Would You Drink It? An Exploratory Study Gauging the Public's Perceptions and Attitudes on the Use of Reclaimed Wastewater in South Africa

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Author Note

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Declaration

I declare that this research report titled - *Would you drink it? An exploratory study gauging the public's perceptions and attitudes on the use of reclaimed wastewater in South Africa* is my own work. It is submitted for the Degree of Master's by Coursework and Research Report at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination at this or any other University. All sources cited have been indicated and acknowledged through complete references.

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Abstract

Increasing population figures globally, and in South Africa, and other factors, such as climate change could result in countries and regions suffering severe water scarcity. Alternative water sources, such as wastewater reclamation, are available which could bridge the supply and demand gap. Historically consumers have been against the use of water from water reclamation plants. This study aimed to determine consumers' attitudes and key trade-offs toward alternative water sources, and to inform policy-and decision-makers for improved future public engagement. This could potentially improve the support for, and success, of future water reclamation plants. With the use of traditional surveys consumers' willingness to consider alternative water sources are often determined after having assumed that they have existing knowledge of often complex topics. In this study, a decision pathway design allowed for information provision within an adaptive online survey with a set of linked questions. This encouraged the deliberate construction of opinions and views. In this way, respondents' choices were more likely to be based on correct information before being asked to provide their opinions. By selecting one pathway information was revealed about respondents' trade-offs and reasoning processes. Quantitative data were collected, and various demographical variables and responses were explored. Respondents' most preferred water alternatives were provided at two points (at the start and at the end of the survey). The data revealed that there were changes between respondents most preferred alternative at the start and end of the survey. Furthermore, under situations of severe water scarcity most South African consumers would be in support of direct reclamation, however, respondents' level of trust in the government, and the associated level of affect, could play a determining factor in the future successful implementation and operationalisation of water reclamation plants.

Keywords: *Water Reclamation, Decision Pathway Survey Design, Direct Reuse, Alternative Water Sources, Water Scarcity, Sustainability*

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Acronyms and Abbreviations

ACWA	Association of California Water Agencies
ATSE	Australian Academy of Technological Science and Engineering
AUD	Australian Dollar
DPR	Direct potable reuse
DWA	Department of Water Affairs
EU	European Union
HPCSA	Health Professions Council of South Africa
IR	Incidence rate/response rate/qualifying rate
IPR	Indirect potable reuse
kW	Kilowatt
ℓ	Litre
l/c/d	Litres per capita per day
LOI	Length of interview/survey
mm/year	Millimetre per year
pH	Potential of hydrogen – Acidic, Neutral or Basic
PIS	Participant information sheet
SA	South Africa
SDG	Sustainable Development Goals
TDS	Total Dissolved Solids
TSE	Treated sewage effluent
UK	United Kingdom
UV	Ultraviolet irradiation
WRP	Water reclamation plant
WWTP	Waste water treatment plant

Would You Drink It? An Exploratory Study Gauging the Public's Perceptions and Attitudes on the Use of Reclaimed Wastewater in South Africa

1.1. Introduction

The aim of this study was to determine consumers' attitudes toward alternative water sources, including recycled water, in order to provide policymakers with information useful for decision-making. This is because effective engagement with consumers can result in more informed decisions. It also helps to inform on consumers' underlying values, opinions, and concerns, leading to more informed decisions on their part around the future of an already scarce resource and affect the success of future water schemes and projects within South Africa.

To achieve the study aims, a decision pathway survey was designed to collect information on general support for alternative water sources as well as more specific questions around support for various types of reclaimed water of different standards. The study also assessed South African's pre-existing knowledge on water terminology. The survey also aimed to determine if participants' reluctance to reclaimed water use could be diminished through information provision and if there were other demographic factors that made them more or less likely to support future reclamation projects. Respondents' choices of most preferred water alternative at the beginning and end of the survey were compared to determine the effect of information provision.

The survey design was informed by previous environmental studies, and research on survey design and decision-making (Aubert & Lienert, 2019; Bier, 2001; Drew et al., 2002; Gregory et al., 1997; Gregory et al., 2016; Gregory & Wellman, 2001; Kenyon et al., 2003; Robinson et al., 2019; St Laurent et al., 2018), while the specific survey questions were informed by a qualitative study in which major themes around reclaimed wastewater use were identified during focus group sessions (Levin, 2019). Furthermore, having used a decision-pathway survey, a set of linked questions were included which provided information about respondents' trade-offs and reasoning processes, as one path was selected while others were avoided.

1.2. Aim and Research Questions

The primary aim of this research was to explore consumers' decisions and thought processes as they progressed through the survey and were confronted by a topic that they either have little or no knowledge of, or which is not often thought about at all. The decisions and trade-offs individuals made were explored through the use of a decision pathway survey, a process that provides information, specific to a topic and useful for public education and engagement. This was done by firstly determining respondents' level of knowledge, then providing them with vignettes of information at particular points during the survey, which also worked to explain unfamiliar terminology. The path that each respondent took through the survey was determined by their answer at each level (Gregory et al. 1997). Through selecting one pathway and avoiding others, information was revealed about respondents' key trade-offs and their reasoning processes (Gregory et al. 1997). One key aim of information provision was to activate a slower and more deliberate thinking process (Gregory et al., 2016; Kahneman, 2011).

Ultimately, South African consumers' perceptions could affect the success of water schemes and alternative water projects. Should the engagement between consumers and governmental or municipal bodies be improved, and consumers be provided with information on environmental topics and technologies available which could ease the environmental burden, future projects could potentially have greater levels of success.

South Africa faces a looming water crisis. Consumers' perceptions of alternative water play an important role in the successful implementation of alternative water sources, including reclaimed water. As such, the following research questions were identified and are addressed in subsequent chapters:

1. What are the most preferred alternative water sources in South Africa, and what is the predominant reason for supporting the water alternative?
2. What are the decision pathways around support for alternative water sources and reclaimed-water acceptance in a South African context?
3. Can attitudes toward alternative sources of water be changed through information provision to consumers?
4. Are there differences in perceptions of reclaimed water, and changes to preferences among uninformed and informed respondents?

To answer these questions the following variables needed to be considered:

- pathways chosen in the decision pathway survey,
- respondents’ most preferred alternative water source at the start of the survey,
- respondents’ most preferred alternative water source at the end of the survey,
- respondents’ pathway and responses to the questions within each pathway, and
- a consideration of various biographical variables.

The central difference in the methodology of this study and those of previous studies was the use of a decision pathway survey to determine consumers’ underlying perceptions of reclaimed wastewater and their understanding of available water alternatives.

The study was undertaken in four main tasks:

Task 1: A decision pathway survey was designed, and various other relevant variables were identified;

Task 2: Experts were engaged to provide input on the content validity of the survey;

Task 3: The survey was pre-tested and pilot tested;

Task 4: The survey was distributed online to volunteer South African consumers.

1.3. Chapter Organisation

The research project is organised into five chapters, the first chapter offers an introduction to the study.

Chapter 2: Literature review - The chapter focuses on the severity of water scarcity globally, and specifically in South Africa, alternative water treatment processes and their future viability, and consumer decision-making. Through a better understanding of the various terms used to describe the fundamentals of hydrology and by understanding the severity of the water crisis, the importance of this study can be placed into perspective. Furthermore, an understanding of consumers' decision-making could provide insights into the reasons for choices for, and against water reuse and ultimately the impact they could have on ensuring a sustainable approach to water management in the future.

Chapter 3: Method – An exploratory and descriptive quantitative approach was adopted with a predominantly non-experimental design. One of the research questions could be classified as a one-group pre-test post-test. Themes identified during a quantitative study by Levin (2019) informed the choice of questions, while the overall decision pathway design was based on work by Gregory et al. (1997). The survey collected responses on general knowledge of water terminology and demographics while the decision pathway consisted of 11 distinct paths. A sample of experts validated the newly designed survey, after which it was piloted- and pre-tested before distribution to a sample of 668 South African consumers. There was no random assignment of respondents or a control group. Several steps were followed to maintain the integrity of the collected data before analysis. Descriptive statistics were used along with several correlations and chi-square tests with Bonferroni *post-hoc* tests. During and after data collection, all participants were protected from psychological and physical harm, and the data were treated as confidential as prescribed by the Health Professions Council of South Africa and the University of the Witwatersrand's Human Research Ethics committee.

Chapter 4: Results – The results chapter provides insight into the respective research questions with a clear distinction between respondents' willingness to explore alternative water sources, the respective pathways, and how respondents preferred alternatives changed as a result of having received information on the topic. Other findings are also included, more specifically, results on respondents' self-reported understanding of the municipal water treatment technologies and the results from the general knowledge questions, the number of water-saving, energy-saving, and eco-friendly initiatives employed, and results on the demographic differences and respondents' preferred water alternative and respective pathways.

Chapter 5: Discussion and conclusions – The paper concludes with a discussion around the research questions. More specifically discussions on respondents' most preferred alternative water source in South Africa and the primary reason for their support; what the decision pathways around the support for alternative water sources and reclaimed-water acceptance are in South Africa; and whether there are differences between uninformed and informed respondents' perceptions and attitudes toward alternative water sources. The change in respondents' attitudes and perceptions will be considered after information provision of the various alternatives available, and thus, having activated a more thoughtful and slower decision-making process rather than opinions gathered from more traditional surveys. Limitations specific to the study are also presented along with suggestions for future research.

2. Literature Review

2.1. Introduction

From space, Earth is seen as a big, blue sphere. It is quite unique from other planets as more than 60% of its surface is covered by an ocean of water (Boulware, 2013; Boyd, 2020). Despite this, there is not an abundance of water available for human consumption. The planet also has a closed hydrological cycle: the amount of water is constant, it cannot be increased or decreased but is endlessly "recycled". Water in the hydrological cycle, in ice caps, lakes, rivers, ponds, streams and underground, accounts for an extremely small percentage of fresh water suitable for human consumption and is unevenly distributed across the globe (Boulware, 2013, Marshall, 2013; Mullen, n.d.).

There is a constant increase in demand for fresh water, predominantly because of an increasing population, but also due to rising living standards, and adverse weather events as a result of global warming (Mekonnen & Hoekstra, 2016; Swartz et al., 2015; Tsiourtis, 2017). These are very relevant factors in South Africa, which is classified as a water-scarce country with a history of severe droughts (Parks et al., 2019). Rising demand places the future supply of water at risk, and supply is forecasted to soon fall short of demand (World Economic Forum [WEF], 2019). Therefore, it is vitally important to look beyond the historic means of securing a water supply and to consider alternative strategies and water sources to ensure a continuous supply of fresh water now, and in the future. Many alternatives exist, each with its own degree of feasibility and expected success.

A notable issue that could adversely influence the successful implementation of various water reuse projects is consumers' perceptions of the effectiveness and cost of the methods used and the quality of the water produced. This could include their perceptions of the water's purity, negative affect associated with disgust, health risks of using the water, and their trust in local and national government and experts to maintain water quality at optimum levels (Etale et al., 2020; Falkenmark et al., 2007; Po et al., 2003; Swartz et al., 2015).

This study focuses on the perceptions and values of South African consumers in relation to reclaimed wastewater as an effective alternative water source in South Africa. It examines their underlying drivers when faced with often novel decisions and trade-offs between alternative options, such as water reuse, for indirect or direct potable use. The study used a decision pathway survey, as an alternative to more traditional survey designs, which provides respondents with information on an often-novel topic as they progress through the survey. This allows them to deliberate on relevant information before making a decision, which could result in informed rather than intuitive decision-making. The survey design followed a constructivist approach, which is designed to elicit attitudes about complex problems in an attempt to provide policy- and decision-makers with detailed information on the reasons consumers hold specific beliefs (Bier, 2001; Gregory et al., 1997). The survey design also allowed for the inclusion of many questions. However, respondents were not required to answer every question but rather their answers determined the set of questions they received. This more adaptive survey approach helps avoid respondent fatigue.

The literature review introduces various terminologies used when discussing water, considers the global water crisis, then focuses on South Africa and its unique water situation. Various alternative water sources were considered; however, the main discussion focuses on wastewater reclamation as the most viable and cost-effective alternative for South Africa. Notable examples of the successful implementation of wastewater reclamation projects are provided. The barriers policy makers and governments often face when considering this alternative are discussed, followed by a discussion on human decision-making and the motivation for using the pathway survey design.

2.2. Water Terminology

Water is vital to our survival – without it, all life on Earth would perish. It has symbolised life, fertility and refreshment, and has been called the "elixir of life". Many daily activities supporting society, industry, and the economy depend on water. Yet, we do not often consider the volume of water needed to rear livestock for meat, wheat for bread or cotton for clothing, or to process metals for everyday consumer goods (Hoekstra & Chapagain, 2007). Water is so critical that major scientific explorations are undertaken in the hope of discovering water on other planets in our solar system. Still, very few people know of or understand some of the fundamentals of hydrology or how water is purified for domestic use. This limited knowledge could act as a barrier to consumers' support of more sustainable water sources, which are desperately needed (Dolnicar & Hurlimann, 2009; Slabbert & Green, 2020).

Hydrology is defined as "the study of the global water cycle and the physical, chemical, and biological processes involved in the different reservoirs and fluxes of water within this cycle" (Marshall, 2013, p. 1). It, therefore, provides the basis for any discussion on water. Water appears in different states such as a liquid, vapour, or in solid form such as ice within the *hydrological cycle* (see Figure 1) (Association of California Water Agencies [ACWA], 2017; Boulware, 2013; Mullen, n.d.). Furthermore, the hydrological cycle describes the exchange of water between global reservoirs (the ocean, atmosphere, land surface, soils, groundwater systems and the solid earth) (Marshall, 2013).

The volume of water, as has been stated, cannot be increased and we still have access to the same volume of water as has been available since the Jurassic period (Boulware, 2013). This water is broadly categorised as either saline (ocean water) or fresh water. Available fresh water is found in ice caps and glaciers (water in its solid phase), groundwater, and surface water. Evaporation from these sources and transpiration and evaporation from plants enter the cycle where it condenses and fall to earth as precipitation. This precipitation, which is distributed unevenly across the planet, is then again stored in ice caps, rivers, streams or lakes, or seeps into soils, groundwater aquifers or vegetation (Boulware, 2013; Marshall, 2013). *Surface water* is water collected from rainfall on the surface of the ground, or in rivers and dams, while *groundwater* is water that seeps underground through porous soil, sand, and rock into aquifers (Boulware, 2013; Mullen, n.d.; Parks et al., 2019). *Return flow* is water “that returns to surface or ground water after human use” (Montagna, n.d. par. 1).

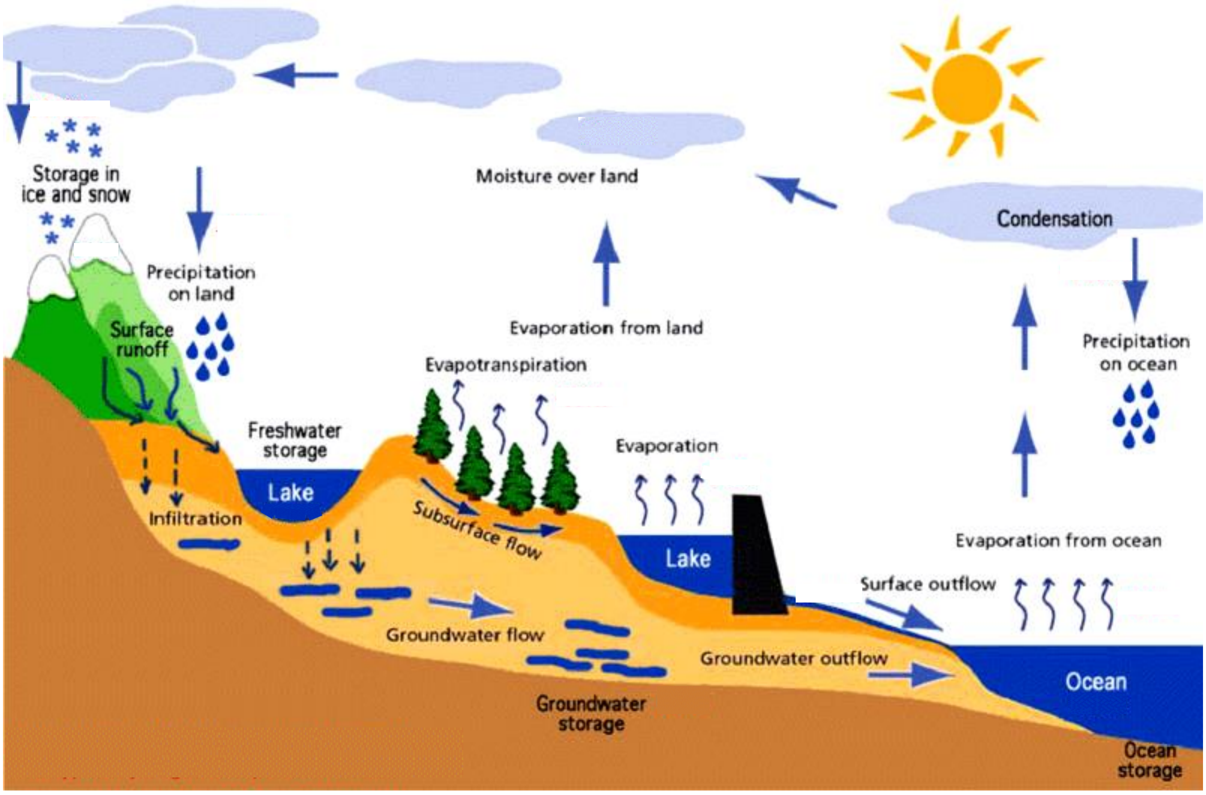


Figure 1: *Earth’s Hydrological Cycle*

Note. From Wikimedia Commons, by Sunson08, 2016, https://commons.wikimedia.org/wiki/File:F3_hydrological_cycle.png. Copyright Creative Commons Attribution-Share Alike 4.0 International. Reprinted with permission.

An estimated 96.3% of the earth's water is in the ocean, and more than half the remaining water is inaccessible, trapped in glaciers and ice sheets in the Antarctic. Of that which remains, a considerable portion is below the surface in groundwater aquifers (Marshall, 2013). The fresh water, on which all of humanity depends, constitutes only a small portion of the earth's total water supply, with surface water making up only an estimated 0.02% (Marshall, 2013). It is for this reason, along with its regional disparity, mounting global water demand, climate change-induced water stress, increased pollution, and aquifer depletion, that water is considered a generally scarce and valuable resource (Marshall, 2013).

Water availability refers to "available water resources, constrained by the physical hydrological cycle and human activities (e.g., water abstraction and regulation) in river basins", while *potential water demand* is the "estimated water use accompanying human activities regardless of water availability" (Hanasaki et al., 2013, p. 2376). *Water scarcity* is broadly described as "a shortage in the availability of freshwater relative to demand" (Taylor, 2009, p. 237) and can be classified as either physical or economic water scarcity.

Physical water scarcity, as is the case in many parts of the world, occurs when there is not enough water to satisfy the demands of all water users, or when natural water resources are inadequate to supply a region's demand (Damkjaer & Taylor, 2017; Falkenmark et al., 2007). Economic water scarcity occurs when renewable water resources are adequate, but there is not enough investment in water infrastructure to make the resources available (Damkjaer & Taylor, 2017; Falkenmark et al., 2007).

As per Falkenmark et al. (2007), there are four drivers of physical water scarcity: (1) demand-driven water scarcity; (2) population-driven water scarcity; (3) climate-driven water scarcity; and (4) pollution-driven water scarcity. Demand-driven water scarcity occurs when water demand is higher than the capacity of available water sources. This is frequently due to population-driven water scarcity, where high population levels place pressure on the amount of water available and leads to a per capita water shortage. Climate-driven water scarcity occurs when a region's geographical location affects rainfall and runoff, while pollution-driven scarcity is often caused by the degradation of water to the point of it becoming unusable, although this could be managed with stricter policy and legislation controls (Falkenmark et al., 2007). It could be argued that water scarcity in South Africa is largely population-driven and climate-driven. However, inadequate investment in infrastructure during the apartheid era could have resulted in economic scarcity, particularly in rural areas.

Water reuse alternatives often use novel technologies to mimic the natural water cycle to produce clean water, thereby easing water scarcity (ACWA, 2017). These alternatives include: harvested rainwater, harvested storm water, captured condensate, purified water from desalination plants, water from atmospheric water generation, and reclaimed wastewater (U.S. Department of Energy, n.d.). A vast amount of energy is ordinarily required to treat the small percentage of fresh water available to get to acceptable drinking levels or to purify saline water, through a process of desalination (ACWA, 2017; Parks et al., 2019). For the traditional treatment of raw water, an estimated 0.1 kW of energy per 3,800 litres (1,000 gallons) is required; this can range between 0.4 kW and 1.2 kW per 3,800 litres for purifying wastewater discharge, and be as high as 12 kW for a comparable amount of water from the desalination of seawater (Boulware, 2013; National Research Council, 2012). Regrettably, even though the traditional treatment of raw water is the least energy intensive, it is not sustainable. It is for this reason that Cooley and Phurisamban (2016) compared the overall costs of various indirect water reuse alternatives. Their study provided a summary of the overall costs for some of the most popular water reuse schemes - seawater desalination plants, storm water capture projects, and municipal or blackwater recycling - found storm water capture to be the least expensive, desalination projects the most expensive, and water reclamation costs in the middle.

The cost of alternative water sources and the availability of the water source in South Africa are major factors influencing the viability and feasibility of alternative water schemes. During 2015, the agricultural sector was the largest consumer of water, using 63% of available water, followed by the municipal sector (27%) and industrial sector (10%), with these levels of consumption forecasted to remain consistent over the next few years (Donnenfeld et al., 2018). The water that is withdrawn is often discarded as waste water after a single use. The flow and collection of liquid waste from industries and domestic residences in sewer systems make up a considerable portion of a potential renewable resource which could ensure future availability of water and reduce the burden on South Africa's energy suppliers. Given the currently accepted approach to managing wastewater (i.e., the discharge of wastewater as effluent to surface water bodies after only partial treatment), a more effective and sustainable process, such as wastewater reclamation, could reduce the pharmaceuticals, hormones, organics, bacteria, and nutrients that pollute rivers, streams, and the ocean (Boulware, 2013; Donnenfeld et al., 2018).

In this study, *wastewater* refers to both greywater (water from homes or office buildings that does not contain faecal matter and, with minimal treatment, can often be easily re-used for non-potable or irrigation purposes), and blackwater or sewage water, which contains human waste (ACWA, 2017; Drewes & Khan, 2015; Hardy et al., 2015). *Water reclamation* is defined as "the direct reuse of treated sewage effluent to replace a proportion of the fresh water demand" (Grobicki & Cohen, 1999, p. 2). Water from water reclamation plants can be treated to a potable standard, for drinking, or non-potable standard for purposes such as irrigation or industrial use (ACWA, 2017).

The process of making water schemes operational is referred to as *planned reuse* or the intentional reuse of wastewater for either *indirect* or *direct potable reuse*. Indirect use involves mixing reclaimed water with other environmental systems (such as a river, reservoir or groundwater basin) before it is extracted, treated and reused to supply drinking water (Swartz et al., 2015). This water supply and treatment loop is depicted with solid lines in Figure 2, while the possible flow of treated sewage effluent (TSE) is indicated with a broken line (Grobicki & Cohen, 1999). Indirect reuse is not vastly different from the traditional cycle of treating water and wastewater.

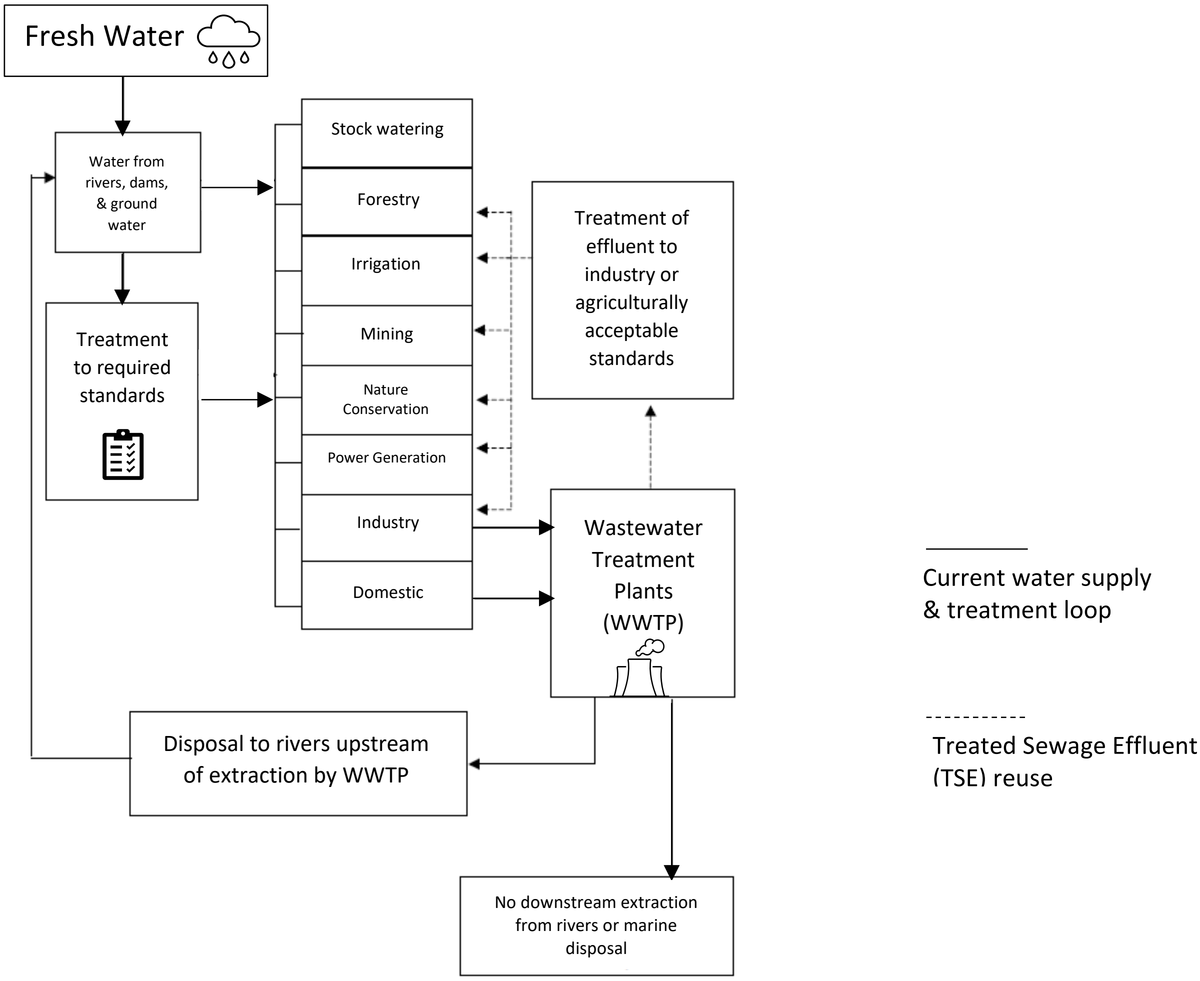


Figure 2: *Simplified Water Supply and Treatment Loop*

Note. Adapted from "Water reclamation for direct re-use in urban and industrial applications in South Africa and its projected impact upon water demand," by A. Grobicki, and B. Cohen, 1999, *Report to the Water Research Commission. WRC Report No: KV118/99*, p. 3. Copyright 1999 by Water Research Commission.

Direct potable reuse, in contrast, involves pumping the reclaimed water directly into a potable water supply distribution system; the water is not placed into a natural "buffer" but is used directly after treatment (ACWA, 2017) (see Figure 3). Quite often, consumers may agree with, or be completely against, indirect reuse without knowing the water has been treated upstream before being extracted by the treatment plant downstream. This is also known as de facto, unacknowledged, or unplanned potable reuse. Whereas planned potable reuse is intentional, *de facto or unplanned reuse* is “a situation where reuse of treated wastewater is in fact practiced, but is not officially recognised (e.g., a drinking water supply intake located downstream from a wastewater treatment plant discharge point)” (National Research Council, 2012, p. 14). There are considerable advantages to opting for direct potable reuse over indirect potable reuse. These include cost savings due to the shorter distance of the water flow between waste and drinking water treatment plants. In comparison, the capital and operational costs of indirect potable reuse plants are significantly higher. As noted in an Australian Academy of Technological Science and Engineering (ATSE) report (ATSE, 2013), a direct potable reuse system was estimated to cost around AUD616 million, while an indirect potable reuse system cost AUD1,287 million. Operational costs for indirect reuse systems were also reported to be considerably higher: an estimated AUD53 million per year for a direct potable reuse system compared to AUD72 million per year for the indirect potable reuse system (Martin, 2013). Other advantages include a reduced carbon footprint and an overall increase in water security. Disadvantages of direct potable reuse could include additional setup costs (including additional water testing), safety concerns if water testing is not at a high standard, and the public’s perception and possible rejection of any water from the plant (ATSE, 2013; Martin, 2013).

Ultimately, direct potable reuse is a more cost-effective and energy-efficient way to ensure future water security than many other alternatives (ATSE, 2013; Cooley & Phurisamban, 2016). Advanced technology currently available, if managed effectively, can ensure the water quality is of the highest standard, often higher than conventionally treated water. Although this is a non-conventional approach to water management, it is becoming a preferred and increasingly common method internationally, especially in countries that have water shortages as it is a more efficient and sustainable alternative with the primary source of water readily available (Grobicki & Cohen, 1999).

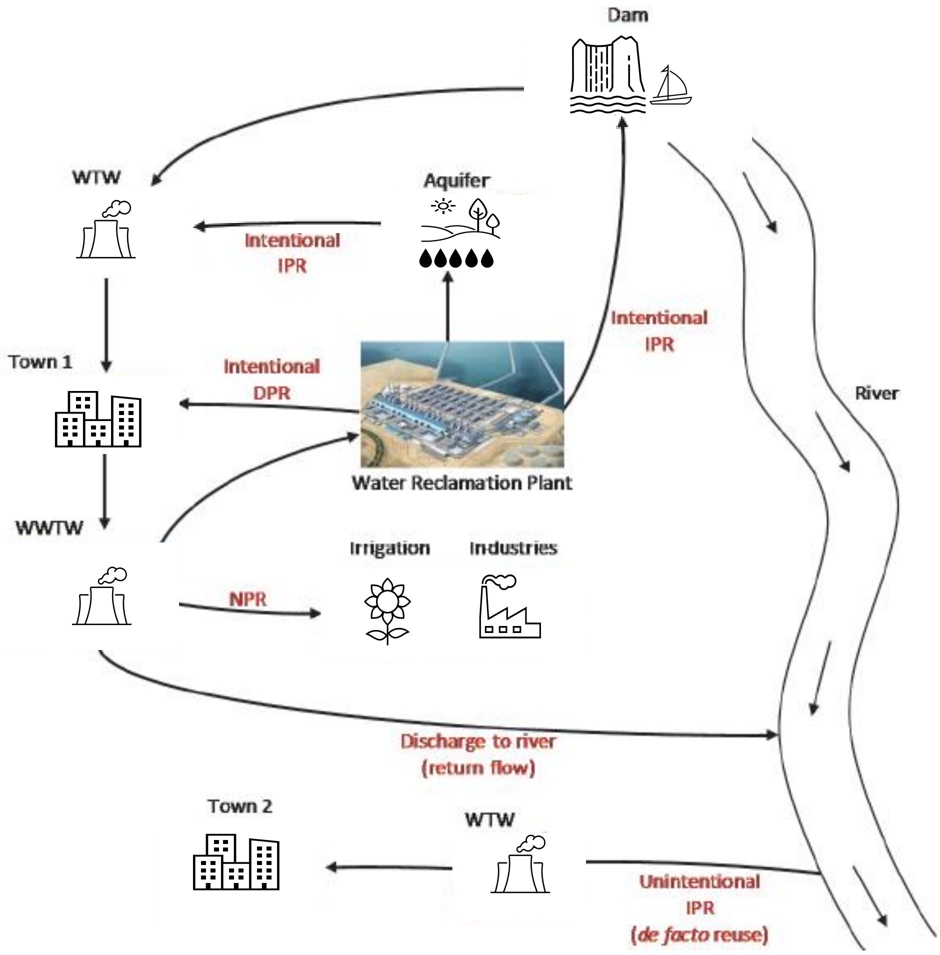


Figure 3: *Schematic Diagram Showing Different Types of Water Reuse*

Note. DPR = Direct Potable Reuse; IPR = Indirect Potable Reuse; NPR = Non-Potable Reuse; WTW = Water Treatment Works; WWTW = Wastewater Treatment Works.

Adapted from "Direct reclamation of municipal wastewater for drinking purposes WRC Report No. TT641/15," by C. D. Swartz, B. Genthe, J. G. Menge, J. G. Coomans, G. Offringa, 2015, *Water Research Commission*, p. 5. Copyright 2015 by the Water Research Commission.

2.3. The Global Water Crisis

Humans' need for fresh water is ever-increasing and can be attributed to an increase in global population figures, industrialisation, globalisation, and human-induced climate change (Falkenmark et al., 2007; Hanasaki et al., 2013; Mekonnen & Hoekstra, 2016). Because of this, the global demand for fresh water is expected to soon surpass the available supply, which could have devastating consequences for countries that already suffer water shortages (WEF, 2019, p. 71). Lack of access to fresh water could result in a global water crisis. As per the World Economic Forum's Risks Report 2019, this could in turn create a global food crisis, given that agricultural water withdrawal globally accounts for roughly 70% of total water withdrawal (Hanasaki et al., 2013; Lautze et al., 2014). It could also increase the spread of infectious diseases and result in a global health crisis. In addition to effective vaccines, access to fresh water and proper sanitation play a key role in preventing the spread of disease. Water scarcity is, therefore, a stark reality that must be acknowledged, as water is one of the most important resources not only for humanity's wellbeing but its ultimate survival due to its interconnectedness with other global factors and risks. The increasing demand for industrial and municipal water withdrawals, which account for roughly 30% of the total global water withdrawal (Hanasaki et al., 2013), and the possible future shortfall to supply such demand, will also have a negative impact on the United Nations' Sustainable Development Goals (SDG), particularly the goals concerning water and sanitation for all, and reducing the number of people suffering from water scarcity (Parks et al., 2019; WEF, 2019).

In recent years there has been a growing interest in domestic per capita usage. In the UK, it has been reported that the average person uses about 132 litres of water each day (Energy Saving Trust, 2014), while in Iraq the average per capita consumption was found to be between 241 and 290 litres per day (Hussien et al., 2016). The average estimated consumption in South Africa is around 237 litres per capita per day (l/c/d), which is greater than the global average of approximately 175 l/c/d (Department of Water Affairs [DWA], 2014; Donnenfeld et al, 2018; EU Chamber, 2019). In Mozambique, however, this figure is 10 l/c/d which is far lower than the minimum of 50 to 100 l/c/d prescribed by the World Health Organization for personal hygiene and cooking (Ramulongo et al., 2017). Both globally and in South African, consumers' average water use is unsustainable and places an increasing burden on the environment.

It is predicted that by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity (Lazarova et al., 2013). A more recent study shows water scarcity is already a reality (Mekonnen & Hoekstra, 2016). It is estimated that roughly 71% of the global population, or 4.3 billion people, live with moderate to severe water scarcity at least one month of the year: about 66% live with severe water scarcity at least one month of the year; and 1.8 to 2.9 billion people face severe water scarcity for at least four to six months per year, with the majority of these people living in densely populated countries such as China and India (Mekonnen & Hoekstra, 2016). Libya, Somalia, Niger, and Jordan face severe water scarcity all year round (Mekonnen & Hoekstra, 2016). Furthermore, water scarcity is not just a problem for developing countries, as even the United States of America (USA), France, Italy, Belgium, and the UK have suffered the negative impact of successive droughts on their water supply (Angelakis & Bontoux, 2001).

In countries such as China and India, scarcity is more often classified as population-driven physical scarcity. In parts of the US, due to highly irrigated agriculture, demand-driven physical scarcity is more common (Mekonnen & Hoekstra, 2016). Water scarcity can, however, also be as the result of natural disasters, extreme weather events and other factors beyond human control. Proper planning around decisions and actions involving current and future needs can influence future sustainability (The International Water Association [IWA] Publishing, 2010). Given the general agreement that an over-reliance on rainfall to replenish groundwater aquifers and surface water resources is unsustainable, there has been an increase in research exploring alternative sources of water to ensure future supply (Boulware, 2013; Cooley & Phurisamban, 2016; Hardy et al., 2015; IWA, 2010; Marks et al., 2006; Parks et al., 2019). As a result of an increase in research, corrective action has been taken and several strategies to manage water shortages have been implemented in Europe. Such strategies include the construction of transfers from water-rich watersheds to water-deficient areas; however, these projects are extremely expensive and require significant investments and large civil engineering works, which could negatively impact the environment (Angelakis & Bontoux, 2001). Other strategies include water savings, such as suppressing the leakage of supply networks, using more efficient irrigation techniques, and reducing demand through pricing increases (Angelakis & Bontoux, 2001). In other parts of the world, such as India, water supply is severely restricted and supplied intermittently for a few hours a day (Ramulongo et al., 2017). All of these strategies possess various levels of feasibility and involve economic, institutional, cultural, and political issues that do not necessarily solve the core issue of ensuring a sustainable water supply.

Research on alternative sources of water, which are more sustainable and not supplied from surface water include rainwater harvesting, wastewater reclamation, and desalination plants (U.S. Department of Energy, n.d.). These alternative sources of water have their own levels of feasibility implementation challenges, costs, and pros and cons (Cooley & Phurisamban, 2016; Hardy et al., 2015; Rygaard et al., 2010). Even though several countries have successfully incorporated some of these strategies and alternative approaches to securing water as part of their continuous search for more sustainable water sources, success is not guaranteed (Gulamussen et al., 2019; Po et al., 2003; Swartz et al., 2015). The high costs associated with such projects and a general agreement that the public is a determining factor of a project's success means it is vital to accurately gauge consumers' perceptions, attitudes, and trade-offs between available options before governments endeavour to implement such schemes.

2.4. The South African Water Situation

South Africa has a history of devastating droughts (Wilhite, 2000). It also has a countercyclical consumption cycle, where the demand for water is often at its highest when the water availability is at its lowest (Mekonnen & Hoekstra, 2016). South Africa is therefore categorised as a semi-arid to arid country with an average annual rainfall of only 450 mm, far lower than the global average of about 860 mm/year (Botai et al., 2019). South Africa is classified as a water-stressed country and is ranked among the thirty driest countries in the world (DWA, 2014; Mabhaudhi et al., 2019). Some areas experience moderate to severe water scarcity for more than half the year (Mekonnen & Hoekstra, 2016, p. 1). In 2015, the South African Weather Service recorded the lowest annual rainfall since 1904 - 403 mm - which had a devastating effect on South African dam levels (Donnenfeld et al., 2018). This, along with the drought during 2017 and 2018, had a severe impact on the Western Cape, which narrowly averted a "Day Zero" as the province almost exclusively relied on surface water (EU Chamber, 2019; Parks et al., 2019). The scarcity of water constitutes a real and imminent threat to all South Africans, especially with water demand projected to surpass supply in the medium term, with a predicted shortfall of 17% by 2030 (EU Chamber, 2019). Even though national dam levels increased, due to increased rainfall in the latter part of 2020, the National Water and Sanitation Department urged residents to consume water sparingly, as some dam levels were still not sufficient and below 60% capacity, while others, such as the Vaal Dam, were below the 50% mark (Rand Water, 2020; Times Live, 2020).

