THE FEASIBILITY OF AUGMENTING THE STELLENBOSCH POTABLE WATER SUPPLY BY ESTABLISHING A DIRECT POTABLE REUSE PLANT

By

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A thesis submitted in partial fulfilment
of the requirements for a

Masters of Engineering – Water Quality Engineering

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October 2019

ABSTRACT

The Western Cape has suffered severe droughts over the past decade which has placed severe strain on raw water resources for both agriculture and municipal use. The crisis was due to many factors including climate change, increasing urbanisation and ageing infrastructure to name a few. The water scarcity problems will persist in the future globally unless water management authorities are able to augment existing raw water resources with a mix of desalination, groundwater and reclamation of treated effluent. The town of Stellenbosch was selected as part of a case study to determine the feasibility of implementing a direct potable reuse (DPR) plant to augment the future water resource mix from a technical, social, environmental and economic standpoint.

Over the past two decades there has been a global shift towards direct and indirect potable reuse schemes to augment existing surface and groundwater resources. The shift has been accelerated by advances in treatment technology, water quality monitoring and research which have reduced the costs of potable reuse when compared to conventional water resources. The effluent from the Stellenbosch Wastewater Treatment Works was investigated as a reliable raw feed water source for the Stellenbosch DPR Plant.

The Stellenbosch DPR Plant treatment train followed the multiple barrier approach to ensure high quality product water and mitigate potential risks to human health. The process design favoured granular activated carbon filtration instead of reverse osmosis due to the lower costs, inland location and brine disposal issues along with the acceptable total dissolved salt levels within the source water. The process design was developed further to determine the energy consumption, chemical consumption and process monitoring and control framework for the plant.

A technical feasibility was done on three scenarios which were selected based on mix of reclaimed water and current surface water resources to supply the town of Stellenbosch with potable water.

Scenario A – ‘do-nothing’ approach whereby the Stellenbosch Municipality would continue to be supplied with bulk raw water from the Theewaterskloof Dam treat it at the Paradyskloof WTW
Scenario B – DPR Plant which produced potable water and injected it upstream of the Paradyskloof WTW
Scenario C - DPR Plant which produced potable water and injected it downstream of the Paradyskloof WTW

The research found that it would be feasible to implement a DPR scheme in Stellenbosch to improve the towns’ water security to meet future demands. The technical, social and environmental issues introduced in this research would need to be considered and developed further once a decision was made to pursue DPR. The unit costs of DPR would be higher than expanding the current raw surface water allocation and conventional water treatment works, which would have a knock-on effect on consumer tariffs. These economic costs would need to be compared to the towns risk exposure to climate change and water demands from surrounding areas within the Western Cape should they continue to abstract water from surface water resource not under their control.

ACKNOWLEDGEMENTS

I would firstly like to thank the University of Cape Town for allowing me the privilege of completing my Master's degree in Water Quality Engineering. They have provided me with a solid platform upon which I have expanded my engineering knowledge in a key field of the built environment.

I would like to thank my supervisor Professor George Ekama, who although does not specialise in the field of water reuse, provided me with valuable insight, resources and a constant sounding board for my research framework. I feel privileged to be one of the final Masters students being taught under your guidance and hope to further develop this knowledge gained from you within my professional career.

I would like to thank James Beukes, Bradley Dyers and Willem De Kock from the Stellenbosch Municipality for their valuable input and operational data provided. They were always available and willing to assist during this research which was critical in reporting on water quality data and developing an accurate lifecycle costing model. I would also like to thank the various suppliers of chemicals who provided me with key data and market related pricing.

I would also like to make mention of Dr. Edward Archer at the Stellenbosch University who provided me with valuable insight on the contaminants of emerging concern within Stellenbosch's rivers as part of his post doctorate research.

A big thank you to Louis Koen and Neeren Govender from Aurecon for their input into my research and helping me develop a framework which would provide meaningful and relevant outcomes. Your enthusiasm and dedication to the water and wastewater consultancy sector inspires me and other young engineers around you to continually develop into well rounded professionals.

Finally, I would like to thank my family for all the support they have provided over the past year in helping me to achieve my goal of completing my Masters!

DECLARATION

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.........Signed by candidate...............

Murray Raubenheimer Pr.Eng

Table of Contents

TABLES

FIGURES

LIST OF ABBREVIATIONS

AOP	Advanced oxidation processes
AMD	Acid mine drainage
AWT	Advanced water treatment
AWTW	Advanced water treatment works
BAC	Biological activated carbon
BNEPR	Biological nutrient and excess phosphate removal
CAS	Conventional activated sludge
CAPEX	Capital expenditure
CCP	Critical Control Points
CEC	Contaminants of emerging concern
CIP	Cleaning in place
COD	Chemical oxygen demand
COP	Critical Operating Points
CMA	Catchment Management Agency
DBO	Design-Build & Operate
DBP	Disinfection by-product
DOC	Dissolved organic carbon
DPR	Direct potable reuse
DWS	Department of Water and Sanitation
EBCT	Empty bed contact time
EC	Electrical conductivity
EDC	Endocrine disrupting compounds
EIA	Environmental Impact Assessment
ESB	Engineered storage buffer
FIDIC	Fédération Internationale Des Ingénieurs-Conseils
FRT	Failure response time
GAC	Granular activated carbon
IPR	Indirect potable reuse
LERIB	Lower Eertse River Irrigation Board
LRC	Log removal credit
MBR	Membrane biological reactor
MF	Microfiltration
MLE	Modified Ludzack- Ettinger
NDMA	N-nitrosodimethylamine
NEC	New Engineering Contract
NGWRP	New Goreangab Water Reclamation Plant
NF	Nanofiltration
NTU	Nephelometric Turbidity Units
NWRI	National Water Research Institute (USA)
NWRS	National Water Resource Strategy (RSA)

OGWRP	Old Goreangab Water Reclamation Plant
OPEX	Operational expenditure
O&M	Operation and maintenance
PCP	Personal care products
PPP	Public Private Partnership
PVDF	Polyvinylidene fluoride
RO	Reverse osmosis
SANS	South African National Standards
SCADA	Supervisory control and data acquisition
SPV	Special purpose vehicle
TCEQ	Texas Commission of Environmental Quality
TDS	Total dissolved solids
THM	Trihalomethanes
TOC	Total organic carbon
TMP	Transmembrane pressure
TSS	Total suspended solids
TWDB	Texas Water Development Board
UF	Ultrafiltration
U.S.	EPA U.S Environmental Protection Agency
UV	Ultraviolet
VOC	Volatile organic compound
VSS	Volatile suspended solids
WCWSS	Western Cape Water Supply System
WC/DM	Water conservation and demand management
WHO	World Health Organisation
WMA	Water Management Area
WRC	Water Research Commission
WSDP	Water Services Development Plan
WTW	Water treatment works
WUL	Water Use Licence
WWTW	Wastewater treatment works

1. INTRODUCTION

1.1 Background

The Western Cape is a water stressed region and has suffered severe droughts over the past decade which has placed strain on raw water resources for both agriculture and municipal use. The looming crisis came to a tipping point in March 2017 when the Western Cape Government declared the area a disaster zone. This led media to proclaim a ‘Day Zero’ which was then used by the City of Cape Town to describe when the Western Cape Water Supply System (WCWSS) would drop below 13.5% capacity. At this stage the City of Cape Town would introduce extreme restrictions to ensure the remaining accessible water would last a further three months. These restrictions would lead to shutting off potable water supply to residential areas and forcing residents to collect water daily from collection points. Only commercial and industrial centres would remain connected to the municipal supply as well as key installation such as hospitals, government buildings and other critical facilities. The crisis was due to many factors including climate change, increasing urbanisation and ageing infrastructure to name a few. The crisis was averted through strict water conservation and demand management of existing resources (Ziervogel, 2019). These water scarcity problems will persist in the future unless water management authorities are able to augment existing raw water resources with a mix of desalination, groundwater and reclamation of treated effluent.

Stellenbosch is located approximately 50km from the Cape Town Metropole. The town of Stellenbosch forms part of the Stellenbosch Local Municipality in the Western Cape with a population of approximately 23 689[1]. The town is situated below the Simonsberg and Jonkershoek Mountains on the banks of the Eerste River. The town is a popular tourist destination all year around due to the abundant wine estates, restaurants, galleries and markets. The town is also home to the Stellenbosch University which sees an influx of students during term times who add to the town’s water demand patterns. The tourist and student population play a significant role in contributing to the local economy and therefore it was essential that water supply can meet the growing demand to sustain the local economy in the future.

The town forms part the WCWSS and was subjected to severe water restrictions from 2016 to 2018 imposed by the Department of Water and Sanitation. The town was however able to cope these restrictions when compared to rest of the Western Cape. This was due to the Stellenbosch water supply system not relying solely on the City of Cape Town’s bulk supply from the Theewaterskloof Dam, which forms part of the Breede Water Management Area (WMA) run by the Breede-Gouritz Catchment Management Agency (CMA). Stellenbosch forms part of the Berg WMA which is managed by the newly established Berg-Olifants CMA. The town is supplied with bulk raw water from three sources, namely; the Riviersonderend Government Water Scheme (Theewaterskloof Dam), the Kleinplaas Dam and the Idas Valley Dams (Hatch, 2017). The ability to augment their raw water supply from three separate sources improved the Municipalities resilience and shielded them from the harsh restrictions which were implemented elsewhere in the Western Cape. The ability to future proof themselves from droughts in future however cannot only be through diversifying surface water resources, which are under continual strain due to increasing water demands, lack of sufficient space for new dams and increasingly uncertain rainfall.

[1] Census 2011 figure of 19 068 escalated to 2019 at 2.75% which is equal to the population growth rate between the 2001 and 2011 Census data.

The Stellenbosch Municipality has previously identified the potential for the reclamation of water from the Stellenbosch Wastewater Treatment Works as long-term intervention (WSDP, 2012). The ability to treat wastewater effluent using advanced treatment processes and augment the existing raw water supply through either direct or indirect potable re-use will provide greater resilience to the water scarcity problems currently facing the Stellenbosch Municipality.

There have been significant developments in research into water reclamation from wastewater effluent in the past two decades both within South Africa and internationally. These studies have focussed on the identifying the constituents of this raw water source to determine the most effective treatment technologies to mitigate health risks to the public. The development of water reuse guidelines within the United States, Australia and Singapore have provided other countries with benchmarks upon which to develop their own guidelines based on local conditions. South Africa, through the Department of Water and Sanitation and Water Research Commission, have begun to conduct research and publish papers based on international best practice which will be explored further within this thesis. The other factors which must also be addressed in any water reclamation scheme are as follows (Swartz, 2016):

- Wastewater pollutants
- Costs (capital and operational)
- Waste / residual streams
- Public health risks
- Social acceptance
- Environmental concerns

The success of any re-use scheme must address all of these components for it to be successful.

1.2 Aims and Objectives

The aim of this research is to investigate the feasibility of implementing a Direct Potable Reuse (DPR) scheme within Stellenbosch by utilising the Stellenbosch WWTW effluent. The study will look at current DPR schemes both within South Africa and internationally and apply the principles from these case studies to the Stellenbosch local conditions. The study will review all relevant legislation and regulatory frameworks for water reclamation to understand how this water resource can be managed to augment current raw water supply.

