WATER QUALITY MANAGEMENT OF A SECTION OF THE DWARS RIVER, CERES, WESTERN CAPE

By

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DECLARATION

I, **Andrew Thomas McLean**, declare that the contents of this dissertation/thesis represent my own unaided work, and that the dissertation/thesis has not previously been submitted for academic examination towards any qualification. Moreover, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Signed **Date**

ABSTRACT

Water quality analyses reports originating from routine monitoring indicate that pollutants of a faecal nature, and possible disease-causing bacteria, are constantly entering into the Dwars River through multiple sources rendering the river unusable from a domestic, industrial and agricultural use perspective (CWDM, 2010). This is a major concern since both the quantity and quality of available freshwater play a vital role in the economy in the area through which the Dwars River meanders (Anon, 2012a:5). The main objective of this study is to conduct a thorough investigation to determine why the water quality of the Dwars River is continuously being impaired through faecal contamination by employing a mixed method approach involving a combination of qualitative and quantitative research to analyse data collected from a number of sources and by using various techniques (USCL, 2016). To achieve the objective, the study sets out to determine the importance of the Dwars River and identify the various land uses in the vicinity of the study area to determine the potential impact the faecal pollution, analyse current surface water quality management system(s) in place to prevent the faecal pollution, evaluate the existing surface water quality management strategies aimed at preventing faecal pollution, examine the sampling methodologies employed and their efficacy towards the prevention of faecal pollutants ending up in the Dwars River, identify factors inhibiting and contributing to the effective implementation of the water quality management strategies and subsequently provide appropriate recommendations to water resource managers, institutions, scientists, decision-makers, and the public concerning the management of the quality of Dwars River's water. Findings made suggested that the Dwars River is of value for agricultural practices, domestic use, recreational activities, industrial use, economic development, ecosystem health, and aesthetics. However, the microbiological water quality of the water which the Dwars River carries is alarmingly poor and does not conform to the recommended minimum requirements. The main causes of faecal pollution of the Dwars River includes the mismanagement and inadequate operation of the local wastewater treatment works, control of polluted stormwater runoff, meagre municipal service delivery and substandard surface water quality management. Findings made indicate that a surface water quality management strategy in the form of a Catchment Management Strategy is in the process of being developed and that no surface water quality management strategy is actively being implemented. There are also no resource specific water quality related objectives for the Upper Breede River Area and members of the public and other stakeholders confirmed that their needs and expectations were not taken into account during decision making and the development of the water resource management strategy. Additionally, data collected suggests that there are no surface water quality management systems (i.e. integrated Water quality management plan, implementation plans, guidelines, systems and/or procedures and so forth) providing clear instructions or mandates regarding required management actions, responsibilities, resources available, and timeframes to

mitigate or remediate existing and future surface water quality related issues currently in place. In conclusion, the study found that the underlying reasons for the continuous impairment of water quality of the Dwars River through faecal contamination are due to the fact that there is no surface water quality management strategy, system or integrated water quality management plan currently in place designed to prevent, report, and counter faecal pollution along the Dwars River.

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DEDICATION

I dedicate this thesis to my wife Leana and my two children: Christopher and Connor McLean. May this work be an inspiration to you.

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ACRONYMS

BGCMA	**Breede-Gouritz Catchment Management Agency**
BOCMA	**Breede-Overberg Catchment Management Agency**
BRIP	**Breede River Improvement Project**
CMA	**Catchment Management Agency**
CMS	**Catchment Management Strategy**
CSO	**Combined Sewer Overflows**
CPUT	**Cape Peninsula University of Technology**
CWDM	**Cape Winelands District Municipality**
DWAF	**Department of Water Affairs and Forestry**
DWS	**Department of Water and Sanitation**
FIB	**Faecal Indicator Bacteria**
GLOBALG.A. P	**Global Good Agricultural Practice**
IWRM	**Integrated Water Resource Management**
IWRMS	**Integrated Water Resource Management Strategy**
NMMP	**National Microbial Monitoring Programme**
NWSMP	**National Water and Sanitation Master Plan**
PPECB	**Perishable Products Export Control Board**
RQO	**Resource Quality Objectives**
SAWQG	**South African Water Quality Guidelines**
UBCMA	**Upper Breede Catchment Management Area**
WHO	**World Health Organisation**
WMA	**Water Management Area**
WUA	**Water User Association**
WQM	**Water Quality Management**
WWTW	**Wastewater Treatment Works**

CHAPTER ONE
GENERAL INTRODUCTION

1.1. Introduction

Freshwater flowing across the earth’s surface is central to human existence and is of major environmental, biological, and ecological importance given its influential role in “agriculture, industry, transport, energy, and health” (Mutamba, 2019:47). Previous and current research suggests that changing environments and growing populations pose significant challenges to freshwater supply and availability worldwide (Duan et al., 2019). South Africa's available surface water resources are virtually fully utilised (DWS, 2017; Edokpayi et al, 2017) and the fact that the “pollution of South Africa’s rivers is at an unacceptable level” (DWS, 2020:1) places these resources “under immense strain” (Dallas and Rivers-Moore, 2014:5). Considering the current unsustainable withdrawal rates, the growing demand for freshwater, restrictions on supply, lack of reliable runoff, the constant contamination and substandard quality of available water resources and the fact that South Africa is deemed “a water-scarce country” (Donnenfeld et al., 2018:2), it can be said that surface water is one of the severely limited natural resources in South Africa (Midgley et al., 1994).

1.2. Background to the Research Problem

The Dwars River meanders through the centre of Ceres, the administrative centre and largest town of the Witzenberg Local Municipality in the Western Cape, and eventually merges with the Titus River to form the Breede River. The importance of the Dwars River is no different from other surface water resources in South Africa given the fact that it plays a life-sustaining role in the lives of the Witzenberg Community. Ceres is not only synonymous with the fruit juice of the same name, but is an important agricultural town surrounded by export-orientated fruit farmers as well as a popular holiday destination (DWS, 2019). The town is situated on a fertile plain and is one of the country's most important deciduous fruit growing and wine producing centres (DWAF, 2011). Intensive agricultural areas are located along the Dwars River’s course with fruit and vegetable production being key economic activities within the area. Fruit farming contributes to more than 50% to the Gross Farming Income in South Africa and Ceres is one of the major fruit growing areas in the Breede Overberg region. Agriculture not only forms the backbone of the local economy, the Witzenberg Valley also relies on the said industry to feed its people. The Dwars River plays a significant part in the local economy and water is abstracted from different parts of the Dwars River in unmeasured quantities for irrigational purposes as well as for domestic and industrial purposes (DWAF, 2011). The river is also utilised for recreational purposes and plays an important role in the area’s tourism industry (DWAF, 2011).

The Dwars River can be found approximately 150 km to the north-east of Cape Town in the region of the Upper Breede Catchment Management Area (UBCMA). The Upper Breede and Central Breede Catchment Management Areas fall under the jurisdiction of the Cape Winelands District Municipality (CWDM) and as a result these areas were included in the 2008 to 2010 Breede River Improvement Project (BRIP). The main objectives of the BRIP were to determine the microbiological and chemical status of the portion of the Breede River and its tributaries that fall within the jurisdiction of the CWDM, identify the main sources of water pollution, establish the extent of contamination, and to establish corrective measures to improve the existing water quality (CWDM, 2010:8).

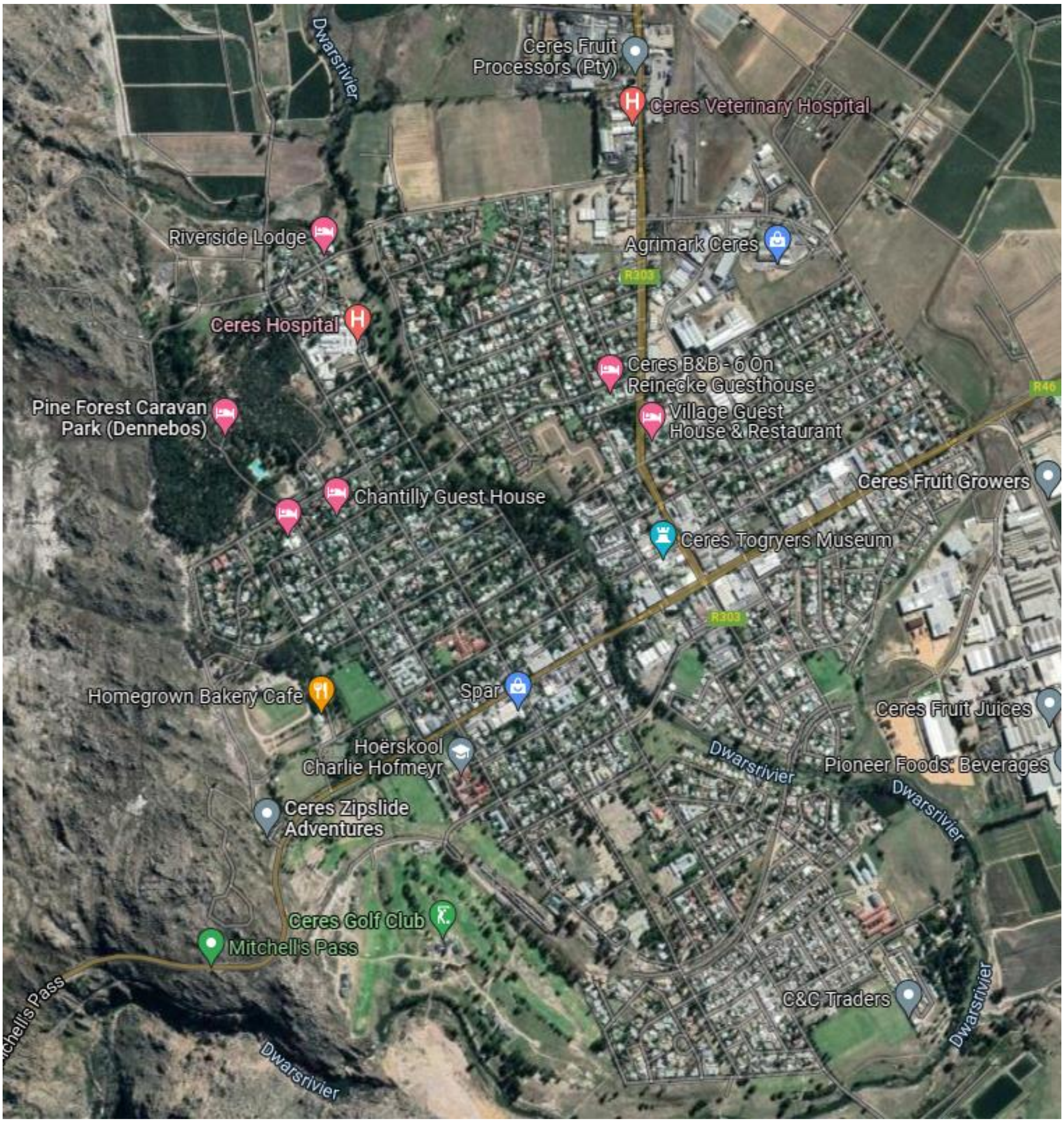

Figure 1.1: Location of the Dwars River (Google, 2019)

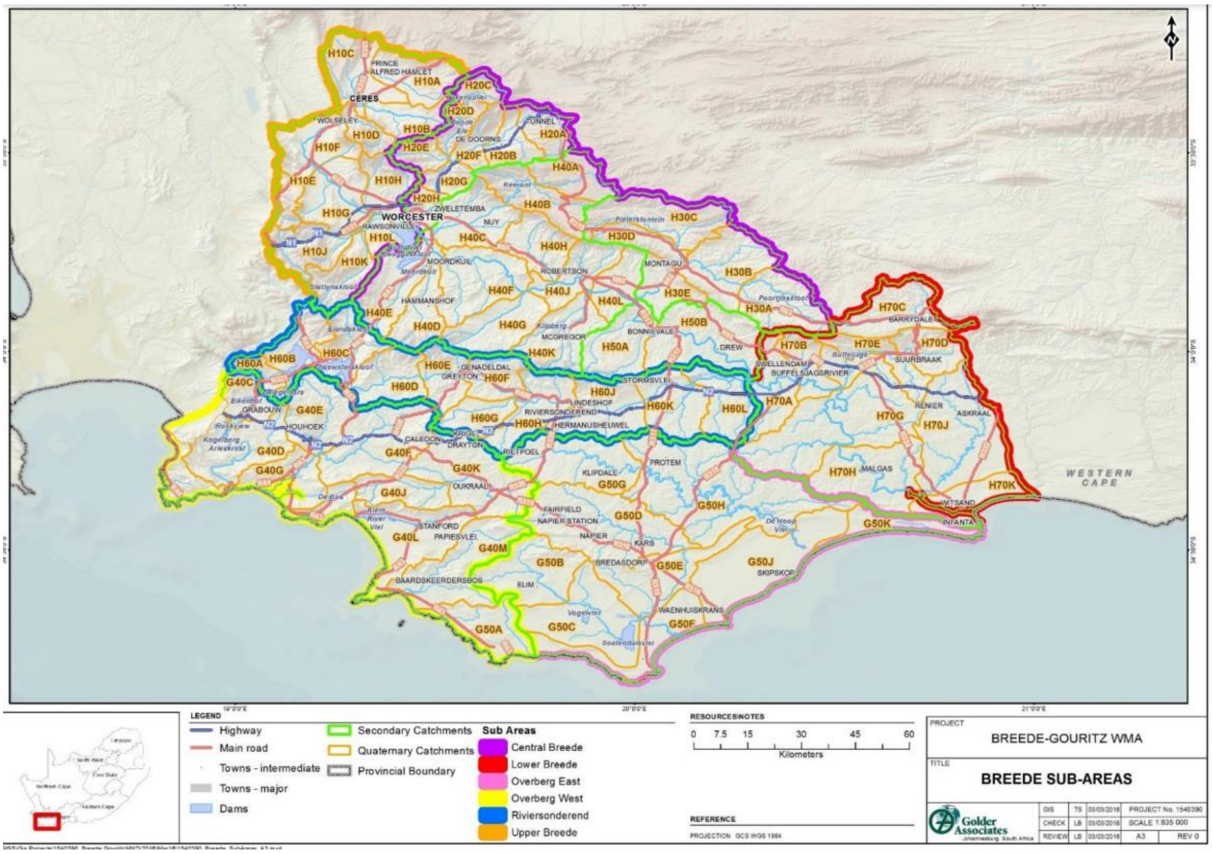

Figure 1.2: Breede – Gouritz Catchment Sub Areas (BGCMA, 2017)

Figure 1.3: Cape Winelands District Municipality (CWDM, 2017)

To meet the BRIP objectives along the Dwars River, three predetermined monitoring points, each with its own geospatial coordinates, were used as locations for data collection to provide data regarding the microbiological water quality status of the river. The Breede River Improvement Project commenced in 2007/2008 and the final report, compiled by the CWDM officials, was made available to the Department of Water Affairs and Forestry (DWAF) in 2010. Following the discontinuation of the BRIP, the Breede-Gouritz Catchment Management Agency (formerly known as the Breede – Overberg Catchment Management Agency) took over the assessment of the Dwars River's water quality from the CWDM (CWDM, 2010:10) and subsequently initiated the Breede River Water Quality Monitoring Programme. The purpose of the Breede River Water Quality Monitoring Programme was to provide the information needed to assess and manage the water quality of the Breede River and its tributaries and to identify possible signs of deterioration and pollution (Anon, 2012a:5).

Based on the water quality assessments performed as part of the BRIP, it was explicitly reported that the microbiological water quality of the water which the Dwars River carries is alarmingly poor and cannot be used for domestic purposes (CWDM, 2010:19). The river's sample analyses report indicated that its quality did not conform to the recommended minimum requirements specified by the South African National Standards (SANS), the World Health Organisation, the Perishable Products Export Control Board (PPECB), Global Good Agricultural Practice (GLOBALG.A.P), and the South African Water Quality Guidelines (SAWQG) for drinking water quality, livestock watering, recreational use, and agricultural use (CWDM, 2010:19). According to the BRIP's microbiological compliance rates for the water samples collected from the Dwars River's water between 2008 and 2011 for use on irrigation equipment amounted to 89.66%, 68.6% for irrigation of fruit trees and grapes, 60.92% for irrigation of fruit for export, 60.5% for livestock watering purposes, 37.66% for recreational use, 33% for livestock watering, 1.16% for irrigational purposes, and 0.58% for domestic purposes or drinking water (CWDM, 2010:19)[1]. For the CWDM this was a major concern since faecal pollution from humans, livestock, and wild animals could contain various disease-causing pathogens.

Further research conducted by the CWDM and DWA (Department of Water Affairs) as well as current information provided by BGCMA, has shown that the situation pertaining to microbiological water quality remains unchanged (BGCMA, 2019). According to the water quality related information provided by the BGCMA collected during routine monitoring at predetermined sampling points, Faecal Indicator Bacteria (FIB) in the Dwars River over the

[1] Water samples were collected and analysed by an accredited laboratory as part of BRIP. Data procured through analyses was compared to microbiological requirements listed in SANS and Water Quality Guidelines to establish compliance of samples taken. Compliance rates were expressed in percentage (percentage of samples collected and analised that conformed to microbiological requirements).

past years reached high counts of 18900 faecal streptococci per 100 ml and 10200 faecal coliform bacteria per 100 ml on one occasion (BOCMA, 2014; BGCMA, 2019). According to the South African Water Quality Guidelines for Agricultural Water Use for example, acceptable levels of the aforesaid FIB when used as irrigation water is 1 to a 1000 counts/100ml. The guideline further states that utilising surface water, with FIB counts equal to or exceeding these levels, for irrigation purposes “will result in the transmission of human pathogens” (DWAF, 1996b:66). The South African Water Quality Guidelines for Recreational Water Use suggests that full recreational contact with surface waters indicating faecal coliform counts of > 2 000 per 100ml will coincide with a the risk of contracting gastrointestinal illness. “As the faecal coliform count increases above this limit, the risk of contracting gastrointestinal illness increases. The volume of water ingested in order to cause adverse effects decreases as the faecal coliform density increases carry an increasing risk of gastrointestinal illness” (DWAF, 1996a:46).

1.3. Statement of the Research Problem

Surface water quality monitoring is continuously being conducted by the BGCMA and CWDM in the Dwars River which is located in the Upper Breede River Catchment Area in the Western Cape (BGCMA, 2018; BGCMA, 2019). Water Quality Analyses reports originating from routine monitoring indicate that pollutants of a faecal nature, and possible disease-causing bacteria, are constantly entering into the Dwars River through multiple sources rendering the river unusable from a domestic, industrial, and agricultural use perspective (CWDM, 2010; BGCMA, 2019). The information presented in these reports are utilised by surface water resource managers and water quality control officers to establish whether the Dwars River meets the required criteria as prescribed in relevant guidelines, standards, and regulations and to devise suitable corrective actions in the event of an incident by identifying current faecal pollution trends and spikes.

Regardless of the reports and information made available to relevant authorities, the condition of the Dwars River with regards to faecal pollution remains unchanged since 2008 (BGCMA, 2019). This is a “major concern” since both the quantity and quality of available freshwater plays a vital role in “export-orientated irrigated agriculture and the tourism industry” (Anon, 2012a:5; Cullis et al., 2018:46).

The public has also expressed their concern regarding the Dwars River’s heavily polluted water (Rivett, 2012; Kruger, 2016) and the river has subsequently been labelled as the “ugly duckling” of the Cape Rivers (Reinders, 2012) due to its bad reputation. People have even gone so far as to warn others from entering the river (Playak, 2009) and some have publically declared that they have fallen ill after spending time in the watercourse (Chaplin, 2013).

The presence of FIB in the Dwars River signifies faecal pollution and the possible presence of pathogenic microorganisms. The report compiled by the CWDM and the datasheets provided by the BGCMA clearly indicates that these bacteria are constantly present at high levels in the Dwars River (CWDM, 2010, BGCMA, 2019). Surface water sources, such as the Dwars River, serve as an inert carrier of such pathogenic microorganisms and according to the BGCMA, "the consequences of not monitoring and addressing this water quality challenge are profound given that about half of the deciduous fruit and table grapes cultivated in the Upper Breede River area are exported from South Africa and about a quarter goes into the higher end domestic market" (BOCMA, 2010; Verlicchi et al., 2020). Setting the economic aspect aside, the significance of using contaminated surface water containing microbial pollutants and specific pathogens, such as *Escherichia coli*, is that it can bring about diarrhoea in humans and animals and may even give rise to an outbreak of water-related diseases such as typhoid fever, cholera, shigellosis, hepatitis, jaundice fever, and amoebiasis (Odonkor et al., 2020). Exposure to disease causing pathogens may also result in the death of children and those that are immunocompromised (Odonkor et al., 2020). Therefore, faecal pollution of Dwars River's water can have serious consequences, placing members of the Witzenberg community and those individuals who are directly or indirectly exposed to its water and disease-causing organisms at risk of contracting a water-related disease.

In South Africa, water quality standards as well as water quality management strategies (WQMS) have been established in response to the surface water pollution management orientated challenges and water quality management objectives have been implemented successfully in certain catchment areas. In November 2007, the BOCMA (now known as BGCMA) became the second operational Catchment Management Agency (CMA) in South Africa. BOCMA was established in line with the conditions of the National Water Act, 1998 (Act No. 36 of 1998) (NWA) and was entrusted with water resource and quality management responsibilities within its jurisdiction for the benefit of everyone living in the area (BOCMA, 2013:7). One of the responsibilities of the BGCMA is water resource protection through the continued assessment of water quality and to simultaneously devise strategies to protect water resources under their control (BOCMA, 2013:14). In other words, the BGCMA was formed as part of an initiative with the intention of monitoring and subsequently improving the current situation surrounding the quality of water resources such as the Dwars River through the development and implementation of a Catchment Management Strategy (CMS).

Generally, in the event of a water quality related incident, the BGCMA's officials would receive a report related to the water quality issue, establish the origin of the specific problem, liaise with the responsible party or polluter, and analyse relevant regulations and standards governing the aspects of the situation. Corrective actions would then be developed and once all affected parties accept the conditions of the way forward, the BGCMA's officials will then monitor post-corrective action compliance and ensure that corrective action has been taken and that legislation is being adhered to (Anon, 2010:2).

Witzenberg Municipality, responsible for basic service delivery within the area, responded to the pollution of surface water located within their municipal boundaries through the development of relevant management strategies as well as the enabling of necessary projects to counter any challenges. The upgrading of the wastewater treatment works, monitoring industrial effluent, establishing pollution control measures, engaging with Cape Nature daily, implementing applicable legislation, launching educational and awareness campaigns, and exploring alternative funding channels/sources are all examples of proposed preventative and control measures designed to manage water quality and prevent river pollution (Witzenberg Municipality, 2014:115).

Despite the efforts of Witzenberg Municipality and the Department of Water and Sanitation (DWS) acting through the BGCMA, the wastewater treatment works (WWTW) being upgraded, the poor stormwater and sewerage system issues being discussed at various stakeholder engagements, and the overloading and lack of maintenance of sewage systems being identified as early as 2007, the microbiological water quality of the Dwars River remains unchanged (BGCMA, 2019). Numerous possible causes for the constant influx of faecal matter into the Dwars River have been identified. Examples of these include the absence of suitable and effective WQMS, water pollution cases being left unresolved, overflowing of upstream sewerage pump stations, informal farming activities, and pollution from households along the river (CWDM, 2010; WWF, 2015, WWF,2016; WCG, 2018). The current reactive approach taken by water resource managers and water quality officers in the areas has not improved the condition or quality of the Dwars River's water or mitigates the risk of the community's exposure to pathogenic organisms (BGCMA, 2019). To improve the current situation and to develop suitable strategies related to water quality management (WQM), the focus of water quality management institutions and managers needs to shift from merely monitoring the surface water of the Dwars River and subsequently attending to any irregularities to taking a holistic, proactive, and multi-faceted approach regarding the management of the river as a freshwater resource. This study will attempt to determine the importance of the Dwars River as a source of fresh water , gain insight into the microbiological quality of Dwars River and its Tributaries, determine the reasons for the water quality of the Dwars River continuously being impaired through faecal contamination, what is the current surface WQMS designed to prevent, report, and counter faecal pollution along the Dwars River, determine the efficacy of the current microbiological sampling programs implemented, and whether or not the current surface WQMS designed to prevent, report, and counter faecal pollution along the Dwars River are suitable and effective. Further to this, this study will attempt to determine what factors can improve the effectiveness of the current Dwars River water quality management practices to potentially improve the current strategies implemented to manage and/or prevent the continuous introduction of faecal matter into the Dwars River at levels far greater than the prescribed limits listed in relevant guidelines and standards.

1.4. Significance of the Study

The Dwars River's water is abstracted in unmeasured quantities for domestic, industrial, and agricultural use. The river is also used for recreational purposes and plays an important role in the area's tourism industry. Apart from fishing and swimming the Dwars River also attracts canoe enthusiasts. Therefore, the information will be used to assist DWS, BGCMA, CWDM, and Witzenberg Municipality with the following:

- Identify WQM inadequacies and the reasons why pollutants of a faecal nature are continuously entering the water carried by the Dwars River.
- Recommend corrective measures that might potentially improve existing WQMS.
- Assist with the development of more effective and proactive WQMS designed to improve the current status of the microbiological quality of the Dwars River and reduce the potential public health risk.
- The research will be available as an instrument to be used in further research.

1.5. Research Questions

- Main research questions:
  - What are the reasons, from a WQM perspective, for the water quality of the Dwars River continuously being impaired through faecal contamination?
  - What WQM factors can improve the effectiveness of the current Dwars River water quality management practices?
- Sub research questions
  - Is there a current surface WQMS designed to prevent, report, and counter faecal pollution along the Dwars River?
  - Are the current microbiological sampling programmes implemented along the Dwars River effective in assisting with the prevention of faecal contamination?
  - Are the current surface WQMS designed to prevent, report, and counter faecal pollution along the Dwars River suitable and effective?

1.6. Aims and Objectives

The main objective is to conduct a thorough investigation to determine why the water quality of the Dwars River is continuously being impaired through faecal contamination. To achieve this objective, the following needs to be realised:

- Determine the importance of the Dwars River and identify the various land uses (agriculture, industrial, residential and so forth) in the vicinity of the study area to determine the impact faecal pollution of the Dwars River might have.
- Analyse current surface water quality management system(s) in place to prevent the faecal pollution of the Dwars River.
- Evaluate the existing surface water quality management strategies aimed at preventing faecal pollution of the Dwars River.
- Examine water quality monitoring/sampling methodologies employed and their efficacy towards the prevention of faecal pollution in the Dwars River.
- Identify factors inhibiting and contributing to the effective implementation of the WQMS.
- Provide appropriate recommendations to water resource managers, institutions, scientists, decision-makers, and the public concerning the WQM of the Dwars River's.

1.7. Delineation of the Research

The study will be conducted along the Dwars River in the Western Cape (Figure 7). The study site selected ranges from Point A (33°20'53.16"S, 19°17'55.20"E) situated in a South-westerly direction from Ceres towards Cape Town to Point B (33°22'58.77"S, 19°18'38.49"E) situated in a North-easterly direction from Ceres towards Prince Alfred Hamlet. The reasons behind the selection of the study area are based on the following:

- The surface water quality is currently being monitored by BGCMA within the demarcated section of the Dwars River (See Figure 3.1).
- Water monitoring results indicate that the surface water located between Point A and Point B is continuously being contaminated by pollutants of a faecal nature.
- The area mentioned above falls within BGCMA's as well as Witzenberg and the CWDM's jurisdiction. All three institutions have WQM duties to a certain degree.
- The demarcated section of the Dwars River will be included as a surface water source in BGCMA's water resource management strategy.

1.8. Thesis Outline

The thesis outline, which aims to provide further structure to the research and to facilitate the location of relevant information is discussed in this section. The research comprises of five chapters presented as follows:

- **Chapter 1**: **General introduction** attempted to provide an overview of the research project, to state the purpose of the study and to explain the study's significance.

- **Chapter 2: Literature review** describes and analyses previous research or literature relevant to the research goals of this thesis. The literature focuses on concepts and variables which are contained in the research questions, aims and objectives of the study.

- **Chapter 3**: **Research methodology** outlines the theoretical framework and research methods (i.e. the methods used for data collection, analysis and interpretation) followed to provide an answer to the research questions and to address the research problem and the abovementioned research objectives of this research study.

- **Chapter 4: Results and discussion** provides details of the data collected by the researcher with the described information gathering tools for the purpose of this research study and provides an interpretation of the findings.

- **Chapter 5: Conclusion and recommendations** concludes the entire research study by highlighting and discussing the main findings regarding the surface water quality management of the Dwars River made during the data collection process of this study. Furthermore, this chapter highlights recommendations for interventions. and future research.

In conclusion, this chapter has provided the background and overview of the research study, signifies the importance of the study through the research problem, research questions and objectives as well as the significance of the research. Given the outline of this thesis, the following chapter will aim to provide background information on the study topic, become acquainted with work published with regards to surface WQM, the effectiveness of existing WQMS and systems as well as factors that affect WQM beneficially and detrimentally with and to provide the building stones for a conceptual framework for the study.

CHAPTER TWO
LITERATURE REVIEW

2.1. Introduction

Water quality management (WQM) is a process implemented to accommodate the coordination and planning of water, land, and environmental resources (Louckes et al., 2017). The availability, quality, consumption or use of water sources (including surface water sources) and the steps taken to ensure its sustainability forms part of the WQM process itself and the development thereof. Previous research suggests that surface water sources are continuously being polluted and that various factors, including substandard or the lack of WQM, contributes to the worldwide phenomenon (Genthe et al, 2013; Verlicchi et al., 2020).

Research studies have been conducted focussing on the pollution of surface water and the associated impacts on the environment and public health. Relatively few studies specifically focus on how ineffective and/or lack of proper WQM contributes to surface water quality deterioration. To bridge this gap in the research, the research questions within the ambit of this study are:

- Main research questions:
  - What are the reasons, from a WQM perspective, for the water quality of the Dwars River continuously being impaired through faecal contamination?
  - What WQM factors can improve the effectiveness of the current Dwars River water quality management practices?
- Sub research questions
  - Is there a current surface WQMS designed to prevent, report, and counter faecal pollution along the Dwars River?
  - Are the current microbiological sampling programmes implemented along the Dwars River effective in assisting with the prevention of faecal contamination?
  - Are the current surface WQMS designed to prevent, report, and counter faecal pollution along the Dwars River suitable and effective?

This literature review was based on a concept centric approach in which the variables and constructs contained in the research questions listed above are used to build the literature review (Webster and Watson, 2002). This literature review will "(a) methodologically analyse and describe water quality literature, (b) provide a firm foundation to a research topic, (c) provide a firm foundation to the selection of research methodology, and (d) demonstrate that the proposed research contributes something new to the overall body of knowledge or advances in the research field's knowledge base" (Levy and Ellis, 2006:182). Variables and concepts focussed on during the literature review will include:

- Faecal pollution of surface water sources.
- WQMS and systems.
- Factors inhibiting the effectiveness of surface WQMS and systems.
- Factors enhancing the effectiveness of surface WQMS and systems.
- Water quality monitoring/sampling methodologies.
- Water quality management practices.

Considering these concepts and variables contained in the research question, the purpose of this literature review is therefore to provide background information on the study topic, become acquainted with work published with regards to surface WQM, the effectiveness of existing WQMS and systems as well as factors that affect WQM beneficially and detrimentally with the intention of realising the research objectives set out in Chapter 1 and to provide the building stones for a conceptual framework for the study. To achieve the objectives, the first part of the literature review identifies and discusses current water quality management systems and strategies applied to surface water sources. The second part discusses the effectiveness of existing surface WQMS and systems. The final part provides information regarding factors that inhibit or enhance the effectiveness of current surface water WQMS and systems.

2.2. Faecal Pollution of Surface Water Sources

Freshwater is an indispensable and finite natural resource that is essential for human existence (e.g. drinking purposes and food production), wellbeing of communities, maintaining the integrity of the environment, and for economic development and its "availability is one of the major problems facing the world" (Edokpayi et al., 2016; Walker et al.,2019). Further to this, it has been established that surface water plays an essential role in supporting productive human activities such as agriculture, energy and industrial production and processing, sanitation, transportation, recreation, and tourism (Nurul-Ruhayu et al., 2015; Walker et al.,2019). In fact, the sustainable protection of surface waters as freshwater resources is a policy goal worldwide and one of the United Nations Sustainable Development Goals (Derx et al., 2016). Unfortunately, as important as surface water is, present-day accessible sources do not guarantee adequate supply to all users due to a variety of factors influencing or impacting on its quality (Afroz et al., 2014). One of these factors includes the continuous influx of pollutants into surface water systems (Raji et al., 2015; Verlicchi et al., 2020).

Previous and contemporary surface water pollution orientated research has proven that the persistent pollution of surface water bodies is most certainly a reality and deemed a serious problem in both developed and developing countries (Afroz et al., 2014; Ngoc et al., 2019).

Data collected suggests that pollutants deteriorate the quality of ambient water bodies and impacts negatively (refer to Table 2.1) on the sustainability of these sources rendering it unsuitable for domestic and industrial use, irrigation, and aquatic life (Genthe et al, 2013; Raji et al., 2015; Paruch et al., 2019). Essentially, as surface waters become more and more polluted due to the constant inflow of faecal matter it becomes less attractive to be exploited as a resource (Afroz et al., 2014; Paruch et al., 2019). Therefore, it has been put forward that faecal pollution of surface water systems exacerbates existing complications associated with the quality of surface waters by increasing the amount of pressure on an already over utilised and limited resource (Naidoo and Olaniran, 2013; Dantas et al., 2020). More importantly however is that researchers envisage that the persistent release of pollutants of a faecal nature in surface waters will continue to influence water quality into the future with current reports indicating an annual deterioration of water quality (Afroz et al., 2014; Hogan, 2014).

