWAF limits for domestic use, agricultural, irrigational use and industrial use (Table 2.1). The high conductivity value at the Pienaars River may be due to the wastewater effluents from the Baviaanspoort WWTP and the residential areas (informal and low-cost housing) along the Pienaars River. Santos et al. (2008) assessed the influence of effluents from a WWTP in a coastal creek from southern Brazil. The results showed that conductivity was higher downstream from the WWTP than at other land use activities. Shabalala et al. (2013), investigated the effect of farming activities on the water quality of the Bosman Dam in South Africa. The results of the study revealed that agricultural activities (with increased nutrient loads) often led to high EC values where farming as a land-use. A study conducted by Zamani et al. (2013) found high conductivity values resulting from agricultural and built-up land use along the Ziarat Catchment. The results of the study were similar to findings obtained in the present study.

The Cl values across the entire catchment varied significantly, with the highest value (70.17 mg/L) at the Pienaars River and the lowest (1.82 mg/L) at the Edendalespruit (Figure 4.1). Also, chloride ion was significantly higher in the dam versus the river (all rivers combined) (Figure 4.1). The measured values were higher than the prescribed acceptable limit of 0.1 mg/L for agricultural use but fell within acceptable DWAF limits for domestic and industrial use (Table 2.1). The high levels of Cl at the Pienaars may be due to domestic waste from surrounding informal and low-cost housing and from industrial wastewater. Marchand et al. (2012) detected a Cl value of 48 mg/L from the RD, which proved to be one of the water quality parameters above the recommended levels. The results of the study illustrated that residential and industrial wastewater together with agricultural effluents are responsible for the high Cl value in the dam.

Among the waterbodies measured, the Pienaars River had the highest N value of 48.92 mg/L (Figure 4.1). The N value was significantly higher in the river (all rivers combined) versus in the dam (Figure 4.1). Nitrogen values were higher than the prescribed acceptable limit of 0.5 mg/L for agricultural use and aquatic ecosystems, indicating a hypertrophic system. The high N values at the Pienaars Rivers could result from domestic, industrial and small-agricultural fields along the river. Mulders (2015) found significantly higher N values at the Pienaars River than at the other waterbodies. The highwas related to the wastewater effluents discharged directly from the Baviaanspoort WWTP. Several studies (Withers and Lord, 2002; Gunningham and Sinclair, 2005; Marchand et al. 2012; Shabalala et al., 2013; Haung et al., 2015; Cheng et al., 2018) found that nutrients from non-point sources of nitrogen such as livestock fertilisers and pesticides from poorly managed agricultural activities tend to influence surface water quality.

Lastly, the highest SO_4 value was recorded at the Pienaars River (65.72 mg/L) while the lowest SO_4 value (13.24 mg/L) was found at Edendalespruit (Figure 4.1G). Also, SO_4 value is significantly higher in the dam versus the river (all rivers combined) (Figure 4.1). Sulphate values fell within the acceptable limits of 0-200 mg/L for domestic and recreational use but were higher than the prescribed acceptable limit of 0-20 mg/L for agricultural use (Table 2.1). The high SO_4 values at the Pienaars may be due to the domestic, industrial and agricultural activities along the river. This is due to the fact that industrial activities near waterbodies tend to discharge sulphates from acid mine waste and other industrial processes (DWAF, 1996a). Fashae et al. (2019) analysed the impact of land use types on surface water quality in an emerging urban city. A considerably higher SO_4 value was observed from industrial and residential activities as compared to agricultural and vegetated land use. This can be attributed to domestic and sewage waste, which may have irreversible harmful effects through direct consumption of food supplies in contact with the surface water (Fashae et al., 2019).

From statistical perspectives, the variations in EC, N and SO_4 translated into significant differences, only when water bodies are compared individually. In addition, Cl showed significant differences in both scenarios: comparison of individual waterbody all rivers combined vs. dam. The expectation was that there would be differences in chemical concentrations (EC, N, Cl and SO_4), among rivers on one hand and between rivers and dam, on the other. This expectation was based on a variety of studies (Santos et al., 2008; Shabalala et al., 2013; Zamani et al., 2013; Cheng et al., 2018), which reported positive correlations between chemical concentrations and land-uses and activities such as WWTPs, residential, agricultural, and industrial.

5.2 Land Use and Land Cover Change

Land use and land cover change is one of the major environmental changes happening around the Roodeplaat Catchment Area and consequently it has been affecting water quality of the dam-river system. This section discussed how the different LULC activities have changed over the study period and how the potential effects of these changes affect the quality of water in the RD.

The results showed that agricultural land increased in size from 31.9 km^2 in 2007 to 38.3 31.9 km^2 in 2017 (1.5%) (Table 4.2). However, from a statistic perspective, a significant negative change was identified between agricultural land and chemical concentrations (Cl and N). These results indicate that an increase in agricultural land tends to reduce Cl and N concentrations. The expectation is that there would be a positive difference between the chemical concentrations (Cl and N) and agriculture, which is based on previous studies in many parts of the world (Yusuf et al., 2017; Shukla et al., 2018). These studies found that agricultural land contributes to nutrient loads in waterbodies due to excess release of fertilizers (NPK). However, this was not the case in other studies (Ding et al., 2015; Gyawali et al., 2015) which were in agreement to the present study. Lee et al. (2009) indicated that the degree of negative influence that agricultural land use has on water quality depends on farming practices and geographic location. The inverse relationship observed in this study may be associated with improved agricultural methods; replacing chemical pesticides with organic methods or changing the timing of fertilizer, which could potentially reduce the risk of increased nutrient load (Lee et al., 2009; Solheim et al. 2010).

Built-up area increased in size from 11.8 km^2 in 2007 to 71.9 km^2 (14.5 %) in 2017 (Table 4.2). ANOVA revealed a significant positive change between built-up area and chemical concentration (N and SO_4). This indicates an increase in built-up area, which tends to increase Cl and N values. Several studies (Haidary et al., 2013; Haung et al., 2013; Ding et al., 2015; Ogbozige and Alfa, 2019) found similar results to the present study. The expectation was that there would be a positive correlation between the chemical concentrations (N and SO_4) and built-up area, which results from the increase in discharge of untreated sewage and surface run-off from the expansion of residential and industrial activities in the catchment area. Ding et al. (2015) found that impermeable surfaces in built-up areas may also contribute to an increase in surface run-off and can increase concentrations of nutrients and other pollutants in the waterbodies.

Furthermore, the results showed that bareland decreased from 58.3 km^2 in 2007 to 13.2 km^2 in 2017 (12.3 %) (Table 4.2). Statistical analyses revealed a negative correlation between bareland and chemical concentration (EC and N). This indicates an increase in bareland, tends to reduce EC and N concentrations. The negative relationship between bareland and concentrations (EC and N) indicates that bareland played a role in reducing the EC and N pollutants towards the declining water quality in the dam-river system, which was in agreement to the results obtained by Haung et al (2013). A study conducted by Ogbozige and Alfa (2018), revealed similar results, but were associated with reduced runoff from domestic industrial and agricultural wastewater during dry seasons.

Finally, the results show that grassland and dense vegetation decreased from 132.3 km^2 in 2007 to 95.8 km^2 in 2017 (8.7% %) (Table 4.2). However, from a statistic perspective, grassland and dense vegetation correlate significantly with Cl (positive, P=0.09) but correlate negatively with EC (P=0.07), respectively. This indicates that an increase in grassland and dense vegetation tends to increase Cl and reduce EC. The positive relationship between land uses (grassland and vegetation) and Cl exists due to the fact that these two land uses can be used as grazing areas for livestock farming. Therefore, runoff and other dissolved solids from vegetated areas carry livestock waste may discharge chloride into the waterbodies (Ogbozige and Alfa, 2018). Moreover, reduced EC values with an increase in grassland and vegetated land can be explained by the reduced agricultural runoff during dry seasons (Dabrowski et al., 2014; Ogbozige and Alfa, 2018).

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5.3 Understanding community perspectives on water resource management

For the purpose of this study, the communities perceptions were assessed through understanding their perspectives on water quality, uses of water, their involvement in the management and their satisfaction of the current management of the RD. Comparative analysis of the findings indicated that demographic characteristics (income levels, age, and gender) played a negligible role in people's perceptions and behaviours of water management.

The results revealed a negative correlation between people's perception on the quality of water and their level of education. This indicates that highly educated people tend to qualify the quality of the water in the dam- river system as bad, regardless of their surroundings. This may be due to educated people being more aware of environmental issues such as water pollution and water shortages (Noga and Wolbring, 2013). The expectation is that educated people tend to quantify the quality of water in the dam-river system as bad. The expectation was grounded on the assumption that educated people are more aware of water pollution and have a better knowledge on the chemical parameters causing pollution. Educated people tend to have more knowledge on the environmentally responsible behaviour, are conscious about environmental protection and are likely to be active members the community (Syme et al., 2000; Frick et al., 2004; Phiri, 2014). Lotz-Sisitka and Burt (2006) highlighted the fact that many South Africans still need to be educated on the environment. Therefore, awareness of environmental issues such as water pollution, water quality and quantity are important for understanding the implications of different users. Greater awareness and education are required to promote the monitoring, management and conservation of water resources at community level (Nare et al., 2011; Noga and Wolbring, 2013). By doing so, local communities are encouraged and trained to take care of their own health and wellbeing through learning.

People's satisfaction level on the current management of the dam-river system were negatively correlated to their employment status, irrespective of whether residential area was corrected for or not. This meant that employed people tend to be very dissatisfied with the current management of the dam-river system. During the questionnaire survey, majority of those employed were highly dissatisfied with the implementation of the current management plan by DWS (Appendix D). The unemployed population clearly indicated that they were reluctant to participate in the management of the dam-river system, due to not receiving incentives towards this participation. The community also mentioned that the CoT municipality needs to involve them in the planning, monitoring and management of dam-river system (Appendix D). Heyd and Neef (2004) investigated the participation of local people in water management from the Mae Sa watershed in Northern Thailand. The communities perception on water management were analysed through semi- structured interviews, focus group discussions and literature review. Heyd and Neef (2004) found that community members were dissatisfied with how their government managed their water resources. As a result, the community was very sceptical and expressed their distrust towards the officials. In a study to analyse the perceptions and levels of satisfaction from water users, Thompson et al. (2013) highlighted that local communities would be more satisfied with the management of water resources provided they are involved in participation and included in the decision-making processes, which is in agreement with the results of the present study.

Statistical analyses revealed that both gender and education levels explain people's perceptions on the potential effects of declining water quality on communities. When compared to their female counterparts, the male population perceived water quality to have a greater negative effect on the community. Wendland et al. (2018) reported that the differences and inequalities between women and men influence how individuals respond to changes in the environment and these power relations in communities make it difficult for women to voice opinions that contradict the views of those in power. These power differentials may even affect who participates in specific meetings (GWA, 2006). Highly educated people tend to not only quantify the quality of water as bad but also perceive the declining quality of water to have a negative effect on the communities. As mentioned above, educated people tend to be more concerned on water quality issues and have more knowledge on issues related water quality and the availability thereof

(Noga and Wolbring, 2013).