South Africa's water usage comprises 77% surface water, 9% groundwater, and 14% re-use of return flows, while water demand mirrors that of global trends (DWA, 2014). Roughly, 61% of available water in South Africa is used for agriculture and around 27% is used by municipalities and for domestic use (DWA, 2014; Department of Water and Sanitation, 2018). Furthermore, it is estimated that only 73% of households have access to running water, either in the house (46%), or from a tap in the yard (27%) (DWA, 2014). South Africa also has a unique political history plagued with inequality, the consequences of which are far reaching and still felt today. This should be regarded as a contributing factor to the current situation. These consequences, unfortunately, include limited access by many to fresh water, and the politicisation of water management and service delivery, often resulting in service delivery protests (Jankielsohn, 2012). South Africa's history of apartheid and the government's management, then and now, of an already scarce resource with limited and failing infrastructure is a stark reality. South Africa progressed from a time of segregation and discrimination, where access to water was often restricted for use by the white minority, while many households in settlements had little to no infrastructure or a limited supply of water and sanitation services, to a country where a "right to sufficient water" was included in the country's Constitution (Muller, 2008).

The South African government post-1994 inherited a water sector with limited infrastructure, and 12 million South Africans who lacked basic access to water (Muller, 2008). It was therefore not incremental population growth but the requirement to serve millions of previously disadvantaged individuals and households that caused an increase in demand. South Africa's existing infrastructure was largely incapable of supplying water to millions, causing a critical need to prioritise the building and expansion of infrastructure and service delivery, and the amendment of legislation, to service those previously excluded (Jankielsohn, 2012; Muller, 2008). Water policies were therefore amended, and legislation passed to bring about water reform to include free or subsidised water delivery to millions (Muller, 2008). Funding issues arising from free service delivery, the mismanagement of funds, lack of political will, and limited engineering design, and institutional capacity, aggravated the current situation, as existing infrastructure was expanded but not properly maintained (Jankielsohn, 2012). Policies and legislation were introduced to ensure the protection and sustainability of South African freshwater resources, but were not always thoughtfully or efficiently implemented or managed (Sershen et al., 2016). In a 2016 study, experts' perceptions on challenges to water security in South Africa included a belief that there is a lack of skills and political will in government and mistrust among consumers regarding government's intention and capability to deliver water-related services, often due to a failure to up-scale existing water reuse technology and infrastructure (Sershen et al., 2016).

As has been stated, fresh water (water in ice caps, ponds, lakes, rivers, streams, and underground water) is generally a scarce resource (Boulware, 2013), especially in South Africa. The looming water crisis is therefore a real threat. The quality of this scarce resource is also at risk, due to failing infrastructure, an increase in pollution, the destruction of river catchments due to urbanisation, damming of rivers, mining, energy use, and water pollution (Rand Water, n.d.). The increased demand for fresh water, deteriorating water infrastructure and drastically fluctuating dam levels calls for the reconsideration and adaption of water policies and alternative sources of water to mitigate the current and future crisis (Donnenfeld et al., 2018). The feasibility of implementing water policies and alternative sources of water in South Africa is thus heavily impacted by numerous social, geographical, legislative, and political factors.

Irrespective of the barriers to increase service delivery and secure South Africa's water future, numerous alternatives do exist. It is the responsibility of every South African consumer to use water responsibly and to be adaptable to using more sustainable alternatives to help secure water availability in the future. By adopting affordable technologies, government, businesses, and private households can help to realign supply and demand. South Africa's coastal regions could consider building and implementing desalination plants. Unfortunately, these are costly and would not be feasible for inland areas. Dry and arid central regions, such as large parts of the Northern Cape, have limited alternatives available. Some of the western regions have an average rainfall of only 100 mm per year (DWA, 2014). South Africa's geographical location and varying climates thus play a role in making the reliance on rainfall to fill dams unsustainable, and the implementation of certain alternative water sources, such as storm water- and rainwater-harvesting, impractical (Mabhaudhi et al., 2019). It is therefore argued that reclaiming wastewater is one of the most viable and realistic options available in South Africa, given the availability of the resource, South Africa’s location and the country’s seasonal water consumption cycle (Drewes & Khan, 2015; Ghernaout, 2018; Hardy et al., 2015).

Various reclamation plants have already been constructed in the country. With regards to treated sewage effluent for industrial use, within Port Elizabeth numerous industries including paper mills and leather tanneries use a total of approximately 26.2 Ml/day, with 95% of the Adamas Fine Paper plant’s water requirements met using treated sewage effluent (Grobicki & Cohen, 1999). Other reclamation plants include plants in Beaufort West for direct potable reuse, also the second direct reclamation plant in the world (Marais & von Dürckheim, 2011), in George for indirect potable reuse, and in Mossel Bay for reuse for industrial purposes only (Swartz et al., 2015). Furthermore, it was reported in 2015 that direct potable reuse plants were at advanced planning stages for Durban’s eThekwini Municipality, and in Port Elizabeth, Cape Town, and Hermanus (Swartz et al., 2015). Since then, the Cape Town reclamation plant has been reported to be operational and an enormous relief for many in the Western Cape with a recovery rate of more than 85% (Cloete, 2019). No further information was available on the Port Elizabeth or Hermanus plants, and it is debatable whether the eThekwini plant will come to fruition. In 2020 Durban’s eThekwini Municipality reported a need for R21 billion to fix a deteriorating and ageing water and sanitation infrastructure (Magubane, 2020); it is therefore assumed that any available funds would be directed to repairs rather than the building of a reclamation plant.

Other than cost and energy implications, one of the most significant hurdles to overcome - not just in South Africa but globally - when considering alternative sources of water is the public's perception and their levels of acceptance of the water (Dolnicar & Schäfer, 2009; Fielding et al., 2019). The public's perceptions and acceptance of reclaimed water are of psychological concern and could mean the success or failure of such projects (Po et al., 2003). According to Po et al. (2003), it was only a few years prior to their paper that research shifted to understanding the various factors that influence public perceptions of water reuse and how these influence consumers' decision-making processes. Previously, social marketing or persuasion through incentives or other behavioural methods were used, but were found to be ineffective in influencing consumers. People generally conclude that our current water use is unsustainable and know that technologies are available to secure water from alternative sources for the future; nevertheless, they are hesitant to support such projects if it means they would have to personally use the water (Po et al., 2003). The various factors that could influence the behavioural acceptability of reuse schemes include a disgust or "yuck" factor, consumers' perception of risk, their trust in the government to maintain the infrastructure, their knowledge on the topic, and their attitudes toward the environment (du Pisani, 2006; Etale et al., 2020; Levin, 2019; Po et al., 2003). It is also extremely important to note that a single incident of illness stemming from the inadequate management of water quality at a plant, after it has been brought into operation and accepted, could lead to a whole community rejecting the plant, or result in financial losses due to lawsuits and the closure of the plant for long periods while under investigation (Marais & von Dürckheim, 2011; Swartz et al., 2015).

Limited public knowledge on water and water reuse also plays a part, as evidenced by the increased acceptance of reclaimed water from the Beaufort West community as a result of continuous education and information provision (Marais & von Dürckheim, 2011) and in a 2019 study by the Water Research Commission in South Africa (Slabbert & Green, 2020).

Within Beaufort West the success of the plant has been attributed to numerous factors which include the plant being on a performance-based contract, advanced testing, and most importantly “a comprehensive awareness campaign was launched with various groups and scholars visiting the plant” (Marais & von Dürckheim, 2011, p. 64). This included having regular visits by scholars to the plant during which they were encouraged to taste, smell, and touch 100% reclaimed water, as well as making the tests results of the final water available public by publishing it regularly in the local newspaper (Marais & von Dürckheim, 2011). The study by Slabbert and Green (2020) found that South Africans’ knowledge of the water cycle and water terminology was particularly poor; yet, similar to the findings of Australian studies, almost half the respondents in the study indicated they would support water reuse and even direct potable reuse in severe drought situations (Slabbert & Green, 2020). Also, from a study by Etale et al., (2020) it was implied that should the resistance to using reclaimed water stem from negative affect or the disgust elicited by the water it may be possible to increase willingness to use by lowering disgust by inducing positive affect and not necessarily only through information provision. However, it is critical to remember that intent is different from action, and that these studies were conducted through the use of self-report surveys and not the direct observation of respondents using reclaimed water for domestic purposes. Ultimately, the public’s unfamiliarity with present technologies and terminologies, and their affect influences the choices they make and their answers to surveys on water reuse or the implementation of alternative water projects and schemes. Their uninformed opinions could affect policymakers’ decisions, and in turn, future policies and legislation.

2.5. Alternative Water Sources

Traditionally, developed countries such as the USA relied on groundwater as the primary source of drinking water for almost half of the population (Boulware, 2013). Alternative water sources have different levels of feasibility depending on a country’s geography, the application of the water, and people's acceptance of the alternative sources, as has been stated. These alternative sources, which are not supplied from surface water or groundwater, could include: harvested rainwater, harvested storm water, reclaimed wastewater, captured condensate, water desalination, water from atmospheric precipitation, and more technologically advanced methods, such as cloud seeding (U.S. Department of Energy, n.d.; WEF, 2019).

With the implementation of alternative water projects, effective and meticulous planning is necessary to ensure the right water sources are collected for the most appropriate uses, and that public health, economics, environmental impacts, and institutional considerations are measured (National Research Council, 2012). This planning includes choosing sites with adequate alternative sources and high water use. For instance, if rain or storm water collection is implemented, there must be adequate rainfall in the region. Water projects must be implemented based not just on current demand but an accurate forecast of future demand to ensure adequate supply in the future. The costs and energy associated with a specific project are equally determining factors, along with the end user's acceptance and willingness, or not, to consume or use the water (Office of Energy Efficiency & Renewable Energy [Energy.Gov], n.d.).

2.5.1. Harvested Rainwater and Storm Water

Harvested rainwater refers to rainwater that is collected in large onsite tanks, pots or cisterns before it hits the ground (Hardy et al., 2015). Many individuals think this water is pure and abundant. This is not necessarily the case. South Africa, as a semi-arid country, has seasonal and regional rainfall patterns, and the water loses quality due to air pollutants and particulate matter when rooftop rainwater harvesting systems are used (Hardy et al., 2015). The level of treatment required depends on what the water will be used for. For instance, for irrigation, minimal treatment is required, and it may be necessary only to remove any debris from the water before use. However, if the water is contaminated or classified as acid rain, it will not be usable even for irrigation without extensive treatment (USGS, n.d.). For potable uses, more comprehensive treatment and disinfection are required, which could include removing debris from the collection system then disinfecting the water with ozone or ultraviolet (UV) light systems, after which it may need to be filtered and chemically treated before use (Energy.Gov, n.d.).

Storm water collection is similar to rainwater harvesting. It is the collection of rain water in storm water drains as runoff from hard surfaces such as sidewalks, streets, and parking lots before it enters a waterway. More treatment is required due to other pollutants from drainage systems and surfaces (Hardy et al., 2015). As per McArdle et al. (2011), this source of water is most often used for non-potable purposes due to higher levels of contamination. The diversion of storm water could have an effect on other consumers downstream from the diversion point (Energy.Gov, n.d.). In high-rainfall regions, these sources of water could be one of the cheapest and most viable options available due to the minimal treatment required. However, the initial high costs of implementing storm water harvesting systems could be disadvantageous (Cooley & Phurisamban, 2016; Hardy et al., 2015; McArdle et al., 2011). Ultimately, for this to be feasible adequate rainfall would be needed.

2.5.2. Captured Condensate

Captured condensate from air conditioning units, or as a product from power plant heating, can often easily be reused for non-potable purposes (Boulware, 2013; Boyd, 2020; Grobicki & Cohen, 1999). This water does contain high concentrations of nitrogen, phosphorous and ammonia, and the cost of treatment for power plant cooling could be substantial, while the actual supply of condensate could be minimal (Grobicki & Cohen, 1999).

2.5.3. Atmospheric Water Generation

Atmospheric water generation, also called air water harvesting, is similar to condensate extraction. Water vapour is extracted directly from the air in the form of humidity by utilising cooling surfaces, desiccant capture, or gas separation (Energy.Gov, n.d.). The temperature and humidity of a location affect the efficiency of this technique. Colder and less humid environments require more energy than those with warmer and more humid conditions. (Energy.Gov, n.d.). A more specific technique is fog harvesting. Fog harvesting has been used successfully in more than 17 countries in the last decade (Korkmaz & Kariper, 2020). This process is based on the accumulation of suspended water droplets on a vertical mesh. The technology required is highly promising, and a low-cost collection mechanism with minimal treatment is required to convert it to a potable standard (Daniel, 2020; Korkmaz & Kariper, 2020). A pilot project has been launched in Cape Town and results from the Table Mountain programme will be known by 2023. Preliminary studies have shown that yearly fog precipitation in the region is around 3,294 mm, which is triple that of Cape Town’s annual rainfall (Daniel, 2020).

2.5.4. Desalination

In 2007, it was reported that there were more than 7,500 desalting plants in operation worldwide (Wagner, 2007). The majority (57%) of these plants were in the Middle East and 12% were in the USA (Wagner, 2007). Desalination plants are one of the most energy-intensive and costly alternatives available, with an estimated 12 kW of energy required to purify 3,800 litres (1,000 gallons) of seawater (Boulware, 2013; Cooley & Phurisamban, 2016; National Research Council, 2012). It also produces a highly concentrated salt-based by-product which requires proper disposal. With a continuous drive to develop more cost-effective desalination treatment options, it does have the potential to reduce or eliminate water scarcity issues in countries classified as arid or semi-arid, such as South Africa, provided that the country has access to the ocean (Hardy et al., 2015). Should it be implemented, and more cost-effective solutions become available, the distribution costs could still be high (Cooley & Phurisamban, 2016; Tsiourtis, 2017). The desalination process involves removing dissolved minerals, salts, and other contaminants from the water through, for example, membrane processes such as reverse osmosis or electrodialysis (Buros, 2000; Tsiourtis, 2017). Through reverse osmosis, water is pumped through semi-permeable membranes which salts cannot pass through. The by-product created - a highly concentrated salt solution or brine - is usually pumped back into the ocean and could be harmful to the environment and sea life. Electrodialysis provides a more cost-effective solution and involves membranes which permit the selective passage of ions, thereby creating concentrated and diluted solutions in spaces between alternating membranes (Buros, 2000). Thermal processes are also available, which include heating or rapidly boiling the water. Heat is used to evaporate and condense the water to purify it by applying methods such as Multi-Stage Flash Distillation, Multi-Effect Distillation, or a Vapour Compression Distillation method (Tsiourtis, 2017). The most prominent advantage of this process is that it is not dependent on rainfall, while disadvantages could include high capital costs, high energy demand, and possible negative environmental impacts (Tsiourtis, 2017; Wagner 2007). These disadvantages reduce the feasibility and viability of using this process in South Africa, a country with an energy supply crisis.

2.5.5. Cloud Seeding

Many regions across the globe are reliant on the melting of snow and runoff for their water supply. Due to climate change, these regions are under threat from lower-than-usual snowfall or higher-than-normal average temperatures. Cloud seeding is considered an unconventional and advanced technique in which an aerosol, such as silver iodide, is introduced into super-cooled liquid orographic clouds in semi-arid mountainous regions to increase snowfall (French et al., 2007). This is hypothesised to lead to the nucleation of ice crystals, followed by ice particle growth, which, when big enough, fall to the ground (French et al., 2017). Although the Chinese government has announced that their cloud seeding project will cover about 56% of China's entire surface area by 2025 (Bostock, 2020), this technique's impact on a specific region is still highly contested (French et al., 2017). The magnitude and cost implications of such a project would make this technique unsustainable in South Africa.

2.5.6. Wastewater Reclamation

The abundance of waste water in circulation is ordinarily not thoroughly considered as a viable alternative to expensive sources (Po et al., 2003), even though direct and indirect water reclamation has been successfully implemented in many countries and even in South Africa. One of the first direct reclamation plants was built in Namibia, while the second in the world was built in Beaufort West in South Africa (Marais & von Dürckheim, 2011). The plant in Beaufort West has extensive safety measures in place to ensure automatic shut down if there is deterioration in unit processes, while the treatment process includes nine stages (Marais & von Dürckheim, 2011).

In 1996 it was estimated that only 3% of treated sewage effluent in South Africa was reused; the largest portion was discharged into inland water bodies (rivers, lakes and dams) or the sea (Grobicki & Cohen, 1999). In 2014, an estimated 14% of return flow was reused (DWA, 2014). This means billions of litres of water from rivers and streams still undergo numerous stages in water treatment plants and are often discarded after a single use. Wastewater undergoes some treatment and pathogens, and toxic substances are removed through conventional water treatment technologies such as coagulation, flocculation, sedimentation, filtration and activated carbon absorption, or pressurised filtration (Okwadha & Ahmed, 2017). The treated wastewater is then discharged into rivers and streams to restart the cycle again (Ghernaout, 2018; Hardy et al., 2015). This cycle of pumping water out of rivers or streams, using it once, then discarding it back into the rivers, often results in de facto or unplanned indirect potable reuse (ACWA, 2017) with the stream and river acting as a natural buffer (Po et al., 2003). The wastewater reclamation process operates in a similar manner, however, instead of discharging the water into a river or stream, additional purification can be included to treat the water, so it is of a quality suitable to be pumped back into municipal reservoirs, which results in direct potable reuse. For example, the stages in the treatment processes at the Beaufort West Water Reclamation Plant include: (1) phosphate removal, (2) settling, (3) pre-disinfection, (4) filtration, (5) ultra-filtration, (6) reverse osmosis, (7) advanced oxidation, (8) post stabilisation and disinfection, and (9) blending of the water (Marais & von Dürckheim, 2011). This treatment process is much more extensive than the traditional treatment of water pumped from rivers or streams as part of traditional water treatment and could result in higher quality water.

However, communities are often reluctant to accept treated wastewater without the natural buffer of rivers or dams, especially if they lack knowledge of the water treatment process (Marais & von Dürkeheim, 2011). They may have misconceptions that wastewater cannot be treated effectively, that it is disgusting and could put them at a greater risk of disease; in addition, they may not trust their government to maintain the infrastructure, which could result in poor quality water, or fear the government could increase water tariffs (du Pisani, 2006; Levin, 2019; Po et al., 2003). Other social, economic, and institutional constraints to introducing water reclamation - which the USA faced and are applicable to South Africa - include not having a market for reclaimed water because consumers are not willing to use it, even after initial interest was shown, due to issues of water quality, water price, and the reliability of supply. The use of treated sewage effluent also poses an environmental risk, as water needed to maintain flows in rivers and dam levels will be reduced (Grobicki & Cohen, 1999). Furthermore, the initial development and capital costs are high, and many developers are against high costs when it is the end user that gets most of the benefit. Technical constraints such as the consistency of water quality and reliability of supply are also factors to consider (Grobicki & Cohen, 1999). The appropriateness of a reclaimed water supply for reuse, therefore, depends on three factors: the level of quality to which the water is treated, the consistency of treatment quality, and the cost implications of reuse (ATSE, 2013; Cooley & Phurisamban, 2016; Grobicki & Cohen, 1999).

As previously stated, recycled wastewater or treated sewage water effluent can fall into two categories; potable (drinkable) and non-potable (non-drinkable) water (Cooley & Phurisamban, 2016; Grobicki & Cohen, 1999; Lautze et al., 2014). Grobicki and Cohen (1999) list the following applications for reclaimed water: agriculture or irrigation; construction (dust control, concrete making); groundwater or aquifer recharge (returned water to rivers); industrial use (cooling towers, quenching); domestic non-potable use (firefighting, toilet flushing, irrigation); and potable use (drinking water supplied directly or indirectly).

Non-potable recycled water has lower costs because less treatment is required, but distribution to homes may require additional piping systems to separate it from potable water, which could increase the overall cost. The various uses of non-potable water are summarised in Table 1, however, the limitations of using non-potable water must also be acknowledged.

The current water treatment process relies extensively on a natural buffer like a river, stream, or dam from which the water is extracted, and treated, then supplied to consumers. It is then partially treated and discharged back into rivers, streams, or dams. The natural buffer is presumed to prevent loss of water identity and provide a measure of safety, as there is time to address quality issues with the treated water. Direct potable reuse, however, introduces purified water directly into a municipal water supply system (Grobicki & Cohen, 1999; Marais & von Dürckheim, 2011; Leverenz et al., 2011). This significantly reduces the distance that purified water would need to be pumped and the energy required to do so, thereby reducing costs (Leverenz et al., 2011).

Table 1: *Uses of Reclaimed Water*

Category of Use	Specific Types of Use	Limitations
Landscape irrigation	Parks; playgrounds; cemeteries; golf courses; roadway rights-of-way; school grounds; greenbelts; residential and other lawns	• Dual distribution system costs • Uneven seasonal demand • Reclaimed water high in total dissolved solids (TDS) can adversely affect plant health
Agricultural irrigation	Food crops; fodder crops; fibre crops; seed crops; nurseries; sod farms; silviculture; frost protection	• Use and source are often some distance apart • Dual distribution system costs • Uneven seasonal demand • Reclaimed water high in total dissolved solids (TDS) can adversely affect plant health
Non-potable urban uses (other than irrigation)	Toilet and urinal flushing; fire protection; air conditioner chiller water; commercial laundries; vehicle washing; street cleaning; decorative fountains and other water features	• Dual distribution system costs • Building-level dual plumbing may be required • Greater burden on cross-connection control
Industrial uses	Cooling; boiler feed; stack scrubbing; process water	• Dual distribution system costs for industrial sites vary based on proximity • Treatment required depends on end use
Impoundments	Ornamental; recreational (including full-body contact)	• Dual distribution system costs • Nutrient removal required to prevent algal growth • Potential ecological impacts depending on reclaimed water quality and sensitivity of species
Environmental uses	Stream augmentation; marshes; wetlands	• Nutrient and ammonia removal may be required • Potential ecological impacts depending on reclaimed water quality and sensitivity of species
Groundwater recharge	Aquifer storage and recovery; seawater intrusion control; ground subsidence control	• Appropriate hydrogeological conditions needed • High level of treatment may be required • Potential for water quality degradation in subsurface
Potable water supply augmentation	Water supply treatment	• Very high level of treatment required • Requires post-treatment storage • Can be energy-intensive

Note. Adapted from "Water reuse. Potential for expanding the nation's water supply through reuse of municipal wastewater," by The National Research Council, 2012, p. 29. Copyright 2012 by the National Academy of Sciences.

Currently available technologies can minimise costs for the direct reuse of treated wastewater for potable use. This is achieved by treating wastewater to highly purified levels, then returning it directly into the drinking water system without the natural environmental buffer of rivers or streams and using existing piping systems to distribute it to homes (Cooley & Phurisamban, 2016). Various other non-monetised costs and benefits of reuse exist. Non-monetised benefits may include: improved reliability, enhanced self-sufficiency, enhanced reputation for environmental stewardship, enhanced regional economic vitality, increased water for the environment, and improved surface water quality (National Research Council, 2012).

Non-monetised costs could, however, include: the effects on the overall carbon footprint of water supplies, however, some treatment methods could increase the carbon footprint compared to existing supplies, public health effects, public perception of reduced quality, effects on downstream flows, water quality impacts, and effects on soils and plants (National Research Council, 2012).

Despite the quantifiably lower costs of direct reuse, the alternative is one of the least accepted methods of water reuse applications within communities, as many would opt for indirect potable water reuse due to the belief that the natural buffers add additional purification, or opt to use the water only for non-potable use (ATSE, 2013; Lautze et al., 2014; Leverenz et al., 2011).

2.6. Water Saving as an Alternative

When energy consumption exceeded energy supply in South Africa, load shedding was introduced, and all consumers were urged to use electricity sparingly. Similarly, during Cape Town’s water shortage, water rationing, and water restrictions were introduced to reduce the use of a limited water supply. Consumers nationally also received requests from the government to reduce water usage by implementing further water-saving initiatives. However, unlike electricity, water can be stored in buckets or containers, limiting the effectiveness of water rationing. A study of the effectiveness of water restrictions in Norfolk County, Massachusetts, found that consumers used even more water on days which did not have water restrictions, possibly in anticipation for the days which did have restrictions; thus, this strategy was largely ineffective (Robinson & Conley, 2017).

Water-saving initiatives can potentially reduce the burden on the supply chain if implemented very strictly (Angelakis & Bontoux, 2001). Similarly, the burden on the supply chain can be reduced by local governments by ensuring municipal pipes are not leaking and wasting water (McKenzie et al., 2013). Nevertheless, the initiatives do not mitigate the imminent threat of taps running dry. Even though the agricultural sector is responsible for the largest withdrawal of water (DWA, 2014), it is of equal importance for domestic consumers to reduce their demand and consume water sparingly. To be effective, water-saving initiatives rely heavily on the provision of information to consumers and the availability of technology (Watson, 2017). Furthermore, understanding household decision-making is crucial, and behavioural change is central, to achieving rational domestic water consumption. Water consumption can be reduced drastically if habits and behaviours can be changed to be more “conservative”, as shown in Table 2. For instance, the simple act of not letting a tap run when brushing one’s teeth can reduce water used by an estimated 22 litres every time one brushes, while changing showering behaviour can save up to 80 litres of water per shower (Keramitsoglou & Tsagarakis, 2011). Other domestic water-conserving activities could include: checking toilets, taps, and pipes for leaks; only flushing the toilet when necessary; irrigating the garden in the evening; using water-saving showerheads or flow restrictors; planting drought-resistant trees and plants; using a broom to clean driveways, sidewalks, and steps; or to place a cover over a swimming pool (Murphy et al., 1991; Tarantini & Ferri, 2003).

Table 2: *Water Consumption per Activity for Normal and Conservation Use.*

Activity	Normal Use		Conservation Use	
Brushing teeth & shaving	Tap running	25 ℓ	Wet brush; turn water off; rinse	3 ℓ
Washing hands or face	Tap running	8 ℓ	Plug and fill basin	4 ℓ
Showering	Water running	95 ℓ	Wet down; soap down	15 ℓ
Bathing	Tub full	150 ℓ	Minimal water level	45 ℓ
Flushing toilet	Tank size (dependent on tank size)	16 ℓ	Displacement bottles in tank	12 ℓ
Washing dishes & fruit by hand	Tap running	150 ℓ	Wash and rinse in dishpan or sink	25 ℓ
Garden watering	Hose down during day	100 ℓ	With drips during night	10 ℓ
Washing car	Hose down	5 ℓ /min	With pot/bucket	10 ℓ
Dishwasher	Full cycle	60 ℓ	Short cycle	26 ℓ
Washing clothes	Full cycle, top water level	300 ℓ	Short cycle, minimal water level	130 ℓ

Note. Adapted from "Raising effective awareness for domestic water saving: evidence from an environmental educational programme in Greece," by K. M. Keramitsoglou, and K. P. Tsagarakis, 2011, *Water Policy*, *13*, p. 829 (https://doi.org/10.2166/wp.2011.103). Copyright 2018 by IWA Publishing.

It has been claimed that Australia is at the forefront of water-saving strategies and technologies due to the continent being persistently threatened by drought and water shortages (Watson, 2017). Regardless of some similarities between Australia and South Africa, it must be noted South Africa's unique social and political environment, history, and policies and legislation could hamper the effectiveness of strategies that have been implemented successfully elsewhere. An example of how policies could shape behaviour comes from the UK, where water is charged for at a yearly flat rate, which has led to many people being unaware of, or indifferent to, the cost of household water consumption (Walker, 2009; Watson, 2017).

South Africa included the right to water in its Constitution and has introduced subsidies and initiatives such as free water, which could place South African consumers in a similar standing to those in the UK (Muller, 2008; Watson, 2017). Irrespective of which initiatives or strategies are used, it is claimed that water companies and governments strongly rely on eliciting an affective response from consumers. In the UK messages such as “to care for the environment” or “to be water wise” have been used in attempts to mobilise environmental concern and were found to be effective in households with higher levels of education and higher incomes (Watson, 2017).

In addition to introducing water-saving technology or initiatives, it is equally necessary to change consumers’ level of knowledge, behaviour, habits, and attitudes to ensure the success of water-saving initiatives. A study by Moore et al. (1994) found that, to a large extent, media interventions relating to water-saving were perceived as highly influential in changing toward conservation, while Keramitsoglou and Tsagarakis (2011) found that awareness by itself does not necessarily lead to attitude change, especially when a person lacks a basic understanding of a problem. It is therefore paramount to understand that knowledge (which is accurate and relevant) is one of the most crucial elements to changing habits or behaviour.

The responsibility to save water lies with consumers as well as government and municipalities. In 2012, roughly 37% of available potable water in South Africa, to the value of ZAR7.2 billion a year, was classified as non-revenue water with a quarter of that being water lost due to leakages (McKenzie et al., 2013). Non-revenue water refers to water that is lost through physical leakage or commercial losses, such as meter under-registration, billing errors, or theft, as well as unbilled authorised consumption for example for fire-fighting. Therefore, it is maintained that municipalities should lead by example and treat water management and scarcity as a serious issue, as this may convince other consumers to do the same.

2.7. Can Wastewater Reclamation Work?

The process for treating water for reuse, as explored in the existing literature, can be summarised as follows: evaporation from oceans, lakes, rivers, and streams creates precipitation that enters surface water (streams, lakes, dams, and rivers) or groundwater (aquifers) sources. Through an energy-intensive process, water is extracted from these sources and pumped upstream to water-treatment plants where it is treated with chemicals. It is then used once before being discarded as wastewater. Wastewater is pumped into sewage, or wastewater-treatment plants, re-treated, and discharged into rivers to start the cycle again (Hardy et al., 2015). This traditional treatment of water, as depicted in Figure 4, is also followed in South Africa, with chlorine as the main disinfectant (Rand Water, n.d.; Sedibeng Water, 2016).

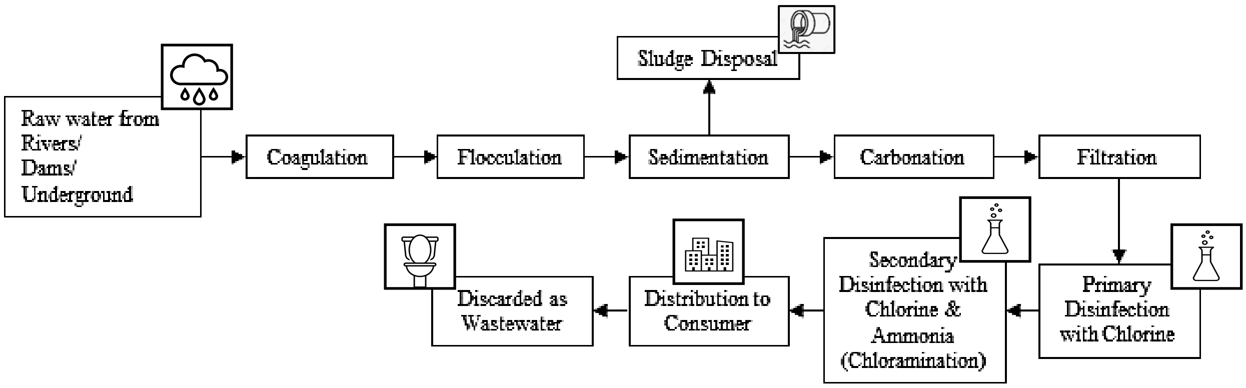


Figure 4: *Rand Water Treatment Process Flow Diagram for Potable Water*

Note. Adapted from “Water & infrastructure management,” by Rand Water, n.d.

2.7.1. Traditional Water Treatment

Rand Water and Sedibeng Water are two of South Africa’s largest water utilities. Rand Water is one of the biggest, serving 25% of South Africa’s population and distribution includes to two large cities Johannesburg and Pretoria, and Sedibeng Water supplies water services over an area of 86,000 square kilometres over two provinces (Habede, 2004). Rand Water and Sedibeng Water’s treatment process broadly involves seven stages: coagulation, flocculation, sedimentation, stabilisation, filtration, disinfection, and chloramination (Rand Water, n.d.; Sedibeng Water, 2016). Rand Water's raw water is drawn from the Vaal Dam via a gravity pipeline and pumped from the Vaal River Barrage Reservoir at Lethabo, Zuikerbosch, and Vereeniging, with a small quantity of water also drawn from underground sources at Zuurbekom. Conventional treatment is used to remove the suspended material and disinfect the water before distribution. First, slaked lime or calcium hydroxide, silicon dioxide and ferric chloride are added to the water as coagulants and flocculants to destabilise the electrostatic charges of suspended particles in the water and form heavier visible particles, called floc. Between 95% and 97% of suspended particles are removed during sedimentation. During this stage, flocs are allowed to settle in specially designed tanks, which also help with the removal of sludge. The sludge is disposed of at Panfontein, where it is dosed with an organic flocculent in gravity-thickening plants to aid the separation of solids from the liquid. After sedimentation, the water is stabilised to reduce scale and rust forming, which could damage pipes. This is done through carbonation to reduce the pH of the water to between 8.0 and 8.4 ($pH < 7$ is acidic, $pH > 7$ is basic or alkaline). The water is then filtered through covered rapid-gravity sand-filter beds to remove any remaining suspended particles, after which it is further treated in a two-stage disinfection process. It is first disinfected in the pipeline with chlorine to kill micro-organisms, bacteria, and any viruses that are present in the water. It then goes through a secondary disinfection process, as chlorine does not remain active for longer than six to eight hours, so secondary disinfection with a less powerful agent is required, which will remain active for longer. This is managed by dosing the water with chlorine and ammonia at the booster pumping station, protecting the water against bacterial growth for up to eight days (Rand Water, n.d.). The water treatment process for domestic potable use is therefore not as intensive as it often is for wastewater reuse, which uses newer technology and more advanced methods of purification (National Research Council, 2012). Consumers often fail to consider that a vast amount of raw sewage or poorly treated wastewater is often discharged into rivers and streams, as was reported as recently as 2019 in the local news (Saba, 2019) which results in unacknowledged reuse.

The energy and costs saved to remove the middle step of pumping water from ground- or surface-water sources to water-treatment plants are quantifiable and significant (Rygaard et al., 2010). Removing this step has been shown to increase sustainability and has been successfully implemented globally through numerous schemes to ensure the continuous supply of water for urban, suburban, agricultural, industrial, recreational, and environmental use (Ghernaout, 2018).

2.7.2. Wastewater Reclamation Treatment Explored

The primary drivers behind wastewater reclamation are twofold: firstly, it addresses the rising demand for water and limited availability of freshwater, and secondly, it has economic benefits and is more sustainable (Lautze et al., 2014). Wastewater reclamation is not a new strategy to overcome water shortage. Grobicki and Cohen (1999) reported that Israel was leading the field in 1994, with the country treating and reusing 84% of their sewage effluent for agriculture, in comparison to South Africa, which at the time reused 3% of treated sewage effluent. The reuse in South Africa was largely for irrigation purposes, in small-scale urban applications, with no large-scale schemes (Grobicki & Cohen, 1999). In 2001, similar low levels of reuse were reported for many European countries. However, because water is generally abundant in European countries, investment in wastewater reuse has been low, and where it was introduced it was primarily for non-potable use such as sanitation, environmental protection purposes, tourism (such as golf course irrigation), or agriculture (Angelakis & Bontoux, 2001). Various limiting factors which influence the future feasibility of using only treated wastewater for non-potable or indirect use, have been identified by Leverenz et al. (2011), and include the additional costs associated with constructing additional pipe systems to convey recycled water. This is exacerbated by the dispersed nature of demand and long distances between municipal recycled water supplies and major agricultural demand areas and communities. Indirect potable reuse could also be limited in communities due to a lack of suitable hydrogeology for groundwater recharge (Laverenz et al., 2011).

Direct wastewater reclamation has been implemented successfully in many countries, including: Australia, Israel, Namibia, Singapore, and the USA (Po et al., 2003). The first introduction of direct reuse for potable purposes was in Windhoek, Namibia, in the 1960s, with an upgrade to the Goreangab reclamation plant in the 1990s, being in full operation since August 2002. It supplies 35% of the daily requirements of the city (du Pisani, 2006; Po et al., 2003). The new plant was set up with three safety barriers to mitigate the risk of particular substances or contaminants in the water to the user. These include non-treatment, treatment, and operational barriers (du Pisani, 2006). More specifically, these barriers include: policing and diversion of industrial effluents to a separate treatment plant; monitoring at the inlet and outlet of the sewage treatment plant, which allows for action to be taken before the water reaches the reclamation plant; extensive monitoring of drinking water quality; and blending water from the reclamation plant with water of different origins so that, at most, 35% of the drinking water is reclaimed water (du Pisani, 2006). The introduction of raw water as part of the treatment process is very similar to treatment processes in other countries and just one step in a multi-stage treatment process, as presented in Figure 5. Alternative advanced treatment flow processes can include further ozonation, the inclusion of biologically activated carbon, nanofiltration, advanced oxidation, UV disinfection, and electrodialysis (Leverenz et al., 2011). As has been shown to be effective at the Beaufort West plant which uses extensive treatment and also mixed the water to a ratio of 1:4, and thus, the town's water is made up of 20% reclaimed water which could be increased to 25% if necessary (Marais & von Dürckheim, 2011).