Table 2.1: Impact of faecal pollution of surface water on various water uses (Edokpayi, et al., 2017; Cullis et al, 2018; Paruch et al, 2019)

Water Pollution Category	**Water Use**	**Impacts**
Faecal Pollution	Aquatic ecosystems	Eutrophication Harmful algal blooms Reduces the diversity of the aquatic microbial community Community shifts Fish mortality Physiological and behavioural changes
	Agriculture	Decline in international exports Decrease in production value Economic/financial loss Job security Loss of income Food insecurity Exposure to pathogenic organisms Illness/Disease/Death
	Recreational	Exposure to pathogenic organisms Illness/Disease/Death Tourism Job security Loss of income Economic/financial loss
	Domestic	Exposure to pathogenic organisms Illness/Disease/Death Indirect costs (time lost at work etc.) Declining living standard Social well-being Increased public health costs
	Industrial	Economy/financial loss Increased treatment costs Job security Loss of income Food insecurity Negative economic growth

As stated above, faecal pollution of surface waters is not a recent environmental issue and is predominantly linked to developing countries. Statistically, the regions most affected by faecal contamination are Africa and South-East Asia. The faecal contamination of surface waters is especially prevalent in urban, peri-urban, and rural areas within these regions due to high population densities and where water supply and treatment infrastructure is often informal and therefore unregulated (Rochelle-Newall et al., 2015; Verlicchi et al., 2020). Results of previous studies indicate that the surface water courses in populous countries have become surface level cesspools due to the accumulation of faecal contamination (Bain et al., 2014). In Malaysia for example, an estimated load of 945 tonnes of domestic treated and partially treated faecal matter is discharged into the countries' surface water systems on a daily basis (Afroz et al., 2014). Surface water bodies such as the Al Shabab and Al Arbaeen coastal inlets along the eastern Red Sea coast is subjected to 100,000.00 m^3 of raw and semi-treated faecal matter a day (Sayed et al., 2013). The faecal pollution of surface water systems is also a serious challenge in developed countries. In the United States for instance, a mixture of raw sewage and storm water estimated at a value of 785.4 GL is released into U.S. receiving waters each year (Youjun, 2015).

There are numerous sources that can be linked to the introduction of faecal pollution into surface waters. With the aim of simplifying source determination and differentiating between human and agricultural sources, surface water pollution can be categorised into two super groups. These super groups or categories are known point source run-off and non-point source run-off (Hogan, 2014).

Point source pollution can be described as a discharge to a body of water at a distinct location. Regarding faecal contamination, a point source is considered as a single and easily identifiable point of pollution which typically has a continuous flow of potentially disease-causing bacteria (Jiake et al., 2011:50-51). The characteristics of a point source allows the collection, treatment or controlling of point source discharges to seem uncomplicated compared to the management of diffuse or non-point sources (Osei-Twumasi and Falconer, 2014). Nevertheless, constant and increasing levels of faecal pollution of surface waters associated with point source discharges is a growing concern and untreated municipal wastewater has been identified as the most hazardous to water ecosystems due to the large amounts of nutrients and organics content (Parris, 2011; Collins et al. 2018). The main reason being that inputs of indicator bacteria from point sources often exceed inputs from non-point sources (Rusiñol et al., 2014). Examples of potential point source contamination associated with the faecal pollution of surface water sources include wastewater treatment plant effluent, industrial plant (including hospitals and so forth) wastewater discharge, point source run-off from agricultural undertakings, illicit sewer connections, combined sewer overflows, sanitary sewer overflows, discharging untreated sewage water directly into river systems, discernible municipal stormwater system discharges to surface waters and effluent discharge from a wide variety of food production activities including wineries, abattoirs/ slaughterhouses and dairy farms (Quattara et al., 2014; Smolders et al., 2015).

In contrast to point source pollution, the term non-point source is used to describe water pollution that affects a body of water from diffuse and intermittent sources that are often rainfall driven (Jiake et al., 2011:50). Non-point-source pollution varies greatly at multiple spatial and temporal scales (Chen et al., 2014). As a result, it has proven challenging and expensive to identify, isolate and control non-point sources (Lai et al., 2011; Tang et al., 2011; Verlicchi, 2020). Receiving waters are likely to be fouled by non-point sources of faecal pollution such as pollution from households (washing laundry, bathing, swimming and so forth) along river systems, exfiltration and overflowing of wastewater in sewerage networks of densely populated urban areas, defective or malfunctioning septic tank wastewater treatments systems, sewerage spills, unsustainable agricultural practices and polluted runoff originating from lawns and gardens, construction sites, logging areas, road and rail networks, parking lots and poor or lack of access to proper sanitation in informal settlements and the subsequent runoff from these settlements into the aquatic environment (Iloms et al, 2020; Osei-Twumasi and Falconer, 2014; Smolders et al., 2015, Zehra and Gulzar, 2018; Paruch et al., 2019). Access to safe sanitation is a growing challenge in informal settlements and approximately a quarter of people in urban areas of South Africa have less than basic sanitation (UNICEF, 2017). The aforesaid has been identified as "one of the biggest social issues of post-apartheid South Africa" and can be attributed to a variety of factors or barriers including space limitations, distance to facilities, lack of privacy, unsafe effluent discharge, inadequate cleanliness, security risks associated with using shared facilities, and so forth (DWS, 2016; Sinharoy et al., 2019).

Data gathered from previous research has made it clear that source and non-point sources of faecal pollution are a major cause of the impairment of surface waters in many countries and are regarded as serious and sometimes life-threatening issue.

Methods for source detection and regulation have been improved and have become advanced over time and origin recognition and understanding is essential in assessing potential health risks, remediating contaminated areas, and preventing future pollution (Santo Domingo et al., 2012; Holcomb and Stewart, 2020). An important focus point that requires significant attention is to answer the question as to why these point and non-point sources continue to pollute surface water bodies. To answer this question, one needs to investigate the underlying factors that cause and/or directly or indirectly contribute to the persistent faecal pollution surface water systems. There are numerous underlying factors associated with the faecal pollution of surface water, and if left unaddressed, the current situation is more than is likely to worsen in coming decades (Santo Domingo et al., 2012; Paruch et al., 2019).

One of the main causes or contributors to the faecal pollution of surface water systems is population growth. The world population has surpassed the 7.0 billion mark. According to the United Nations Water Global Annual Assessment of Sanitation and Drinking Water's (GLAAS) report there are already approximately 884 million people throughout the world that are currently lacking access to safe or improved water sources (Naidoo and Olaniran, 2013). Should the current global population growth rate continue at current projections, the world population could increase to 9.7 billion in 2050 (Guppy and Anderson, 2017; Roser, 2020). Water demand is projected to grow by 50% by 2030 and by 2050, more than half of the world's population will be living in water-stressed areas (WWAP, 2018). As population pressures increase across the globe, it is becoming increasingly apparent that the underperformance of and the operational constraints experienced by existing wastewater treatment plants are linked to rapid population growth (Teklehaimanot et al., 2015).

The discharge of raw sewage or poorly treated effluent originating from wastewater treatment plants is a widely renowned surface water quality challenge (Collins et al. 2018). This point source pollution can, as suggested in the paragraph above, be directly linked to higher volumes of wastewater generated due to rapid population growth, industrialisation and urbanisation causing the wastewater treatment plants to become overloaded beyond their capacity (Paruch et al., 2019). Population growth and the increase in production of sewage are synonymous. However, the development or upgrade of municipal sewage works do not coincide with the ever-growing human population resulting in overloading of existing works and pollution problems. The discharge of raw sewage into rivers is often seen as a short-term solution or coping mechanism for this shortfall. Over and above overloaded capacity issues of existing facilities, the malfunctioning of wastewater treatment plants can also be attributed to design weaknesses, improper operation and lack of maintenance and the upkeep of wastewater infrastructure. In addition to rapid population growth, industrialisation and urbanisation other underlying and often interconnected factors responsible for the failing state of wastewater treatment plants and affecting their effectiveness to treat wastewater adequately include improper planning, the lack of expertise and appointment of inadequately trained personnel, understaffing, lack of financial resources hampering the hiring of additional staff, substandard or non-existent management, ineffective preparedness and response procedures or protocols, lack of or infrequent final effluent quality and/or surface water quality compliance monitoring. In addition to the aforesaid, (Edokpayi, et al., 2017).

Also closely connected to rapid population growth is an increase in subserviced informal settlements and an ever-growing burden on unmaintained and ageing water and sewerage infrastructure. For example, sewer systems in older cities such as Boston in the United States of America, and the surrounding communities, commonly include Combined Sewer Overflows (CSO's), which are a result of combined sewer and stormwater systems. CSOs discharge into rivers when extreme rain events occur due to the fact that the volume of water exceeds system capacity. Situations such as these are further affected or exacerbated by the various government institutions' inability to fund large infrastructure investments with the intention of providing for newly required basic services or to maintain the existing facilities (Miller, 2016).

The abovementioned causes of faecal pollution entering surface water systems are only a few examples of many. These are real-time issues affecting communities and ecosystems on a global scale. Interventions are required involving the management surface water systems in a holistic way to protect the planet's limited freshwater resources and to protect human populations from exposure to harmful water-related pathogens. Central to an intervention such as this is forward planning with the intention and objective of preventing and/or adequately mitigating poor water quality and alleviating current faecal contamination related pressures exerted on surface waters. Additionally, the assessment of the current quality of ambient water bodies, the identification of controlled and uncontrolled point and non-point sources of pollution, the evaluation of underlying factors which contribute to contamination and the formulation of water quality related strategies, policies, systems, and action plans will be key components in achieving the said objective (Fukue et al., 2004).

2.3. Water Quality Management Strategies and Systems

The inability of surface water systems to meet the diverse needs for fresh water due to persistent pollution of freshwater resources and rapid population growth has, amongst other water quality related concerns, stimulated governments around the globe to develop and implement formal surface water quality related management strategies as well as to establish cooperative partnerships with relevant stakeholders to ascertain the systematic introduction of these strategies. The surface water quality management strategies differ in format and layout; however, the basis of these strategies consists of a combination of policies, systems, management techniques and systems designed to provide a framework for water resource management organisations and service providers to address water quality related issues, prevent and control water pollution, achieve resource specific objectives and subsequently ensure that the supply keeps up with the demand (DWS, 2017). Respective governments design their water quality management structures, policies, programmes, and systems in accordance with legislation, relevant guidance documents and so forth. Though established under widely different circumstances, these structures, systems, policies and so forth nonetheless confront similar challenges and establish water quality management targets and objectives in line with each country's needs (UN, 2019).

In South Africa, The National Water Act (Act 36 of 1998) forms the basis for water management at national and catchment level and provides conditions and guidance for the protection of water resources and the framework for the "establishment of mechanisms to ensure equitable and efficient water use" (Claasen, 2013:328). The said legislation lists the responsibilities of various role-players including the Minister and Director General, Catchment Management Agencies and Water User Associations (WUAs) at a sub-basin level and requires the "development and establishment of a National Water Resource Strategy" which provides an outline for the "protection, use, development, conservation, management and control of water resources" for the country as a whole (South Africa, 1988:17; South Africa, Department of Water Affairs, 2013:1). It also provides the "framework within which water bodies will be managed at regional or catchment level and in defined water management areas to ensure that "national water resources are protected, used, developed, conserved, managed and controlled in an efficient and sustainable" (South Africa, 1998:17; South Africa, Department of Water Affairs, 2013:1). According to Claasen (2013:327) "the National Water Act (Act 36 of 1998), *inter alia*, calls for the transition from a water management system based on riparian rights and administrative boundaries towards licensing of water use and catchment management. This includes the restructuring of the water management bodies of the DWS, the introduction of CMA at the intermediate level, and Water User Associations (WUA) at the local level respectively" (Claasen, 2013:327-330).

"In October 1999, the government of South Africa established 19 water management areas (WMA) and in 2012 reduced the 19 planned CMAs to nine" (Meissner and Funke, 2014:26). A CMA is responsible for certain water management functions which involve the "protection, use, development, conservation, management and control of the water resources in its water management area" (Meissner and Funke, 2014:26). The mandate of each CMA is to manage the water resources of the country across different types of uses by "managing stakeholder participation, empowerment, institutional development and coordination of associated activities" and "promoting community participation in water resource management within its water management area" (South Africa, 1998:92; BGCMA,2017:7). The functions of CMAs as described in the National Water Act, 1998 (Act No 36 of 1998) include the following:

- "Investigate and advise interested persons on the protection, use, development, conservation, management and control of the water resources in its water management area" (BGCMA, 2017:6).
- "Co-ordinate the related activities of water users and of the water management institutions within its water management area" (BGCMA, 2017:6).

- "Promote the co-ordination of its implementation with the implementation of any applicable development plan established in terms of the water services act, 1997 (Act 108 of 1997)" (BGCMA, 2017:6).
- "Promote community participation in the protection, use, development, conservation, management and control of the water resources in its water management area" (BGCMA, 2017:6).
- "Localised management activities related to local management, conservation, protection and monitoring activities" (BGCMA, 2017:6).
- "Registration and water use verification in support of improved water use authorisation processes and improved understanding of water resource availability" (BGCMA, 2017:6).
- "Various functions that CMA needs to undertake as set out in Annexure A of the Pricing Strategy, dated 28 July 2016" (BGCMA, 2017:6).
- "Institutional development with emphasis on water user association establishment processes" (BGCMA, 2017:6).

Over and above these functions, "the CMA is obliged to develop a CMS" that considers pertinent "existing policies and plans developed at a provincial and national level and inputs from various stakeholders" to meet the objectives of the National Water Act (Act 36 of 1998) and the National Water Resource Strategy (Herrfahrdt-Pähle, 2010:8-19; BGCMA, 2017:10). A CMS can be defined as "a plan that takes into account the needs and expectations of existing and potential water users to be rolled out to ensure "the protection, use, development, conservation, management and control of water resources" within a CMAs given WMA (South Africa, 1998). The main aim of a CMS is to "provide a clear approach and intent for managing water resources in the WMA". According to the National Water Act (Act 36 of 1998), the CMS must include "the strategies, objectives, plans, guidelines and procedures of the catchment management agency for the protection, use, development, conservation, management and control of water resources within its water management area" (South Africa, 1998). Based on the content of the National Water Act (Act 36 of 1998), it can be derived that the CMS subsequently gives effect to the role and functions of a CMA (Meissner et al., 2017). As mentioned previously, the CMA is responsible for developing and implementing, in collaboration with various institutions, a CMS which considers the "needs and expectations of existing and potential water users" and "enabling the public to participate" throughout the entire process (BGCMA, 2017:12). On completion of the document, CMS will be a stakeholder driven document that will be gazetted as a statutory document that is binding on the CMA and the Minister of Water and Sanitation (BGCMA, 2017). Existing CMSs consist of and make provision for a vision and mission statement linked to strategic measures and specific objectives designed to achieve the measure and specific actions to achieve the objectives. An example of one of BGCMA's management objectives for water quality management and pollution control listed under strategic measures is to "develop an integrated water quality management plan that will support improved compliance in municipal WWTW and collection systems, prioritise agricultural and industrial sources of pollution (specifically related to emerging contaminants) and identify specific management options for implementation" (BGCMA, 2017:45). With a water quality management plan in place, the development of an Integrated Water Resource Management Strategy (IWRMS) for the CMA could be considered as an additional measure to strengthen the existing water quality management programme.

The required legal framework of the National Water Act, (Act No 36 of 1988) and the CMS together with good governance and support from a management and institutional capacity is all that is needed to give effect to an IWRMS (Claasen, 2013). As stated by the United Nations (UN) Water, "integrated water resource management can be defined as a holistic framework for addressing different demands and pressures on water resources, across sectors and at different scales. At its core, integrated water resource management provides a framework to ensure that water resources are developed, managed, and used in an equitable, sustainable, and efficient manner" (UN, 2018). IWRM generally consists of an enabling environment of policies laws and plans, institutional arrangements for cross-sectoral and multilevel coordination, and stakeholder involvement, management instruments such as data collection and assessments and instruments for water allocation that facilitate better decisions as well as financing for water infrastructure and on-going costs of water resources management (UN, 2018). The successful implementation of IWRM, according Claasen, (2013:325) can potentially bring about the following benefits:

- "The IWQM Policy Provides overall Vision for Water Quality Management (WQM) in South Africa and Sets out the fundamental Norms, Values and Rules for WQM" (Claasen, 2013).
- "The IWQM Strategy sets out those strategic actions which are required to be undertaken to realise the vision and goals for water quality in South Africa. It articulates the broader process of IWQM and provides the prioritised strategic actions that need to take place over a short to medium term. - Describes the prioritised strategic actions that need to take place to achieve the Vision for WQM in South Africa. Is aligned with broader water and development strategies" (Claasen, 2013).
- "The Implementation Plan outlines the pragmatic approach to strategic implementation and clearly articulates roles and responsibilities, resource (financial and human capacity) requirements and linkages and dependencies between key activities and describes the roles, responsibilities, timeframes, and resource requirements to achieve the priority strategic actions" (Claasen, 2013).

- “The Monitoring and Evaluation Framework articulates the indicators to be monitored to determine the progress of the actions to be implemented and provide the foundation required to manage water quality adaptively. It also outlines the reporting structures and processes to be followed - Roll-out of Implementation Plan and Monitoring and Reporting on Implementation performance and effect the policy and strategy implementation has had on resource water quality” (Claasen, 2013).

In addition to the establishment of CMAs and the development of CMSs and IWRMS, the National Water and Sanitation Master Plan (NWSMP) and the National Microbial Monitoring Programme (NMMP) are also surface water quality administration tools used to manage limited water resources. The NWSMP has been developed by DWS and in partnership with all relevant and points out the priority actions required until 2030 and beyond. The idea behind the NWSMP is to develop and implement a co-ordinated approach to “information management, monitoring and evaluation to ensure the successful management and regulation of water resources” (South Africa, 2018:44). The NMMP on the other hand is implemented to monitor the extent of faecal contamination in surface waters and acts as a “central hub for microbial water quality data in South Africa” (Luyt, et al, 2012). The specific objectives of the NMMP are to:

- “Locate, assess and prioritise those areas in the country where potential health risks related to faecal pollution of water resources are highest” (DWAF, 2002:25)
- “Provide information on the status and trends in faecal pollution in the potential high-risk areas” (DWAF, 2002:25)
- “Provide information to help assess the potential health risk to humans associated with the possible use of faecal polluted water resources” (DWAF, 2002:25).
- “To help assess the effectiveness of measures to protect water resources against faecal pollution” (DWAF, 2002:25).

Based on the findings of existing research papers, CMSs, IWRMS, Water Quality Management Programmes and so forth established in response to the water quality challenges have been implemented successfully in certain catchment areas have the capability to contribute effectively to the sustainable management and addressing interrelated problems of surface water systems in areas that have no such management tools. Despite the existence of water quality orientated policies, strategies, plans and legislation that have been promulgated in South Africa and various other countries across the world, the receiving water bodies such as rivers and dams are persistently contaminated with pollutants of a faecal nature. Population growth increased economic activity and changes in land use are some of the major contributors to increased water pollution (Claassen, 2013;

UN, 2019). The section below will identify factors inhibiting the effectiveness of surface water quality management strategies and systems.

2.4. Factors Inhibiting the Effectiveness of Surface Water Quality Management Strategies and Systems

Achieving sustainable water quality management through an IWRM, CMS and so forth is high on the agenda for countries that have identified the need thereof. However, various anthropogenic problems or challenges and implementation barriers exist preventing the water quality orientated policies, strategies, plans, programmes, and legislation from being developed, implemented, and achieved. These water quality issues or challenges are inhibiting water quality management institutions' water quality management duties related to the implementation of effective mitigation measures that minimize human health risks associated with the pollution of their river systems (Smolders et al., 2015).

2.4.1 Stakeholder inclusion and public participation challenges

Addressing environmental orientated problems such as water quality deterioration often involves multiple stakeholders with different perspectives, capacities, and goals. This can be a significant hurdle as well as time consuming because different stakeholders have different needs, missions, and mandates (Meissner et al., 2017). In previous studies, water resource management institutions such as CMAs have indicated that it is not "always feasible to include all stakeholders in a water management area in the development of the CMS" and that the "sheer number of people that want to attend meetings can draw out the process unnecessarily and make it time-consuming" (Meissner et al., 2017:21).

2.4.2 Rapid population growth

Rapid population growth has not only led to the underperformance of, and the operational constraints experienced by existing wastewater treatment plants it will generate a growing demand for other water services, both natural and built as well. With a growing demand and little growth in the economy, government budgets will be constrained (BGCMA, 2017). An increase in population growth and urbanisation subsequently results in increases in growth of inadequately serviced densely populated settlements. According to the Department of Water Affair's Water Quality Management Strategy the "development of poorly serviced urban settlements" has an impact on water quality when the waste that is generated as part of the day-to-day activities "pollutes local streams, rivers and aquifers, resulting in wetland degradation" (DWS, 2017:13). Stormwater drainage in these settlements is often non-existent or non-functioning and runoff from rainfall washes sediment, faecal matter, and litter into "local and downstream water courses, as well as underlying groundwater resources", which also impacts the quality of the water resource (DWS, 2017:13).

2.4.3. Cross-sectoral coordination and cooperative governance

The absence of cross-sectoral coordination to balance needs and impacts across sectors and inadequate cooperative governance, overlapping mandates and discontinuous regulatory interfaces between the water quality management institutions and departments (including their provincial counterparts) responsible for managing and implementing the requirements of water quality orientated policies, strategies, plans, programmes, legislation and so forth (DWS,2017). Unclear or overlapping responsibilities is one of the Department of Water Affair's Water Quality Management Strategy's "five primary water quality challenges" and has the potential to result in reduced interagency cooperation from conflicting interests or policies also lead to "poor cooperative governance and inadequate cross-regulatory interfaces" (DWS, 2017:9-87).

2.4.4. Service delivery shortcomings

According to the DWS (DWS, 2017:24) "inadequate implementation of best management land-use practices and the dysfunction in relevant municipalities" along with poor urban land-use planning has resulted in, *inter alia*, an increase in wide-spread stormwater runoff from formalised an informal pervious and impervious urban areas or sewer overflows into stormwater conduits Dysfunctional municipalities and poor planning also result in the lack of proper sanitation facilities, inappropriate financial prioritisation, inadequate problem reporting/response systems, lack of pro-active infrastructure maintenance to name a few (DWS, 2017). Effective service delivery is also detrimentally affected in scenarios where towns and/or informal settlements either "lack formal infrastructure" or, where these are present, seldom work effectively or are "inadequate, overloaded or poorly managed" resulting in the "subsequent deterioration of water quality in our rivers, streams, dams, wetlands, estuaries and aquifers, the river systems" (DWS, 2017:6).

2.4.5. Infrastructure challenges

Although water and sanitation, as well as bulk services and sewerage infrastructure are available in most of the informal settlements, infrastructure challenges such as ageing infrastructure rapid and often unpredictable population and urban growth remain in terms of the ability to deliver adequate services to areas. Infrastructure challenges has the potential to result in or cause other significant challenges to existing Dams, canals, pipelines, tunnels, measuring facilities and other infrastructure (BOCMA, 2013). Other causes that lead to infrastructure challenges often include the lack of or inappropriate infrastructure, "inadequate financial and operational planning, inappropriate financial prioritisation, inadequate problem reporting/response systems, insufficient refurbishment, lack of pro-active infrastructure maintenance, lack of appropriate technically skilled personnel and financial shortfalls" (DWS, 2017:87). Substandard and malfunctioning sewerage infrastructure and the lack of maintenance thereof can be directly linked to onerous funding challenges. The DWS in South Africa "estimates an investment requirement of R1.4-billion each year, solely to maintain current infrastructure. It has been estimated that they will require an additional R63 billion per annum to upgrade and repair infrastructure to meet projected demands" (WWF, 2015).

2.4.6. Water quality monitoring and water quality related data challenges

The monitoring of the quality of water resources is critical to the effective and sustainable management of these resources and aids in determining the nature and extent of existing and emerging bacterial, chemical, and physical contamination of surface waters. Inadequate water quality monitoring and outdated water quality related information (Anon. 2012a) creates a gap in information regarding the geographical prevalence of pollutants resulting in problematic areas, sources and specific pollutants not being classed or deemed as a priority (DWS, 2016). Gaps created in water quality related data, existing research specifies that water quality compliance monitoring shortcomings in a compliance monitoring system include the insufficient translation of data into appropriate information, improper data capturing and dissemination, the infrequency, reduced number and limited spatial extent of monitoring points, shortage of staff to carry out monitoring, and the failure to monitor of new and emerging contaminants. Further challenges to water quality management includes the substandard or absence of a water quality monitoring strategy, the second-rate water quality monitoring approach adopted by water quality management institutions and their failure to operationalize, enforce, and monitor compliance with legislation, policies, and relevant standards (BGCMA, 2018).

2.4.7. Education and public awareness challenges

The Department of Water and Sanitation's Water Quality Management Swot Analysis has identified the "lack of public awareness regarding the importance of WQM" as an internal weakness (DWS, 2017:95). Further to this, according to the Department of Water and Sanitation, in order realise integrated water resource management, it is necessary to "enhance stakeholder's level of understanding on issues" regarding WQM such as demand management, water quality, supply planning and so forth (DWS, 2017:95). "Public awareness and information dissemination" are two concepts that have been identified as being crucial to reach overall "efficient water use and management" objectives (South Africa, 2013:99). Population pressure and land use activities in urban areas are deteriorating the health of rivers and there is a rapid decline in educational standards and a general lack of public awareness regarding importance of WQM and efficient water use. The continued lack of public awareness will contribute to surface water pollution and often leads to vandalism and theft of the sewerage infrastructure (UN, 2018).

The necessary knowledge and information are essential for drawing up and implementing effective water quality management policies, strategies, objectives, plans, programmes and so forth (Van der Merwe-Botha, 2009). From a secondary and tertiary educational standpoint, it has been pointed out that limited technical capacity exists in governments and that there is a lack of sufficient, suitably qualified, technically skilled and experienced staff in water quality management institutions resulting in weaknesses in authorisation of waste discharges, gaps in water quality and compliance monitoring, including failure to take effective action against polluters subsequently contributing to high levels of pollution from point and non-point sources, (Anon. 2012a).

2.4.8. Personnel issues

A significant shortage of human capacity or understaffing challenge exists within the water sector and has a significant effect on the planning for and/or implementation processes which affects the status of water management structures, and impedes the institution’s ability to plan, assess and monitor activities (Meissner et al.,2017). “In terms of financial and human resources, establishing water quality management governing bodies as well as the water quality related documentation can be a demanding and taxing process from a public administrative perspective (Meissner et al., 2017:22)”. Considering the human resources aspect, for instance, the water quality management strategy roll-out and implementation process can require a significant specialised staff compliment and consultations with employees from the various governing departments. Research suggests that water quality management institutions simply do not have enough resources to effectively act on their mandate and to reach water quality related objectives. A recent Municipal Demarcation study conducted by DWS indicated that only “72% of municipal posts were filled and only 76% of municipal organogram posts were budgeted for. Of the funded posts 33% were vacant. The average municipal manager remained in his post for three years and possessed only nine years relevant work experience, whilst the technical manager had eleven years’ experience. Half of the technical managers are under-qualified and unable to adequately manager their infrastructure. There is an on-going chronic shortage of municipal engineers and a high management turnover with 25% of management posts being vacant for more than 3 months. 1 in 6 managers exited the municipality in the course of the year” (DWS, 2017).

Lastly, in addition to a high turnover rate of appropriately skilled staff, repeated restructuring that hampers functionality and demoralises staff and the poor staff morale subsequently leading to decreasing productivity, the majority appointed officials involved in performing water quality related obligations show no signs of responsibility towards the environment or the local communities, no concern over surface water pollution, the prevention of further pollution, or the rehabilitation of the existing contaminated areas and accepts no accountability for their actions or the lack thereof (Anon. 2012a, DWS, 2017).

2.4.9. Management shortcomings

Water quality management institutions face a number of current and emerging issues related to effective water resource management most of which can be attributed to the use of preventive ("at-the-source") approaches over the corrective ("end-of-pipe") approaches is emphasised (DWS, 2017). The following are additional challenges faced by water quality management institutions limiting the effectiveness of the development and implementation of water quality related policies programmes and so forth:

- Lack of an integrated water quality management approach. In South Africa for example, "IWRM is not fully realized, and internal institutional problems delayed acceptance of IWRM by water managers, there is also insufficient cooperation between sectors and policies, and there are difficulties in the involvement of stakeholders in decision-making, all of which are hindering full IWRM implementation" (Claasen, 2013:329).
- No coordination is among all stakeholders exist and there is a lack of suitable supporting strategic and operational direction (DWS, 2017).
- There is a lack of firm guidance should in the form of operational procedures and technical guidelines to facilitate the implementation of a water quality management system.
- Inadequate measures to counter adverse land use and pollution incidents and water quality management institutions fail to implement corrective measures, and poor reaction time regarding faecal pollution incidents (Witzenberg Municipality, 2012a).
- Significant research gaps in water quality and limited uptake of innovation from Water Research Commission (WRC) and other academic and research institutions (DWS, 2017).
- The roles and responsibilities of relevant water quality management institutions in the have not been clearly defined.
- Lack of or substandard point and non-point source strategies, resource specific IWQM plans, and water quality management plans are outdated or unavailable.

2.4.10. Funding

The success of water quality management related activities "depends largely on the capacity, resources and expertise of the institutions concerned" (Van der Merwe-Botha, 2009:26). A shortage or lack of funding places water quality management institutions under immense pressure since their ability to address the water quality challenges of the country is restricted. (Van der Merwe-Botha, 2009). An insufficient budget allocation inhibits planning, human resource allocation ability, number of the spatial and technical extent of monitoring networks, reduces the economy of scale; increases the ultimate cost of service provision, places demand on water storage, and is a “major contributor to poverty and the national health burden” (Van der Merwe-Botha, 2009:25).

2.5. Water Quality Management Practices

Subsequent to the development and approval of resource directed water quality policies and water quality management strategies the next key components to be identified, formulated and implemented for the management of water quality are the water quality management practices and instruments that will ultimately convert policy into practice (DWS, 2015). Water quality management practices are *inter alia* designed with the protection of water sources and alleviating water quality problems associated with pollution in mind and include details regarding project information, relevant objectives, roles and responsibilities, resource requirements, control measures, record keeping and procedures for monitoring the implementation and progress of each water quality management instrument and forms a key component for converting policy into practice. Point and non-point water pollution control plans are examples of water quality management practices designed to reduce or eliminate pollutants introduced or discharged into surface water systems (RWQCB, 2013). Resource specific water pollution control instruments are documented in these pollution control plans specifically designed to target problem areas and resolve reoccurring pollution issues. Water management institutions have the challenging task of selecting which resource specific water quality management approach and instrument(s) will most be best suited to provide solutions to the contemporary water quality pollution orientated problems. Currently, there are four main categories of water pollution control instruments (See Figure 2.5) namely economic, social, technological, and legal measures (Himanshu et al., 2015).

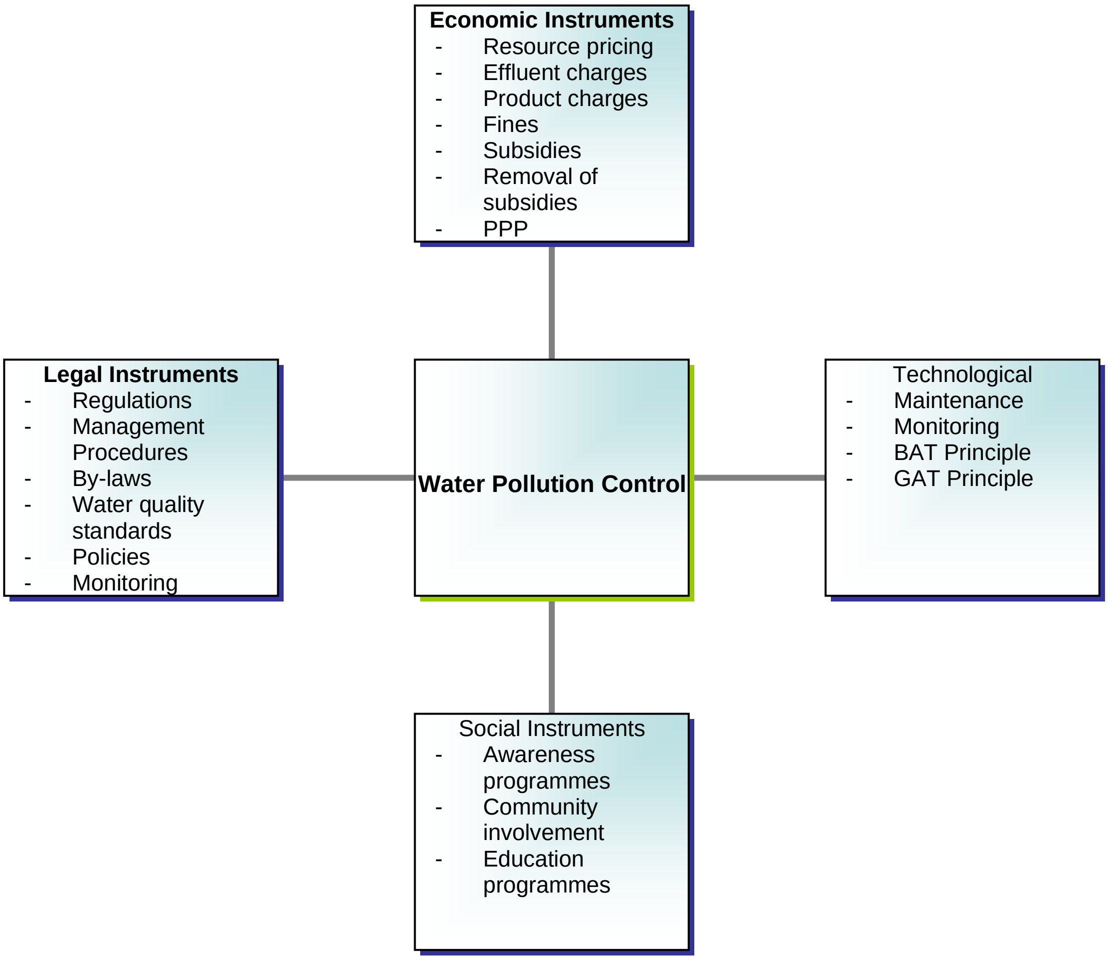

Figure 2.5: Water pollution control instruments (Larsen and Epson, 1997)

According to the Organisation for economic Co-operation and Development the implementation of economic instruments to combat water pollution as opposed to regulatory measures is "challenging" (OECD, 2017:8). "Economic instruments are increasingly employed by governments to improve or replace simple legal provisions or regulations" to ensure that water quality objectives are achieved by influencing behaviour and decision-making. The revenue gained as a result of the implementation of economic instruments can be utilised to "increase the cost effectiveness of pollution control" and ensuring that water quality objectives are met (OECD, 2017:8). Examples of economic instruments used to gradually improve the quality of water sources are:

- Demanding that existing and potential polluters pay for existing and future environmental pollution through taxes and fees (WRC, 2018).
- "Creating a market in which economic agents may buy or sell the "right" to cause pollution through tradable permits" (WRC, 2018:5).
- A disincentive and incentive system can be used as a regulatory support measure as a way of influencing the actions of individuals and corporations by penalising those who are in contravention of relevant legislation and standards through fines and

simultaneously providing incentives to industries or individuals for environmentally sound behaviour (FAO, 2015; WRC, 2018).