The results also indicate the ‘use’ of water from the dam-river system and the level of participation in water management depends on the ethnic group. The Black population indicated their use of water in the dam-river system for domestic activities (cooking, bathing and washing of clothes), entrepreneurship (brick making) and cultural and religious practices (baptism) (Appendix D). Majority of the white population indicated their use of water for irrigational purposes and recreational activities such as fishing, boating and canoeing (Appendix D). In a study conducted in North West Province in South Africa, Coetzee et al. (2016) assessed people’s perceptions of people on the sources and uses of water among Africans. A study conducted by Coetzee et al. (2016) in South Africa, assessed people’s perceptions of people on the sources and uses of water among the African population. The results of the study revealed that water uses relating to spiritual and cultural beliefs were identified by Black South Africans. A few participants indicated their strong spiritual connection with water which included using the water as means to establish contact with ancestors, spiritual cleansing to drive out evil spirits and to initiate traditional healers (Coetzee et al., 2016).

Finally, when asked about their involvement in the management of the dam- river system, the white communities showed more interest in the involvement of the management of the dam- river system. Majority of the white community members (Leeuwfontein Estate and Sable Hills Waterfront Estate) showed interest towards the participation of the management of the dam-river system. A few of these people mentioned that have been involved in river clean-up programs. Those closer to the dam have also been largely involved in the manual removal of water hyacinth, which has been conducted through hand pulling from the water surface using a pitchfork (Appendix D). However, Black and Coloured communities of Mamelodi East and West, Derdepoort and Eesterust expressed their disinterest in the participation towards the management of the dam-river system. Vavricka (2013) emphasised that while Africans considered both individuals and the government responsible for environmental issues, ethnic groups such as Indians, Chinese, Filipinos, Japanese and Koreans living in America held the government primarily responsible for environmental protection. A more recent study conducted by Yan (2016) to investigate the ethnic and cultural correlations on water consumption highlighted how different ethnic groups perceive the management of water resources due to the uses from each group. The study concluded that it is important to understand water use patterns from different ethnic and cultural backgrounds, and how these differences may influence water usage and conservation (Yan, 2016).

Chapter 6 Conclusion

South Africa continues to face serious water quality problems as a consequence of population growth, increasing anthropogenic activities and climate change (Oelofse and Strydom 2010; Mwangi, 2014; DWS, 2015; Sibanda et al., 2015; Rodda et al., 2016; Swanepoel et al., 2017). Water quality concerns affecting the country include faecal pollution, salination, acid mine drainage and eutrophication (DWAF, 2009; DWS, 2017). The RD in particular, has been classified as a hypertrophic system requiring eutrophication management (van Ginkel, 2005; Marchand, 2009; DWS, 2014; Harding, 2015). The DWS developed a RMP for the management of the water quality in the RD. The report highlighted the deteriorating quality of water and the concerning presence of water hyacinths (*Eichhorinia crassipes*) and cyanobacteria as a result of the algal blooms. The water quality problems of the RD were attributed to the surrounding land uses and the wastewater effluents discharged from Baviaanspoort WWTP. It was concluded that the poor water quality in the RD could be a direct result of the poor water quality entering from the three Rivers (Edendalespruit, Pienaars River and Hartbeesspruit) (DWAF 2008; Modley et al., 2020). The plan was set out to ensure that the objectives in the NWA which include access to good quality water and the protection of water resource against pollution and degradation are met (DWAF, 2008). Moreover, the RMP was designed to include local communities and relevant stakeholders to participate in the protection and management of water resources at the RD. However, the local community was not engaged effectively nor was it given the opportunity to get involved in this process. This emphasizes the contribution of the current study in providing information, which may contribute to the development of a community-based water resource management plan. This chapter will provide a comprehensive synthesis and conclusion to the study aim and objectives.

The water quality analyses showed that pH, EC, and SO_4 were below the WQGs as set by DWAF (DWAF, 1996a, b, c, d, e). However, Cl, N, P and *E. coli* were above the set detection limits, which confirmed the eutrophic status of the dam as reported by other studies ((van Ginkel, 2005; van Ginkel and Silberbauer, 2007). From the water quality analyses, it can be concluded that the Pienaars River has been the cause of pollution towards the RD, with the main sources of pollution coming from the Baviaanspoort WWTP, informal and low-cost housing (Mamelodi Township) and the small-agricultural holdings (Marchand et al., 2012; Lomberg, 2010, Mulders, 2015; Modley, 2020). Statistical analyses revealed positives correlations between waterbodies and chemical concentrations (EC, N, Cl and SO_4). These differences can be explained by the proximity of the land uses (Baviaanspoort WWTP, agricultural land and residential areas) which discharge directly into the Pienaars River (Shabalala et al., 2013; Zamani et al., 2013; Cheng et al., 2018).

When testing the relationship between LULCC and water quality, it was observed that the LULC activities surrounding the Roodeplaat Catchment Area show a variety of potential impacts. Figure 4.2 and Figure 4.3 the possible sources of pollution along the dam-river system with Hartbeesspruit and Edendalespruit being impacted by bareland, sparse and dense vegetation, agricultural land and formal settlements. While the Pienaars River is mostly impacted by built-up area (industrial and residential) and some agricultural land. Statistical analyses revealed a negative correlation between agricultural land and chemical concentrations (Cl and N) which was in agreement to studied conducted by Ding et al., 2016; Gyawali et al., 2015). A positive relationship was revealed between built-up area and chemical concentrations (N and SO_4). This relationship exits due to the increased discharge of untreated sewage and surface run-off from the expansion of residential industrial activities along the catchment area (Haidary et al., 2013; Haung et al., 2013; Ding et al., 2015; Ogbozige and Alfa, 2019).

The community perspectives on water quality and water management were successfully investigated and interesting results were observed. A negative correlation was revealed between people's perceptions on the quality of water and their level of education. Surprisingly, people's satisfaction level with the current management plan were negatively correlated to their employment status. Statistical analyses revealed that gender explains people's perceptions on the potential effects of declining water quality on communities. For this specific study, the male population perceived water quality to have a greater negative effect on the community. The use of water and the participation in water management was highly dependent on the communities' ethnic group. The results showed that the Black population tends to use water for domestic activities, entrepreneurship and cultural and religious practices. While the White population use the White population tend to use water for irrigational purposes and recreational activities (fishing, boating and canoeing). It was also indicated that the Black and Colored population were less interested in the participation towards the management of the dam-river system. However, majority of the White population showed interest towards the participation of the management of the dam-river system.

Based on the water quality results observed in this study, it is evident that a more effective and sustainable approach is needed to manage the water quality in the Roodeplaat Catchment Area. A community-based management approach is possible, provided that the local communities are included in the planning, monitoring and decision-making processes towards the management of the RD and its tributaries. The information from this study can be presented to the DWS and CoT Municipality to bring about awareness of the communities' perspectives of the water quality and water management in their areas. Subsequently, these perceptions can be incorporated into the existing water resources management plan to ensure a community-based management approach.

6.1 Recommendations

The following recommendations are proposed to help promote and inform effective water management in the RD and its inflowing rivers:

- The poor water quality in the RD could be a direct result of the poor water quality entering from the three Rivers (Edendalespruit, Pienaars River and Hartbeesspruit)
  - The DWS needs to improve on the implementation of existing legislation whilst incorporating Good International Industry Practice (GIIP) to the concept of IWRM.
  - The Pienaars River requires priority monitoring to determine changes in water quality from surrounding land uses.

- The CoT Municipality needs to create a platform where community members are able to report on any water quality related issues. For example, a Toll-free number where they can call to report daily water related concerns.

- Community perspectives on water resource management depend on demographic characteristics such as educational level, employment status, gender and ethnic group
    - Develop programmes focusing on education and creating awareness to the surrounding communities on water quality and the impacts of their day-to-day practices on the quality of water.
    - The DWS needs to ensure collaboration and participation of all I&APs) within the catchment. The process should also aim to promote capacity building to all stakeholders involved, which includes the local community as well as government officials.
    - Develop an ongoing community-based water management plan which adopts a bottom-top approach which incorporated community perspectives and opinions into final decision-making process.

6.2 Methodological Reflections

The study employed a mixed research methodology, which was both qualitative and quantitative in nature for the purpose of investigating the perceptions and roles of local communities on water resource management. Water quality data was collected and analysed to assess the levels of pollution in the dam-river system. The eutrophic status of the dam could have been better determined by included Chlorophyll-a, Total Nitrogen (TN) and Total Phosphorus (TP) during the selection of the water quality parameter. The LULCC maps were classified into seven categories. The overall accuracy of the maps could have been confirmed by performing a confusion matrix. The three ways used to measure the local communities perspectives on water resource management were effective and provided a good understanding of their perceptions.

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Appendices

Appendix A: Water Quality Data for the study period

Parameter	Dry Season 2007					Wet Season 2007				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175
pH	7.66	8.02	7.76	8.01	7.91	8.21	8.39	7.98	8.17	8.13
EC (mS/m)	52.30	68.40	73.56	50.15	39.84	43.45	16.46	62.22	43.20	8.13
Nitrogen (mg/L)	5.78	5.39	15.00	4.23	1.18	N/A	2.23	10.49	4.29	1.25
Phosphorus (mg/L)	0.65	0.93	2.29	0.14	0.05	N/A	0.42	2.07	0.53	0.14
Chloride (mg/L)	24.51	35.02	70.17	45.62	26.15	21.53	68.41	64.96	43.72	27.02
Sulphate (mg/L)	33.82	24.75	53.30	41.15	25.86	23.06	17.07	43.32	36.75	21.67
E. Coli (cfu/1000ml)	0.50	168.00	575.00	61.50	380.00	0.00	3800.00	14895.00	2875.00	0.17

Parameter	Dry Season 2008					Wet Season 2008				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site5 90175
pH	7.94	8.20	8.10	8.22	8.37	8.05	8.34	8.04	7.79	8.15
EC (mS/m)	44.45	35.67	60.32	47.35	49.97	44.98	38.64	53.86	46.32	32.36
Nitrogen (mg/L)	2.34	1.47	7.05	2.12	1.64	N/A	N/A	N/A	N/A	N/A
Phosphorus	0.18	0.12	1.58	0.08	0.09	0.17	0.11	1.28	0.17	0.07
Chloride (mg/L)	32.01	11.61	46.73	19.01	37.97	40.28	19.41	47.07	25.62	26.69
Sulphate (mg/L)	25.96	13.96	56.43	27.29	30.05	36.47	21.76	45.06	24.16	23.06
E.Coli (cfu/1000ml)	4.60	173.40	111981	2133.3	305.33	6.00	133.00	1386.00	30600	30700.0

Parameter	Dry Season 2009					Wet Season 2009				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175
pH	7.73	8.20	7.86	8.46	8.18	8.03	7.66	7.83	8.37	8.11
EC (mS/m)	47.24	37.90	58.30	49.12	50.25	46.25	35.76	52.50	46.76	36.36
Nitrogen (mg/L)	2.25	3.12	6.91	1.81	1.96	N/A	N/A	N/A	N/A	N/A
Phosphorus (mg/L)	0.27	0.39	2.84	0.03	0.048	N/A	N/A	N/A	N/A	N/A
Chloride (mg/L)	40.31	20.51	61.04	23.54	43.75	43.37	14.22	55.62	19.74	26.53
Sulphate (mg/L)	32.64	16.27	44.91	25.62	33.26	31.07	13.24	36.48	19.94	22.28
E. Coli (cfu/1000ml)	N/A	N/A	N/A	N/A	N/A	1.00	684.00	3360.00	2880.00	384.00