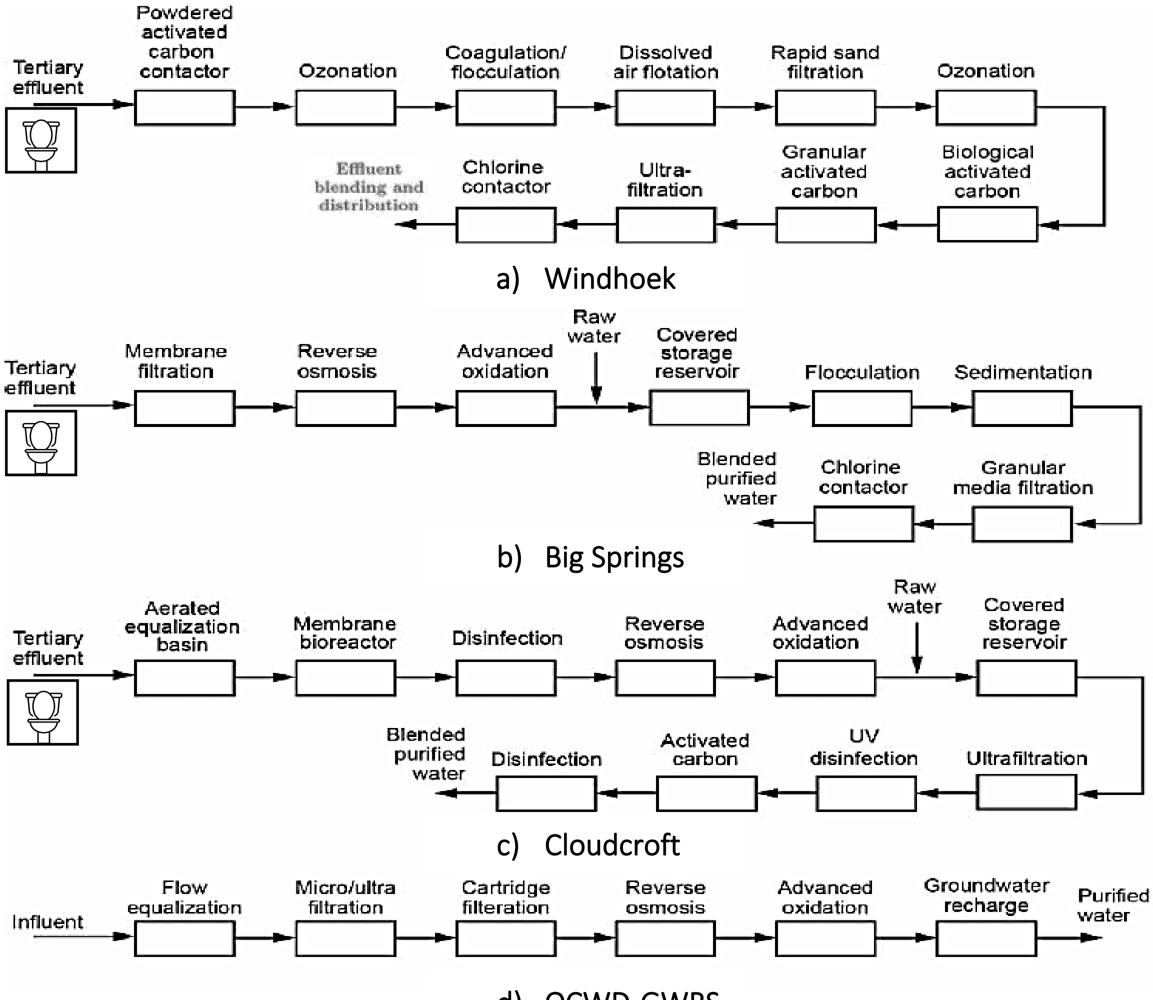


Figure 5: *Representative Treatment Process Flow Diagrams for Direct Potable Reuse*

Note. (a) Windhoek, Namibia; (b) Big Springs, Texas; (c) Cloudcroft, New Mexico; (d) Orange County Water District (OCWD) Groundwater Replenishment System (GWRS), Fountain Valley, California.

Adapted from "Direct potable reuse: a future imperative," by H. L. Leverenz, G. Tchobanoglous, and T. Asano, 2011, *Journal of Water Reuse and Desalination, 2*(10), p. 6 (https://doi.org/10.2166/wrd.2011.000). Copyright 2011 by IWA Publishing.

Although technologies and processes exist to produce water that meets all potable standards, and there are guidelines which address the perceived health risks associated with its use, it is still often rejected due to the water being associated with a negative affect from notions of disgust or various other factors (Etale et al., 2020). One of the main obstacles to introducing potable reclamation into communities is the public's negative perception (du Pisani, 2006). The success of the Namibian Goreangab reclamation plant was due not only to vigorous and extensive monitoring and testing of the water quality at every stage, but also largely to "public acceptance and trust of consumers in the quality of this water" (du Pisani, 2006, p. 82). The community's trust in the process is maintained through continuous media communication and school-level education (du Pisani, 2006), similarly as what has been credited for the successful operationalisation of the Beaufort West plant (Marais & von Dürckheim, 2011).

Other successful water reuse schemes include projects in Sydney, Bolivar, Queensland, Singapore, Texas, New Mexico, and California (Lautze et al., 2014; Leverenz et al., 2011; Po et al., 2003). The success of most of these projects has been credited to the high level of involvement of the community, with the Monterey County Water Recycling Project in Californian taking close to 20 years of planning before being fully operational (Po et al., 2003). Reasons for the success of the project include identification and cost sharing of and between all beneficiaries, that the water is affordable, and the effective collaboration of parties with different interests, thus taking politics into account (Haddad, 2002). Projects such as those in San Diego, San Gabriel Valley, Los Angeles, and others in Australia were not as successful, even when there was some public engagement. The indefinite postponement or cancellation of projects were repeatedly a result of political differences between political parties, health concerns, and public perception, as was the case for another project in California, where a headline in a local paper dubbed the project as a *"Toilet to Tap"* scheme (Po et al., 2003; Rozin et al., 2015). This shows the sensitivity with which such projects should be approached. Factors that favour direct potable reuse include the following: that there is no need for a separate reclaimed water distribution system; the traditional reliance on surface water and groundwater is limited; purified water is a reliable source of supply and exists in proximity to demand; direct potable reuse is often less costly, requires less energy, and avoids potential water quality issues associated with groundwater and surface water sources; and technologies are available to remove contaminants effectively and reliably, to replace the environmental buffer with an engineered storage buffer (Leverenz et al., 2011).

In South Africa, due to severe droughts, direct potable reuse plants have been commissioned and are already in operation on a small scale. For instance, in Beaufort West advanced water reclamation technologies of ultrafiltration, reverse osmosis, UV treatment, and treatment with hydrogen peroxide have been used as a multi-barrier approach since 2010 (Swartz et al., 2015). George has an indirect potable reuse plant and numerous feasibility studies were conducted for potable reuse in Durban, Port Elizabeth, Hermanus, and Cape Town prior to 2015 (Swartz et al., 2015).

Even though planned reuse can result in benefits for the environment and countries as a whole, it is often faced with numerous barriers (Lautze et al., 2014). Non-technical barriers include institutional barriers, such as a lack of political will, funding bias towards conventional infrastructure investment, a lack of expertise in health and environmental risk assessment and mitigation or relevant legislation. Other barriers include public perception or educational barriers (i.e., lack of information), which have been identified on numerous occasions as the most important determining factors of success, with consumers' perceived risk being a major determining factor (Lautze et al., 2014). Consumers are often most concerned about the water quality, and rightfully so, as poor water quality could result in major health issues.

As per the National Research Council's 2012 report, individual contaminants pose different hazards in one context than they do in another context, and their associated risks depend on the dose and paths of exposure. Waste discharge contains a range of biological, inorganic, and organic constituents which can be harmful to people and to eco-systems if not treated correctly. Constituents which are potentially hazardous to human health include enteric pathogens (National Research Council, 2012). Other contaminants that would require advanced treatment include prions; inorganic chemicals such as metals and metalloids; salts, oxyhalides; nutrients; other engineered nanomaterials; and various organic chemicals such as pesticides, pharmaceutical residues, and steroidal hormones. It could be argued that the costs for testing the water quality could be high. Nevertheless, traditionally treated surface water should also be periodically tested to ensure optimal quality, so the costs would be comparable (Swartz et al., 2015).

Various steps should be taken to ensure the optimum water quality of potable and non-potable water reuse projects, and address potential public health impacts from microbial pathogens and chemical contaminants. As prescribed by the National Research Council (2012, p. 97) these steps could include:

- the implementation and maintenance of an effective source control programme;
- the utilisation of appropriate technology which is specific to the site conditions;
- utilising multiple, independent barriers for the removal of microbiological and organic chemical contaminants;
- employing quantitative reliability assessments to monitor and assess performance;
- establishing a trace organic chemical monitoring programme which extends beyond regulated contaminants;
- documenting a strategy to provide retention time, which allows for time to respond to system failures or upsets;
- providing alternative means to divert sub-par product water;
- avoiding “short-circuiting” in environmental buffers to maintain appropriate retention times within the buffers;
- training and certifying operators of advanced water reclamation facilities; and
- instituting formal channels of coordination between water reclamation agencies, regulatory agencies, and agencies responsible for public water systems. This allows for

speedy communication and immediate corrective action to be taken by the appropriate department when the reclaimed water does not meet regulatory or other requirements.

Within such a complex system, where human error is a possibility, the number of deviations from a set standard are limited and could result in catastrophic consequences. It could be argued that the public's resistance to and scepticism toward a government's ability to ensure safe water provision is therefore valid. However, by ensuring corrective measures are in place and the suggested steps followed, potential hazards to public health could be reduced and result in potable water that is purer than potable water treated in the conventional manner.

2.8. Deciding to use Reclaimed Wastewater

As per the literature cited in this review and, more specifically, in the National Research Council's report (2012), there are numerous challenges that need to be addressed when considering the reuse of municipal water. Communities that have introduced the practice of water reuse have seen the benefits and are able to use the water to supplement demand even if it is only for non-potable use, such as landscape irrigation, use in municipal parks and on golf courses, or when reusing the water for cooling. These communities have therefore become familiar with the benefits and advantages of such reuse. This is often not the case for larger water reuse projects, specifically those which aim to reduce costs and environmental impacts, such as direct potable reuse schemes. Therefore, public engagement must carefully be managed to ensure fragile public relationships are not damaged and the possibility of consensus is not lost (Gregory, 2017). The National Research Council states that "people have been trained for generations to provide separation in both time and space between their wastes and their water supplies, and therefore the public is concerned about the safety of using wastewater effluent for domestic purposes" (National Research Council, 2012, p. 17).

2.8.1. Behaviour Shaped by Policy

Through the introduction of policies and legislation, governments could have intensified consumers' resistance toward the use of reclaimed water and increased consumers' levels of perceived risk associated with such use. For instance, in the state of Massachusetts just over a century ago, sewage or untreated wastewater could be discharged into rivers serving as a drinking water supply if the outfall was located as little as 32km upstream of the drinking water intake (Tarr, 1979). Similarly, in Europe - as in most parts of the world - it was only during the late 1800s that some steps were included, but not necessarily required, in the removal, treatment and disposal of wastewater; however, disposal on land, or through discharge into rivers or the sea was still permitted (Wall, 2018). In South Africa, the first municipal wastewater treatment works were commissioned in Bloemfontein in 1904, Wynberg in 1905, and Pietermaritzburg in 1908, where wastewater was used in its untreated state for irrigation. Prior to this, and again similar to the global management of waste, waste was often disposed of within a short walking distance of households or in open street channels and drains that were discharged into streams, rivers or the ocean (Wall, 2018). Only in 1919, with the introduction of the Union Health Act No. 36 of 1919, did it become prohibited to discharge effluent into rivers, and dedicated areas for discharge were made available. In 1956, the Water Act No. 54 of 1956 was introduced, which brought about radical change. This new act reversed the regulation of 1919 legislation and again allowed the discharge of wastewater into rivers and streams; however, the wastewater had to be treated to some extent before discharge (Wall, 2018). It was only as late as the 1990s, with the introduction of the National Environmental Management Act No. 107 of 1998 and the Waste Act No. 59 of 2008, that South Africa recognised the importance and scarcity of fresh water and the need for proper water management, including that of wastewater (Department of Environmental Affairs, 2014; Wall, 2018; Water Research Commission, 2015). Historically, legislation has paved the way for the general public's disregard for the conservation of the environment, more specifically water, while also creating a sense of mistrust in governments to manage such a valuable resource.

2.8.2. Public Engagement

The planning for water reuse projects regularly (but not always) includes public involvement and evaluation. The goals for such engagement are to inform the public of pending decisions, and seek public input or direct public approval (National Research Council, 2012). According to Gregory (2017), the inclusion of the public in decision-making should be done correctly. However, this is often not the case and limited resources and overwhelming public input often result in decision-makers and the public engaging only superficially, or with reclaimed water scheme implementation being approached as a top-down, or "decide, announce, and defend", process, which has more often than not proven to be ineffective (Gregory, 2017; Po et al., 2003). With this approach, the public is informed only after the government has made changes, often based solely on experts' advice.

Since the mid-1990s, research on public perception with respect to water reuse has been conducted predominantly in Australia with the rest of the world showing more interest since the early 2000s. There is general agreement that one of the biggest concerns globally with regard to wastewater reclamation is that of risk, or the fear of contamination and health issues because of the possible poor quality of water. However, perceptions of risk differ significantly among consumers, or "non-experts", and experts (Levin, 2019). It is therefore reasonable to believe that understanding the general public's reasoning behind and frames of reference toward risk before making changes would lead to greater acceptance of such schemes (Gregory et al., 1997; Po et al., 2003).

2.8.3. Consumers' Fears and Perceived Risks

"Fear of contaminated water (or anything that is perceived to be contaminated) is a common human response" (National Research Council, 2012, p. 186). Even though there might be a general understanding of the need to explore and implement reclaimed water projects for the future, consumers often reject such schemes due to a fear of contamination or the possible associated health risks of consuming reclaimed water (Doria, 2010; Rozin et al., 2015). The "yuck" or disgust factor can be triggered very suddenly when something is perceived to be contaminated (Rozin et al., 2008). The public often prefers the traditional or "natural" water purification process - although the water can be of lower quality without advanced treatment, it is still perceived as suitable for consumption because it came from a tap (Doria, 2010; National Research Council, 2012). To overcome the perception of contamination and avoidant behaviour associated with the disgust factor, reclaimed water is often renamed and marketed as *NEWater*, *processed water*, *eco-water*, or *repurified water* to increase acceptance (ATSE, 2013; Lautze et al., 2014; Swartz et al., 2015). This approach is similar to that followed by marketers seeking to evoke an emotional or affective response in consumers to save water (Etale et al., 2020; Watson 2017), however, it is more specifically aimed at reducing possible links between the origin of the water and its utility. It could be argued that this approach is unethical or an attempt to deceive consumers.

It has been claimed that "the perception of drinking water risks is largely influenced by the same cognitive-emotive processes that affect risk perception in general" (Doria, 2010, p. 3). Factors that could influence risk perception regarding tap water and specifically treated urban wastewater, include: sensory input (odour, colour and taste), with some studies claiming that taste is more important than odour in some Western countries; delivery context (tap or bottle; visual cues from surface waters); prior experience with the water; sources of information (informal, interpersonal); the words used to describe the water; knowledge of the treatment processes; level of trust in the water purveyor; and one's perceived control over the quality of the water (Doria, 2010; Etale et al., 2020; Rozin et al., 2015). Regarding the risk perception of using treated wastewater, Rozin et al. (2015) focused predominantly on the Australian context, while the study by Etale et al. (2020) focused on the association people from both Australia and South Africa have with recycled and desalinated water. Furthermore, Rozin et al. (2015)

focused mainly on understanding a single theme: the emotion of disgust. A presumable basis for resistance lies in the powerful emotion of disgust, “which causes a feeling of offense and behavioural withdrawal from the relevant entity” (Rozin et al., 2008, p. 761).

Contamination or contagion happens in one of two ways: material contagion, which can be neutralised by a combination of washing, filtering, boiling and other treatments, and “spiritual contagion” or “magical contamination”. This refers to a strong belief in the idea of “once in contact, always in contact” - for instance, that treated wastewater can never be purified completely because it was previously used for human consumption. The only way, if at all, to cancel negative spiritual contagion is with an opposite spiritual essence, such as the natural buffer through which water flows (Nemeroff et al., 2020; Po et al., 2003; Rozin et al., 2008). Thus, the water is “purified” when it is either stored in aquifers for long periods or passed down a swift-flowing river, although, for a minority of individuals no level of treatment reduces the level of “spiritual contagion” (Robinson, 2019; Rozin et al., 2015). For instance, even though some consumers may have higher levels of perceived risk, results from a nationwide study in the USA by Rozin et al. (2015) found that 38% of respondents stated they would be willing to drink “certified safe recycled water”; 49% were uncertain, and; only 13% said they would not drink the water no matter the extent of the purification process. A criticism of this and similar other research could be that actual behaviour was not observed and the studies focused mainly on self-reported intent. Ultimately, intent is not the same as behaviour or action. However, this could also show that consumers would be willing to try alternatives if they have relevant knowledge on the purification and other processes, when they are faced with severe drought or water restrictions, or when the associated negative affect of using the water is reduced.

Beckwith (1996) found that it is important to fully consider all risks when making decisions (which could be applied to unfamiliar situations such as the introduction of new technologies or deciding to support alternative water sources). Individuals who supported the introduction of a risk were willing to consider both individual and societal advantages and benefits as part of their decision-making strategy, while those who opposed the introduction of a risk did not factor these benefits into their thinking (Beckwith, 1996). The use of reclaimed wastewater is not without risk. Toxicological testing and population-level epidemiological studies become critically important for assessing the acceptability of a reclaimed-water project (National Research Council, 2012). If this information is communicated in an understandable manner and consumers are educated through this, it could reduce the perceived level of risk and possibly make them more accepting of change. Po et al. (2003, p. 17) offered some insight into perceived risk, stating that "risk perceptions are different between experts and lay people". Their definition of risk, as perceived by the general public, included concepts such as uncertainty, dread, controllability and equity, while for experts the definition of risk focused on chance events or accidents. They claim this could result in people using different social and moral values and different frames of reference to evaluate situations and risks (Po et al., 2003). In light of these findings, consumers and experts may agree on the risks associated with reclaimed water use but differ on the acceptability of using the water associated with the risk. For instance, the study by Etale et al., (2020) found that respondents had different perceptions and levels of affect of reclaimed water and desalinated water, which stemmed from the possible belief that desalinated water is 'just water' with minerals removed, while recycled water had higher levels of negative affect due to its association of having previously been consumed. Often, these different levels of acceptance are accompanied by the individual's inclination to avoid risk and reduce potential or anticipated regret (Po et al., 2003). It is therefore extremely important to remember that a single illness within a community perceived as being due to the poor quality of the treated water could have severe consequences, such as rejecting the water and closing the plant during investigations (Swartz et al., 2015). Thus, every attempt should be made to increase non-experts' level of knowledge to ultimately increase the success of water projects.

2.8.4. Consumers' Level of Knowledge

A minority within a community or country can slow down institutional changes in a democratic and litigious society that serves the public good (Rozin et al., 2015). While people may understand that our current level of water use is unsustainable the idea of waste water management is relatively new and most people lack relevant knowledge of alternative sources available, the technology necessary for water treatment, or the hydrological cycle overall. They may also have an incorrect understanding of the problem or available solutions, and prefer to maintain the status quo rather than deal with the reality of a global problem. When faced with the idea of using reclaimed waste water, consumers therefore have a predominately negative perception without having considered all relevant information. Po et al. (2003) also identified key factors influencing public perceptions towards water reuse which relate to the previous factors mentioned. These include: the disgust factor; perceptions of risk associated with using recycled water; specified uses of recycled water; sources of the recycled water; issues of choice, trust and knowledge; attitude towards the environment; environmental justice issues; the cost of recycled water; and socio-demographic factors. These themes are largely consistent with South African consumer concerns, as found in a study by Levin (2019).

The general public and more specifically consumers' unfamiliarity with available technologies and terminologies could also influence the choices they make about whether or not to use the water, as well as their answers to surveys aimed at gaining insight into consumers' preferences. Glick et al. (2019) conducted a study which focused predominantly on the USA and respondents' knowledge, or lack thereof, of water recycling technologies, and found that in their sample only one in four true-or-false questions about facts relating to recycled water were answered correctly. Furthermore, they found that relevant knowledge was the strongest predictor of support for drinking reclaimed water and that a modest increase in public understanding of basic facts about water recycling technologies could translate into significant increases in public support for the technology. Glick et al. (2019) had strong support for increasing the public's understanding of water treatment technologies, which in turn addresses issues around "toilet to tap" detractors on increase overall public acceptance. This understanding could stem from the media and be even more effective if introduced at school level. The differences in responses could be attributed to the public being inclined toward "fast" thinking when traditional surveys are used to gauge their perception and possible acceptance of alternatives and more sustainable technologies, and could lead decision-makers to conclude that the public is opposed to change without fully understanding their underlying motives, values, or reasons for their answers, or disregarding their input as they expect a negative response (Gregory et al., 2016). The process of fast thinking can be likened to the traditional five-stage consumer decision-making model which include the stages of need recognition, information search, evaluation of alternatives, purchase (or use), and post purchase behaviour (Stankevich, 2017). However, instead, by employing a decision pathway survey design (as will be discussed), information provision is part of the survey and allows for deliberation and more informed decision making. This could directly influence the information search and evaluation of alternatives stages and their responses can become more informed, and the result could be a set of more accurate responses and insights into consumer behaviour (Gregory et al., 2016). Thus, a respondent can learn about the topic as they progress through the survey. Saaty (2008) described that there were two ways to learn about anything which included:

> to examine and study it in itself to the extent that it has various properties, synthesize the findings and draw conclusions from such observations about it. The second is to study that entity relative to other similar entities and relate it to them by making comparisons (p. 84).

The decision to accept reclaimed wastewater, and the possible risks and benefits, is a complex one that has lasting effects on both the individual and a community with numerous stakeholders or beneficiaries (Haddad, 2002; National Research Council, 2012). As per Glick et al. (2019), most studies on attitudes to recycled water have used traditional surveys, focusing on drought-stricken regions, major metropolitan areas, or managers of water reuse facilities. While these studies provide important insights, such a specific focus has an impact on generalisability. Individuals are asked to comment or decide on a topic they may be unfamiliar with or simply not have thought of at all, which requires "substantial cognitive input and thought" (Gregory et al., 1997, p. 241). These decisions can be seen as problems that need to be solved, and aren't familiar or everyday choices - they require the individual to weigh up alternatives and consider the consequences of their choices (Gregory at al., 1997; Saaty, 2008). Thus, a respondent needs to deliberate and switch from a "fast" thinking and intuitive "expert" thought process to a slower, more effortful form of thinking (Kahneman, 2011). A decision pathway survey is a novel way to activate this form of thinking and determine the public's trade-offs, perceived risks and deliberations on a complex topic such as water reuse.

2.9. Decision-Making, Decision Trees and Decision Pathway Surveys

One of the most basic cognitive processes underlying human behaviour is decision-making, or the process through which a preferred option or course of action is chosen from a set of alternatives (Harris, 1998; Wang & Ruhe, 2007). This simplistic approach does leave room for error, and if there is a lack of knowledge such as of the available options, people can make a "wrong" choice. It is claimed that people often revert to fast, intuitive thinking instead of slower and more deliberate thinking when faced with a novel topic (Gregory et al., 2016; Kahneman, 2011; Nemeroff et al., 2020).

Decision theories have been categorised into two paradigms: descriptive and normative theories. Descriptive theories are based on empirical observation and experimental studies of choice behaviours, while normative theories assume a rational decision-maker who follows well-defined preferences that obey certain axioms of rational behaviours (Wang & Ruhe, 2007). A normative approach to decision-making assumes a rational decision-maker who aims to choose an alternative which is most likely to maximise their utility (or value system), and where the decision is based on information available to them on the various alternatives (Schmoldt et al., 2001). The outcomes of a decision-making process are therefore determined by the decision-making strategies selected by decision-makers when a set of alternative decisions has been identified (Saaty, 2008; Wang & Ruhe, 2007). According to Wang and Ruhe (2007), the taxonomy of strategies and corresponding criteria for decision-making can be classified into four categories: intuitive, empirical, heuristic, and rational. These strategies and their criteria for decision-making are depicted in Table 3.

Intuitive or "fast" decision-making and empirical decision-making can be argued to be less effective than more rational or complex decision-making strategies. Within the rational decision-making strategy classification two sub-categories exist: static and dynamic decision-making. Most existing decision-making strategies are static, as changes in the decision-makers' environments are independent of the decision-makers' activities, and include determining the minimum cost or maximum benefit, or the maximum utility based on the cost-benefit ratio of alternatives (Fülöp, 2005; Wang & Ruhe, 2007). Different decision-making strategies can be selected within the same or similar situation or environment, based on a decision-maker's values and attitudes toward risk and their predictions of future outcomes. Dynamic strategies and criteria of decision-making are those where "all alternatives and criteria are dependent on both the environment and the effect of the historical decisions made by the decision maker" (Wang & Ruhe, 2007, p. 77). Classic dynamic decision-making methods can be represented as a decision tree, in decision grids, or modelled by games (Edwards & Fasolo, 2001).

Table 3: *Taxonomy of Strategies and Criteria for Decision-Making*

Category	Strategy	Criterion
Intuitive	Arbitrary	Based on the most easy or familiar choices
	Preference	Based on propensity, hobby, tendency, expectation
	Common senses	Based on axioms and judgement
Empirical	Trial and error	Based on exhaustive trial
	Experiment	Based on experimental results
	Experience	Based on existing knowledge
	Consultant	Based on professional consultation
	Estimation	Based on rough evaluation
Heuristic	Principles	Based on scientific theories
	Ethics	Based on philosophical judgement and belief
	Representative	Based on common rules of thumb
	Availability	Based on limited information or local maximum
	Anchoring	Based on presumption or bias and their justification
Rational		
Static	Minimum cost	Based on minimising energy, time, money
	Maximum benefit	Based on maximising gain of usability, functionality, reliability, quality, dependability
	Maximum utility	Based on cost-benefit ratio
	- Certainty	Based on maximum probability, statistical data
	- Risks	Based on minimum loss or regret
	- Uncertainty	
	- Pessimist	Based on maximin
	- Optimist	Based on maximax
	- Regretist	Based on minimax of regrets
Dynamic	Interactive events	Based on automata
	Games	Based on conflict
	- Zero sum	Based on $\sum$ (gain + loss) = 0
	- Non zero sum	Based on $\sum$ (gain + loss) $\neq$ 0
	- Decision grids	Based on a series of choices in a decision grid

Note. Maximin - Involves selecting the alternative that maximises the minimum payoff achievable; Maximax - Involves selecting the alternative that maximises the maximum; Minimax – A strategy that minimises the maximum regret (Fülöp, 2005; Kaplan, 2007).

Adapted from “The cognitive process of decision making,” by Y. Wang, and G. Ruhe, 2007, *International Journal of Cognitive Informatics and Natural Intelligence*, *1*(2), p. 76. Copyright 2007 by Idea Group Inc.

The maximisation of “value” or “utility” and the minimisation of “cost” or “loss” is described as normative decision-making (Schmoldt et al., 2001). By ensuring a decision-maker is as informed as possible, a basis for decision support is formed. The decision basis should ultimately include four actions: a structure of the alternatives available; information about the consequences associated with these alternatives or an assessment of the possible impacts of each; the preferences among these consequences; and an evaluation and comparison of decision alternatives (Bradshaw & Boose, 1990; Keeney, 1982; Schmoldt et al., 2001).

By using a utility model, decision-makers can evaluate alternatives and choose one that has the highest utility value not just for them but also for others, based on altruistic elements. As per Schmoldt et al. (2001), utility is influenced by all attributes of a decision problem that have value to the decision-maker and is ultimately a measure of “subjective desirability”. Furthermore, humans have an ancestral heuristic which aids with decision-making - for instance, brown water, no matter how pure, is more likely to be rejected than clear water which might have harmful microbes or other toxins in it (Doria, 2010; Nemeroff et al., 2020). Decision-making can be better understood by also understanding that there are biases or gaps between heuristics and “normative” thinking, and there are two systems which can help to explain the older or more ancestral decision-making process still prevalent in humans today (Nemeroff et al., 2020). System 1 is fast and heuristic-based, and heavily influenced by affect. This system is sometimes maladaptive and can be over-ridden by a slower more, effortful system - System 2. System 2 is a slower, more thoughtful process, where people selectively attend to sensory and more abstract or unfamiliar information. This is very similar to how Gregory et al. (1997) described respondents’ adoption of simplifying strategies to make decisions easier, especially when faced with more complex decisions, when they lack a holistic or integrated view of an entire situation, or when faced with a novel topic or decision.

Nemeroff et al. (2020) summarised the heuristics and biases consumers employ in relation to water as follows:

1. A preference for simplifying dichotomies: Simple, dichotomous categories rather continuums are preferred, such as good and bad, safe and not safe.
2. A monotonic mind: The often-shared belief that if something is harmful at high levels, it is also harmful at lower levels - for example, believing salt-free or fat-free diets are healthier than a diet with a small amount of salt or fat. Some people do not think in terms of dose-response curves, which distinguish between the impacts of lower and higher exposures to harmful or harmless substances which might be present in water.
3. Difficulty dealing with very low probabilities: Risk factors are often ignored or sometimes exaggerated, for instance, a one-in-a-million chance of becoming ill from using reclaimed water may be exaggerated, while a one-in-10 million chance of winning the lottery does not deter people from playing.
4. A simplification of causal models: This describes the hunt for a single cause of real-world phenomena. This is relevant when dose level and susceptibility to harmful microbes in reclaimed wastewater is considered.
5. Affect heuristic: This is associated with System 1 decision-making. Disgust and fear are the two main emotions associated with attitudes to water-related risks. From the numerous studies cited, it appears that disgust towards and outright rejection of reclaimed water are quite low, and depend largely on the wording used to describe it or perception of respondents. Low levels could indicate higher levels of willingness to use the water. Nemeroff, et al. (2020) also claim that fast responses do not necessarily access emotion-based motivations because they are more automatic, while slower responses and deliberation can override a “head-versus-gut” response. This may also explain respondents’ immediate personal risk avoidance regarding the use of reclaimed

wastewater, even if the greater risk of being without water is much higher if they do not change their behaviours (Etale et al., 2020).

6. Contagion or contamination: The belief in the idea of "once in contact, always in contact", or spiritual contagion, in addition to physical contagion. This is where the natural buffer plays a role of a positive contact which neutralises the negative.
7. Morality, moralisation, and sacred values: Some decisions are influenced by believing in protected or sacred values, which are not subject to compromise by facts. People could therefore reject reclaimed water no matter how minimal the risks or great the benefits, because it goes against their personal morals, beliefs, or values to do so.
8. Natural preference or bias: Some people have an innate belief that anything natural is good and safe, while anything acted upon by humans is bad and less safe, as was also found by Etale et al. (2018). For instance, a mountain stream can be seen as safe, while reclaimed water, despite having a much higher quality, can be seen as bad.

Decisions are often made by relying on our understanding and pre-existing knowledge and anticipation of the outcomes, and are perceived as a repetitive application of the fundamental cognitive processes (Wang & Ruhe, 2007). We rely on our mental models, or shared mental models, which are "blueprints" of how the world around us works, to inform our choices and decisions. These can often be incorrect, or we could be biased because we can never have all available information on a topic or process to make complete and informed decisions. This dilemma is often aggravated by the fact that technological advances and developments in science and medicine happen at speeds far exceeding the pace at which information disseminates through to us through our education system or other media (Nemeroff et al., 2020). Furthermore, we are faced with overwhelming amounts of information and sensory input which we have to continuously interpret accurately to cope with uncertainty and minimise risks (Saaty, 2008). Thus, consumers may also adopt an avoidance approach or fear of the unknown; in this case, the three dominating factors influencing consumers' decisions are disgust, "neophobia" (with relation to food, a fear of trying new and potentially risky foods), and safety concerns or risk perception (Savchenko et al., 2019).

2.10. Traditional- and Decision Pathway-Surveys

With a better understanding of consumer decision-making and accounting for the differences between experts' and consumers' risk perceptions and differing levels of correct and relevant knowledge, more informed responses can be collected and decision- and policy-makers can have a better understanding of consumers' true motives, values, and possible trade-offs in relation to reclaimed water. This is vital to ensure future water reclamation projects stand a better chance of success. The consumer's decision-making process and answers to questions in a survey then assume the role of providing insight into their goals, objectives, desires, and values, while also considering the probability of success or level of effectiveness between choices (Harris, 1998).

Surveys have been seen as inexpensive mechanisms for developing a broad-based understanding of public views, especially when used to provide input on policies which are often made in a closed circle of agency (expert-driven decision-making) (Boyte, 1995). In traditional surveys, respondents are presented with a list of questions, but researchers are often limited by the length of the survey, as longer surveys could result in responder or participant fatigue. Contrary to traditional surveys, a decision pathway survey design does not just ask questions but informs respondents as they proceed through the survey and results in a more informed consideration of all available alternatives provided, and as per Gregory et al. (1997) could yield information about key trade-offs and provide policy-relevant profiles of respondents' attitudes.

Decision pathway surveys mimic decision trees in structure. Decision trees are made up of a series of nodes and branches and are used to show complex decisions or establish classification systems based on multiple covariates, where each branch represents an alternative course of action (Almuallim et al., 2002; Magee, 1964; Song & Lu, 2015). Each subsequent, complete alternative course is associated with a trade-off resulting in a specific outcome, and individual's decisions are based on the information they have available at that point. Decision trees also act as a form of classification (Magee, 1964) and, with computer technology, can allow a researcher to apply an adaptive survey design or "skip logic branching" when administering surveys.

Gregory et al. (1997) proposed one of the first decision pathway surveys which builds on behavioural decision theory, and the "fast and slow" thinking cognitive processes. They used it in an attempt to reveal important information about an individual's key trade-offs and reasoning processes (Gregory et al., 2016). Similar to others, they claim the public is often asked for their input into complex issues, such as conservation or environmental issues, but they often lack knowledge or confidence to balance benefits against costs or risks (Gregory et al., 1997). A decision pathway survey design helps participants complete three fundamental decision steps which include framing a decision, defining key objectives, and making trade-offs among objectives, with the aim of helping the participant complete survey questions in a more valid and reliable manner than with conventional surveys (Gregory et al., 1997). This is done by providing respondents with information (which they may not have known) at different stages of the survey, thus recognising fast thinking, while activating slow thinking which mirrors the reasoning strategies most people go through when making novel decisions in a thoughtful manner (Gregory et al., 2016). Researchers can also include more questions in each pathway to gain a richer understanding of respondents' attitudes and, through adaptive survey programming, avoid or minimise response rate error, social desirability and conformity bias, or item non-response error, which tend to be more frequent with pen-and-paper or telephonic branching surveys.

2.11. Conclusion

Globally, there is a water crisis. Many alternative sources of water are available, and consumers' levels of perceived risk, knowledge, affect, and disgust regarding some of these alternatives are influential in their success. A significant determining factor in these perceptions is the consumers' decision-making approaches. They are often faced with making familiar decisions, but novel or more complex scenarios – such as the reuse of water, which has multiple benefits and risks, both real and perceived - require more deliberation and the incorporation of new information or different decision-making strategies. Terminology, which is seen as basic, is used to describe water and water treatment processes, however, these are often not fully understood. Other than a possible lack of knowledge of the basic terms used to describe water, policies and legislation have also historically influenced people's behaviour and support for 'new' or different approaches and technologies used to manage water as a scarce resource. Water reclamation is a viable alternative within South Africa as it has been successfully introduced in the country and into many other countries, however, the level of engagement between decision-makers and the public is vital to such water projects' success. Conventional surveys have historically been used during such engagement. However, conventional surveys unintentionally encourage respondents to respond quickly when making a decision, which could be reflective of their automatic choices. A decision pathway approach to survey design aims to address the concerns of being faced with an unfamiliar and complex scenario by providing respondents with easy-to-understand information they can thoughtfully consider before making a final decision. This could result in respondents being better informed about the trade-offs of a sensitive or novel subject. With this information, and based on their own values, they are therefore able to deliberate and consider the utility of their decision. This in turn provides decision- and policy-makers with a more accurate representation of what the public thinks about the topic.

3. Method

3.1. Introduction

The chapter outlines the research method used during the study. It provides further insight into the aims, research design, sampling techniques, samples used, the procedure followed, survey design, method of data collection, data analysis, and ethical considerations.

Based on the information presented in the introduction and the literature review chapters, implementing alternative water sources, specifically water reclamation, could be the most sustainable option to manage increasing demand for water globally, and in South Africa. Water reclamation for direct reuse can potentially play a vital role in reducing the burden on the environment by balancing the demand and supply and mitigating future water shortages. The key difference of the method of this study and those of many previous studies is that a decision pathway survey was used, which provided respondents with information on an often-novel topic as they progressed through the survey. This allowed for the inclusion of more questions in the survey without the requirement to read or respond to all the questions. Respondents were directed through the survey, by use of skip logic branching, to follow a path specific to their concerns or willingness to explore alternative water sources.

3.2.Aims

This research aimed to explore the various decision pathways South African consumers follow when faced with an often-unfamiliar topic such as alternative water sources. The primary purpose of this research was to design a decision pathway survey for use in South Africa and possibly in other water-scarce countries. The design was based on research by Gregory et al. (1997) and Gregory et al. (2016). Similar decision pathway designs have been used in environmental studies by Demski (2011), Drew et al. (2002), Kask et al. (2002), and St Laurent et al. (2018). And conceptually described by Lahtinen et al. (2017) and Aubert et al. (2018). The tool can assist decision- and policy-makers to gain a deeper understanding of consumers’ reasoning processes when making decisions on unfamiliar topics, more specifically on the exploration and use of direct and indirect reclaimed water prior to more formal engagement. Having administered the survey to a sample of South African consumers the specific pathways were analysed, and insight was gained on whether information provision, relevant to a topic, could result in a different response and more informed decision-making.

3.3. Research Design

The research adopted an exploratory and descriptive quantitative approach. By employing quantitative techniques, information can be gathered from considerable numbers of people and allows for generalisations from a sample to broader groups beyond a specific sample (Holton & Burnett, 2005). The research had a predominantly non-experimental design with an element of a pre-experimental design or quasi-experimental design. One of the research questions could be classified as a one-group pre-test post-test (Bonds-Raacke & Raacke, 2014; Mauldin, n.d.). There was no random assignment of respondents or a control group. The data consisted of a collection of respondents' self-reported answers without supervision. These responses were quantitatively analysed. Information on alternative sources of water and water reclamation were introduced throughout the decision pathway survey in sections which resulted in the manipulation of an independent variable (i.e., respondents' knowledge on the topic of water, water alternatives, and water reclamation). Respondents were only asked to complete one survey at one point in time and the study was a cross-sectional study (Price, n.d.).

Bartlett (2005) provided a five-step process for conducting survey research which was combined with William's (2003) nine-step process for writing and analysing a questionnaire or survey. These steps were reduced to nine steps. The steps that were followed included:

1. The survey's purpose, objectives, research questions, and study population were defined.
2. Decisions on how the questionnaire would be administered were made, and the sample

was determined.

3. Questions and responses were formulated.
4. The survey's layout was determined and designed.
5. The survey was developed, then pre-piloted.
6. The instrument was piloted, and validity, reliability, and acceptability were tested.
7. Respondents were contacted through the survey process.
8. A coding scheme was designed, and the final version of the survey was programmed.
9. Data were collected, reduced, and analysed.

A positivist research philosophy was adopted, with the aim of objectively analysing respondents' pathways and seeking facts, while the researcher acted as an objective analyst (Swanson, 2009; Žukauskas et al., 2018). Positivism assumes that an objective world can be mirrored with science and that provisional truth and facts can be uncovered as quantitatively specified relations among variables (Swanson, 2009). The positive research paradigm is frequently associated with terminology such as experimental, correlation, and determination (Swanson, 2009; Žukauskas et al., 2018). The primary method of investigation was quantitative, with the collection and analysis of primary data to understand more general characteristics of the South African population, such as relations between demographics and level of support for water alternatives. The paradigms' ontology can be described as "objective and perceived" (Žukauskas et al., 2018, p. 126), and the epistemology was based on the acquisition of knowledge not related to value and moral content, and independent of the observer (Aliyu et al., 2014; Žukauskas et al., 2018). Quantitative techniques are preferred to qualitative techniques specifically when studying large groups of people and for allowing generalisations. However, some of the deep and detailed understandings which qualitative techniques offer can be lost (Holton & Burnett, 2005) but can be recovered with the inclusion of a choice to include information that is not part of the options provided, such as open-ended responses.