The study will look at all available advanced water treatment technologies suitable for a DPR plant to ensure the multiple barrier approach is followed to remove all Contaminants of Emerging Concern (CECs) which pose a health hazard to humans. The selected treatment train will then be further developed in terms various scenarios and production capabilities which shall focus on the technical aspects to ensure the DPR plant can be integrated into the Stellenbosch water supply system. The study must also focus on the social and environmental aspects of DPR which could have an impact on the plant’s acceptance by relevant stakeholders.

The DPR plant capital and operational expenditure will then be modelled over a 20-year lifecycle and compared with the ‘do nothing’ scenario to determine its financial sustainability. The research will investigate whether or not the Stellenbosch Municipality should rather increase their allocation from the current surface water resources or augment their current allocation with reclaimed water. The study will compare the unit costs of various scenarios and what impact these would have on the current drinking water tariffs which consumers are charged.

1.3 Research Hypothesis

The Stellenbosch Municipality will need to expand its potable water resources in future to meet the growing demand of users within the town. It is hypothesised that a direct potable reuse plant is a feasible water intervention, which could be implemented to augment the future water resource mix.

1.4 Key Research Questions

The research will focus on answering the following key questions:

- What is the current status of DPR within South Africa and internationally?
- What are the risks to human health associated with water reclamation and how can these be mitigated?
- What water reclamation regulations, standards and policies does South Africa have in place?
- Will Stellenbosch be able to meet its future water demands through current surface water supply schemes?
- What is the most suitable advanced water treatment process for DPR for the Stellenbosch conditions and does this meet international best practice?
- What are the important technical, social and environmental considerations which must be taken into account when analysing the DPR plant in Stellenbosch?
- Can a DPR plant in Stellenbosch produce drinking water at a lower unit cost than current practices?

1.5 Scope and Limitations of Research

The study only focusses on DPR as an alternative water resource for the Stellenbosch potable water supply. The study does not investigate other water resources such as desalination, groundwater extraction, rainwater harvesting and new dams which should form part of a water reconciliation strategy to determine the most feasible solution.

The operational and water quality data obtained for the Theewaterskloof Dam and Paradyskloof WTW was incomplete. The water quality results from the Theewaterskloof Dam was only available from a single data set supplied by the Stellenbosch Municipality. This was due to the raw water only being tested quarterly by an external laboratory and the historical results were not available. The Paradyskloof WTW operational and water quality data set was interrupted due to the works undergoing a refurbishment whilst this research was undertaken.

The research is also limited by the amount of data on DPR plants within South Africa and internationally. DPR forms less than 1% of the world's drinking water supplies and there are currently only two DPR plants within Southern Africa. The lifecycle costing model within this research is therefore only based on two data sets taken from these local case studies. It is therefore difficult to predict the accuracy of the model outputs developed as part of this research.

2. LITERATURE REVIEW

2.1 Planned Potable Re-use

There are two forms of planned potable reuse which are prevalent in wastewater reclamation using advanced water treatment technologies. These are Direct Potable Reuse (DPR) and Indirect Potable Reuse (IPR). The treatment train process design and final water quality requirements are similar for both types of planned potable reuse. The subsequent discharge location of this product water after undergoing advanced water treatment is where the two types differ.

2.1.1 Indirect Potable Reuse

IPR occurs when product water from an advanced water treatment plant is discharged into an environmental buffer such as a dam, groundwater aquifer, river or reservoir before going through a conventional water treatment plant. This is the most common form of planned potable reuse due to the benefits of an environmental buffer to mitigate potential health hazards.

The need for an environmental buffer prior to conventional water treatment is due to three main reasons. The first being that it allows for a response time should the product water not meet water quality standards which will allow downstream process units to react accordingly (Tchobanoglous et al., 2015). The second reason is that the buffer can act as a storage facility when excess product water is available during months of heavy rainfall when water supply exceeds demand (Gerrity *et al*., 2013). The third factor is due to natural water treatment processes occurring in these environmental buffers, which further breakdown any organics or other harmful micropollutants (Tchobanoglous et al., 2015).

The above advantages of discharging product water into an environmental buffer can also come at a higher cost due to infrastructure requirements and energy consumption to transport the product water to the environmental buffer. This is evident in Las Vegas whereby wastewater effluent is discharged into a river course before being pumped over mountains to an advanced water treatment plant and discharged into the municipal water supply (Gerrity *et al*., 2013). The second example is in San Diego whereby wastewater effluent undergoes full advanced treatment before being pumped out of the metropolitan area to a reservoir where it then gravitates back into the metropole. The lifecycle costs associated IPR systems can therefore make DPR a more attractive option in terms of costs and energy efficiencies (Gerrity *et al*., 2013).

2.1.2 Direct Potable Reuse

Direct Potable Reuse (DPR) occurs when wastewater effluent undergoes advanced water treatment before either being discharged into a raw water source immediately upstream of a conventional water treatment plant, blended with the product water from a conventional water treatment plant, or immediately introduced into a potable distribution system (Gerrity *et al*., 2013). There are both local and international DPR plants operational whereby product water is discharged into either the raw water source or blended with conventional water treatment product water and shall be further discussed in Chapter 0. There are only two current examples[2] of the third type of DPR, whereby it is injected directly into the municipal potable supply. These plants however are both treating acid mine drainage (AMD) water to potable standards and hence are beyond the scope of this research. The lack of DPR plants which reclaim municipal wastewater and inject it directly back into a potable distribution system is due to the many unknowns and public health risks (Tchobanoglous et al., 2015).

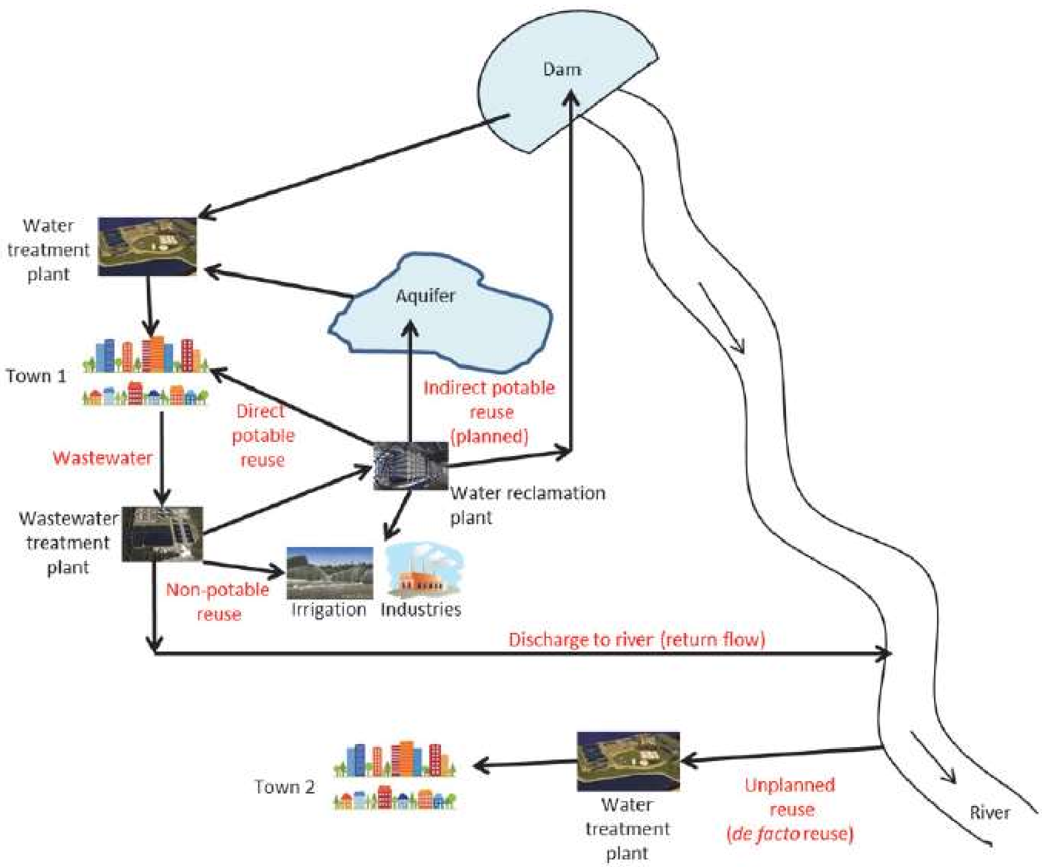

Figure 1: Schematic diagram of different types of water reuse

2.2 Unplanned Potable Reuse

Unplanned or *de facto* potable reuse occurs when wastewater effluent is discharged into a water body (usually a river) which is then used a source of drinking water downstream (Tchobanoglous *et a*l., 2015). The wastewater effluent is then usually abstracted and treated in a conventional water treatment plant. This type of unplanned potable reuse occurs throughout South Africa and internationally (Swartz *et al*., 2015). This is prevalent in the Vaal River system which extracts water from the Vaal Barrage which is the final destination for numerous wastewater treatment plants effluent. The contamination of the Hartbeespoort Dam, Roodeplaat Dam, Rietvlei Dam and Vaalkop Dam due to eutrophication caused by the excess nutrients in the effluent from wastewater treatment plants have led to major public health concerns across South Africa (Swartz *et al*., 2016). These raw water sources feed into conventional water treatment plants which do not have the advanced water treatment technologies installed to remove the pollutants found in wastewater effluents.

[2] eMalahleni Water Reclamation Plant (Mpumalanga, South Africa) and Optimum Coal Mine Reclamation Plant (Mpumalanga, South Africa)

The environmental and health concerns which are currently emerging due to unplanned potable reuse will either lead to advanced water treatment technologies being installed downstream of conventional WWTW or upstream of conventional WTW depending on the type of source control. Current studies show that most surface and groundwater is contaminated with chemicals found in wastewater effluent (Barnes *et al.*,2008) in the USA. These CECs have been detected in South African surface and groundwater recently and there is ongoing research to quantify them in terms of risk of human exposure (Swartz *et al.*, 2018).

2.3 Direct Potable Reuse Schemes

2.3.1 Local case studies

Beaufort West Reclamation Plant

The 2.0Mℓ/d Beaufort West Reclamation Plant was the first DPR scheme within South Africa when it was commissioned in January 2011. The need for DPR was the result of severe drought in the Beaufort West region in the Great Karoo. The municipality put the DPR project out to tender as a Design-Build & Operate (DBO) contract with a 20-year concession. The scheme went through the appropriate Environmental Impact Assessment (EIA) and community participation processes in a short space of time due to the dire need to find an alternative water source, as the surface and groundwater resources had dried up (Marais *et al.*, 2011).

The DPR scheme uses treated effluent from the Beaufort West WWTW as its only raw water source before undergoing advanced water treatment. The process design was based on the multi-barrier approach with the treatment train consisting of the following steps depicted in Figure 2.