Parameter	Dry Season 2010					Wet Season 2010				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175
pH	7.70	8.17	7.85	8.11	8.23	8.80	8.23	7.74	8.19	7.75
EC (mS/m)	45.60	34.71	54.50	53.35	46.00	48.70	31.66	53.75	41.10	2.92
Nitrogen (mg/L)	3.10	1.43	5.31	5.57	1.88	2.56	2.08	N/A	3.52	1.49
Phosphorus (mg/L)	0.49	0.18	1.78	1.11	0.02	0.10	2.26	N/A	0.20	0.15
Chloride (mg/L)	38.45	14.73	39.55	20.47	34.59	42.12	15.05	42.81	20.92	1.95
Sulphate (mg/L)	29.54	11.83	38.72	24.89	28.42	29.54	23.09	39.77	25.51	19.34
E. Coli (cfu/1000ml)	1	43	42680	8100	149	0	2970	42400	315000	5200

Parameter	Dry Season 2011					Wet Season 2011				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175
pH	8.23	8.42	7.82	8.31	8.42	7.77	7.79	7.72	7.77	8.44
EC (mS/m)	45.32	39.24	53.51	48.87	47.92	47.48	41.52	45.38	39.02	35.56
Nitrogen (mg/L)	3.95	2.53	9.41	3.78	1.89	1.38	3.21	5.52	0.75	1.77
Phosphorus (mg/L)	0.38	0.12	1.84	0.16	0.03	0.05	0.13	1.16	0.22	0.04
Chloride (mg/L)	32.07	16.82	37.82	17.57	37.54	36.07	17.82	25.32	15.32	23.42
Sulphate (mg/L)	25.14	13.32	43.36	25.01	28.70	33.16	21.41	36.23	21.54	16.99
E. Coli (cfu/1000ml)	2	337	116610	432	110	0	420	14000	1635	240

Parameter	Dry Season 2012					Wet Season 2012				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175
pH	8.40	8.53	8.43	8.45	8.30	8.56	8.32	6.79	7.48	8.11
EC (mS/m)	47.83	40.00	71:20	50.73	44.17	40.29	41.63	51.09	52.25	26.49
Nitrogen (mg/L)	4.89	1.21	N/A	5.024	1.23	6.21	3.38	N/A	2.25	1.68
Phosphorus (mg/L)	0.32	0.03	N/A	0.30	0.16	0.53	0.34	10.48	1.49	0.05
Chloride (mg/L)	37.18	15.80	56.21	21.61	27.60	40.31	23.81	34.06	23.05	16.67
Sulphate (mg/L)	33.32	15.48	54.86	27.22	24.95	35.62	14.41	54.13	23.98	21.55
E. Coli (cfu/1000ml)	0	46	32	225	6560	0	3280.00	1440	572000	86

Parameter	Dry Season 2013					Wet Season 2013				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175
pH	8.42	8.56	8.40	8.40	8.31	8.46	8.56	8.41	8.35	8.31
EC (mS/m)	47.86	40.76	71.34	50.57	44.12	40.29	41.68	51.09	52.64	26.49
Nitrogen (mg/L)	4.89	1.21	N/A	5.02	1.23	4.89	3.38	N/A	2.25	1.68
Phosphorus (mg/L)	0.32	0.03	N/A	0.30	0.16	0.53	0.34	10.48	1.49	0.05
Chloride (mg/L)	37.18	15.80	56.21	21.61	27.60	40.31	23.81	34.06	23.04	16.67
Sulphate (mg/L)	33.32	15.48	54.86	27.22	24.95	35.62	14.41	54.13	23.98	21.55
E. Coli (cfu/1000ml)	0	37	3300	2479	6080	0	3500	1320	5720000	972

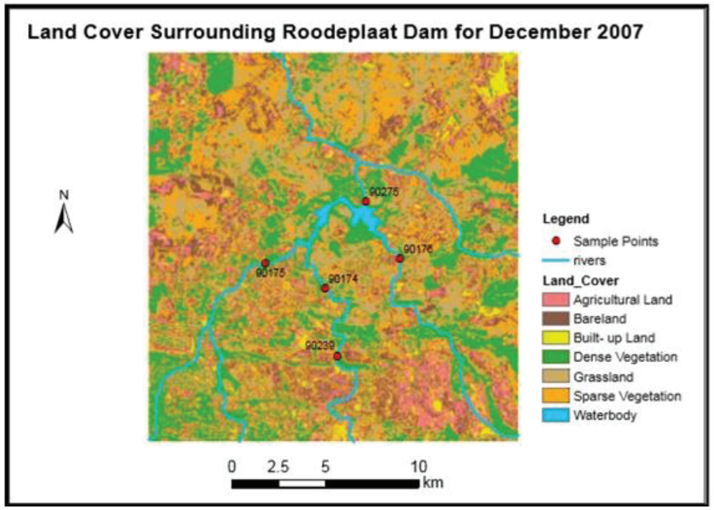
Parameter	Dry Season 2014					Wet Season 2014				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175
pH	8.94	8.32	8.47	8.45	8.39	8.31	8.61	7.89	8.64	8.24
EC (mS/m)	44.32	39.53	68.25	50.65	47.36	50.26	48.24	52.24	41.67	25.67
Nitrogen (mg/L)	8.74	6.45	18.46	5.51	2.61	6.31	10.86	4.73	2.39	1.93
Phosphorus (mg/L)	0.64	0.27	2.16	0.23	0.05	0.34	0.50	1.44	0.16	0.06
Chloride (mg/L)	43.42	20.53	44.62	26.93	35.25	38.38	1.82	41.23	19.62	17.33
Sulphate (mg/L)	39.35	19.15	55.25	33.52	30.29	37.43	14.40	41.0	20.94	20.74
E. Coli (cfu/1000ml)	N/A	180	56800	3060	594.00	N/A	N/A	N/A	N/A	N/A

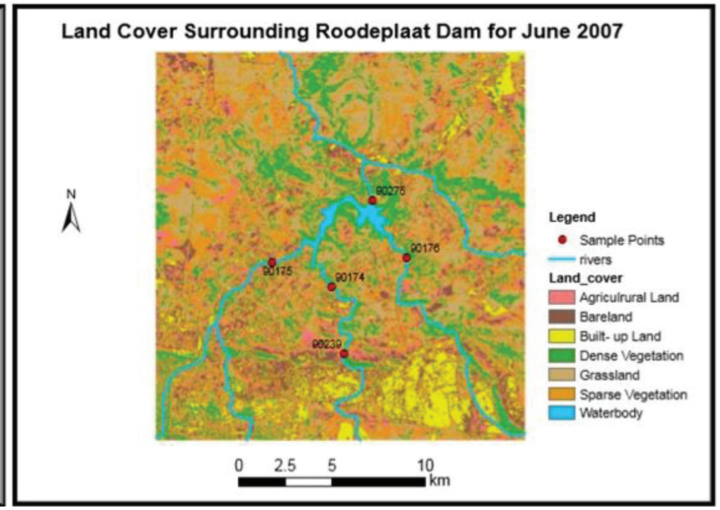
Parameter	Dry Season 2015					Wet Season 2015				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175
pH	8.19	8.17	7.80	8.16	8.21	8.91	8.24	7.50	6.64	8.25
EC (mS/m)	49.83	46.76	79.57	48.50	44.20	54.16	61.50	63.40	58.56	38.33
Nitrogen (mg/L)	6.87	4.60	26.01	4.34	2.15	37.37	4.62	40.17	48.92	1.10
Phosphorus (mg/L)	0.65	0.27	6.89	0.22	0.05	0.41	0.01	1.78	9.32	0.04
Chloride (mg/L)	38.43	24.81	53.98	24.47	31.17	46.28	38.65	50.89	35.28	27.67
Sulphate (mg/L)	37.09	21.68	58.25	26.95	28.35	59.89	42.91	56.02	27.44	25.78
E. Coli (cfu/1000ml)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	70775	400000	380

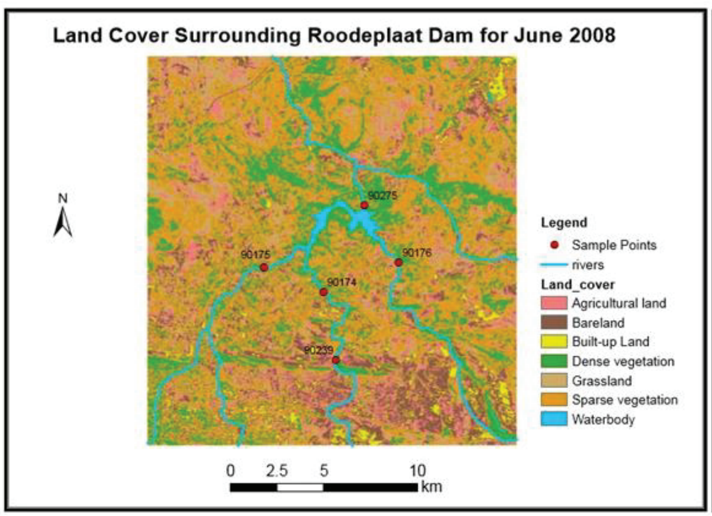
Parameter	Dry Season 2016					Wet Season 2016				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 590175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175
pH	8.37	8.15	7.19	7.74	8.54	8.26	8.74	7.83	7.72	8.25
EC (mS/m)	48.37	53.45	68.26	75.84	44.59	46.42	46.98	59.43	61.74	39.77
Nitrogen (mg/L)	5.174	8.84	N/A	30.15	1.66	5.62	9.037	30.36	19.52	1.95
Phosphorus (mg/L)	0.48	0.54	N/A	7.33	0.03	1.07	1.088	3.57	2.85	0.06
Chloride (mg/L)	40.36	36.76	51.50	50.62	35.47	44.43	44.64	45.60	48.85	30.77
Sulphate (mg/L)	39.23	34.12	60.26	41.28	24.87	55.74	64.93	47.26	60.94	24.18
E. Coli (cfu/1000ml)	N/A	1564	142635	557450	604	0.50	0.50	648800	1986300	1918

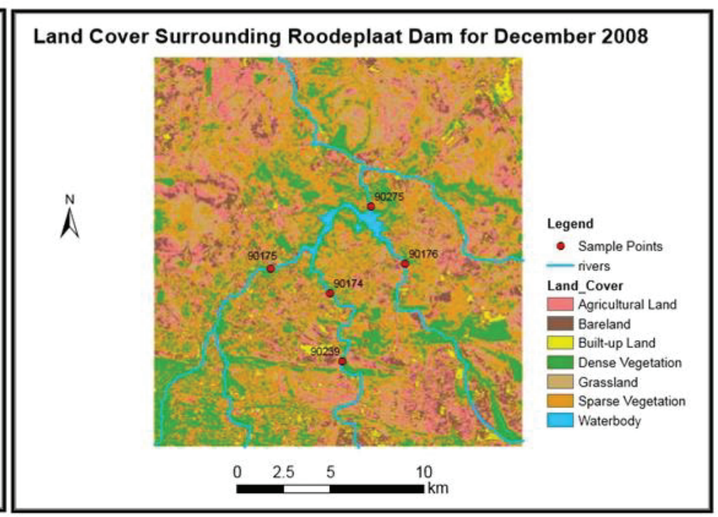
Parameter	Dry Season 2017					Wet Season 2017				
	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175	Site 1 90275	Site 2 90176	Site 3 90174	Site 4 90239	Site 5 90175
pH	8.05	8.45	7.45	7.45	8.35	8.68	8.40	7.40	7.40	8.38
EC (mS/m)	47.56	61.25	65.45	58.14	42.45	49.65	63.34	64.38	68.69	30.00
Nitrogen (mg/L)	7.93	10.55	20.79	5.90	1.83	8.29	22.99	16.56	30.48	2.76
Phosphorus (mg/L)	0.84	0.64	7.13	0.55	0.02	0.98	2.50	1.40	1.82	0.16
Chloride (mg/L)	36.98	28.26	48.72	38.54	28.38	49.28	45.58	45.87	62.85	17.55
Sulphate (mg/L)	38.87	21.67	65.72	46.41	25.35	48.25	17.32	60.65	57.25	16.15
E. Coli (cfu/1000ml)	0.50	217	131400	63830	49	0.50	98600	30600	283300	864