Educating communities and social groups on water pollution and associated environmental and public health impacts to promote sustainable development as well as encouraging pollution prevention is a social orientated water pollution prevention instrument employed by various water quality management bodies (Karataş et al., 2016). Techniques used to achieve desired results include:

- Relevant Water Quality Management Institutions provide formal and informal training and consultation on water pollution prevention legislation, standards, permits and social, economic, health and environmental problems associated with the pollution of water (Karataş et al., 2016).
- Encourage and ultimately assist members of the community to participate in water pollution related law enforcement and investigation into water pollution cases to provide social. According to Karataş (2016) “participants are to be allowed to be actively involved at all levels in working toward resolution of water quality and water pollution related problems” (Karataş et al., 2016:67).
- Provide opportunities for members of the community to develop skills that will enable them to identify, assess and solving water pollution related problems (Karataş et al., 2016).
- Launch awareness campaigns to manifest a feeling of concern about the environment and motivate social groups and individuals to actively participate in the improvement of current conditions and assist in attempts to conserve and protect the environment (Karataş et al., 2016).

Surface water pollution occurs when undesirable materials enter water or when the physical, chemical, or biological properties are altered and ultimately changes the quality of water (Alrumman et al., 2016). Water pollution in this regard can be controlled by a variety of methods and there are numerous technological and engineering measures and solutions available that could be adopted to enable Water Management Institutions and Governments to strengthen their existing water pollution prevention and control programmes (Liu et al., 2019). Examples of current technological and engineering instruments used to improve the quality of surface water are:

- Trapping, diversion and treatment of municipal wastewater through the construction of new and upgrading of existing wastewater treatment plants equipped with activated sludge bio filters, bioreactors and so forth, pumping stations and associated collection pipeline networks (Liu et al., 2019).

- Construction of new and/or the upgrading of existing industrial effluent infrastructure ultrafiltration, bio filters, dissolved air flotation and so forth (Liu et al., 2019);
- Designing and construction of artificial wetlands to trap and treat urban runoff (Liu et al., 2019).
- “Anaerobic lagoon treatment, which makes use of highly loaded lakes creating anaerobic conditions” (Inyinbor et al., 2018:39).
- Decentralised wastewater treatment systems as a treatment process where water and wastewater treatment plants are located at the site of water supply and/or demand.

Water quality standards, legislation, conditions (permits and so forth) and guidelines and regulatory systems have been published and incorporated by various Water Management Institutions, authorities, agencies, and Governments with the purpose of protecting human health and aquatic life by defining the “maximum allowable concentrations” of water pollution by various pollutants and simultaneously creating the legal framework for water pollution related litigation (Inyinbor et al., 2018).

2.6. Water Quality Monitoring/Sampling Methodologies

Water quality can be defined as “the chemical, physical and biological characteristics of water usually in respect to its suitability for a designated use” (Roy, 2019). Water quality monitoring and analysis is a process involving water sampling, measurement of parameters and subsequent assessment implemented by *inter alia* water management institutions to measure chemical, physical, and biological parameters of a surface or subsurface aqueous system by “following standard sampling methods” to establish water quality and its suitability for a designated use (Roy, 2019). Water quality sampling can further be defined as a water sample abstracted from for example a river, stream, or wetland by employing various techniques for the purpose of analysing its constituent water chemistry, establishing pollution and pollution trends and so forth (DES, 2018; WHO, 1996).

According to the World Health Organisation (WHO), “water quality is the foundation on which water quality management is based” (Bartram et al., 1996) and water quality monitoring and analysis is considered as one of the aspects of water quality management and is implemented for various reasons. According to the State of Queensland’s Water Department of Environment and Science, reasons for monitoring and analysis include, *inter alia*, “the provision of information to government for policy and investment decision-making, to support natural resource management decisions by governments and relevant stakeholders, to assess potential impacts, facilitate the proactive management of the quality of surface water resources and to educate and inform relevant stakeholders and the community” (DES, 2018:1). More specifically, water quality monitoring and analyses can be utilised to achieve the following pertaining to water quality management:

- Characterise current conditions, identify point and non-point sources of pollution, detect deviations from baseline water quality conditions, and identify emerging water quality problems and trends and enable response to emergencies (DWS, 2015).
- Formulate and implement water quality management objectives, policies, strategies, and systems and regulate compliance thereto (DWS, 2015).
- Evaluate the efficacy of water use activities and water quality management strategies undertaken to manage the impacts effecting water quality (DWS, 2015).
- Implementation of effective pollution remediation, prevention, and control measures (DWS, 2015).

In addition to the above, water quality monitoring and analyses can be utilised to regulate, and limit water use based on the physical, biological, and chemical characteristics of the water sample taken when compared to criteria prescribed in relevant guidelines, standards and regulations standards. For example, according to the South African Water Quality Guidelines the target microbiological water quality range for surface water intended for the irrigation of crops that are consumed raw is one count *Escherichia coli* per 100ml sample taken (CWDM, 2010). This target has been established for the protection of public health and the health of the environment. *Escherichia coli* counts exceeding the recommended limit will render the water source unusable due its potential of spreading pathogenic organisms (WRC, 2012). Assessing the microbiological quality of surface water is challenging process due to the fact that water quality is variable over space and time and as a result of the complexity of contamination sources. Many advances have been made with respect to improving microbiological water quality monitoring processes as well as comparing the microbiological characteristics of water samples taken during monitoring with required criteria as prescribed in relevant guidelines, standards, and regulations standards (Wen et al., 2020).

With the purpose of establishing and underpinning contemporary objectives concerning water quality as well as to ascertain that surface water quality complies with water quality guidelines or standards, water quality monitoring along with the reviewing and assessment of associated results are performed by trained officials employed by water quality management institutions, Catchment Management Agencies, Water User Associations as well as local, provincial and national government organisations. Before the actual collection of samples can commence, it is necessary to clearly define what information is needed, what gaps are to be filled, what are the objectives and how these objectives will be met (DWS, 2015). To meet these objectives, provision of technical support, capacity building, resource planning and integrated decision making for water monitoring and analysis needs to take place. As a result, water quality management institutions develop and implement a coordinated and fit-for-purpose water quality monitoring strategies as part of a water quality management plan to provide the basis and guidance to meet water quality monitoring orientated goals. One of the implementation tools of a water quality monitoring strategy is a water quality monitoring or compliance program and associated management plans which acts as a guidance tool for water quality management institutions and considers and documents the following (Behmel et al., 2016):

- Selection of monitoring objectives such as the gathering of water quality data for maintenance purposes, assessment to establish whether designated uses are met and degradation and restoration of the chemical, physical and biological integrity of surface water (KDHE, 2019).
- Selection of the type and nature of monitoring and sampling (periodic grab sampling, passive sampling, fixed stations, remote sensing and so forth), instrument selection as well as selection regarding the approach to monitoring to be used such as problem investigation monitoring and effectiveness monitoring (Altenburger et al, 2019).
- Identification of physical, biological, and chemical water quality parameters to provide relevant and representative information in line with monitoring objectives (Altenburger et al, 2019).
- Identifying potential sampling location or sampling frame, frequencies, duration and schedules (KDHE, 2019).
- Development of management and implementation plans to achieve monitoring objectives (KDHE, 2019).
- Development of compliance monitoring related documentation such as assessment reports, data management plans, complaint response plans and so forth (KDHE, 2019).
- Planning and formulating a funding strategy to support and cover operational resources, logistics and so forth as well as water quality monitoring or compliance program design, initiation and implementation related costs (KDHE, 2019).

2.7. Factors Enhancing the Effectiveness of Surface Water Quality Management Strategies and Systems

In theory, the use of water quality management plans, policies, strategies and so forth which have been developed will help to resolve potential water quality related challenges. The following are factors that can enhance the effectiveness of surface water quality management strategies and systems:

- According to Claasen (2013), an enhancement tool to be considered is the implementation of a “holistic Integrated Water Resource Management system that seeks to integrate the management of the physical environment within the broader socio-economic and political framework” (Claasen, 2013:323).

- Strategic management of water quality challenges through the engagement with appropriate decision-making representatives of the affected government entities and drastic intensification of cooperative governance and regulatory interfaces among the various affected government entities (DWS, 2017).
- According to Van der Merwe-Botha "Financial investment in water quality and its various enablers is not simply necessary but is critical and non-negotiable if a water-secure country is envisioned" (Van der Merwe-Botha, 2009:25).
- Forge highly focused, fit-for-purpose, civil society and corporate business partnerships that are relevant to each primary water quality challenge (DWS, 2017).
- Attention needs to be given to succession planning within the water quality management functions. (DWS, 2017).
- Water quality models and monitoring strategies "plays an important role in better understanding the magnitude and impact of WQ issues and in providing evidence for policy-making and implementing measures to mitigate water pollution" (Tang et al., 2019:39).
- Formulation of potential strategies and intra-government engagement will need to include to deal with dysfunctional municipalities (DWS, 2017)
- Defragmentation of water quality planning and management i.e. there are different directorates in head office that deal with elements of Water Quality and Water Quality Management needs to be elevated as a priority (DWS, 2017).
- Effective management of stakeholder relations, public involvement in planning and decision-making processes and the involvement of relevant role-players, at a level where they may provide strategic and operational direction in the conceptualisation and finalisation of key areas and outputs (DWS, 2017).
- The implementation of institutional roles and functions and as suggested by Claasen (2013) "while some management instruments are in place, there is a need to address significant gaps, for instance in monitoring and decision support" (Claasen, 2013:334).
- A strategic water quality management implementation roadmap is required to not only address the current challenging water situation, but it also provides an advanced and smart water management approach to take the countries forward into a more positive, water secure future (Claasen, 2013).
- Create community and stakeholder awareness and enhance the level of understanding on issues about the IWQM policies and strategies (DWS, 2017).

CHAPTER THREE
RESEARCH METHODOLOGY

3.1. Introduction

A research design can be defined as the plans and procedures implemented to logically address a research problem and the selected research questions. The research design forms the basis or framework of a research project and focuses on what kind of study is being planned and what research objectives and results are aimed at (Saunders et al., 2009).The research methodology on the other hand concentrates on the system of methods and individual steps or research methods in the research process and comprises, inter alia, the specific data collection, analysis and interpretation methods used during research as well as their relevance and logic behind the selection of each method (Igwenagu, 2016).

This chapter outlines the theoretical framework and research methods (i.e. the methods used for data collection, analysis and interpretation) followed to provide an answer to the research questions and to address the research problem and the abovementioned research objectives of this research study.

3.2. Theoretical Framework

3.2.1. Introduction

The theoretical framework is the foundation from which all knowledge is constructed for a research study. It is the guide for a research project and as defined by Grant and Osanloo "describes the theory that explains why the research problem exists. It also serves as the structure and support for the rationale for the study, the problem statement, the purpose, the significance, and the research questions. The theoretical framework provides a grounding base, or an anchor, for the literature review, and most importantly, the methods and analysis" (Grant and Osanloo, 2014:12). Further research suggests that "the management of water resources requires the ability to assess the changes that may result (e.g. changes in water quality conditions) from the implementation of some management alternative" (Edinger et al., 2007:32).

3.2.2. Problem

In South Africa, water quality standards as well as water quality management strategies have been established in response to the surface water pollution management orientated challenges and water quality management objectives have been implemented successfully in certain catchment areas. There is no doubt that the officials from the newly established DWS (Department of Water and Sanitation previously known as Department of Water Affairs), BGCMA, and the CWDM are attempting to achieve a similar result for the Dwars River.

Nevertheless, as previously stated, the water quality of the Dwars River has remained unchanged since 2008.

The persisting water quality problem suggests poor water quality management as a result of institutional inefficiencies or merely the absence of suitable and effective water quality management strategies. Considering the fact that South Africa is approaching a situation of physical water scarcity, the economic importance of the Dwars River, and given the current state of the said water resource, sustainable water management is therefore crucial (Iloms et al., 2019). To improve the current situation and to develop suitable strategies, the focus of water quality management institutions and managers needs to shift from merely monitoring the surface water of the Dwars River and subsequently attending to any irregularities to taking a holistic, proactive, and multi-faceted approach regarding the management of the river as a freshwater resource. The focus points will include concentrating on the factors influencing the river's water quality to degrade, assessing the degree of harm associated with pollutant levels to humans as well as the environment, providing and implementing suitable mitigation and preventative measures, and subsequently monitoring the effectiveness of such measures.

Evidence has shown that the Dwars River collects pollutants along its course and faecal pollution indicator organisms have been present in its water as early as 2008 (CWDM, 2010; Witzenberg Municipality, 2012a, and BOCMA, 2014, BGCMA, 2019). However, according to previous research conducted by the CWDM and DWS as well as current information provided by BGCMA, the situation pertaining to microbiological water quality remains unchanged. The results for faecal coliforms and Escherichia coli have exceeded and continuous to exceed the SAWQG for drinking water quality, livestock watering, recreational use, and agricultural use (CWDM, 2010, BGCMA, 2019).

The faecal pollution of rivers and other natural water bodies is a "notable" phenomenon widespread throughout South Africa and can be attributed to urbanisation, industrialisation, and an increase in population (DWAF, 2004; Iloms et al., 2019:2). Nevertheless, the current adverse alteration of microbiological water quality of the Dwars River can have serious consequences, placing members of the Witzenberg community and those individuals who are directly or indirectly exposed to its water at risk of contracting a water-related disease. It is evident that various water quality strategies have been devised and objectives set by DWS, BGCMA, as well as local and district municipalities to improve the water quality of the Dwars River. Unfortunately, various challenges exist preventing the water quality strategies from being developed, implemented, and associated objectives being achieved.

3.2.3. Purpose

The purpose of this study is two-fold. First to identify shortcomings regarding the water quality management of a section of the Dwars River; and secondly, to provide possible solutions to improve the strategies implemented to manage and/or prevent the continuous introduction of faecal matter into the Dwars River.

3.2.4. Significance

This research is significant because it will recommend corrective measures that might potentially improve existing water quality management strategies. Potentially assist with the development of more effective and proactive water quality management strategies designed to improve the current status of the microbiological quality of the Dwars River and reduce the potential public health risk. The research will also serve as an instrument for further research.

3.2.5. Research questions

- Main research questions:
  - What are the reasons, from a WQM perspective, for the water quality of the Dwars River continuously being impaired through faecal contamination?
  - What WQM factors can improve the effectiveness of the current Dwars River water quality management practices?
- Sub research questions
  - Is there a current surface WQMS designed to prevent, report, and counter faecal pollution along the Dwars River?
  - Are the current microbiological sampling programmes implemented along the Dwars River effective in assisting with the prevention of faecal contamination?
  - Are the current surface WQMS designed to prevent, report, and counter faecal pollution along the Dwars River suitable and effective?

3.2.6. Literature review

Variables and concepts focussed on during the literature review will include:

- Faecal pollution of surface water sources
- Water quality management strategies and systems
- Factors inhibiting the effectiveness of surface water quality management strategies and systems
- Factors enhancing the effectiveness of surface water quality management strategies and systems
- Water quality monitoring/sampling methodologies
- Water quality management practices

3.2.7. Theoretical framework

Multiple theories give varying perspectives on the same issue. However, this research used the Theory of Planned Behaviour as a "lens to build an argument, conduct the data analysis, establish the context of the problem, and explain findings" (Kivunja, 2018:46). The focus is on determining "attitudes towards, subjective norms of, perceived behavioural control of behavioural intent to and actual engagement with water quality management of the Dwars River in the Western Cape to provide possible solutions to improve the strategies implemented to manage and/or prevent the continuous introduction of faecal matter (Okumah et al., 2019:2).

This research sought to look at water quality management and water quality management strategies implemented in the UBCMA. Water quality management of the Dwars River in the Western Cape is the topic of research in this thesis. This is the dependent variable in the research. The following key theoretical principles and concepts as derived from the research questions and objectives were considered as the independent variables for this study:

- Faecal contamination of surface water.
  - The presence of faecal material of humans & animals in surface water
- Water quality sampling effectiveness.
  - Current microbiological sampling programmes implemented along the Dwars River effective in assisting with the prevention of faecal contamination
- Water quality management strategies.
  - Formalised "roadmap" used by water management institutions to ensure sustainable management of water resources.
- Water quality management practices.
  - Water pollution control methods implemented to protect surface water sources

The theoretical framework will now outline why the Theory of Planned Behaviour is relevant to this research and how the information derived from it will be used to conduct and evaluate the research findings.

Water quality standards as well as water quality management strategies have been established in response to the surface water pollution management orientated challenges and water quality management objectives have been implemented successfully in certain catchment areas. There is no doubt that the officials from the newly established DWS (Department of Water and Sanitation previously known as Department of Water Affairs), BGCMA, and the CWDM are attempting to achieve a similar result for the Dwars River. Nevertheless, as previously stated, the water quality of the Dwars River has remained unchanged since 2008.

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The Witzenberg Municipality's aim is "to make great strides in service delivery through the improvement of water quality and waste management with the objective of becoming a competitive tourism destination and a first-rate investment option for the agricultural and business sectors" (Witzenberg Municipality, 2013). One of the problems faced by the municipality is the pollution of their river systems, including the Dwars River, of which industrial and agricultural runoff was identified as the major causes of water quality deterioration within the municipal area (Witzenberg Municipality, 2012b:43). Research done in the Witzenberg municipal area has shown that problems surrounding water quality management and the pollution of the Dwars River have been greatly exacerbated by service delivery challenges experienced by the Witzenberg Municipality (CWDM, 2010). Examples of challenges includes the lack of funding, shortage of staff and equipment, under-expenditure of the wastewater management budget, increased vandalism and theft of municipal property, failure to implement corrective measures (Witzenberg Municipality, 2012a), poor reaction time regarding sewerage problems, and the fact that the local wastewater treatment works cannot accommodate industrial effluent and is underachieving with regards to its Green Drop status (Department of Water and Sanitation, n.d). Further to this, subsequent to the reporting of sewage spills in the area, certain officials appointed for the Witzenberg Municipality showed no concern over river water pollution caused by the said sewage spills, the prevention of further pollution, or the rehabilitation of the sewage spills. It was also noted that legislation as well as the principles of cooperative government and intergovernmental relations was manipulated in the past to avoid prosecution (CWDM, 2010).

Witzenberg Municipality's response to the river pollution dilemma involved the development of relevant management strategies as well as the enabling of necessary projects to alleviate the situation. The upgrading of wastewater treatment works, monitoring industrial effluent, establishing pollution control measures, engaging with Cape Nature daily, implementing applicable legislation, launching educational and awareness campaigns, and exploring alternative funding channels/sources are all examples of proposed control measures designed to manage water quality and prevent river pollution. The problem however is that the water quality of the Dwars River continuous to deteriorate even though water quality and the pollution of rivers being identified as key issues (a Witzenberg Municipality, 2014:115), the wastewater treatment works being upgraded, the poor storm water and sewerage system issue being discussed at various stakeholder engagements, and the overloading and lack of maintenance of sewage systems being identified as early as 2007.

Microbiological water quality related information included in the final report disclosed that high levels of faecal coliforms, Escherichia coli, and faecal streptococci were introduced into the Dwars River at levels far greater than the prescribed limits listed in relevant guidelines, placing thousands of people at risk of being exposed to disease-causing organisms. According to the report, this was attributed to frequent faecal pollution incidents. For the CWDM this was a major concern since faecal pollution from humans, livestock, and wild animals contain various disease-causing pathogens. Ceres' wastewater treatment works was identified as one of the main sources of faecal pollution, but the report further stated that the water samples taken from sampling points along the river located ahead of the wastewater treatment works' effluent inflow showed coliform counts that were even higher than the said effluent itself. Other suspected sources such as upstream sewerage pump stations, informal farming activities, and pollution from households along the river were also pointed out in the report. After establishing the nature and extent of the faecal pollution in the Dwars River as well as identifying the lack of water quality management measures available to prevent pollution, officials of the CWDM formally requested DWS to step in and to investigate the situation further. DWS withdrew from the area but appointed and tasked BOCMA to assess the situation and act on their behalf within the CMA with regards to water quality management. The CWDM received no feedback from BOCMA officials prior to and after the completion of the BRIP final report (CWDM, 2010).

The CWDM officials performing water quality monitoring, management, and reporting related activities also experienced some difficulties while executing their duties. These included the following:

- Water pollution cases were left unresolved due to DWS's high personnel turnover.
- The lack of experience of newly appointed personnel to solve an on-going water quality related problem. This prolonged the time it took to solve a specific problem.
- Understaffing of the DWS, especially regarding water quality personnel.
- Water sample analysis and the issuing of results took too long to implement effective response and control measures.
- CWDM personnel received limited assistance from the Department of Water and Sanitation CWDM, 2010).

"The National Water Act (Act No. 36 of 1998) sets the framework for the protection, use, conservation, management and control of water resources in South Africa" and provides for the establishment of water management institutions including Catchment Management Agencies (South Africa, 1998:55). The Catchment Management Agencies are "accountable to the Minister of Human Settlements, Water and Sanitation" and works in "close cooperation with the Department of Water and Sanitation" who acts through the Minister (South Africa, 1998:7; BGCMA, 2015:2).

In November 2007, BGCMA became the second operational CMA in South Africa. BGCMA was established in line with the conditions of the National Water Act, 1998 (Act No. 36 of 1998) and was entrusted with water resource and quality management responsibilities within its jurisdiction for the benefit of everyone living in the area (BOCMA, 2013:7). BGCMA has the responsibility to create awareness regarding water quality and pollution and to coordinate responses to pollution and emergency incidents within their area (South Africa, 1998:34). Another function of BGCMA is water resource protection through the continued assessment of water quality and to simultaneously devise strategies to protect water resources under their control (BOCMA, 2013:14). In other words, BGCMA was formed as part of an initiative with the intention of monitoring and subsequently improving the current situation surrounding the quality of water resources such as the Dwars River through the development and implementation of a CMS. To achieve this BGCMA was tasked to acquire baseline water resource quality information to support both current and future research and enabling them to prioritise and develop, in collaboration with local authorities, dense settlement water management strategies for priority urban pollution sources. To fulfil their obligations BGCMA has since established various Water Quality Monitoring Programmes and in the process of developing specific CMS (Anon. 2012b:3).

Management strategies, such as a CMS, "focuses on priority water resource management issues, and details specific activities, resources, responsibilities, timeframes and institutions required to address these priorities in an efficient and sustainable manner" (BGCMA, 2017:15). The following are examples of what has been included in the BGCMA's draft CMS regarding enhancement of water quality management:

- "Develop an Integrated Water Quality Management Plan" (BGCMA, 2017:40).
- "Determine Resource Quality Objectives for the WMA" (BGCMA, 2017:40).
- "Implement water quality, and quantity and ecosystems monitoring" (BGCMA, 2017:40).
- "Identification and prioritisation of all pollutants and their sources" (BGCMA, 2017:45).
- "Develop decentralised platforms for on-going stakeholder engagement and communication" (BGCMA, 2017:84).
- "Develop a communication method that is regular, open and accessible that will allow for meaningful and functional participation" (BGCMA, 2017:85).
- "Undertake compliance monitoring of all water use" (BGCMA, 2017:87).
- "Implement a programme to monitor Resource Quality Objectives" (BGCMA, 2017:98).
- "Implement a programme to assess compliance against water use authorisations" (BGCMA, 2017:100).
- "Identify and develop information management needs" and "ensure communication of information to and from stakeholders" (BGCMA, 2017:103).

"Regulatory and control functions such as water use authorisations, monitoring, compliance and auditing, prohibition of land-based activities, regulatory measures to control and manage water use" also form part of the BGCMA's draft CMS management objectives (BGCMA, 2017:43). According to BOCMA's 2013 Annual Report, non – compliance issues regarding the quality of water resources under their jurisdiction are continuously being investigated and pre-directives and warnings are issued where necessary (BOCMA, 2013). Generally, officials would receive a report pertaining to a water quality issue, establish the origin of the specific problem, liaise with the responsible party or polluter, and analyse relevant regulations and standards governing the aspects of the situation. Corrective actions are then developed and once all parties accept the nature and conditions of the actions to be taken, they will monitor post-corrective action compliance and ensure that corrective action has been taken and that legislation is being adhered to (Anon. 2010:2). Irrespective of the current approach to water quality issues being enforced and a comprehensive written CMS being available for implementation, the water quality sample results from 2011 up to 2014 provided by the Water Resource Management Division of BGCMA indicate that the water quality of the Dwars River remains unchanged. A possible contributing factor to the persistent faecal pollution of the

Dwars River might be the fact that BGCMA have been experiencing some challenges that are inhibiting their water quality management duties (BOCMA, 2010). Examples of these include:

- No water quality management plan available for the Witzenberg area.
- Prolonged approvals of the annual performance plans / business plans.
- Irregular and untimely transfers of seed funding inhibit BGCMA's planning and human resource allocation ability.
- Low morale among personnel which has the potential to disrupt service delivery.
- Understaffing.
- Location of offices makes it very difficult to attract skilled personnel.

Outdated and uneven information (datasheets provided by the BGCMA displaying monthly sample results clearly demonstrates that samples are not taken every month of the year. Throughout 2011 only faecal coliforms were tested for, in 2012 the first monthly water sample was taken in April only, in 2013 no sample results are available for April, October and December, and the 2014 results for March and May are missing); More frequent extreme events such as floods and droughts; Institutional transformation and change management; and legitimacy issues (BOCMA, 2010).

Water serves as an inert carrier of pathogenic microorganisms and as a result, the on-going faecal pollution of the Dwars River calls for immediate attention to improve the current water quality situation (Verlicchi et al., 2020). According to BGCMA, "the consequences of not monitoring and addressing this water quality challenge are profound given that about half of the deciduous fruit and table grapes cultivated in the Breede are exported from South Africa and about a quarter goes into the higher end domestic market" (BOCMA, 2010). Setting the economic aspect aside, disease causing microorganisms in the Dwars River also poses significant risk for those utilizing the river recreationally and for the health of the community especially the immunocompromised, infants and the elderly. Seeing that "water is a key determinant in all aspects of social, economic and environmental development" all users, communities and water quality management institutions should change their approach and mindset towards the management of water quality (WWAP, 2015:6). BGCMA's current reactive approach will not improve the condition or quality of the Dwars River's water, mitigate the risk of the community's exposure to pathogenic organisms, or most importantly maintain public health. The situation calls for a comprehensive water pollution prevention and management system to be implemented and rigorously enforced.

3.2.8. Conceptual framework

This section provides a conceptual framework or visual representation of the projected relationships between key variables identified and isolated during the literature review and provides an overview of what is expected to found through the research study. The nature of the said relationships is discussed in the forthcoming sections.

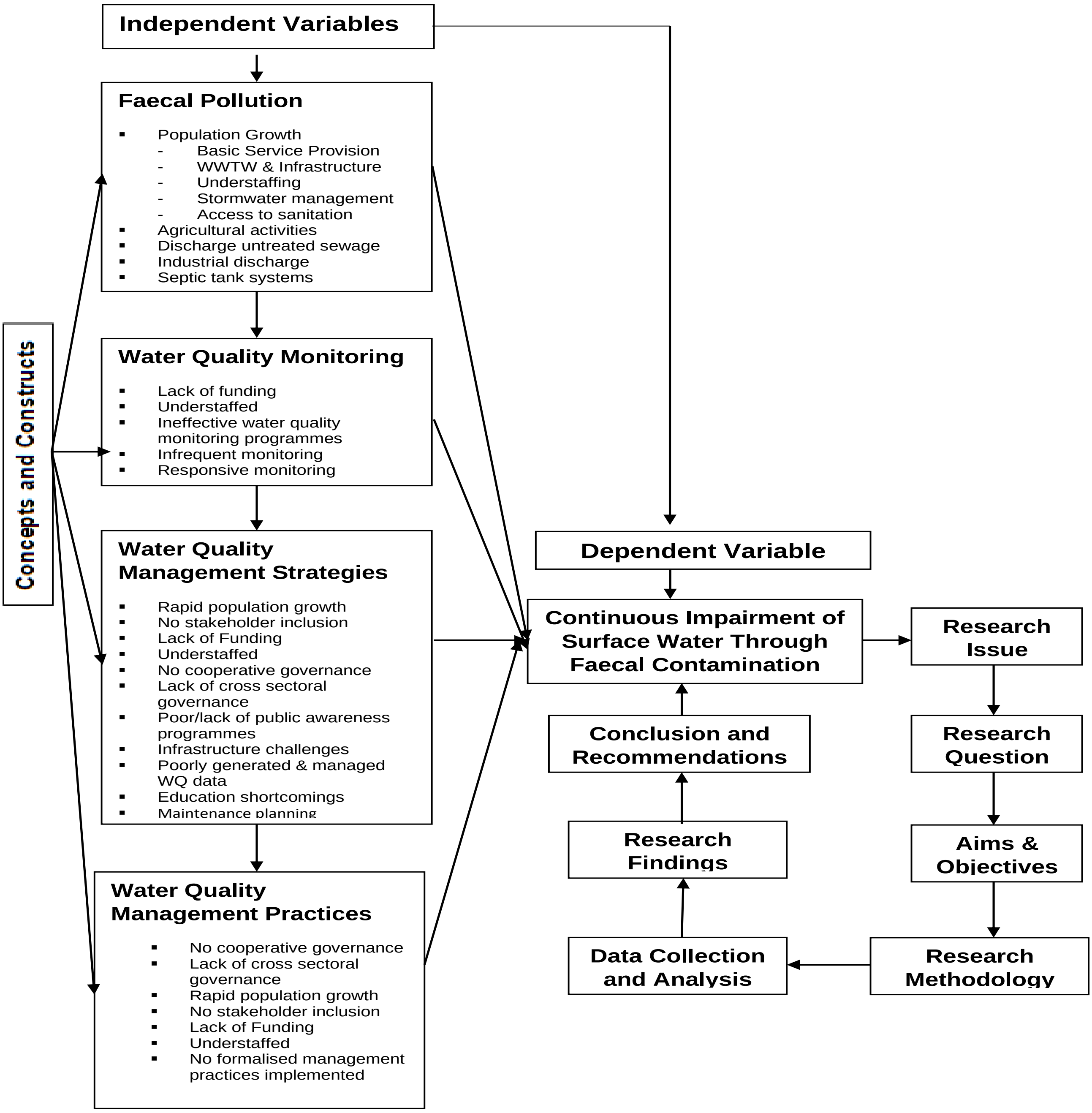


Figure 3.1: Conceptual framework

3.3. Research Methodology

3.3.1. Research design

Researchers have the option of selecting from twelve major types of research designs, namely descriptive, exploratory, experimental, historical, observational, longitudinal, action research, case study, causal, cohort, cross-sectional, and meta-analysis to address a research problem and answer selected research questions. A research design approach can be viewed from two perspectives, namely a quantitative research design or a qualitative research design perspective (Pathak et al., 2013; USCL, 2016). Qualitative research can be defined as non-numerical research designed to explore how and why something is happening as well as what the research problem involves. A qualitative research design employs interviews, focus groups, observations, and analysis of documents as methods of subjective data collection (Crawford, 2013). In contrast to qualitative research, quantitative research involves generating, transforming, and organising numerical data into useable statistics to explain phenomena and to quantify a research problem (Essays, 2018).

The research questions examined within the ambit of this study are:

- Main research questions:
  - What are the reasons, from a WQM perspective, for the water quality of the Dwars River continuously being impaired through faecal contamination?
  - What WQM factors can improve the effectiveness of the current Dwars River water quality management practices?
- Sub research questions
  - Is there a current surface WQMS designed to prevent, report, and counter faecal pollution along the Dwars River?
  - Are the current microbiological sampling programmes implemented along the Dwars River effective in assisting with the prevention of faecal contamination?
  - Are the current surface WQMS designed to prevent, report, and counter faecal pollution along the Dwars River suitable and effective?

As highlighted in the first chapter, the main research objectives, formulated from the research questions, were to investigate the water quality management of a section of the Dwars River in Ceres and to conduct a thorough investigation to determine why the water quality of the Dwars River is continuously being impaired through faecal contamination. To achieve this, it was determined that the following sub-objectives need to be met:

- Determine the importance of the Dwars River and identify the various land uses in the vicinity of the study area to determine the potential impact the faecal pollution of the Dwars River might have.
- Analyse current surface water quality management system(s) in place to prevent the faecal pollution of the Dwars River.
- Evaluate the existing surface water quality management strategies aimed at preventing faecal pollution of the Dwars River.
- Examine water quality monitoring/sampling methodologies employed and their efficacy towards the prevention of faecal pollution in the Dwars River.

- Identify factors inhibiting and contributing to the effective implementation of the water quality management strategies.
- Provide appropriate recommendations to water resource managers, institutions, scientists, decision-makers, and the public concerning the management of the quality of Dwars River's water.

Given the nature of the research questions and objectives, the research approach used for this study was the mixed method approach involving "a combination of qualitative and quantitative research" to collect and analyse the data. (Makrakis, 2016:145) A fact-finding cross sectional descriptive research design was then selected with the intention of using qualitative and quantitative research methods for investigating the why and what orientated research questions pertaining to the water quality management of a section of the Dwars River. The reasoning behind selecting a descriptive research design can be attributed to fact that the design provides a framework and research methods befitting for the purpose of this research study seeing that it allowed the researcher to describe the selected research problem and its characteristics as well as to provide research specific answers to research questions (USCL, 2016). The rationale behind using this approach was that interviews were conducted and scientific journals, local legislation, catchment management plans, technical evaluation reports and water quality related statistics were interrogated.

There are three prominent strategies or approaches to a descriptive research design, namely the survey, case study and observational research method. In survey research, respondents from a target population provide pertinent information by answering questions administered through interviews, surveys, questionnaires, or polls and allows for standardisation of data (Rahi, 2017). Case study research involves "in-depth data collection and analysis of a bounded system over time" (Harrison et al., 2017:33). The observational method is a participatory study used to collect data through observing a phenomenon it its natural setting. (Alison et al., 2017)

For this study, the researcher made use of a cross sectional survey research method and associated research techniques to study respondents selected from a sample population's current understanding and opinions regarding the research questions surrounding the water quality management of a section of the Dwars River in Ceres. The research methods used to apply correct procedures to determine solutions to the research problem and the actual individual data collection techniques applied for data collection purposes will now be discussed.