Rapid sand filtration – Membrane filtration – Reverse Osmosis – Advanced Oxidation – Disinfection

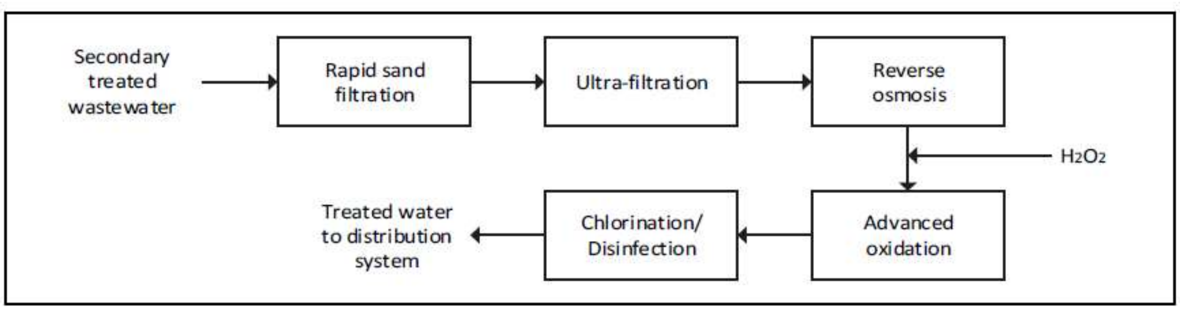

Figure 2: Beaufort West Reclamation Plant treatment train (Swartz et al., 2014)

The WWTW process upstream of the reclamation plant is also an important factor in the design on the reclamation plant. The WWTW is a conventional activated sludge process operating in a Modified Ludzack-Ettinger (MLE) configuration. This biological process does not remove excess phosphate and therefore the activated sludge is dosed with ferric chloride ($FeCl_3$) prior to secondary settlement. The presence of phosphate in concentrations above 0.5mg/ℓ causes accelerated biological growth on the RO membranes which impact on the frequency of chemical cleaning of the membranes and reduce life expectancy. The effluent then passes through another large storage basin which settles out any further suspended solids and acts as an engineered buffer between the WWTW and reclamation plant (Marais *et al.*,2011).

The product water from the reclamation plant is then blended in a 1:4 (20%) ratio (which can be increased to 25%) with conventionally treated water from the Beaufort West WTW in a storage reservoir prior to entering the potable distribution system. The product water is monitored according to the SANS 241-1 (2011) drinking water quality requirements but this does not include CECs and other micropollutants which shall be further discussed in Chapter 2.6. The basis for not carrying out these tests is that the process design is based on the Singapore NEWater Reclamation Plant which has a comprehensive water quality monitoring programme in place (Seah *et al*,. 2008). The CECs however within wastewater effluent will differ from country to country due to varying organic and inorganic constituents, pharmaceuticals and other micropollutants. This assumption must be further tested and is discussed in Chapter 4.8.

eMalahleni Water Reclamation Plant

The eMalahleni Water Reclamation Plant in Mpumalanga has been operational since 2007. The reclamation plant treats 30 Mℓ/d of acid mine drainage water from four different colliery's into potable water. 20 Mℓ/d of the product water is conveyed to the eMalahleni municipal reservoirs to make up approximately 20% of the potable water supply for the area. The remaining 8 -10 Mℓ/d of the product water is reused for mining applications such as dust suppression and domestic use. The advanced water treatment process train is represented in Figure 3 below and utilises the following technologies:

- Neutralisation
- Clarification
- Ultra-filtration
- Reverse Osmosis
- Chlorination

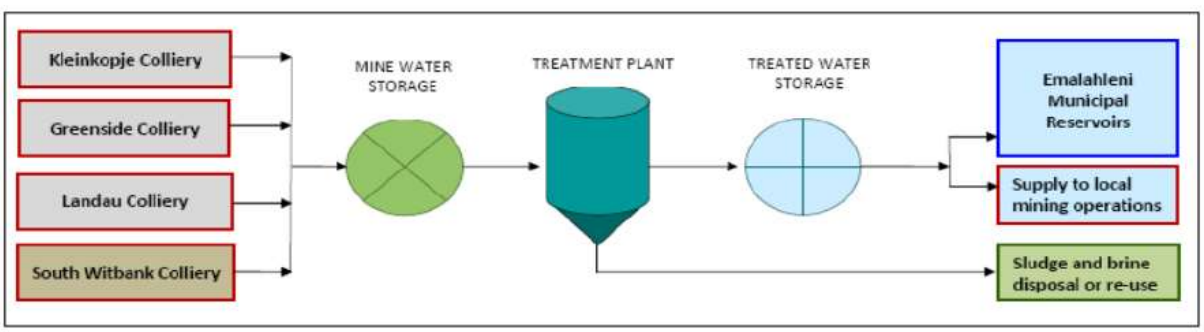

Figure 3: eMalahleni West Reclamation Plant treatment train (Bhagwan, 2012)

The water quality is tested against SANS 241-1 (2015), the World Health Organisation drinking water quality standards and the Department of Water Affairs (DWA), now the Department of Water and Sanitation, Aquatic Ecosystem Guidelines (Sergienko, 2015).

The project was a first for South Africa in terms of the procurement strategy used owing to the eMalahleni Municipality's budgetary constraints and lack of resources to operate the reclamation plant. The Municipality in conjunction with Anglo-America and BHP-Billiton entered into a Public-Private Partnership (PPP). The reclamation plant is operated by the mines whilst the municipality has entered into a water purchasing agreement.

Optimum Coal Mine Reclamation Plant

The Optimum Coal Mine Reclamation Plant also resides in Mpumalanga and treats 15 Mℓ/d of used mine water. The product water from the advanced water treatment plant is then further polished before being injected into the Steve Tswete Local Municipality potable water distribution system. The additional product water is either used for mining activities or discharged into the tributary of the Klein Olifants River to replenish the run off loses due to the open cast mining activities. The plant uses a similar advanced water treatment process train as the eMalahleni Water Reclamation Plant as can be seen in Figure 4 below.

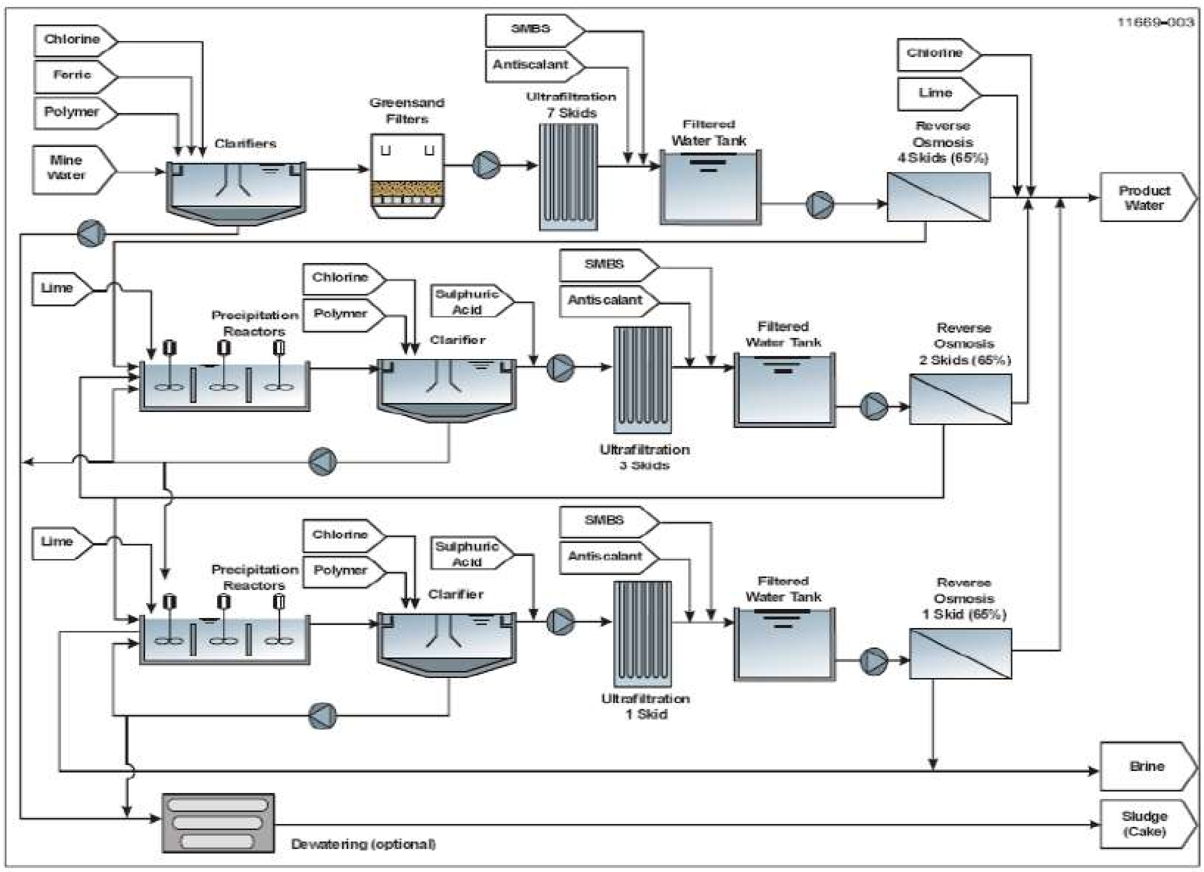

Figure 4: Optimum Coal Mine Reclamation Plant treatment train (Cogho & van Niekerk, 2009)

The brine stream (2% of raw water volume) from the plant is stored in lined evaporation dams to be further concentrated. It is unclear what happens with this concentred brine once all the water has evapourated or whether it goes for further treatment. The sludge waste stream is also stored in lined dams to be dewatered and begin the process of product recovery (Cogho & van Niekerk, 2009).

Optimum Coal Holdings and the Steve Tswete Local Municipality setup Memorandum of Understanding (MoU) to reach a non-binding agreement in 2006, to make the potable water available to municipality from the reclamation plant (Cogho & van Niekerk, 2009). This was taken a step further in 2010 when a water supply agreement was signed between both parties (Cogho, 2012).

2.3.2 International case studies

Old / New Goreangab Water Reclamation Plant (Windhoek, Namibia)

The Old Goreangab Water Reclamation Plant in Namibia was the first DPR plant treating wastewater effluent in the world. The Windhoek area during the 1960's faced a severe drought which led to the first 4.8Mℓ/d reclamation plant being built and commissioned in 1968 which provided 4% of the total potable water supply. The reclamation plant capacity was further extended to 14Mℓ/d in 1992 in response to another drought (Haarhof, 1991). The plant used a blend of wastewater effluent from the Gammams WWTW and surface water from the Goreangab Dam for its feedwater. It is important to note that the Gammams WWTW only treated domestic wastewater and all industrial wastewater was sent to another WWTW to reduce the risks associated with chemical contaminants found in industrial wastewaters, as little research had been done on their public health impacts.

The Old Goreangab WRP treatment train in 1968 consisted of very limited advanced water treatment technologies when compared to the current advanced water treatment technologies used today. The water quality standards at the time were fairly rudimentary in terms of monitoring of pollutants and would not have met current targets used today. The reclamation plant's process design (Figure 5) was based upon removal of all suspended solids and organics within the raw water feed. This differs to the current multibarrier approach adopted in DPR schemes, which focus on multiple barriers to breakdown all classes of pollutants.