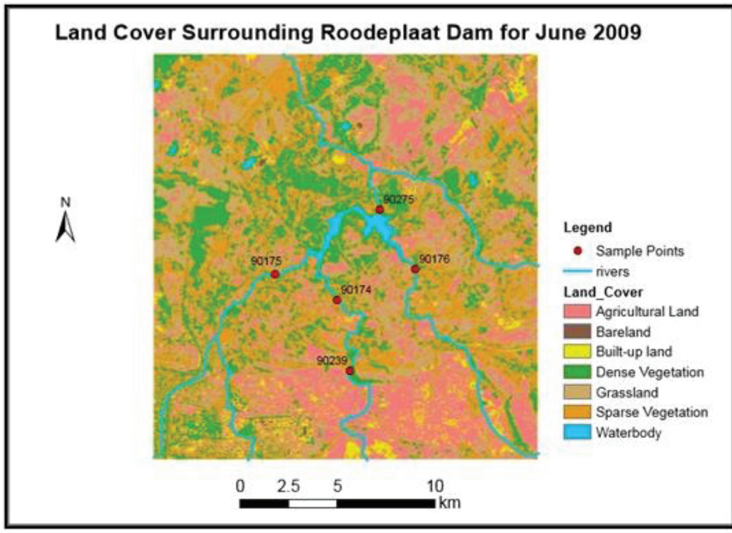
Appendix B: LULCC Maps from 2007-2017










Land Cover Surrounding Roodeplaat Dam for June 2009
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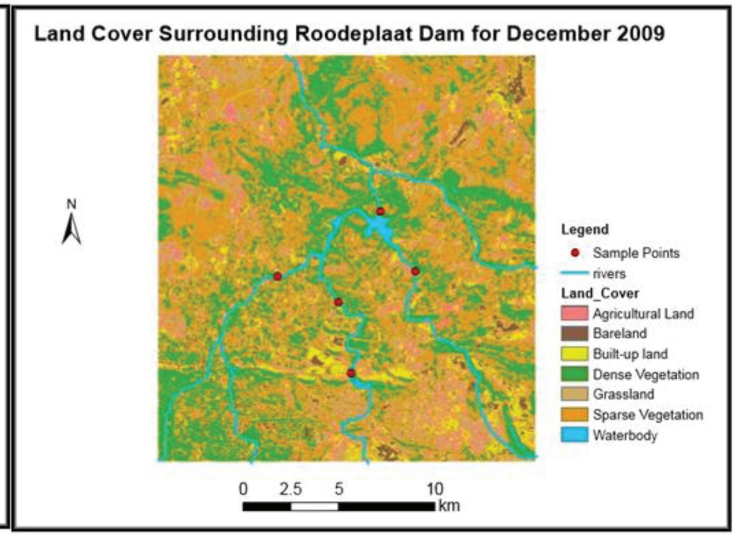
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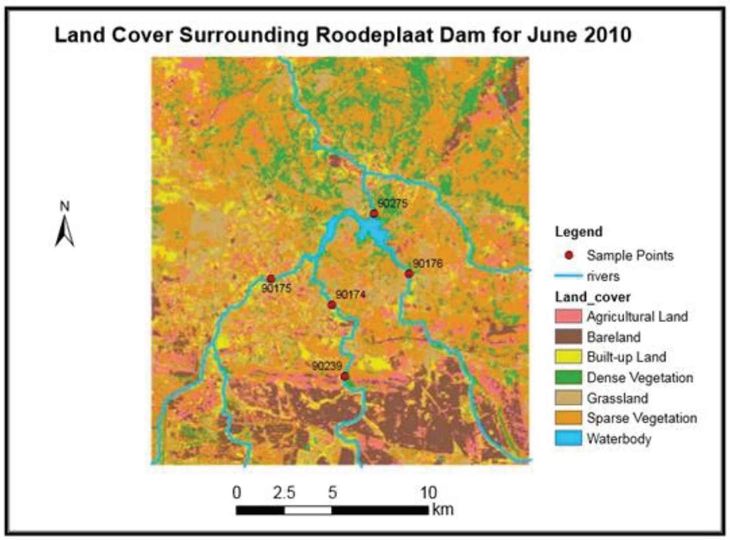
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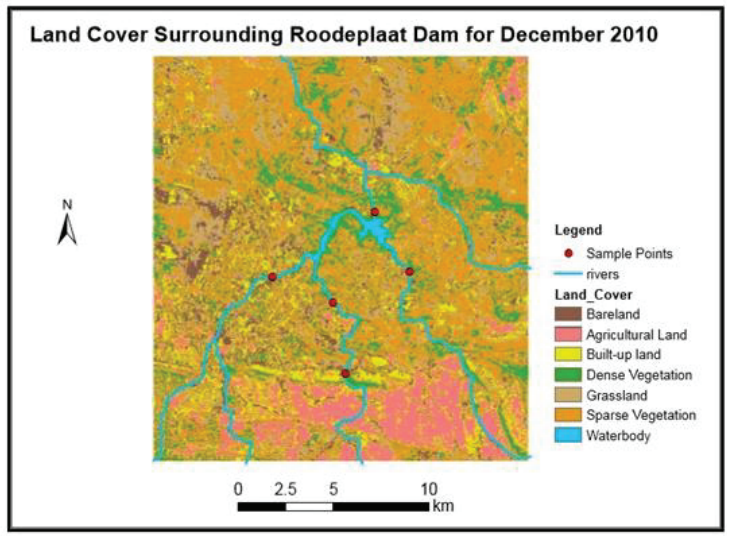
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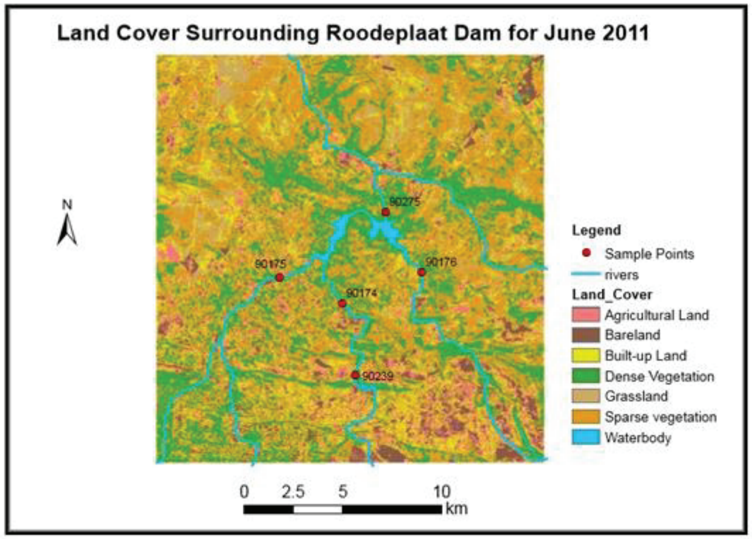
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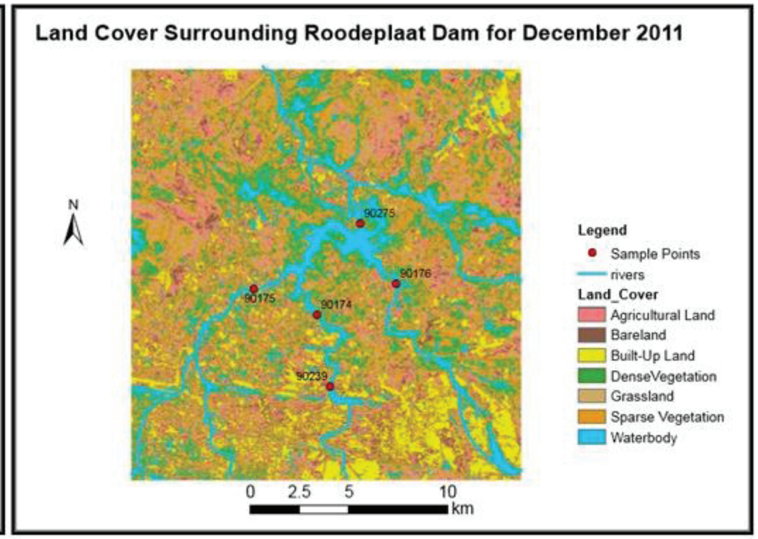
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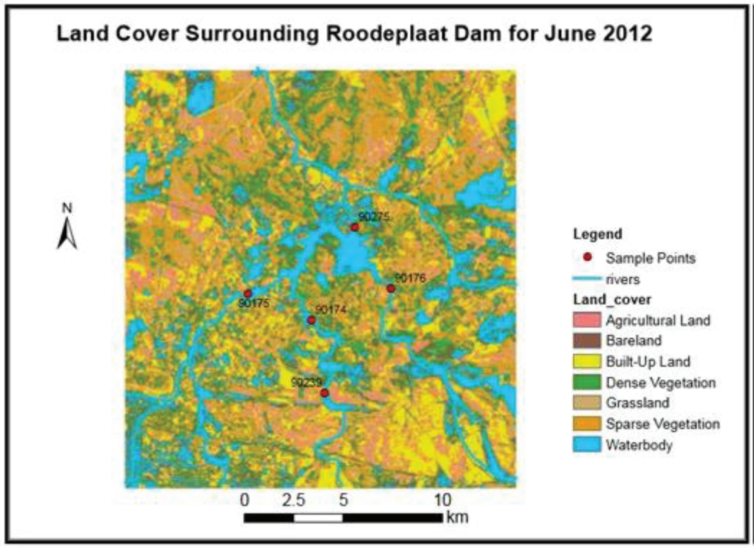