3.4. Sample, Sampling and Data Collection

The public's perceptions and knowledge of alternative water sources and projects, and input during public engagement, could determine a water project's success. In turn, respondents' input during public engagement, or gathered from surveys, can impact the implementation of public policies, which can influence other environmental concerns and have an impact on whole communities. It is for these reasons that a broad and general public sample was required which allowed for greater generalisability.

Sampling methods are predominantly divided into two broad types (Bartlett, 2005) - probability and nonprobability sampling. Probability sampling is representative of the entire population, while nonprobability sampling is relatively convenient and economical to construct. Even though nonprobability sampling is not all-inclusive a large sample can allow for findings to be generalised to the general population. Within the study two samples were utilised, an expert sample and a volunteer sample. The development of a new survey called for a sample of experts to provide input on the validity of the survey. A sample of South African public consumer volunteers completed the newly developed survey. A description of the sample calculation will follow then a presentation of the recruitment processes and the respective samples.

3.4.1. Sample Estimation

Two samples were required which consisted firstly of experts within South Africa in the field of water, water management and psychology, while the second sample comprised volunteers from within South Africa that represented diverse ethnic, socioeconomic, and age populations. The minimum sample size for the expert sample was not set. The expert sample size was determined by the availability and workload of the expert respondents. Experts who partook in a previous qualitative study were contacted to provide comments on the survey and were requested to nominate other experts from the respective fields, thus, snowball sampling.

South Africa has an estimated population of over 58.78 million residents (Statistics South Africa, 2019). The population is diverse with many differences but also some similarities. The aim of selecting a sample size would be to have a representative, reliable, and appropriate sample from the broader population. There are numerous “rules of thumb” for determining a sample size, and it can be calculated in different ways (Field, 2000; Kar & Ramalingam, 2013). Cochran’s formula for calculating a sample size from within South African was used. Within this formula, the required sample size is calculated by considering the margin of error, the standard variant for the desired confidence level, and the estimated proportion of an attribute that is present in the population (Guwahat, 2013; Kar & Ramalingam, 2013). The formula is presented as: $n_0 = (z^2pq) / e^2$. Within this formula n_0 is the sample size, z is the selected critical value of the desired confidence level (95% or *z-value* = 1.96), p is the estimated proportion of an attribute that is present in the population (50% at maximum variability), $q = 1 – p$, and e is the desired level of precision (±5%). The sample size was calculated for $p = 0.5$ and $q = 1 – 0.5 = 0.5$; $e = 0.05$; and $z = 1.96$. Thus, $n_0 = (1.96^2 \text{ x } 0.5 \text{ x } 0.5) / 0.05^2 = 384{,}16$.

The sample size, with the given criteria, was calculated to be 384 respondents. Research is often resource-intensive and the investment of resources versus the minimum required sample was considered. This figure characterised a sample that was optimum to meet efficiency (cost) and reliability (precision). However, this was a minimum sample size and to increase the accuracy of estimates the value was increased and a larger sample size, within an allocated budget, was used. The final sample of completed responses ($N = 668$) fell within the 99% confidence level (*z-value* = 2.58), with a level of precision of ±5%.

Online surveys’ response rate, also known as the incidence rate, or qualifying rate (IR), is between 50% and 70%. The service provider was informed that a minimum sample of 600 completed responses was required from the final version of the survey. The final figure of completed responses totalled 668 responses, which included responses from the service provider, WhatsApp, and Facebook. A summary table (Table 4) presents the number of respondents from the sources. The service provider was provided with the quota, and a direct link to the survey was shared on a public platform. It was not possible to calculate the exact IR as participation was voluntary, however, the number of respondents who attempted the survey, but did not complete it was low, with the completion rate (attempts/completed) of 83.19%.

Table 4: *Number of Survey Attempts against Completed Responses.*

	Attempted (*n*)	**Completed (*n*)**
Lightspeed Research BV Database	751	638
Facebook	22	12
WhatsApp	12	7
Pre-Pilot	18	11
Total	**803**	**668**

3.4.2. Expert Sample and Validation

A total of 39 South African experts were approached to validate the questions in the survey during a period from July to August 2020. The sampling frame included experts who partook in a qualitative study by Levin (2019), experts who were sourced from various online platforms, and referrals by the experts who were contacted. Expert participation was requested through email and was dependent on their availability and workload. Thus, nonprobability expert sampling, a sub-type of purposive sampling and snowball sampling was used.

From the prior qualitative study, six experts were contacted, and a further 25 experts were sourced through online searches on Researchgate, LinkedIn, Facebook, Google, and university websites, and eight came from referrals. Keywords used for online searches included: reclaimed water, water management, and environmental affairs. Individuals who had published papers on the topics that were part of the search terms in South Africa or who expressed an interest in consumer behaviour, water reclamation, or water treatment were contacted (N = 39).

They received an introductory email (Appendix A) and then a copy of the un-programmed survey for comments and their professional feedback. The survey was programmed with a free online tool - Cognitoforms (https://www.cognitoforms.com/), and a link to the programmed version was supplied to the experts to view the full survey. The experts' results did not form part of the analysis. They were not restricted to follow a specific path and could skip between questions without capturing any information.

Feedback was received, through email, from 12 (n = 12) experts from various institutions which included: The Centre for Environmental Management (Environmental Advisor), a local municipality in the North West (Sanitation and Waste Management), University of Cape Town (Future Water Research Institute), and The University of the Witwatersrand (Faculty of Engineering and the Built Environment, Global Change Institute, School of Civil and Environmental Engineering, and the Department of Psychology). The final sample consisted of five males and seven females. All experts had extensive knowledge of or an interest in change and water management, sustainability, survey design, consumer behaviour, or reclaimed water and waste management. The final sample size of experts was fairly limited. No further invitations for feedback from non-responders were sent after the three-month period as time was a determining factor. The survey was adapted with the suggested changes and pre- and pilot tested. Feedback received was consistent, and the content validity was rated by the experts as good to excellent.

All experts received an *Expert Participant Information* sheet with further details of the study and suggested guidelines on what was expected of them (Appendix B). The request included commenting on the survey design and the questions in the survey, more specifically, that they had to provide comments on:

- The clarity of the instructions for completing the survey, and the clarity of the questions.
- The mutual exclusivity of the response choices.

- To include any suggestions regarding the addition or deletion of questions, the clarification of instructions, or improvements of the format.
- To comment on the language used and whether questions were easy to understand.
- To comment on whether the questions were short and specific.
- To comment on whether any of the questions were leading.
- To comment on the validity of the survey.

Feedback received was overall positive, however, concerns were raised on the length of the survey. This was expected as expert respondents received the full-length survey which included all possible pathways to comment on, and not the final programmed survey which employed skip logic branching.

Expert feedback received included the following comments:

- *Simplify wording for the demographic section and ensure questions were phrased as questions not as statements, for example: "What is the household's income per month?" and not "Household income per month:".*
- *The addition of an 'Other' option to ensure questions are not leading or too restrictive.*
- *Ensure the snippets of information are not too long or too technical.*
- *Use demographic categories in line with Statistics South Africa reporting and South Africa's census data to increase generalisability and increase the robustness of the research method.*
- *Simplify terminology, for example, use "taps" instead of "faucets."*

The purpose of having subjected the survey to expert scrutiny, to a pilot test and a pre-test, was to determine the validity of the survey and to identify any technical issues (including device adaptability) before administration to the larger sample. This included reducing ambiguity in the questions and ensuring there were adequate response codes for each question. Furthermore, it meant aligning the questions with the principles as set out by Dillman (2000) and Williams (2003), before pilot testing, pre-testing and administration. These principles were in line with the suggested expert changes and included: choosing simple (not specialised) words, thus, avoiding jargon; choosing as few words as possible to pose the question and to avoid ambiguities; using complete sentences to ask questions; avoiding specificity that exceeds the respondent's potential for having an accurate, ready-made answer; developing mutually exclusive response categories and avoiding leading questions; and avoiding double-barrelled or double negative questions.

3.4.3. Pre-test Sample

A programmed version of the survey was sent to fellow students, friends, and previous work colleagues over the age of 18 (N = 33) for further comments as part of a pre-pilot test during September 2020. Eighteen responses were received of which 11 were complete. Thus, a response rate of 54.54% and a completion rate of 33.33%.

The respondents in the pre-pilot study were between the ages of 24 and 50 years old with a mean age of 33 years, six (n = 6) females and five (n = 5) males. Ten of the 11 respondents did not have children under the age of 18 years in the household, while one respondent had a child aged between 11 and 18 years. Most respondents lived in a cluster house or townhouse in a complex and indicated that their primary source of drinking water for the household was supplied through pipes inside the house from the municipality. The group predominantly resided in Gauteng and consisted of White (n = 7); Black African (n = 2); Coloured (n = 1); and Indian or Asian (n = 1) respondents. Respondents' most spoken language at home was English (n = 7); Afrikaans (n = 2); IsiZulu (n = 1); and Sesotho (n = 1), while all respondents had some tertiary education except for one respondent who only completed High School (Matric or Grade 12).

The respondents received instructions as part of the Participant Information Sheet (see Appendix C) to note down any suggested changes, concerns, comments, or questions and to capture these at the end of the survey. The instructions included to note:

- Any instructions, wording of questions or response codes that were unclear.
- The time it took to complete the survey.
- Any technical 'bugs', error messages or scripting errors.
- Comments on the design and layout of the survey and its adaptability to various devices.
- Their understanding of the questions.
- The order of the questions and if there were any inconsistencies.
- The appropriateness and completeness of responses.
- The relevance of questions.

Respondents provided valuable feedback and included suggestions to change the number of questions per page; to further clarify some terminology such as 'detached house' and 'in-house conventional meter'; and to further clarify differences between direct– and indirect-reuse.

3.4.4. Pilot Test Sample

A service provider - Lightspeed Research BV based in the Netherlands and part of the Kantar group – was pre-selected based on the cost for their services and the sample quota, and the time it would take to collect the responses from their available database. The pilot-test sample size was set at 50 completed responses from the provider. The survey was sent to 70 randomly selected participants from their database during September 2020 and 51 completed responses were collected. The respondents' age ranged from 21 to 73 years with a mean age of 39 and included females (n = 28) and males (n = 23). Respondents were Black Africa (n = 23), Coloured (n = 4), Indian or Asian (n = 2), Mixed Race (n = 1), and White (n = 20). One respondent preferred not to disclose their population group. The pilot test was used to determine the dropout rate per question and within sections, and the completion time. Responses were also monitored for potential errors in the programming of which none were noted. A high drop-out rate was noted within one of the sections. To decrease the drop-out rate for the larger sample, a single question, related to the ordering of the water treatment process, was made non-compulsory. All completed responses were included in the analysis of the full sample.

3.4.5. Volunteer Consumers in South Africa

The samples of volunteers who completed the final version of the survey were drawn from all nine provinces within South Africa, were male or female, and over the age of 18 years. Thus, nonprobability voluntary response sampling. The selection criteria were broad. The initial prerequisites for inclusion in the sample were that respondents had to have running water in their homes; had to reside in suburban or urban areas within major cities in South Africa and be responsible for the monthly utility bill. The prerequisites were changed to limit participation only to respondents from throughout South Africa, that were male or female, and who were over the age of 18 years.

The survey was programmed using paid-for online software (SurveyMonkey) and survey links were distributed by the service provider to their existing database, and by the researcher on Facebook and through WhatsApp. The database sample consisted of online volunteers, whose names were known by Lightspeed Research BV but not by the researcher. The service provider, in turn, did not have access to the final responses. This was done to ensure the anonymity of respondents. The service provider provided a full description of their processes and security protocols to ensure the privacy and protection of respondents' information (Kantar Group, 2020). Lightspeed also ensured the integrity of data by employing proxy detection, IP GeoFencing, email address verification, digital fingerprinting, and an honesty detector. Table 5 presents the frequency distributions and descriptive statistics for the completed responses from most to least frequent.

Table 5: *Frequency Distributions and Description of the Consumer Sample.*

Demographic	Frequency (*n*)	Percentage
Total Number of Completed Responses (*N*)	**668**	
Age		
Mean	37.23 (*SD* = 13.02)	
Range	61	
Minimum	18	
Maximum	79	
Sex		
Female	386	57.78
Male	280	41.92
Prefer not to say	2	0.30
Population Group		
Black African	330	49.40
White	208	31.14
Coloured	79	11.83
Indian or Asian	39	5.84
Prefer not to say	8	1.20
Mixed Race	4	0.60
Province		
Gauteng	252	37.72
Western Cape	111	16.62
KwaZulu-Natal	102	15.27
Eastern Cape	54	8.08
Free State	37	5.54
Limpopo	33	4.94
North West	33	4.94
Mpumalanga	31	4.64
Northern Cape	15	2.25
Home Language		
English	279	41.77
Afrikaans	115	17.23
IsiZulu	79	11.83
IsiXhosa	43	6.44
Setswana	39	5.84
Sesotho	32	4.79
Sepedi	31	4.64
Tshivenda	18	2.69

Demographic	Frequency (*n*)	Percentage
Home Language		
Xitsonga	12	1.80
SiSwati	10	1.50
IsiNdebele	5	0.75
Other	5	0.75
Religion		
Christian	497	74.40
No religious affiliation or belief	41	6.14
Traditional African Religion	37	5.54
Prefer not to say	26	3.89
Islamic	19	2.84
Atheist	16	2.40
Hindu	12	1.80
Agnostic	11	1.65
Jewish	6	0.90
Bahaism	1	0.15
Buddhist	1	0.15
Judaic Buddhist	1	0.15
Education		
High School completed – Matric/Grade 12	195	29.19
Vocational or FET College – Diploma or Certificate	177	26.50
Bachelor's degree	167	25
Honours Degree	54	8.08
Master's degree	30	4.49
Some High School	29	4.34
Doctoral Degree	9	1.35
Primary School completed	7	1.05
Combined Monthly Household Income		
R25 601 – R51 200	166	24.85
R12 801 – R25 600	154	23.05
R6 401 – R12 800	125	18.71
R51 201 – R102 400	64	9.58
R3 201 – R6 400	39	5.84
R1 601 – R3 200	35	5.24
Prefer not to say	32	4.79
R102 401 – R204 800	14	2.10
No income	12	1.80
R204 801 or more	11	1.65
R801 – R1 600	8	1.20
R1 – R400	6	0.90
R401 – R800	2	0.30

Demographic		Frequency (*n*)	Percentage
Type of House			
	Detached House	281	42.37
	Cluster house/townhouse in a complex	183	27.40
	Flat or apartment in a block of flats	85	12.72
	A house on a small-holding, plot or farm	68	10.18
	Room in backyard	27	4.04
	Informal house or shack	24	3.59
Occupancy			
	Owned – Fully paid off	233	34.88
	Rented – From a private individual	173	25.90
	Owned – Not fully paid off	166	24.85
	Occupied Rent-free	64	9.58
	Rented – From other (including municipality and social housing institutions)	32	4.79
Source of Drinking Water			
	Piped (tap) water inside the house from a municipality	483	72.31
	Bottled water only	66	9.88
	Piped (tap) water inside the yard from a municipality	65	9.73
	Borehole	27	4.04
	Public or communal tap	6	0.90
	Watercarrier or tanker	6	0.90
	Spring	5	0.75
	Neighbour's tap	3	0.45
	Rain-water tank	3	0.45
	Flowing water, stream, or river	2	0.30
	Well	2	0.30
Responsible for Monthly Utility Bill			
	Yes	507	75.90
	No	161	24.10

With the research being quantitative, the newly designed survey was used as the primary data collection tool. Data collection began after ethical clearance was obtained from the University of the Witwatersrand, Human Research Ethics committee (non-medical) protocol numbers **H20/02/13** and **MAORG/20/04** (see appendices D and E). Data were collected from the main sample over the course of a week during September 2020.

3.5. Survey Development Procedure

The exploratory nature of the study required secondary questions to be included in the survey in addition to the decision pathway section. The survey comprised various sections (see Appendix E for a copy of the full survey). More specifically the sections included: an instructions page, demographic question section, questions on the respondent's household, general knowledge questions on wastewater terminology, the decision pathway section, and additional questions for a parallel study as explained below. SurveyMonkey was used to split the questions into 52 pages. Respondents, on average, required 16 minutes to complete the survey. Two screening questions were included at the start of the survey. Only respondents who provided informed consent and who were over the age of 18 years could proceed with the survey. If informed consent was not provided, or a respondent was under the age of 18 years, the respondent was re-directed to an end page. All questions were mandatory except for the question which required the re-ordering of various steps in the water purification process at the end of the survey. Data validation techniques provided by the online programming tool were employed which included: setting a minimum age restriction of 18 years for participants, setting data type restrictions for numeric values; limiting the multiple-choice responses to only one response per question; and flagging missing responses to questions.

Questions from the Global Change Institute at the University of the Witwatersrand were included in the survey for a parallel study named: *Urban water futures: Bridging supply-demand gaps in Accra and Johannesburg through reuse,* protocol number **H20/02/13**. More specifically questions on the steps water treatment plants follow to purify water, a question matrix with six-point Likert style questions, and seven True or False questions.

The demographic and household questions were informed by a sample copy of the *Statistics South Africa household questionnaire A* (Statistics South Africa, 2011). This was done to increase the generalisability of findings. The demographic section was split into two parts, firstly, to introduce the participant to the online format and ease them into the survey, and a section at the end of the survey which acted as a de-brief, after having answered potentially difficult questions.

The options within each question were coded to be mutually exclusive, as exhaustive as possible, precise, and meaningful (Brace, 2004). Respondents were requested to fill in their age in completed years. The demographic and household sections consisted of 22 pre-coded questions which prompted respondents to choose from multiple options. An *Other*, open-ended option was also included within most questions, while an *I prefer not to say* or an *I don't know* option, or both were included for some demographic questions (i.e., sex, population group, religious affiliation, and gross monthly household income). The general knowledge section comprised nine multiple-choice questions and seven true or false questions. The "*I don't know"* option was consistently included as an option for the technical terminology questions; this was done to ensure respondents did not choose a random answer which could potentially skew the data (Brace, 2004).

Demographic questions collected information on respondents' age, sex, population group, usual province of residence, most spoken language, religious affiliation, level of education, gross monthly income, and the type of residence and occupancy. The household section asked respondents to select their main source of drinking water, their drinking water supplier, and whether they regularly practised any of the listed water-, energy-, or eco-friendly-initiatives. Thirty-eight initiatives were included in the water-, energy-, and eco-friendly question section along with an option "*None of these are practised"* and "*Other"*, which provided respondents with the opportunity to include other initiatives not mentioned in the three lists. A question matrix with questions for the parallel study was added after the decision pathway section, to avoid a high drop-out rate or possible responder fatigue. The question matrix required respondents to indicate, on a six-point Likert scale (*strongly disagree* to *strongly agree*), their level of agreeableness on 22 statements. On the second last page of the survey, respondents were requested to re-arrange six steps in the water purification process. The survey concluded with a *Thank you* page.

The questions and pathways, for the decision pathway section of the survey, were developed based on themes identified between laypeople and experts during a qualitative study by Levin (2019) during which alternative water futures were explored. Some overlapping themes between laypeople and experts included: the level of (dis)trust in government, issues around infrastructure and technology, and concerns around health perceptions and aesthetics of reclaimed water. A summary table (Table 6) shows the themes identified within each group and the overlapping themes which informed the questions within this survey.

Table 6: *Summary of Themes Identified Between Laypeople and Experts on Water Reclamation*

Themes	Laypeople	Experts
Trust or distrust in government or municipalities	X	X
Available infrastructure & technology	X	X
Health perception & aesthetics	X	X
Awareness of water reclamation	X	X
Cost implications	X	X
Role of media & advertising	X	X
Only available option during – scarcity and crisis	X	X
Environmental buffer	X	
Water reclamation as a viable source		X
Incentives to use the water	X	
Ignorance is bliss	X	
Personal perception		X
Maintenance of infrastructure		X

Note. Adapted from “Alternative water futures: Developing a water reclamation decision pathway survey,” by G. Levin, 2019, Unpublished manuscript, University of the Witwatersrand.

3.5.1. Pathway Structure

The survey's structure was based predominantly on the work of Gregory et al. (1997) and the work of other authors as previously mentioned. The decision pathway section of the survey consisted of 34 questions. The longest path a respondent could follow was 13 questions, and the shortest path a respondent could follow consisted of eight questions. A description of the flow of the decision pathway follows with a graphical representation of the general structure in Figure 6.

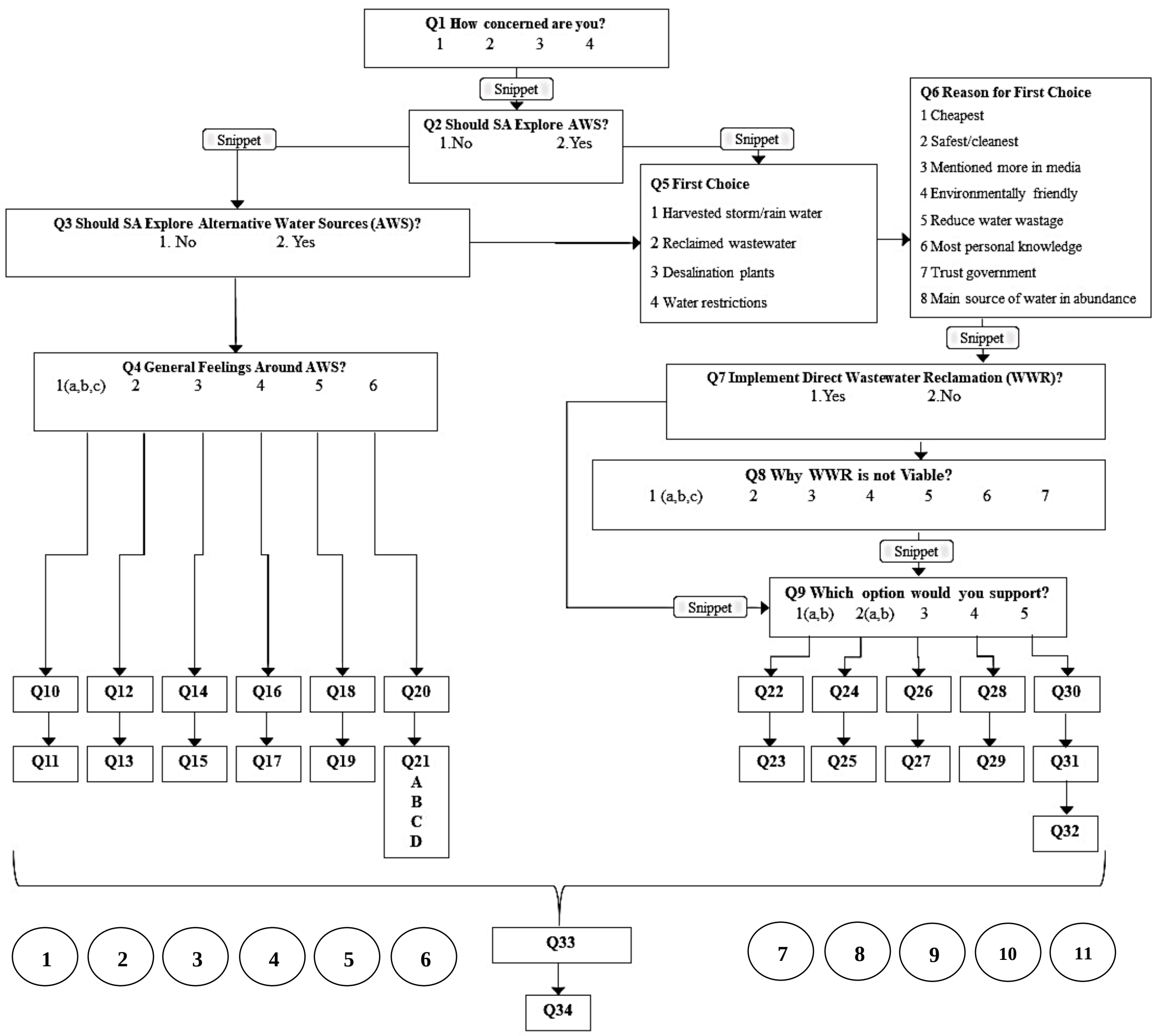


Figure 6: *Decision Pathway Structure*

Key. AWS = Alternative Water Sources; WWR = Waste Water Reclamation

3.5.1.1. The first split. Question one in the pathway section focused on a respondent's level of concern for South Africa's water security and provided them with four alternatives: 1) Not concerned at all, 2) Somewhat concerned, 3) Concerned, and 4) Very concerned. A short snippet of information on the scarcity of water in South Africa and three alternative sources of water was provided. The snippet of information read: *More than 60% of the earth's surface is covered by the ocean, but only a very small percentage of that is freshwater. South Africa experiences moderate to severe water scarcity during more than half of the year. Alternative sources of water include storm and rain-water harvesting, reclaimed wastewater, and water from desalination plants.* The information aimed to inform respondents of the looming water crises and the availability of some alternative sources of water. Respondents were required to indicate whether they supported the exploration of alternative water sources in South Africa (yes pathway) or not (no pathway). The question acted as the first split between respondents and skip logic branching was used to guide the respondent through the rest of the decision pathway survey.

3.5.1.2. The 'No' pathway. Respondents who indicated that alternative sources of water should not be explored were provided with definitions of some of the alternative sources of water available and given the opportunity to change their response to whether alternative sources of water should or should not be explored in South Africa. Respondents received the following definitions:

- *Storm- and rain-water harvesting involves collecting and storing rain from run-off and building roofs in ponds and aquifers or in rainwater tanks.*
- *Reclaiming wastewater involves treating wastewater from industries, as well as residential and commercial buildings for potable (drinking) or non-potable (non-drinking) use.*
- *Desalination involves treating seawater to remove salt and minerals, to make it suitable for drinking or irrigation.*

- *Water restrictions involve limiting water usage.*

Respondents who did not change their response proceeded to the next question of the *No pathway* (paths 1 to 6). Respondents who indicated, after having gained a better understanding of the meaning of alternative water sources, that South Africa should explore alternative water sources proceeded to paths seven to 11.

If a respondent indicated that alternative sources of water should *Not* be explored, they were asked to choose one of eight provided reasons which best explained their resistance to the exploration of alternative water sources. The questions were developed to gain a deeper understanding of respondents' trust, fears, perceived risks, and subjective norms. Each choice led the respondent to questions directly aimed to better understand the basis of their concern, levels of trust, or the specific information they deem important to make more informed choices when exploring alternative water sources.

Path one (as depicted in Figure 6) provided a respondent with three options which all originated from a similar theme and were combined into a single path which led to questions ten and eleven. The *No* path was split into six pathways:

- Path 1: (a) Believing that the government or municipalities did not have enough knowledge to safely implement the use of alternative water sources; (b) Believing that scientists did not know enough about the technology required to safely implement the use of alternative water sources; (c) Thinking or feeling that there was not any technology that could safely treat alternative water sources to drinking quality.
- Path 2: Respondents who felt they did not have enough knowledge or information to make an informed decision.
- Path 3: Respondents did not trust the government or municipalities' ability to manage the processes required to implement the use of alternative water sources.
- Path 4: Respondents felt water was abundant in the world and that municipalities should

continue to do things the way they were done.

- Path 5: Respondents were more worried about other environmental issues because it was reported more in the news and/or spoken about by celebrities.
- Path 6: Respondents believed alternative water sources would be too expensive to implement.

The pathway section (paths 1 to 6) concluded with two questions. A question in which a respondent was asked to indicate their most preferred alternative from a list of four alternatives (storm water and rainwater harvesting, desalination plants, water reclamation, water restrictions, and an *Other* open-ended option), and the action they would take should they visit an area in South Africa where the local municipality had introduced an alternative source of water they did not agree with.

3.5.1.3. The 'Yes' pathway. If a respondent indicated that alternative sources of water should be explored (paths 7 to 11), they were provided with the same definitions as previously been listed of some of the alternative sources of water available and asked to rank the given alternatives in their order of preference. This first ranking of a respondent's most preferred water alternative was essential to allow for the answering of the respective research questions. A follow-up question provided various reasons which respondents could choose from which best explained the reason for their most preferred alternative. The reasons a respondent could choose from included having a belief that the cost would be lowest; the water would be purest; the media influenced the respondent's choice; the respondent believed that it was an environmentally friendly alternative; the respondent believed that the option would reduce water wastage; the respondent had the most knowledge on the option, or the respondent trusted the governments' management of the process.

This was followed by a snippet of information specifically worded to inform respondents of wastewater reclamation and relevant related water re-use terminology.

Respondents had to indicate whether they agreed that implementing direct wastewater reclamation could help to ensure a sustainable water supply for South Africa in the future or not. The snippet that was included read as follows: *South Africa can use reclaimed wastewater. Reclaiming water involves treating wastewater from industries, and sewage from residential and commercial buildings for potable (drinking) or non-potable (non-drinking) use. Two routes exist for water reclamation: direct and indirect. In indirect reclamation, wastewater from homes and industrial facilities is treated at wastewater plants and delivered to a buffer (an underground aquifer or a surface water body). After some time, the water is collected and treated at a treatment plant to the required standard, and delivered to municipal reservoirs and you the user. With direct reclamation, wastewater from homes and industrial facilities is treated at a wastewater plant to the required standard then delivered to municipal reservoirs and you the user. There is no natural buffer between the treated wastewater and you the user*.

Respondents were provided with a list of options to choose from which best described their reluctance to support direct reclamation when they were not in support of direct water reclamation. The options that they were allowed to choose from, to provide insight on the reason for their reluctance to explore direct reuse included concerns around: the governments' or municipalities' knowledge on available technology to safely implement direct reuse; scientists' knowledge on the technology to safely implement direct reuse; personal lack of knowledge on available technology; trust or mistrust in the governments' management of the process; a concern for other environmental issues; a concern around the cost; and a belief that there is no water crisis.

Respondents who agreed and disagreed with the statement - direct wastewater reclamation is a viable option – received further information on reclaimed water before being directed to choose between pathways seven to 11. More specifically, they were provided with the meaning of direct and indirect reclamation for potable and non-potable reuse, and the vignette read as follows: *Recently, Cape Town was close to a 'day zero' the point at which the city would have run out of water. Day zero is a national concern, and could happen in other South African cities. Wastewater can be treated to different standards: potable (drinkable) or non-potable (not-drinkable) standards. Indirect Reuse means: wastewater is treated then released into groundwater or surface water bodies (environmental buffer). After a time, it is pumped back out and treated to a potable or non-potable standard. Direct Reuse means: wastewater is treated to potable or non-potable standards and introduced directly into a municipal water supply system without an environmental buffer.* The question posed a hypothetical scenario of severe water scarcity.

The paths aimed to provide insights on how comfortable respondents were with the idea of using direct reclaimed water, indirect reclaimed water and water from these sources of a potable or non-potable standard. Seven options were provided and options one (a) and (b) followed path seven while options two (a) and (b) followed path eight. The paths were split into support for:

- Path 7: (a) Direct potable reuse – where there is no natural buffer and the water would be used for domestic (including drinking), industrial, and agricultural use; (b) Direct non-potable reuse – where there is no natural buffer, but the water would be used for domestic (not drinking), industrial and agricultural use.
- Path 8: (a) Indirect potable reuse – there is a natural buffer, and the water would be used for domestic (including drinking), industrial, and agricultural use; (b) Indirect non-potable reuse – there is a natural buffer, and the water could be used for domestic (not-drinking), industrial, and agricultural use;
- Path 9: Support for dedicated pipes run to homes for reclaimed wastewater so that respondents could decide for themselves what to use the water for.
- Path 10: Respondents were given an option to indicate that they would not use reclaimed

wastewater even under severe water shortages.

- Path 11: Respondents were provided with an option to indicate that they believed that better alternatives than wastewater reclamation existed.

Pathway sections seven to 11 concluded by asking a respondent to firstly, indicate out of a list of five options the most viable (practical and effective) option for South Africa, then on the action they would take should they visit an area in South Africa where the local municipality had introduced an alternative source of water they did not agree with. These two questions were the same for the respondents who followed path one to six.

3.5.1.4. Summary of paths. In summary, the paths were split as follows, with respondents opposed to the exploration of alternative water sources following paths one to six and those in support of alternative water sources following paths seven to 11:

- Path 1: Opposed to the exploration of alternative water sources in South Africa with general negative feelings toward (a) the government or municipalities' knowledge on the technology required to safely implement the use of alternative water sources; (b) the scientists level of knowledge on the technology required to safely implement the use of alternative water sources; and (c) the respondent's perceived level of knowledge on the available technology that can safely treat alternative waters to drinking quality.
- Path 2: Respondent's perceived level of knowledge on alternative sources of water and their ability to make an informed choice.
- Path 3: Respondent's level of trust in the government or municipalities' ability to manage the processes required to implement the use of alternative water sources.
- Path 4: Respondent's acknowledgement of the water crisis, and/or their level of acceptance of the change.
- Path 5: Respondent's level of concern with other environmental issues which they deem more important.

- Path 6: Respondent's level of concern around the costs associated with implementing alternative water sources.
- Path 7: Not opposed to the exploration of alternative water sources in South Africa, and generally in support of reclaimed wastewater as a last resort through (a) direct potable reuse or (b) direct non-potable reuse.
- Path 8: Not opposed to the exploration of alternative water sources in South Africa, and generally in support of reclaimed wastewater as a last resort through (a) indirect potable reuse, or (b) indirect non-potable reuse.
- Path 9: Not opposed to the exploration of alternative water sources in South Africa, but will only support water reclamation if they had a choice in what they would use the water for.
- Path 10: Not opposed to the exploration of alternative water sources, however, will not use reclaimed wastewater.
- Path 11: Not opposed to the exploration of alternative water sources in South Africa, but does not see water reclamation as the best alternative.

The survey, therefore, allowed a respondent to follow through a sequence of questions to choose only one of the pathways as a constructed representation of their point of view. The survey was programmed for online use through available software and collector links were created. Firstly, Cognitoforms was used, and the link was provided to experts to view it and make suggestions for changes, and secondly, links were created on Surveymonkey. As part of the validation process, the survey was supplied to experts in the field of water treatment and reclamation, as well as experts in the field of Industrial Psychology for feedback on the content and face validity. It was tested for compatibility with mobile devices to improve the response rate and the completed survey, after having received expert feedback, it was pre-pilot and pilot tested.

3.6. Data Analysis

Several steps to analyse quantitative data were followed which included: data preparation, editing, and data coding (Bhatia, n.d.; Field, 2000; Albers, 2017). The primary data preparation stage included exporting the data from the online software into an Excel format and combining the data from the service provider and other collector links. To ensure the integrity of the data, two data cleaning stages were undertaken. The primary data cleaning stage included screening the data and excluding incomplete responses or attempts from respondents who did not provide informed consent, responses with duplicate IP addresses (the first completed response was kept within the datasheet), and respondents who completed the survey in less than ten minutes, the minimum time necessary to meaningfully read and answer all questions as established from the pre-test. The secondary data cleaning stage included further checking the data for outliers and recapturing all *Other* biographical answers and answers to other questions with an open-ended option into the relevant existing categories or creating new categories where applicable. Lastly, variables were coded for statistical analysis.

The quantitative nature of the study required descriptive statistics to be run which included obtaining means, frequencies, standard deviations, and other tests to assess the normality of the data. The results and the assumption that respondents' answers could be classified as at least interval or ordinal data were used to inform the researcher of the use of parametric or non-parametric statistical tests. Statistical analyses were performed in IBM SPSS Statistics 26. Descriptive statistics including means, modes, medians, and frequencies were also used throughout to summarise the variables under study (Field, 2000). Attempts to draw correlations from experimenter-selected independent variables, such as demographic information and respondents' selected answers in the designed survey were made with a distinct consideration for any analysis' assumptions. More specifically the assumptions more common to most techniques include: level of measurement, random sampling, independent observations, normal distribution, and homogeneity of variance were applicable (Field, 2000).

The frequencies of the different pathways, along with the frequencies at each decision point were determined as a first step and allowed for statistical evaluation by considering the relationships between different pathways or decisions made by respondents (Breckler, 1990; Gregory et al., 1997). The one group pre-test post-test design allowed for a chi-squared test and Bonferroni *post hoc* test with adjusted residuals. To allow for the chi-squared test several assumptions had to be met which included: independence of observations, and that the value of the expected cell counts should be five or more in at least 80% of the cells with none of the expected frequencies below one (Field, 2018), to meet this assumption data were collapsed across some of the demographic variables, for example Coloured, Indian or Asian, Mixed Race, and those who did not prefer to say their population group were collapsed into an 'Other' category and compared to Black African and White. Several correlations were also included as part of the analysis, similarly, the analysis' assumptions were considered and met.

3.7. Ethical Considerations

Following ethical standards are paramount in conducting research (Fleming & Zegwaard, 2018). The researcher aimed to maintain the dignity and welfare of all participants through fair and ethical treatment. The researcher had the necessary training and education for conducting research and had the survey approved for use prior to distribution. Ethical clearance was obtained from the University of the Witwatersrand, Human Research Ethics committee and (non-medical) protocol numbers **H20/02/13** and **MAORG/20/04** were issued. The service provider provided a full description of their processes and security protocols to ensure the privacy and protection of respondents' information (Kantar Group, 2020).

All participants were protected from psychological and physical harm as is prescribed by the Health Professions Council of South Africa (HPCSA) in Form 223 (Health Professions

Council of South Africa [HPCSA], 2006). The ethical principles of psychologists and code of conduct as set out by the America Psychological Association (APA) were also consulted which are aimed at "ensuring the accuracy of scientific findings, protecting the rights and welfare of research participants and subjects, and protecting intellectual property rights" (American Psychological Association [APA], 2017; American Psychological Association [APA], 2020, p.11). Experts were provided with a Participation Information Sheet (PIS) via email and were requested to provide their informed consent electronically. With regards to the final online survey, each participant was requested to provide informed consent before starting the survey as part of the Participant Information Sheet page. No specific identifiers which could be used to identify any individual were collected. The sample group consisted of willing volunteers and were exposed to low risk as water reclamation may be perceived as a sensitive topic.

Through the distribution of the Participant Information Sheet (PIS), as the first page of the survey, a thorough explanation of the purpose of the study was provided and informed respondents on how their anonymity and confidentiality would be maintained and that the study was voluntary. Respondents were informed that they were free at any point during the completion of the survey to withdraw their participation, and that there were no advantages or disadvantages if they chose to participate or not. They were not able to withdraw their informed consent once they had submitted their responses as their responses were anonymous. The first page of the survey also provided respondents with all relevant and necessary contact details for the University's Human Research Ethics Committee (Non-Medical) should they have had any concerns or complaints regarding the ethical procedures of the study. As part of the PIS, respondents were informed that the results will be written up in a research report and may be written up as journal articles or conference presentations, and that they could request a summary of the results through an email to *AlternativeWaterStudy@gmail.com*; this would, however, break anonymity.