3.3.2. Research methods

This study is based on both primary and secondary data which have been collected from various sources and by using various techniques (Driscoll, 2011). Primary data can be described as new data collected by a researcher or investigator for a specific purpose. Secondary data on the other hand is described as "data which has been collected by individuals or agencies for purposes other than those of a particular research study" (Crawford, 2007:15; Driscoll, 2011).

a) Primary data

There are various research techniques or primary data collection practices associated with the survey research method. The most frequently applied methods include questionnaires and interviews (Ponto, 2015). According to DiCicco-Bloom and Crabtree (2006), "An interview is described as an individual face-to-face conversation, which seeks to foster learning about individual experiences and perspectives on a given set of issues" or a desired subject (DiCicco-Bloom and Crabtree, 2006:314). Three types of interviews are used in research, namely structured, which consists of a set of questions in a predetermined order; semi-structured, which contains a guide of topics to be discussed but the interviewee's responses determine the way in which the interview is directed, and narrative interviews where the interviewer and interviewee discusses topics related to the research in an informal, conversational manner (Stuckey, 2013). As opposed to interviews, a questionnaire is defined as a research instrument used for collecting data and normally involves respondents completing a set of oral or written questions with minimum contact with the researcher. For the purpose of this research study, semi-structured interviews were used instead of questionnaires to generate primary data.

i) Semi-structured interviews

The rationale behind selecting the semi-structured interview technique was to allow the researcher to attain an in-depth understanding and first-hand information of the selected respondent's views with regards to the research topic (Jamshed, 2014). The information was obtained by recording respondent's descriptive answers to a pre-planned set of questions listed on a formal standardised interview questionnaire during one-on-one interviews.

ii) Interview questionnaire design

A formal prescribed standardised questionnaire was used (see Appendix B) with the intention of ensuring that each respondent receives the same stimuli, information was aggregated as reliably as possible, every single participant was presented with the same pre-planned set of questions and that questions were handled consistently (Jamshed, 2014). The research questions and research objectives were used as the foundation for formulating the pre-planned set of questions forming part of the interview questionnaire. This study's research questions were used as headings for every section of the interview questionnaire. Questions were then developed and pre-assessed to ensure that they address the relevant research questions and contributed to the achievement of the research objectives. Subsequent to determining each question's relevance they were grouped under the appropriate section heading. The interview questionnaire mainly consisted of direct and follow-up open-ended questions to ensure that answers provided by respondents during interviews were as descriptive as possible and allow for the generation and analysis of in-depth qualitative data (Thoughtco, 2019). The questionnaire was pretested in person on two individuals. Pretest respondents were similar to those respondents identified under section 3.3.2(iii). Once the interview questionnaire design was drafted and finalised the sample population and required sample techniques were considered.

iii) Sampling technique and sample population

Sampling techniques are grouped into two major categories, "namely probability sampling and non-probability sampling" (Showkat and Parveen, 2017:2). Showkat and Parveen (2017) defines Probability sampling as sampling, where "each sample has an equal probability of being chosen. We can say a probability sample is one in which each element of the population has a known non-zero probability of selection. This method of sampling gives the probability that our sample is representative of a population" (Showkat and Parveen, 2017:2). Non-probability sampling on the other hand is dependent on the researcher's ability to select elements for a sample from a population they are interested in studying (Palinkas et al., 2016).

For the purpose of this study, a non-probability sampling approach was followed due to the fact that the data required to answer the research questions was of a specialised nature and the individuals forming part of the sample population needed to have had practical experience with and be knowledgeable about the selected research problem (Palinkas et al., 2016).

Expert sampling, a purposive non-probability technique, was selected as the most suitable option for this research study. Reason being that the technique involves the selection and subsequent interviewing of participants who are experts in the field the researcher is studying and that processing of their views and understanding of the research problem would ensure that the needs of this study are fulfilled (Palinkas et al., 2016). In this case, the sample population included participants with knowledge regarding the water quality management and/or water quality monitoring of a section of the Dwars River in Ceres.

In addition to the experts selected, the population for this study included water users or landowners located adjacent to the Dwars River who utilises water from the river for agricultural, domestic and/or industrial purposes. From the population, samples were identified (See Table 1) which consisted of individuals who have come into contact with the Dwars River, who utilises the resource and officials who have performed surface water quality management, monitoring and/or data capturing related duties within the Upper Breede-Gouritz Catchment Management Area. More specifically, Environmental Health Practitioners, landowners, Water Quality Control Officers, CMA Coordinators and Resource Managers were earmarked to be interviewed as part of the research study

Table 3.1: Sample population

Sector	No. of Potential Participants
Local Municipality	2
District Municipality	4
National Government	2
Water Management Institutions	5
NGOs	2
Water Users/Landowners	3
Public Institutions	1
Total	**19**

The rationale behind the selection of the respondents were based on the fact that the individuals selected had experience with water quality monitoring and water quality management and were involved with water quality monitoring, surface water management UBCMA. Once the participants were identified, requests for participation were emailed to respondents selected from the sample population along with the interview questionnaire, consent form and a letter of information providing specifics regarding the study and confidentiality.

iv) Interview procedure

Subsequent to the voluntary acceptance of participation and the submission of signed consent forms arrangements were made for the researcher to engage with each of the participants. Seeing that the one-on-one interview method was followed, the researcher's aim was to achieve minimum disruptions during interviews by selecting settings with the least number of distractions. To ensure minimum disruptions, respondents were requested to choose the location of the interview to maximise convenience for each respondent. Each respondent taking part in this study requested the interview to be conducted in their offices. Prior to conducting the interview, respondents were informed that participation was completely voluntary and there were no known risks for participating in the study. The nature of the study, the objectives of the research and potential benefits of the study were discussed. Interviews commenced and data were recorded electronically immediately through documenting responses to each question. Once an interview was completed the researcher revisited the answers to each question in the presence of the respondent so that latter could verify the answers.

v) Ethical consideration and confidentiality

After the interviews were concluded, respondents were informed that responses will remain confidential and anonymous, and that data collected will be protected and no one other than the researcher will be able to link individual answers to each respondent. Respondents were also reassured that all the information generated during the interviews will be treated as confidential and that participants will be referred to as respondents and will be assigned with a reference number which will be used for referencing purposes (i.e. participants' name/surname will not be inscribed in the research paper).

b) Secondary data

For this study, secondary data dated between 1991 and 2021 was collected by scrutinising and summarising written water quality management related data obtained from scientific journals, local legislation, catchment management plans, and technical evaluation reports that referred to this study's research problem and the study site (see Figure 3.1 below). Information forming part of the Dwars River's surface water quality related data sets, which includes microbiological surface water quality sampling results, presented on Microsoft Excel spread sheets were also analysed and summarised for the purpose of this study. The water quality related information was requested, in writing, from and provided by the BGCMA, CWDM and the DWS.

3.4. Research Site

The study was conducted along the Dwars River in the Western Cape (Figure 3.1) and the research site or study area selected ranged from Point A (33°20'53.16"S, 19°17'55.20"E) situated in a South-westerly direction from Ceres towards Cape Town to Point B (33°22'58.77"S, 19°18'38.49"E) situated in a North-easterly direction from Ceres towards Prince Alfred Hamlet. The study focused exclusively on the water quality management and faecal pollution of the specified stretch of the Dwars River from January 2008 – July 2019.

Figure 3.1: Demarcation of study site (Google Earth, 2014)

3.5. Data Analyses

Data was gathered using two different instruments, namely interviews and document analysis. According to Babar (2015:59) “a document is a piece of written, printed, or electronic matter that provides information or evidence which relates to some aspect of the social world” (Babar, 2015:59). Secondary data recorded and summarised from documents such as scientific journals, local legislation, catchment management plans, and technical evaluation reports were analysed and interpreted using the document analysis strategy. Numerical data such as the water quality monitoring results was described, summarised, and processed by using Microsoft Excel as the data management software. Numeric data collected and reviewed was diagrammatical illustrated in the form of columns and charts by making use of the same software (Blandford, 2013; Interaction Design Foundation, 2019).

The researcher applied a structured thematic analysis method for analysing the data produced by the semi-structured interviews. The thematic analysis method allowed the researcher to become familiar with the data collected. The said data analysis method was used to categorise data by generating and assigning preliminary codes to the dataset and collating data relevant to each code to describe the content. After the coding process, patterns and themes were identified and a thematic map of the data was created. Themes were defined, named, and reviewed followed by the structuring and presentation of the participant’s in-depth perspectives regarding the research problem (Blandford, 2013; Interaction Design Foundation, 2019). Data analysis and findings have been discussed under Chapter 4 of this research study.

Question 2.8 In your opinion, what, from a faecal pollution perspective, are the major factors impacting on the Dwars River's water quality?

Questionnaire Section	Questionnaire Question	Chapter 4 Section
Section 2	Question 2.8	4.3.1.6

Categories: Population growth (Pg), Service delivery (Sd), Surface water quality management (Swqm), Interdepartmental relations (Ir), Wastewater treatment works (Wwtw), Unsure (U), Existing Infrastructure (Ei), Stormwater runoff from informal settlements (Sris), Stormwater runoff from town (Srt), Defecation (D), Incident response (Irs)

Pg, Sd, Ir, Ei, Irs *RS 1*: Population growth vs. service delivery. The current infrastructure cannot cater for the current population size. Especially when considering the temporary influx of seasonal farmworkers. Internal politics within the DWS prevents problem areas from receiving the necessary attention and we often struggle to get hold of DWS employees to report noncompliance, request information etc.

Swqm *RS 2*: Integrated Water Resource Management does not currently exist

W *RS 3*: It will have to be the sewage works in the area

Sd, W *RS 4*: Witzenberg Municipality's service delivery and the poor management of the local WWTW

Sd, Irs, Swqm, Ei, Sris *RS 5*: No proper enforcement of legislation by DWS, incident rehabilitation response time, actions taken are problematic, and monitoring of surface water quality is not adequately performed. Due to the current population size, the informal settlements do not have the required sanitation facilities

Sris *RS 6*: Runoff from informal settlements

Sris *RS 7*: Stormwater runoff from informal settlements

Sris *RS 8*: Stormwater runoff from informal settlements

U *RS 9*: No Idea

W, Ei, Sris *RS 10*: The WWTW and associated infrastructure's capacity is not adequate to cope with current loads. Informal settlements do not have the required sanitation facilities resulting in excrement ending up in rivers.

Srt *RS 11*: Stormwater runoff through town into the river

Srt, D *RS 12*: Ceres's stormwater runoff and people as well as animals defecating in the river

Figure 3.2: Sample of dataset coding (Question 2.8 of the questionnaire)

3.6. Validity and Reliability

Bolarinwa's research describes validity as an expression of the degree to which a measurement measures what it purports to measure (Bolarinwa, 2015). Reliability, on the other hand, according to Taherdoost (2016), "is the extent to which results are consistent over time" (Taherdoost, 2016:33). For the purpose of this study, the researcher used a content validity approach which involved the extensive review of literature to formulate a predetermined set of questions for the interview questionnaire followed by a peer review of the content of the questionnaire and the selected study population to ensure that the questions are relevant to the research study's objectives (Taherdoost, 2016). To ensure the sample population was representative, the researcher selected respondents for interviews from various organisations involved with water quality management. Furthermore, to ensure that this study was valid, a Cape Peninsula University of Technology (CPUT) supervisor was assigned to manage the researcher for the duration of the research study. The supervisor as well as the Higher Degree Committee at CPUT verified that the research problem, research questions and data collection methods were derived from the literature and confirmed the validity of the study.

3.7. Limitations of the Study

The researcher experienced three main limitations. Firstly, there were some missing information on the water quality related datasheets which were supplied by the BGCMA, CWDM and the DWS. The collection of samples and consequent analysis was not uniform due to budget restraints, lack of human resources and intradepartmental differences regarding sample frequency. There were months without or with incomplete data which made it difficult to find faecal pollution patterns. The second limitation involved the researcher having restricted access to certain respondents seeing that officials of the Witzenberg Municipality declined to take part in the study. Finally, some of the respondent’s feedback or responses lacked depth and provided limited detailed information as a result. Fortunately, there was no need to redesign or restructure the research study due to the restricted access to Witzenberg Municipality’s officials, short-sighted answers of a few respondents or the limited water quality related data. Reason being that, as a result of the copious amount of reliable primary and secondary data available to the researcher from other sources, the findings discussed under Chapter 4 of this research study are still reliable and valid despite the previously mentioned limitations.

3.8. Conclusion

This chapter outlined the research design, methodology and approach selected for this study. The detailed information regarding the descriptive research methods, population and sample, validity and reliability of the study, ethical considerations and data analysis and its relevance to this study was provided in this chapter. The following chapter provides details of the data collected by the researcher with the described information gathering tools for the purpose of this research study and provides an interpretation of the findings.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Introduction

This chapter discusses the main findings regarding the surface water quality management of the Dwars River made during the data collection process. The findings relate to the research questions as per chapter one of this study and briefly describe the surface water quality of the Dwars River, the current surface water quality management strategies and management system, the implementation of surface water quality management strategies and recommendations concerning the management of the microbiological quality of the Dwars River. Data were collected through literature reviewed and by conducting structured interview questionnaires with individuals who have come into contact with the Dwars River and officials who have performed surface water quality management, monitoring and/or data capturing related duties within the UBCMA. Charts, graphs, and tables were used for data presentation and categorisation to give an overall view of the findings and to reveal general patterns or connections in the data.

4.2. Response Rate

A total of 19 potential participants were earmarked for this study. As soon as a participant was identified, as many as six attempts were made to arrange an interview. Of the 19 individuals selected to whom requests for participation were sent, only 14 respondents agreed to form part of the study. Three of the five non-respondents indicated that they were unavailable to participate due to various reasons while the remaining two failed to reply to requests to participate in the study. Based on the data this renders an overall response rate of 74% (See Table 1).

Table 4.1: Response population and questionnaire response rate

Sector	No. of Potential Participants	No. of Responses	Non-Responsive	Response Rate (%)
Witzenberg Municipality	2	0	2	0
CWDM	5	4	1	80
DWS	2	1	1	50
BGCMA	3	3	0	100
Water Irrigation Board	1	0	1	0
WWF	1	1	0	100
Water Users	3	3	0	100
GIZ	1	1	0	100
Cape Nature	1	1	0	100
Total	19	14	5	

A total of 14 questionnaires were completed and deemed usable for the purpose of this study. This represents a 100% of the responsive population but 74% of the potential participants which were earmarked for this study. The structured interview questionnaire comprised of the following five sections and data generated have been presented accordingly:

- The first section comprises of data related to the microbiological water quality of the Dwars River.
- In the second section data describing the current surface water quality management strategies are discussed.
- The third section comprises of data related to the existing surface water quality management system.
- Section four deals with the implementation of the contemporary surface water resource management strategy.
- In the fifth section data relating to recommendations concerning the management of the microbiological quality of the Dwars River will be discussed.
- Lastly, this chapter will also be used to diagrammatical illustrate and describe surface water quality related data procured through the analysis of documented government publications, annual reports, historical water quality related data sets, development plans, and strategies of the DWS, CWDM, Witzenberg Municipality, and the BGCMA.

4.3. Findings

4.3.1 Surface water quality of the Dwars River

Section 2 of the questionnaire, consisted of eleven questions developed to probe the sample populations' perception of the importance of the Dwars River, located in the Upper Breede management zone, as a natural resource and the water source's quality and fitness for a variety of uses. Additionally, this section provides some insight as to the respondent's involvement in surface water quality monitoring, their knowledge regarding current and potential faecal pollution sources, and their opinion concerning the major microbiological surface water quality concerns that are impacting or might potentially influence the microbiological water quality of the Dwars River.

4.3.1.1 Importance of the Dwars River as a natural resource

Question 2.1 of the questionnaire was included to establish whether the sample population regards the Dwars River as an important natural resource. All 14 of the respondents confirmed that the Dwars River is indeed an important natural resource for various reasons. The Dwars River, considered one of the Breede River's main tributaries, is no different from other surface water resources in South Africa in the sense that it plays an important and life-sustaining role in the lives of the Witzenberg Community for various reasons. The Dwars River meanders through the centre of Ceres in the Western Cape and eventually becomes part the Breede River (DWAF, 2011). Based on the river's location and activities in the surrounding area, the Dwars River is deemed important for various reasons which will be discussed in the sections below.

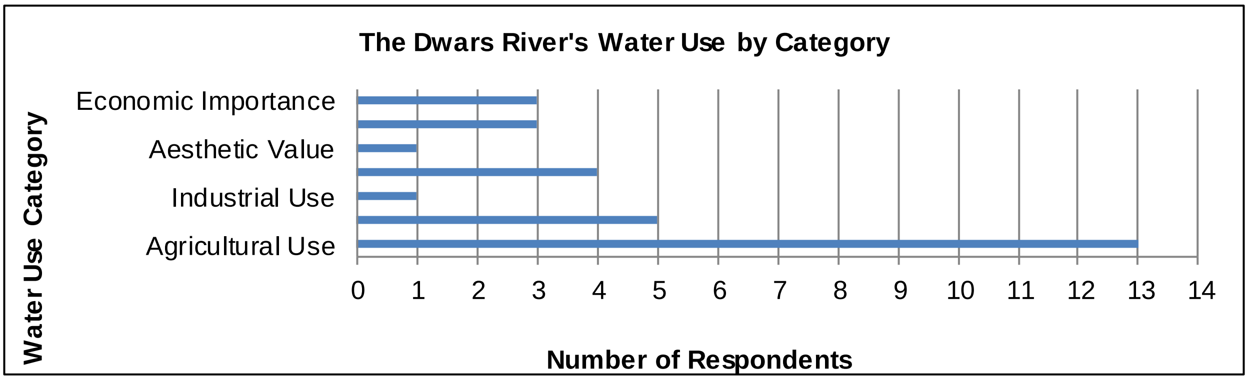
4.3.1.2 Reasons why the Dwars River is regarded as an important resource

Question 2.2 of the questionnaire required respondents to provide their opinion as to why they consider the Dwars River to be an important natural resource. Respondents indicated (See Table 4.2) that the Dwars River is of value for agricultural practices, domestic use, recreational activities, industrial use, economic development, ecosystem health, and aesthetics. Based on data from Table 4.2 and from the statistical analysis (See Figure 4.1), it is apparent that the majority (92, 85%) of the respondents are of the opinion that the Dwars River is important for local and downstream agricultural activities followed by domestic use. It is also evident in the data provided that the river is also utilised for recreational purposes and plays an important role in the area's tourism industry.

Table 4.2: The importance of the Dwars River

Theme	Selected Responses	Respondent
Agriculture	"Farming activities are prominent in the area, hence all water resources are important"	RS 3, RS 1, RS 4
	"water is important for local and post Mitchell's Pass agricultural activities"	RS 9
	"The river's water is important seeing that it is used for agricultural purposes"	RS 7, RS 8
	"High intensive farming takes place in our area"	RS 13, RS 2, RS 11, RS 12, RS 14
	"Farmers irrigate their land with water from the Dwars River"	RS 10
Domestic Use	"Farmworkers abstract water for personal use which includes drinking water"	RS 5, RS 10
	"small community that live in Mitchells Pass adjacent to the river. According to my knowledge they use the Dwars River's water for domestic purposes"	RS 13, RS 11, RS 12
Industrial Use	"businesses in town depend on surface water"	RS 4
Economic Prosperity	"It plays an important part in job security seeing that the farmers in the area deliver to the overseas markets"	RS 7, RS 8, RS 10
Aesthetic Value	"Dwars River and its tributaries also have significant aesthetic values to the local community"	RS 6
Recreation	"have been known to be attractive for a number of water-based and water-enhanced recreational/tourist activities"	RS 6
	"The river has recreational value"	RS 7, RS 8, RS 9
Ecological Importance	"The Dwars River and its tributaries are biologically diverse and productive habitats which make them important natural resources. They act as habitats for various species of fauna and flora"	RS 6, RS 7, RS 8
	"water body has an ecological importance (high biodiversity value)"	RS 7, RS 8

Figure 4.1: The Dwars River's water use by category



The reason why the majority of the respondents deem the Dwars River important for agricultural use can be attributed to the fact that Ceres is not only synonymous with the fruit juice of the same name, but is an important agricultural town surrounded by export-orientated fruit farmers. The town is situated on a fertile plain and is one of the country's most important deciduous fruit growing and wine producing centres. Intensive agricultural areas are located along the Dwars River's banks with fruit and vegetable production being key economic activities within the area. Fruit farming contributes to more than 50% to the Gross Farming Income making Ceres one of the major fruit growing areas in the UBCMA. It is clear that agriculture not only forms the backbone of the local economy, the Witzenberg Valley also relies on the industry to feed its people. The Dwars River plays a significant part in the local economy and water is abstracted from different parts of the river in unmeasured quantities for irrigational purposes as well as for domestic and industrial use (DWAF, 2011).

4.3.1.3 Microbiological water quality monitoring of the Dwars River

Respondents were asked (See Question 2.3) if they were involved in activities relating to the microbiological water quality monitoring of the Dwars River. The reason for Question 2.3 is to add credibility or merit to previous and forthcoming answers. Based on the results (See Figure 4.2) obtained via the structured questionnaire, it is evident that the majority (78, 6%) of the respondents were involved with the monitoring of the Dwars River at some stage in their careers.

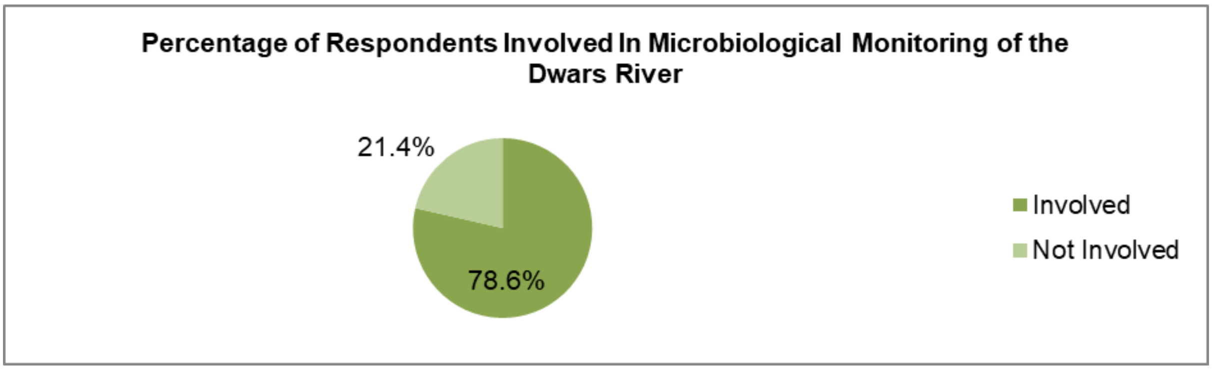


Figure 4.2: Percentage of respondents involved in the microbiological monitoring of the Dwars River

The residual 21.4% of the responsive group were either directly involved with the processing and/or dissemination of water quality related information applicable to the Dwars River in the past or came into contact with the river in one form or another.

4.3.1.4 Microbiological water quality of the Dwars River

Question 2.4 allowed respondents to describe their opinion of the microbiological water quality of the Dwars River. 86% of the respondents (See Figure 4.3) were of the opinion that the microbiological quality of the Dwars River's water is poor.

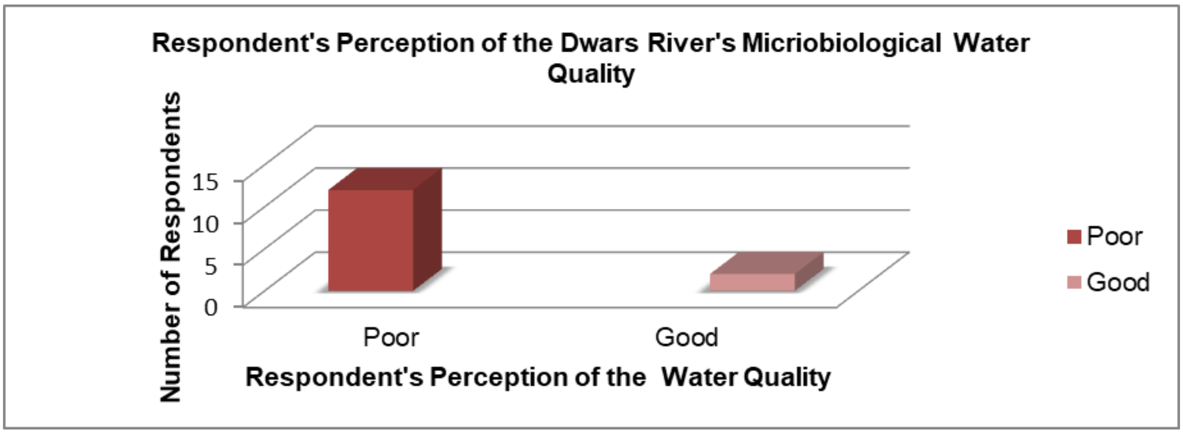


Figure 4.3: Respondents' perception of the Dwars River's microbiological water quality

Subsequent to a number of surface water quality assessments being performed at predetermined sampling points (See Figure 4.4 and 4.5), it was reported that the microbiological water quality of the water which the Dwars River carries is alarmingly poor and does not conform to the recommended minimum requirements specified by the South African National Standards, the World Health Organisation, the PPECB, GLOBALG.A.P, and the SAWQG for drinking water quality, livestock watering, recreational use, and agricultural use (CWDM, 2010:19). Microbiological compliance rates for the water samples collected from the Dwars River's water between 2008 and 2011 for use on irrigation equipment amounted to 89.66%, 68.6% for irrigation of fruit trees and grapes, 60.92% for export irrigational purpose, 60.5% for livestock watering purposes, 37.66% for recreational use, 33% for livestock watering, 1.16% for irrigational purposes, and 0.58% for domestic purposes or drinking water[2] (CWDM, 2010:19). Current data suggests that the Dwars River's water quality has somewhat improved, however, the monitoring frequency and sampling locations have been reduced. Further research conducted by the CWDM and the DWS as well as current information provided by BGCMA, proves that the situation regarding the water course's pollution remains a concern. Figures 4.6 to 4.13 have been generated from

[2] Water samples were collected and analysed by an accredited laboratory as part of BRIP. Data procured through analyses was compared to microbiological requirements listed in SANS and Water Quality Guidelines to establish compliance of samples taken. Compliance rates were expressed in percentage (percentage of samples collected and analised that conformed to microbiological requirements).

BGCMA's Dwars River surface water quality related data sets, which includes microbiological surface water quality sampling results, presented on Microsoft Excel spread sheets which were analysed and summarised (BGCMA, 2019).

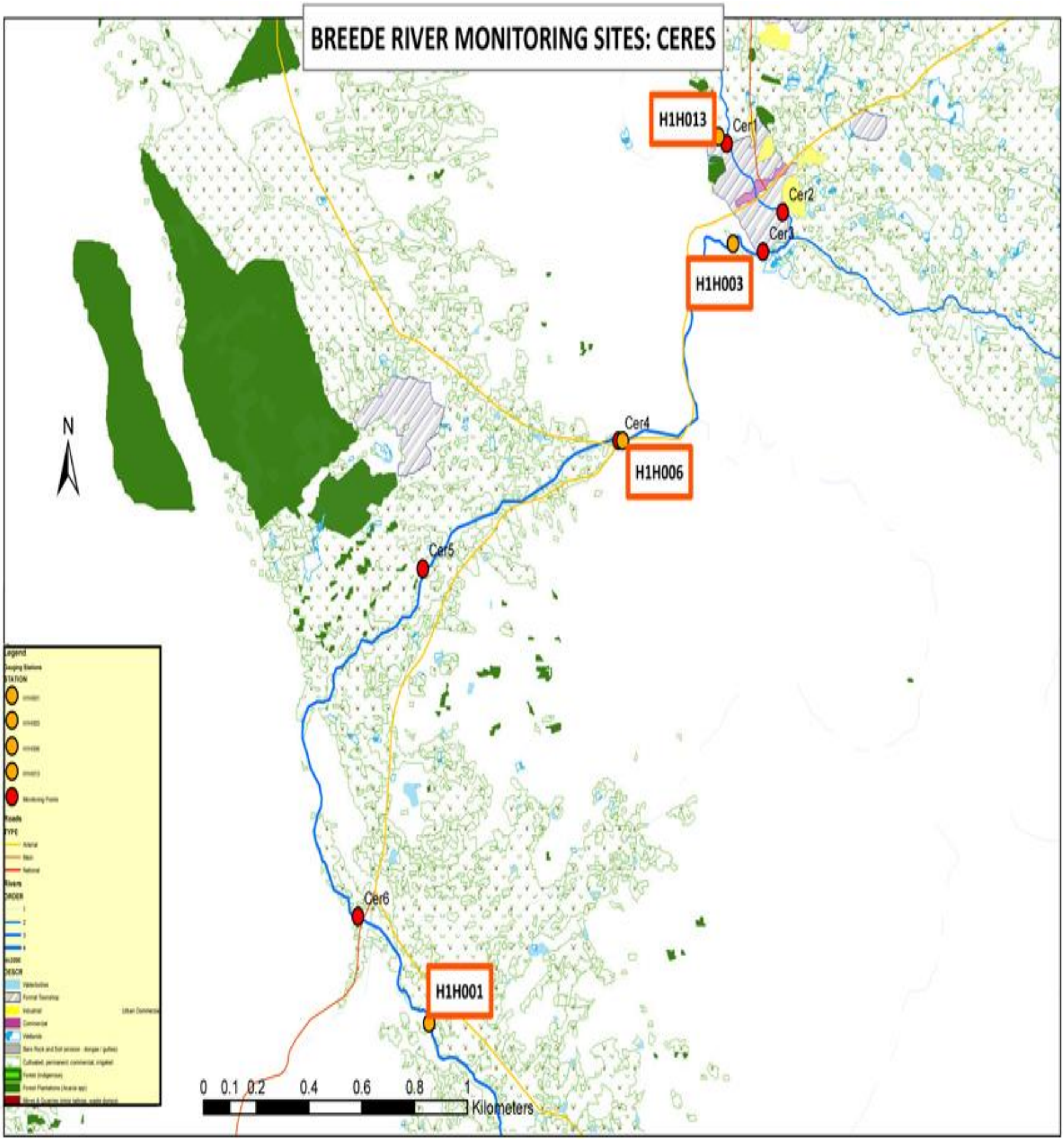


Figure 4.4: BGCMA's sampling points along the Dwars River (Breede-Gouritz Catchment Management Agency, n.d)

Figure 4.5: Sampling points along the Dwars River (BGCMA, n.d)

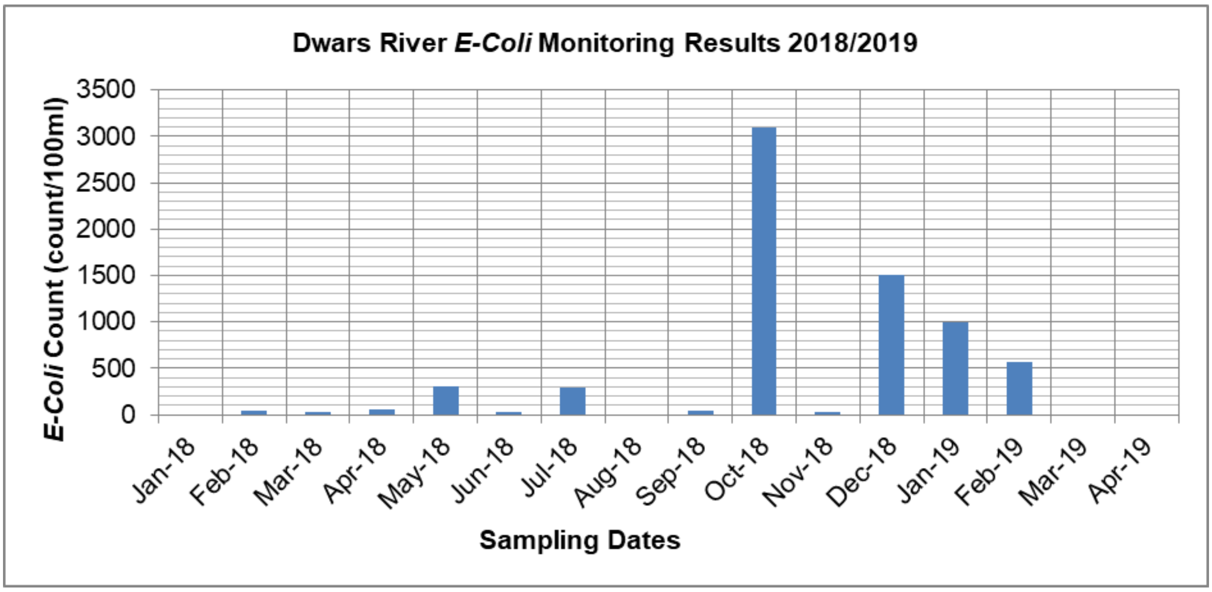


Figure 4.6: The 2018-2019 *E-Coli* per 100ml results for samples taken in the Dwars River. No Samples taken during the month of January and August 2018 (BGCMA, 2019)

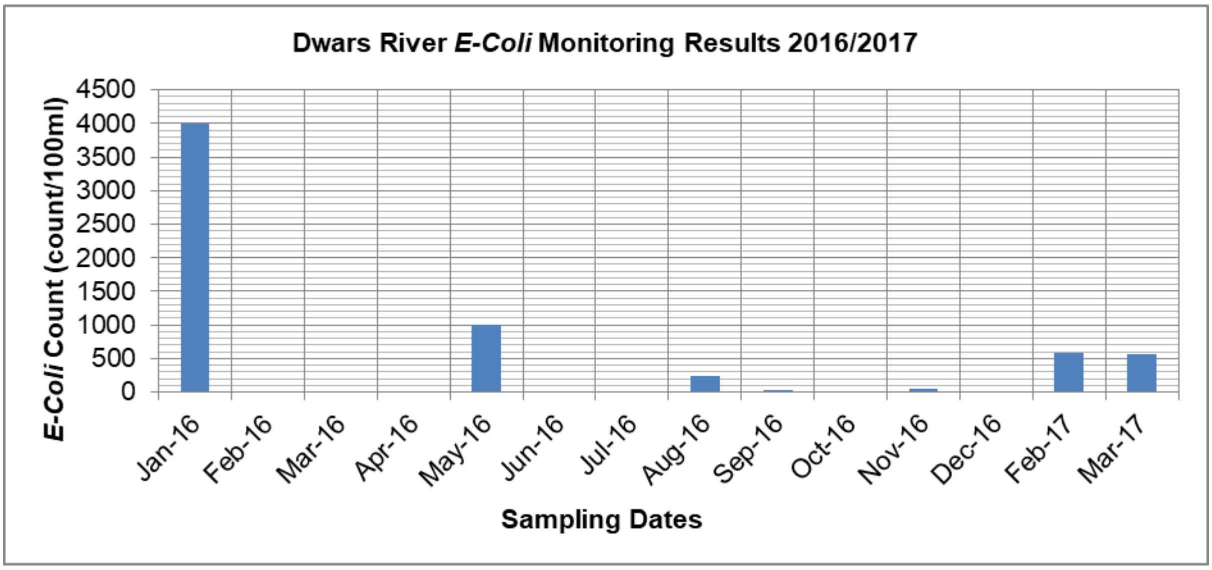


Figure 4.7: The 2016-2017 *E-Coli* per 100ml results for samples taken in the Dwars River. No Samples taken during the month of April, June, July, October, and December (BGCMA, 2017)