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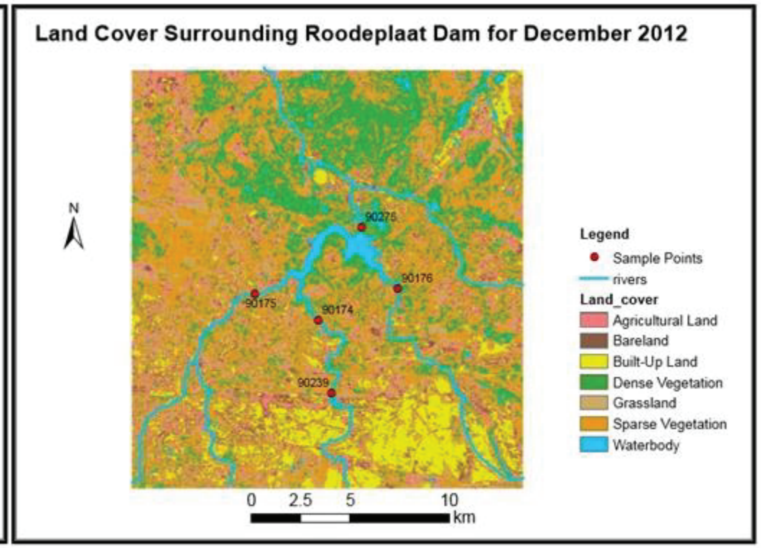
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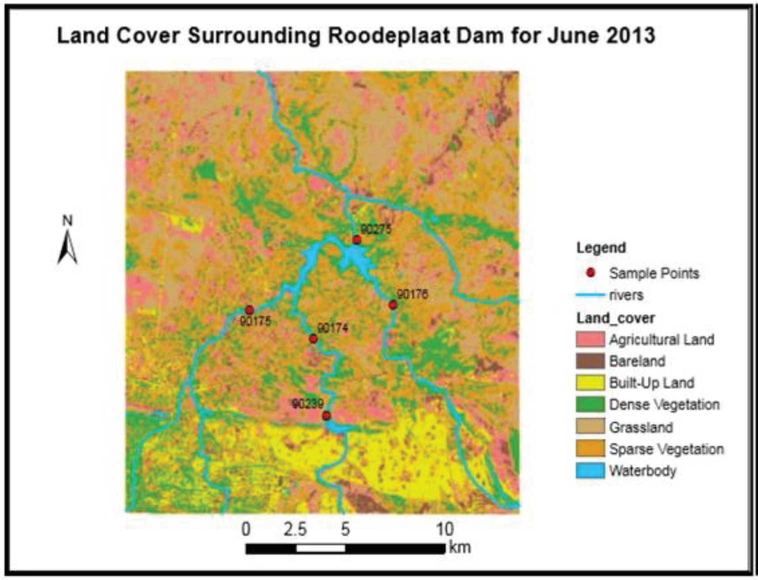
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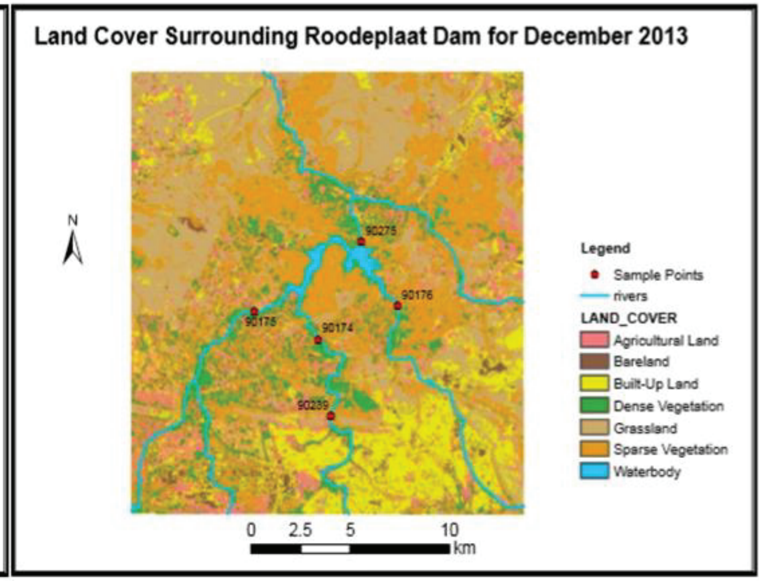
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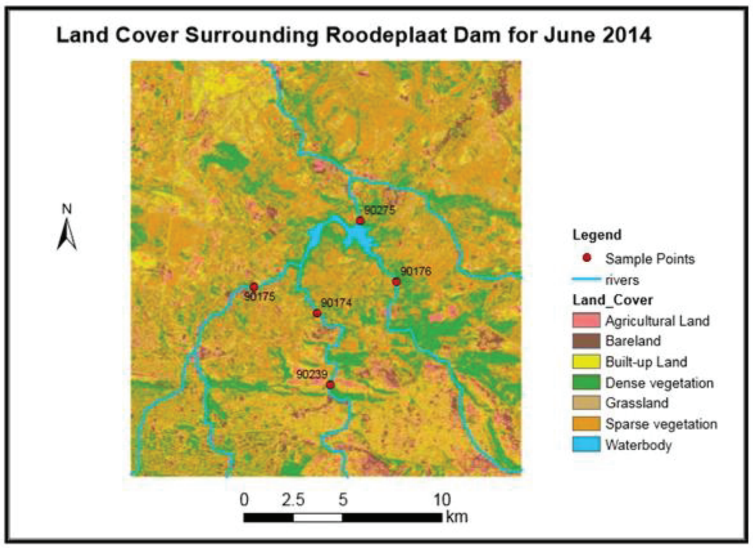
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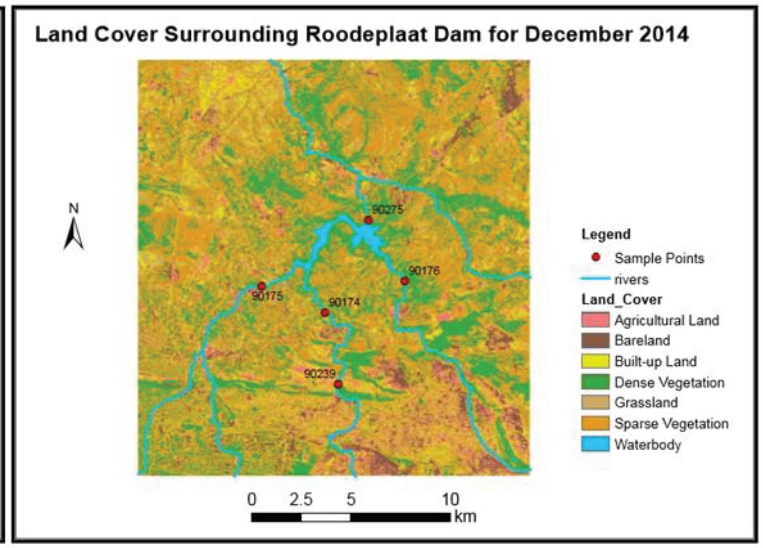
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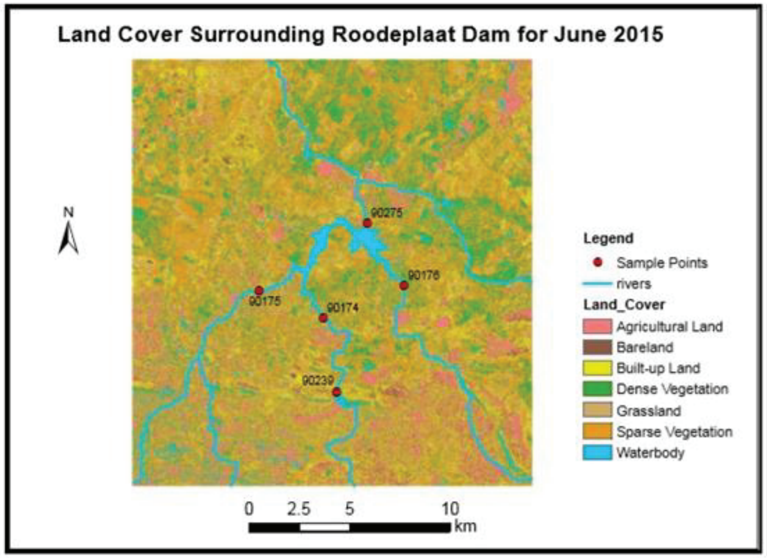
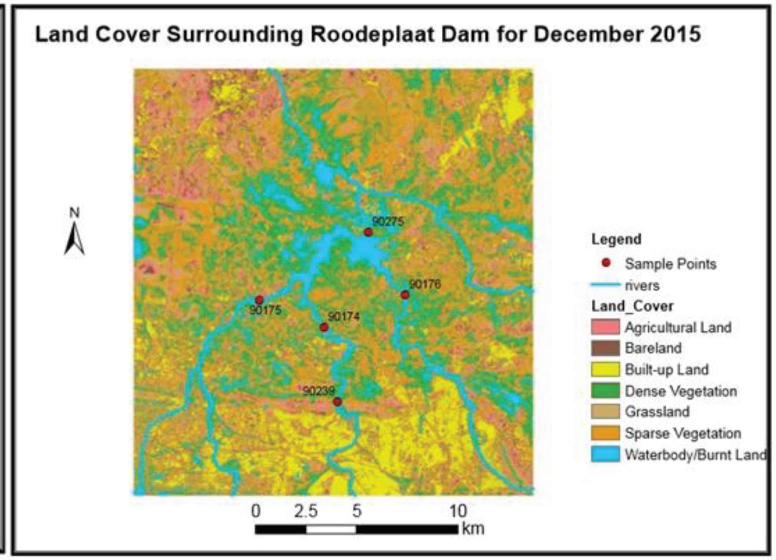
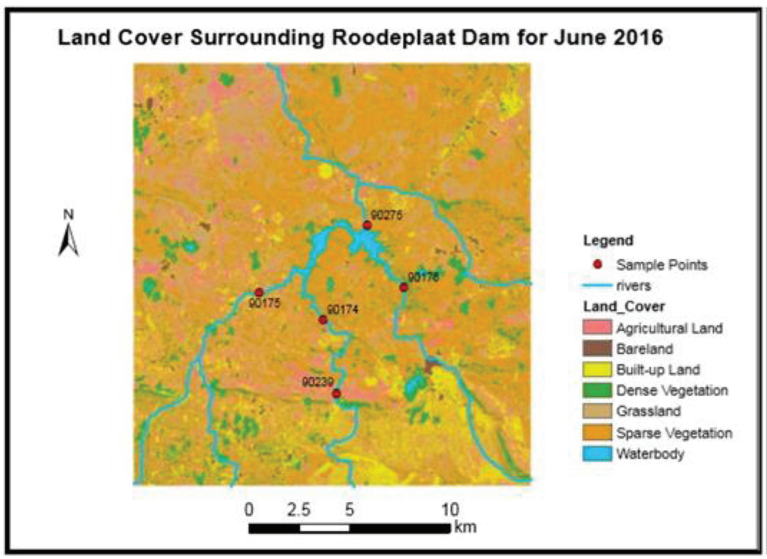
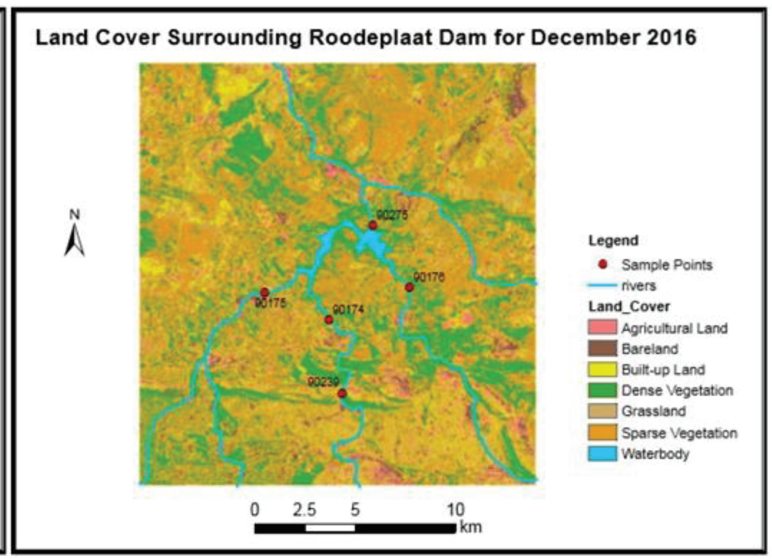
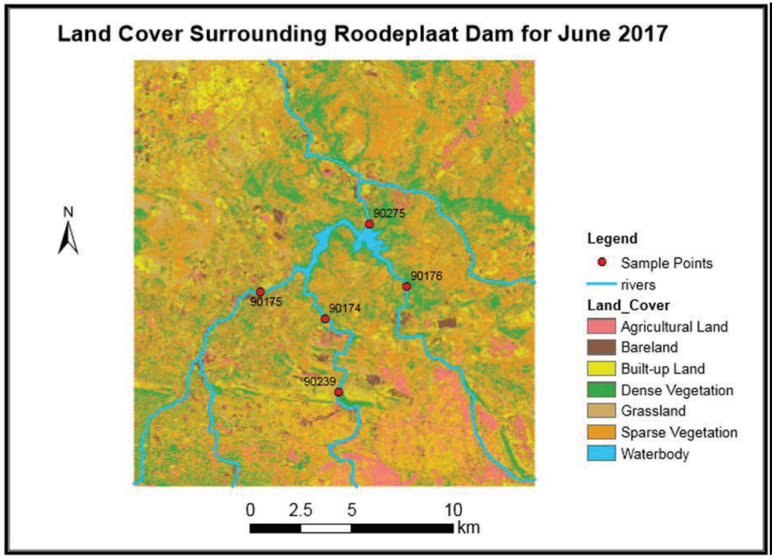
0 2.5 5 10
km