All collected responses were treated as confidential and are stored in an electronic format in a secure location with access restricted to the researcher and direct supervisors only (HPCSA, 2006), and analyses were conducted at a group level, meaning that responses were acknowledged in relation to all other responses. Respondents were also informed that the data may be made available to the University of the Witwatersrand for future secondary analysis by student industrial psychologists under supervision. Throughout the study acknowledgement of works of other authors used in any part of the paper were referenced using the American Psychological Association referencing system seven (APA, 2020).

3.8. Delimitations of the Study

This research did not use minors under the age of 18 years as part of the sample, as it would have been difficult to obtain their guardians' informed consent. Feedback and data were collected over a period of a few months which did not allow for a longitudinal study. Engagement with the expert sample was limited to a period of three months with a limit of two follow-up emails for non-responders. This study is limited to experts and volunteer consumers within South Africa. Respondents who did not submit completed responses were excluded from the analysis as the responses were missing completely at random and no inferences were made to account for incomplete cases.

3.9.Conclusion

Water is extremely valuable, yet very few people realise the importance of the resource and its scarcity. Globally humanity may be faced with a water crisis that could affect millions. The interdependence with water could result in other crises. Many alternatives are available which could alleviate the burden on the environment and ensure a more sustainable water future, however, consumers' perceived risks, level of knowledge, and perceptions of new technologies or water alternatives could hamper the implementation of such alternatives. By improving public engagement decision- and policymakers can better understand the public's concerns and reservations. A decision pathway survey design could improve consumers' decision-making processes and result in more informed decisions, ultimately improving public engagement and increasing the successful implementation of future water projects. Through the use of a quantitative exploratory study, as set out in this research, the results from the study could be generalised to the larger South African population.

4. Results

4.1. Introduction

This chapter will provide the results from the study, presented using figures, charts, or tables, to answer the research questions. Respondents' demographic summary can be found in chapter three, section 3.4.5., and Appendix H. The exploratory nature of the study called for several additional variables to be included in the survey and analysis. Analyses were conducted, more specifically, frequencies, correlations, and chi-square analysis.

4.2. Research Question 1

What are the most preferred alternative water sources in South Africa, and what is the predominant reason for supporting the water alternative?

Respondents who supported the exploration of alternative water sources (n = 661) ranked four alternatives in their order of preference and provided a reason for their first choice. The alternatives were ranked from most preferred to least preferred as follows:

1. Harvested storm water and rainwater (n = 332, 50.23%);
2. Desalination plants (n = 116, 17.55%);
3. Water restrictions (n = 108, 16.34%);
4. Reclaimed wastewater (n = 105, 15.89%);

There was only a small difference between the number of respondents who chose water restrictions and reclaimed wastewater as their preferred alternative. This may mean that the public might be equally willing or supportive, or not supportive of water reclamation when very strict water regulations and restrictions are introduced, and if no other alternatives are available.

1. A majority of the sample who chose storm water and rainwater harvesting as their most preferred choice indicated that they believed the water would be the cleanest and safest to drink (n = 135, 20.42%), or that it would be the cheapest option (n = 79, 11.95%).
2. Similarly, most respondents who chose desalination as an alternative also indicated that

they believed the water would be the cleanest and safest to drink (n = 57, 8.62%) or that they believed it was an environmentally friendly alternative (n = 23, 3.47%).

3. Respondents who chose water restrictions as their preferred alternative believed that it could reduce water wastage (n = 37, 5.60%), or that the water they received was the cleanest and safest to drink (n = 27, 4.08%).
4. From the respondents who indicated reclaimed wastewater as their preferred alternative, a majority indicated that they believed the water would be the cleanest and safest to drink (n = 35, 5.30%) or that the option would be the cheapest alternative (n = 22, 3.33%).

Respondents were requested at two sections within the survey to provide their most preferred alternative source of water. Results pertaining to their most preferred alternative at the end of the survey will be presented as part of research questions three and four. Table 7 provides a summary of the count for each water alternative and the most likely reason respondents gave for their support of the alternative.

Table 7: *Cross-tabulation of First Choice by Reason for First Choice (Count and % of Total).*

	Water would be cleanest & safest		**Most knowledge on this**		**Trust government**		**Environ-mentally friendly**		**Often mentioned in the media**		**Would reduce wastage**		**The option would be the cheapest**	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Harvested storm water & rainwater	135	20.42	8	1.21	8	1.21	59	8.93	7	1.06	36	5.45	79	11.95
Desalination plants	57	8.62	4	0.61	7	1.06	23	3.47	11	1.66	8	1.21	6	0.91
Water restrictions	27	4.08	4	0.61	1	0.15	17	2.57	3	0.45	37	5.60	19	2.87
Reclaimed wastewater	35	5.30	3	0.45	7	1.06	19	2.87	6	0.91	13	1.97	22	3.33
Total	254		19		23		118		27		94		126	

4.3. Research Question 2

What are the decision pathways around support for alternative water sources and reclaimed water acceptance in a South African context?

The frequency analysis allowed the identification of the distribution of respondents within each pathway. The pathways represent the various levels of support for exploring alternative water sources and various types and standards of reclaimed water in South Africa. A vast majority (n = 647, 96.86%) of respondents felt that it would be prudent for South Africa to explore alternative water sources. Only 21 respondents (3.14%) were against South Africa exploring alternative water sources, of which 14 changed their response after having received more information on the definitions of the alternatives available. Eleven pathways were available to respondents. The pathway frequencies are summarised in Figure 7. Some pathways attracted very few respondents, while others attracted a substantial number.

4.3.1. Path Comparisons (Paths 1 to 6)

Very few respondents (n = 21, 3.14%), from the total sample (N = 668) indicated that they were against exploring alternative water sources in South Africa. These respondents were provided with information on each of the water alternatives which included definitions of storm water and rainwater harvesting, reclaiming wastewater, desalination, and water restrictions. They were provided with an opportunity to change their answer from: "*South Africa should not explore alternative water sources*" to, "*South Africa should explore alternative water sources.*"

Of 21 respondents who initially indicated "No", seven (1.05%) from the total sample, did not change their answer and followed Paths one to six, while 14 followed Paths seven to 11. Respondents who did not support the exploration of alternative water sources were asked questions directly related to their reason or level of resistance in an attempt to garner a deeper understanding of their concerns, and perceived potential risks.

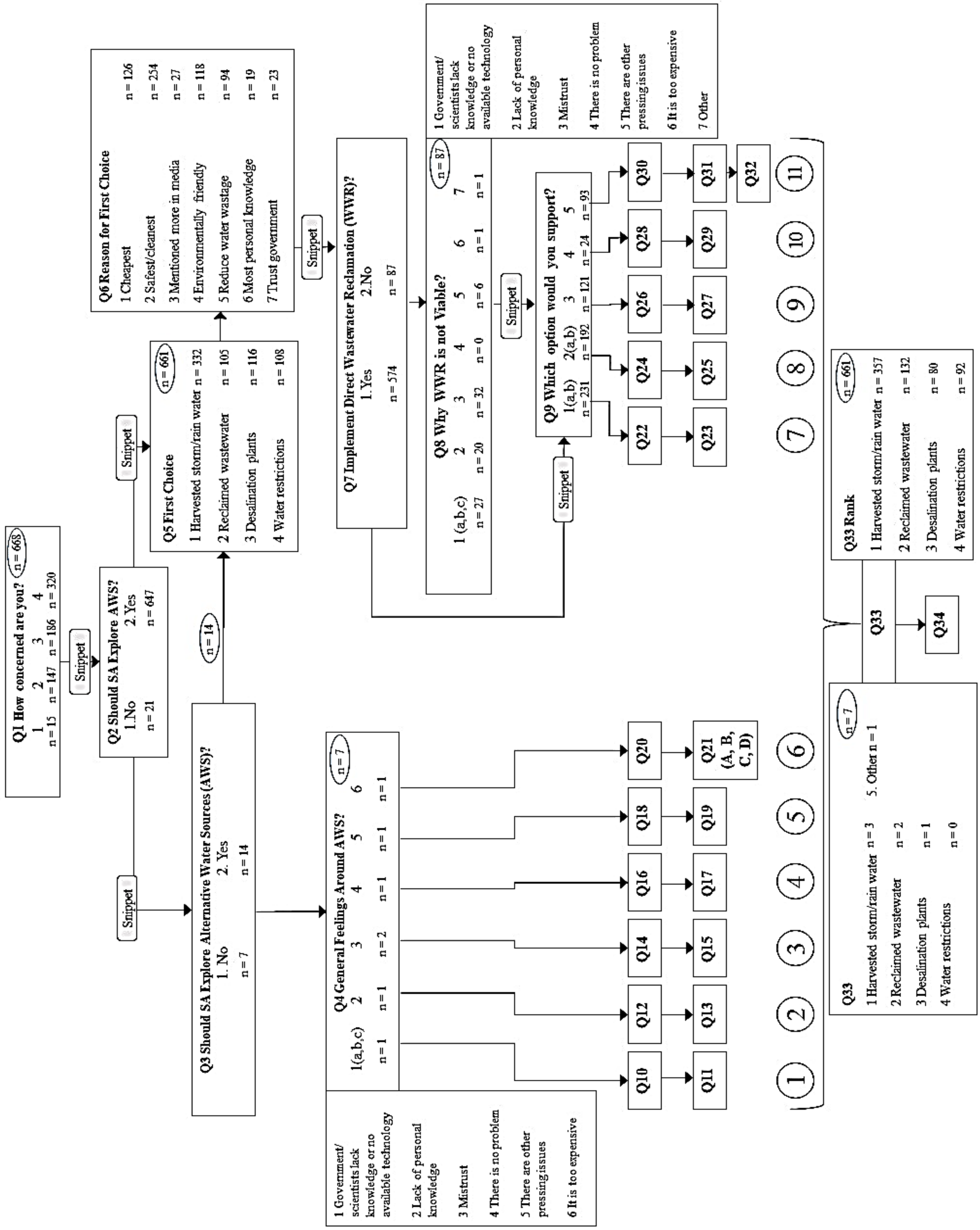


Figure 7: *Decision Pathway Map and Frequencies*

- Path 1: A single respondent (n = 1, 0.15%) indicated that they believed the government or municipalities did not know enough about the technology required to safely implement the use of alternative water sources. Their concern was rooted in that they believed the government and, or scientists do not have the public's best interest at heart and more specifically that they did not trust the government to manage complex environmental issues.
- Path 2: One respondent (n = 1, 0.15%) indicated that they did not know enough about alternative water sources to make an informed choice. The respondent indicated that they would find information on the quality of the water and any associated health risks most valuable and that children should be taught about alternative water sources at school.
- Path 3: Two respondents (n = 2, 0.30%) indicated that they did not trust the government or municipalities' ability to manage the processes required to implement the use of alternative water sources. To increase the public's trust, one respondent believed that the government and municipalities should allow citizens to vote on the available options before implementation, while the other did not choose an option from the list but indicated that they believed it was necessary to restructure and retrain employees. Both respondents indicated that the role of the government and municipalities in managing complex environmental issues should be restricted and that the final decision on the implementation of alternative water sources should be with communities or left to scientists and environmentalist.
- Path 4: A single respondent (n = 1, 0.15%) indicated that water is abundant in the world, and the municipalities should continue to do things the way they were done.
- Path 5: A single respondent (n = 1, 0.15%) indicated that they were more worried about other environmental issues such as deforestation or pollution because it was reported more in the news or spoken about more by celebrities.
- Path 6: A single respondent (n = 1, 0.15%) indicated that they believed alternative sources

of water would be too expensive to implement. This respondent was provided with a figure showing the rising costs of different alternatives, from *water restrictions (cheapest option) -> rainwater harvesting -> water reclamation -> desalination (most expensive)*, and requested to indicate their most preferred alternative, they suggested stricter water restrictions. However, the respondent indicated that they were most comfortable using bottled water for drinking, feeding a baby and for cooking, while they were comfortable with using water from a reclamation plant to water their garden.

4.3.2. Path Comparison (Paths 7 to 11)

Respondents who changed their answer from *'No'* to *'Yes'* (n = 14), and respondents who agreed that South Africa should explore alternative water sources (n = 649) followed paths seven to eleven. This sample group made up a considerable portion of the sample (n = 661, 98.95%). All 661 respondents received a vignette on the meaning of the various alternative sources of water and information explaining the difference between indirect and direct reuse as well as the difference between potable and non-potable standards. Respondents support for direct or indirect reuse and potable or non-potable standards are summarised in Figure 8.

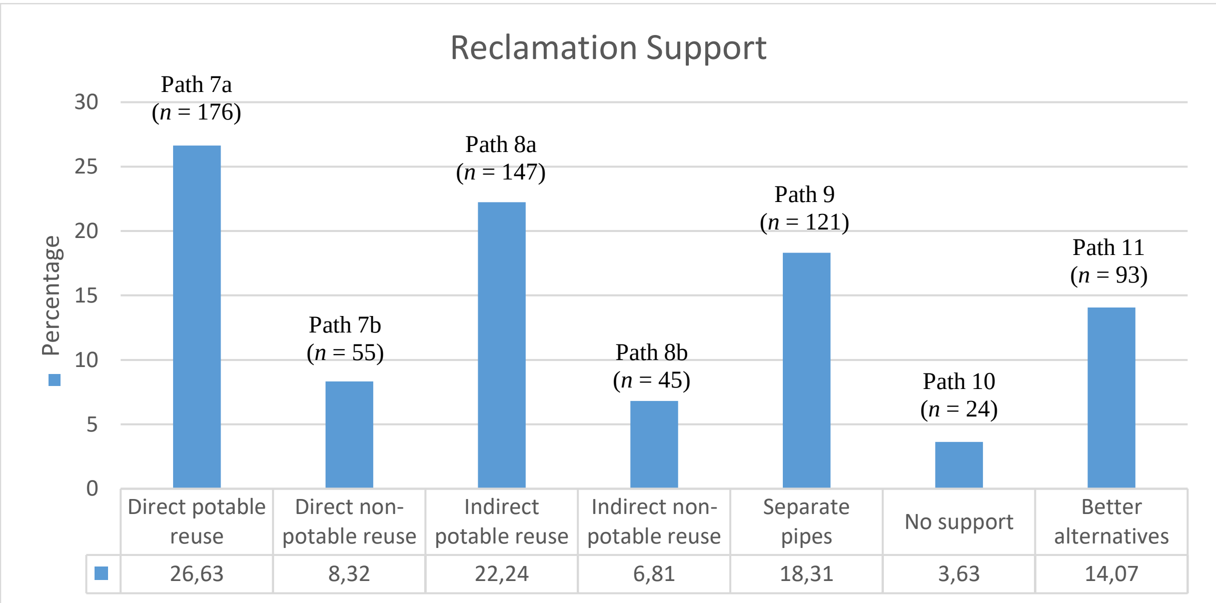


Figure 8: *Summary of Reclamation Support.*

Support for Direct Potable or Non-Potable Reuse (Path 7 a & b). Many respondents (*n* = 231, 34.95%) supported direct potable and non-potable reuse. The support for direct potable reuse – with no natural buffer, and water to be used for domestic- (including drinking), industrial- and agricultural-use was the highest (*n* = 176, 26.63%). Support for direct non-potable reuse – where there is a natural buffer, and the water would be used for domestic- (not drinking), industrial- and agricultural- use was much lower (*n* = 55, 8.32%).

Direct reuse (potable and non-potable) was firstly chosen for its possible cost-effectiveness within South Africa (*n* = 105, 45.45%), and secondly, a smaller number of respondents believed that the government, municipalities, and scientists had sufficient knowledge on the process (*n* = 52, 22.51%), thirdly, respondents indicated that it would reduce the burden on the environment (*n* = 31, 13.42%). Respondents' most perceived challenges or associated risk for implementing direct reclamation were that there could be a rise in disease if the water quality was bad (*n* = 111, 48.05%), while the costs to implement (*n* = 48, 20.78%) was less of a factor. This was followed by a feeling that people might not want to use the water (*n* = 42, 18.18%), and respondents who believed that there would not be any problem with implementing direct reuse (*n* = 30, 12.99%).

Support for Indirect Potable or Non-Potable Reuse (Path 8 a & b). The support for indirect potable and non-potable reuse was lower (*n* = 192, 29.05%), than direct reuse. Support for indirect potable reuse – where there is no natural buffer, and the water could be used for domestic- (including drinking), industrial- and agricultural-use (*n* = 147, 22.24%) was higher than the support for indirect non-potable reuse – where there is a natural buffer, and the water could be used for domestic- (non-drinking), industrial- and agricultural-use (*n* = 45, 6.81%).

Respondents believed that water reclamation should only be indirect because:

1. Respondents did not think the government or municipalities could maintain the infrastructure (*n* = 63), which was 32.81% of the respondents within Path 8.

2. Respondents did not trust the government or municipalities to maintain the water quality (n = 53, 27.60%).
3. Respondents were worried that drinking reclaimed water could have health risks (n = 39, 20.31%).
4. Respondents were worried that the costs would be too high to treat water to a drinkable standard (n = 11, 5.73%).
5. Respondents indicated that the thought of drinking reclaimed water was disgusting (n = 7, 3.65%).
6. Respondents indicated that it was against their religion to drink reclaimed wastewater (n = 4, 2.08%). Three of the respondents indicated their religious affiliation as Christian, while one indicated their religious affiliation as an Atheist.

The respondents' perceived challenge or associated risk of using reclaimed water for potable use were: A possible rise in disease if the water quality is bad (n = 112, 58.33%), followed by those that believed costs would be high and the water would become unaffordable (n = 43, 22.40%), then by those that indicated that consumers might not want to use the water (n = 29, 15.10%). Only eight (n = 8, 4.17%) of the respondents indicated that they do not think that there would be any problem with implementing reclaimed water reuse for potable use.

Support for Additional Piping (Path 9). Fewer respondents (n = 121, 18.31%) who chose the '*Yes'* pathway indicated that additional piping should be run to homes for reclaimed wastewater so that consumers could decide what they wanted to use the water for. A majority of respondents from this path (n = 50, 41.32%) indicated that they did not trust the government or municipalities to maintain the level of the water quality, and that separate pipes would ensure the water was not contaminated, while fewer respondents (n = 36, 29.75%) indicated that drinking reclaimed wastewater could have health risks, and fewer still (n = 26, 21.48%) were hesitant to trust the government or municipalities to maintain the infrastructure. Disgust at the thought of using reclaimed water (*n* = 6, 4.96%) and trust in the scientists to maintain the water quality (*n* = 3, 2.48%) had few responses.

No Support for Direct- or Indirect Reuse (Path 10). Very few respondents (*n* = 24, 3.63%) indicated that if reclaimed wastewater were the only viable option for South Africa's water crisis that they would still not support its use. The reasons for respondents' strong opposition to the use of reclaimed water include:

1. Respondents indicated that they did not know enough about wastewater reclamation (*n* = 7, 29.17%).
2. Respondents did not trust the government or the municipalities' ability to manage the infrastructure or water quality (*n* = 6, 25%).
3. Respondents indicated that they believed the government/municipalities did not know enough about the technology required to safely implement wastewater reclamation (*n* = 5, 20.83%).
4. Very few respondents thought it was disgusting (*n* = 2, 8.33%).
5. The least selected options were: doubting scientists' knowledge on the technology required for wastewater reclamation (*n* = 1, 4.17%), and the possible cost implications (*n* = 1, 4.17%).
6. None of the respondents indicated that using wastewater was against their religion, that water is abundant in the world and municipalities should continue to do things the way they have always done, or that awareness campaigns may change their opinion.

These respondents future anticipated problems with South Africa's water supply were: South Africa could run out of water in the future (*n* = 13, 54.17%), while fewer respondents (*n* = 5, 20.83%) indicated that they realised water rationing could happen, and fewer still (*n* = 4, 16.67%) acknowledged that higher demand for a limited resource would make municipal water more expensive. Two (*n* = 2, 8.33%) respondents indicated that they did not foresee any future problems with South Africa's water supply.

Support for Other Alternatives (Path 11). Some respondents indicated that they believed that there were better alternatives than wastewater reclamation for South Africa's looming water crisis (*n* = 93, 14.07%). Their preferred alternatives included: Storm or rainwater harvesting (*n* = 48, 51.61%), water restrictions (*n* = 24, 25.81%) and desalination plants (*n* = 21, 22.34%). Respondents indicated the most likely reason for their first choice was that they trusted the cleaning or purification process more than the cleaning or purification process of water reclamation (*n* = 26, 27.96%), or that they thought their suggested alternative was a cheaper alternative than water reclamation (*n* = 24, 25.81%).

The respondents thought or believed the dominant reason for other consumers being against using water from wastewater reclamation plants included: perceived health risks (*n* = 40, 40.10%), that others might think that it is disgusting to use reclaimed water (*n* = 13, 13.83), or that other consumers might be more worried about the costs (*n* = 12, 12.93%).

4.4.Research Questions 3 and 4

Can attitudes toward alternative sources of water be changed through information provision to consumers; are there differences in perceptions of reclaimed water, and changes to preferences among uninformed and informed respondents?

4.4.1. Changes in Attitudes Towards Alternative Sources of Water

Very few respondents (*n* = 21, 3.14%), from the total sample (*N* = 668) indicated that they were against exploring alternative water sources in South Africa. However, after receiving more information on the alternatives available, such as storm and rainwater harvesting, wastewater reclamation, desalination, and water restrictions, 14 of the 21 respondents who did not support the exploration of alternative water sources initially changed their responses and agreed that alternative water sources needed to be explored.

Furthermore, even amongst the 661 respondents who followed pathway seven to eleven, 87 (13.16%), did not initially consider the implementation of direct wastewater reclamation as a viable option for South Africa. Their reasons included:

1. Lack of trust the government or the municipalities' ability to manage the processes (including infrastructure) required to implement reclaimed water use (*n* = 32, 36.78%).
2. Limited knowledge about water reclamation to make informed decisions (*n* = 20, 22.99%).
3. Belief that technologies to safely treat reclaimed water to drinking water quality were still not available (*n* = 14, 14.09%).
4. Belief that the government/municipalities did not know enough about the technology required to safely implement the use of alternative water sources (*n* = 13, 14.94%).
5. Greater concern about other environmental issues such as deforestation or pollution because it was reported more in the news and/or spoken about by celebrities (*n* = 6, 6.90%).
6. One respondent believed that alternative sources of water such as direct water reclamation would be too expensive to implement (*n* = 1, 1.15%).
7. One respondent believed that scientists did not know enough about the technology required to safely implement the use of reclaimed water (*n* = 1, 1.15%).

However, when a hypothetical scenario of water scarcity in South Africa was proposed very few respondents (*n* = 24, 3.63%) did not support any form of direct or indirect reuse as was presented in section 4.3.2. Furthermore, a number of respondents (*n* = 318, 48.11%) indicated that should they visit an area that had introduced an alternative water source they did not endorse, they would put aside their reservation, because if it was safe to use by others then it should be safe for them too. Others indicated that they would be somewhat upset or discuss it with other people (*n* = 226, 34.19%), while some said they would call a Minister or someone high up in government to try and influence a change in the policy (*n* = 93, 14.07%), or try challenge the decision in court (*n* = 24, 3.63%).

4.4.2. Choice Comparison (Start of Survey vs. End of Survey)

All 661 respondents who followed paths seven to eleven had two opportunities to provide their most preferred water alternative – at the start of the decision pathway survey and at the end of the survey. The most preferred water alternative at the start and end of the survey was harvested storm water and rainwater, with increased support from 50.23% of the respondents to 54.01%. The second most preferred water alternative at the start of the survey was water from desalination plants (17.55%), while the second most preferred alternative at the end of the survey was water from reclamation plants, which had increased support from 15.89% to 19.97% of respondents. Table 8 summarises the ranking of respondents' (*n* = 661) most preferred choice at the start of the survey and their most preferred choice at the end of the survey.

When examining all possible combinations of preferred water alternatives at the start of the survey and the most preferred water alternative at the end of the survey, it was seen that the probability that a respondent would choose storm water and rainwater harvesting at the end of the survey increased by 3.78%, from 50.23% to 54.01%, similarly for a respondent choosing reclaimed wastewater, an increase was noted of 3.78% from 15.89% to 19.67%. The probability of a respondent choosing water from a desalination plant decreased by 5.45% from 17.55% to 12.10%, while that of water restrictions as a preferred choice decreased by 2.42% from 16.34% to 13.92%.

Table 8: *Frequency and Percentage of Preferred Alternative at the Start and end of the Survey (N = 661).*

	Frequency and Percentage at Start of Survey		**Ranking at Start of Survey**	**Frequency and Percentage at End of Survey**		**Ranking at End of Survey**
	n	**%**		***n***	**%**	
Harvested storm water & rainwater	332	50.23	1st	357	54.01	1st
Desalination plants	116	17.55	2nd	80	12.10	4th
Water restrictions	108	16.34	3rd	92	13.92	3rd
Reclaimed wastewater	105	15.89	4th	132	19.97	2nd

A chi-square test was used to examine the differences between respondents' most preferred water alternative at the start of the survey and the most preferred water alternative at the end of the survey. In the sample of 661 respondents, there was a significant association between respondents' preferred water alternative at the start of the survey and the end of the survey, χ^2 (9, n = 661) = 145.17, $p < .001$. A post hoc comparison, using the Bonferroni adjusted alpha level, a_{Bon} = .00313 per test (.05/16) with a corresponding critical value of $N(0,1)_{1\text{-}a\text{Bon}/2}$ = 2.96, was done. Having corrected the critical value, six of the cells had Pearson residuals significantly different than expected under the null hypothesis of no association (z = -2.96, $p <$ .003, two-tailed). More specifically the cells with: A preference for harvested storm water and rainwater at the start and end of the survey; preferring harvested storm water and rainwater at the start of the survey and desalination plants as the preferred alternative at the end of the survey; harvested storm water and rainwater at the start of the survey and water restrictions as the preferred alternative at the end of the survey; desalination plants at the start of the survey and harvested storm water and rainwater as the preferred alternative at the end of the survey; desalination plants at the start and the end of the survey; and water restrictions at the start and end of the survey. Table 9 provides the cross-tabulation of preferred alternative at the start and end of the survey.

Table 9: *Cross-tabulation of Preferred Alternative at Start of Survey by Preferred Alternative at End of Survey.*

Preferred Alternative at Start of Survey		Preferred Alternative at End of Survey: Harvested stormwater- and rainwater	Reclaimed wastewater	Desalination plants	Water restrictions	**Total**
Harvested stormwater – and rainwater	Count	228	56	21	27	**332**
	Expected Count	179.3	66.3	40.2	46.2	
	% within First choice at Start	68.67%	16.87%	6.33%	8.13%	
	Adjusted Residual	7.59981*	-2.00419	-4.57494*	-4.31709*	
	Bonferonni Correction (*p* of 0.05/16 = 0.00313)	0.00000*	0.04550	0.00000*	0.00002*	
Reclaimed wastewater	Count	48	32	6	19	**105**
	Expected Count	56.7	21	12.7	14.6	
	% within First choice at Start	45.71%	30.48%	5.71%	18.10%	
	Adjusted Residual	-1.85949	2.93630	-2.18842	1.34824	
	Bonferonni Correction (*p* of 0.05/16 = 0.00313)	0.05743	0.00373	0.02781	0.19360	
Desalination plants	Count	35	26	43	12	**116**
	Expected Count	62.7	23.2	14.0	16.1	
	% within First choice at Start	30.17%	22.41%	37.07%	10.34%	
	Adjusted Residual	-5.67293*	0.72515	9.07926*	-1.22454	
	Bonferonni Correction (*p* of 0.05/16 = 0.00313)	0.00000*	0.48393	0.00000*	0.23014	
Water restrictions	Count	46	18	10	34	**108**
	Expected Count	58.3	21.6	13.1	15	
	% within First choice at Start	42.59%	16.67%	9.26%	31.48%	
	Adjusted Residual	-2.60263	-0.93876	-0.99058	5.76507*	
	Bonferonni Correction (*p* of 0.05/16 = 0.00313)	0.00932	0.36812	0.31731	0.00000*	
Total		**357**	**132**	**80**	**92**	**661**

Note. Significant values are indicate with an asteriks (*) at $a = 0.00313$ and z-critical value = -2.95517 (two-tailed).

From the cross-table it was evident that: (1) a significant number of respondents who chose storm water and rainwater harvesting at the start of the survey also chose it as their preferred alternative at the end of the survey ($n = 228$), (2) significantly fewer respondents than expected who chose storm water and rainwater harvesting at the start of the survey changed their support to water from desalination plants, or (3) to prefer the implementation of water restrictions, (4) significantly fewer respondents than expected who chose water from desalination plants at the start of the survey changed to support for storm water and rainwater harvesting, (5) a significant number of respondents who chose water from desalination plants at the start of the survey also chose it as their preferred alternative at the end of the survey, (6) a significant number of respondents who chose water restrictions as their preferred alternative at the start also chose it at the end of the survey.

4.5. Additional Findings

4.5.1. Understanding: Municipal Water Treatment Technologies, and Water Terminology

The sample of respondents who followed paths seven to 11 (n = 661) self-reported their level of understanding of their municipal water treatment technologies. The frequencies are listed as: no understanding (n = 190), some understanding (n = 318), knowledgeable (n = 122), or very knowledgeable (n = 31). While respondents who followed paths one to six (n = 7) self-reported their level of understanding of their municipal water technologies as: no understanding (n = 1), some understanding (n = 3), knowledgeable (n = 2), and very knowledgeable (n = 1). The seven general knowledge water term's results, that was tested before starting with the decision pathway survey section are summarised in Table 10. Most respondents knew what the terms *greywater* and *blackwater* meant, with fewer knowing the meaning of the other terms, with the least number of respondents knowing the meaning of *alternative water sources.*

Additionally, from the total sample (M = 3.84, SD = 2.03), only 68 (10.18%) of the respondents had all seven terms' meaning correct, 98 (14.67%) had six correct, 100 respondents (14.97%) scored five of the seven correct, 128 (19.16%) had four correct, 92 (13.77%) had three out of seven, 82 (12.28%) had two correct, 50 (7.48%) had only one correct, and 50 (7.48%) had none of the terms correct. The 68 respondents who had all seven term's meaning correct indicated their support for alternative water sources at the start of the survey as: support for harvested storm water and rainwater (n = 43); support for stricter water restrictions (n = 10); water from desalination plants (n = 8); and support for reclaimed wastewater (n = 7). However, at the end of the survey these respondents' most preferred alternatives were harvested storm water and rainwater (n = 28); support for reclaimed wastewater (n = 28); support for water from desalination plants (n = 7); and stricter water restrictions (n = 5).

Table 10: *Responses to Water Terminology.*

Question/Terminology	Options		*n*	%
The term 'wastewater' means	a)	Water that is safe to drink	47	7.04
	b)	**Used water from homes, businesses, or industrial activities ***	423	63.32
	c)	Water that is of potable standard	48	7.19
	d)	Water in municipal reservoirs	71	10.63
	e)	I do not know	79	11.83
The term 'greywater' means	a)	Water that is clean	33	4.94
	b)	**Water from baths, showers, sinks, washing machines, and other kitchen appliances ***	453	67.81
	c)	Water from toilets that contain a mixture of urine, faeces, and flush water	55	8.23
	d)	I do not know	127	19.01
The term 'blackwater' means	a)	Water that is clean	15	2.25
	b)	Water from baths, showers, sinks, washing machines, and other kitchen appliances	54	8.08
	c)	**Water from toilets that contain a mixture of urine, faeces, and flush water ***	448	67.07
	d)	I do not know	151	22.60
The term 'potable water' means	a)	Water that is NOT safe to drink or is NOT safe for cooking	61	9.13
	b)	**Water that is safe to drink and can be used for cooking ***	312	46.70
	c)	Water directly from lakes, rivers, or the ocean	117	17.51
	d)	I do not know	178	26.64
The term 'non-potable' means	**a)**	**Water that is NOT safe to drink or is NOT safe for cooking ***	362	54.19
	b)	Water that is safe to drink and can be used for cooking	40	5.98
	c)	Wastewater that is treated to drinkable quality	49	7.33
	d)	I do not know	217	32.48
The term 'reclaimed water' means	a)	Untreated wastewater	48	7.18
	b)	**Treated wastewater (black & greywater) ***	322	48.20
	c)	Treated greywater	101	15.11
	d)	Treated blackwater	14	2.09
	e)	I do not know	183	27.39

Question/Terminology		Options	*n*	%
The term 'alternative water sources' means	a)	Water from desalination plants	40	5.98
	b)	Harvested rainwater	122	18.26
	c)	Reclaimed wastewater	30	4.49
	d)	**All of the above ***	246	36.82
	e)	Only options a and b	130	19.46
	f)	I do not know	100	14.97

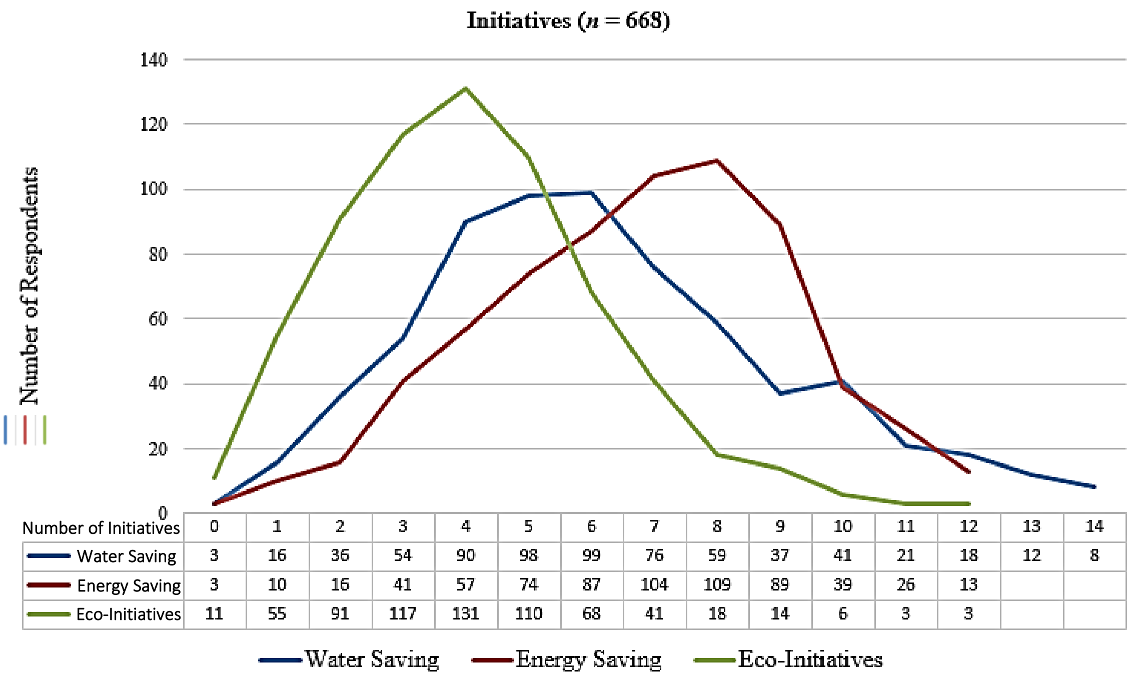
Note. * The correct answer to each question is in bold.

4.5.2. Concern for Availability of Water in South Africa

The first question in the decision pathway section requested respondents to indicate their level of concern for water availability in South Africa, now and for the near future, within 10 to 20 years. Four options were provided to choose from. Most of the respondents from the sample (N = 668) indicated that they were very concerned (n = 320, 47.90%), while fewer indicated that they were concerned (n = 186, 27.84%), somewhat concerned (n = 147, 22.01%), or not concerned at all (n = 15, 2.25%).

4.5.3. Water-saving, Energy-saving, and Eco-friendly Initiatives Used

Within the survey, three separate questions asked respondents to indicate: (1) out of a list of 14 options, whether they actively saved or conserved water, (2) from a list of 12 options to choose the electricity-saving initiatives they practiced, and (3) from a list of 12 options whether they employed any of the provided eco-friendly practices. Within each question, respondents could have indicated that *None of these or other techniques are used* or could have provided an *Other* option in which they could have captured any initiative not on the list. The responses gathered from the *Other* option were re-coded accordingly. A graphic representation of the number of initiatives and the number of respondents per category is provided in Figure 9.



Number of Initiatives	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Water Saving	3	16	36	54	90	98	99	76	59	37	41	21	18	12	8
Energy Saving	3	10	16	41	57	74	87	104	109	89	39	26	13		
Eco-Initiatives	11	55	91	117	131	110	68	41	18	14	6	3	3		

Figure 9: *Comparison of the Number of Initiatives Respondents Employed (Water-Saving, Energy-Saving, and Eco-Initiatives).*

Note. The number of initiatives employed (from a total of 12 listed for Energy Saving and Eco-Initiatives, and a total of 14 listed as Water Saving initiatives) and the number of respondents per category are provided in the table in Figure 9, with the curves showing the distribution of the number of respondents.

Three (n = 3, 0.45%) respondents indicated that they did not employ any water-saving initiatives, while most respondents (n = 99, 14.82%) indicated that they employed at least six of the 14 water-saving initiatives (M = 6.22, SD = 2.89). Similarly, three (n = 3, 0.45%) respondents indicated that they did not employ any energy- or electricity-saving initiatives. These were not the same respondents who did not employ any water-saving initiatives. Most respondents (n = 109, 16.32%) indicated that they employed at least eight of the 12 energy- or electricity-saving initiatives (M = 6.76, SD = 2.44). Eleven respondents (n = 11, 1.65%) did not employ any of the eco-friendly initiatives, while many of the respondents (n = 131, 19.61%) indicated that they employed at least four of the 12 initiatives (M = 4.13, SD = 2.15).

The top five water-saving initiatives that were selected are listed as:

1. Turning off the water while brushing teeth (*n* = 574, 85.93%)
2. Checking taps and pipes for leaks (*n* = 547, 81.89%)
3. Checking toilets for leaks (*n* = 503, 75.30%)
4. Turning off the water while shaving (*n* = 409, 61.23%)
5. Using a broom and not a hosepipe to clean driveways and sidewalks (*n* = 374, 56%).

Just over half of the respondents 53.59% (*n* = 358) indicated that they flushed toilets if it was really needed, which leads to the conclusion that the rest flush after each use.

The top five energy- or electricity-saving initiatives are listed as:

1. Switching off lights when you leave the house (*n* = 621, 92.96%)
2. Switching off lights in rooms in the home which are not in use (*n* = 588, 88.02%)
3. Using energy-saving light bulbs (*n* = 527, 78.89%)
4. Boiling only as much water as is needed in a pot or kettle (*n* = 423, 63.32%)
5. Using warm clothing or blankets instead of an electric heater (*n* = 404, 60.48%)

The option that was selected the least number of times was whether a respondent used a solar water heater instead of an electric geyser (*n* = 87, 13.02%).