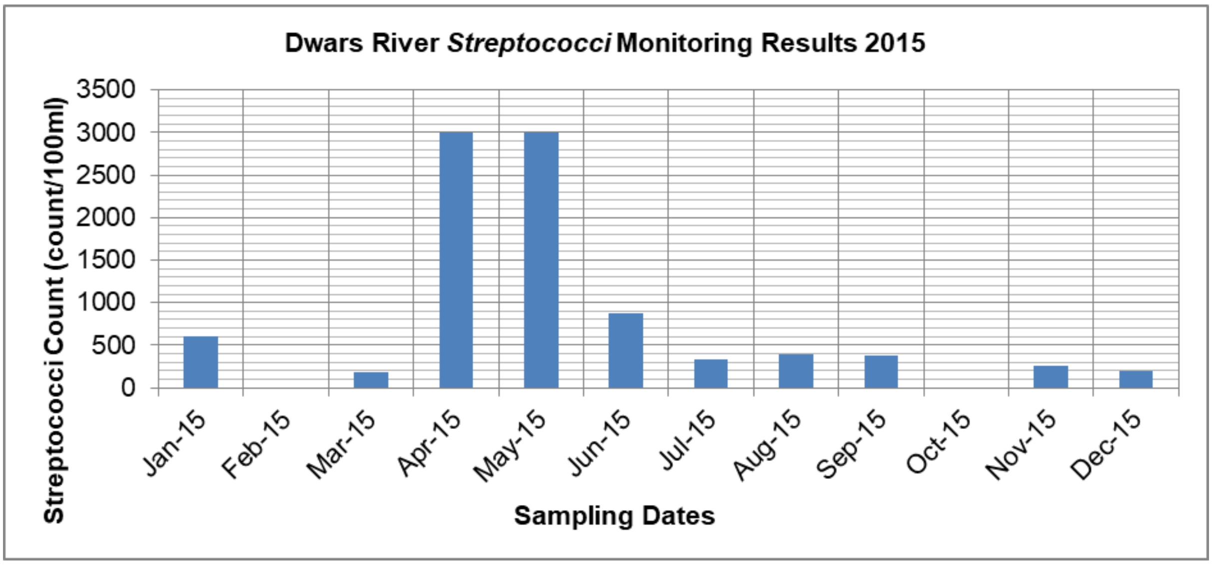


Figure 4.8: The 2015 faecal streptococci per 100ml results for samples taken in the Dwars River (BGCMA 2015)

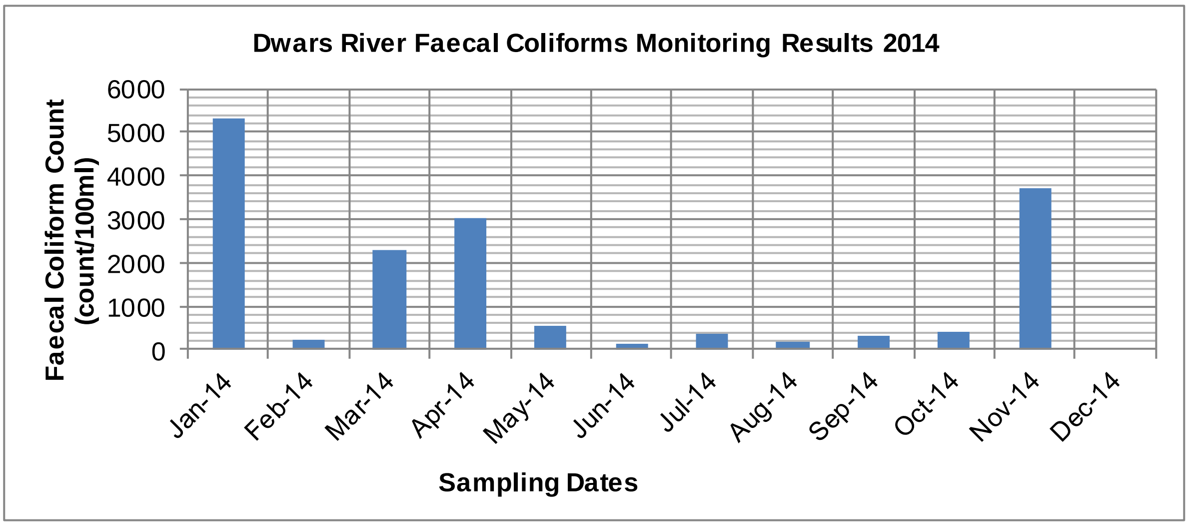


Figure 4.9: Faecal coliforms per 100ml results for samples taken in the Dwars River (BOCMA, 2014)

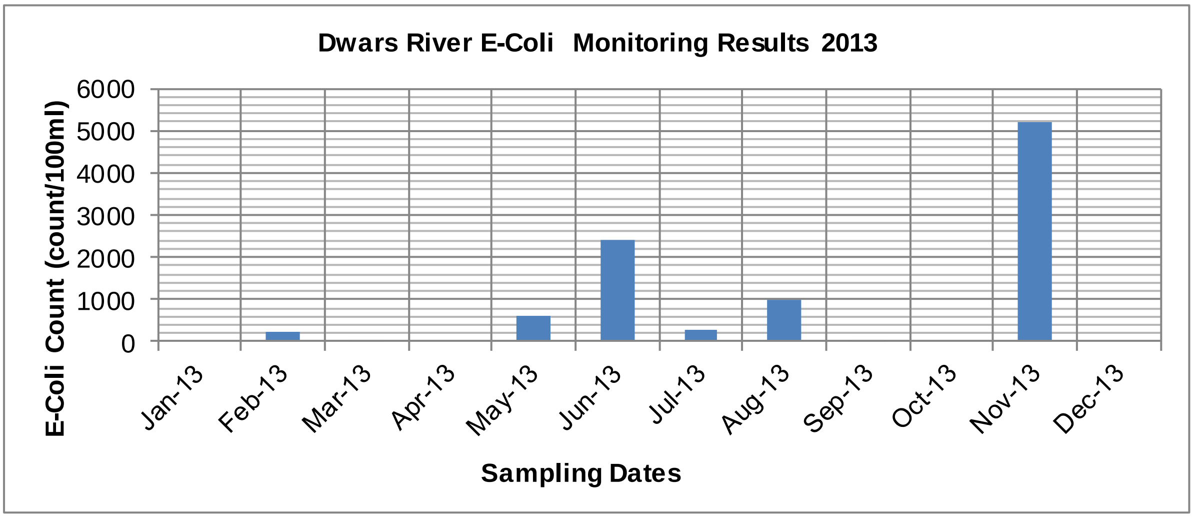


Figure 4.10: The 2013 *E-Coli* per 100ml results for samples taken in the Dwars River (BOCMA, 2014)

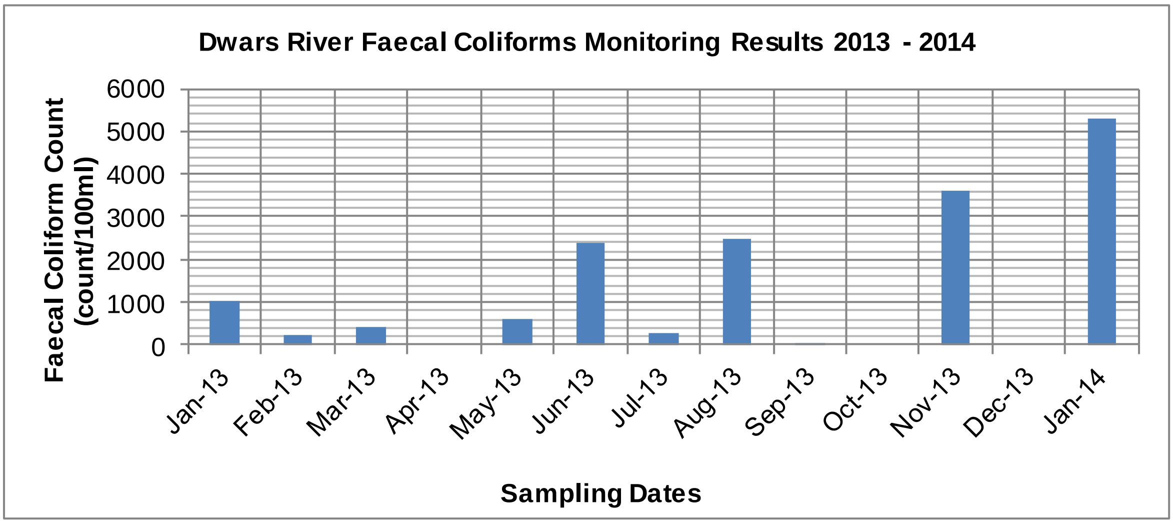


Figure 4.11: The 2013 *E-Coli* per 100ml results for samples taken in the Dwars River (BOCMA, 2014)

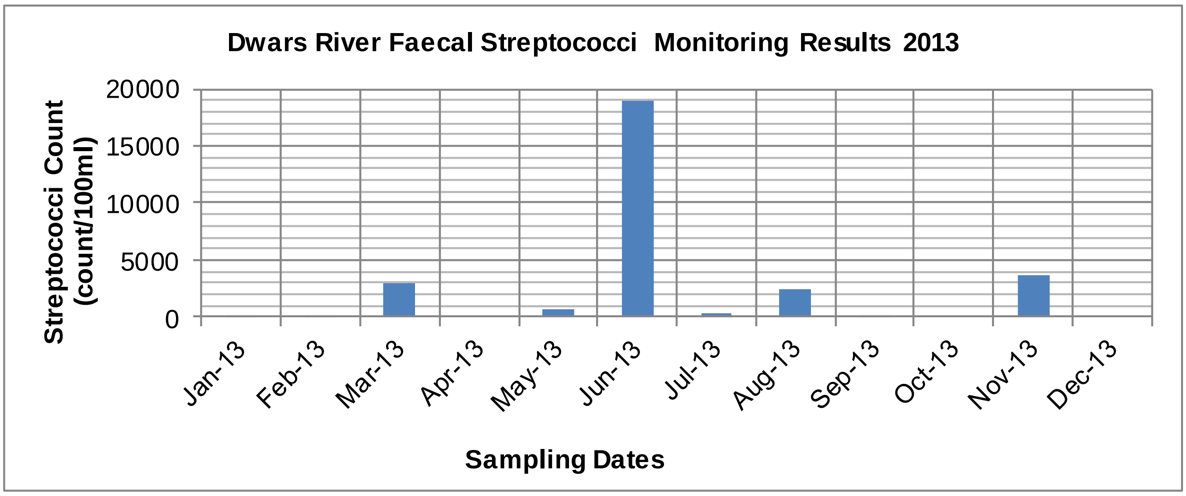


Figure 4.12: The 2013 faecal streptococci bacteria per 100ml results for samples taken in the Dwars River (BOCMA, 2014)

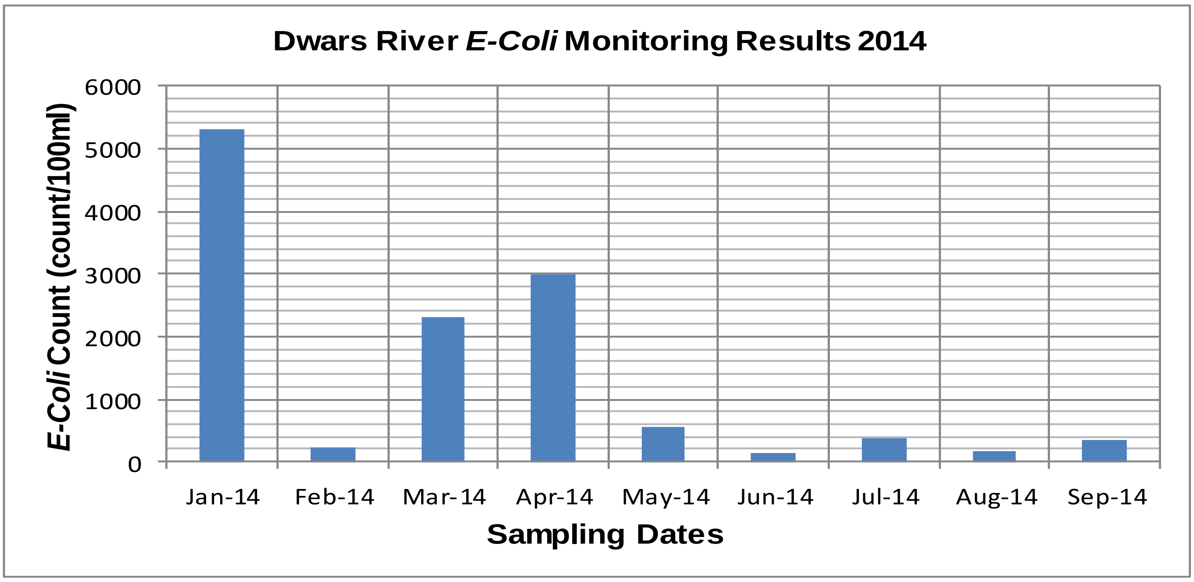


Figure 4.13: The 2014 *E-coli* per 100ml results for samples taken in the Dwars River (BOCMA, 2014)

As part of Question 2.5 of the questionnaire, participants were also asked to elaborate as to why they believe the Dwars River's water quality to be either good or poor.

Table 4.3: Reasons for stating why the Dwars River's water quality is either good or poor

Category	Reason	Selected Responses	Respondent
Good	Complies with Standards	"River water quality sample results comply with relevant standard"	RS 1, RS 2
Poor	Noncompliance with Standards	"The river water's *E. coli* count exceeds the allowable limit for irrigation, especially in late summer"	RS 3, RS 7, RS 8, RS 11, RS 12, RS13, RS 14
	Faecal Pollution	"Faecal pollution also enters the Dwars River at various points such as the WWTW's".	RS 5, RS 3, RS 6, RS 7, RS 8, RS 10, RS 13, RS 14, RS 4, RS 5
	Fish Mortality	"witnessed fish mortality from time to time"	RS 10, RS 12
	Illness	"I got sick twice after entering the Dwars River"	RS 9
	Smell	"You could smell the water. It smelt like human excrement"	RS 9

Table 4.3 reveals that faecal pollution and noncompliance with relevant standards are the main reasons why the majority of the respondents consider the Dwars River's water quality to be poor, while "Complies with Standards" dominates the "Good" category. Members of the general public has also expressed their concern regarding the Dwars River's heavily polluted water (Rivett, 2012). The river has subsequently been labelled as the "ugly duckling" of the Cape Rivers (Reinders, 2012) due to its bad reputation. People have even gone so far as to warn others from entering the river (Playak, 2009) and some have publically declared that they have fallen ill after spending time in the watercourse (Chaplin, 2013). One respondent said "I got sick twice after entering the Dwars River on my river board and kayak. My partner got sick as well. The doctor confirmed that it was a bacterial related illness, and we were given a broad-spectrum antibiotic".

Previous and contemporary surface water pollution orientated research has proven that the persistent pollution of surface water bodies is most certainly a reality and deemed a serious problem in both developed and developing countries (Afroz et al., 2014). Data collected suggests that pollutants deteriorate the quality of ambient water bodies and impacts negatively on the sustainability of these sources rendering it unsuitable for domestic and industrial use, irrigation and aquatic life (Genthe et al., 2013; Raji et al., 2015). Essentially, as surface waters become more and more polluted due to the constant inflow of faecal matter it becomes less attractive to be exploited as a resource (Afroz et al., 2014). Therefore, it has been put forward that faecal pollution of surface water systems therefore exacerbates existing complications associated with the quality of surface waters by increasing the amount of pressure on an already over utilised and limited resource (Naidoo and Olaniran, 2013).

4.3.1.5 Sources of faecal pollution along the Dwars River

In Question 2.6 of the questionnaire, participants were asked if they were aware of any sources of faecal pollution along the Dwars River and as illustrated by Figure 4.14, thirteen of the fourteen respondents confirmed that they are aware of pollution sources with the potential of contributing to the faecal contamination of the Dwars River.

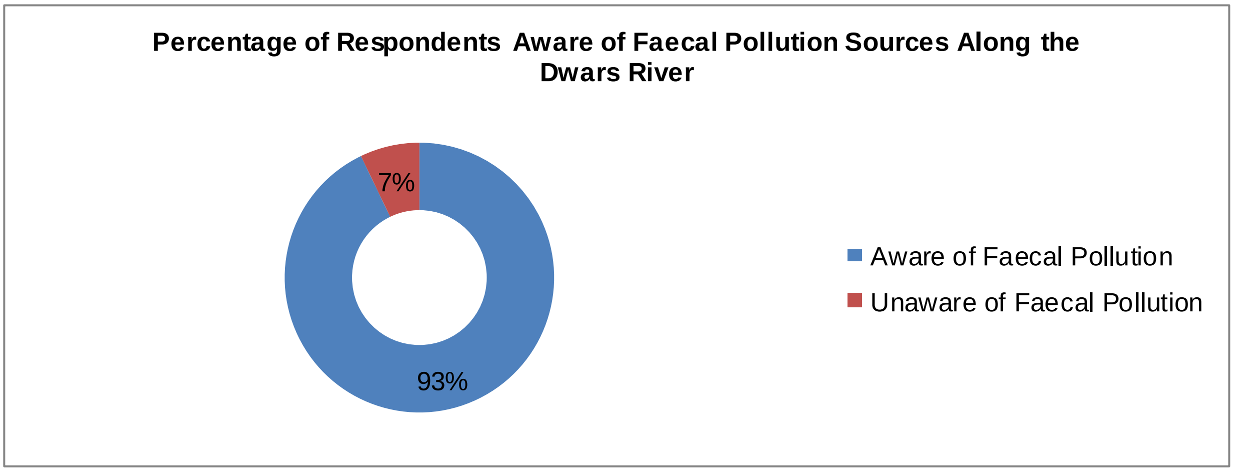


Figure 4.14: Proportion of respondents aware of pollution sources along the Dwars River

To gain additional information, in Question 2.7 respondents were given the opportunity to describe the sources of faecal pollution that they were aware of during the time the questionnaire was conducted. One of the respondents commented, “Tourists stopping at the Witbrug and members of the community socialising next to the river defecate in the water. Members of the community wash their clothes, nappies etc. in the river and the stormwater from the town and the WWTW definitely reduces the microbiological quality of the river water”. The remaining respondent was not aware of any specific pollution sources along the Dwars River during the time the questionnaire was completed. Nonetheless, the remaining respondent was of the opinion that faecal pollution is in fact occurring. Pollution sources identified by the respondents (See Table 4.5) have been divided into two super groups, namely, point source and non-point sources of faecal pollution.

Table 4.4: Known sources of pollution along the Dwars River

Category	Source	Selected Response	Respondent
Point source pollution	Ceres's WWTW	"Ceres's WWTW is a known source of pollution"	RS 2, RS 1, RS 4, RS 5, RS 9, RS 10, RS 11, RS 12, RS 13, RS 14
	Pump Stations	"pump stations which can overflow but which have been provided with backup generators"	RS 1, RS 4, RS 5, RS 7, RS 8
	Polluted Tributaries	"at least two of the Dwars River's tributaries, one of which flows passed the informal settlement, contribute to the faecal pollution of the Dwars River" "Members of the community wash their clothes, nappies etc. in the river"	RS 4 RS12
	Polluted Canals	"polluted canals leading from farms"	RS 7, RS 8
Non-point source pollution	Irrigation	"unmonitored use of untested final effluent on sport fields for irrigation purposes can contribute to faecal pollution"	RS 1, RS 2, RS 10
	Stormwater Runoff	"Stormwater runoff from Ceres" "runoff from mainly industrial areas" "Runoff from informal settlements" "stormwater blockages"	RS 5, RS 4, RS 1, RS 11, RS12, RS 6, RS 7, RS 8
	Agricultural Activities	"faecal polluted runoff from livestock farming activities"	RS 8, RS 6, RS 7
	Septic Tanks	"septic tank overflows"	RS 7, RS 8
	Defecation	"Tourists stopping at the Witbrug and members of the community socialising next to the river defecate in the water"	RS 12

Based on the information gathered from the responses received to Question 2.7, Ceres's WWTW and sewage pump stations are known point sources of faecal pollution in the Dwars River with 10 of the 14 respondents listing the sources as a definite concern. Stormwater runoff and runoff resulting from agricultural activities are the two non-point sources of faecal pollution which were mentioned when conducting the questionnaires. In addition to this, pollution related complications currently experienced in the Witzenberg Municipal Area have been attributed to the fact that the area's river systems are running through densely inhabited residential areas. Various industrial plants and factories are also adjacent to the river and cause contamination one way or the other. Rivers such as the Dwars River flow through extensive agricultural lands and the contaminated runoff is causing major pollution of the river systems (Witzenberg Municipality, 2017). Other suspected sources such as the irrigation of sports fields and so forth by means of WWTW effluent and pollution from households along the river were also pointed out in these surface water quality related reports (CWDM, 2010).

Surface water quality related reports compiled by officials of DWS, BGCMA and CWDM revealed that faecal coliforms, *Escherichia coli* and faecal streptococci were and are being introduced into the Dwars River at levels far greater than the prescribed limits listed in relevant standards and guidelines. As a result, thousands of people are at risk of being exposed to disease-causing organisms. According to the reports, the situation can mostly be attributed to frequent faecal pollution incidents. Ceres' WWTW was identified as one of the main sources of faecal pollution and warrants further investigation as mentioned in the recommendations (See Section 5.3). The surface water quality related reports also suggests that the water samples taken from sampling points along the Dwars River located upstream of the wastewater treatment works' effluent outflow showed coliform counts that were even higher than the said effluent's readings (CWDM, 2010, BGCMA, 2019).

4.3.1.6 Major microbiological surface water quality concerns for public and environmental health along the Dwars River

Question 2.8 was incorporated to establish what the respondents consider to be the major factors or causes, from a faecal pollution perspective, that are of particular concern and detrimentally impacts on the Dwars River's water quality. The findings are illustrated in Table 4.6 as well as Figure 4.15.

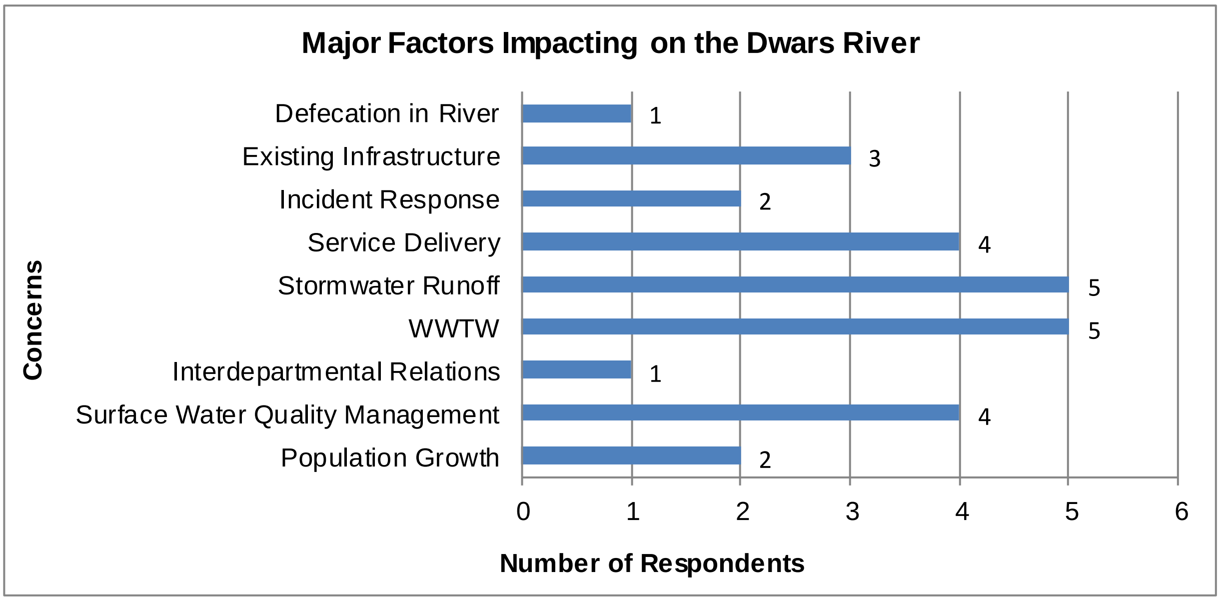


Figure 4.15: Major Microbiological Surface Water Quality Concerns for Public and Environmental Health along the Dwars River

Data captured revealed that the respondents had different views regarding the surface water quality concerns along the Dwars River. According to Figure 4.15, 38% of the respondents considered the management and operation of the local wastewater treatment works as well as stormwater runoff to be of particular concern. The forenamed factors are followed closely by municipal service delivery and surface water quality management at 29%.

Table 4.5: Major Microbiological Surface Water Quality Concerns

Water Quality Concerns	Selected Responses	Respondent
Population Growth	"The current infrastructure cannot cater for the current population size" "Due to the current population size, the informal settlements do not have the required sanitation facilities"	RS 1 RS 5
Surface Water Quality Management	"Integrated Water Resource Management currently doesn't exist" "No proper enforcement of legislation by DWS"	RS 2 RS 5, RS 1, RS 13
Interdepartmental Relations	"we often struggle to get hold of DWS employees to report non-compliances, request information etc." "internal politics within the DWS prevents problem areas from receiving the necessary attention"	RS 1
Wastewater Treatment Works	"the sewage works in the area" "poor management of the local WWTW"	RS 3, RS 10 RS 4, RS 13, RS 14
Stormwater Runoff	"Constant stormwater runoff from informal settlements" "Stormwater runoff running through town and into the river"	RS 6, RS 7, RS 8 RS 11, RS 12
Service Delivery	"incident rehabilitation response time associated actions taken are problematic" "Witzenberg Municipality's service delivery"	RS 5, RS 1 RS 4, RS 10
Incident Response	"incident rehabilitation response time and actions taken are problematic"	RS 5, RS 1
Existing Infrastructure	"associated infrastructure is not adequate to cope with current loads"	RS 10, RS 1, RS 5
Defecation in River	"people as well as animals defecating in the river"	RS 12
Unsure	'No idea"	RS 9

Data in Table 4.5 illustrates that the water quality related concerns highlighted by the respondents are focused on the act of pollution rather than the potential outcomes associated with the faecal contamination of surface water sources. Based on existing information, the persistent faecal pollution of surface waters is a common phenomenon and has a long list of serious detrimental consequences (Allevi et al., 2013; Frey et al., 2013; Marti et al., 2013). Data collected during epidemiological studies indicate that faecal pollution poses public health risks, has the potential to create environments detrimental to aquatic ecosystems, affects freshwater availability, and impacts negatively on the economy (Vincy et al., 2015).

4.3.1.7 Impact of the Dwars River's current microbiological quality on public health and/or the natural environment

Respondents were asked whether the current microbiological water quality of the Dwars River is adversely affecting local community's health and/or the natural environment (See Question 2.9 and 2.10 of the Questionnaire). Of the responses (See Figure 4.16), only four participants stated that the current state of the Dwars River poses no threat to the human population in the area or to the existing environment.

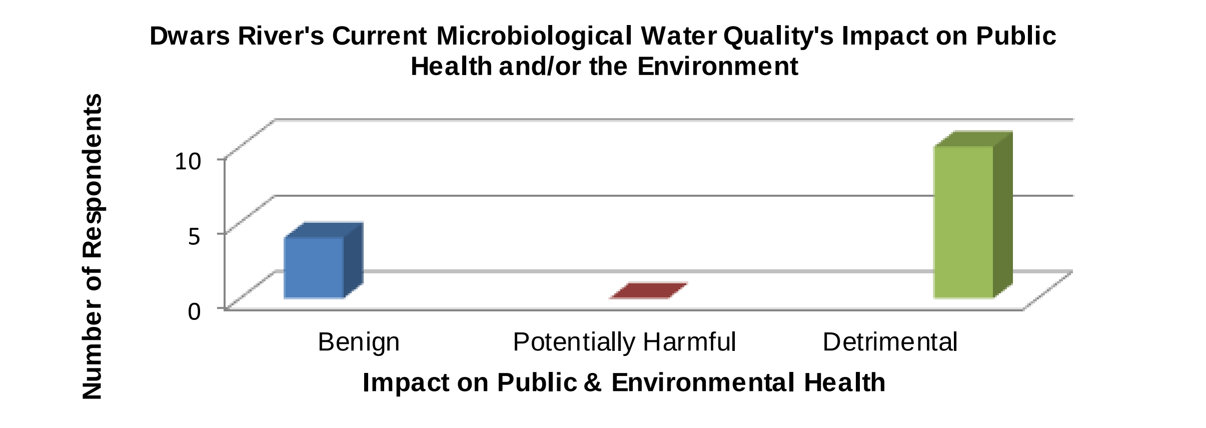


Figure 4.16: Impact of the Dwars River's current microbiological quality on public health and/or the environment

The respondents, which includes downstream users, were also asked as part of Question 2.9 to state why they regarded the impact(s) as being benign, potentially harmful, or detrimental. One of the respondents who was of the opinion that the impact is detrimental commented, "It damages the ecosystem as can be seen with the fish deaths and we cannot use the water for farming activities due to its poor biological quality which means the resource is wasted". Another respondent said, "The persistent faecal pollution of the Dwars River definitely has a negative impact on farmers downstream towards Wolseley and those individuals residing along the river in Mitchells Pass". The replies were grouped together into relevant categories and are summarised in Table 4.6 below.

Table 4.6: Impact of the Dwars River's current microbiological quality on public health and/or the environment

Impact	Reason	Selected Responses	Respondent
Benign	Sample Results	"River water quality sampling results comply with relevant standards"	RS 1
		"The microbiological quality of the Dwars River complies with relevant standards"	RS 2
	System Flushed	"problem is solved locally by flushing the system with water from the dam"	RS 4
Detrimental	Public Health Risk	"huge public health risk" "affecting the quality of life of the community"	RS 5, RS 7, RS 8, RS 9, RS 13, RS 11, RS 10
	Degradation	"can cause irreparable damage to the natural environment" "significant impact on health of the river"	RS 6, RS 12 RS 7, RS 8
	Agricultural Practices	"affects the agricultural practices downstream"	RS 12, RS 13, RS 14
	Water Availability	"community in the area won't be able to use the river's water for whatever purpose"	RS 10, RS 11, RS 12

The presence of FIB in the Dwars River signifies faecal pollution and the possible presence of pathogenic microorganisms. The surface water quality reports compiled by the CWDM and the datasheets provided by the BGCMA clearly indicate that these bacteria are constantly present at high levels in the Dwars River. Surface water sources such as the Dwars River serve as an inert carrier of such pathogenic microorganisms (Verlicchi et al., 2020) and according to the BGCMA, “the consequences of not addressing this water quality challenge are profound given that about half of the deciduous fruit and table grapes cultivated in the Upper Breede River Area are exported from South Africa and about a quarter goes into the higher end domestic market” (BOCMA, 2010). Setting the economic aspect aside, the significance of using contaminated surface water containing microbial pollutants and specific pathogens, such as *Escherichia coli*, is that it can bring about diarrhoea in humans and animals and may even give rise to the outbreak of water-related diseases such as typhoid fever, cholera, shigellosis, hepatitis, jaundice fever, and amoebiasis. Globally, an estimated 1.2 million people died as a result of unsafe water sources in 2017 and “exposure to pollutants will increase dramatically” in these countries (Ritchie, 2019; WWAP, 2018; Olalemi, 2020:93). Therefore, faecal pollution of Dwars River’s water can have serious consequences, placing members of the Witzenberg community and those individuals who are directly or indirectly exposed to its water and disease-causing organisms at risk of contracting a water-related disease. Environmental Health Practitioners from CWDM considers the poor microbiological quality of the Dwars River a major dilemma due to the fact that faecal pollution associated with human activity, livestock, and wild animals contain various disease-causing pathogens (CWDM, 2010). According to Schachtschneider (2016:8), “deteriorating water quality is a real risk to the agricultural sector. Should the sector ever lose a market due to a water-quality scare, it will impact on the labour market and the well-being of the urban Ceres Valley residents” (Schachtschneider, 2016:8).

The connotation between faecal contamination of surface water systems and associated introduction of pathogenic organisms has long been a significant water quality and public health issue. The health risk involved is linked to human exposure to these faecal contaminated surface water bodies. Previous studies have, for example, established that direct contact with and/or consumption of surface water contaminated with faecal matter can lead to the transmission of waterborne, water-washed, and water-related disease, water-based infections and even death (Richards et al., 2015). The reason for this is that surface water systems act as reservoirs and distribution networks for a variety of disease-causing bacteria, protozoa, trematodes, and viruses (Bhardwaj et al., 2015).

Exposure to disease causing pathogens, either by consumption or contact activities, has led to countless water-related disease outbreaks (Marti et al., 2013). According to the World

Health Organisation's (WHO) protecting surface water for health 2016 report, 842 000 people die each year due to their exposure to unsafe surface water and 58% of these deaths are caused by diarrhoea. Approximately 361 000 of these deaths occur in children aged under 5 years (WHO, 2016). The United Nations Children's Fund's (UNICEF) research shows that 4000 children die each day as a result of their exposure to faecal contaminated water (UNICEF, 2014). Statistics such as these provide evidence that disease causing microorganisms, examples of which are listed in paragraphs below, are a major public health threat resulting in their understanding becoming essential to safeguard communities against the spread of pathogenic diseases (Osuolale et al., 2015).

4.3.1.8 Institutions involved in the microbiological water quality management of the Dwars River

Respondents were asked in Question 2.11 which institutions are involved in water quality management along the Dwars River. After conducting the questionnaire, it was obvious that all the respondents that replied were aware of at least one institution playing a role in the microbiological water quality management of the Dwars River. From the statistical analysis (See Figure 4.17), the majority of the respondents believe that Witzenberg Municipality and the Department of Water and Sanitation perform functions related to surface water quality management.