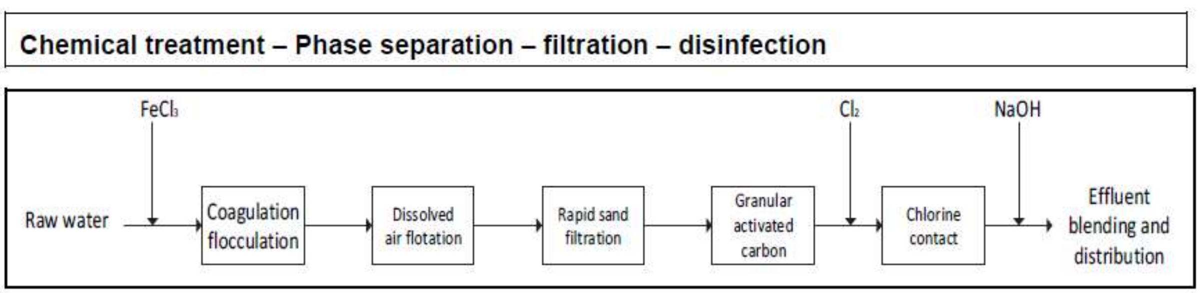

Figure 5: Old Goreangab Water Reclamation Plant (Swartz et al., 2014)

The advances in advanced water treatment technologies in the subsequent years following the plants commissioning and further climatic conditions prevalent in Windhoek in 1997, led to the New Goreangab Water Reclamation Plant being built adjacent to the old plant in 2002. The New Goreangab WRP had a capacity of 21Mℓ/d and like its older counterpart, reclaimed a blend of wastewater effluent from the Gammams WWTW and Goreangab Dam. The New Goreangab WRP utilises the old plants treatment train steps as pre-treatment prior to further advanced water treatment technologies to provide a more comprehensive multiple barrier approach to target a wider spectrum of pollutants.

The new plant incorporates ozonation after the original treatment steps to further oxidize any organic compounds and provide superior pathogen inactivation due to lower suspended solids than in the pre-ozonation step (Aurecon, 2018). The water is then dosed with hydrogen peroxide (H_2O_2) to remove any ozone residuals before passing through BAC and GAC filters for biodegradable matter and organics removal respectively (Swartz *et al.*, 2014). The water then passes through ultrafiltration (UF) membranes before chlorination, stabilisation and final blending at a ratio of 1:3 with conventionally treated water. The process flow diagram is set out in Figure 6.

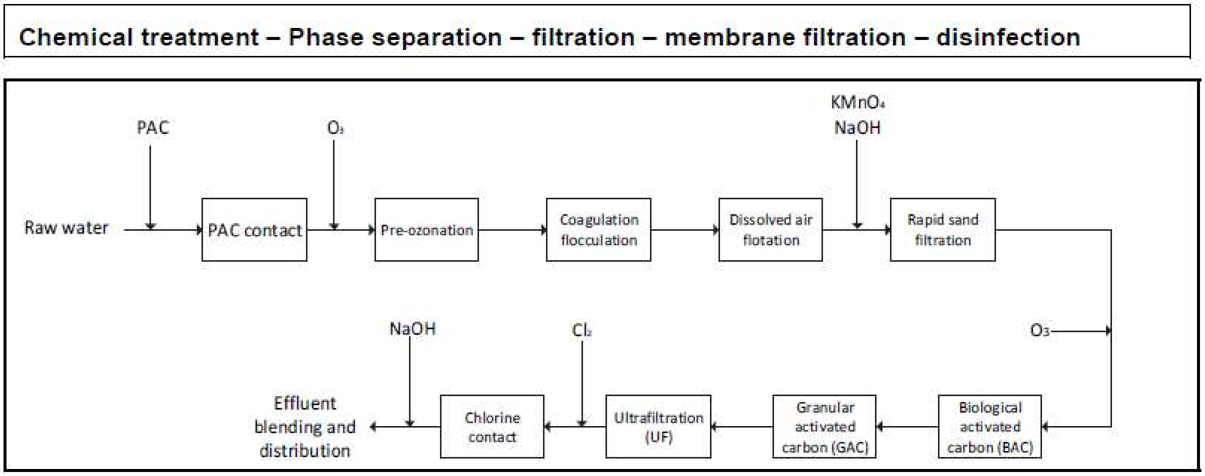

Figure 6: New Goreangab Water Reclamation Plant treatment train (Swartz et al., 2014)

The New Goreangab WRP is managed through a 20-year design, build and operate concession through the Windhoek Goreangab Operating Company Ltd. (WINGOC). WINGOC was the special purpose vehicle (SPV) setup by three separate companies; Berlinwasser International, VA TECH WABAG and Veolia Water. Since its inception in 2002 the plant has been used extensively for research into raw water and product water characteristics to determine the effectiveness of the various treatment barriers in removal of pollutants.

Cloudcroft (New Mexico, USA)

The village of Cloudcroft in New Mexico was facing water shortages due to continual droughts in the area and seasonal fluctuations of visitors, which increased the population from 850 to 2000 people. These challenges forced the town to look at innovative ways of augmenting their current raw water resources from springs and wells. This led relevant water authorities in 2009 to construct a 0.379Mℓ/d DPR plant to treat the wastewater effluent from the local WWTW which incorporated MBR technology. The MBR wastewater effluent is then treated in an advanced water treatment plant before undergoing blending with 51% of other raw water resources and further treated in conventional water treatment plant. The advanced water treatment plant and conventional water treatment plant process trains are represented in
Figure 7.

Big Spring Raw Water Production Facility (Texas, USA)

The Big Spring Raw Water Production Facility rose out of necessity due to the prolonged drought conditions experienced within Texas. The 7.6Mℓ/d reclamation plant was commissioned in 2013 and treats wastewater effluent from the Big Spring WWTW using advanced water treatment technologies. The plant utilises microfiltration (MF) prior to reverse osmosis (RO) and advanced oxidation processes (AOP). The product water is then blended with other surface water resources in a reservoir to make up less than 20% of the total raw water. The raw water is then conveyed to a conventional water treatment works for further treatment before being distributed to the municipal supply network. The treatment process design is illustrated in Figure 8.

Reverse Osmosis – Advanced Oxidation – Blending – Membrane filtration – UV disinfection – Activated Carbon – Disinfection

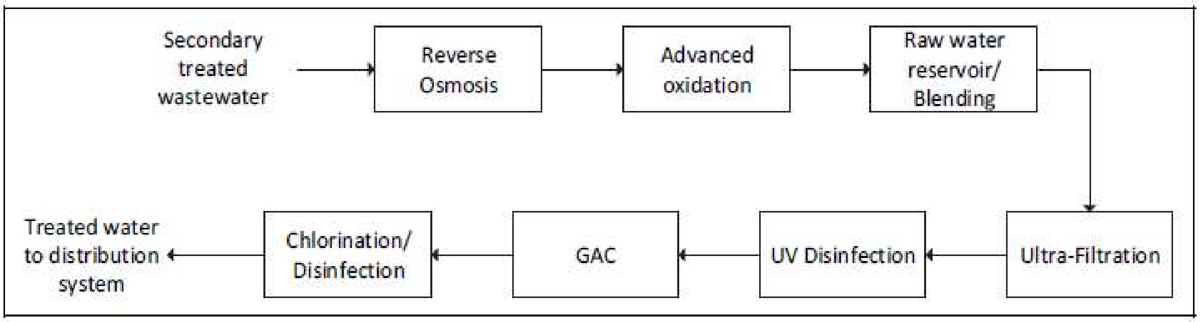

Figure 7: Cloudcroft DPR Plant treatment train (Swartz et al., 2014)

Membrane filtration – Reverse Osmosis – Advanced Oxidation – Blending – Flocculation – Sedimentation – Filtration – Disinfection

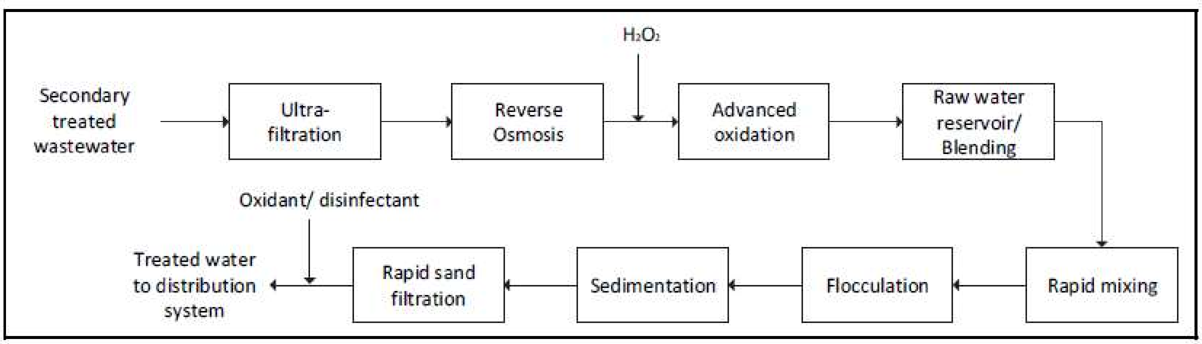

Figure 8: Big Spring Raw Water Production Facility treatment train (Swartz et al., 2014)

The Big Spring reclamation plant has undergone substantial water quality testing regimes to better understand the multiple barrier approach and effectiveness of each advanced treatment technology in removing harmful pollutants. The sampling campaign focussed on a large list of pollutants including the following among others (Steinle-Darling *et at*., 2016):

- Pharmaceuticals,
- Personal care products (PCP),
- conventional disinfection by-products and their formation potentials, and others),
- Pathogens (viruses, protozoa, and bacteria),
- Chemical and microbial surrogates.

The initial results published have shown that the reclaimed water in comparison to the raw surface water from the Moss Creek Lake have been superior in all of the above pollutants (Steinle-Darling *et at*., 2016). These results provide conclusive evidence that not only is reclaimed water superior in quality to surface water resources but also that surface water resources are contaminated with pollutants found within wastewater effluent. This study is only representative of Big Springs and its water resources but must surely be an important point when arguing for the benefits of DPR over IPR.

2.4 Wastewater Pollutants

There are numerous constituents in wastewater effluent which must be taken into consideration to determine their impacts on public health depending on their concentrations and period of exposure. There have been studies conducted in Namibia, USA, Singapore and recently in South Africa to detect and determine what impact these constituents, which are not prevalent in conventional raw water resources, have on epidemiological and toxicological health aspects. These studies have produced water quality guidelines for monitoring reclaimed water which shall be discussed further in Chapter 2.6. These guidelines focus on monitoring of biological, organic and inorganic constituents present in final wastewater effluents and are illustrated in Figure 9.