The top five eco-friendly initiatives that were chosen included:

1. Recycling plastic bags when going shopping (*n* = 453, 67.81%)
2. Drinking, tap or filtered water, not bottled water (*n* = 423, 63.32%)
3. Recycling plastic and/or glass (*n* = 365, 54.64%)
4. Having a vegetable garden (*n* = 291, 43.56%)
5. Recycling bathwater for use in the garden (*n* = 252, 37.72%)

When combining respondents who carpooled (*n* = 64) and those who used public transport (*n* = 236) it is the fourth highest selected initiative (*n* = 300, 44.91%).

There was a significant, moderate, and positive, relationship between the number of water-saving, energy-saving, and eco-friendly initiatives respondents practised and their level of concern around the future availability of water in South Africa, $r_s = .258$, 95% BCa CI [0.19, 0.331], $p < .001$. Thus, the more concerned a respondent was for the future water availability in South Africa, the more water-, energy-saving, and eco-friendly initiatives they practised.

4.5.4. Demographical Differences, Preferred Alternative and Pathways

Various demographical variables (age, sex, population group, province of usual residence, language, religion, education, and monthly income) were explored with chi-square analysis to explore whether they would be influential in a respondents' most preferred water alternative (storm water and rainwater harvesting, desalination, water reclamation, or water restrictions) and the selected pathway. Pathways one to six (not in support of exploring alternative water sources) were excluded from the analysis. Categories within demographic variables were collapsed to ensure the assumption for a chi-square analysis were met and that no more than 20% of the expected counts were less than five and all individual expected counts were one or greater (Starnes et al., 2010; Field, 2018).

Age. Respondents were grouped according to age: 18 and 30 (n = 251), 31 to 40 (n = 183), 41 to 50 (n = 122), and 51 years and older (n = 105). There was no significant association between respondents' age and preferred water alternative at the start of the survey, χ^2 (9, n = 661) = 11.03, p = .274, or between respondents' age and the respective pathways χ^2 (12, n = 661) = 13.29, p = .348. A summary is provided in Table 11.

Table 11: *Most Preferred Water Alternative within Age Group.*

	Harvested Stormwater and Rainwater		**Desalination Plants**		**Water Restrictions**		**Water Reclamation**		**Total within Age Group**
	n	%	*n*	%	*n*	%	*n*	%	
18 to 30 years	116	46.22	44	17.53	50	19.92	41	16.33	251
31 to 40 years	95	51.91	27	17.75	25	13.66	36	19.67	183
41 to 50 years	64	52.46	22	18.03	18	14.75	18	14.75	122
51 years and older	57	54.29	23	21.90	15	14.29	10	9.52	105
Total within Preferred Alternative	**332**		**116**		**108**		**105**		**661**

Sex. Two respondents who preferred not to provide their sex were excluded from the analysis, and only female (*n* = 381) and male (*n* = 278) responses were considered. There was no significant association between respondents' sex and their preferred water alternative at the start of the survey, χ^2 (3, *n* = 659) = .555, *p* = .907, or between respondents' sex and the respective pathways χ^2 (4, *n* = 659) = 7.84, *p* = .097. Table 12 provides a summary of the most preferred water alternative within sex each group.

Table 12: *Most Preferred Water Alternative within Sex Group.*

	Harvested Stormwater & Rainwater		**Desalination Plants**		**Water Restrictions**		**Water Reclamation**		**Total within Sex Group**
	n	%	*n*	%	*n*	%	*n*	%	
Female	190	49.87	65	17.06	65	17.06	61	16.01	381
Male	141	50.72	51	18.35	42	15.11	44	15.83	278
Prefer not to say	1	50.00	-	-	1	50.00	-	-	2
Total within Preferred Alternative	**332**		**116**		**108**		**105**		**661**

Population Group. Population group were collapsed into Black African (*n* = 326), White (*n* = 207), and an 'Other' group (*n* = 128). There was a significant association between population group and respondents' preferred water alternative at the start of the survey χ^2 (6, *n* = 661) = 25.49, *p* < .001. A post hoc comparison was done using the Bonferroni adjusted alpha level of .00417 per test (.05/12) and adjusted residuals. Results indicated that there were significant differences (*z* = -2.87, *p* < .004, two-tailed) for some population groups and the preferred water alternative. Significantly fewer Black African respondents chose desalination plants as their preferred alternative, while there were significantly more Black African respondents who chose reclaimed wastewater as an alternative. Significantly fewer White respondents than expected chose water reclamation as an alternative. There was no significant association between population group and the respective pathways χ^2 (8, n = 661) = 14.32, p = .074.

Table 13: *Most Preferred Water Alternative within Population Group.*

	Harvested Stormwater & Rainwater		Desalination Plants		Water Restrictions		Water Reclamation		Total within Population Group
	n	%	*n*	%	*n*	%	*n*	%	
Black African	155	47.55	43	13.19	62	19.02	66	20.25	326
White	121	58.45	42	20.29	25	12.08	19	9.18	207
Other									
Coloured	36	46.15	15	19.23	15	19.23	12	15.38	78
Indian or Asian	13	34.21	15	39.47	3	7.89	7	18.42	38
Mixed Race	3	75.00	-	-	1	25.00	-	-	4
Prefer not to say	4	50.00	1	12.50	2	25.00	1	12.50	8
Total within Preferred Alternative	**332**		**116**		**108**		**105**		**661**

Province of Usual Residence. Province of usual residence was collapsed into provinces with coastal access (n = 279), Western Cape, Northern Cape, Eastern Cape, and KwaZulu Natal, and inland provinces (n = 382), Free State, North West Province, Gauteng, Limpopo, and Mpumalanga. There was no significant association between province of usual residence and respondents' preferred water alternative at the start of the survey χ^2 (3, n = 661) = 7.16, p = .067, or province of usual residence and pathways χ^2 (4, n = 661) = 4.15, p = .386. Table 14 provides a summary of respondents most preferred alternative within each province.

Table 14: *Most Preferred Water Alternative within Provinces.*

	Harvested Stormwater and Rainwater		Desalination Plants		Water Restrictions		Water Reclamation		Total within Province
	n	%	*n*	%	*n*	%	*n*	%	
Coastal Access									
Western Cape	56	50.90	25	22.73	18	16.36	11	10.00	110
Northern Cape	8	53.33	2	13.33	4	26.67	1	6.67	15
Eastern Cape	31	57.41	7	12.96	8	14.81	8	14.81	54
KwaZulu Natal	49	49.00	22	22.00	13	13.00	16	16.00	100
Inland Provinces									
Free State	17	45.95	5	13.51	8	21.62	7	18.92	37
North West Province	16	48.48	4	12.12	9	27.27	4	12.12	33
Gauteng	129	51.60	37	14.80	39	15.60	45	18.00	250
Limpopo	11	33.33	7	21.21	6	18.18	9	27.27	33
Mpumalanga	15	51.72	7	24.14	3	10.34	4	13.79	29
Total within Preferred Alternative	**332**		**116**		**108**		**105**		**661**

Language. Languages were collapsed into English (n = 276), Other (n = 192), Afrikaans (n = 114), and IsiZulu (n = 79). There was a significant association between language and respondents' preferred water alternative at the start of the survey, χ^2 (9, n = 661) = 22.76, p < .05. A post hoc comparison was done using the Bonferroni adjusted alpha level of .00313 per test (.05/16) and adjusted residuals. Results indicated that there was a significant difference (z = -2.96, p < .003, two-tailed). Significantly fewer respondents who speak English most at home chose water from desalination plants as their preferred alternative than expected. There was no significant association between language and pathway χ^2 (12, n = 661) = 16.75, p = .159. Table 15 provides a summary of respondents most preferred alternative within each group of most spoken languages.

Table 15: *Most Preferred Water Alternative within Most Spoken Language.*

	Harvested Stormwater & Rainwater		Desalination Plants		Water Restrictions		Water Reclamation		Total within Language
	n	%	*n*	%	*n*	%	*n*	%	
English	134	48.55	65	23.55	43	15.58	34	12.32	276
Afrikaans	69	60.53	16	14.04	14	12.28	15	13.16	114
IsiZulu	41	51.90	11	13.92	12	15.19	15	18.99	79
Other									
Greek	-	-	1	100	-	-	-	-	1
IsiNdebele	3	60.00	-	-	1	20.00	1	20.00	5
IsiXhosa	21	48.84	5	16.63	9	20.93	8	18.60	43
Sepedi	12	38.71	7	22.58	4	12.90	8	25.81	31
Sesotho	19	59.38	1	3.13	10	31.25	2	6.25	32
Setswana	10	26.32	6	15.79	10	26.32	12	31.58	38
Shona	3	100	-	-	-	-	-	-	3
SiSwati	3	33.33	1	11.11	1	11.11	4	44.44	9
Tshivenda	10	55.56	2	11.11	2	11.11	4	22.22	18
Xitsonga	7	58.33	1	8.33	2	16.67	2	16.67	12
Total within Preferred Alternative	**332**		**116**		**108**		**105**		**661**

Religion. Religion was collapsed into Christian (n = 492) and Other (n = 169). There was no significant association between religion and respondents' preferred water alternative at the start of the survey χ^2 (3, n = 661) = 3.96, p = .266, however, there was a significant association between religion and respondents' pathway χ^2 (4, n = 661) = 10.40, p < .05. A post hoc comparison was done using the Bonferroni adjusted alpha level of .005 per test (.05/10) and adjusted residuals. Results indicated that there were significant differences (z = -2.81, p < .005, two-tailed). Significantly fewer respondents, who indicated their religion as Christian, than expected chose pathway 11 (that there were better alternatives than water reclamation), while significantly more respondents from other religious groups chose path 11. Table 16 provides a summary of respondents most preferred alternative within each group of religions.

Table 16: *Most Preferred Water Alternative within Religion.*

	Harvested Stormwater & Rainwater		Desalination Plants		Water Restrictions		Water Reclamation		Total within Religion
	n	%	*n*	%	*n*	%	*n*	%	
Christian	254	51.63	78	15.85	81	16.46	79	16.06	492
Other									
No religious affiliation	23	56.10	6	14.63	6	14.63	6	14.63	41
Traditional African	12	32.43	8	21.62	6	16.22	11	29.73	37
Prefer not to say	14	53.85	4	15.38	6	23.08	2	7.69	26
Islamic	5	29.41	5	29.41	4	23.53	3	17.65	17
Atheist	10	62.50	2	12.50	3	18.75	1	6.25	16
Hindu	3	25.00	7	58.33	0		2	16.67	12
Agnostic	7	63.64	2	18.18	1	9.09	1	9.09	11
Jewish	3	50.00	2	33.33	1	16.67	-	-	6
Bahaism	-	-	1	100	-		-	-	1
Buddhist	-	-	1	100	-		-	-	1
Judaic Buddhist	1	100	-	-	-		-	-	1
Total within Preferred Alternative	**332**		**116**		**108**		**105**		**661**

Education. Education was collapsed into no schooling or Primary School completed (*n* = 36), some High School or High School completed (*n* = 192), Vocational education (*n* = 174), Bachelor's Degree completed (*n* = 166), and Post Graduate education (*n* = 93). There was no significant association between education level and respondents' preferred water alternative at the start of the survey χ^2 (12, *n* = 661) = 9.65, *p* = .647, or education and respondents' chosen pathway χ^2 (16, *n* = 661) = 14.68, *p* = .548. Table 17 provides a summary of respondents most preferred alternative within each education level.

Table 17: *Most Preferred Water Alternative within Education Level.*

	Harvested Stormwater & Rainwater		Desalination Plants		Water Restrictions		Water Reclamation		Total within Education Level
	n	%	*n*	%	*n*	%	*n*	%	
Primary School Completed	3	42.86	2	28.57	2	28.57	-		7
Some High School and High School Completed									
Some HS	18	62.07	4	13.79	5	17.24	2	6.90	29
HS Completed	95	49.48	34	17.70	30	15.63	33	17.19	192
Vocational Education	94	54.02	27	15.52	26	14.94	27	15.52	174
Bachelor's Degree	77	46.39	29	17.47	27	16.27	33	19.88	166
Post Graduate Education									
Honours degree	24	44.44	12	22.22	12	22.22	6	11.11	54
Master's degree	18	60.00	4	13.33	4	13.33	4	13.33	30
Doctoral degree	3	33.33	4	44.44	2	22.22	-		9
Total within Preferred Alternative	**332**		**116**		**108**		**105**		**661**

Income. Monthly income was collapsed into several groups: monthly combined incomes of R0 to R6,400 (n = 100), R6,401 to R12,800 (n = 123), R12,801 to R25,600 (n = 152), R25,601 and more (n = 254), and those who preferred not to provide their monthly income (n = 32). There was no significant association between respondents' monthly income and respondents' preferred water alternative at the start of the survey, χ^2 (12, n = 661) = 16.36, p = .175, or between monthly income and their chosen pathway χ^2 (16, n = 661) = 15.05, p = .521. Table 18 provides a summary of respondents most preferred alternative within each combined monthly household income group.

Table 18: *Most Preferred Water Alternative within Income Group.*

	Harvested Stormwater & Rainwater		Desalination Plants		Water Restrictions		Water Reclamation		Total within Income Group
	n	%	*n*	%	*n*	%	*n*	%	
R0 to R6 400									
No income	4	33.33	5	41.67	1	8.33	2	16.67	12
R1 – R400	3	50.00	-	-	2	33.33	1	16.67	6
R401 – R800	-	-	-	-	1	50.00	1	50.00	2
R801 – R1 600	2	25.00	1	12.50	1	12.50	4	50.00	8
R1 601 – R3 200	25	71.43	2	5.71	6	17.14	2	5.71	35
R3 201 – R6 400	13	35.14	4	10.81	9	24.32	11	29.73	37
R6 401 to R12 800	61	49.59	19	15.45	23	18.70	20	16.26	123
R12 801 to R25 600	75	49.34	26	17.11	19	12.50	32	21.05	152
R25 601 and more									
R25 601 – R51 200	88	53.01	33	19.88	27	16.27	18	10.84	166
R51 201 – R102 400	30	47.62	15	23.81	10	15.87	8	12.70	63
R102 401 – R204 800	7	50.00	4	28.57	2	14.29	1	7.14	14
R204 801 or more	5	45.45	1	9.09	4	36.36	1	9.09	11
Prefer not to say	19	59.38	6	18.75	3	9.38	4	12.50	32
Total within Preferred Alternative	**332**		**116**		**108**		**105**		**661**

4.6. Summary

From the analyses in this chapter it can be shown that: (a) South African respondents' most preferred alternative water source, in general and before having received any additional information on the topic, is harvested storm water and rainwater, while the other alternatives had only small differences in the number of supporters; (b) the reason cited most for supporting any of the alternatives was a belief that the water would be the cleanest and safest to drink; (c) most South African respondents were in support of South Africa exploring alternative water sources; and (d) under a situation of water scarcity a majority of South Africans would support direct potable reuse; (e) from the very few who were against the exploration of water reclamation did not trust the government or municipalities' ability to manage the processes required to implement reclaimed water use; (f) respondents' most preferred water alternatives did change from the start to the end of the survey; and (g) very few respondents knew the meaning of all seven water terms, however, the most well-known term was ‘greywater’, (h) for some respondents the level of associated affect between using reclaimed water was negative and information provision was not sufficient to increase their level of support for water reclamation. Lastly, there were some significant results between respondents’ population group and their most preferred water alternative, and between language, religion, and their most preferred alternative.

5. Discussion, Implications, and Conclusions

5.1. Introduction

The final chapter draws out the key conclusions from the various research phases and aims to critically address and integrate the results of the study and the theoretical foundations discussed in the literature review. The research, undertaken using a decision pathway survey, was able to provide insights stemming from respondents' opinions, and preferences that allowed the researcher to answer the main research questions. Although the survey investigated perceptions and attitudes toward different water alternatives, attitudes toward reclaimed wastewater are discussed in particular. The assumption that there is limited support for reclaimed wastewater is challenged and alternative explanations and ideas are discussed. Key strengths and contributions of the study are highlighted, limitations are addressed, and future avenues for research are suggested.

5.1.1. Setting the Scene

The global water crisis calls for global action to ensure water availability for ever-growing populations. This is even more true for South Africa which is classified as a semi-arid to arid country (Bontai et al., 2019), and where a portion of the population, an estimated 27% of households do not have access to running water (DWA, 2014). Superficial engagements between policy- and decision-makers and the general public, and a "decide, announce, and defend" approach to sensitive decisions or decisions with potentially immense impacts on communities have proven to be ineffective (Po et al., 2003). One such decision is the implementation of alternative water sources, and more specifically water reclamation. Other notable issues that could adversely influence the success of water reuse projects are consumers' perceptions of the effectiveness and cost of alternative methods and the quality of the water that is produced. This could include perceptions of the water's purity, associated health risks of using the water, the "yuck" or disgust factor, and their trust in actors including local and national governments and experts (Falkenmark et al., 2007; Po et al., 2003; Rozin et al., 2008; Swartz et al., 2015). These perceptions and resistance to support new technologies or processes could also be due to limited knowledge on the topic (Dolnicar & Hurlimann, 2009; Slabbert & Green, 2020).

Traditionally, questionnaires and surveys have been used to gather information from participants through a set of questions and answers. Surveys, therefore, acted as a type of standardised interviewing platform with little opportunity by researchers to probe or clarify understanding and only provided a snapshot of public opinion (Brace, 2004; Phellas et al., 2012). These surveys are often aimed at explaining respondents' attitudes by only considering their demographic background, and asking for their uninformed opinions (Gregory et al., 2016). In contrast, in this study, a survey was designed and used to determine a participant's perceived level of knowledge on a topic, their preferred alternatives, and a decision pathway section was used to understand their reasoning processes as they progressed through the survey (Gregory et al., 1997). Within the decision pathway, respondents received relevant information on alternative water sources, including reclaimed water. This allowed them to make more informed decisions as a slower and more deliberative decision-making process was activated (Gregory et al., 2016; Kahneman, 2011). Through the activation of a more deliberative decision-making process, or System 2 decision-making, and the simplification of decision strategies, respondents' pre-existing knowledge was explored, and incorrect knowledge and frames of references corrected (Nemeroff et al., 2020; Wang & Ruhe, 2007). Information produced from such a survey can provide valuable insights to policymakers for implementation and engagement strategies in selecting alternatives during water scarcity. Furthermore, when respondents choose one pathway and avoid others, insights into their underlying values are gained (Gregory et al., 1997). Throughout the study, the focus was on the four main research questions.

Research question one examined the most preferred alternative source of water in South Africa and respondents' most cited reason for supporting the alternative. This research question allowed for information on 'uninformed' respondents' preferences before information provision to be obtained.

Research question two provided insight into South African respondents' underlying values and trade-offs when faced with a scenario of severe water scarcity and their level of support for various alternatives and water quality, more specifically, direct- and indirect reclamation. The research question was answered through the use of a newly designed decision-pathway survey which relied on information provision to activate a more deliberated opinion.

Research questions three and four examined how respondents' attitudes toward alternative water sources changed as a result of information provided on the topic of water reclamation which was also aided by the use of the decision-pathway survey. Respondents' level of knowledge on water terminology was determined prior to starting the survey, and their preferences analysed at the start and end of the survey to determine whether the provision of information changed respondents' most preferred water source alternative.

5.2. Addressing the Research Questions and Drawing out Implications

5.2.1. Research Question 1

What are the most preferred alternative water sources in South Africa, and what is the predominant reason for supporting the water alternative?

Notable issues that have been found that could adversely influence the successful implementation of various water reuse projects are consumers' perceptions of the effectiveness and cost of the methods used to purify the water, the quality of the water produced, and their levels of perceived risk. A vast amount of energy is ordinarily required to treat the small percentage of fresh water available to get to acceptable drinking levels or to purify saline water, through a process of desalination (ACWA, 2017; Parks et al., 2019). As was discussed in the literature review section of this report, for the traditional treatment of raw water, an estimated 0.1 kW of energy per 3,800 litres (1,000 gallons) of water is required; this can range between 0.4 kW and 1.2 kW per 3,800 litres for purifying wastewater discharge and can be as high as 12 kW for a comparable amount of water from the desalination of seawater (Boulware, 2013; National Research Council, 2012). Energy-intensive processes would not be feasible in South Africa, or be sustainable, given the current constraints to the country's energy and water resources. Furthermore, even though the traditional treatment of raw water is the least energy-intensive, it may not be sustainable given the country's classification as a semi-arid to arid country. It is for these reasons that the overall costs for the various alternatives, as set out in the study by Cooley and Phurisamban (2016), need to be considered. Their study, which included the overall costs for some of the most popular water alternatives found storm water capture to be the least expensive, desalination the most expensive, and water reclamation costs to be in the middle. Despite water reclamation having quantifiably lower costs, the alternative is one of the least accepted methods of water reuse applications for communities (ATSE, 2013; Lautze et al., 2014; Leverenz et al., 2011).

Considering the most preferred alternative water sources in South Africa, the results were consistent with previous claims that water reclamation is not supported outright (Dolnicar & Hurlimann, 2009). In this study, most respondents supported harvested storm water and rainwater, followed by support for desalination, stricter water restrictions, and lastly support for reclaimed wastewater. This could point to a possibility that respondents did not take into account the various other factors involved in implementing rainwater harvesting, or the high costs of operating desalination plants. However, the most frequently cited reasons for respondents' support for a specific alternative were beliefs that the water would be the cleanest and safest to drink, or that the alternative would be the cheapest. Potential health risk concerns and costs were therefore taken into account to some extent.

It is, however, important to note that for the most preferred alternative, in this case, storm water and rainwater harvesting, to be sustainable, adequate rainfall is required. Within South Africa that may not be a reality in light of climate change forecasts. These options would therefore give respondents a false sense of water security. Respondents may also have been biased in choosing this alternative by focusing predominantly on its lower costs. Rainwater may also have been perceived as the most natural and eco-friendly alternative. Respondents, therefore, could have employed heuristics or biases such as were mentioned by Nemeroff et al. (2020) and simplified dichotomies, or in their preference for the most "natural" alternative had a skewed belief that anything natural would be safer and better than anything acted upon by humans (Etale et al., 2018). There is also a possibility that respondents were influenced by the order in which the alternatives were presented within the survey. Future research in which a decision-pathway survey is used could examine whether this is so.

Even though there was no significant relationship between respondents' province of usual residence and their preferred water alternative at the start of the survey it was interesting to note that within the Western Cape, support for desalination plants was lower (22.73%) than support for harvested storm- and rainwater (50.90%), even though the province has ample access to the ocean and desalination plants have already been made operational (Swartz et al., 2015). It was expected that due to the closely averted 'Day Zero' in recent years that respondents would have primarily been in support of desalination plants as this was a widely discussed option during that crisis. In KwaZulu Natal and Mpumalanga, support for desalination plants was the second most preferred alternative.

Within the Northern Cape, Free State, and the North West Provinces the most preferred alternative, after harvested storm- and rainwater, was support for stricter water restrictions. With limited to no access to the ocean, residents of these provinces are more reliant on rainfall to ensure a sufficient water supply. Not having had prior exposure to water from desalination plants may have influenced their preferences. In Gauteng and the Limpopo provinces, water reclamation was also the second most preferred alternative after harvested storm- and rainwater harvesting. The Eastern Cape's most preferred alternative, after storm- and rainwater harvesting, were both the implementation of water restrictions and water from water reclamation plants. This could be as a result of being more familiar with water reclamation and the use of treated sewage effluent by small and large industries who serve as employers, that include paper mills, or also due to the success of the neighbouring province's Beaufort West Water Reclamation Plant. The possibility, therefore, exists that the implementation of water reclamation projects may be accepted more readily within different provinces especially during periods of prolonged drought or water scarcity. Similarly, within provinces that rely predominantly on rainfall for agriculture, the sector with the biggest withdrawal of potable water (61%) (DWA, 2014; Department of Water and Sanitation, 2018).

There was a significant association between the population group (Black African, White, and Other) and respondents' preferred water alternative at the start of the survey. From the statistical analysis, significantly more Black African respondents chose reclaimed wastewater as a second preferred alternative, while fewer Black African respondents chose desalination plants as the second most preferred alternative. Even though not significant, this is in contrast to the White and Other respondents' second highest preference which was desalination plants. This could point to a difference between the respective respondents' understanding of the cost implications to implement the various alternatives. Also, significantly fewer White respondents than expected, from the analysis, chose water reclamation as a preferred alternative. These findings would, however, have to be verified in future research. Likewise, when considering language (English, IsiZulu, Afrikaans, and Other), there was a significant association between language and respondents' preferred water alternative at the start of the survey. Significantly fewer respondents than expected, who speak English most at home, chose water from desalination plants as their preferred alternative. However, for future research it might be beneficial to ensure the survey is available in all the official languages within South Africa as this would allow the researcher to draw more definite conclusions of the various groups. All age groups' most preferred alternative was harvested stormwater and rainwater, however, through a closer inspection of the groupings it was interesting to note that there was not a big difference between respondents preferred second, third, and fourth alternatives. Respondents aged between 18 and 20 years, most preferred harvested storm and rainwater (46.22%), however, their second-highest preference was to implement water restrictions (19.92%). This was a similar trend for those aged between 41 and older. However, for respondents aged between 31 and 40 years, harvested stormwater and rainwater (51.91%) was still the most preferred, nevertheless, their second-highest preference was water reclamation (19.67%). The demographic identifiers presented in the results section further provide insight into the possible differences in support for various alternatives.

From the results, respondents' most preferred water alternative across most demographics was harvested storm- and rainwater. In addition, their support stemmed from either the belief that the water would be the cleanest and safest to drink, or that it would be the cheapest alternative. These findings are consistent with previous studies. This could mean that for water reclamation plants to be successful, provision of information on the technology, quality, costs, policy implications, and the viability of the various alternatives available is as important (Glick et al., 2019). Furthermore, respondents gave their preferred alternative before and after a hypothetical scenario of severe water scarcity, yet, their most preferred alternative at the end of the survey was still harvested stormwater and rainwater, which could point to a further lack of understanding that severe drought would mean limited rainfall which is key to the viability of the preferred alternative. However, other affect-driven underlying factors as well as cultural views may also be responsible for this result and drivers of rejection (Etale et al., 2020).

The most preferred alternative at the end of the survey in comparison to the most preferred alternative at the start of the survey will be discussed in full as part of research questions three and four.

5.2.2. Research Question 2

What are the decision pathways around support for alternative water sources and reclaimed-water acceptance in a South African context?

Other than cost and energy implications, one of the most significant hurdles to overcome, not just in South Africa but globally when considering alternative sources of water, is the public's perception and acceptance of the water produced (Dolnicar & Schäfer, 2009; Etale et al., 2018; Fielding et al., 2019). The public's perceptions and acceptance of reclaimed water are of psychological concern and could mean the success or failure of such projects (Po et al., 2003). People can generally conclude that our current water use is unsustainable and know that technologies are available to secure water from alternative sources for the future; nevertheless, they are hesitant to support such projects if it means they would have to personally use the water (Po et al., 2003). The various factors that could influence the behavioural acceptability of reuse schemes include a disgust or "yuck" factor, consumers' perception of risk, their trust in the government to maintain the infrastructure, their knowledge on the topic, and their attitudes toward the environment (Po et al., 2003; du Pisani, 2006; Levin, 2019).

From the total sample of South African respondents most were very concerned (47.90%), less were concerned (27.84%), with the least number of respondents being only somewhat concerned (22.01%) for the future water availability in South Africa. Similarly, most of the respondents supported the exploration of alternative water sources (98.95%). This could point to South Africans understanding that our current level of consumption is unsustainable.

However, a clear distinction should be made between support for, the intent to use, and the actual use of water from alternative sources. Supporting alternative water sources does not necessarily translate to behavioural changes in the preservation or the actual use of water produced from alternative sources.

When energy consumption exceeded energy supply in South Africa, load shedding was introduced, and all consumers were urged to use electricity sparingly, and have in sorts adapted to the ‘new’ norm of having intermittent electricity supply. Similarly, during Cape Town’s water shortage, water rationing, and water restrictions were introduced to reduce the use of a limited supply of water. Consumers nationally, during that time, also received requests from the government to reduce water usage by implementing further water-saving initiatives. However, unlike electricity, water can be stored in buckets or containers, limiting the effectiveness of water rationing. A study of the effectiveness of water restrictions in Norfolk County, Massachusetts, found that consumers used more water on days which did not have water restrictions, possibly in anticipation for the days which did have restrictions; thus, this strategy was largely ineffective (Robinson & Conley, 2017).

Water-saving initiatives can reduce the burden on the supply chain if implemented very strictly and in addition to ensuring municipal pipes are not leaking and wasting water. Nevertheless, they do not mitigate the imminent threat of taps running dry. However, when considering the average number of water-, energy-saving, and other eco-friendly initiatives employed by respondents, more energy-saving initiatives were employed, on average, by a larger number of respondents than water-saving, or eco-friendly initiatives (on average a majority of respondents employed eight energy-saving initiatives, six water-saving initiatives, and four other eco-friendly initiatives). This could point to a better understanding by South African respondents of the countries’ dire energy-crises, and more specifically, to them having experienced some form of energy rationing due to rolling load-shedding to reduce the strain on the grid, however, less of an understanding of the severity of the water crisis. Given that there was a significant, moderate, and positive relationship between the number of water-saving, energy-saving, and eco-friendly initiatives respondents practiced and their level of concern for the future availability of water in South Africa, the more dire the water crisis becomes the higher their levels of concern would be, which could result in a forced increase in support for water alternatives.

It could be argued that should South African consumers experience water rationing or water restrictions to the same extent to which they are experiencing energy-rationing their overall perceptions would change to alleviate their level of discomfort of not having access to water. Thus, they might re-consider their perceived potential risks and re-evaluate the utility gained from having uninterrupted access to water, which could in turn lead to a positive affect and a potential increase in overall support for reclaimed water (Etale et al., 2020). It is also pertinent to mention that the country's current energy crises have received extensive exposure and media coverage, which could be seen as an indirect form of education and information sharing. In addition to introducing water-saving technology or initiatives, it is equally necessary to change consumers' level of knowledge, behaviour, habits, and attitudes to ensure the success of water-saving initiatives. A study by Moore et al. (1994) found that, to a large extent, media interventions relating to water-saving were perceived as highly influential in a change toward conservation, while in contrast Keramitsoglou and Tsagarakis (2011) found that awareness by itself does not necessarily lead to attitude change, especially when a person lacks a basic understanding of a problem. It can therefore be deduced that relevant knowledge, and not just awareness, is one of the most crucial elements to changing habits or behaviour.

Having provided respondents in the study with the most basic information on the topic of water alternatives and water reclamation a better reflection of their true level of support and the possible future success of water projects was gained. Very few respondents (1.05%) were against the exploration of alternative water sources, while 87 (13.16%) of the respondents did not agree that implementing direct wastewater reclamation could help to ensure a sustainable water supply for South Africa in future, and only 117 (17.70%) were against supporting any form of water reclamation or preferred other water alternatives during a hypothetical scenario of severe water scarcity. Overall, 544 (82.31%) respondents supported water reclamation to some extent (direct potable reuse = 26.62%; direct non-potable reuse = 8.32%; indirect potable reuse = 22.24%; indirect non-potable reuse = 6.81%; support for reuse with additional piping = 18.31%).

The support for direct and indirect potable reuse (48.86%) was similar to those from a study by Slabbert and Green (2020), with a sample size of 3,319 urban and rural South African respondents. During their study it was found that there was support for the treatment of wastewater to drinking water quality (potable quality) by 48.50% of their sample.

Similarly, this study's results are comparable to those from a nationwide study that was done in the USA by Rozin et al. (2015). It was found that 49% of American respondents (in a sample of 2,680 American subjects) supported the use of recycled water which was "certified safe recycled water", thus, direct or indirect reclaimed water of a potable standard. Fewer respondents, from the Rozin et al. (2015) study (38%), were uncertain, and 13% said they would not drink the water no matter the extent of the purification process. The respondents from their study who did not support and who refused to try recycled water, and some of the respondents who were uncertain of using recycled water, had higher levels of perceived disgust or "spiritual" contamination, which the researchers stated may reduce the effectiveness of strategies which include providing respondents with more details about the water purification process. In stark contradiction, the reasons most cited for not supporting either alternative water resources or direct water reclamation in this study was the level of trust in the government or the municipalities' ability to manage the processes, or a lack of knowledge to make an informed decision. South African consumers' increased levels of mistrust in the local authorities or the national government could be aggravated due to South Africa's increasingly turbulent political climate and also recent increased public awareness of corruption and failing infrastructure, and mismanagement of funds for public services. With regards to a lack of knowledge, this could ultimately stem from water alternatives and water reclamation not receiving as much media exposure as the energy crisis, or from a need to adapt and change the education system to have an increased focus on sustainability and future resource demand and supply.

Likewise, respondents who followed path eight and were only in support of indirect reuse of water of a potable or non-potable standard (29.05%) believed that the government or municipalities could not be trusted to maintain the infrastructure (32.81%) or water quality (27.60%), or that they could be exposed to health risks (20.31%). However, respondents who followed pathway seven and supported direct reuse and water of a potable or non-potable standard (34.90%) indicated that their support for direct reuse stemmed from their belief that the alternative would be cost-effective (45.45%), that they believed the government, municipalities or scientists had sufficient knowledge of the water purification process (22.51%), or that it would reduce the burden on the environment (13.42%).

The distinct differences between the level of respondents' support for various levels of reuse could be explained by considering their level of utility. For some, the associated costs outweighed the potential lower health risks associated with using reclaimed water, while for others the lack of trust in the government and the possible mismanagement of the process and a possible increase in disease was the strongest influencing factor. The concern for possible health risks was raised as a concern, however, it did not feature as a prominent reason for lack of support, thus, respondents understood that if the government and municipalities worked effectively and upheld the standard of the water produced then possible health risks could be reduced. It is still extremely important to note that a single incident of illness stemming from the inadequate management of water quality, and respondents' possible low levels of trust, could lead to a whole community rejecting the water from a plant (Swartz et al., 2015). This conclusion could be supported by the study by considering the results for respondents' most preferred water alternative and the reason for supporting it. The dominant reason for having chosen any of the alternatives was a belief that the water would be the cleanest and safest to drink, except for stricter water restrictions, which was chosen for the possible reduction in water wastage.

Overall, it was surprising to find that a majority of respondents were in support of direct potable reclamation in a scenario of severe drought conditions, this could point to some understanding of the water cycle, and that their previously stated first choice of harvested storm and rainwater would not be feasible. Thus, when driven by necessity they would support direct reclamation. What was not surprising was that most resistance stemmed from a lack of trust in the management of the infrastructure or water purification processes, which points to the fact that without increasing South African consumers' trust in the government or municipalities, or their level of knowledge on the topic of water alternatives and water reclamation, continuous resistance could be expected. What was evident from the Namibian Goreangab reclamation plant's success was the importance that was placed on the vigorous and extensive monitoring and testing of the water quality at every stage, but also the emphasis on "public acceptance and trust of consumers in the quality of this water" (du Pisani, 2006, p. 82). The community's trust in the process at that plant was maintained through continuous media communication and school-level education (du Pisani, 2006). Within South Africa increasing the public's trust in the government and the management of the water purification processes will not be easy, however, transparent, and open communication from authorities and continuous public engagement, communication, and education (i.e., information provision) could improve the acceptance and ultimate success of reclamation projects in the future.

5.2.3. Research Questions 3 and 4

Can attitudes toward alternative sources of water be changed through information provision to consumers; are there differences in perceptions of reclaimed water, and changes to preferences among uninformed and informed respondents?

A limited level of knowledge of the basics of hydrology and an unfamiliarity with the terminology used to describe alternative water sources have been shown to act as a barrier to consumers' support of more sustainable water sources (Dolnicar & Hurlimann, 2009; Slabbert & Green, 2020). For instance, Glick et al. (2019) conducted a study that focused predominantly on the USA and respondents' knowledge, or lack thereof, of water recycling technologies, and found that only one in four true-or-false questions about facts relating to recycled water were answered correctly. They found that relevant knowledge was the strongest predictor of support for drinking reclaimed water, and that a modest increase in public understanding of basic facts about water recycling technologies could translate into significant increases in public support for the technology.

From this study, most respondents reported that they had some understanding (48.05%) of their municipal water treatment technologies, while many had no understanding (28.59%), and fewer were knowledgeable (18.56%) or very knowledgeable (4.79%). In this study, respondents were seen as less informed at the start of the survey, and more informed at the end of the survey after having progressed through the sections and received various snippets of information about alternative waters. Furthermore, with regards to the general knowledge questions, 68 (10.18%) of respondents had all seven water terminologies correct, while 98 (14.67%) had six correct, 100 respondents (14.97%) scored five of the seven correct, 128 (19.16%) had four correct, 92 (13.77%) had three out of seven, 82 (12.28%) had two correct, 50 (7.48%) had only one correct, and 50 (7.48%) had none of the terms correct. Since the terminologies used were very basic terms and worded so that they were easy to understand and multiple-choice answers were provided to choose from, if a cut-off score of 50% were to be set, 394 (58.98%) of respondents would pass. This could be indicative of a relatively basic understanding of the terms used to describe water by most South Africans.

From the responses on the general knowledge question respondents were most familiar with the term greywater as 67.81% had the term correct. The second highest familiar term was blackwater (67.07%). The terms wastewater (63.32%), non-potable water (54.19%), reclaimed water (48.20%), potable water (46.70%), and alternative water sources (36.82%) were not as well-known, with fewer respondents having identified the definition correctly.

Within six of the seven questions the second-highest selected answer for each term was the "*I do not know"* option. Interestingly, within the question in which they had to define the term alternative water sources, many respondents knew what the term meant, however, many also indicated that it was only water from desalination plants and harvested rainwater (19.46%), while many also believed that it was only a term used to describe harvested rainwater (18.26%).

In total, 63.32% of respondents correctly identified the term wastewater as used water from homes, businesses, or industrial activities, while 11.83% indicated that they did not know. Furthermore, 67.81% of respondents correctly identified the term greywater as water from baths, showers, sinks, washing machines, and other kitchen appliances, while 19.01% indicated that they did not know the answer. This is in stark contrast to a study by Slabbert and Green (2020), in which only 35% of respondents correctly identified the term for wastewater from bathing, washing clothes and dishes as greywater, while 28.20% of respondents did not know the term for wastewater from bathing, washing clothes and dishes. The difference in the number of correct responses could be attributed to the way the question was presented, or that respondents in this study were not supervised and could have used alternative means to gather information to answer the questions. The recent period of water stress experienced by regions within South Africa could also have served as an opportunity during which respondents searched for specific information related to the water crisis and which influenced their level of knowledge and answers (Stankevich, 2017). In this study, the word's definition had to be identified from several definitions, while in Slabbert and Green's (2020) study the definition was provided and the name of the type of water had to be identified. It could, therefore, also be plausible that respondents identified the definition correctly in this study through a process of elimination.