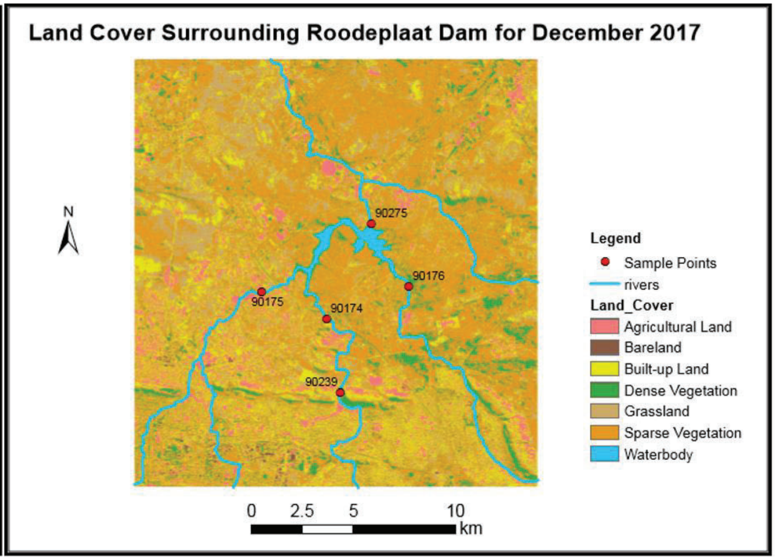

Land Cover Surrounding Roodeplaat Dam for June 2015
N
90275
90176
90175
90174
90239
Legend
Sample Points
rivers
Land_Cover
Agricultural Land
Bareland
Built-up Land
Dense Vegetation
Grassland
Sparse Vegetation
Waterbody
0 2.5 5 10
km


Land Cover Surrounding Roodeplaat Dam for December 2015
N
90275
90176
90175
90174
90239
Legend
Sample Points
rivers
Land_Cover
Agricultural Land
Bareland
Built-up Land
Dense Vegetation
Grassland
Sparse Vegetation
Waterbody/Burnt Land
0 2.5 5 10
km


Land Cover Surrounding Roodeplaat Dam for June 2016
N
90275
90176
90175
90174
90239
Legend
Sample Points
rivers
Land_Cover
Agricultural Land
Bareland
Built-up Land
Dense Vegetation
Grassland
Sparse Vegetation
Waterbody
0 2.5 5 10
km


Land Cover Surrounding Roodeplaat Dam for December 2016
N
90275
90176
90175
90174
90239
Legend
Sample Points
rivers
Land_Cover
Agricultural Land
Bareland
Built-up Land
Dense Vegetation
Grassland
Sparse Vegetation
Waterbody
0 2.5 5 10
km


Land Cover Surrounding Roodeplaat Dam for June 2017
N
90275
90176
90175
90174
90239
Legend
Sample Points
rivers
Land_Cover
Agricultural Land
Bareland
Built-up Land
Dense Vegetation
Grassland
Sparse Vegetation
Waterbody
0 2.5 5 10
km


Land Cover Surrounding Roodeplaat Dam for December 2017
N
90275
90176
90175
90174
90239
Legend
Sample Points
rivers
Land_Cover
Agricultural Land
Bareland
Built-up Land
Dense Vegetation
Grassland
Sparse Vegetation
Waterbody
0 2.5 5 10
km

Appendix C: Questionnaire used for data collection in the present study

UNIVERSITY OF JOHANNESBURG

Research interview questionnaire

Date:	Respondent number

Instruction: Please place and (X) or fill in where applicable

Section A: Demography

1. Residential Area

Leeufontein Estate
Sable Hills Waterfront Estate
Mamelodi East
Mamelodi West
Eersterust
Derdepoort
Other

2. Please indicate your gender:

   Female ☐

   Male ☐

3. Please indicate your age:

   18-29 ☐ 30-39 ☐ 40-49 ☐

   50-59 ☐ 60+ ☐

4. Please indicate your ethnic group:

   Black ☐ Coloured ☐ White ☐ Indian/Asian ☐

5. Please indicate your highest level of education completed:

   Primary school ☐ High school ☐ Tertiary education ☐

6. Please indicate your employment status:

   Employed ☐ Unemployed ☐ Self-employed ☐ Pensioner ☐

7. Type of housing:

   Free standing house ☐ Informal shelter ☐ Flat ☐ Other ☐

Section B: Perceptions of water quality by communities

1. What is the current water quality state of the dam?

Very bad	Bad	Good	Very good

2. What is the reason for the current water quality state?

   ____
   ____
   ____
   ____

3. Does the water quality of the Roodeplaat Dam and its inflowing rivers affect the surrounding community? If so, How?

   ____
   ____
   ____
   ____

4. Would you consider yourself as a 'user; of the dam or its inflowing rivers? If so, what do you use it for?

   ____
   ____
   ____

Section C: Community perceptions of functional value of the dam-river

5. Do you perceive the system as useful for the environment and the community? If yes, what ecosystem goods and services does it provide?

____

____

____

Section D: Community perception of their level of participation

6. Who is responsible for the management of the dam-river system?

____

____

7. Do you think the responsible institution is doing their best in managing the system?

____

____

____

8. Does the community get involved in the management of the dam-river system? If yes, please rank your involvement?

Poor	Good	Excellent

____

____

____

Section E: Community perception of their level of satisfaction on the existing management plan

9. What is your level of satisfaction for the existing management plan?

Very Dissatisfied	Dissatisfied	Neutral	Satisfied
Very Satisfied			

Thank you for participating in this survey.

Appendix D: All the data collected from the questionnaire

Residential _area	gender	age	ethnic_group	education _level	employment	Water_ quality	does_water_quality_affect _community	are_you_a_user	Type_ecosyst_goods_ services	community_involvement	satisfaction_ level
Mamelodi_East	female	50	1	2	3	Very_bad	1	1	water	0	Very_dissatisfied
Mamelodi_East	male	30	1	2	3	very_bad	1	0	No	0	very_dissatisfied
Mamelodi_East	male	30	1	2	3	bad	1	0	No	0	dissatified
Mamelodi_East	female	18	1	3	3	very_bad	1	1	water	0	very_dissatisfied
Mamelodi_East	male	30	1	3	3	bad	1	0	religion	0	very_dissatisfied
Mamelodi_East	male	18	1	1	1	bad	1	0	no	0	very_dissatisfied
Mamelodi_East	male	40	1	2	3	bad	1	0	religion	0	very_dissatisfied
Mamelodi_East	male	30	1	2	3	very_bad	1	0	no	0	very_dissatisfied
Mamelodi_East	male	40	1	2	1	bad	1	0	no	0	dissatified
Mamelodi_East	male	30	1	2	1	bad	1	0	no	0	dissatified
Mamelodi_Ea	male	18	1	2	3	very_bad	1	0	no	0	dissatified

st											
Mamelodi_East	male	30	1	2	3	very_bad	1	0	no	0	very_dissatisfied
Mamelodi_East	female	18		2	3	very_bad	1	0	no	0	dissatified
Mamelodi_East	male	18	1	2	3	very_bad	1	0	religion	0	very_dissatisfied
Mamelodi_East	female	18	1	2	1	bad	1	0	no	0	very_dissatisfied
Mamelodi_East	male	60	1	2	2	bad	1	0	no	0	very_dissatisfied
Mamelodi_East	male	40	1	2	3	very_bad	1	0	no	0	very_dissatisfied
Mamelodi_East	male	18	1	2	1	bad	1	0	no	0	dissatified
Mamelodi_East	male	19	1	2	1	bad	1	0	no	0	very_dissatisfied
Mamelodi_East	male	18	1	2	1	bad	1	0	no	0	very_dissatisfied
Mamelodi_East	male	60	1	1	2	bad	1	0	no	0	very_dissatisfied
Mamelodi_East	female	50	1	2	3	bad	1	1	religion	0	dissatified
Mamelodi_East	female	30	1	1	3	bad	1	1	religion	0	dissatified
Mamelodi_East	female	50	1	2	3	bad	1	0	no	0	very_dissatisfied

Mamelodi_East	female	20	1	3	1	bad	1	0	no	0	dissatisfied
Mamelodi_East	female	20	1	2	1	bad	1	0	no	0	very_dissatisfied
Mamelodi_East	male	30	1	2	1	bad	1	0	no	0	very_dissatisfied
Mamelodi_East	male	30	1	2	3	bad	1	0	no	0	dissatisfied
Mamelodi_East	female	30	1	3	3	bad	1	0	no	0	very_dissatisfied
Mamelodi_West	female	18	1	3	3	bad	1	0	no	0	dissatisfied
Mamelodi_West	male	40	1	2	3	bad	1	0	no	0	very_dissatisfied
Mamelodi_West	male	50	1	2	3	bad	1	0	no	0	very_dissatisfied
Mamelodi_West	male	18	1	2	1	very_bad	1	0	no	0	very_dissatisfied
Mamelodi_West	female	18	1	2	1	very_bad	1	0	no	0	very_dissatisfied
Mamelodi_West	female	60	1	2	2	bad	1	1	no	0	dissatisfied
Mamelodi_West	male	18	1	3	1	bad	1	0	no	0	very_dissatisfied
Mamelodi_West	male	30	1	3	3	very_bad	1	0	no	0	dissatisfied
Mamelodi_West	male	30	1	2	1	bad	1	0	no	0	very_dissatisfied

Mamelodi_West	male	60	1	3	2	very_bad	1	0	no	0	very_dissatisfied
Mamelodi_West	male	50	2	3	3	bad	1	0	no	0	very_dissatisfied
Mamelodi_West	female	40	1	2	3	bad	1	0	no	0	very_dissatisfied
Mamelodi_West	male	40	1	2	1	good	1	1	no	1	satisfied
Mamelodi_West	male	50	1	3	3	bad	1	0	no	00	dissatisfied
Mamelodi_West	female	30	1	3	3	bad	1	0	no	0	dissatisfied
Mamelodi_West	female	30	1	2	1	bad	1	0	no	0	very_dissatisfied
Mamelodi_West	male	40	1	2	1	bad	1	0	no	0	dissatisfied
Mamelodi_West	male	30	1	1	3	good	1	1	no	1	satisfied
Mamelodi_West	male	40	1	2	3	bad	1	0	no	0	very_dissatisfied
Mamelodi_West	female	40	1	2	3	bad	1	0	no	0	dissatisfied
Eersterust	female	50	2	2	3	bad	1	0	fishing	0	very_dissatisfied
Eersterust	male	50	2	2	1	very_bad	1	1	fishing	0	very_dissatisfied
Eersterust	female	60	2	2	3	good	0	1	fishing	0	very_dissatisfied