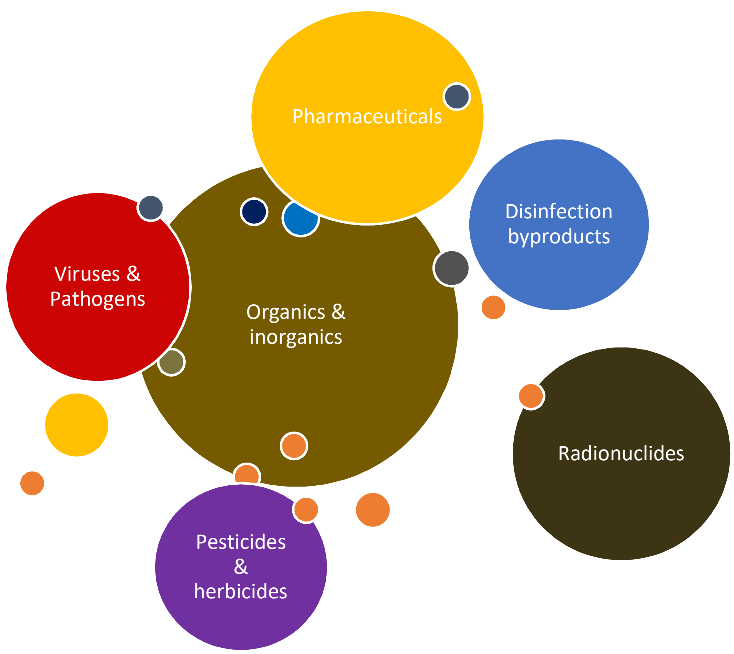

Figure 9: Wastewater pollutants (Aurecon, 2016)

The importance of understanding and identifying the types of pollutants found in wastewater is to determine the necessary treatment train, associated costs and operation and maitenance required to reduce the pollutant levels to acceptable standards prior to reuse for drinking water supplies. A range of new analytical instrumentation has been developed to detect extremely low concentrations of organic and inorganic pollutants in wastewater. These instruments and analyses techniques are however extremely expensive and therefore cannot always be conducted for each type of pollutant. The U.S. EPA (2008) reported over 26,000 types of chemical compounds which could be found in drinking water, of which roughly 100 chemical compounds were chosen to be investigated further (NWRI, 2015). It is therefore of critical impotance to any DPR project that a comprehensive effluent sampling regime is carried out prior to the process design selection. The seven main categories of wastewater pollutants detected in recent studies are developed in the sub sections below.

Organic Compounds

Organics occur in raw wastewater through sources such as faecal matter, kitchen waste, oils, greases and other substances. They also contain volatile organic compounds (VOCs) usually found in industrial wastewater streams from products such as fuels, solvents, paints and adhesives (Aurecon, 2016). The physical and biological wastewater treatment processes are able to remove most of the biodegradable soluble, biodegradable particulate and unbiodegradable particulate organics. The unbiodegradable soluble organics are however usually discharged with the wastewater effluents in acceptable water quality concentrations for non-potable reuse.

The parameters for measuring organics within wastewater effluent are usually total organic carbon (TOC) and chemical oxygen demand (COD) within South Africa. COD is usually measured in South African WWTW effluents and provides an indication of the amount of oxygen required to decompose organic matter and chemically oxidizable pollutants. These organic compounds can be transformed into harmful disinfection by-products (DBPs) when chlorine is used for disinfection of final effluent. It is noted that the Stellenbosch WWTW MBR does not use any form of disinfection and would therefore be devoid of any potential DBP issues prior to any advanced water treatment process. The DBPs associated with residual organic compounds would however be of concern downstream in the advanced water treatment plant or conventional water treatment plant, should chlorination be included in the process.

Disinfection By-Products (DBPs)

Chemical disinfectants are used in wastewater and water treatment to kill off a wide range of microorganisms. They are also strong oxidants which can form harmful DBPs if consumed by humans. These DPBs have been proven to bring about the onset of certain forms of cancer due to their carcinogenic properties (U.S. EPA, 2008). The three main types of DBPs detected in disinfected water are trihalomethanes (THM), haloacetic acids (HAAs) and oxyhalides. These three main groups of DBPs have several sub groups of chemicals whose concentrations should be determined prior to potable reuse.

The number of DPBs detected in potable water exceeds 600 but has been narrowed down to the main three groups above by the U.S. EPA. The majority of these DPBs have been detected in such low concentrations that the above common DPB groups are classed as sufficient in terms of sampling requirements for potable reuse schemes. There has been further research conducted and non-common DPBs such as N-nitrosodimethylamine (NDMA) have been found in wastewater effluent (U.S.EPA, 2017). This DPB is resistant to certain advanced water treatment technologies (such as reverse osmosis) and must be addressed in the treatment process through other technologies due to its carcinogenic properties.

Inorganic Compounds

Inorganic compounds found in wastewater effluent are usually metals, salts, nutrients, oxyhalides and nanomaterials. These inorganic constituents found in wastewater effluent are dependent on the type of treatment process at the WWTW. The conductivity or total dissolved solids (TDS) concentrations are a fairly good indicator of the inorganic compounds within the wastewater effluent. The majority of these inorganic compounds can be removed at WWTW to levels well below drinking water quality standards for typical wastewater of municipal origin.

In most municipal wastewater the presence of heavy metals is low and well below the guidelines for drinking water. The salts within wastewater effluent are important to measure as they can impact on the salinity of the product water from a DPR plant which does not utilise RO technology. This can cause aesthetic concerns due to the taste of the product water, scaling and corrosion of distribution networks (Loewenthal et al., 1986).

Nutrient removal in most wastewater processes occurs biologically and this deals with nitrates and phosphates adequately for most effluent discharge standards. This however is not the case for water reclamation, as the nutrient load can have an effect on the downstream advanced water treatment technologies if not dealt with appropriately upstream.

Bromate (formed from bromide) and chlorite are oxyhalides which are formed in the presence of ozonation and chlorine dioxide disinfection systems respectively. These compounds can be particularly harmful to human health should they fall above the guideline concentrations in drinking water.

Nanomaterials are particles which are measured on the nanoscale and can be organic, inorganic or a composite of both. These materials are used in certain products for their unique surface chemistry, catalytic properties, strength, weight, and conductive properties compared to their larger-scale counterparts (National Science and Technology Council, 2011). These nanomaterials are starting to be used extensively in consumer products, however in current research to date, no link between human health issues and exposure to these nanomaterials has been made (U.S. EPA, 2012).

Pathogens

Pathogens are a group of microorganisms found in wastewater, of which some can pose a risk to human health. These microorganisms are present in the faecal matter of infected humans and are classified as enteric pathogens. The enteric pathogens cause disease in the host, where they live within the intestinal tract. These pathogens are classified into three categories: bacteria, parasites and viruses. This group of pathogens must be deactivated or removed from water via the treatment process prior to consumption to avoid an outbreak of diseases such as diarrhoea, typhoid fever, leptospirosis and many others (Swartz *et al*., 2018). The removal of these microorganisms is measured on the log scale because of their high concentrations in wastewater and method of measurement.

Bacteria are microscopic organisms which are excreted in human faeces of infected individuals and can therefore take on many different forms depending on the prevalence in the human and animal community from which the wastewater originates (U.S. EPA, 2012). These pathogens are spread via the faecal-oral route and are one of the leading causes of death in developing countries where a lack of adequate sanitation is common. Bacteria are monitored in water quality via two established faecal coliforms *E.coli* and *entrococus*. The first being one of the main wastewater effluent parameter measured across South Africa by laboratories. *E.coli* requires a minimum 9-log reduction during treatment prior to human consumption (NWRI, 2015). The World Health Organisation has listed over 12 bacteria which must be tested for in drinking water for disease prevention.

Parasites are cysts, spores, oocysts or eggs which can be extremely resistant to environmental conditions such as heat, sunlight and cold which would usually kill off other pathogens. The main two types of parasites found in wastewater are helminth and protozoa. Helminths are parasitic worms present in the form of adults, larvae, eggs or ova. Most helminths are not transmitted through drinking water except *Dracunculus medinensis* and *Schistosoma spp*. Protozoa are heterotrophic microorganisms which are extremely resilient to chemical disinfection. The main two harmful groups of protozoa to human health in wastewater are *Cryptosporidium* and *Giardia*. *Cryptosporidium* must be reduced by a minimum 10-log reduction during treatment before being consumed by humans in drinking water (NWRI, 2015). Helminths and protozoa are usually removed via sedimentation in wastewater due to their size and ability to cling onto other organisms for mobility. They are resistant to chemical disinfection via chlorine and other chemicals but are inactivated by ultraviolet (UV) disinfection which disrupts their cellular structure.

Viruses are the smallest of the three main types of pathogens in wastewater and rely on finding a host cell to replicate on. There are over 100 enteric viruses which cause waterborne diseases and produce infections in humans (U.S. EPA, 2012). The main viruses which are of particular importance in water reuse are enteroviruses, noroviruses, rotaviruses and adenoviruses. These viruses are usually reduced by up to a 3 to 4-log reduction using ultrafiltration membranes (as found at Stellenbosch WWTW) in tertiary treatment of wastewater which is insufficient to meet the minimum criterion of a 12-log reduction (NWRI, 2015).

Pharmaceuticals & Personal Care Products (PCPs)

Pharmaceuticals and their metabolites in recent years have emerged as potential endocrine disrupting compounds (EDCs) and have been detected in wastewater effluents. These chemical compounds are consumed through various medicines which eventually end up in the wastewater system and have been found in environmental water bodies, reclaimed water and drinking water (Kolpin *et al*., 2002, Brun *et al*., 2006). These chemicals range from antibiotics, estrogen (birth control pills), steroids, ibuprofen and paracetamol (all found in common medicines). These contaminants have been found in very low concentrations which are not harmful to human health and fall within the guideline concentrations for potable water reuse (Jones *et al*,. 2005).

Personal care products (PCPs) such as shampoo, sunscreen, lotions and fragrances are usually washed off in the shower or bath during the day and end up at the wastewater treatment works in significant quantities. Certain fragrances have been found in recent studies by Heberer (2002) and Ramirez *et al*. (2009) to be present in aquatic life residing in downstream waterbodies of wastewater treatment works.

Pesticides & Herbicides

Pesticides, herbicides and their metabolites can be discharged into the sewerage system through run off in areas surrounded by agricultural land. These contaminants have been found at nano levels within wastewater effluents, well below the regulated guidelines. The reason for these trace levels of contaminants is because they are not being directly discharged into wastewater systems but diluted during periods of rainfall. The trace contaminants which have not been absorbed by the various crops and soils are transported by surface run off into stormwater or sewerage systems. This issue is more prevalent in countries with combined sewer systems close to agricultural activity whereby contaminated stormwater run-off is blended with sewage before entering the wastewater treatment works. The abundance of vineyards and other agricultural activities in and around Stellenbosch is unique to the town and therefore these contaminants should be tested and identified in the final effluent so that they can be addressed within the advanced water treatment train.