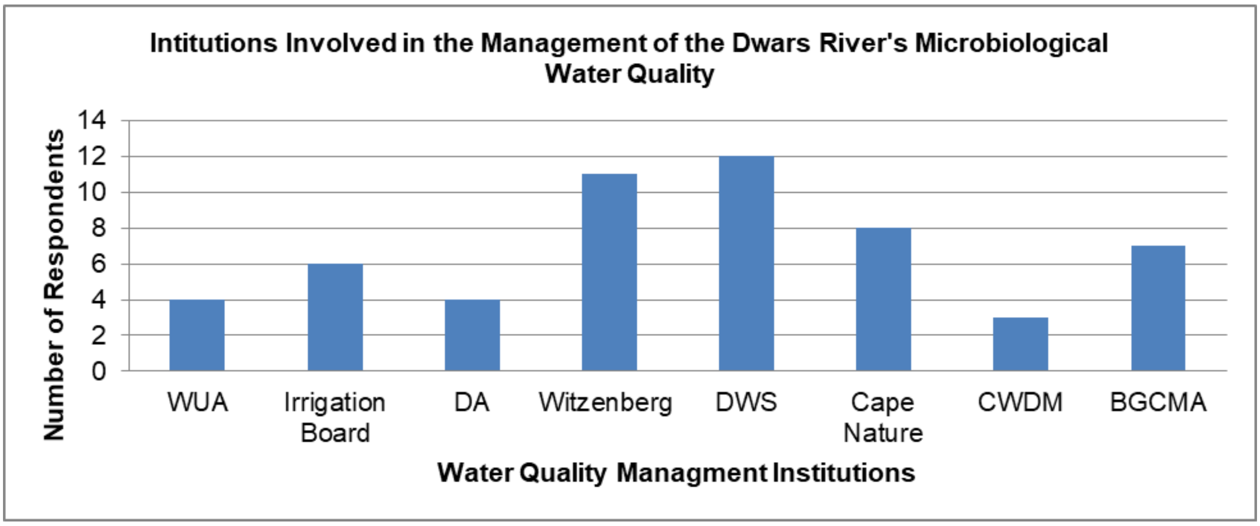


Figure 4.17: Institutions involved in water quality management along the Dwars River

In November 2007, Breede-Overberg Catchment Management Agency (BOCMA) now known as the Breede-Gouritz Catchment Management Agency (BGCMA) became the second operational CMA in South Africa. BGCMA was established in line with the conditions of the National Water Act, 1998 (Act No. 36 of 1998) and was entrusted with water resource and quality management responsibilities within its jurisdiction for the benefit of everyone living in the area (BOCMA, 2013:7). BGCMA then, as a CMA, became accountable to the Minister of Department of Water and Sanitation but reported through the Western Cape regional office of Department of Water and Sanitation (DWAF, 2011). One of the inherent responsibilities of the BGCMA is water resource protection through the continued assessment of water quality and to simultaneously devise strategies to protect water resources under their control and the compilation of a Catchment Management Strategy (BGCMA, 2017). The Witzenberg Municipality's aim is to make great strides in service delivery through the improvement of water quality and waste management with the objective of becoming a competitive premium tourism destination and a first-rate investment option for the agricultural and business sectors (BGCMA, 2013). Two of their key performance areas include the management of main pipes and pump stations and water pollution control (DWS, 2017).

4.3.2 Surface Water Quality Management Strategies

Section 3 of the questionnaire, consisted of thirteen questions developed to gain some insight into the sample populations' perception, knowledge and understanding of the water quality management system and strategy implemented within the study area.

4.3.2.1 Existing surface water quality management strategies

In this section of the questionnaire, respondents were verbally explained, prior to proceeding with the section's questions what a water quality management strategy as well as a catchment management strategy is and what it entails. They were subsequently questioned (See Question 3.1) regarding whether or not they are aware of a surface water quality orientated management strategy being developed or if they are aware of an established surface water quality management strategy that is currently being implemented for the area through which the Dwars River flows (i.e. the Upper Breede River Catchment Area).

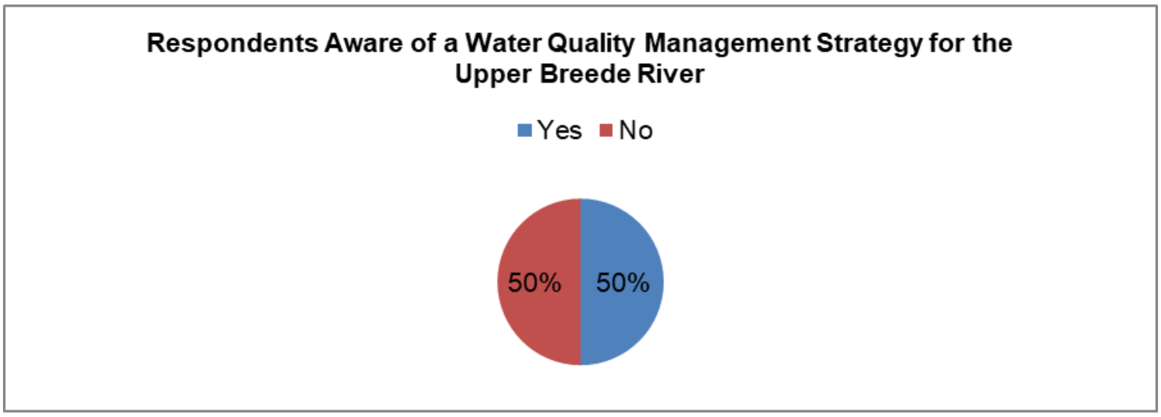


Figure 4.18: Proportion of respondents aware of pollution sources along the Dwars River

According to Figure 4.18, only 50% of the participants are aware of a surface water quality orientated management strategy being developed for sections of the Breede River which included the Upper Breede River Area. None of the respondents were of the opinion that the surface water quality management strategy is actively being implemented. The remaining

50% consider the water quality management strategy to be non-existent. As part of Question 3.2, the respondents who stated that they are aware of the area specific surface water quality management strategy were also requested to provide their view regarding the degree to which the strategy has been implemented to date (See Table 4.7). Respondents who claim not to have knowledge of the surface water quality management strategy were asked to provide their viewpoint as to why a surface water quality management strategy has not been developed, established and/or implemented for the Upper Breede River Catchment Area. Question 3.3 allowed those respondents who were not aware of a surface water quality management system for the area to provide their opinion as to why such a strategy has not been developed.

Table 4.7: Status of the Catchment Management Strategy

Category	Phase	Selected Responses	Respondent
Developed	Established	“The situation analysis for the CMS has been conducted, vision and goals formulated, objectives have been formulated and steps have been taken in order to reach objectives.”	RS 2
	Draft Stage	“Since the change from BOCMA to BGCMA there has been a draft CMS compiled and made available, but it is still in its developmental and public participation stage”	RS 1, RS 3, RS 14
	Unsure	“Unsure as to the status of the strategy’s implementation”	RS 8, RS 7, RS 6
Non-Existent	Not Required	“No need for a CMS as opposed to water stressed areas where quantity and quality is an issue.” “the water source has not been identified as being an area of concern” “I’m not sure if a CMS is required for this area or not, but I would say that there is not enough interest in the river pollution or awareness of the current state of affairs to warrant something such as an area specific CMS”	RS 4 RS 2 RS 13
	Unsure	“We have never been involved with the development of any CMS”	RS 5, RS 9, RS 10, RS 11, RS 12

The BGCMA has developed a draft CMS that makes reference to a water quality management plan. The CMS is a framework for water resource management in the water resource management area, and establishes the “principles for allocating water to existing and prospective users, considering all matters relevant to the protection, use, development, conservation, management, and the control of water resources (South Africa, 1998:23-24). The newly developed draft plan took into consideration the previous draft CMS for and BGCMA is currently in the final phase of the development of its overarching strategy document (BGCMA, 2017). The development and implementation of a surface water quality management strategy is instrumental in addressing water quality deterioration (DWS, 2015). Based on the information gathered, it can be deduced that the surface water quality management strategy or CMS has not been or is not being implemented, implemented partially or, even though the opposite is the case, according to some respondents the CMS simply does not exist.

4.3.2.2 Surface water quality management component of the water quality management strategy

Questions 3.4 to 3.8 were directly related to specific details regarding the water quality management strategy. Only respondents who were aware of and/or familiar with the contents of the water quality management strategy were encouraged to answer these questions. This group who answered questions 3.4 to 3.8 represented 50% of the responsive population.

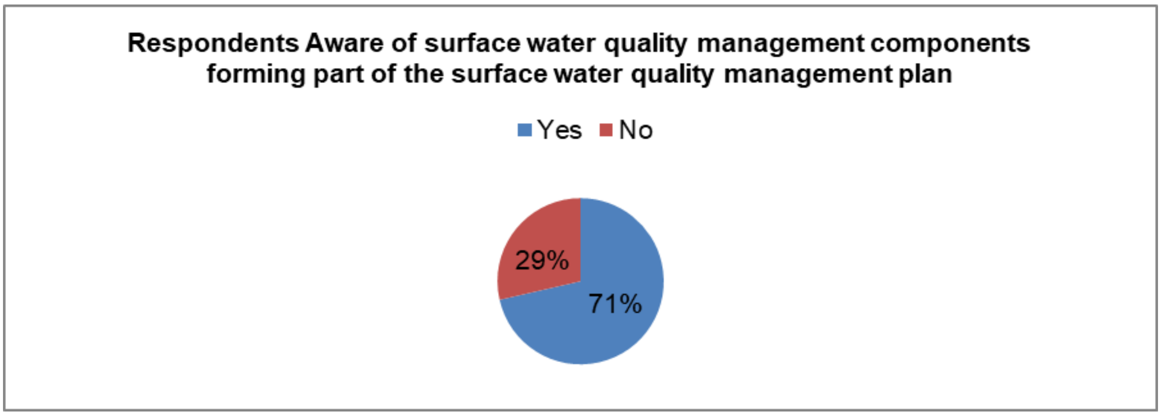


Figure 4.19: Proportion of respondents aware of surface water quality management components

The CMS does include water quality orientated management components such as details regarding programmes to monitor Resource Quality Objectives (RQOs), the management pollution control and emergency incidents and source-directed controls to achieve resource quality objectives (BGCMA, 2017). As per Figure 4.19, 71% of this group suggested that surface water quality management components do in fact form part of the surface water quality management strategy or CMS. None of the respondents could provide any specific details regarding the said surface water quality management components. All the respondents said that the surface water quality management components listed in water quality management strategies are not specific (See Table 4.8) to the Upper Breede River Catchment Area or the Dwars River for that matter. Respondents were also asked for their opinion as to why surface water quality management components are not area specific (See Table 4.9).

Table 4.8: Reasons why surface water quality management components are not area specific

Category	Selected Response	Respondent
Compliance monitoring	"The monitoring of rivers and response to spikes is what is being implemented at this stage"	RS 2
Response to incidents	"response to incidents is being implemented"	RS 1
Unsure	Unsure of the specific details	RS 7, RS 8
Maintaining the status quo	In the meantime, we are maintaining the Status Quo	RS 2

The fact that compliance monitoring is performed, noncompliance responded to and the current Status Quo being maintained was provided as reasons for the surface water quality management components not being resource or area specific.

4.2.2.3 Surface water quality objectives specific to the Dwars River

Under Question 3.9, respondents were asked if they are acquainted with any microbiological quality objectives and source management objectives specific to the Dwars River.

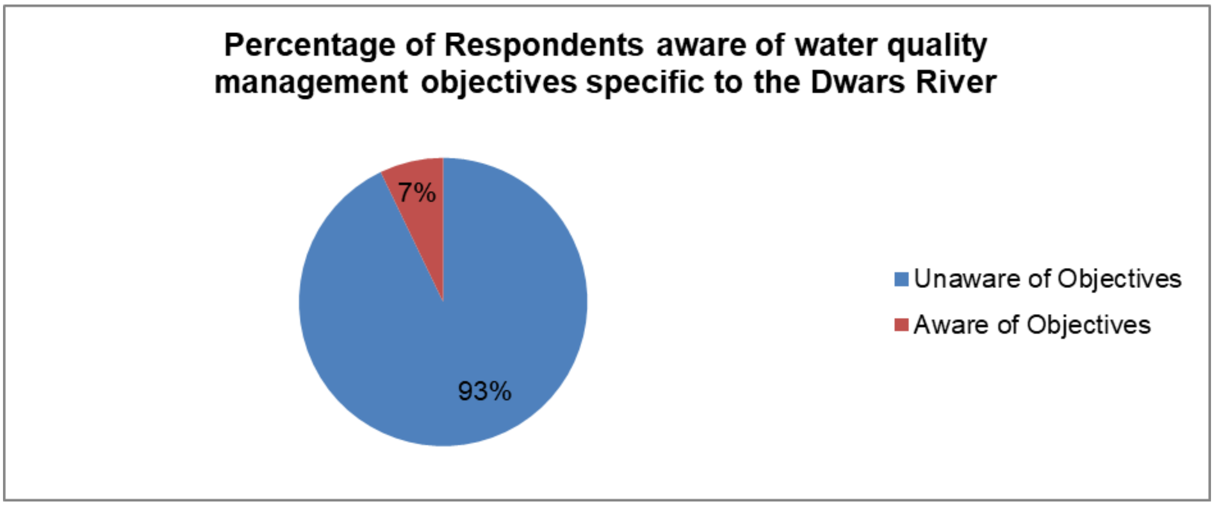


Figure 4.20: Percentage of respondents aware of water quality management objectives specific to the Dwars River

Thirteen (93%) of the respondents said they were unaware of any Dwars River specific surface water quality objectives (See Figure 4.20). The respondent who suggested that such objectives do in fact exist was unsure of details pertaining to these objectives. According to the CMS "the management objectives for water quality management and pollution control are to develop an integrated water quality management plan that will support improved compliance in municipal WWTW and collection systems; prioritise agricultural and industrial sources of pollution (specifically related to emerging contaminants) and identify specific management options for implementation". None of the water quality management objectives are specific to the Dwars River.

Question 3.10 requested respondents to provide particulars regarding the surface water quality objectives specific to the Dwars River currently in place. Question 3.11 of the questionnaire prompted respondents to provide their viewpoint as to why a water quality management strategy has not been developed, established, and/or implemented for the Upper Breede River Catchment Area. The data collected from Questions 3.10 and 3.11 have been included in Figure 4.21 and Table 4.10.

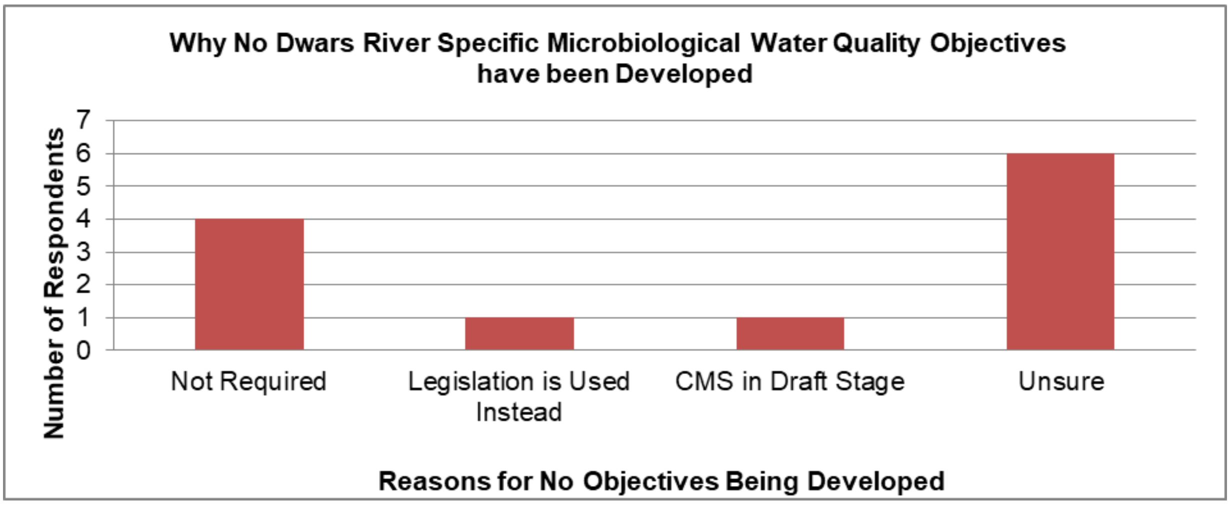


Figure 4.21: Reasons why no Dwars River specific microbiological water quality objectives have been developed

Table 4.9: Reasons why the reasons why respondents were of the opinion that no Dwars River specific microbiological water quality objectives have been developed

Category	Selected Response	Respondent
Legislation	"objective is to meet the requirements of relevant standards and legislation to accommodate fruit irrigation as well as contact recreation" "We use legislation and standards to ensure that the water quality remains compliant"	RS 2 RS 4
Not required	"There is in my opinion no need for specific objectives seeing that we monitor continuously" "objectives are not necessary since the Dwars River is not a problem area" "the water source is not deemed important enough"	RS 1 RS 4 RS 10
Unsure	"I am unsure of any details pertaining to the objectives"	RS 5, RS 6, RS 7, RS 8
Draft Stage	"this is due to the fact that the CMS is still in draft stage"	RS 14

Based on the data collected, no Dwars River specific microbiological water quality objectives have been developed according to the respondents. The majority of the respondents are unsure of why this is the situation; however, the data suggests that area specific microbiological water quality objectives are not required for the Dwars River due to legislation being enforced.

4.2.2.4 Needs and expectations of current and potential water users

As part of Question 3.12 and Question 3.13, respondents were asked if they were aware of the public, private and civil society stakeholders being engaged in the process to develop water quality management related policy, strategies, and implementation plans.

Table 4.10: Needs and expectations of current and potential water users taken into account during decision making and the development of the water resource management strategy

Number of respondents stating that the needs and expectations of current and potential water users were considered during decision making and the development of the water resource management strategy	3
Number of respondents stating that the needs and expectations of current and potential water users were not considered during decision making and the development of the water resource management strategy	11
Total	14

In accordance with the National Water Act, 1998 (Act No 36 of 1998), water quality management strategy related decision making must involve and "consider the needs and expectations of existing and potential water users" (south Africa, 1998:25). BGCMA states that the "CMS is a catchment document that has been developed by the Catchment Management Agency (CMA) with inputs from various stakeholders" and requires their feedback during the "proposal of General Authorisations for a particular water use or a specific catchment and so forth" (BGCMA, 2017:10-73). Data collected as part of Question 3.12 and Question 3.13 and depicted in Table 4.10 shows that the majority of the respondents believe that the needs and expectations of current and potential water users were not taken into account during any stage of the development of the water quality management strategy covering the Upper Breede River Management Area.

4.3.3 Surface Water Quality Management System

Section 4 of the questionnaire consisted of sixteen questions and analyses the aspect of the questionnaire that dealt with the surface water quality management system implemented in the region through which the Dwars River flows. The first element of this section probed the respondent's knowledge of such a system. Questions 4.1 to 4.6 focused on documentation such as surface water quality management plans, information management systems, implementation plans, guidelines, systems and/or procedures currently in place to assist with the management of the microbiological quality of surface water resources. The second part of this section probed the respondent's familiarity with microbiological orientated surface water quality management measures and/or faecal pollution prevention instruments specifically applied to sections of the Dwars River. Lastly, this section explored the particulars regarding current surface water quality monitoring performed in the along and in the vicinity of the Dwars River as well as response to noncompliance relating to surface water quality.

4.3.3.1 Implementation of surface water quality management system

Question 4.1 requested the respondents" opinions on whether or not they are aware of a surface water quality management system (i.e. implementation plans, integrated Water quality management plan, guidelines, systems and/or procedures and so forth) for the management of the microbiological quality of surface water resources being developed or implemented to give effect to water resource quality related objectives and mandates.

Table 4.11: Respondents" opinions on whether or not they are aware of a surface water quality management system currently being implemented

Number of respondents stating that they are aware of a surface water quality management system currently being implemented	0
Number of respondents stating that they are not aware of a surface water quality management system currently being implemented	14
Total	14

"Implemented" being the key word in this question, the data collected and displayed in Table 4.11 demonstrates that all the respondents retorted with a "NO" answer. Respondents were aware of a surface water quality management system or elements thereof but the data collected suggests that not a single respondent was aware of surface water quality management system or part thereof being implemented for the Upper Breede River Area. 50% of the respondents suggested that various other management tools are currently being used to achieve the water resource quality objectives. Question 4.3 allowed the respondents to provide their opinion regarding the management tools implemented to achieve water quality related objectives. The responses to Question 4.3 are depicted on Figure 4.22 below.

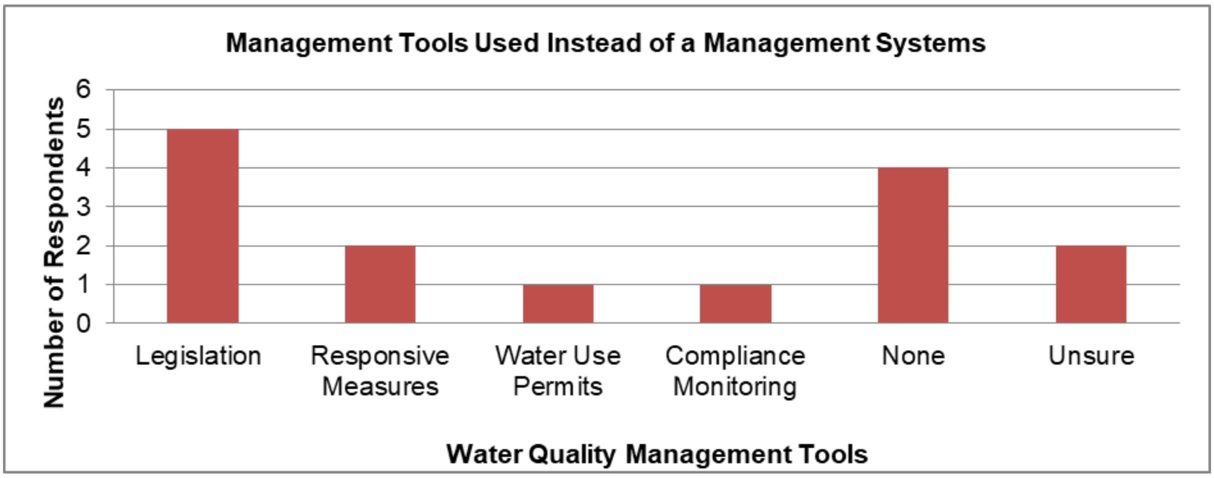


Figure 4.22: Management tools used to achieve the water resource quality objectives

Based on the findings, the implementation of water quality related legislation, conditions of water use permits and national standards as well as the responsive measures taken in the event of non-compliance are being used as substitute for a formalised water quality management system in to meet water quality related objectives. However, it must be said that the questionnaire assisted the researcher in establishing that there are no resource specific water quality related objectives for the Upper Breede River Management Area.

Question 4.4 requested the respondents‟ opinions on whether or not the existing surface water quality management system (i.e. implementation plans, guidelines, systems and/or procedures and so forth) provide clear descriptions of management actions, responsibilities, resources available, and timeframes to mitigate or remediate existing of future surface water quality related issues.

Table 4.12: Respondents‟ opinions on whether or not the existing surface water quality management system (i.e. implementation plans, guidelines, systems and/or procedures and so forth) provide clear descriptions of management actions, responsibilities, resources available, and timeframes to mitigate or remediate existing of future surface water quality related issues.

Number of respondents stating that they are aware of the existing surface water quality management system (i.e. implementation plans, guidelines, systems and/or procedures and so forth) providing clear descriptions of management actions, responsibilities, resources available, and timeframes to mitigate or remediate existing or future surface water quality related issues.	0
Number of respondents stating that they are not aware of the existing surface water quality management system (i.e. implementation plans, guidelines, systems and/or procedures and so forth) providing clear descriptions of management actions, responsibilities, resources available, and timeframes to mitigate or remediate existing or future surface water quality related issues.	14
Total	14

The data collected and displayed in Table 4.12 demonstrates that all the respondents responded with a “NO” answer. The data suggests that not a single respondent was aware of whether or not the existing surface water quality management system (i.e. implementation plans, guidelines, systems and/or procedures and so forth) provides clear descriptions of management actions, responsibilities, resources available, and timeframes to mitigate or remediate existing of future surface water quality related issues.

One of the functions of BGCMA is water resource protection through the continued assessment of water quality and to simultaneously devise strategies to protect water resources under their control (BOCMA, 2013:14). In other words, BGCMA was formed as part of an initiative with the intention of monitoring and subsequently improving the current situation surrounding the quality of water resources such as the Dwars River through the development and implementation of a Catchment Management Strategy. To achieve this BGCMA was tasked to acquire baseline water resource quality information in to support both current and future research and enabling them to prioritise and develop, in collaboration with local authorities, dense settlement water management strategies for priority urban pollution sources. To realise and fulfil their obligations, BGCMA has since established various Water Quality Monitoring Programmes in the catchment management area (Anon. 2012b:3). Based on the CMS, CMAs should include a "water quality management framework-plan indicating the management requirements and responsibilities" to achieve water quality related objectives (DWAF, 2003:13). "A water quality management framework-plan strategy represents a subcatchment load allocation to different sector-source types, to achieve the specified source water quality management objectives. It also highlights the water quality management plans required to give effect to this load allocation, and a programme for implementation" (DWAF, 2003:106). In addition to the water quality management framework-plan and CMS, it is suggested that "individual water quality management implementation plans should be developed to give effect to the water quality management framework-plan" as well as the objectives of the CMS (DWAF, 2003:13). Together, these make up the water quality management component of the CMS. As such, they "must be reviewed at intervals of not more than five years" to accommodate the "on-going development of the catchment" (South Africa, 1998:24; DWAF, 2003:13).

4.3.3.2 Microbiological surface water quality management measures applied to sections of the Dwars River

Respondents were asked whether they were aware of microbiological surface water quality management measures and/or faecal pollution prevention instruments specifically applied to sections of the Dwars River (See Question 4.7 of the questionnaire). Question 4.8 prompted respondents who answered "YES" to Question 4.7 to provide examples of the microbiological surface water quality management measures and/or faecal pollution prevention instruments they were aware of at the time the questionnaire was conducted (See Table 13). Respondents who answered "NO" to question 4.7 were requested to provide their view as to what is being implemented to prevent faecal pollution of the Dwars River instead of formalised microbiological surface water quality management measures and/or faecal pollution prevention instruments.

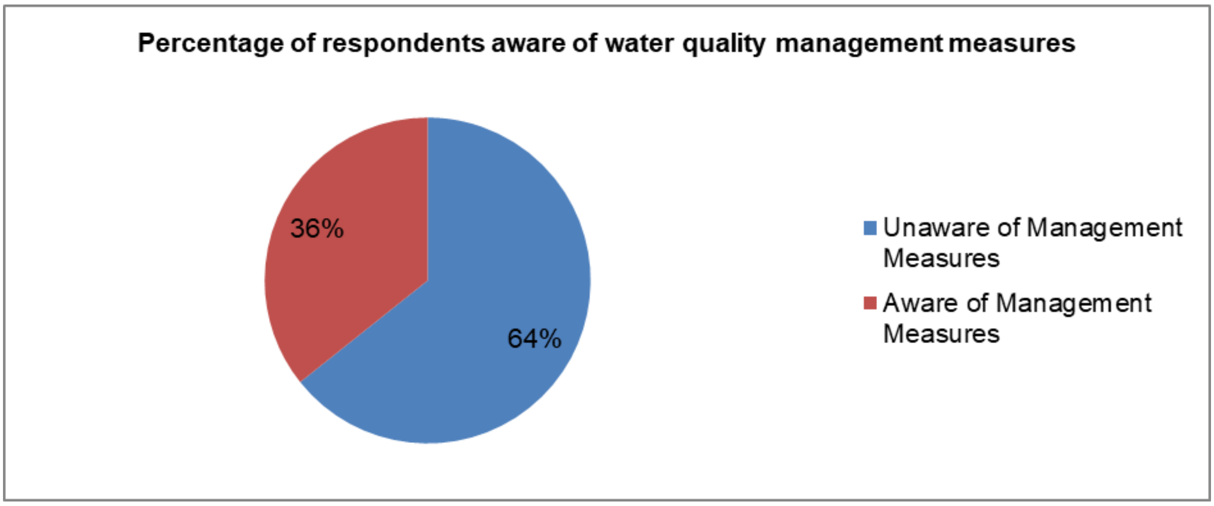


Figure 4.23: Percentage of respondents aware of microbiological surface water quality management measures and/or faecal pollution prevention instruments specifically applied to sections of the Dwars River

As depicted in Figure 4.23, nine (64%) of the respondents answered “NO” while only five (34%) answered “YES”. Those respondents who answered “YES” where further prompted to provide examples of the microbiological surface water quality management measures and/or faecal pollution prevention instruments specifically applied to sections of the Dwars River they were aware of (See Table 4.14). The respondents who were unaware of formal management and/or prevention measures were asked what in their opinion is being done to prevent the faecal pollution of the Dwars River (See Table 4.13).

Table 4.13: Microbiological surface water quality management measures and/or faecal pollution prevention instruments

Measures	Selected Responses	Respondent
Dilution through Flooding	“Diluting of faecal pollution through release of water from the dam upstream”	RS 4
Compliance Monitoring	“Our department monitor’s compliance with standards and legislation” “Sampling of the river and analysis of results”	RS 4, RS 5, RS 6, RS 13, RS 14
Alarm Systems	“Alarms on pump stations (triggered if faulty)”	RS 5

A total of three management measures were identified (See Table 4.13), namely dilution through flooding, water quality compliance monitoring and alarm systems linked to the sewage pump stations. Dilution through flooding involves the flushing or release of large quantities of water from an upstream dam to “flush” out any faecal contaminants present in the Dwars River. The second management measure identified was compliance monitoring which according to the respondents is used to coordinate and monitor the Dwars River’s compliance with water quality related legislation, standards, and guidelines. Lastly, sewage pumping stations used for pumping wastewater or sewage from a lower to higher elevation are, according to one of the respondents, “fitted with alarm systems that provide an immediate alert when high sewage levels are reached, or a sewage pump failure is detected".

Table 4.14: Alternatives to microbiological surface water quality management measures and/or faecal pollution prevention instruments

Measures	Selected Responses	Respondent
Risk Abatement Plan	"Witzenberg Municipality's Risk Abatement Plan assists with the management of WWTW"	RS 1
Incident Response	"I am only aware of responsive measures"	RS 1, RS 2, RS 7, RS 8
Water Use permits	"issuing of water use permits"	RS 10
None	"there are no visible prevention measures that I am aware of"	RS 9, RS 12
Compliance Monitoring	"Compliance monitoring"	RS 1, RS 2, RS 1)
Unsure	"I don't know"	RS 11

Alternative techniques (See Table 4.14) employed to prevent the faecal pollution of the Dwars River identified by the respondents included incident response measures, the issuing and the implementation of water use permits, compliance monitoring as well as Witzenberg Municipality's Wastewater Risk Abatement Plan. Incident response refers to Witzenberg Municipality, Department of Water and Sanitation and BGCMA's reactive response to faecal pollution related incidents. Compliance monitoring and the issuing of water use permits and the subsequent monitoring of the conditions thereof according to the respondents is used as a preventative measure to coordinate and monitor the Dwars River's compliance with water quality related legislation, standards and guidelines. Another preventative measure that was mentioned during the questionnaire is the implementation of Witzenberg Municipality's Risk Abatement Plan which allows the municipality to have a comprehensive risk-based approach enabling the identification of hazards and their contribution to the local wastewater treatment plant's final effluent quality risks, to enable efficient, effective and rapid response to incidents thereby limiting negative impacts on the community and facilitate communication with the appropriate authorities.

Witzenberg Municipality, responsible for basic service delivery within the area, responded to the pollution of surface water located within their municipal boundaries through the development of relevant management strategies as well as the enabling of necessary projects in an attempt to alleviate the situation. The upgrading of the wastewater treatment works, monitoring industrial effluent, establishing pollution control measures, engaging with Cape Nature on a daily basis, implementing applicable legislation, launching educational and awareness campaigns, and exploring alternative funding channels/sources are all examples of proposed control measures designed to manage water quality and prevent river pollution (Witzenberg Municipality, 2014:115).

4.3.3.3 Microbiological Water Quality Monitoring of the Dwars River

Respondents were asked if, according to their knowledge, the microbiological water quality of the Dwars River is being monitored and assessed or not (See Question 4.10 of the questionnaire). Question 4.11 prompted respondents who answered "YES" to Question 4.10 to state what is being done water quality related information (See Table 4.15). Respondents who answered "NO" to question 4.10 were requested to provide their view as to what other measures are used to ensure water quality compliance (See Table 4.16).

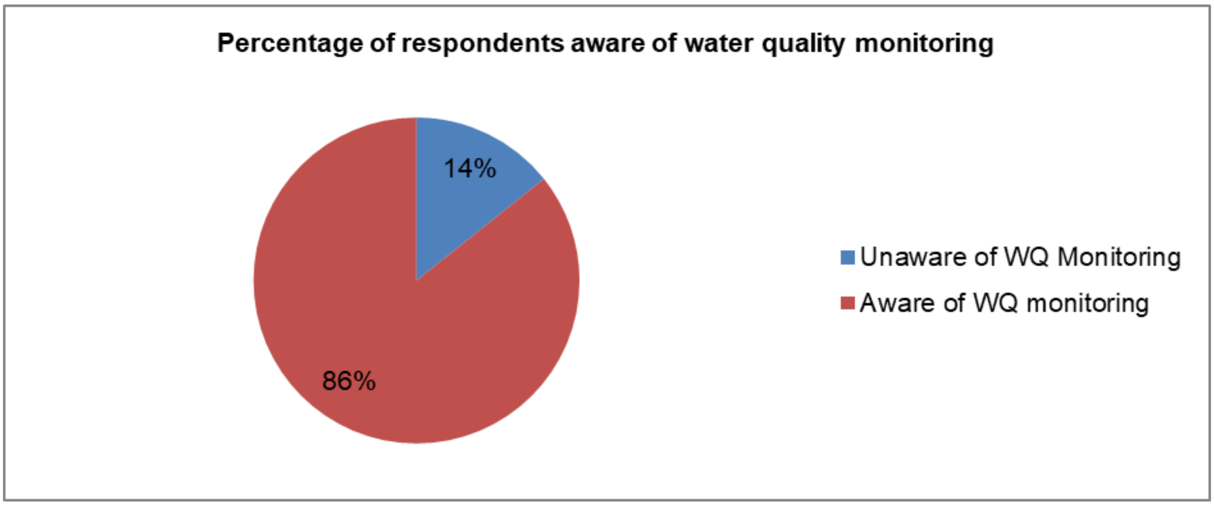


Figure 4.24: Percentage of respondents aware of the Dwars River's water quality being monitored and assessed

Figure 4.24 indicates that 86% of the respondents, which included experts and water users, believed the Dwars River was being subjected to microbiological water quality monitoring. The remaining 14% was unaware of any water quality monitoring taking place during the time the questionnaire was conducted.