Eersterust	female	60	2	2	1	bad	1	1	no	0	very_dissatisfied
Eersterust	male	18	2	2	3	good	0	1	no	0	dissatisfied
Eersterust	male	30	2	3	3	very_bad	1	0	no	0	very_dissatisfied
Eersterust	female	18	2	2	3	very_bad	1	0	no	0	very_dissatisfied
Eersterust	female	18	2	2	3	bad	1	0	no	0	dissatisfied
Eersterust	female	30	2	2	1	good	0	1	fishing	0	very_dissatisfied
Eersterust	female	50	2	2	3	good	0	1	fishing	0	very_dissatisfied
Eersterust	male	30	2	2	3	bad	1	0	no	0	very_dissatisfied
Eersterust	male	60	2	3	3	bad	1	0	no	0	dissatisfied
Eersterust	male	60	2	2	3	bad	1	0	no	0	very_dissatisfied
Eersterust	male	60	1	3	2	bad	1	0	no	0	dissatisfied
Eersterust	male	60	2	3	2	bad	1	0	recreation	0	dissatisfied
Eersterust	male	60	2	2	3	very_bad	1	0	recreation	0	very_dissatisfied
Eersterust	female	30	2	2	3	bad	1	0	no	0	dissatisfied
Eersterust	female	30	2	2	3	good	0	1	NA	1	satisfied
Eersterust	male	18	2	3	1	bad	1	1	no	0	dissatified
Eersterust	male	20	1	2	1	very_bad	1	1	no	0	satisfied
Eersterust	female	20	2	1	3	good	1	1	no	1	satisfied

Eersterust	female	40	4	3	3	bad	1	0	no	0	satisfied
Eersterust	female	18	3	3	3	bad	1	0	no	0	satisfied
Eersterust	male	30	3	3	3	very_bad	1	0	no	0	very_dissatisfied
Eersterust	male	30	3	3	3	very_bad	1	0	no	0	very_dissatisfied
Eersterust	male	40	2	2	3	bad	1	0	no	0	very_dissatisfied
Eersterust	male	30	2	2	3	bad	1	0	no	0	very_dissatisfied
Eersterust	female	18	1	2	1	good	0	1	NA	1	satisfied
Eersterust	female	20	2	2	1	bad	1	0	no	0	very_dissatisfied
Eersterust	female	20	2	2	1	bad	1	0	no	0	very_dissatisfied
Derdepoort	male	50	4	3	3	bad	1	0	recreation	0	dissatisfied
Derdepoort	female	20	4	3	3	bad	1	0	no	0	very_dissatisfied
Derdepoort	male	20	4	3	3	bad	1	1	fishing		dissatisfied
Derdepoort	male	40	1	3	3	bad	1	0	fishing	0	dissatisfied
Derdepoort	male	30	1	3	3	bad	1	0	no	0	very_dissatisfied
Derdepoort	female	20	4	2	3	bad	1	0	no	0	dissatified
Derdepoort	female	20	4	3	3	bad	1	1	fishing	0	very_dissatisfied
Derdepoort	male	60	4	3	2	bad	1	0	no	0	very dissatfied

Derdepoort	female	50	1	2	3	bad	0	0	no	0	dissatisfied
Derdepoort	male	30	4	3	3	bad	1	0	recreation	0	dissatified
Leeufontein	female	40	1	2	3	bad	0	0	no	1	very_dissatisfied
Leeufontein	female	20	4	2	3	very_bad	1	0	recreation	0	dissatisfied
Leeufontein	male	30	4	3	3	bad	1	1	recreation	0	dissatisfied
Leeufontein	female	20	4	3	3	bad	1	1	recreation	0	very_dissatisfied
Leeufontein	male	40	1	3	3	bad	1	1	recreation	0	very_dissatisfied
Leeufontein	male	50	4	3	3	bad	1	1	fishing	0	dissatisfied
Leeufontein	male	40	1	3	3	very_bad	1	1	recreation	0	dissatisfied
Leeufontein	female	30	4	3	3	bad	1	0	no	0	dissatisfied
Leeufontein	male	60	4	3	2	very_bad	1	1	fishing	1	satisfied
Leeufontein	female	60	4	3	2	very_bad	1	0	recreation	1	satisfied
Leeufontein	female	40	1	3	3	bad	1	1	fishing	0	dissatisfied
Leeufontein	male	40	1	2	3	bad	1	1	fishing	0	very_dissatisfied
Leeufontein	male	20	4	3	1	bad	1	1	recreation	0	very_dissatisfied
Leeufontein	female	20	1	2	3	bad	1	1	recreation	0	dissatisfied
Leeufontein	female	30	1	3	3	bad	1	1	no	0	very_dissatisfied
Leeufontein	male	60	4	3	2	bad	1	1	fishing	0	very_dissatisfied

Leeufontein	female	60	4	3	2	bad	1	0	no	0	dissatisfied
Leeufontein	male	40	1	3	3	bad	1	1	recreation	0	very_dissatisfied
Leeufontein	female	40	4	2	3	bad	1	0	fishing	0	dissatisfied
Leeufontein	male	50	4	3	3	bad	1	1	fishing	0	dissatisfied
Leeufontein	female	50	4	3	3	bad	1	1	fishing	0	dissatisfied
Sable_hills	male	30	4	3	3	very_bad	1	1	recreation	1	dissatisfied
Sable_hills	male	20	4	3	3	very_bad	1	1	agriculture_household	0	very_dissatisfied
Sable_hills	male	30	4	3	3	very_bad	1	1	household_recreational	0	disstisfied
Sable_hills	male	50	4	3	3	bad	1	1	recreation		dissatisfied
Sable_hills	female	29	4	3	3	bad	1	1	recreation	1	satisfied
Sable_hills	male	20	4	3	3	very_bad	1	1	recreation	0	very_dissatisfied
Sable_hills	male	30	4	3	3	bad	1	1	recreation	0	dissatisfied
Sable_hills	female	40	4	3	3	bad	1	1	recreation	1	satisfied
Sable_hills	female	20	4	3	1	verybad	1	1	recreation	1	satisfied
Sable_hills	male	40	4	3	3	bad	1	1	recreation	1	satisfied
Sable_hills	male	30	4	3	3	bad	1	1	recreation	0	dissatisfied
Sable_hills	male	30	4	3	3	bad	1	1	recreation	0	very_dissatisfied
Sable_hills	female	30	4	3	3	bad	1	1	recreation	0	very_dissatisfied
Sable_hills	male	20	1	3	1	bad	1	1	recreation	0	dissatisfied

Sable_hills	female	20	4	3	3	bad	1	1	recreation	0	dissatisfied
Sable_hills	female	40	1	3	3	bad	1	1	recreation	0	very_dissatisfied
Sable_hills	male	60	1	3	2	bad	1	1	fishing	0	dissatisfied
Sable_hills	male	50	4	2	3	bad	1	1	recreation	0	very_dissatisfied
Sable_hills	male	50	4	3	3	bad	1	1	recreation	0	dissatisfied
Sable_hills	female	60	4	2	2	bad	1	1	recreation	0	dissatisfied
Sable_hills	female	20	1	3	3	bad	1	1	recreation	0	very_dissatisfied
Sable_hills	female	30	4	3	3	bad	1	1	recreation	0	very_dissatisfied
Sable_hills	male	30	4	2	3	bad	1	1	recreation	0	dissatisfied
Sable_hills	female	20	4	3	3	bad	1	1	recreation	0	dissatisfied
Sable_hills	male	40	4	3	3	bad	1	1	fishing	0	very_dissatisfied
Sable_hills	female	40	4	3	3	bad	1	0	recreation	0	dissatisfied
Sable_hills	male	20	4	3	3	bad	1	1	recreation	0	very_dissatisfied
Sable_hills	female	30	4	2	3	bad	1	1	recreation	0	dissatisfied
Sable_hills	male	40	4	3	3	bad	1	1	recreation	0	very_dissatisfied
Sable_hills	male	60	4	3	2	bad	1	1	recreation	0	very_dissatisfied
Sable_hills	female	20	4	3	3	bad	1	1	recreation	0	dissatisfied
Sable_hills	male	20	4	3	3	bad	1	1	recreation	0	very_dissatisfie

											d
Sable_hills	female	30	1	2	3	bad	1	1	recreation	0	dissatisfied
Sable_hills	male	50	1	2	3	bad	1	1	recreation	0	dissatisfied
Sable_hills	female	40	4	3	3	bad	1	1	fishing	0	very_dissatisfied
Sable_hills	male	60	4	3	2	bad	1	1	fishing	0	very_dissatisfied
Sable_hills	male	60	1	2	2	bad	1	1	fishing	0	dissatisfied
Sable_hills	female	50	4	3	2	bad	1	1	fishing	0	very_dissatisfied
Sable_hills	male	60	4	3	2	bad	1	1	fishing	0	dissatisfied

Appendix E: Code List used for the questionnaires

Ethnic Group	Education Level	Employment status	Does water affect community?	Are you a user of water in the dam-river system?	Community Involvement
1 – Black 2 – Coloured 3 – Indian 4 – White	1 – Attended Primary school 2 – Attended secondary school 3 – Attended tertiary education	1 – Unemployed 2 – Pension 3 – Employed	0 – No 1 – Yes	0 – No 1 – Yes	0 – Poor 1 – Good 2 – Excellent