Radionuclides

Radionuclides such as Radium -226 and 228, Radon – 222 and Uranium have been found in trace concentrations within wastewater effluents and reverse osmosis brine concentrate, particulary within in America (NWRI, 2015). These trace levels have been well below those which can pose a risk to human health but can still have a detrimental affect on water reclamation plants if not managed properly. These radionuclides can be discharged into the wastewater system through laboratories, universities, medical institutions and naturally occuring radioactive materials. The town of Stellenbosch is home to the Stellenbosch University, private and public hospitals and numerous laboratories which utilise radioactive material. These institutions should have proper procedures in place to dispose of radioactive waste but it would still be important to understand the levels of these trace contaminants prior to the implementation of a DPR plant.

2.5 Advanced Water Treatment Technologies

In recent years there have been advances in water treatment technologies which are able to remove a wide spectrum of contaminants within water. These have been labelled as advanced water treatment technologies and when used in a multi-barrier approach can be utilised for water reclamation from wastewater effluent. The multi-barrier approach refers to the number of advanced treatment steps with a specific process train to target the entire spectrum of known pollutants found in the raw water. The multi-barrier approach is used in water reclamation across the world to ensure no single process is relied on for complete removal of a particular contaminant, to mitigate the risk, incase that process is non-functional in the treatment train. The multi-barrier approach is the cornerstone for DPR and the main advanced treatment technologies available are discussed below, including their performance in removing the contaminants described in Chapter 2.4. The performance of these technologies is vital in determining the final water quality and referencing this against the available water reclamation guidelines.

2.5.1 Membrane Biological Reactors

Membrane Biological Reactors (MBR) have been implemented throughout the world as a type of advanced wastewater treatment technology. This technology was initially developed in the 1960's for particular applications and on a small scale which made the technology expensive and prohibitive to use. In recent years stricter environmental regulations imposed on wastewater discharge along with increasing water scarcity issues have led to significant cost reductions and advancements which have now made this a viable option for wastewater treatment.

The membrane step is used for liquid solid separation after biological treatment within the reactor. The membranes utilise a pressure differential across the membrane to reject most, if not all of the total suspended solids (TSS) and contaminants which are greater than the membranes pore sizes. The dissolved constituents within the wastewater are allowed to pass through the membranes, resulting in a permeate with very low turbidity. The presence of low turbidity levels are a vital precursor to any advanced water treatment technology.

The membranes can either be the submerged within the reactor or mounted on skids externally. There are numerous configurations of membranes from flat sheet to hollow fibre on the market but this study will not delve any further into this topic as the current Stellenbosch WWTW MBR utilises hollow fibre membranes (see Chapter 3.2). There are three types of membrane filtration categories commonly used for wastewater treatment and these are based on the pore sizes of the membrane which determine what contaminants and percentage of these contaminants they remove. These types of membranes will be discussed in further detail in Chapter 2.5.4.

2.5.2 Ozonation

Ozonation disinfection can be used as either a pre-treatment or post treatment step in advanced water treatment. Ozone occurs when oxygen (O_2) molecules and oxygen atoms collide to form ozone (O_3). These ozone molecules are powerful oxidising agents and lead to oxidation of contaminants. The disinfection mechanism works by disrupting the pathogens cell membrane and nucleic acids. This process causes irreversible damage to the cell's DNA which effectively deactivates it. The recent developments in identifying CECs have led to ozonation being included in most DPR configurations. It also has secondary treatment benefits to the aesthetics of the water by removing colour, taste and odours whilst leaving no residual traces as it decays in minutes. The effectiveness of the ozone disinfection is dependent on the dosage, contact time and oxidizable material present in the water into which it is introduced. The following table is a list of contaminants which are oxidised by ozone disinfection.

Table 1: Disinfection targets of ozonation (Aurecon, 2016)

Ozonation Disinfection		
Inorganic oxidation	**Pathogen deactivation**	**Organics oxidation**
iron	viruses	complex organic molecules
manganese	giardia	cyanides & phenols
hydrogen sulphide	cryptosporidium	endocrine disruptors
bromide	bacteria	pharmaceutical compounds
		natural & synthetic hormones
		surfactants & detergents
		colour and odours
		pesticides

Ozone disinfection can be used as a pre-treatment step to break down larger organic compounds into smaller compounds, as well as oxidation of soluble heavy metal ions into their insoluble oxidised forms (Aurecon, 2016). This treatment step when used in conjunction with granular activated carbon filtration can be extremely effective in the removal of soluble organics. This is desirable as it reduces biofouling on downstream process units such as ultra/nanofiltration and reverse osmosis which can extend membranes life expectancy, improve energy efficiencies and reduce chemical consumption for cleaning. These factors will lead to an overall improvement in treatment efficiencies and reduce lifecycle costs.

2.5.3 Granular Activated Carbon and Biological Activated Carbon Filtration

Granular activated carbon (GAC) filtration removes contaminants through absorption only whilst biological activated carbon (BAC) provides a media for both absorption and biological degradation of organics to occur.

The carbon media absorbs the contaminants as molecules collect and adhere to the surface. This is due to the attractive forces between the contaminants and the carbon overcoming the forces of the liquid. The granular media provide a large surface area to volume ratio which allows for maximum absorption within either a carbon bed or rapid rate filter. This also provides a host to microbial biomass which degrades biodegradable matter to the benefit of the filtration process. This process is usually referred to as BAC filtration and occurs in the presence of oxygen in the feedwater which provides an ideal habitat for microbes which feed on the inorganic and organic matter. The BAC process is usually preceded by an ozone dosing station to introduce oxygen into the water and further breakdown larger compounds for the microbes to breakdown in the filter.

GAC and BAC filters can be constructed in series or parallel depending on operational and maintenance processes with regard to replacement and/or regeneration of carbon. The absorption equilibrium is reached over time between the inlet contaminants and the effluent as the granular carbon media becomes saturated and cannot absorb any more contaminants. The filter is then taken off line and the carbon removed and regenerated via thermal activation. This requires carbon media to be baked in an 800°C furnace, which removes the contaminants. During this process the other filters can still operate in series providing a multi-barrier approach within a single advanced water treatment process. GAC and BAC processes have shown to be able to remove up to 50% of dissolved organic carbon (DOC) and 90% of toxic organic compounds and CECs (Snyder *et al*., 2007). Recent studies by Zhang *et al*. (2010) have shown that BAC processes can remove up to 4 times the number of organics (COD, TOC and DOC) that a GAC process can. Recent research has also indicated that certain pharmaceutical compound removal efficiencies are increased by up to 36% (Sbardella *et.al*., 2018). The target contaminants which GAC and BAC are effective in removing are as follows:

- Pharmaceuticals (enhanced with BAC)
- PCPs
- Industrial chemicals
- Endocrine disrupting compounds
- Complex organic molecules (enhanced with BAC)
- Pesticides and herbicides

2.5.4 Membrane Filtration

Membrane filtration is commonly used in most advanced water treatment processes due to its reliability to reject a wide spectrum of contaminants found within wastewater effluent. Membranes are able to remove salts, microorganisms, particulate matter and dissolved organics. Membranes are mostly made from polyvinylidene fluoride (PVDF) but there are others on the market made from other composite materials depending on their specific application. Membranes provide a physical barrier for liquid solid separation using differential pressure as the driving force to draw the filtrate or permeate through the membranes pores whilst any larger particles are left behind within the residual or waste. The type of membrane filtration selected is dependent on the feedwater quality along with the permeate quality requirements which must be achieved within the treatment step.

Microfiltration membranes generally have pore sizes ranging from 0.1 to 1.0μm but can also be as small as 0.05μm or as large as 3.0μm. Microfiltration is used as a pre-treatment step within advanced water treatment trains to remove suspended solids as well as bacteria and parasites (*Cryptosporidium* and *Giardia*) but does not remove viruses. The process is able to produce a 3-log reduction (99.9%) for *Cryptosporidium* and *Giardia* (SWTR, 2008). They operate under low transmembrane pressures (TMP) due to their pore sizes which effectively means lower energy requirements when compared to ultrafiltration and nanofiltration. They have recovery rates of between 85 – 95% which will result in a residual or waste stream of 15 – 5%.

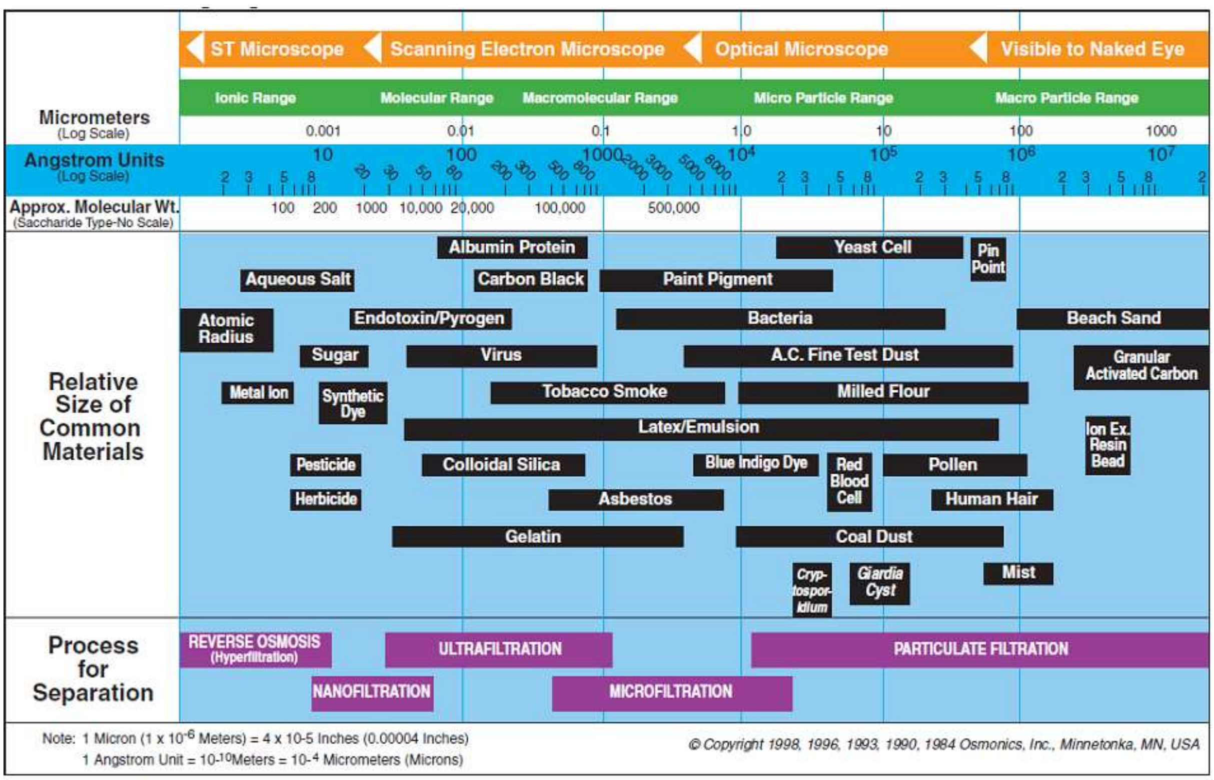

Figure 10: Membrane filtration scale guide (Radcliff, 2004)

Ultrafiltration membranes have pore sizes smaller than microfiltration but larger than nanofiltration ranging from 0.01 to 0.1µm. These membranes are able to remove a wider spectrum of contaminants due to their smaller pore sizes, including most types of viruses. They are also able to remove aesthetic determinants of water such as colour and odour but cannot remove pesticides and herbicides. The membranes use similar TMP, energy consumption and recovery rates as microfiltration. Ultrafiltration membranes are currently used at the Stellenbosch WWTW MBR for liquid solid separation which provides superior effluent quality water for a potential DPR plant. The benefit of having an MBR upstream of a DPR plant is that fewer advanced water treatment technologies are required to meet potable water quality requirements in terms of the various guidelines to be discussed in Chapter 2.6.