Table 4.15: How surface water quality data is applied

Area of Application	Selected Response	Respondent
Identify Trends	"We use our information to identify trends"	RS 1, RS 2
Respond to Non-Compliance	"analyse water quality results, investigate complaints, incidents and non - compliance and follow-up to ensure that corrective action is taken" "data is forwarded to the Water Use Officers who act on non-conformances"	RS 2, RS 1 RS 14
Data Capturing	"information is captured on a system called the Water Management System" "results are captured on our database"	RS 3 RS 14
Evaluation of Water Quality Related Issues	"data is used in the evaluation of the water quality issues"	RS 7, RS 8
Compliance Monitoring	"conduct compliance monitoring on authorisations in the area"	RS 3, RS 1, RS 2, RS 5
Reported to Water Management Organisations	"report non-compliance to Witzenberg Municipality and BGCMA"	RS 5

	"information is submitted to BGCMA and DWS" "Information is used by DWS and CWDM to respond to non-compliance"	RS 6 RS 10
Litigation	"complaints are followed up until addressed. Litigation where required"	RS 3, RS 1
Usability	"We test the microbiological quality Dwars River flows through our farmland to determine its usability for farming and associated operations"	RS 11, RS 12

Based on the data gathered and the information displayed in Table 4.15, water quality monitoring and associated results are captured on a database and used to monitor compliance, identify faecal pollution trends, determine the water source's usability and to respond to contamination events and/or incidents of noncompliance. Incident response includes the identification of high-risk areas and "hot spots", investigation of incidents as well as complaints, the dissemination of information to water management organisations to facilitate litigation and the follow-up and close-out of incidents.

Table 4.16: Alternative measures used to ensure water quality compliance

Category	Selected Response	Respondent
Nothing	"We are not monitoring water quality at this point in time seeing that the winter rains dilute the sewage entering the river"	RS 4
Unsure	"I have no idea"	RS 9

Information gathered from the respondents who answered "NO" to Question 4.10 indicated that alternative measures used to ensure water quality compliance is to monitor and report noncompliance to Witzenberg Municipality and BGCMA and inform the polluter. No formal measures and/or water quality monitoring is performed seeing that the practitioner who performed the sampling duties resigned (See Table 4.17). Further to this, water quality monitoring is only performed throughout the summer months since the winter rains dilute the sewage entering the river.

The Breede River Improvement Project came into effect in 2007 following the Cape Winelands District Municipality's Municipal Health Services Department's decision to introduce a comprehensive management and monitoring programme of all surface water sources under their authority with the purpose of ensuring the wellbeing of communities directly and indirectly affected by condition of the river (CWDM, 2010). The Breede River Improvement Project commenced in 2007/2008 and the final report, compiled by the CWDM officials, was made available to the then Department of Water Affairs (DWA) in 2010. Following the discontinuation of the Breede River Improvement Project, the Breede – Overberg Catchment Management Agency took over the assessment of the Dwars River's water quality from the CWDM (CWDM, 2010:10) and initiated the Breede River Water Quality

Monitoring Programme. The purpose of the Breede River Water Quality Monitoring Programme was to provide the information needed to assess and manage the water quality of the Breede River and its tributaries and to identify possible signs of deterioration and pollution (Anon. 2012a:5).

4.3.3.4 Details of the location and frequency of water quality monitoring points along the Dwars River

As part of Question 4.13 respondents were requested to provide details regarding the selection of monitoring points, the location of existing monitoring points and the frequency of sampling at these points. The responses to the question are shown in Table 4.17.

Table 4.17: Monitoring Points and Frequency of Sampling

Monitoring Point(s)	Selection Criteria	Sampling Frequency	Respondent
As per Breede River Improvement Project Report	Breede River Improvement Project Report	Monthly to Quarterly	RS 1
Unsure of location	Breede River Improvement Project Report	Monthly to Quarterly	RS 2
National Microbial Monitoring Programme	Potential high-risk areas	Bi-Monthly	RS 3
Potential high-risk areas	Unsure	Monthly	RS 5
Unsure of location	Unsure	Quarterly	RS 6
Final effluent of WWTW	Emergency Response	Monthly	RS 13
Oewerbrug	“as per Breede River Improvement Project”	Quarterly	RS 14
None	Potential high-risk areas	No sampling	RS 4

According to the information gathered, the location of monitoring points (See Figure 4.4) is mainly based on the areas identified in the Breede River Improvement Project Report and the frequency varies from monthly to quarterly. To meet the Breede River Improvement Project’s objectives along the Dwars River, three predetermined monitoring points, each with its own geospatial coordinates, were used as locations for data collection to provide the necessary information on the microbiological water quality status of the river. The monitoring points used during the implementation of the Breede River Water Quality Monitoring Programme were in line with those used for the Breede River Improvement Project. According to BGCMA, the three monitoring points were reduced to one, namely, Cer1 or Oewerbrug and samples are collected once every three months (BGCMA, 2019) and the DWS currently does not take samples in the Upper Breede River region. The last set of microbiological data DWS has available is for May 2014. CWDM does not take samples; neither does Witzenberg Municipality according to available data.

4.3.3.5 Actions taken in the event of the Dwars River's water becoming noncompliant from a microbiological point of view

Respondents were requested to provide their view as to what transpires in the event of faecal contamination (See Question 4.14). The responses to the question are shown in Figure 4.25.

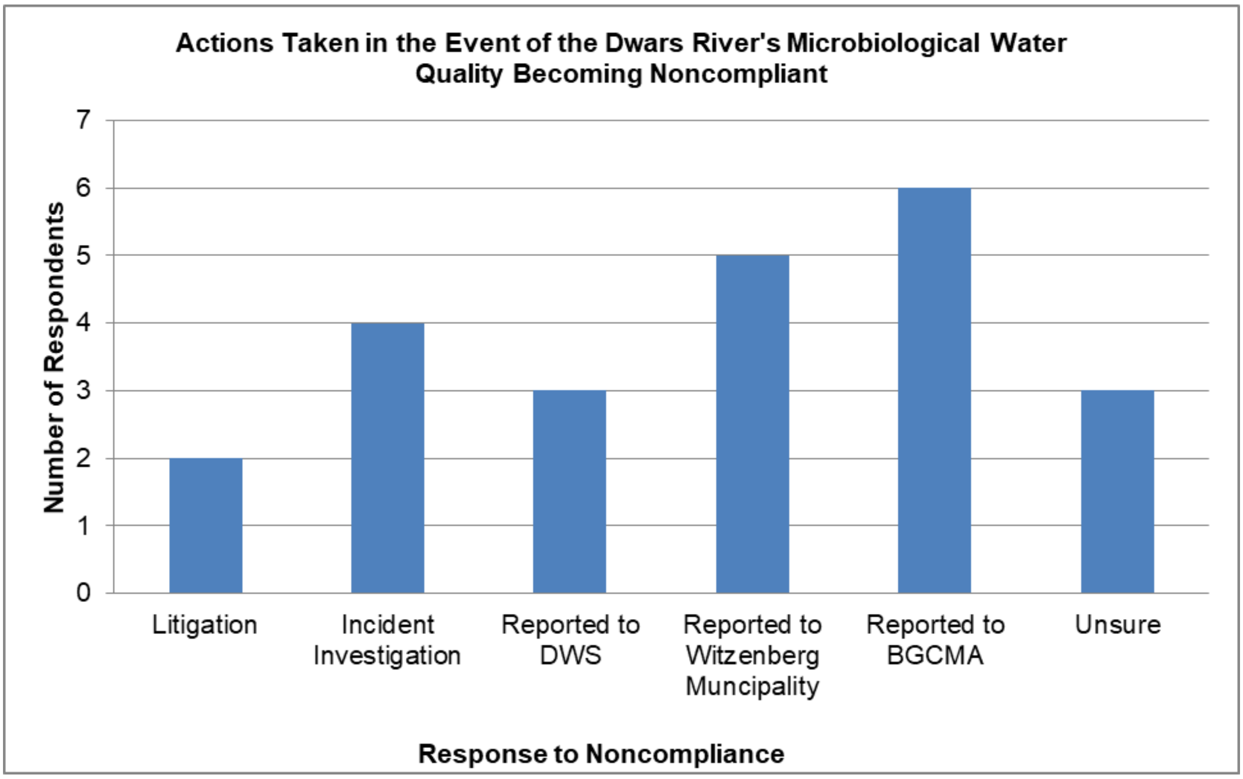


Figure 4.25: Respondents' reply when asked what actions are taken in the event of the Dwars River's water becoming noncompliant from a microbiological point of view

From the data, it is evident that most of the responses differ marginally and suggests that the actions taken in the event of the Dwars River's water becoming noncompliant from a microbiological point of view involves the reporting of information to basic service providers (Witzenberg Municipality) and or water management organisations (BGCMA and DWS) to initiate incident investigation procedures and litigation. The majority of the respondents are of the opinion that BGCMA is the organisation to whom faecal pollution incidents should be reported followed closely by Witzenberg Municipality.

According to BOCMA's 2013 Annual Report, non – compliance issues regarding the quality of water resources under their jurisdiction are continuously being investigated and pre-directives and warnings are issued where necessary. Generally, officials would receive a report pertaining to a water quality issue, establish the origin of the specific problem, liaise with the responsible party or polluter, and analyse relevant regulations and standards governing the aspects of the situation. Corrective actions are then developed and once all parties accept the nature and conditions of the way forward, they will monitor post-corrective action compliance and ensure that corrective actions are implemented (BOCMA, 2013).

4.3.3.6 Systems in place that identifies faecal pollution events and determines the nature and extent of contamination

Respondents were asked if they were aware of a system that is in place that identifies faecal pollution events and determines the nature and extent of contamination to accommodate prompt response and to assist in the development of appropriate site-specific rehabilitation and preventative solutions (See Question 4.15). The responses to the question are shown in Figure 4.26 below.

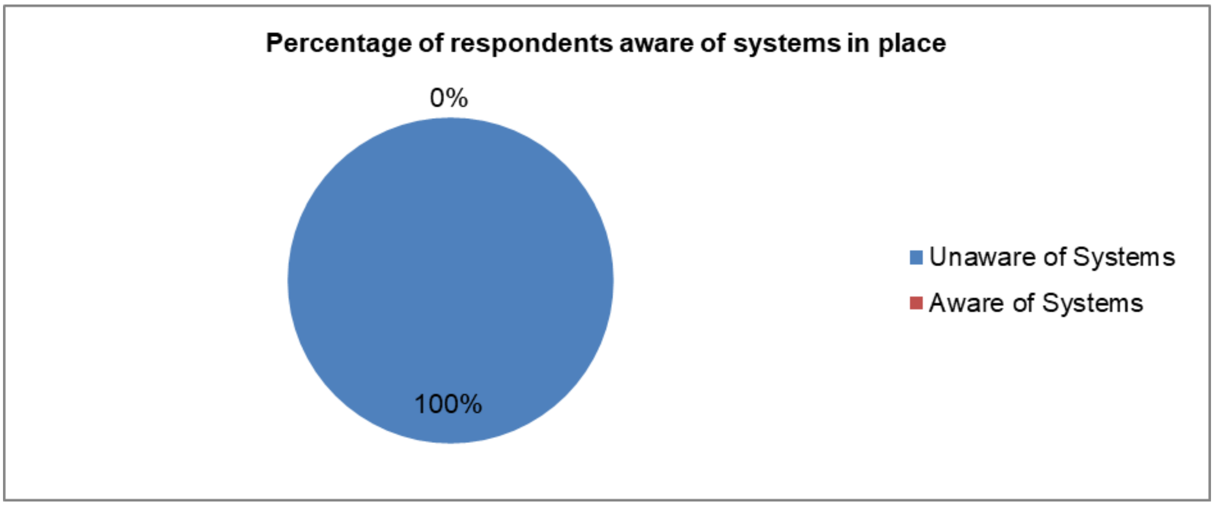


Figure 4.26: Percentage of respondent's aware systems in place that identifies faecal pollution events and determines the nature and extent of contamination

100% of the respondents answered "NO" when asked if they are aware of a system being in place that identifies faecal pollution events and determines the nature and extent of contamination to accommodate prompt response and to assist in the development of appropriate site-specific rehabilitation and preventative solutions.

4.3.4 Implementation of Surface Water Resource Management Strategy/Measures

Section 5 of the questionnaire consisted of five questions developed to probe the sample populations' perception of the implementation status of the surface water quality management strategies and systems discussed under Sections 3 and 4 of the Questionnaire.

4.3.4.1 Current measures directed at the management of the microbiological quality of surface water and the prevention of faecal pollution

Respondents were requested to provide their opinion with regards to whether or not the current measures directed at the management of the microbiological quality of surface water and the prevention of faecal pollution along the Dwars River contributing effectively to the successful protection of the said river against faecal pollution (See Question 5.1 of the questionnaire).

Table 4.18: Responses received regarding the effectiveness of the current measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River contributed effectively to the successful protection of the said river against faecal pollution

Measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River have contributed to the protection of the Dwars River against faecal pollution	2
Measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River have not contributed to the protection of the Dwars River against faecal pollution	12
Total	14

The results in response to Question 5.1 as depicted on Table 4.18 above shows that the majority of the respondents are of the opinion that (refer to previous questions) measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River have not contributed to the protection of the Dwars River against faecal pollution.

Respondents who were of the opinion that the measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River have contributed to the protection of the Dwars River against faecal pollution were asked to provide details regarding factors contributing to its success (See Question 5.2 of the Questionnaire). Responses have been listed in Table 4.19 below.

Table 4.19: Success factors

Category	Selected Response	Respondent
External departmental relations	“Growing cooperation and involvement between the Witzenberg Municipality and the BGCMA”	RS 1, RS 2
Community Involvement	“partial community involvement also assists with reaching water quality related objectives	RS 1, RS 2

Respondents suggested that the cooperation between organisations involved in the management and monitoring of water quality in the Upper Breede River Area as well as the involvement of the local community in achieving water quality related objectives plays a key role in the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River (See Table 4.19).

Respondents who were of the opinion that the measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River have not contributed to the actual protection of the said water course against faecal pollution were asked to provide details regarding key challenges and constraints (See Question 5.3 of the Questionnaire).

Table 20: Key challenges and constraints

Category	Selected Response	Respondent
Maladministration WQMS	"The systems are good, but it is not management properly. There is no synergy between the systems that's available"	RS 3, RS 13, RS 14, RS 11
Lack of Responsibility	"Nobody takes the lead or follow-up on non-compliances identified"	RS 4
Poor Service Delivery	"Informal settlements do not have the required sanitation facilities resulting in excrement ending up in rivers"	RS 10, RS 4
Incompetent Staff	"Management does not have the capacity to perform their required functions"	RS 10, RS 4
Non-existent Environmental Conservation Aspect	"There is no environmental conservation aspect involved in the work they are doing"	RS 4, RS 6
Poorly Written Legislation	"legislation governing the responsibilities for water quality management is poorly written and ambiguous."	RS 5
Substandard Enforcement of Legislation	"DWS is not visible at all which results in poor enforcement of legislation"	RS 5
Constant Personnel Changeover	"DWS undergoes frequent constant personnel change which influences litigation and the closing out of incidents"	RS 5
Lack of Funding	"significant lack of funding in the Witzenberg Area that inhibits the monitoring of problem areas upstream" "budget for sampling is also problematic as it reduces the frequency of sampling along the Dwars River"	RS 5, RS 7, RS 8 RS 14
Surface Water Quality Management	"Not enough attention is given to the actual management of the rivers especially smaller rivers such as the Dwars River"	RS 6, RS 11, RS 12, RS 13
Irresponsible Behaviour	"There are too many people who think that a river is just a drain"	RS 6, RS 7, RS 8,
Infrastructure challenges	"Changes made to infrastructure does not necessarily coincide with existing sewerage systems" "current systems are too small to handle the increased load generated by the ever-increasing local population" "The WWTW and associated infrastructure's capacity is not adequate to cope with current load"	RS 7, RS 8 RS 7, RS 8 RS 10
Management approach	"BGCMA and Witzenberg Municipality is reactive instead of proactive" "Problems are responded to sometimes but never solved"	RS 7, RS 8 RS 4
Uninvolved Local Government	"Witzenberg Municipality is not available when a way forward regarding water quality issues are discussed"	RS 7, RS 8
Substandard Interdepartmental	"we never receive any response or feedback from Witzenberg Municipality in the event of non-	RS 13

communication	compliance regarding microbiological water quality”	
Poor incident response	“results from the labs is way too long resulting in response to incidents becoming ineffective or complicated”	RS 14, RS 4, RS 12
Population Growth	“rapid population growth associated with employment opportunities”	RS 8, RS 7
Unsure	“I got sick twice which means there must be a problem somewhere”	RS 9

The key challenges and constraints preventing the measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River contributing to the protection of the Dwars River against faecal pollution listed in Table 4.20 have been allocated to Major Categories for ease of reference (See Table 4.21) and to obtain a category percentage (See Figure 4.27).

Table 21: Categories of key challenges and constraints

Major Category	Subcategory
Water Quality Management	Maladministration WQMS
	Substandard Enforcement of Legislation
	Surface Water Quality Management
	Management approach
	Uninvolved Local Government
	Poor incident response
	Poorly Written Legislation
	Substandard Enforcement of Legislation
Incident Response	Lack of Responsibility
	Poor incident response
Personnel	Incompetent Staff
	Non-existent Environmental Conservation Aspect
	Irresponsible Behaviour
	Constant Personnel Changeover
Infrastructure	Infrastructure challenges
Service Delivery	Poor Service Delivery
Resources	Funding
Population Growth	Population Growth

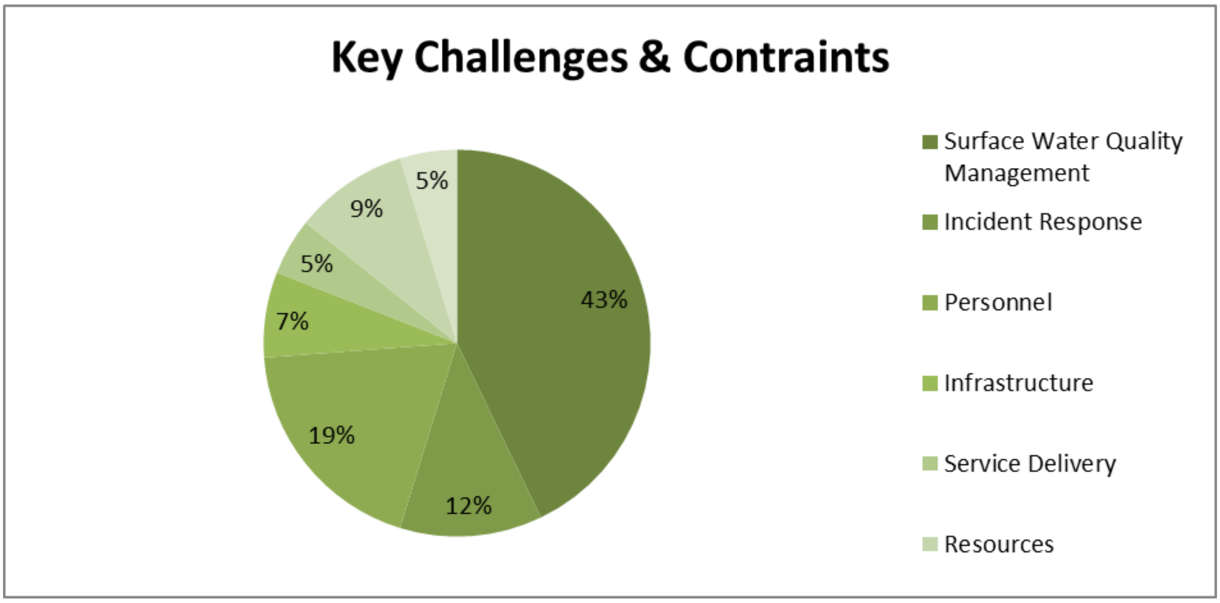


Figure 4.27: Key challenges and constraints

Figure 4.27 depicts that 43% of the answers to Question 5.3 of the questionnaire describes poor or improper water quality management as a key constraint preventing the measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River actually contributing to the protection of the said water course against faecal pollution. Synergy between the water quality data systems that is available, and the maladministration of the water quality management system is prominent in this category. Incident response, infrastructure challenges, service delivery and funding are listed as separate categories but are not only interrelated but have a close connection with water quality management. Combined these categories were mentioned in 33% of the answers to Question 5.3. Personnel challenges, referred to in 19% of the answers, were also identified by various respondents as a concern and a definite water quality management and service delivery challenge and constraint. Respondents believed the personnel appointed by the water quality management institutions of not being conscious of the environment and they did not have the capacity to perform their required functions.

Further research done in the Witzenberg municipal area has shown that problems surrounding water quality management and the pollution of the Dwars River have been greatly exacerbated by service delivery challenges experienced by the Witzenberg Municipality (CWDM, 2010). Examples of the these challenges includes the lack of funding, shortage of staff and equipment, under-expenditure of the wastewater management budget, increased vandalism and theft of municipal property, failure to implement corrective measures (Witzenberg Municipality, 2012a), poor reaction time regarding sewerage problems, and the fact that the local wastewater treatment works cannot accommodate industrial effluent and is underachieving with regards to its Green Drop status (Department of Water and Sanitation, n.d). Further to this, subsequent to the reporting of sewage spills in the area, certain officials appointed for the Witzenberg Municipality showed no concern over river water pollution caused by the said sewage spills, the prevention of further pollution, or the rehabilitation of the sewage spills. It was also noted that legislation as well as the principles of cooperative government and intergovernmental relations was manipulated in the past to avoid prosecution (CWDM, 2010). The CWDM officials performing water quality monitoring, management, and reporting related activities also experienced some difficulties while executing their duties. These included the following:

- Water pollution cases were left unresolved due to DWA's high personnel turnover.
- The lack of experience of newly appointed personnel to solve an on-going water quality related problem. This prolonged the time it took to solve a specific problem.
- Understaffing of the DWA, especially regarding water quality personnel.
- Water sample analysis and the issuing of results took too long to implement effective response and control measures.
- CWDM personnel received limited assistance from the Department of Water Affairs (CWDM, 2010).

Furthermore, BGCMA have been experiencing some challenges that are inhibiting their water quality management duties (BOCMA, 2010). Examples of these include:

- No water quality management plan available for the Witzenberg area.
- "Timeous approvals of the annual performance plans" (BGCMA, 2015:3).
- Irregular and untimely transfers of seed funding inhibit BOCMA's planning and human resource allocation ability.
- Understaffing.
- Low morale among personnel which has the potential to disrupt service delivery.
- Location of offices makes it difficult to attract skilled personnel.
- "Outdated and uneven information" (BOCMA, 2010:19). For example, datasheets provided by the BOCMA displaying monthly sample results clearly demonstrates that samples are not taken every month of the year. Throughout 2011 only faecal coliforms were tested for, in 2012 the first monthly water sample was taken in April only, in 2013 no sample results are available for April, October and December, and the 2014 results for March and May are missing.
- Frequent extreme events such as floods and droughts.
- Institutional transformation and change management.
- Legitimacy issues (BOCMA, 2010).

4.3.4.2 Current surface water quality management strategies and control measures

As part of Question 5.4, respondents were asked whether or not the water quality management strategies and control measures currently in place are sufficient to address future microbiological water quality issues along the Dwars River.

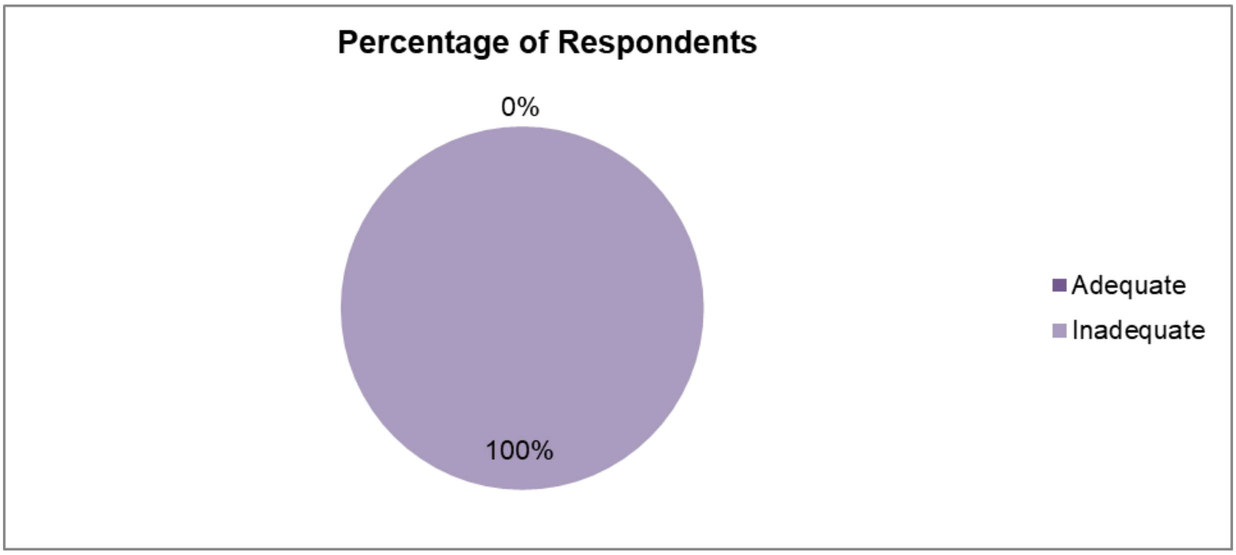


Figure 4.28: Respondents' opinion whether or not the water resource quality management strategies and control measures currently in place sufficient to address future microbiological water quality issues along the Dwars River

As per Figure 4.28, all respondents agreed that current water quality management strategies and control measures are not sufficient to address future microbiological water quality issues along the Dwars River. Reasons for their answers as part of Question 5.5 of the questionnaire are depicted in Table 4.22 below.

Table 4.22: Reasons why current water quality management strategies and control measures are not sufficient to address future microbiological water quality issues along the Dwars River

Category	Selected Response	Respondent
Funding	"We have a restricted budget and monitor sampling points only once a month" "Certain sections close to informal settlement are also not being monitored due to the restricted budget" "Municipalities don't have the necessary funding to address microbiological contamination related issues	RS 1, RS 8 RS 2, RS 7
Understaffing	"we do not manage to reach all points due to understaffing"	RS 1
Sampling Frequency	"BGCMA will only be sampling the rivers once a term starting this year" "sampling a river for faecal pollution once every three months is not adequate"	RS 1 RS 14
Sampling Footprint	"sections close to informal settlements are also not being monitored"	RS 1
External departmental communication	CWDM also take samples as but they do not share information/results "relationship between the Witzenberg Municipality and other governmental departments and NGOs is poor"	RS 1 RS 2
Service Delivery	"Population growth vs. service delivery is a growing concern" "Infrastructure maintenance is a huge problem" "Sanitation management is absent"	RS 1 RS 4 RS 12

Personnel Changeover	"BGCMA often struggles to get hold of DWS employees to report non-compliances etc. There is a constant staff changeover it seems"	RS 1
Responsibility	"no clear guidelines for execution of water quality related duties. It seems that no one at DWS knows their role/scope of work when it comes to the implementation of the CMS."	RS 1
Incident Response	"Incidents and the response thereto are not well documented, and complaints are not reacted to" "Incidents are not responded to effectively enough and polluters are not prosecuted"	RS 2, RS 12 RS 5
Integrated Water Resource Management	"Integrated Water Resource Management does not exist"	RS 2
Water Quality Data	"gaps in the water quality related data due to contracts not being secured early"	RS 3
Irresponsible Behaviour	"clear that the Witzenberg Municipality simply does not care about the environment"	RS 4, RS 6, RS 7, RS 8
Competency	"lack of knowledge and experience is at the order of the day" "They simply do not have sufficient environmental related training to manage a WWTW sustainably." "management does not have the capacity to perform their required functions"	RS 4 RS 10
Prevention	"Problems are not solved, and preventative measures are not implemented"	RS 5
Surface Water Quality Management	"Not enough attention is given to the actual management of the rivers especially smaller rivers such as the Dwars River" "Lack of proper management" "significant water quality management gaps"	RS 6 RS 11, RS 12 RS 13
Infrastructure	"Changes made to infrastructure does not necessarily coincide with existing sewerage systems" "current systems are too small to handle the increased load generated by the ever-increasing local population" "The WWTW and associated infrastructure's capacity is not adequate to cope with current load" "existing WWTW and sewage infrastructure is unable to cope with the growing population"	RS 7, RS 8 RS 7, RS 8 RS 10, RS 12 RS 2
Management approach	"BGCMA and Witzenberg Municipality is reactive instead of proactive" "a reactive response will not be enough"	RS 7, RS 8 RS 14
Involvement of Local Government	"Witzenberg Municipality is not available when a way forward regarding water quality issues are discussed"	RS 7, RS 8

The reasons why current water quality management strategies and control measures are not sufficient to address future microbiological water quality issues along the Dwars River listed in Table 4.22 have been allocated to Major Categories for ease of reference (See Table 4.23) and to obtain a category percentage (See Figure 4.29).

Table 23: Categories of reasons why water quality management strategies and control measures are not enough to address future microbiological water quality issues along the Dwars River

Major Category	Subcategory
Surface Water Quality Management	External departmental communication
	Responsibility
	Integrated Water Resource Management
	Water Quality Data
	Prevention
	Surface Water Quality Management
	Management approach
	Involvement of Local Government
Personnel	Competency
	Irresponsible Behaviour
	Personnel Turnover
Infrastructure Challenges	Infrastructure
Service Delivery	Incident Response
	Poor Service Delivery
Resources	Funding
	Understaffing
Population Growth	Population Growth
Compliance Monitoring	Sampling Frequency
	Sampling Footprint

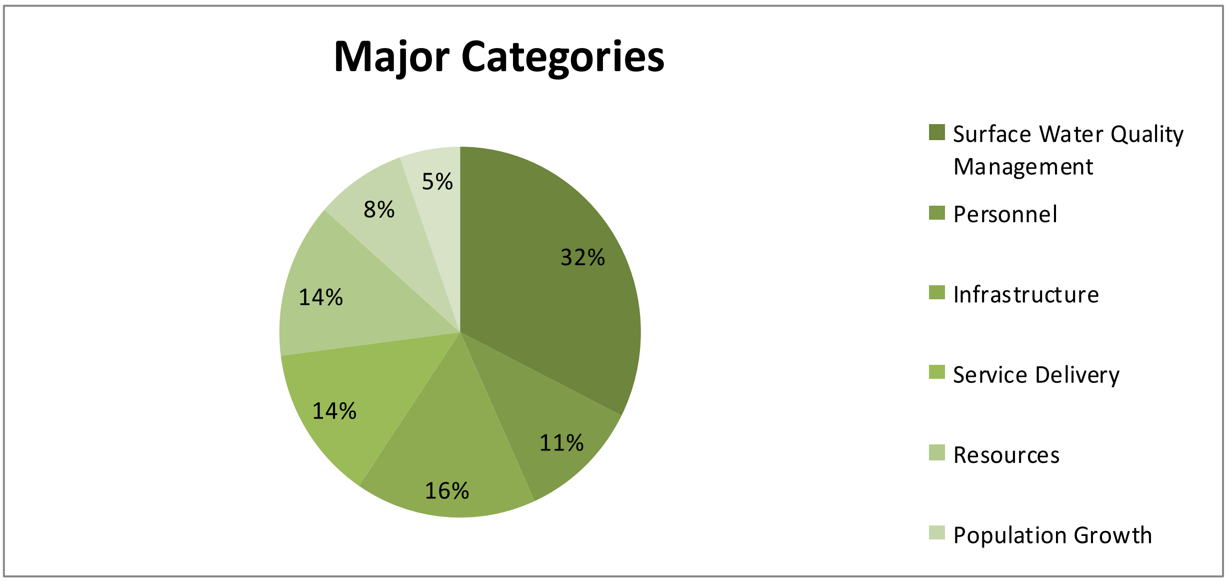


Figure 4.29: Major Categories

The data depicted in Figure 4.29 suggests that substandard surface water quality management practices, the lack of involvement of the local municipality as well as communication and information sharing between various water quality management institutions are the main reasons why current water quality management strategies and control measures are not sufficient to address future microbiological water quality issues along the Dwars River. Service delivery, infrastructure challenges, compliance monitoring and resources are listed as separate categories but are not only interrelated but have a close connection with surface water quality management. Combined these categories were mentioned in 79% of the answers to Question 5.5. Further to this, according to BGCMA, the constrained economy resulting in decreased budgets and reduced capital invested in infrastructure development population growth and the associated growing demand for fresh water and water treatment related services are reasons why the ability to deliver adequate services to some areas and the water quality management strategies and control measures are not sufficient to address future microbiological water quality issues along the Dwars River (BGCMA, 2017).

4.3.5 Recommendations Concerning the Management of the Microbiological Quality of the Dwars River

Section 6 of the questionnaire consisted of two questions developed to prompt the sample population to provide examples of alterations/improvements they implement to the existing water resource quality management strategies and control measures designed to address surface water contamination of a faecal nature in the Dwars River.

4.3.5.1 Proposed recommendations to address surface water contamination of a faecal nature in the Dwars River

As part of Question 6.1, respondents were asked if there were any alterations/improvements they would bring about to the existing water resource quality management strategies and control measures designed to address surface water contamination of a faecal nature along the Dwars River. All respondents provided examples of alterations/improvements to the existing water resource quality management strategies as part of Question 6.2 of the questionnaire, those of which are listed in Table 4.24.