Overall, compared to the earlier South African study by Slabbert and Green (2020), respondents in this study had somewhat a better understanding of some of the basic water terminologies. Nevertheless, respondents may not have had the same, or even a similar understanding of other factors relating to alternative water sources. Therefore, the inclusion of the snippets within the survey ensured respondents had the same information to base their responses on. However, their interpretation or understanding of the written text could not have been accounted for even though most respondents had at least completed high school.

From the sample of respondents who indicated that South Africa should not explore alternative water sources (i.e., 21 respondents), 14 respondents changed their answer that South Africa should explore alternative water sources after having received short definitions on the alternatives available, which stated: *Storm water and rainwater harvesting involves collecting and storing rain from run-off and building roofs in ponds or aquifers or in rainwater tanks; Reclaiming wastewater involves treating wastewater from industries, as well as residential and commercial buildings for potable (drinking) or non-potable (non-drinking) use; Desalination involves treating sea water to remove salt and minerals, to make it suitable for drinking or irrigation; Water restrictions involve limiting water usage.* Thus, by only bringing a more direct realisation into the respondents' frame of reference and stating that there were alternatives available there was a change in their decision-making processes as more information was included on which to base their decision. Seven of the respondents did not change their response from the non-support pathway, and from within the support pathway there were also some who, even under a scenario of severe water scarcity, said that they would not use reclaimed water. This could mean that for some individuals information provision may not be enough to convince them of the purity, or low safety risks of reclaimed water, but rather that other approaches may be required to illicit more of an affective response (Etale et al., 2018; Watson, 2017). As was found and stated by Etale et al. (2018, p. 144) “affective reactions often reflect learned responses to stimuli and a stimulus which evokes a positive affective reaction the first time, will evoke a similar reaction during subsequent exposures, and vice versa.” Therefore, should a respondent, who refused to use any type of reclaimed water or support any water alternative, actually be faced with severe water shortages and use reclaimed water once, and it alleviates their need and does not cause any adverse effects, their support might increase, and they may become more comfortable with using the water. This would then be as a result of the negative affect decreasing and the positive affect increasing and the reclaimed water may be seen as ‘just water’ (Etale et al., 2020). Their negative affect which may have been the result of early learning, or exposure to media or advertisements could therefore be diminished through physical exposure to the water, like with water from the Beaufort West plant (Marais & von Dürckheim, 2011), instead of just through information provision (Etale et al., 2020).

Although, respondents’ preference for harvested storm water and rainwater at the start and end of the survey were comparable (50.23% and 54.01%, respectively), their second most preferred alternative changed from water from desalination plants (17.55%) to reclaimed wastewater (19.97%) after information provision. It is also important to note that the information provided to the respondents was not meant to result in a change toward any specific water alternative but to provide information for decision-making. It would therefore seem that support for wastewater reclamation did increase, and that should harvested storm and rainwater harvesting not be possible, a good number of people could support water reclamation instead of water restrictions.

Ultimately, respondents did indicate that should they visit an area in South Africa that introduced an alternative they did not agree with they would either ignore it, because if it is safe to use by others then it should be safe to use by them (48.11%), they would be somewhat upset or discuss it with other people (34.19%), while fewer said they would call a Minister or someone high up in government to try and influence a change in the policy (14.07%), and even fewer said that they would challenge the decision in court (3.63%). Therefore, it would be natural to assume that should water reclamation or any other alternative be introduced into communities without any incidents related to health and safety a growing level of support could be possible.

5.3. Limitations of the Study, Suggestions for Future Research and Conclusion

5.3.1. Limitations

Limitations to any study concern "potential weaknesses that are usually out of the researcher's control" (Theofanidis & Fountouki, 2018). The study has potential limitations which should be considered. The terms "wastewater", "treated wastewater", and "reclaimed blackwater" were terms that formed the basis of part of the survey. There may have been individuals who were not familiar with the terms (Slabbert & Green, 2020). These terms were explained as part of the information snippets meant to educate the participants throughout the survey, however, English is only one of South Africa's official languages and translating the survey into the other official languages specific to a respondent's home language may provide different results.

The sampling method used relied on volunteers which could have resulted in the sample not being representative of the population. Firstly, respondents who received an invitation to complete the survey may have had an interest in future water technologies, or water sustainability and may have been more likely to complete the survey than those respondents who do not share similar interests. Additional questions could have been included to gauge a respondent's level of interest in the topic which in turn could have provided a better indication of the range of respondents' interest and could then have been accounted for. Furthermore, much of the previous research originates from Australia, the United Kingdom, and the United States of America and the results from this study is therefore not directly comparable. The experts' participation in the validation of the study was also voluntary. The age and education level, and the fact that their participation was required as part of a master's study could also be a limitation. The researcher could have been perceived to have lacked relevant experience or credibility and have led to lower levels of engagement, commitment on their part, or an overall lower response rate.

The survey was also administered online without direct supervision and relied on respondents' self-reports. Failing internet connectivity could have resulted in respondent drop-offs or incomplete responses that were removed from the analysis. Furthermore, without supervising respondents and with no specific time-limit or cut off time within which a respondent should have completed the survey there is the possibility that respondents used Google or other online search engines to get clarity on the terminology used within the survey.

Differences between self-report web-based and other forms of survey administration (e.g., by an interviewer, in person; telephonically; through paper and pencil) should also be noted (Brace, 2004). Web-based surveys are more effective in addressing sensitive issues, and skip-logic branching programming can more easily be used, the survey can also be adaptive to different devices used for completing the survey. However, a disadvantage of web-based surveys is that they could generate more 'I don't know' responses as respondents cannot clarify questions or options. Advantages of web-based surveys do include that a respondent's set of questions can be determined by their answer to a previous question and the survey is said to be adaptive and responsive as the layout also changes to suit the screen of the device on which it is viewed. This allows for the inclusion of many questions, however, a respondent is not required to answer or even read all the questions. Furthermore, a decision-pathway method of questioning encourages respondents to consider possible value conflicts, costs, and risks associated with their decisions (utility) and aims to produce more accurate responses (Gregory et al., 1997; Gregory, 1999). Furthermore, as per Dillman (2000), there are differences between pen and paper surveys and online surveys. With pen and paper surveys the respondent and designer of the survey view the survey in the same manner. With an online survey, respondents can access the survey through different operating systems, with different browsers, screen configurations and varying network connections. All attempts were made to ensure the survey was compatible with mobile devices as well as computers, however, this should still be listed as a possible limitation along with respondents' comfortability levels with using technology.

Due to the global COVID-19 pandemic, some individuals may have had a more negative perception of reclaimed water and associated perceived health risks of water reuse. Similarly, rainfall during the period during which the survey was administered could have resulted in respondents choosing rainwater or storm water harvesting as their most preferred alternative over other alternatives. It is therefore suggested that a longitudinal study be conducted, or that data be collected at various intervals during a set period such as a year, which could allow trends to be identified.

Possible arguments against using a decision pathway survey, using a quantitative approach, and future improvements on such studies also include: decision pathway approach does not allow for, or severely restricts, advanced statistical analysis of small cell sizes of ordinal data; a quantitative approach could constrain responses available to participants with the inclusion of multiple-choice options, this was however accounted for by also including an 'Other' option in most questions. Very few respondents left additional comments or chose the other option, but this does still point to the possible limitations of the questions or method.

Respondents were asked to complete a self-report survey looking at intent, and actual behaviour was not observed; thus, the analysis may be hypothetical. As was mentioned in the literature section of this report there are, or can be, differences between intent and actual or observed behaviour; the survey was administered to a single sample at a single point in time with no control group or random assignment, therefore, no conclusions can be drawn about actual behaviour or causality. Furthermore, previous experiences could be a confounding factor but would be difficult to determine as it would vary greatly between participants, therefore, respondents were considered to be uninformed at the start of the survey, and were required to complete some general knowledge questions, and seen as more informed at the end of the survey. A longitudinal study with randomly assigned respondents and actual observation of behaviour could allow for further experimental analysis. There also remains a possibility that the order in which the answers appeared in the multiple-choice questions could have resulted in recency bias, the randomisation of options in a future study could avoid this. The snippets of information could also have inadvertently influenced respondents' answers in a way that may have been different if they did not receive any information; the instrument was developed, and the data analysed by the researcher, whose personal beliefs and knowledge of the field of water and water reclamation, may have impaired the interpretation of the results. It was therefore imperative to have a good level of self-awareness of beliefs and biases.

5.3.2. Suggestions for Future Research

Given that the study was based on the self-reported opinions, at a single point in time, of a sample of South African consumers, future longitudinal research would be valuable. Similarly, experiments within which actual behaviour is observed, more specifically, respondents' willingness to drink water produced from various alternative water sources could provide a more in-depth understanding of the factors related to their levels of acceptance or resistance for the implementation of reclamation plants. Given that the South African context is unique with many differences between Western and Eastern countries, future researchers should further explore the dynamics within South Africa.

A replication of the current study with a larger sample, specifically within other provinces within South Africa, might provide different results. Studies comparing communities where water reclamation has already been introduced to those that have been exposed to water desalination, and others who have not been exposed to any alternative water source may also provide a better understanding of the drivers of acceptance and perceptions. Questions on respondents' understanding of global warming, the impact of CO_2 emissions and pollution on the planet and their community could also be included and further explored for links to their level of understanding and preferred water alternative.

5.3.3. Theoretical and Practical Implications

The results achieved in this study have both theoretical and practical implications. Theoretically the research has shown that South African consumers' level of knowledge on a topic could potentially have an influence on their decision-making processes and preferred water source alternatives. Through information provision a deeper understanding was gained into their though processes and trade-offs of what they perceive to be important factors to consider before the implementation of any alternative water projects. Furthermore, it showed that should individuals experience situations of severe water scarcity they might be more willing to support water reclamation and more specifically direct water reclamation. South Africa is faced with a water crisis and this study provided insight into consumers' concerns and perceived risks to supplement the existing international body of knowledge on water reclamation and alternative water sources.

Practically, respondents' most preferred water alternative, harvested storm- and rainwater, was chosen for its perceived lower risk and for a perceived lower cost to implement. However, in a country which is water scarce it would not be a sustainable alternative. Therefore, future research could more specifically focus on the differences between harvested storm- and rainwater and water reclamation and provide respondents with more specific information on the differences and similarities between the alternatives and the treatment processes. Furthermore, through improved engagement between the public and decision-makers, before the implementation of water projects and by using a decision-pathway survey and the provision of information to respondents, a truer reflection of respondents' opinions and concerns from which to base decisions on can be achieved. Future research would, however, be required to determine whether support for direct reclamation is different from actual behaviour, and whether individuals would in fact drink water produced from reclamation plants or other alternative sources. Furthermore, this study can aid future research in the field by laying the groundwork for further improvement of the decision-pathway instrument, and by assessing the study's limitations and recommendations.

5.3.4. Conclusion

This study set out to answer four main research questions which explored South Africans' understanding of some of the fundamental terms used to describe various forms of water and water quality, and their level of support for various alternative water sources. It also considered support for water reclamation under a scenario of water scarcity, and whether information provision could influence South Africans' preferred water alternatives. Despite the study's limitations, it did substantiate the existing research that there are various factors that influence the level of support for water reclamation, of which the most evident is the level of trust in the national and local governments, and municipalities' ability to maintain the water quality. It also considered that for some individuals information provision is not enough to reduce the negative affect associated with reclaimed water.

The most preferred water alternative amongst most South Africans was harvested storm- and rainwater, predominantly due to lower levels of perceived risk in using the water, which could be associated with higher affect, and its potential lower cost to implement. However, the lower level of perceived risk might be misplaced as South Africa is a country classified as semi-arid to arid for the most part. For the most preferred alternative to be viable, frequent rainfall is key to the alternative's success. Furthermore, under periods of severe drought and water scarcity South Africans would support direct water reclamation, however, a single incident related to health and safety could still mean the rejection of the water and the closure of the plant. To further increase support for the exploration and introduction of reclamation plants the engagement between the public and policy- and decision-makers could be improved by fully understanding underlying public concerns or perceived risks through the use of a decision-pathway survey. Moreover, the public's opinions could also be shaped, and perceived risks diminished through continuous open engagement and early information sharing as was evident from the successful operationalisation of the reclamation plants in Namibia and Beaufort West, South Africa.

By increasing the public's awareness and level of understanding and knowledge they may be in a better position to provide more informed opinions. Their opinions would ultimately be one of the determining factors that could influence alternative water projects in the future to bridge the supply and demand gap. However, for some, information provision was not sufficient to reduce negative affect associated with water produced from reclamation, even though it may be more viable and sustainable than the most preferred alternative. Therefore, some may need more 'practical' exposure or experiences, either they would have to experience severe water shortages, and not have any other alternative, or they would have to be exposed to using, smelling, and tasting the reclaimed water. Unfortunately, time is not on our side and this may mean that countries would have to adopt an 'adapt or die' approach to ensure future water availability for many of their citizens within growing populations.

This work has expanded on previous research around reclaimed water, more specifically within the South African context through a quantitative analysis. It has provided insight into people's decision-making processes when faced with decisions structured as part of a decision pathway survey, and the possible difficulties that the introduction of water alternatives, and more specifically water reclamation schemes, might face. This may provide future researchers and decision- and policy-makers with information to improve future engagement with the public in the aim of bridging the water supply and demand gap and ensuring future sustainability.

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Appendices

Appendix A

Introductory Email - Experts

Good afternoon Mr/Mrs/Miss/Dr/Prof,

I hope that you are doing well.

My name is Xavier Prins, and I am a master's student at the University of the Witwatersrand under supervision of Prof Andrew Thatcher and Dr Anita Etale. I found your details on [insert field], and on the [insert field] website and am hoping that you can be of assistance to me.

As part of my studies, I have to undertake a research project in which I will be investigating alternative sources of water and its potential to help alleviate water shortages in South Africa. We would like to explore factors around people's acceptance of alternative sources of water. I would like to invite you to comment and provide feedback on a newly designed survey or guide me in the direction of a knowledgeable person which you think might be able to assist.

As mentioned, if you agree to assist you will be invited to provide feedback on an online survey before it is distributed to a selected sample of urban and suburban dwellers in South Africa. The aim of the study is to examine the pre-existing knowledge and perceptions of alternative water sources amongst South Africans, with a specific focus on reclaimed wastewater through the use of a decision pathway survey. The specific survey design will allow for the exploration of different pathways participants follow when faced with novel ideas and complex decisions by utilising skip logic branching. It also aims to investigate whether a participants' initial answer, on whether alternative sources of water should or should not be explored in South Africa, changes as they progress through the survey and are provided with additional information on the topic.

Looking forward to hearing from you soon.

Kind regards
Xavier Prins

Appendix B
Participant Information Sheet – Expert

Good morning/afternoon [insert name],

Thank you for your willingness to assist, it is truly appreciated.

As mentioned, my name is Xavier Prins, and I am a master's student at the University of the Witwatersrand under supervision of Prof. Andrew Thatcher and Dr. Anita Etale.

As part of my studies, I must undertake a research project. I am investigating alternative sources of water and its potential to help alleviate water shortages in South Africa. We would like to explore factors around people's acceptance of alternative sources of water.

I would like to invite you to comment and provide feedback on a newly designed survey which I am hoping to send out during the first week of August. Before you decide to participate you need to understand why the research is being done and what it would involve of you. Please take time to read the following information carefully.

There will be no personal costs to you if you participate in this project. You will not receive any direct benefits from participation but there are no disadvantages or penalties if you do not choose to participate or if you withdraw from the study.

You have been approached as an expert on water and water-use and to provide feedback on the online survey before it is distributed to a selected sample of urban and suburban dwellers in South Africa. The aim of the study is to examine the pre-existing knowledge and perceptions of alternative water sources amongst South Africans, with a specific focus on reclaimed wastewater through the use of a decision pathway survey. The specific survey design will allow for the exploration of different pathways participants follow when faced with novel ideas and complex decisions by utilising skip logic branching. It also aims to investigate whether a participant's initial answer, on whether alternative sources of water should or should not be explored in South Africa, changes as they progress through the survey and are provided with additional information on the topic.

Your comments and feedback will be treated with the strictest confidence. All information will remain at the Global Change Institute at the University of the Witwatersrand, South Africa. The data and results will be used for research purposes only and possible secondary analysis by student industrial psychologists under supervision. The data will be stored in a secure location during analysis with access restricted to myself and my supervisors only. The results of the research will be made public in a summarised document and will be available on request from *AlternativeWaterStudy@gmail.com.*

If you have any questions during or afterwards about this research, feel free to contact us on the details listed below. This study will be written up in a research report and may be written up as journal articles or conference presentations. If you wish to receive a summary of this report, we will be happy to send it to you. If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email *Shaun.Schoeman@wits.ac.za*.

Thank you for taking part in my research.

Below is a link to the survey which is to act as an example only for your viewing: https://www.cognitoforms.com/UniversityOfTheWitwatersrand3/WouldYouDrinkItAnExploratoryStudy

- Please send your reply along with the following consent confirmation: **"I give my voluntary and informed consent."**

Points to Consider for the Survey:		
	Yes / No:	**Comments:**
Are instructions for completing the survey clear?		
Are questions easy to understand?		
Are the response choices mutually exclusive?		
Is privacy respected and protected?		
Are there any suggestions regarding the addition or deletion of questions, the clarification of instructions, or improvements in format?		
Is the language used understandable?		
Are the questions short and specific?		
Are any of the questions leading?		
Any comments on the survey's validity?		
Other comments:		

Yours sincerely,

Xavier Prins

Researcher:

Franciscus Xaverius Prins, *2245681@students.wits.ac.za*, +27(0) 73 126 2380

Supervisor:

Andrew Thatcher, *Andrew.Thatcher@wits.ac.za*, +27(0) 11 717 4533

Co-Supervisor:

Anita Etale, *Anita.Etale@wits.ac.za*, +27(0) 11 717 6081

Appendix C

Participant Information Sheet – Pilot Volunteers

Dear Participant,

You are invited, as part of a small group, to please help improve a newly designed survey before it is distributed to a larger audience. The survey focuses on alternative water sources and its use in South Africa.

It will take between 20 - 30 minutes of your time.

As you progress through the survey, please note down any suggested changes, concerns, comments, or questions you may have on a notepad. You will be given the opportunity to capture these at the end of the survey.

You are invited to *'play'* with the survey, and explore all the possible routes by making use of the *'Previous'* button. We do urge you to complete the survey until you have captured your comments, or suggested changes then to click on the *'Done'* button.

Things to look out for:

- Any instructions that are not clear
- The wording used in questions or answers that are unclear
- The time it took you to complete the survey
- Any technical 'bugs', error messages you received, or scripting errors
- Comments on the design and layout of the survey
- Your understanding of the questions
- The order of questions
- The appropriateness and completeness of responses
- The relevance of questions

Below you will find the introduction and informed consent request page which all participants should note. We ask that you carefully read this and that you also provide your informed consent before proceeding.

Thank you for taking the time to improve this survey.

Dear Sir/Madam,

My name is Xavier Prins and I am a Masters student at the University of the Witwatersrand, Johannesburg. As part of my studies, I have to undertake a research project, and I am investigating alternative sources of water and its potential to help alleviate water shortages in South Africa under supervision of Prof. Andrew Thatcher and co-supervised by Dr. Anita Etale.

Water scarcity is a global issue and one we will all face in the future. This study would like to explore and understand factors, such as your attitudes and ideas around the acceptance and use of alternative sources of water.

I would like to invite you to take part in a research study by completing a survey which will take 20 to 30 minutes of your time (to ensure your responses are captured please complete the survey until you reach the Thank you page and click on 'Done').

Before you decide to participate please take the time to read the following information carefully to understand what it would involve of you...

- Participation in the completion of the survey is completely voluntary and you can decide to withdraw your consent and participation at any point during the survey without any consequence whatsoever.
- Participation is anonymous and you will not be able to withdraw your consent once you have clicked on the final submit button.
- There will be no personal costs to you if you participate in this project.
- You will not receive any direct benefits from participation but there are no disadvantages or penalties if you do not choose to participate or if you withdraw from the study.

- You do not require any prior knowledge on the topic and completing the survey poses minimal risk to you.
- All information will remain at the Global Change Institute at the University of the Witwatersrand, Johannesburg, South Africa.
- The data and results will be used for research purposes only, and possible secondary analysis by student Industrial Psychologists under supervision.
- The data will be stored in a secure location during analysis with access restricted to myself and my supervisors only.
- The collection and statistical analysis will not provide any conclusions about any individual participant.
- All information will be treated confidentially and will not allow us to draw any conclusions about yourself as an individual.
- The results of the research will be made public in a summarised document and will also be available on request from *AlternativeWaterStudy@gmail.com.* If you wish to receive a summary of this report, we will be happy to send it to you. Please note that by requesting a copy of the document anonymity will be broken.

If you have any questions during or afterwards about this research, feel free to contact us on the details listed below. This study will be written up in a research report and may be written up as journal articles or conference presentations. If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email, *Shaun.Schoeman@wits.ac.za*

Thank you for considering taking part in my research.

Yours sincerely,
Xavier Prins

Researcher:
Francisus Xaverius Prins, *2245681@students.wits.ac.za*

Supervisor:
Andrew Thatcher, *Andrew.Thatcher@wits.ac.za*, +27(0) 11 717 4533

Co-Supervisor:

Anita Etale, *Anita.Etale@wits.ac.za*,

Appendix D

Participant Information Sheet – Volunteers

<u>Perceptions and Attitudes toward Reclaimed Water use in South Africa.</u>

Thank you in advance for your participation.

Water scarcity is a global issue and one we will all face in the future.

I invite you to take part in a research study by completing a survey which will **take about 20 minutes** in which we would like to explore your attitudes and ideas around alternative sources of water.

To ensure your responses are captured please complete the survey until you reach the **last page.**

Before you decide to participate please take the time to read the following information.

- **Participation in the completion of the survey is completely voluntary.**
- **Participation is anonymous.**
- **You will not be able to withdraw your consent once you have clicked on the final submit button.**
- There will be no personal costs to you.
- You will not receive any direct benefits from participation, but there are no disadvantages or penalties should you withdraw.
- **You do not require any prior knowledge on the topic** & completing the survey poses minimal risk to you.
- All information will remain at the Global Change Institute at the University of the Witwatersrand, South Africa.
- **The data and results will be used for research purposes only under supervision.**
- The data will be stored in a secure location during analysis with access restricted to myself and my supervisors only.

- The collection and statistical analysis will not provide any conclusions about any participant.
- **All information will be treated confidentially.**
- The results of the research will be made public in a summarised document and will also be available on request from *AlternativeWaterStudy@gmail.com.* If you wish to receive a summary of this report, we will be happy to send it to you. **Please note that by requesting a copy of the document anonymity will be broken.**

If you have any questions during or afterwards about this research, feel free to contact us on the details listed below. This study will be written up in a research report and may be written up as journal articles or conference presentations. If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email, *Shaun.Schoenan@wits.ac.za*

Yours sincerely,
Xavier Prins
Researcher:
Francíscus Xaverius Prins, *2245681@students.wits.ac.za*

Supervisor:
Andrew Thatcher, *Andrew.Thatcher@wits.ac.za,* +27(0) 11 717 4533

Co-Supervisor:
Anita Etale, *Anita.Etale@wits.ac.za,* +27(0) 11 717 6081

1. Choose one of the following options and click on ‘Next’ to proceed:
- I give my informed consent and wish to proceed to the survey
- I DO NOT give my informed consent

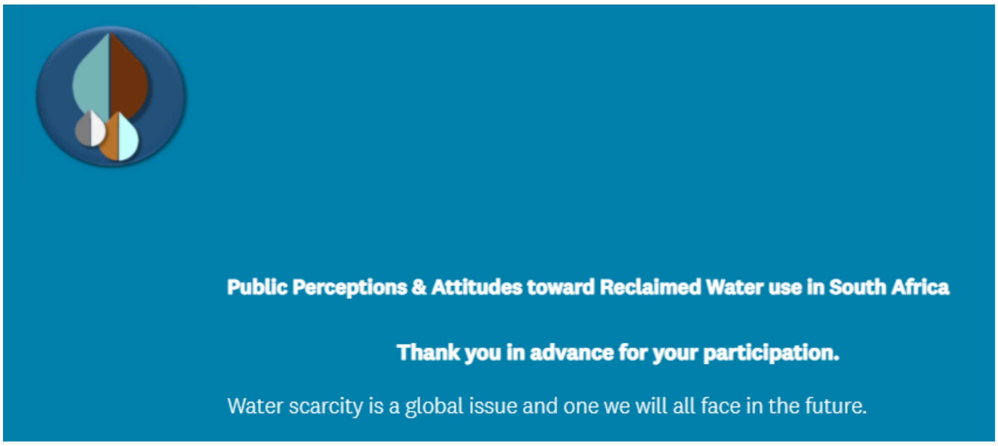
Appendix E

Survey

Survey Sections:

1. Household
2. General Questions
3. Decision Pathway
4. Additional Questions
5. Demographics

Example of computer introduction screen:



Example of mobile phone introduction screen:

1. **<u>HOUSEHOLD</u>**

2. How many people live in your house (including yourself)?

2.1. Numerical Value

3. If children are part of the household, please select their age range:

3.1. There are no children living in the household

3.2. Age between 0-5 years

3.3. Age between 6-10 years

3.4. Age between 11-18 years

4. What is the total gross household income <u>per month</u> before any expenses / deductions? Please consider all sources of income.

4.1. No income

4.2. R1 – R400

4.3. R401 – R800

4.4. R801 – R1 600

4.5. R1 601 – R3 200

4.6. R3 201 – R6 400

4.7. R6 401 – R12 800

4.8. R12 801 – R25 600

4.9. R25 601 – R51 200

4.10. R51 201 – R102 400

4.11. R102 401 – R204 800

4.12. R204 801 or more

4.13. I prefer not to say

5. Are you responsible for paying the monthly utility bill (water & electricity)?

5.1. Yes

5.2. No

6. Which of the following options best describes the house you live in?

6.1. Detached house

6.2. Room in the backyard

6.3. Flat or apartment in a block of flats

6.4. Cluster house/townhouse in a complex

6.5. Informal house or shack

6.6. A house on a small-holding, plot, or a farm -

6.7. Other (please specify)

7. Which option best describes your current residential occupancy?

7.1. Rented from a private individual

7.2. Rented from other (including municipality and social housing institutions)

7.3. Owned but not yet paid off

7.4. Owned and fully paid off

7.5. Occupied rent-free

7.6. Other (please specify)

8. What is the main source of <u>drinking water</u> for your household?

8.1. Bottled water only

8.2. Piped (tap) water inside the house from a municipality

8.3. Piped (tap) water inside the yard from a municipality

8.4. Borehole

8.5. Rain-water tank

8.6. Neighbour's tap

8.7. Public or communal tap

8.8. Water-carrier or tanker

8.9. Flowing water, stream or river

8.10. Dam, pool or stagnant water

8.11. Well

8.12. Spring

8.13. Other (please specify)

9. Who supplies your main source of <u>drinking water</u> for your household?

9.1. A municipality

9.2. A water scheme (e.g. community water supply)

9.3. A water vendor

9.4. A grocery store or other bottled water supplier

9.5. A private borehole

9.6. Flowing water, stream, river, or spring

9.7. Rain water gathered from tanks

9.8. I don't know

- IF RESPONDENT SELECTS OPTION 8.1, GO TO QUESTION 9, ELSE GO TO QUESTION 12.

10. Has your household's municipal water supply been interrupted in the last 3 months?

10.1. Yes – go to question 10

10.2. No – go to question 12

10.3. I don't know– go to question 12

11. Was the water interruption due to unpaid bills?

11.1. Yes

11.2. No

11.3. I don't know

12. What other source of water did the household use during the interruption? (Please select as many as are applicable): -

12.1. Borehole

12.2. Spring

12.3. Well

12.4. Rain-water tank

12.5. Dam, pool or stagnant water

12.6. Flowing water, stream or river

12.7. Water vendor

12.8. Bottled water from a grocery store

12.9. Water tanker or stored water

12.10. We waited for the municipal water to return

12.11. Other (please specify)

13. Which of the following are often used to save/conserve water? (Please select as many as are applicable):

13.1. Check toilets for leaks

13.2. Check taps and pipes for leaks

13.3. You only flush toilets if it is really needed

13.4. Put a plastic bottle or brick in the toilet tank

13.5. Turning off the water while shaving

13.6. Turning off the water while brushing teeth

13.7. Watering the garden only in the evening

13.8. Sharing bathwater among family members

13.9. Keeping to 2-minute showers

13.10. You use water-saving showerheads or flow restrictors

13.11. You plant drought-resistant trees and plants

13.12. You use mulch around trees and plants
13.13. You use a broom instead of a hosepipe to clean driveways, sidewalks, and steps
13.14. You use a cover over the swimming pool
13.15. None of these or other techniques are used
13.16. Other (please specify)

14. Which of the following options do you use to access electricity? (Please select as many as are applicable):

14.1. In-house conventional (post-paid) meter
14.2. In-house prepaid meter
14.3. Other source which the household pays for (e.g. connected to a neighbour's line, paying landlord)
14.4. Generator
14.5. Solar electricity home system
14.6. Battery and/or UPS
14.7. No access to electricity
14.8. I don't know
14.9. Other (please specify)

15. Which of the following do you often do to save energy/electricity in your home? (Select as many as are applicable):

15.1. Switching off lights when you leave the house
15.2. Using energy-saving light bulbs
15.3. Switching off lights in rooms in the home which are not in use
15.4. Switching off appliances (TV, radio) at the wall (not remote control) when not in use
15.5. Switching off the geyser at certain times
15.6. Boiling only as much water as is needed in a pot or kettle
15.7. Using stove plates and the oven as little as possible
15.8. Using warm clothing or blankets instead of an electric heater
15.9. Closing windows and doors when a heater is on
15.10. You use a solar water heater instead of an electric geyser
15.11. You use gas as an alternative energy source
15.12. The geyser and hot pipes in your house are insulated
15.13. We have not used any of the options described
15.14. Other (please specify)

16. Which of the following do you often do? (Select as many as are applicable):

16.1. Recycle plastic and or glass
16.2. Use solar power
16.3. Recycle bathwater for use in the garden
16.4. Recycle plastic bags when you go shopping
16.5. Drive fuel-efficient cars
16.6. Buy from thrift or second-hand stores
16.7. You are part of an environmental group
16.8. You have a compost heap
16.9. You have a vegetable garden
16.10. Carpool
16.11. Use Public Transport
16.12. Drink tap or filtered water, not bottled water
16.13. None of these or other techniques are used
16.14. Other (please specify)

2. GENERAL QUESTIONS

1. How would you rate the overall quality of water services your household has access to or uses? (For example: the maintenance of pipes or water meters and how clean the water is):

1.1. Poor
1.2. Average
1.3. Good
1.4. We do not have access to municipal water
1.5. We do not use municipal water

2. What is your understanding of your municipal water treatment technologies?

2.1. No understanding
2.2. Some understanding
2.3. Knowledgeable
2.4. Very knowledgeable

Please select what you think the following terms mean

3. The term 'wastewater' in the treatment cycle means:

3.1. Water that is safe to drink

3.2. Used water from homes, businesses, or industrial activities

3.3. Water that is of potable standard

3.4. Water in municipal reservoirs

3.5. I do not know

4. The term 'greywater' in the treatment cycle means:

4.1. Water that is clean

4.2. Water from baths, showers, sinks, washing machines, and other kitchen appliances

4.3. Water from toilets that contain a mixture of urine, faeces, and flush water

4.4. I do not know

5. The term 'blackwater' in the treatment cycle means:

5.1. Water that is clean

5.2. Water from baths, showers, sinks, washing machines, and other kitchen appliances

5.3. Water from toilets that contain a mixture of urine, faeces and flush water

5.4. I do not know

6. The term 'potable water' means:

6.1. Water that is NOT safe to drink or is NOT safe for cooking

6.2. Water that is safe to drink and can be used for cooking

6.3. Water directly from lakes, rivers or the ocean

6.4. I do not know

7. The term 'non-potable water' means:

7.1. Water that is NOT safe to drink or is NOT safe for cooking

7.2. Water that is safe to drink and can be used for cooking

7.3. Wastewater that is treated to drinkable quality

7.4. I do not know

8. The term 'reclaimed water' means:

8.1. Untreated wastewater

8.2. Treated wastewater (blackwater & greywater)

8.3. Treated greywater

8.4. Treated blackwater

8.5. I do not know

9. The term 'alternative water sources' means:

9.1. Water from desalination plants

9.2. Harvested rainwater

9.3. Reclaimed wastewater

9.4. All of the above

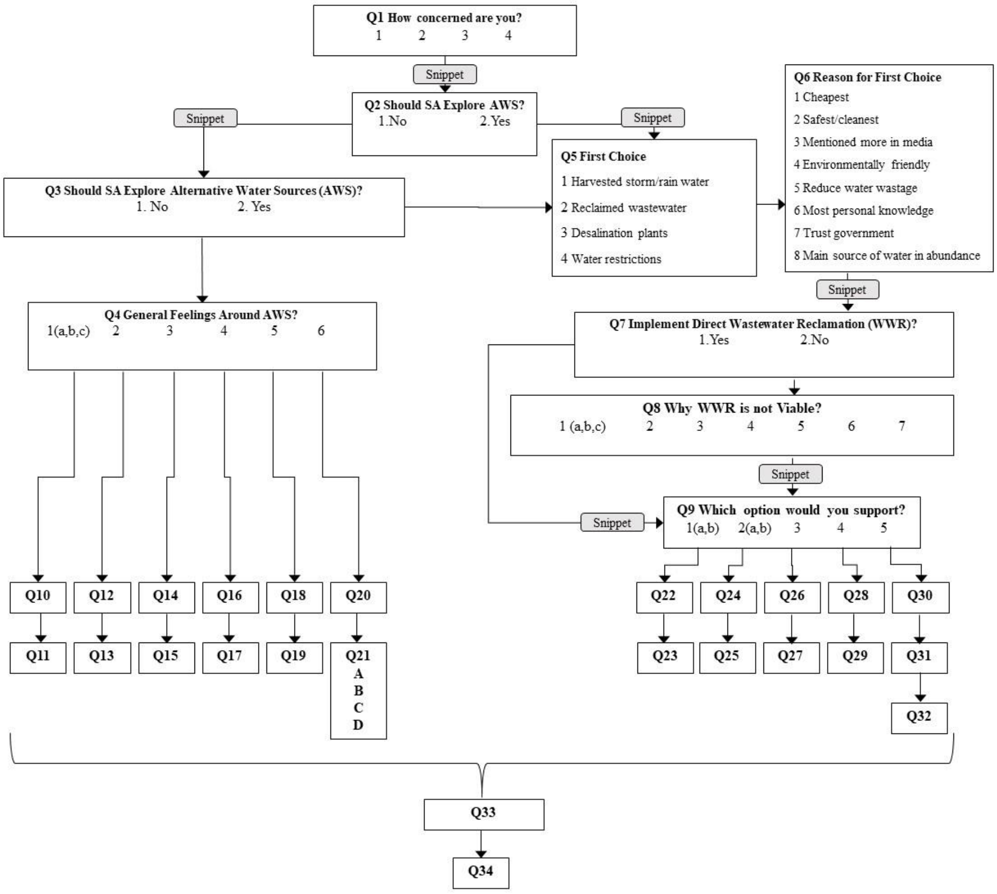
9.5. Only options 1 and 2

9.6. I do not know

10. Would you say the following statements are true or false?

	True	False
a) Ozone can be used for the removal of bacteria and viruses from drinking water		
b) Chlorine is often used to kill bacteria and viruses during drinking water treatment		
c) Bacteria such as *E. coli* are used to determine whether water is safe for consumption		
d) *E. coli* does not need to be entirely absent from treated drinking water, if the levels of *E.coli* are very low, the water would be safe to drink		
e) The raw water that comes into wastewater treatment plants includes industrial wastewater and domestic wastewater		
f) Drinkable water is abundant throughout the world		
g) South Africa is a water-scarce country		

3. DECISION PATHWAY



---

1. How concerned are you about the availability of water in South Africa, now and for the near future i.e. in 10 – 20 years?

1.1. Not concerned at all

1.2. Somewhat concerned

1.3. Concerned

1.4. Very concerned

- GO TO QUESTION 2

2. More than 60% of the earth's surface is covered by the ocean, but only a very small percentage of that is freshwater.

South Africa experiences moderate to severe water scarcity during more than half of the year.

Alternative sources of water include: storm- and rainwater harvesting, reclaimed wastewater, water from desalination plants.

In your opinion, should South Africa explore the use of alternative sources of water?

2.1. No, South Africa should not explore the use of alternative water sources
– GO TO QUESTION 3

2.2. Yes, South Africa should explore the use of alternative water sources
– GO TO QUESTION 5

3.

- Storm- and rainwater harvesting involves collecting and storing rain from run-off and building roofs in ponds or aquifers or in rainwater tanks.

- Reclaiming wastewater involves treating wastewater from industries, as well as residential and commercial buildings for potable (drinking) or non-potable (non-drinking) use.

- Desalination involves treating sea water to remove salt and minerals, to make it suitable for drinking or irrigation.

- Water restrictions involve limiting water usage.

Given this information, do you think alternative sources of water should be explored in South Africa?

3.1. NO, I still think South Africa should NOT explore alternative sources of water
– GO TO QUESTION 4

3.2. Yes, based on this information, I think South Africa should explore alternative sources of water
– GO TO QUESTION 5

4. We would like to know more about why you think South Africa does not need to explore alternative sources of water.

Which of the following reasons best explain your feelings around alternative water sources?

4.1. a. The government/municipalities do not know enough about the technology required to safely implement the use of alternative water sources OR

4.1 b. The scientists do not know enough about the technology required to safely implement the use of alternative water sources OR

4.1 c. I do not think that there is any technology that can safely treat alternative waters to drinking water quality

– GO TO QUESTION 10 +11 FOR OPTIONS 4.1.a. and 4.1.b. + 4.1.c.

4.2. I do not know enough about alternative sources of water to make an informed choice

– GO TO QUESTION 12 + 13

4.3. I do not trust the government or the municipalities' ability to manage the processes required to implement the use of alternative water sources.

– GO TO QUESTION 14 + 15

4.4. There is an abundance of water in the world, and we/municipalities should continue to do things the way they are currently done

– GO TO QUESTION 16 + 17

4.5. I am more worried about other environmental issues such as; deforestation or pollution because it is reported more in the news and/or spoken about by celebrities

– GO TO QUESTION 18 + 19

4.6. Alternative sources of water would be too expensive to implement

– GO TO QUESTION 20 + 21a-d

5. Many alternative sources of water, or ways to regulate water use are available.
   - Storm- and rainwater harvesting involves collecting and storing rain from run-off and building roofs in ponds or aquifers or in rainwater tanks.
   - Reclaiming wastewater involves treating wastewater from industries, as well as residential and commercial buildings for potable (drinking) or non-potable (non-drinking) use.
   - Desalination involves treating sea water to remove salt and minerals, to make it suitable for drinking or irrigation.
   - Water restrictions involve limiting water usage.