Nanofiltration membranes have pore sizes between 0.01 to 0.001µm. They are able to remove small organic compounds, most pesticides and herbicides as well as a portion of aqueous salts (NWRI, 2015). The process is able to achieve greater than 6-log reduction of all pathogenic bacteria, viruses and parasites (Metcalf *et al.*, 2014). Nanofiltration has the benefit of removing a portion of TDS which micro and ultrafiltration cannot. This is important when reviewing the TDS within the feedwater along with the final product water requirements for a DPR plant. The TDS concentration can only be reduced via nanofiltration or reverse osmosis within advanced water treatment technologies with varying TDS rejection rates of 30% and 90-99% respectively, for brackish water (as is the case with wastewater effluent). This process creates a residual stream with a high salinity concentration called brine which must be further treated or discharged. This brine stream becomes problematic at inland locations whereby seawater outfalls are not an option and other discharge methods must be used, which can be expensive and environmentally challenging. Nanofiltration membranes have recovery rates of between 70 – 90% depending on the salinity of the water, TDS removal and chemical cleaning requirements. They are operated under high pressures due to their small pore sizes and hence are more energy intensive than micro and ultrafiltration.

2.5.5 Reverse Osmosis

Reverse osmosis (RO) membranes are typically used in desalination plants due to their ability to reject high concentrations of TDS (up to 99% rejection) with pore sizes ranging from 0.001 to 0.0001µm. RO membranes use both physical exclusion as well as solution/diffusion to remove contaminants. The reverse osmosis process takes place under high pressures (55 – 85 bar) as the water is subjected to a higher hydrostatic pressure than its osmotic pressure across a semi permeable membrane. This results in the ions and larger molecules being rejected at the membrane surface and form part of the brine stream rejected during the process. RO can remove up to 99% of TDS in typical wastewater effluents as well as most other contaminants such as pesticides and herbicides which are not dealt with via conventional membrane filtration technology mentioned above. The RO membranes can recover close to 85% of brackish water but this figure drops substantially for sea water which has much higher salinity concentrations.

RO does have several disadvantages in the context of DPR plants in terms of fouling, operation and maintenance costs and brine disposal. The RO membranes require a high level of pre-treatment to prevent biofouling due to organic build up or mechanical damage due to large particles infiltrating the system. The high rejection of TDS results in high concentrations of micro organics, salts and other contaminants which can block up the membranes leading to reduced recovery rates and higher energy consumption to overcome this type of fouling. Scaling can also occur as inorganic compounds precipitate on the membrane surface and must be cleaned periodically with chemicals. The high pressures required to operate RO membranes also means that on top of the chemical costs for cleaning of the membranes, high energy consumption rates are experienced which increases operational expenditure (OPEX). RO membranes also require highly skilled operation and maintenance staff to ensure they are run optimally and remain this way during their lifecycle, more so than the other types of membrane filtration systems mentioned in Chapter 2.5.4. The third and final major disadvantage of RO systems is brine disposal, especially inland where discharge into surrounding waterbodies can be harmful to the aquatic environment as well as downstream users of the surface or groundwater. There are ways of dealing with the brine through evapouration ponds, groundwater aquifer recharge, return into sewerage network or further treatment to reduce the brine volume. These methods would all need to be tested against the DPR plant sites particular conditions to understand the most economical and environmentally acceptable disposal solution.

2.5.6 Advanced Oxidation Processes (AOP)

Advanced oxidation processes (AOP) are used to describe a number of treatment procedures including ozone (O_3), hydrogen peroxide (H_2S_2), chlorine (Cl_2) and UV. These processes in the past have been used individually but recent research has shown benefits in using combinations of them simultaneously. Used together they help to accelerate the degradation of chemical constituents which have not been oxidized or removed in previous treatment steps. The following AOPs are commonly used in potable reuse treatment:

- UV / Hydrogen Peroxide
- Ozone / Hydrogen Peroxide
- UV / Chlorination

The processes combine UV photolysis (when UV used) and the formation of highly reactive hydroxyl radicals which degrade organic compounds (Asano *et al*., 2007). These hydroxyl radicals are powerful chemical oxidants and are able to target trace organic pollutants and convert them into water, carbon dioxide and salts (Aurecon, 2016). The pH, dosage concentration, contact time as well as the non-target oxidizable species within the water are important parameters when determining what type of AOP is most suited to the required application. AOP containing O_3/H_2O_2 have been found to remove up to 98% of pharmaceuticals such as estrogen, progesterone and testosterone in South African wastewater effluents (Swartz *et al*.,, 2014). This process has been used at Big Spring, Cloudcroft and Beaufort West Water Reclamation Plants with reported success.

2.5.7 Summary

The table below is a summary of the available advanced water treatment technologies and their target contaminants found in wastewater effluents. The selection of the appropriate technologies would be based on a sound understanding of the wastewater effluent quality feeding the DPR Plant and final product water requirements.

Table 2: Treatment Barriers for DPR (adapted from Metcalf et. al., 2014)

Water Quality Variable	Advanced Water Treatment Technologies
COD	MF, UF, NF, RO, BAC, GAC
Particulate solids	MF, UF, NF, RO, GAC
Nutrients: Nitrogen and Phosphorous	Chemical precipitation, MF, UF, NF, RO
Microbiological	MF, UF, NF, RO, AOP
Salinity, Inorganic	NF, UF
Metals	Chemical precipitation, MF, UF, NF, RO
Micro-organics	Chemical precipitation, NF, RO, AOP, BAC, GAC, UV
Pesticides and Herbicides	RO, BAC, GAC, AOP
Disinfection By-products	RO, BAC, GAC, AOP

2.6 Reuse Treatment Standards

The water quality objectives of direct potable reuse are still in their infancy when compared to conventional water treatment standards. The problem with using conventional water treatment standards for potable reuse is the source water quality differs, as certain contaminants are introduced through wastewater effluent which have no minimum threshold within the drinking water guidelines. Potable water reuse guidelines have been developed within the USA (2012 & 2017) and Australia (2008) in recent years to define in terms of CECs, EDC and other trace organic contaminants which must be removed or deactivated during the advanced water treatment process.

The list of wastewater contaminants which could be tested for in the advanced water treatment process are endless and hence certain indicator and surrogate parameters have been developed by various agencies internationally which cover a wider spectrum of constituents. It is important to distinguish between indicators and surrogates when reviewing advanced water treatment quality targets associated with DPR. Indicators are individual constituents which have biodegradable and physiochemical characteristics which are the same as a family of constituents. Surrogates are bulk constituents which are used to evaluate the performance of individual treatment steps (TWDB, 2015).

These indicator and surrogate parameters for wastewater constituents can be broken up into two distinct groups as follows:

- Microorganisms (pathogens)
- Chemical constituents (metals, salts, DBP, pharmaceuticals, nutrients and inorganic compounds)

These two groups are assigned parameters for their various sub groups which must meet accepted log reductions or concentrations in accordance with prescribed guidelines. These guidelines are continuously being developed and expanded upon as research into public health impacts of these constituents continues and therefore cannot be classified as final. This research only focuses on guidelines and studies which have been published to date in 2018.

2.6.1 Southern Africa Guidelines

2.6.1.1 South Africa

South Africa currently has two separate standards for water and wastewater treatment. The drinking water quality standards can be found in SANS 241 (2015) and are based on conventional raw water resources, not including potable reuse. The SANS 241 standards set out maximum allowable concentrations in terms of microbial, physical, aesthetic and chemical determinants. The General Authorisations (in terms of Section 39 of the National Water Act, 1998) for wastewater discharge only account for wastewater effluent discharged into an environmental waterbody or for irrigational reuse. The lack of potable reuse water quality standards has led researchers within South Africa following two approaches:

1. Ensure that potable reuse water quality standards exceed the SANS 241 drinking water standards
2. Adopt international best practice guidelines where research has taken place on the raw and final product water quality for potable reuse

These two approaches both have disadvantages when it comes to applying them to South African potable water reuse schemes. The main issue with the first approach is that the raw water resources which feed conventional water treatment works are different to those that feed advanced water treatment works. The organic, pathogenic and chemical constituents which are discharged from a wastewater treatment works are usually not found in the same concentrations as in conventional water resources such as rivers, dams or aquifers. The conventional water treatment technologies are therefore not designed to remove these contaminants and therefore the water quality standards do not cover their monitoring parameters. The water can therefore be specified as acceptable for human consumption even though there may be high concentrations of other contaminants not listed within the standard.

The second approach can also be misleading as the contaminants found in wastewater are a product of the community which contributes sewage into the wastewater treatment works. This means that contaminants monitored in countries such as the USA, Malaysia (Singapore) and Australia may not be representative of the contaminants found in South Africa's wastewater. The same could be said of high income and low-income areas in the same city which could be served by different wastewater treatment plants and hence have varying concentrations of contaminants. This is a particularly important factor within South Africa where there is widespread inequality in close spatial proximity.

Recent research undertaken by the Water Research Commission in 2012 and 2014 has identified the lack of potable reuse guidelines as an area requiring extensive research. This research will use international best practice potable water reuse guidelines as a benchmark in the lack of any South African guidelines. This approach cannot be assumed to be definitive until such time that official guidelines are published by the Department of Water and Sanitation based on local conditions.

The WRC recently published *Emerging Contaminants in Wastewater Treated for Direct Potable Reuse: The Human Health Risk Priorities* (Swartz *et al.,* 2018) which compiled the first list of commonly found CEC's in reclaimed potable water in South Africa. The study identified compounds detected in South Africa wastewater and also the compounds which are not removed within the wastewater treatment process. The study found that most of CEC's identified were removed to trace levels well below those harmful to human exposure during the water reclamation treatment process. The study did not go as far as recommending their own minimum threshold concentrations for the CEC's identified and still relied on international guidelines.

2.6.1.2 Windhoek, Namibia

The New Goreangab Water Reclamation Plant water quality guidelines were developed between 1992 and 1996 using a combination of the following past experiences and drinking water quality guidelines (Swartz *et al*., 2015):

- Historical raw water quality
- Treatment plant capacity to treat this raw water to a certain standard
- WHO Drinking Water Guidelines (WHO, 1993),
- National Drinking Water Standards and Health Advisories U.S. EPA (U.S. EPA,1996),
- European Community Guidelines for the use of water for human consumption (80/778/EWG) (1980 and 1994 draft) (EC, 1980),
- Guidelines for the Evaluation of Drinking water for Human Consumption (1991) Department of Water Affairs, Namibia (Namibian Guidelines, 1991),
- Rand Water, Potable Water Quality Criteria (Rand Water, 1994).