Table 4.24: Recommendations concerning the management of the microbiological quality of the Dwars River's water

Category	Selected Response	Respondent
Create Awareness	"Pollution awareness movements are to be launched and kept going, together with adopt a river campaigns"	RS 1, RS 4, RS 6 RS 7, RS 8, RS 9 RS 13
Effluent Regulation	"regulation of the WWTW's effluent release must be strictly exercised"	RS 1
Funding	"financial injection into surface water quality management is required"	RS 1
Expand Water Quality Monitoring Footprint	"We need to monitor problem areas further up in the Dwars River close to the informal settlements"	RS 2
Coordination of Water Quality Management	"A department, preferably independent, needs to be in charge of problem solving and "following up" with	RS 2, RS 4

issues	regards to surface water resource quality management issues" "The "governing" department will have the function of coordinating combined efforts to solve surface water resource related issues and to audit various departments to ensure they perform their duties"	
Improved Relations between Departments and Organisations	"synergy between Departments is necessary" "Improve communication with different departments and government bodies" "Relevant parties such as BGCMA, Community, WWF, Witzenberg Municipality etc. needs to cooperate"	RS 3 RS 4, RS 13 RS 7, RS 8
Accountability	"Witzenberg Municipality must be brought under the spotlight seeing that they are not doing their work properly and that they are in fact polluting the environment"	RS 4
Training	"Place environmental responsible personnel in control of the WWTW operations"	RS 4
Local Personnel to Monitor River	"Appoint someone from Ceres to perform monitoring along the Dwars River and to wright reports" "CWDM and the Environmental Health Practitioners should be more involved as they know each area better due to the fact that they actually work in the area every day"	RS 4, RS 5, RS 10 RS 13
Public Health Involvement	"Municipal Health should once again function on its own to provide a proper punch to those who need it"	RS 4
Appoint Additional Staff	"personnel responsible for incident response must be increased and problem areas must be monitored"	RS 5
Responsibility	"landowners are to manage their stretch of the river"	RS 6
Change Management Approach	"Water management institutions must invest in water quality solutions and preventative measures in addition to response mechanisms which will allow them to be proactive instead of reactive" "Information regarding previous microbiological water quality issues could be used to prevent reoccurrences"	RS 7, RS 8 RS 14
Upgrade Current Infrastructure	"The link between job creation and water quality must be recognised and existing infrastructure must be upgraded according to needs"	RS 7, RS 8, RS 11
Water User Involvement	"Involve recreational clubs in decision making"	RS 9, RS 4, RS 7, RS 8
Location of WWTW	"Move WWTW and pump stations away from riverbanks"	RS 9
Information Sharing	"Access to water quality information to all stakeholders"	RS 10, RS 13 RS 14
Frequent Monitoring	"more frequent monitoring"	RS 10, RS 13
Law Enforcement	"stricter enforcement of water use permits"	RS 10
Surface Water Quality Management	"Clean the rivers, upgrade the stormwater and sewage system in Ceres" "Manage/control the social gatherings in Mitchells Pass and prevent members of the community from bathing, washing clothes and cars in and next to the river"	RS 11 RS 12
Data Management System	"upgrade of our internal data management system"	RS 14

Recommendations concerning the management of the microbiological quality of the Dwars River's water listed in Table 4.24 have been allocated to Major Categories for ease of reference (See Table 4.25) and to obtain a category percentage (See Figure 4.30).

Table 4.25: Categories of recommendations concerning the management of the microbiological quality of the Dwars River's water

Major Category	Subcategory
Surface Water Quality Management	Coordination of Water Quality Management issues
	Public Health Involvement
	Accountability
	Responsibility
	Change Management Approach
	Water User Involvement
	Information Sharing
	Law Enforcement
	Surface Water Quality Management
	Data Management System
	Improved Relations between Departments and Organisations
Compliance Monitoring	Effluent Regulation
	Expand Water Quality Monitoring Footprint
	Local Personnel to Monitor River
	Frequent Monitoring
Increased Awareness and Training	Create Awareness
	Training
Resources	Funding
	Appoint Additional Staff
Infrastructure	Upgrade Current Infrastructure

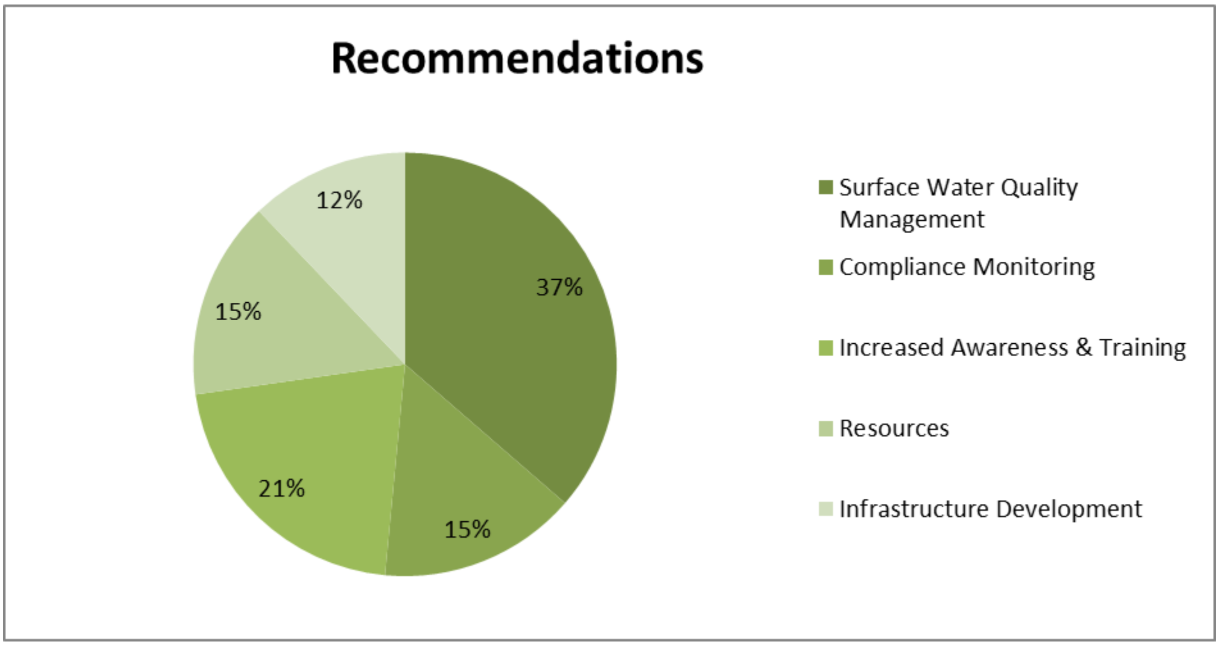


Figure 4.30: Recommendations concerning the management of the microbiological quality of the Dwars River's water

Table 4.24 shows the selected responses to question 6.2 and Table 4.25 simplifies the data further by dividing the data into major categories. Based on the data collected and Figure

4.30, 37% of the respondents are of the opinion that improved surface water quality management practices will improve existing water resource quality management strategies and control measures designed to address surface water contamination of a faecal nature in the Dwars River. Based on the respondent's answers this will need to involve a change in the current surface water management approach, the proper coordination of water quality management issues, involvement of the Public Health Department, the Local Municipality must take responsibility for their sector. Furthermore, water quality management institutions are to involve all stakeholders in decision making processes, improve water quality related data management, improve information sharing and strengthen relations between various departments and water management organisations. Awareness campaigns with water quality issues and pollution prevention as the subject matter as well as surface water quality related training for staff members employed by water management institutions is also deemed important by the respondents. Lastly, compliance monitoring of all high-risk areas and the increase in monitoring points as well the frequency of monitoring is a key factor that will improve existing water resource quality management strategies and control measures designed to address surface water contamination of a faecal nature in the Dwars River.

CHAPTER FIVE

CONCLUSION & RECOMMENDATIONS

5.1. Introduction

The previous chapter revealed the findings of this study. The purpose of this chapter is to conclude the entire research study by highlighting and discussing the main findings regarding the surface water quality management of the Dwars River made during the data collection process of this study. Furthermore, this chapter highlights recommendations for interventions and future research.

5.2. Key Findings

The purpose of this section is to highlight the key findings from quantitative data and qualitative collected as part of this study. The key findings are listed below:

5.2.1. Finding One: Reasons behind the faecal pollution of the Dwars River

The first research question focused on why the water quality of the Dwars River is continuously being impaired through faecal contamination, with findings as follows:

- The Dwars River is of value for agricultural practices, domestic use, recreational activities, industrial use, economic development, ecosystem health, and aesthetics. However, the microbiological water quality of the water which the Dwars River carries is alarmingly poor and does not conform to the recommended minimum requirements specified by the South African National Standards, the World Health Organisation, the Perishable Products Export Control Board, Global Good Agricultural Practice, and the South African Water Quality Guidelines for drinking water quality, livestock watering, recreational use, and agricultural use.
- According to the water quality related information provided by the BGCMA collected during routine monitoring at predetermined sampling points, Faecal Indicator Bacteria (FIB) in the Dwars River over the past years reached high counts of 18900 faecal streptococci per 100 ml and 10200 faecal coliform bacteria per 100 ml on one occasion, 5200 Escherichia coli per 100 ml in 2013, 5300 faecal coliform bacteria per 100 ml in January 2014, and 3000 Escherichia coli per 100 ml in March 2014 (BOCMA, 2014). The water quality data therefore collected proves that the Dwars River continues to collect pollutants along its course and FIB such as faecal coliforms, Escherichia coli, and Streptococcus feacalis remains to be present in its water since 2011 (CWDM, 2010; Witzenberg Municipality, 2012a; BGCMA, 2019).
- Ceres's Wastewater Treatment Works and sewage pump stations are known point sources of faecal pollution and stormwater runoff and runoff resulting from agricultural activities are the two non-point sources of faecal pollution of particular concern.

Faecal pollution related complications currently experienced in the Witzenberg Municipal Area have been attributed to the fact that the area's river systems are running through densely inhabited residential areas.

- Various industrial plant and factories are adjacent to the river and cause contamination and faecal pollution from households along the river were also pointed out in these surface water quality related reports.
- The main causes of faecal pollution of the Dwars River includes the mismanagement and inadequate operation of the local wastewater treatment works, control of polluted stormwater runoff, meagre municipal service delivery and substandard surface water quality management.
- The Dwars River as a water source has not been identified as being an area of concern.
- Faecal pollution of Dwars River's water can have serious consequences, placing members of the Witzenberg community and those individuals who are directly or indirectly exposed to its water and disease-causing organisms at risk of contracting a water-related disease.

5.2.2. Finding Two: Current water quality management strategies and systems

The second research question was concerned with what current surface WQMS were designed to prevent, report, and counter faecal pollution along the Dwars River, with findings as follows:

- A surface water quality management strategy in the form of a Catchment Management Strategy is in the process of being developed. No surface water quality management strategy is actively being implemented.
- The surface water quality management strategy includes water quality orientated management components such as details regarding programmes to monitor Resource Quality Objectives (RQOs), the management pollution control and emergency incidents and source-directed controls to achieve resource quality objectives. These components are not specific to the Upper Breede River Catchment Area.
- There are no resource specific water quality related objectives for the Upper Breede River Area.
- The needs and expectations of current and potential water users were not considered during decision making and the development of the water resource management strategy.
- There are no surface water quality management systems (i.e. integrated Water quality management plan, implementation plans, guidelines, systems and/or procedures and so forth) currently in place that provide clear descriptions of

management actions, responsibilities, resources available, and timeframes to mitigate or remediate existing and future surface water quality related issues.

- Current Microbiological surface water quality management measures applied to sections of the Dwars River include dilution through flooding, water quality compliance monitoring and alarm systems linked to the sewage pump stations.
- Alternative techniques employed to prevent the faecal pollution of the Dwars River includes incident response measures, the issuing and the implementation of water use permits, compliance monitoring as well as Witzenberg Municipality's Wastewater Risk Abatement Plan.
- The locations of monitoring points are mainly based on the areas identified in the Breede River Improvement Project Report published in 2010 and the frequency varies from monthly to quarterly. Compliance monitoring for the entire length of the Dwars River involves the sampling at a single monitoring point, namely, Cer1 or Oewerbrug and samples are collected once every three months. There is no formalised water quality monitoring strategy or water quality monitoring programme.
- No system in place that identifies faecal pollution events and determines the nature and extent of contamination to accommodate prompt response and to assist in the development of appropriate site-specific rehabilitation and preventative solutions.

5.2.3. Finding Three: Effectiveness of the current surface water quality management system

Research question number three focused on whether the current surface water quality management system designed to prevent, report, and counter faecal pollution along the Dwars River is suitable and effective, with findings as follows:

- Majority of respondents are of the opinion that measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River have not contributed to the protection of the Dwars River against faecal pollution.
- Poor or improper water quality management as a key constraint preventing the measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River actually contributing to the protection of the said water course against faecal pollution. Synergy between the water quality data systems that's available and the maladministration of the water quality management system.
- Poor incident response, the lack of involvement of the local municipality, communication and information sharing between various water quality management institutions, infrastructure challenges, substandard service delivery, insufficient

compliance monitoring strategies, lack of funding, personnel challenges were identified as a concern. Furthermore, data suggests that the personnel appointed by the water quality management institutions are not conscious of the environment and they do not have the capacity to perform their required functions.

5.2.4. Finding Four: Factors that can enhance the effectiveness of the current surface water quality management strategies and systems

Research question number four was aimed at determining what factors can enhance the effectiveness of the current Dwars River water quality management practices, with findings as follows:

- Improved surface water quality management practices will improve existing water resource quality management strategies and control measures designed to address surface water contamination of a faecal nature in the Dwars River.
- A change in the current surface water management approach, the proper coordination of water quality management issues, involvement of the Public Health Department, the Local Municipality must take responsibility for their sector.
- Water quality management institutions are to involve all stakeholders in decision making processes, improve water quality related data management, improve information sharing and strengthen relations between various departments and water management organisations.
- Awareness campaigns with water quality issues and pollution prevention as the subject matter as well as surface water quality related training for staff members employed by water management institutions is also deemed important by the respondents.
- Compliance monitoring of all high-risk areas and the increase in monitoring points as well the frequency of monitoring is a key practice that will improve the effectiveness existing water resource quality management strategies and control measures designed to address surface water contamination of a faecal nature in the Dwars River.

5.3. Recommendations

The objective of this section is to propose a series of recommendations based on the findings and in line with the objectives and research questions of this study. The recommendations are as follows:

Finding One: The Dwars River plays a major role in the local economy and is of ecological and social importance, however based on the findings (See 5.2.1) of this study, the current microbiological water quality of the river, the persistent faecal pollution thereof and the high risk of contracting water-related disease associated with the aforesaid has been no cause of concern for the departments managing the water source. It is therefore vital that the Dwars River is deemed an important fresh water source and should be treated as such.

Focus or problem areas (section or sections of the Dwars River) such as the study site of this thesis should be identified and an independent root cause analysis should be conducted to determine as to why the water quality of the Dwars River continuously being impaired through faecal contamination, describe the water quality challenges and associated impacts and to provide insight and guidance on the nature of modifications required to mitigate the current situation. The findings must be recorded in a report which will subsequently be used as a guideline to address water quality related shortcomings in a proactive way. It is imperative that the aforesaid should be driven by BGCMA and involve all relevant departments, service providers, water users, NGOs and the like during the entire process, especially during decision making, to ensure that relevant knowledge and information is shared. Regular meetings should be held to keep all departments up-to-date with regards to progress, barriers and so forth. BGCMA must delegate functions, manage the financial aspect and ensure that various role-players in various departments fulfil their duties, take responsibility for their actions and hold them accountable for non-compliance and/or substandard service delivery.

The major source of pollution, namely the Ceres's WWTW and the associated infrastructure, such as pumpstations, overflowing manholes and so forth, should be the point of departure for the root cause analysis after which households attributing to the pollution, industrial areas, agricultural- and recreational activities should be focused on. As mentioned, Ceres' WWTW was identified as one of the main sources of faecal pollution along the study site and warrants further investigation to ensure that the most effective pollution control instruments, amongst other things, are selected and implemented. The exact causes of this problem should be determined and solutions, such as urgent maintenance and upgrades of the infrastructure, appropriate funding/financing and so forth, must be developed and implemented. Based on previous research and respondent's answers to the questionnaire, polluted stormwater runoff from informal settlements and access to basic sanitation also warrants urgent attention. The World Wildlife Federation has done extensive research regarding this topic in and around the study site and it will be advisable for BGCMA to involve them when they approach this issue. Further to this, community leaders and members can also be approach to gain insight on regarding the cause of the problem. Security issues, distance to ablutions are causes that won't be identified without engaging with community.

The root cause analysis will also need to focus on the main causes of faecal pollution identified during this study, such as mismanagement and inadequate operation of the local

WWTW, control of polluted stormwater runoff, meagre municipal service delivery and substandard surface water quality management and so forth. This will not be an easy fix, and will require both interdepartmental and intradepartmental problem solving and cooperation to ensure that holistic preventative and control measures are formulated. Again, it is imperative that the aforesaid should be driven by BGCMA and should involve all relevant departments, service providers, water users, NGOs and the like to ensure that relevant knowledge and information is shared. Departments must also be made aware of each other's limitations, barriers, resources or obstacles pertaining to water quality management. This will assist the Departments to work in partnership, complement each other, share resources, make-up for shortfalls and prevent duplication of activities.

Finding Two: The Catchment Management Strategy, currently in its development phase must be finalised and implemented. However, prior to and during finalisation, the strategy should allow for the participation of relevant stakeholders, such as the CWDM, landowners, recreational bodies, and so forth, in the decision making process to ensure that their needs and concerns are integrated into the development of the CMS. This can be achieved by engaging with, consulting and inviting, on various platforms, all stakeholders including various departments previously not involved, water users, the private sector and the local community during decision making, the formulation of resource and source specific objectives and so forth. In the meantime, elements of the CMS which have been subjected to the public participation process can be systematically implemented.

The Catchment Management Strategy must allow for the formulation of resource and source specific objectives, management instruments and practices to accommodate all stakeholders. Implementation plans, an integrated water quality management plan, preparedness and response plans, guidelines, systems and/or procedures providing clear descriptions of management actions, responsibilities, resources available, and timeframes and so forth aimed at realising objectives as well as remediating existing and preventing future surface water quality related issues must be developed, rolled-out and actioned by relevant role-players. Current surface water quality management measures applied to sections of the Dwars River such as the dilution through flooding and alarm systems linked to the sewage pump stations are effective in their own right, but are reactive approaches to pollution control. Departments involved with surface water quality management related duties must adopt a proactive approach and utilise proactive pollution control instruments such as those mentioned in this study to the execution of their functions successfully. Long term preventative measures must be put in place to prevent the ingress of pollutants of a faecal nature into the Dwars River to reduce the risk of faecal contamination in the event of incidents and accidents.

Source specific objectives is especially important seeing that each section of the river is utilised by various sectors who have their own water quality needs. The aforesaid can only be achieved if allowance is made or the participation of relevant stakeholders, such as the CWDM, landowners, recreational bodies, and so forth, in the decision making process to ensure that their needs and concerns are integrated into the development of the CMS. It is imperative that the aforesaid should be driven by BGCMA and involve all relevant departments, service providers, water users, NGOs and the like during the entire process, especially during decision making, to ensure that relevant knowledge and information is shared. Regular meetings should be held to keep all departments up-to-date with regards to progress, barriers and so forth. BGCMA must delegate functions, manage the financial aspect and ensure that various role-players in various departments fulfil their duties, take responsibility for their actions and hold them accountable for non-compliance and/or substandard service delivery.

Previous research suggests that "water quality monitoring programs are crucial in order for decision-makers to understand, interpret and use this information in support of their management activities aiming at protecting the resource and enhancing water security" (Behmel et al., 2016:1). One of the root causes of contamination of water resources is the lack of monitoring and reporting of pollution (DWS, 2015). It is therefore imperative that water quality monitoring take place according to a resource specific water quality monitoring programme strategy and that "information from monitoring programmes is fed back into the management system so that any necessary changes to priorities and plans can also be made" (Bartram et al., 1996:12). The current water quality management program and strategy must be re-evaluated and redesigned to address the current water quality situation and the need expand compliance monitoring beyond the major known pollution sources as the current program and strategy is currently used as a routine monitoring tool and pollution control instrument. Upstream and downstream water quality monitoring must be conducted in haste at predetermined and frequent intervals. Locally appointed Environmental Health Officers must be given the mandate to monitor the water quality of the Dwars River. Environmental Health Officers are trained in performing these duties and they are acquainted with the area. Using Ceres based personnel will improve incident response time; ensure that corrective and preventative measures are implemented timeously and that non-compliant water users are prosecuted. Furthermore, utilising local personnel will reduce the funding required for travelling. This could in turn be allocated to an increased number of water quality samples. It is imperative that the aforesaid should be driven by BGCMA and involve all relevant departments, service providers, water users, NGOs and the like to ensure that relevant knowledge and information is shared. Regular meetings should be held to keep all departments up-to-date with regards to progress, barriers and so forth. A formal surface water quality data sharing strategy must be developed to ensure that water quality related data shared amongst relevant organisations as this will be essential to manage the ingress of pollutants of a faecal nature into the Dwars River.

Finding 3: BGCMA has been given the mandate to drive, assist with and monitor the roll-out of the CMS, facilitate the co-ordination and communication between the various stakeholders' role-players, ensure and promote cooperative governance, investigate, process and follow-up on complaints and non-compliances, monitor and audit service delivery and ensure the dissemination and distribution of water quality related data. However, accountability around decision-making and/or the lack thereof must be reaffirmed and communication channels between departments, residents receiving services, private sector partners and the like must be evaluated and reconstructed to accommodate an adequate, double-gated flow of information and knowledge transfer. Most importantly, a partnership must be created between all departments and those involved must be educated on the limitations, such as financial, time lines and so forth, imposed on each department and challenges, both internally and externally, they are confronted with to ensure a strong partnership at organisational level. Lastly, BGCMA must monitor departments tasked with performing surface water quality related functions and ensure that the latter takes responsibility for their actions and held accountable for non-compliance and/or substandard service delivery.

Officials performing surface water quality management related functions should be requested to attend formal courses designed to enable them to understand the principles and the practical approaches and techniques required to effectively monitor, manage and control surface water quality and surface water pollution.

Finding 4: There are various management actions that can be developed and implemented ranging from programs to educate communities on how to reduce contaminants, additional monitoring and improved monitoring programs as mentioned above, introduction of new mechanisms for managing non-regulated sources, more stringent discharge thresholds and hefty fines and so forth. The aforesaid should take into account the findings made during the root cause analyses and must be driven by BGCMA who will involve all relevant departments, service providers, water users, NGOs and the like during the entire process, especially during decision making, to ensure that relevant knowledge and information is shared and that the best possible solutions are agreed upon.

As mentioned as part of the recommendations for previous findings proper, proactive and sustainable planning and management practices are what water quality management institutions are currently lacking. Proactivity is essential for facilitating management of water resources

Develop an awareness campaign in close collaboration with the community and provide information pertaining to the inherent dangers of contaminated rivers, the importance of rivers as a natural resource, sustainable use of natural resources such as water and the benefits of clean and healthy environment.

5.4. Future Studies

It is vital that future work focus on further research to quantify the causes, effects and extent of faecal pollution within the study area seeing that the Dwars River is of value for agricultural practices, domestic use, recreational activities, industrial use, economic development, ecosystem health, and aesthetics. Further to this, Ceres' WWTW was identified as one of the main sources of faecal pollution along the study site and warrants further investigation to ensure that the persistent faecal contamination of the Dwars River is stopped and that the most effective pollution control instruments are selected and implemented.

5.5. Conclusion

As mentioned in the problem statement in chapter one, pollutants of a faecal nature, and possible disease-causing bacteria, are constantly introduced in the Dwars River through multiple sources rendering the river unusable from a domestic, industrial, and agricultural use perspective. Hence, the main objective of this study was to conduct a thorough investigation to determine why the water quality of the Dwars River is continuously being impaired through faecal contamination. This study, by employing a mixed method approach involving a combination of qualitative and quantitative research to analyse data collected from a number of sources and by using various techniques, found that there is currently no formalised surface water quality management strategy, water quality monitoring programme, integrated water quality management plan or implementation plan currently in place designed to prevent, report, and counter faecal pollution along the Dwars River.

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APPENDIX A
STRUCTURED QUESTIONNAIRE

Reference Number:

1. Organisational Information

1.1 What is your Name and Surname?

1.2 What organisation do you work for?

1.3 What is your designation?

1.4 What are your work-related responsibilities?

1.5 Are you/your organisation currently planning/rolling out any water quality related projects/programmes within the Upper Breede Catchment Area?

1.6 Please provide a brief description of what the projects/programmes entail (focus points, objectives etc.) and why it was initiated?

2. Surface Water Quality of the Dwars River and its Tributaries

(In this section you will be asked questions regarding your perception of the Dwars River's biological properties and the source's fitness for a variety of uses and for the protection of aquatic ecosystems)

2.1 In your opinion, can the Dwars River (and its tributaries) be considered an important natural resource?

2.2 Please provide a reason for your answer to **Question 2.1**.

2.3 Have you been involved with the collection and/or analysis (water sampling, analysis of results etc.) of data related to the microbiological quality of any surface water sources within the Upper Breede Catchment Area?

(Please circle) **YES** **NO**

2.4 If **YES**, what specific surface water sources fall within your jurisdiction and what is being done with the data related to the microbiological quality of surface water sources in your area?

2.5 Based on your experience in the Upper Breede River Catchment Area and available data regarding the water quality of surface water sources in the aforesaid region, how would you describe the microbiological water quality of the Dwars River?

(Please circle) **GOOD** **POOR**

2.6 Please provide a reason for your answer to **Question 2.5**.

2.7 Are you aware of any sources of faecal pollution along the Dwars River or any of its tributaries?

(Please circle) **YES** **NO**

2.8 If **YES**, please provide a brief description of these sources.

2.9 From a microbiological surface water quality perspective, what are the major concerns within the area through which the Dwars River makes its course?

2.10 Taking the microbiological quality of the Dwars River and its tributaries into consideration, what is the current and potential impact of its quality on public health and/or the natural environment?

BENIGN	POTENTIALLY HARMFUL	DETRIMENTAL

2.11 Please provide a reason for your answer to **Question 2.10**.

2.12 According to your knowledge, what institutions/organisations play a role in the management of microbiological surface water quality along the Dwars River?

3. Surface Water Quality Management Strategy

(*You will now be asked questions regarding surface water management strategies. These management strategies guide the way water management institutions in a water management area should perform their functions)*

3.1 Are you aware of an existent/draft Catchment Management Strategy that has been or is being developed for the management of surface water resources within the Upper Breede River Catchment Area?

(Please Circle) **YES** **NO**

3.2 If **YES**, what is the implementation status of the Catchment Management Strategy?

3.3 If **NO**, in your opinion, why has a Catchment Management Strategy not been developed for the Upper Breede River Catchment Area?

If No, move to question 3.9

3.4 Does the Catchment Management Strategy include microbiological surface water quality management components?

(Please Circle) **YES** **NO**

3.5 If **YES**, please provide specifics regarding these components.

If No, move to question 3.9

3.6 Are these components specific to each individual surface water sources in the Upper Breede River Area?

(Please Circle) **YES** **NO**

3.7 If **YES**, please provide specifics regarding these components.

3.8 If **NO**, please provide us with your opinion as to why this is the case.

3.9 Have microbiological surface water quality management objectives specific to the Dwars River been formulated?

(Please Circle) **YES** **NO**

3.10 If **YES**, what are the particulars of the microbiological surface water quality management objectives?

3.11 If **NO**, what is your opinion as to why no Dwars River specific microbiological water quality related objectives have been developed?

3.12 According to your knowledge, were the needs and expectations of current and potential water users taken into account during decision making and the development of the water resource management strategy?

(Please Circle) **YES** **NO**

3.13 Please provide a reason for your answer to **Question 3.12.**

4. Surface Water Quality Management System

(You will now be asked questions regarding surface water management system. Such a system includes plans, guidelines, systems and procedures for the management of the quality of water resources to meet objectives forming part of the Catchment Management Strategy)

4.1 Have surface water quality management plans, implementation plans, guidelines, systems and/or procedures for the management of the microbiological quality of water resources been developed or implemented to give effect to the water resource quality objectives referred to in **Question 3.9**?

(Please Circle) **YES** **NO**

4.2 If **YES**, please provide details of the plans, guidelines, systems and/or procedures.

4.3 If **NO**, what is used as guidance to affectively achieve the water resource quality objectives?

If No, move to question 4.7

4.4 Do surface water quality management plans, guidelines, systems and/or procedures provide clear descriptions of management actions, responsibilities, resources available, and timeframes to mitigate or remediate the existing or future quality impacts?

(Please Circle) **YES** **NO**

4.5 If **YES**, what is the status of the execution of these plans and what is being done to ensure compliance and effective implementation of these plans?

4.6 If **NO**, what is used as guidance to affectively put forth the actions?

4.7 Are you aware of microbiological water quality management measures and/or faecal pollution prevention instruments specifically applied to sections of the Dwars River?

(Please Circle) **YES** **NO**

4.8 If **YES**, provide examples of the microbiological water quality management instruments and/or measures?

4.9 If **NO**, what is being done to prevent the faecal pollution of the Dwars River?

4.10 According to your knowledge, is the microbiological water quality of the Dwars River being monitored and assessed?

(Please Circle) **YES** **NO**

4.11 If **YES**, what is done with the information/results?

4.12 If **NO**, what other measures are used to ensure river water quality compliance??

If No, move to question 4.15

4.13 Please provide details regarding the selection of monitoring points, the location of existing monitoring points and the frequency of sampling at these points.

4.14 What actions are taken in the event of non-compliances with microbiological surface water quality standards?

4.15 Are you aware of a system that is in place that identifies faecal pollution events and determines the nature and extent of contamination to accommodate prompt response and to assist in the development of appropriate site-specific rehabilitation and preventative solutions?

(Please Circle) **YES** **NO**

4.16 If **YES**, please provide details regarding the said system.

5. Implementation of Surface Water Resource Management Strategy/Measures

(You will now be asked questions regarding implementation of the surface water resource management strategies and systems discussed under Sections 3 and 4 of this Questionnaire)

5.1 In your opinion, have the measures directed at the management of microbiological surface water quality and prevention of faecal pollution along the Dwars River contributed effectively to the successful protection of the said river against faecal pollution?

(Please Circle) **YES** **NO**

5.2 If **Yes**, please provide details regarding the factors contributing to its success

5.3 If **No**, please provide details regarding the key challenges and constraints

5.4 Based on your experience in the field, are the water resource quality management strategies and control measures currently in place sufficient to address future microbiological water quality issues along the Dwars River?

(Please Circle) **YES** **NO**

5.5 Please provide a reason for your answer to **Question 5.4**.

6. Recommendations Concerning the Management of the Microbiological Quality of the Dwars River

6.1 Are there any alterations/improvements you would make to the existing water resource quality management strategies and control measures designed to address surface water contamination of a faecal nature along the Dwars River?

(Please Circle) **YES** **NO**

6.2 If **YES**, please provide details such improvements/alterations?

7. General

7.1 From your point or of view, are there any additional remarks or any gaps I did not address during the interview? None

7.2 Do you have any questions regarding my research or myself? None

7.3 Do you have any other contacts of interest? None

7.4 Do you have any other comments? None

You have now completed the questionnaire

Do you want to be sent information on our study results? Once we have processed your completed survey this page will be separated from the rest. Your response to this question will not compromise your confidentiality.

- □ No
- □ Yes, please notify me when I can view the results on the internet
- □ Yes, please send me a paper copy

If you would prefer to be notified by e-mail, please leave us your e-mail address below:

Thank you very much for your participation

LETTER OF INFORMATION

Dear Participant,

I, **Andrew McLean,** hereby kindly invite you to participate in a research study entitled: Water Quality Management of a Section of the Dwars River, Ceres, Western Cape. I am currently enrolled in the MTech program at the Cape Peninsula University of Technology and am in the process of writing my Masters Thesis.

Your participation in this research project is completely voluntary and there are no known risks for participating in this study. If answering some of the questions during the interview/questionnaire makes you uncomfortable, you will be free to skip a question, or you can decide to stop participating. Your responses will remain confidential and anonymous. Data collected will be protected and no one other than the principle investigator will know your individual answers to the questionnaire or information shared during the interview.

1. Brief Introduction and Purpose of the Study:

Previous research provided evidence that South African rivers are continuously being polluted and that various factors, such as inadequate surface water quality management, contribute to the phenomenon. Relatively few studies specifically focus on how the shortcomings of effective surface water quality management contribute to water quality deterioration. My research will focus on the observation, description, and documentation of details pertinent to the present-day management of the Dwars River's water quality.

The study aims to achieve the following objectives:

a) Analyse the current surface water resource quality management strategies developed to protect the Dwars River's against faecal pollution;

b) Evaluate the existing surface water resource quality management system(s) (plans, procedures, guidelines, systems and protection measures) implemented to counter the continuing deterioration of the Dwars River's water quality;

c) Identify factors inhibiting and contributing to the effective implementation of the surface water quality management strategy and system(s); and

d) Provide appropriate recommendations to water resource/use managers, institutions, scientists, decision-makers, and the public concerning the management of the microbiological quality of Dwars River's water.

2. Benefits of the Study

Your participation could help us to better understand various factors inhibiting and contributing to the effective implementation of the water quality management strategies in your area, which can benefit you indirectly. The identification of factors inhibiting and contributing to the effective implementation of surface water quality management strategies has the potential to lead to following:

a) Development of possible solutions to improve existing water quality management strategies. This will be part of the research's recommendations;

b) Improved surface water quality management practices can result in decreased incidence of pathogenic bacteria in surface water bodies frequented by the public;

c) Improved surface water quality in the area of Ceres and further down-stream to the benefit of everyone living within the area; and

d) The research will be available as an instrument to be used in further research.

3. Confidentiality

The completed questionnaire and any information shared during the interview will be treated as confidential. The principal investigator will be the only person who will have access to information generated during the interview/questionnaire. Additionally, it is important to note that the participant's will be referred to as respondents (i.e. participants' name/surname will not be inscribed in the research paper). All participants will be assigned with a reference number which will be used for referencing purposes.

Please sign the consent form below if you are willing and able to take part in this study. Your signature is merely an administration requirement and does not bind you to the study in any way. Once you have agreed to take part in the study the principle investigator will request a meeting date at your earliest convenience.

4. Contacts:

If you have any questions regarding this research project, please contact:

Dr Brian Delcarme (Supervisor)	Cell: 082 202 0774
Mr Andrew McLean (Principle Investigator)	Cell: 082 486 2354

Thank you for your assistance in this important endeavour.

Sincerely yours,

Andrew McLean

*Please sign the consent form and return to the Principle Investigator
andrew@csvconstruction.com

CONSENT FORM

Statement of agreement to participate in the research study:

I………………………………………………………………………………………………

(Participant's Name and ID Number)

Have read this document in its entirety and I understand its contents. Where I have had any questions or queries, these have been explained to me by ……………………………………to my satisfaction. Furthermore, I fully understand that I may withdraw from this study at any stage without any adverse consequences. I, therefore voluntary agree to participate in this study.

Participant's Name (print): ………………………………………..

Designation: ………………………………………..

Signature: …………………………… Date: ………………..…

Principle Investigator's Name (print): ………………………………………..

Signature: …………………… Date: ………..…………