Appendix F: R scripts used for data analysis

water quality

By Karabo Maruapula and Dr Kowiyou Yessoufou, University of Johannesburg, South Africa

```
rm(list=ls())

#file.choose()

par(mfrow=c(2,4))

###Accessing the dataset to be analysed on my laptop

data_water <-

read.table("C:\\Users\\kowiyouy\\Desktop\\UJ\\MSc
supervision\\Enviro\\Karabo\\Data\\water quality.txt",header=TRUE)

attach(data_water)

names(data_water)


#comparison of pollution among water bodies

model_pH <-aov(pH~water_bodies_name,data=data_water)

#same comparison but between rivers and dam

model_pH2 <-aov(pH~water_bodies_dam_river,data=data_water

#comparison of pollution among water bodies

model_conduc <-aov(Electrical_Conductivity~water_bodies_name,data=data_water)

plot(Electrical_Conductivity~water_bodies_name, main="A",ylab = "Electrical
conductivity", xlab="water bodies")

#same comparison of pollution between river and dam

model_conduc2 <-aov(Electrical_Conductivity~water_bodies_dam_river
,data=data_water)

plot(Electrical_Conductivity~water_bodies_dam_river, main="B",ylab = "Electrical
conductivity", xlab="water bodies")
```

```
#comparison of pollution among water bodies
model_e.coli <-aov(E_Coli~water_bodies_name,data=data_water)
model_e.coli2 <-aov(E_Coli~water_bodies_dam_river,data=data_water)
#comparison of pollution among water bodies
model_Cl <-aov(Cl~water_bodies_name,data=data_water)
plot(Cl~water_bodies_name,data=data_water,main="C",ylab="Chloride ion",xlab="water bodies")
model_Cl2 <-aov(Cl~water_bodies_dam_river,data=data_water)
plot(Cl~water_bodies_dam_river,data=data_water,main="D",ylab="Chloride ion",xlab="water bodies")
#comparison of pollution among water bodies
model_N <-aov(N~water_bodies_name,data=data_water)
model_N2 <-aov(N~water_bodies_dam_river,data=data_water)
plot(N~water_bodies_dam_river,main="F",data=data_water,ylab="Nitrogen",xlab="water bodies")
#comparison of pollution among water bodies
model_P <-aov(P~water_bodies_name,data=data_water)
model_P2 <-aov(P~water_bodies_dam_river,data=data_water)
#comparison of pollution among water bodies
model_SO4 <-aov(SO4~water_bodies_name,data=data_water)
plot(SO4~water_bodies_name,main="G",data=data_water,ylab="Sulphate",xlab="water bodies")
model_SO4_2 <-aov(SO4~water_bodies_dam_river,data=data_water)
plot(SO4~water_bodies_dam_river,main="H",data=data_water,ylab="Sulphate",xlab="water bodies")
#comparison of pollution among water bodies
model_Alk <-aov(Alk~water_bodies_name,data=data_water)
plot(Alk~water_bodies_name,data=data_water,ylab="Alkalinity",xlab="water bodies")
model_Alk2 <-aov(Alk~water_bodies_dam_river,data=data_water)
plot(Alk2~water_bodies_dam_river,data=data_water,ylab="",xlab="water bodies")
```

```
## Testing relationships between LULCC and water quality
# Agric.
model_agric <-glm(Electrical_Conductivity~Agricultural_land_size,data = data_water)
summary(model_agric)
model_agric2 <-glm(Cl~Agricultural_land_size,data = data_water)
summary(model_agric2)
model_agric3 <-glm(N~Agricultural_land_size,data = data_water)
summary(model_agric3)
model_agric4 <-glm(SO4~Agricultural_land_size,data = data_water)
summary(model_agric4)

# Built up area size
model_built <-glm(Electrical_Conductivity~Built.up_area_size,data = data_water)
summary(model_built)
model_built2 <-glm(Cl~Built.up_area_size,data = data_water)
summary(model_built2)
par(mfrow=c(1,2))
model_built3 <-glm(N~Built.up_area_size,data = data_water)
summary(model_built3) # beta=0.08+/-0.03, P=0.01
plot(log(N)~log(Built.up_area_size),data = data_water)
abline(lm(N~Built.up_area_size))
model_built4 <-glm(SO4~Built.up_area_size,data = data_water)
summary(model_built4)# beta=0.13+/-0.04, P=0.004
plot(log(SO4)~log(Built.up_area_size),data = data_water)
abline(lm(log(SO4)~log(Built.up_area_size)))
#Bareland_size
model_bareland <-glm(Electrical_Conductivity~Bareland_size,data = data_water)
summary(model_bareland)
```

```
model_bareland2 <-glm(Cl~Bareland_size,data = data_water)
summary(model_bareland2)
model_bareland3 <-glm(N~Bareland_size,data = data_water)
summary(model_bareland3)
model_bareland4 <-glm(SO4~Bareland_size,data = data_water)
summary(model_bareland4)

#grassland
model_grassland <-glm(Electrical_Conductivity~Grassland_size,data = data_water)
summary(model_grassland)
model_grassland2 <-glm(Cl~Grassland_size,data = data_water)
summary(model_grassland2)
model_grassland3 <-glm(N~Grassland_size,data = data_water)
summary(model_grassland3)
model_grassland4 <-glm(SO4~Grassland_size,data = data_water)
summary(model_grassland4)
#Dense_Vegetation_size
model_denseV <-glm(Electrical_Conductivity~Dense_Vegetation_size,data =
data_water)
summary(model_denseV)
model_denseV2 <-glm(Cl~Dense_Vegetation_size,data = data_water)
summary(model_denseV2)
model_denseV3 <-glm(N~Dense_Vegetation_size,data = data_water)
summary(model_denseV3)
model_denseV4 <-glm(SO4~Dense_Vegetation_size,data = data_water)
summary(model_denseV4)
```

```
#Sparse_Vegetation_size

model_sparseV <-glm(Electrical_Conductivity~Sparse_Vegetation_size,data =
data_water)

summary(model_sparseV)

model_sparseV2 <-glm(Cl~Sparse_Vegetation_size,data = data_water)

summary(model_sparseV2)

model_sparseV3 <-glm(N~Sparse_Vegetation_size,data = data_water)

summary(model_sparseV3)

model_sparseV4 <-glm(SO4~Sparse_Vegetation_size,data = data_water)

summary(model_sparseV4)


#time series analysis

data_time <- read.table("C:\\Users\\kowiyouy\\Desktop\\UJ\\MSc
supervision\\Enviro\\Karabo\\Data\\temporal change.txt",header=TRUE)

attach(data_time)

names(data_time)


#landcover

sparseVeg <- data_time[,4]

sparseVeg <- ts(sparseVeg)

denseVeg <- data_time[,5]

denseVeg <- ts(denseVeg)

grass <- data_time[,6]

grass <- ts(grass)

bareland <- data_time[,7]

bareland <- ts(bareland)

agric <- data_time[,8]

agric <- ts(agric)

builtup <- data_time[,9]
```

```
builtup <- ts(builup)

dev.off()

par(mfrow=c(3,2))

plot.ts(sparseVeg,ylab="sparse vegetation size (km2)",xlab="",main="A") # plotting time
series -

plot.ts(denseVeg,ylab="dense vegetation size (km2)",xlab="",main="B") # plotting time
series -

plot.ts(grass,ylab="grassland size (km2)",xlab="",main="C") # plotting time series -

plot.ts(bareland,ylab="bareland size (km2)",xlab="",main="D") # plotting time series -

plot.ts(agric,ylab="agricultural land size (km2)",xlab="time (number of
month)",main="E") # plotting time series -

plot.ts(builtup,ylab="built-up size (km2)",xlab="time (number of month)",main="F") #
plotting time series –


# water quality

ph <- data_time[,10]

ph <- ts(ph)

ec <- data_time[,11]

ec <- ts(ec)

ecoli <- data_time[,12]

ecoli <- ts(ecoli)

cl <- data_time[,13]

cl <- ts(cl)

n <- data_time[,14]

n <- ts(n)

p <- data_time[,15]

p <- ts(p)

so4 <- data_time[,16]

so4 <- ts(so4)

alk <- data_time[,17]
```

```
alk <- ts(alk)

par(mfrow=c(4,2))

par(mar=c(4.1,4.1,4.1,2.1))

plot.ts(ph,ylab="pH",xlab="",main="A") # plotting time series -

plot.ts(ec,ylab="electrical conductivity",xlab="",main="B") # plotting time series -

plot.ts(ecoli,ylab="E. coli",xlab="",main="C") # plotting time series -

plot.ts(cl,ylab="chloride ion",xlab="",main="D") # plotting time series -

plot.ts(n,ylab="nitrogen",xlab="",main="E") # plotting time series -

plot.ts(p,ylab="phosphorous",xlab="",main="F") # plotting time series -

plot.ts(so4,ylab="sulphate",xlab="time (number of month)",main="G") # plotting time
series -

plot.ts(alk,ylab="alkalinity",xlab="time (number of month)",main="H") # plotting time
series -


#### Understanding community perspective on water use management

# By Karabo Maruapula and Dr Kowiyou Yessoufou, University of Johannesburg, South
Africa


rm(list=ls(all=TRUE)) # clean R memory

file.choose() # to get the link that help you navigate to your data

data_k <- read.table("C:\\Users\\kowiyouy\\Desktop\\UJ\\MSc
supervision\\Enviro\\Karabo\\Data\\data_karabo.txt",header=TRUE)

attach(data_k)

names(data_k)


library(ordinal)

# How can we explain people's perception of water quality?

# without correcting for people staying in same residential area

factor.name1<-factor(data_k$water_quality,ordered=TRUE, levels=c("Very bad", "bad",
"good"))
```

model1<-
clm(factor.name1~as.numeric(gender)+age+education_Level+as.numeric(ethnic_group
)+employment,data=data_k)

summary(model1)

Let's correct for people staying in same residential area

model1.1<-
clmm(factor.name1~as.numeric(gender)+age+education_Level+as.numeric(ethnic_grou
p)+employment+(1|residential_area),data=data_k)

summary(model1.1)

How can we explain people's satisfaction level of water management?

without correcting for people staying in same residential area

factor.name2<-factor(data_k$satisfaction_level,ordered=TRUE, levels=c("Very
dissatisfied", "dissatisfied", "satisfied"))

model2<-
clm(factor.name2~as.numeric(gender)+age+education_Level+as.numeric(ethnic_group
)+employment,data=data_k)

summary(model2)

Let's correct for people staying in same residential area

factor.name2<-factor(data_k$satisfaction_level,ordered=TRUE, levels=c("Very
dissatisfied", "dissatisfied", "satisfied"))

model2.1<-
clmm(factor.name2~as.numeric(gender)+age+education_Level+as.numeric(ethnic_grou
p)+employment+(1|residential_area),data=data_k)

summary(model2.1)

Testing "community involvement" into water management

As "community involvement" is a binary response variable (poor vs good), we gonna
fit a glm model with a binomial error structure

without correction for people's independence because they belong to same
community

```
model3 <- glm(community_involvement~as.numeric(gender)+age+education_Level+as.numeric(ethnic_group)+employment,family="binomial",data=data_k)

summary(model3)

plot(ethnic_group_coded,community_involvement,xlab="ethnic group",ylab="engagement in management of dam-river system",main="B") #

g=glm(community_involvement~ethnic_group_coded,family="binomial",data=data_k) # run a logistic regression model (in this case, generalized linear model with logit link). see ?glm

curve(predict(g,data.frame(ethnic_group_coded=x),type="resp"),add=TRUE) # draws a curve based on prediction from logistic regression model

library(lme4)

# Let's correct for people staying in same residential area

model3.1 <- glmer(community_involvement~as.numeric(gender)+age+education_Level+as.numeric(ethnic_group)+employment+(1|residential_area),family="binomial", data=data_k)

summary(model3.1)


# Testing people's perception of potential effect of water quality on community

# As this is a binary response variable (yes vs no), we gonna fit a glm model with a binomial error structure

# without correction for people's independence because they belong to same community

model4 <- glm(does_water_quality_affect_community~as.numeric(gender)+age+education_Level+as.numeric(ethnic_group)+employment,family="binomial",data=data_k)

summary(model4)

interaction.plot(education_Level,gender,does_water_quality_affect_community,xlab="education level",ylab="perception on effect of water quality on community")


# Let's correct for people staying in same residential area

model4.1 <- glmer(does_water_quality_affect_community~as.numeric(gender)+age+education_Leve
```

l+as.numeric(ethnic_group)+employment+(1|residential_area),family="binomial",data=data_k)

summary(model4.1)

Testing differences in whether peoples use water from the dam or not

As this is a binary response variable (yes vs no), we gonna fit a glm model with a binomial error structure

without correction for people's independence because they belong to same community

model5 <- glm(are_you_a_user~as.numeric(gender)+age+education_Level+as.numeric(ethnic_group)+employment,family="binomial",data=data_k)

summary(model5)

Let's correct for people staying in same residential area

model5.1 <- glmer(are_you_a_user~as.numeric(gender)+age+education_Level+as.numeric(ethnic_group)+employment+(1|residential_area),family="binomial",data=data_k)

summary(model5.1)

plot(ethnic_group_coded, are_you_a_user,xlab="ethnic group",ylab="usage of dam-river system",main="A") #

g=glm(are_you_a_user~ethnic_group_coded,family="binomial",data=data_k) # run a logistic regression model (in this case, generalized linear model with logit link). see ?glm

curve(predict(g,data.frame(ethnic_group_coded=x),type="resp"),add=TRUE) # draws a

curve based on prediction from logistic regression model