Please rank the following from your most preferred option (1) to least preferred option (4):

5.1. Harvested storm water- and rainwater

5.2. Reclaimed wastewater

5.3. Desalination plants

5.4. Water restrictions

If respondent chose that South Africa should not explore alternative sources of water they did not answer this questions

– GO TO QUESTION 6

6. **Which of the following best describes the reason for your first choice?**

6.1. This option would be the cheapest

6.2. I believe the water would be cleanest and safest to drink

6.3. It is often mentioned in the media

6.4. It is an environmentally friendly alternative

6.5. It would reduce water wastage

6.6. I have the most knowledge on this option

6.7. I trust the government can manage the process

– GO TO QUESTION 7

7. South Africa can use reclaimed wastewater.

Reclaiming water involves treating wastewater from industries, and sewage from residential and commercial buildings for potable (drinking) or non-potable (non-drinking) use.

Two routes exist for water reclamation: direct and indirect.

In indirect reclamation, wastewater from homes and industrial facilities is treated at wastewater plants and delivered to a buffer (an underground aquifer or a surface water body). After some time, the water is collected and treated at a treatment plant to the required standard, and delivered to municipal reservoirs and you the user.

In direct reclamation, wastewater from homes and industrial facilities is treated at a wastewater plant to the required standard then delivered to municipal reservoirs and you the user. There is no natural buffer between the treated wastewater and you the user.

Implementing direct wastewater reclamation could help to ensure a sustainable water supply for South Africa in future?

7.1. Yes, I agree

– GO TO QUESTION 9

7.2. No, I do not agree

– GO TO QUESTION 8

8. **We would like to know more about why you think reclaiming wastewater is not a viable option in South Africa.**

Which of the following reasons best describe your response?

8.1. a) The **government/municipalities** do not know enough about the technology required to safely implement the use of alternative water sources

b) The scientists do not know enough **about the technology required** to safely implement the use of alternative water sources

c) I do not think that there is any technology that can safely treat alternative waters to drinking water quality.

8.2. I do not know enough about **alternative sources** of water to make an informed choice

8.3. I do not trust the government or the municipalities' ability to manage the processes (including **infrastructure)** required to implement the use of alternative water sources

8.4. There is an abundance of water in the world, and we/municipalities should continue to do things the way they are currently done

8.5. I am more worried about other environmental issues such as; deforestation or pollution because it is reported more in the news and/or spoken about by celebrities

8.6. Alternative sources of water would be too expensive to implement

8.7. Other (please specify)

- GO TO QUESTION 9

9. Recently, Cape Town was close to a ‘day zero’ the point at which the city would have run out of water.

   Day zero is a national concern, and could happen in other South African cities.

   Wastewater can be treated to different standards: potable (drinkable) or non-potable (not-drinkable) standards.

   Indirect Reuse means: wastewater is treated then released into groundwater or surface water bodies (environmental buffer). After a time, it is pumped back out and treated to a potable or non-potable standard.

   Direct Reuse means: wastewater is treated to potable or non-potable standards and introduced directly into a municipal water supply system without an environmental buffer.

   Suppose reclaimed wastewater is the only way to ensure the taps do not run dry:

   Under these conditions, which one of the following options would you support?

   9.1. a. Direct potable reuse – there is no natural buffer, the water would be used for domestic (including drinking), industrial and agricultural use.

   - GO TO QUESTION 22 OR

   b. Direct non-potable reuse – there is a natural buffer, the water could be used for domestic (not drinking), industrial and agricultural use.

   - GO TO QUESTION 22

   9.2. a. Indirect potable reuse – there is a natural buffer, the water could be used for domestic (including drinking), industrial and agricultural use.

   - GO TO QUESTION 24 OR

   b. Indirect non-potable reuse – there is a natural buffer, the water could be used for domestic (not-drinking), industrial and agricultural use.

   - GO TO QUESTION 24

   9.3. We should have dedicated pipes run to our homes for reclaimed wastewater so that we can decide what we want to use it for

   - GO TO QUESTION 26

   9.4. Even in this case, I will not use reclaimed wastewater

- GO TO QUESTION 28

9.5. There are better alternatives than wastewater reclamation

- GO TO QUESTION 30

10. Which one of the following answers best describes the basis for your concern?

10.1. The government and/or scientists do not have the public’s best interests at heart

10.2. Alternative water sources require complex science which neither the government or scientists fully understand

10.3. Treating alternative waters requires complex technologies that are still not available in the market

10.4. The government is only looking at the short term and not considering the long term implications of using alternative water sources

10.5. The health risks are too high

- GO TO QUESTION 11

11. **How do you feel, in general, about the role of government and scientists in managing complex environmental issues?**

Would you say:

11.1. You do not trust the government

11.2. You do not trust scientific experts

11.3. Governments and scientists are often self-serving

11.4. The government and scientists should not be able to make such decisions by themselves and the decision should rest with the general public, and the community

11.5. Other country’s experts know better and you will trust their decisions

- GO TO QUESTION 33

12. Which of the following information about alternative water sources would be most helpful to you?

12.1. Information on the different alternative water sources and countries that it has been implemented in

12.2. Information on how countries chose which alternative water source to implement

12.3. Information on the quality of the water and any health risks

12.4. Information on the costs associated with a specific alternative water source

- GO TO QUESTION 13

13. Which would be the best source of this information?

13.1. The government should inform the public

13.2. The media should run campaigns to educate the people

13.3. It should be taught more in schools

13.4. Environmental groups should promote it

13.5. I do not think anyone can help because they are all biased

- GO TO QUESTION 33

14. **Which of the following actions would you recommend governments and municipalities do to increase the public's trust?**

14.1. The government and municipalities should be transparent in their decision making when implementing new processes

14.2. The government and municipalities should run awareness campaigns to inform the public about their processes

14.3. The government and municipalities should allow citizens to vote on the available options before implementation

14.4. They should partner with famous TV personalities and celebrities to highlight issues of concern

14.5. Governments and municipalities should consult with experts

14.6. I don't think any action the government takes would increase my trust in them

14.7. Other (please specify)

- GO TO QUESTION 15

15. Which one of the following sentences best describes how you feel about the role of the government and municipalities in managing complex environmental issues?

15.1. The government and municipalities should not have the final say with big decisions. The community needs to have a say

15.2. Big environmental decisions should be left to scientists and/or environmentalists

15.3. The government is always biased and only serve themselves

15.4. Nature should be left to manage itself

- GO TO QUESTION 33

16. You have indicated that municipalities should continue to do things the way that they have always done.

    This means in most parts of South Africa wastewater is treated at wastewater plants and pumped into rivers. It is pumped out of rivers again and treated at water treatment plants to a drinkable standard before being supplied to homes and businesses. This can be classified as indirect water reuse.

    On the other hand, direct potable use means there is no environmental buffer, wastewater is treated in treatment plants and supplied directly to consumers.

    Which of the following statements do you agree with more?

    16.1. Given this information direct potable reclamation sounds like it can be more efficient and could result in cost- and energy savings

    16.2. Given this information I still believe municipalities should continue to do things the way that they have always done

    16.3. I would rather not know where my drinking water comes from

    - GO TO QUESTION 17

17. **Which of the following options best describes how you feel about the use of a different water source?**

    17.1. I do not like change

    17.2. Any change or implementation of new methods should be left to the government and/or the experts

    17.3. If a new method is more cost-effective, it should be implemented

    17.4. If a new method creates jobs, it should be implemented

    17.5. Any new method that is covered in the media and/or represented widely by famous people should be implemented

    17.6. Nature should be left to manage itself

    - GO TO QUESTION 33

18. Which one of the options below would make you more accepting of alternative sources of water?

18.1. If more famous people, role models, TV personalities, and people from respected professions promoted alternative sources of water

18.2. If I could share my experience about alternative water sources on social media

18.3. If the media ran information campaigns to inform the public about alternative sources of water

18.4. If incentive drives were held in the community

- GO TO QUESTION 19

19. **Which of the platforms below would you say plays the biggest role in influencing your opinion?**

19.1. The news on radio or television

19.2. Printed newspapers or magazines

19.3. Social-media such as Facebook or Instagram

19.4. Local or international television programs with famous actors

- GO TO QUESTION 33

20. Of the available options, the cost to implement an alternative source would increase as follows:

water restrictions (cheapest) -> rainwater harvesting -> water reclamation -> desalination (most expensive)

If the quality of the water was unchanged, which of the following would you suggest governments implement?

20.1. Desalination plants

20.2. Water reclamation plants

20.3. Storm- rain water harvesting

20.4. Implement strict water restrictions

- GO TO QUESTION 21

21. If the cost and quality of the water was equal:

a) Which alternative source of water would you feel most comfortable with to drink?

21.1. Water from a desalination plant
21.2. Water from a wastewater reclamation plant
21.3. Water from storm- rain water harvesting
21.4. The water currently from your tap
21.5. Bottled water

b) Which alternative source of water would you feel most comfortable with to feed to a baby?

21.6. Water from a desalination plant
21.7. Water from a wastewater reclamation plant
21.8. Water from storm- rain water harvesting
21.9. The water currently from your tap
21.10. Bottled water

c) Which alternative source of water would you feel most comfortable with to use for cooking?

21.11. Water from a desalination plant
21.12. Water from a wastewater reclamation plant
21.13. Water from storm- rain water harvesting
21.14. The water currently from your tap
21.15. Bottled water

d) Which alternative source of water would you feel most comfortable with to water your garden?

21.16. Water from a desalination plant
21.17. Water from a wastewater reclamation plant
21.18. Water from storm- rain water harvesting
21.19. The water currently from your tap
21.20. Bottled water

- GO TO QUESTION 33

22. Which one of the following reasons best explains why you support the direct reuse of reclaimed wastewater?

22.1. It is the most cost-effective solution to South Africa's water problem

22.2. I believe the government, municipalities, and/or scientists have sufficient knowledge

22.3. I trust the government, municipalities, and/or scientists' ability to manage such projects

22.4. There is no difference between the quality of reclaimed water and the water we currently get in our taps

22.5. It will reduce the burden on the environment

- GO TO QUESTION 23

23. **What do you think would be the most serious challenge associated with direct reclaimed water use for potable (drinkable) purposes?**

23.1. There could be a rise in diseases if the water quality is bad

23.2. It could cost a lot of money to implement and too expensive to most consumers

23.3. People might not want to use it

23.4. I do not think there would be any problem as the method is already safely used in space missions and by other countries

- GO TO QUESTION 33

24. Which one of the following reasons best explains why you believe we should only reuse reclaimed wastewater indirectly?

24.1. I do not trust that the scientists will be able to maintain the level of water quality

24.2. I do not think the government, or municipalities can maintain the infrastructure

24.3. Drinking reclaimed wastewater could have health risks

24.4. I think it is disgusting to drink reclaimed wastewater

24.5. It is against my religion to drink direct reclaimed wastewater

24.6. It will cost too much to clean the water to a drinkable standard

24.7. I do not trust the government/municipalities to maintain the water quality

- GO TO QUESTION 25

25. What do you believe would be the most serious challenge associated with using reclaimed water for potable use?

25.1. There could be a rise in diseases if the water quality is bad

25.2. It could cost a lot of money to implement and become unaffordable

25.3. People might not want to use it

25.4. I do not think there would be any problem

- GO TO QUESTION 33

26. Which one of the following reasons best explains why you believe that reclaimed wastewater, of a potable or non-potable standard, should be supplied to homes via separate pipes?

26.1. I do not trust the government and/or municipalities that they will be able to maintain the level of water quality, so a separate pipe network would ensure that drinking water is not contaminated

26.2. I do not trust that the scientists will be able to maintain the level of water quality

26.3. I do not think the government, and/or municipalities can be trusted to maintain the infrastructure, so separate a pipe network would ensure that drinking water is not contaminated

26.4. Drinking reclaimed wastewater could have health risks, so a separate pipe network would ensure that drinking water is not contaminated

26.5. It is disgusting to think of reclaimed water and drinking water sharing a piped network but I

- GO TO QUESTION 27

27. What do you believe would be the most serious challenge associated with having two pipes running into homes and businesses; one from the municipal reservoir and one with water from a wastewater treatment plant?

27.1. There could be a rise in diseases if people drink water from the wrong pipe

27.2. People might not want to use the recycled water that was treated at a wastewater treatment plant

27.3. It could cost a lot of money to implement

27.4. People would waste water if they have two taps to choose from

- GO TO QUESTION 33

28. You have indicated that you will not use reclaimed wastewater even if it is as a last resort. **Which one of the following explanations best describes your strong opposition to the use of reclaimed water?**
    28.1. The government/municipalities do not know enough about the technology required to safely implement wastewater reclamation
    28.2. The scientists do not know enough about the technology required to safely implement wastewater reclamation
    28.3. I do not think that there is any technology that can safely treat wastewater to drinking water quality
    28.4. I do not know enough about wastewater reclamation
    28.5. I do not trust the government or the municipalities' ability to manage the infrastructure or water quality
    28.6. There is an abundance of water in the world, and we/municipalities should continue to do things the way they are currently done
    28.7. If there were more awareness campaigns I might change my viewpoint
    28.8. I think it is disgusting
    28.9. Wastewater reclamation plants would be too expensive to implement
    28.10. It is against my religion
        - GO TO QUESTION 29

29. **Do you foresee any future problems with South Africa's water supply?**
    29.1. We could run out of water in the future
    29.2. Higher demand for limited water resources would make municipal water more expensive
    29.3. There will be water rationing
    29.4. I do not foresee any future problems
        - GO TO QUESTION 33

30. **Which of the following do you think is a better alternative to wastewater reclamation?**
    30.1. Desalination plants
    30.2. Storm- rainwater harvesting
    30.3. Water restrictions
    30.4. Other (please specify)
        - GO TO QUESTION 31

31. You have chosen an alternative to wastewater reclamation.

Why would you say your choice is better?

31.1. It is a cheaper option
31.2. It is safer
31.3. The water is cleaner
31.4. It is spoken about more in the media
31.5. I trust the cleaning/purification process more

- GO TO QUESTION 32

32. What would you say is the major reason people are against using water from a wastewater reclamation project?

32.1. It is too expensive
32.2. There are health risks
32.3. They do not trust the government
32.4. It is not spoken about enough in the media
32.5. People do not know about the water crisis
32.6. It is against their religion
32.7. They think that it is disgusting

- GO TO QUESTION 33

33. We shall now revisit the original question. South Africa could make use of alternative sources of water or stricter legislation, such as water from storm- and rainwater harvesting, reclaimed wastewater, from desalination plants, or strictly implement water restrictions.

Given the information you were presented with, which ONE of the following do you see as the most viable (practical/cost effective) option in South Africa?

33.1. Harvested storm- and rainwater
33.2. Reclaimed wastewater
33.3. Desalination plants
33.4. Water restrictions
33.5. Other

- GO TO QUESTION 34

34. Suppose you live or frequently visit an area in South Africa where the local municipality has introduced one of the alternative water methods, e.g. reclaimed water that you do not agree with.

Which one of the following options best describes your most likely reaction?

34.1. I would ignore it; if it is safe to use for other people then the water is safe to use by me

34.2. I would be somewhat upset and/or discuss it with other people

34.3. I would call the Minister or someone else high up in the government to try to influence a change in the policy

34.4. I would challenge the decision in the courts

4. <u>ADDITIONAL QUESTIONS</u>

1. Recycled or reclaimed water is wastewater that has been treated at a water treatment plant by removal of solid impurities and is disinfected to remove disease-causing microbes including bacteria and viruses.

Please rate your agreement with the following statements about recycled water.

	Strongly Disagree (1)	(2)	(3)	(4)	(5)	Strongly Agree (6)
a) Reclaimed water can help to alleviate water shortages						
b) The water we drink now has been used before and can therefore be considered reclaimed water						
c) Towns downstream of rivers often draw or treat water that has been used by other towns located upstream of the same river						

d) I would not support the use of reclaimed water because of the risks of technology failure						
e) The wastewater treatment technologies are unlikely to work efficiently for South African wastewater due to the presence of anti-retroviral drugs (ARVs) and other medication in our wastewaters						
f) I don't think that the technologies currently available for water treatment are able to generate clean water from wastewater						
g) More chemicals are required for production of reclaimed water from wastewater than in conventional water treatment						
h) Chemicals used in wastewater treatment may not be sufficiently removed from reclaimed water						
i) Reclaimed water could contain chemicals harmful to health e.g. endocrine disruptors						
j) Reclaimed water could contain toxic products from reactions between different chemicals used in its treatment						
k) I would be more willing to drink reclaimed water if no chemicals were used in the treatment process						

l) Consuming recycled water will likely expose consumers to high levels of dangerous chemicals						
m) Incorporating reclaimed water into mains supply would lead to high water tariffs						
n) Reclaimed water plants are more expensive to build and maintain						
o) I would be willing to accept reclaimed water if this would mean lower water costs for me						
p) The current water supply benefits all residents						
q) The current water billing structure makes allowances for low-income residents						
r) The pricing structure of supplied water is fair						
s) It is the responsibility of the current generation to ensure that future generations have access to enough clean water						
t) When I think of water security for future generations, it makes me more willing to support the development of reclaimed water schemes						
u) Developing alternative water sources, such as reclaimed water, is one way to ensure that future generations will have access to water						

v) We owe it to future generations, to use currently available water in a way that will allow them to also have access to this resource						

2. **(OPTIONAL QUESTION) There are different ways to make water fit for consumption. In large cities water treatment comprises the steps below.**

Starting with **'Raw water' insert the numbers** insert the numbers 1 – 6 based on the sequence of making water fit for consumption:

Coagulation: The addition of chemicals to enable removal of suspended and dissolved solids	
Residual disinfection: Disinfection to protect water from microbial contamination while it is in the distribution system, on the way to the consumer	
Raw water	
Disinfection: Addition of chemicals, such as chlorine, to kill microorganisms	
Flocculation: The gentle stirring to increase the size of solids	
Sedimentation: Settling of solids by gravity	

5. DEMOGRAPHIC

1. How old are you in completed years?

1.1. Numerical Value

2. What is your sex?

2.1. Female
2.2. Male
2.3. I prefer not to say
2.4. Other

3. In which population group do you belong?

3.1. Black African
3.2. Coloured
3.3. Mixed Race
3.4. Indian or Asian
3.5. White
3.6. I prefer not to say
3.7. Other (please specify)

4. What is your province of usual residence?

4.1. Western Cape
4.2. Eastern Cape
4.3. Northern Cape
4.4. Free State
4.5. KwaZulu-Natal
4.6. North West
4.7. Gauteng
4.8. Mpumalanga
4.9. Limpopo
4.10. Other (please specify)

5. What is your most spoken language at home?

5.1. Afrikaans
5.2. English
5.3. IsiNdebele
5.4. IsiXhosa
5.5. IsiZulu

5.6. Khoi, Nama and San Languages
5.7. Sepedi
5.8. Sesotho
5.9. Setswana
5.10. Sign Language
5.11. SiSwati
5.12. Tshivenda
5.13. Xitsonga
5.14. Other (please specify)

6. What is your religious affiliation or belief?

6.1. Agnosticism
6.2. Atheism
6.3. Bahaism
6.4. Buddhism
6.5. Christian
6.6. Hinduism
6.7. Islam
6.8. Judaism
6.9. No religious affiliation or belief
6.10. Traditional African Religion (E.g. Ancestral, Tribal, Animist, etc.)
6.11. I prefer not to say
6.12. Other (please specify)

7. What is your highest level of education?

7.1. No schooling
7.2. Primary school completed
7.3. Some high school
7.4. High school completed – Matric or Grade 12
7.5. Vocational or FET College - Diploma or Certificate
7.6. Bachelor Degree
7.7. Honours Degree
7.8. Master Degree
7.9. Doctoral Degree

Appendix F

Ethical Clearance Certificate - 1

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Etale

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H20/02/13**
PROJECT TITLE	Urban water futures: Bridging supply-demand gaps in Accra and Johannesburg through reuse
INVESTIGATOR(S)	Dr A Etale
SCHOOL/DEPARTMENT	Global Change Institute/
DATE CONSIDERED	14 February 2020
DECISION OF THE COMMITTEE	Approved Risk level: Minimal
EXPIRY DATE	27 February 2023

DATE 28 February 2020 PP **CHAIRPERSON** (Professor J Knight)

cc: Supervisor : N/A

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature ______________________   Date ____/____/____

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix G

Ethical Clearance Certificate - 2

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

SCHOOL OF HUMAN AND COMMUNITY DEVELOPMENT ETHICS COMMITTEE
CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE:	**PROTOCOL NUMBER: MAORG/20/04**
PROJECT TITLE:	Would you drink it? An Exploratory Study: Gauging the Public's Perceptions and Attitudes on the Use of Reclaimed Wastewater in South Africa
INVESTIGATOR	Prins Xavier (2245681)
SCHOOL/DEPARTMENT OF INVESTIGATOR	SHCD/Psychology
DATE CONSIDERED	05 June 2020
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	Minimal Risk
EXPIRY DATE	31 December 2022

ISSUE DATE OF CERTIFICATE 21 June 2020 **CHAIRPERSON** (Dr Colleen Bernstein)

cc: Prof. Andrew Thatcher (Supervisor)

DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** returned to the Chairperson of the School/Department ethics committee.

I fully understand the conditions under which I am are authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

Signature

Date 01 / 07 / 2020

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

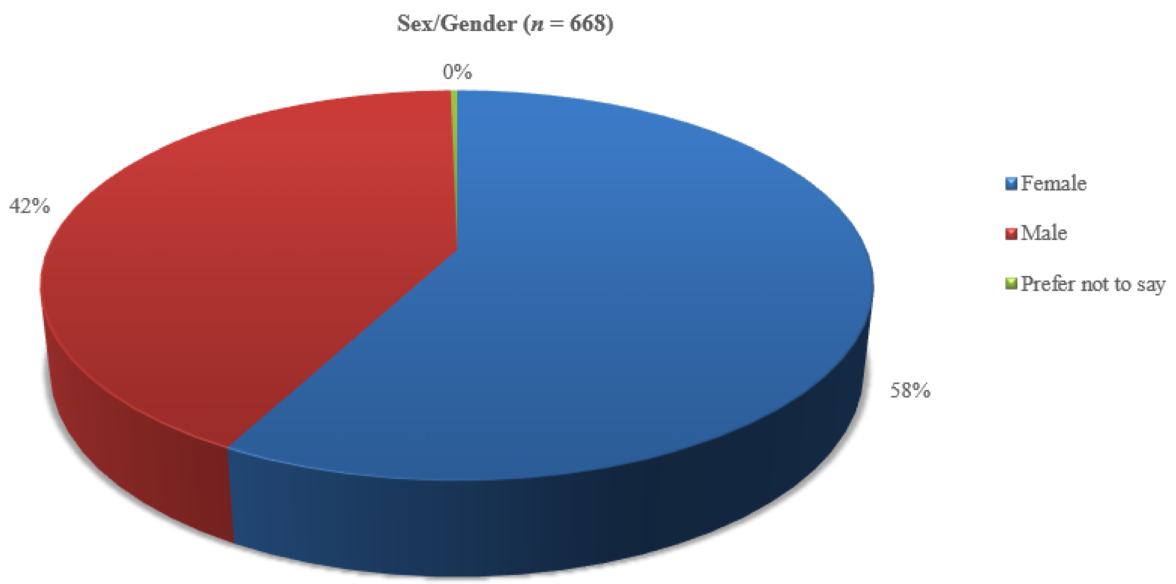
Appendix H
Demographic Profile

1. Sex

Respondents were asked to indicate their sex/gender. The findings reveal that more than half of the respondents were female (58%), while 42% were male. This is consistent with the Statistics South Africa's 2011 census in which a larger proportion of the population is female (51.4%) with a smaller percentage of males (48.7%) (Statistics South Africa, 2011, p. 18). An overview is provided in Figure H1.

Figure H1.

Distribution of Respondents' Sex/Gender.

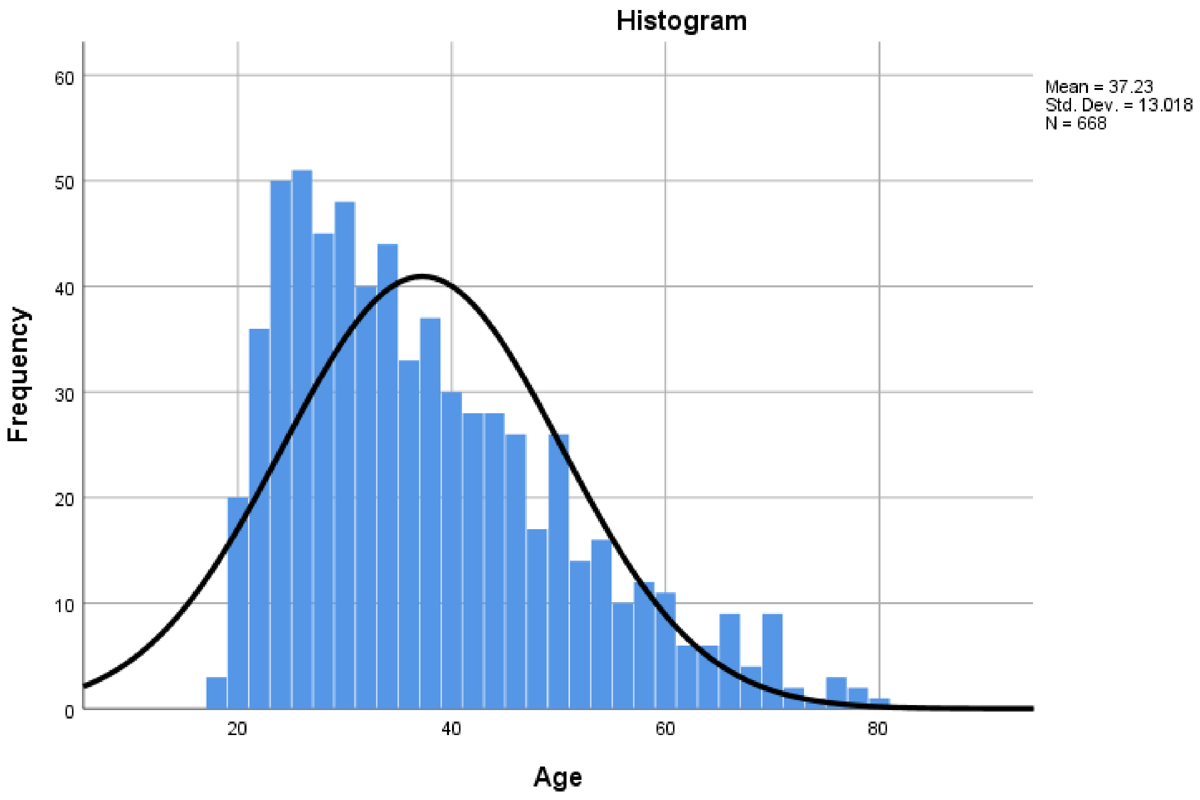


2. Age

Respondents were asked to indicate their age as a numerical value. It was found that the average age of the sample was 37.23 (*SD* = 13.02) and ranged between 18 and 79 years old. A distribution curve of the age is provided in figure 2. With the survey having been distributed electronically it was expected that younger and sometimes more tech-savvy respondents would be more willing to complete survey. See Figure H2.

Figure H2.

Distribution of Respondents' Age.

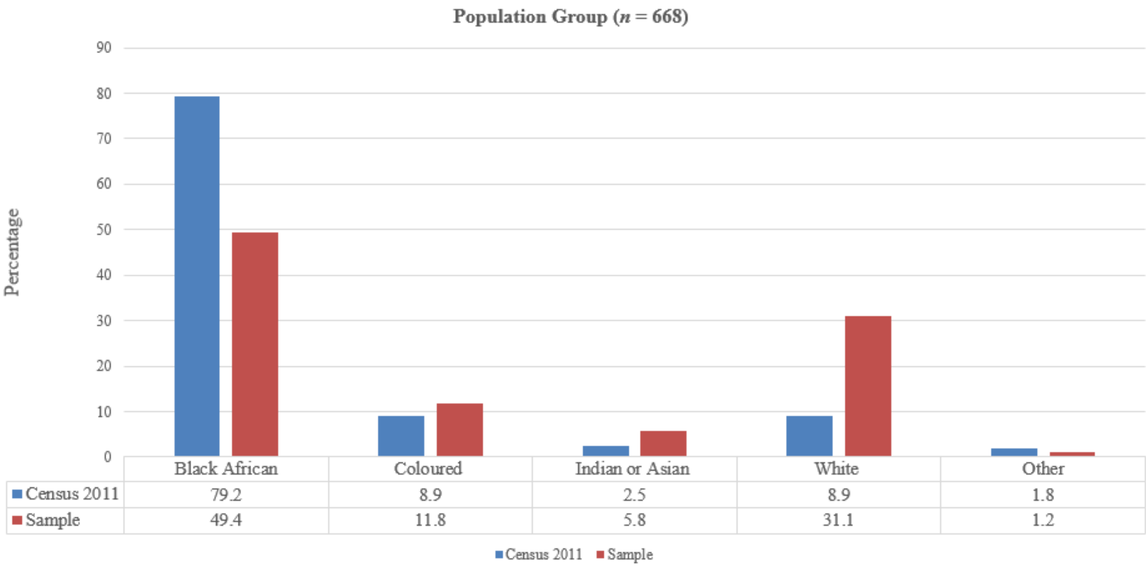


3. Population Group

The findings revealed that most of the respondents who took part in the survey were Black African (49.4%), followed by White respondents (31.1%), Coloured respondents (11.9%), Indian or Asian (5.8%), and respondents who fell into other groups (1.2%). Compared to the South African 2011 census data more White respondents and fewer Black African respondents were recorded. The sample was therefore not fully representative of the population regarding the population group. See Figure H3.

Figure H3.

Distribution of Respondents' Population Group.



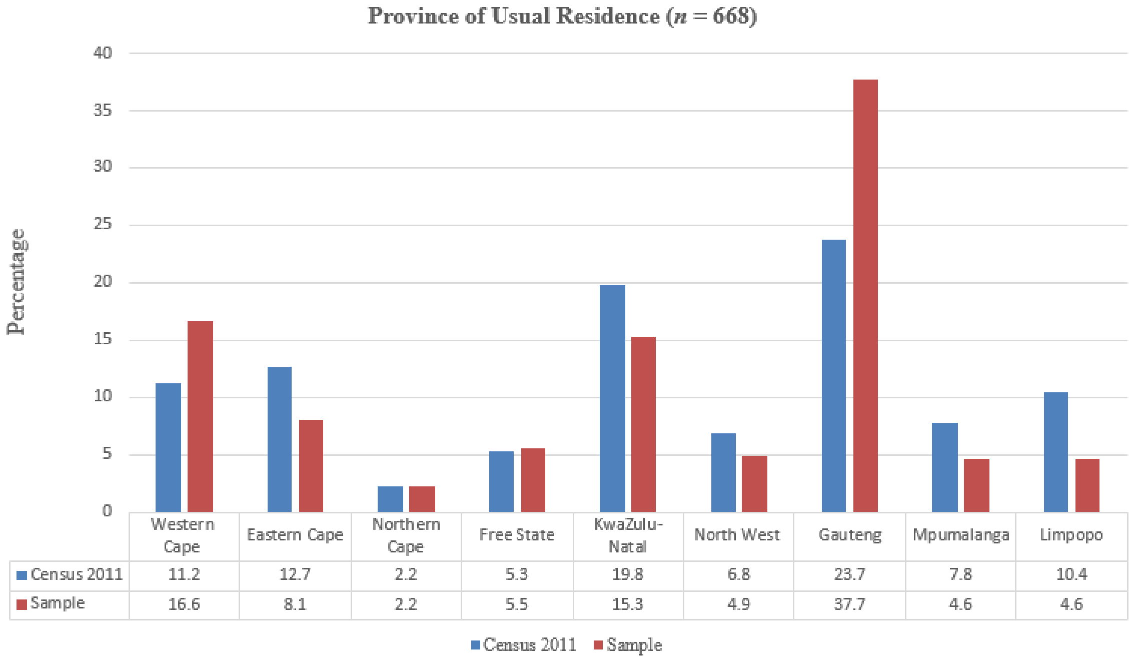
	Black African	Coloured	Indian or Asian	White	Other
Census 2011	79.2	8.9	2.5	8.9	1.8
Sample	49.4	11.8	5.8	31.1	1.2

4. Province of Usual Residence

Most of the respondents indicated that their usual province of residence is Gauteng (37.7%) with the second largest group of respondents residing in Western Cape (16.6%). All nine provinces were represented. See Figure H4.

Figure H4.

Distribution of Respondents' Province of Usual Residence.



5. Language and Education

A large majority of the respondents indicated that their most spoken language at home was English (n = 279), while the second largest group's most spoken language was Afrikaans (n = 115), followed by IsiZulu (n = 79), and IsiXhosa (n = 43). A summary is provided in Table H1.

Table H1.

Summary or Respondents' Most Spoken Language at Home.

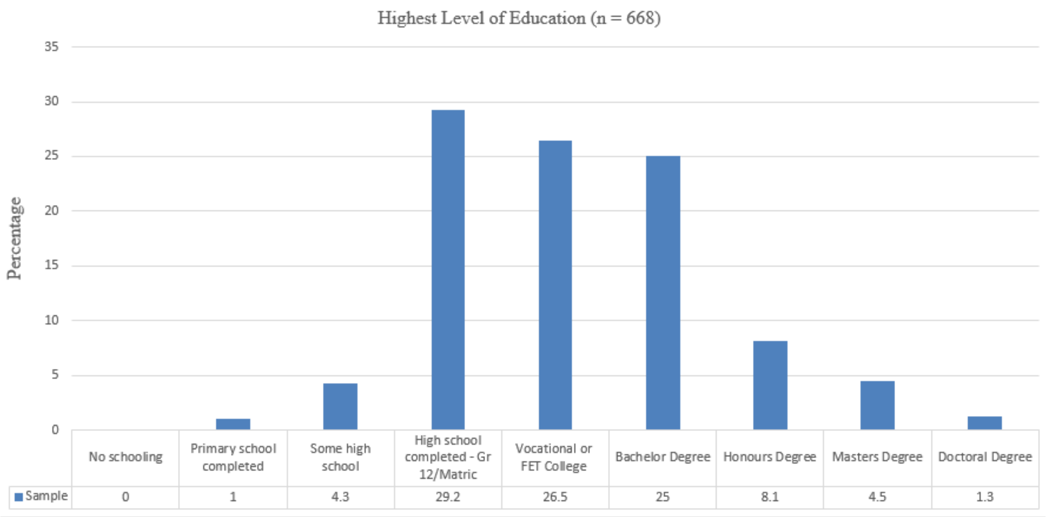
Language	**Afrikaans**	115
	English	279
	Greek	1
	IsiNdebele	5
	IsiXhosa	43

	IsiZulu	79
	Sepedi	31
	Sesotho	32
	Setswana	39
	Shona	4
	SiSwati	10
	Tshivenda	18
	Xitsonga	12

Respondents were requested to provide their highest level of education. This is shown in figure H5. A large majority of respondents (total 80.7%) had either completed High School (29.20%), had attended Vocational or FET College (26.50%), or had a Bachelor Degree (25%).

Figure H5.

Distribution of Respondents' Highest Level of Education.

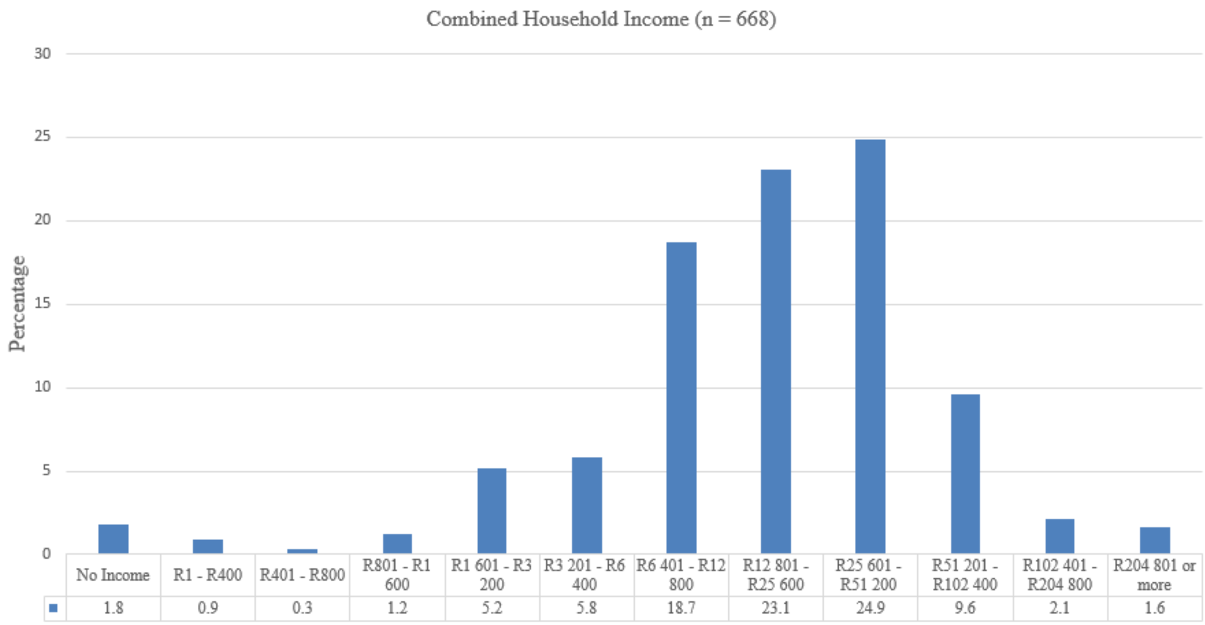


6. Combined Monthly Household Income

Respondents were asked to indicate their gross household income per month before any expenses or deductions and to consider all sources of income. The largest portion (24.9%) of respondents indicated that their monthly household income was in the range of R25 601 and R51 200. See Figure H6.

Figure H6.

Summary or Respondents' Combined Monthly Household Income.



7. Type of Residence and Tenure Status

A large majority of respondents indicated that they live in a detached house (42.1%), followed by respondents living in a cluster house or townhouse in a complex (27.4%). A smaller percentage lived in a flat or apartment in a block of flats (12.7%), followed by those living in a house on a small-holding, plot or farm (10.2%), a room in a backyard (4%), and those living in an informal house or shack (3.6%).

A majority of respondents indicated that their residence was owned and fully paid off (34.9%), followed by those that are renting from a private individual (25.9%), those that own their homes but it is not yet fully paid off (24.9%), those that are occupying a residence rent-free (9.6%), and those that are renting from municipalities or other social housing institutions (4.8%).

8. Main Source and Supplier of Drinking Water

Respondents were requested to indicate their main source of drinking water as well as the drinking water supplier. A majority of the respondents indicated that their main source of drinking water for the household comes from piped (tap) water inside the house from a municipality (n = 469) or piped (tap) water inside the yard from a municipality (n = 61), this accounts for 79.34% of all respondents (n = 668). From the n = 530 respondents who had access to piped water from a municipality, n = 241 had experienced municipal water supply interruptions in the three months leading up to the survey. Fewer respondents indicated that their main source of drinking water is only bottled water from a grocery store or other bottled water supplier (n = 34), or from a private borehole (n = 22).