This helped produce the first potable water reuse standard which has been further developed internationally. The guideline has become outdated as new research has identified new CECs which must be taken into account within the monitoring regime to protect public health. A copy of these raw and product water guidelines is included in Annexure A.

2.6.2 International Guidelines

2.6.2.1 USA

The USA drinking water standards were initially regulated by the Safe Drinking Water Act, 1974 (SDWA) and Clean Water Act, 1977 (CWA) which dealt with drinking water and wastewater discharge respectively. These acts have been updated through the years and provide guidelines for planned potable reuse implementation. The provisions within these documents placed the onus on water service providers to meet or better both the SDWA and CWA standards to;

"provide water quality treatment at a level sufficient to ensure public health protection" (U.S. EPA, 2017).

This provision therefore placed the burden on the water supply authorities to develop their own reuse guidelines to be adopted in each state. These guidelines were initially developed for IPR which is used extensively throughout the USA but only recently since 2012 have there been published guidelines and policies to address DPR. The WateReuse Association and National Water Research Institute (NWRI) appointed an Independent Advisory Panel of leading experts to develop a guideline on direct potable water treatment. The result was the *Framework for Direct Potable Reuse* which was published in 2015. This document was the first definitive DPR guideline published and has been used extensively across the world.

Since the *Framework for Direct Potable Reuse* was published, three states, namely; California, North Carolina and Texas have developed their own draft DPR guidelines. A summary of these three DPR guidelines and their water quality requirements have been extracted from the *EPA Potable Reuse Compendium* (2017) in Table 3.

Table 3: DPR Water Quality Guidelines within the USA (adapted from EPA, 2017)

State	Type of Potable Reuse	Treatment Requirements	Highlights
California	Groundwater Replenishment Using Recycled Water via Surface Spreading and Subsurface Applications (Direct Injection)	Full-Advanced Treatment for Direct Injection Filtration + Disinfection for Surface Spreading	• 12-log virus removal (1-log virus credit given per month of subsurface retention time) • 10-log Cryptosporidium and Giardia removal • 3 or more separate treatment barriers • Each treatment process is granted between 0.5-log and 6-log removal credit • Less than or equal to 10 mg/L total nitrogen(applies to recycled water effluent or blended water concentration)

			• TOC ≤ 0.5 mg/L divided by the fraction of recycled water contribution • < 10 ng/L NDMA • Wastewater management agency must have industrial pre-treatment and pollutant source control program
North Carolina	IPR and DPR	Type 2 reclaimed water facilities: Dual disinfection systems containing UV disinfection and chlorination or equivalent that can meet pathogen reduction requirements	In 2014 a bill was passed allowing for local water supply systems to combine reclaimed water with other raw water sources before treatment if all of the following conditions are satisfied: • Reclaimed water and source water are combined in an impoundment, sized for > 5 days' storage • Average daily flow of reclaimed water into impoundment is ≤ 20% • Public Participation Type 2 Reclaimed Water Effluent Standards • E.coli ≥ log 6 reduction • Coliphage ≥ log 5 reduction • Clostridium perfringens ≥ log 4 reduction • BOD5 ≤ 5 mg/L (monthly avg) • TSS ≤ 5 mg/L (monthly avg) • NH3 ≤ 1 mg/L (monthly avg) • NTU ≤ 5
Texas	IPR and DPR	Case-by-case	• Determined on a case-by-case basis for IPR and DPR • In DPR, assigned log removal credits do not include the WWTW • 8-log virus removal (1-log virus credit given per month of subsurface retention time) • 5.5-log Cryptosporidium removal • 6-log Giardia removal

The California and North Carolina water reuse quality guidelines are slightly misleading in terms of conventional DPR in terms of its definition. This is because both these guidelines require an environmental buffer upstream of any conventional water treatment facility prior to raw water abstraction. The California guidelines only address surface water or groundwater injection of reclaimed water and can therefore not be classified as DPR. The North Carolina guidelines are clear in that the reclaimed water must be impounded and mixed with alternative water resources for a minimum storage period of 5 days before being treated at a conventional water treatment plant. The merits for using these guidelines for DPR schemes cannot be discounted, as the level of treatment required to meet both California and North Carolina's guidelines are stringent and accepted to pose no risk to human health should they be met.

The Texas Water Development Board (TWDB) published the *Direct Potable Reuse Resource Document* in 2015 which is currently the most up to date and comprehensive DPR guideline document published by a specific state. The TWDB has prescribed a list of chemical constituents which must be tested and minimum threshold concentrations met. The guidelines also recommend minimum log reduction credits for pathogens, which has been modified from the previous NWRI (2015), EPA (2012) and WateReuse Research Foundation

(2014) recommended log reductions. The Texas Commission of Environmental Quality (TCEQ) recommended within the *Direct Potable Reuse Resource Document* that the log reductions associated with the wastewater treatment process should be omitted and only those linked to the advanced water treatment and conventional water treatment plant should counted. These two different approaches to pathogen removal requirements are shown in the figures and tables below.

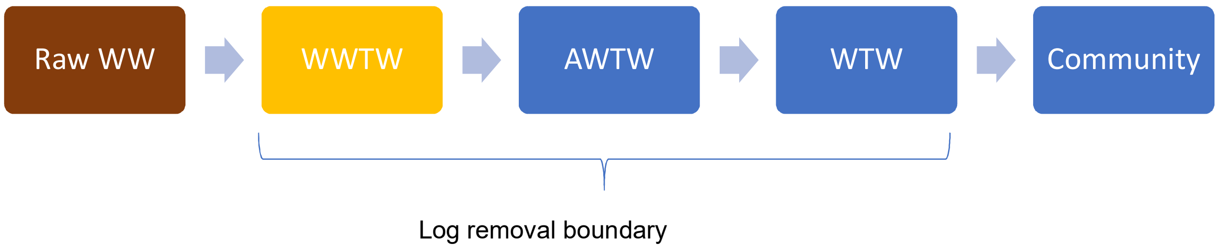

Figure 11: Water reuse cycle and log removal boundary of California, NWRI, EPA and WRRF

Table 4: Pathogen indicator log removals of California, NWRI, EPA and WRRF

	Cryptosporidium	Giardia	Viruses	Total Coliform
Log_{10} removal	10	10	12	9

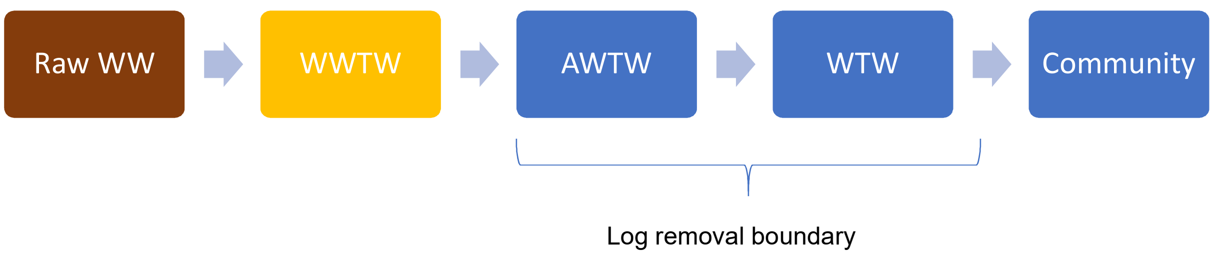

Figure 12: Water reuse cycle and log removal boundary of TWDB

Table 5: Pathogen indicator log removals of TWDB

	Cryptosporidium	Giardia	Viruses	Bacteria
Log_{10} removal	5.5	6	8	-

2.6.2.2 Australia

The *Australian Guidelines for Water Recycling (AGWR)* was released as part of the National Water Quality Management Strategy in 2006 (*Managing Health and Environmental Risks - Phase 1*) and 2008 (*Augmentation of Drinking Water Supplies – Phase 2*). This was national document published in response to numerous states publishing their own set of guidelines on water reuse. The *AGWR Augmentation of Drinking Water Supplies – Phase 2* document is the most comprehensive document which was found during this research. The document provides a complete list of all chemical constituents which should be monitored and their maximum threshold concentrations.

The guidelines also provide recommended log reductions to be achieved for potable reuse which are lower than the various USA guidelines. These lower thresholds may be due to the log reductions not taking into account conventional water treatment plants but only the wastewater and advanced water treatment plant processes. There is further evidence that this is the case in the Queensland Government *Water quality guidelines for recycled schemes* (2008) which only measures log reductions over the wastewater and advanced water treatment processes.

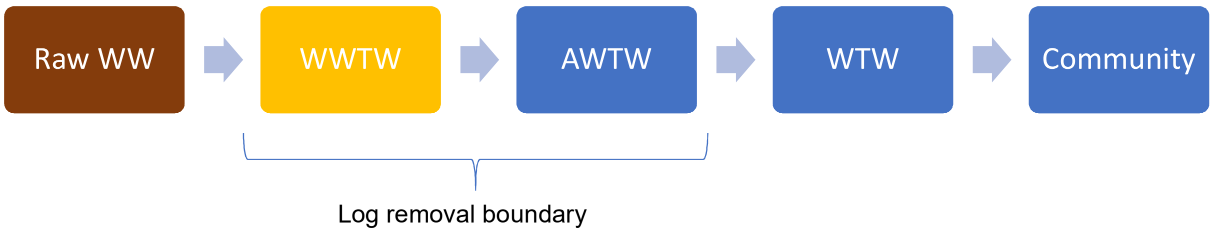

Figure 13: Water reuse cycle and log removal boundary of Australian Reuse Guidelines (2008)

Table 6: Pathogen indicator log removals of Australian Reuse Guidelines (2008)

		Cryptosporidium	Giardia	Viruses	Bacteria
AGWR	Log_{10} removal	8	-	9.5	8.1
Queensland		8	8	9.5	8

2.6.3 Summary

The lack of any clearly defined guidelines for potable reuse in South Africa means that both the USA and Australian guidelines must be used to determine the water quality criteria for a DPR plant in South Africa until such time that South Africa publishes its own. The U.S EPA and Australian guidelines provide a national approach to potable reuse whilst there are also numerous guidelines published by individual states which are based on these national regulations along with local case studies undertaken by the relevant local authorities. This research will take each of the guidelines discussed above and their relevant water quality requirements in terms of log reduction credits and compare them with the proposed advanced water treatment process configuration for the Stellenbosch DPR Plant. This will enable the findings of this research to be credible and validated against international best practice.

2.7 Contaminants Removal Capacity of Advanced Water Treatment Technologies

The indicative removal capacities of the various advanced water treatment technologies have been published in recent reuse studies and guidelines (Metcalf *et.al*., 2014; U.S. EPA, 2017; Snyder *et al*., 2007; AGWR, 2008) after pilot and full-scale testing across a range of chemical and pathogenic contaminants. These reference tables provide a benchmark upon which specific advanced water treatment plants process designs can be validated against international standards for potable reuse.

Table 7: Indicative log removals of pathogens

Type of Microorganism	Indicator microorganisms			Pathogenic microorganisms				
	Escherichia coli **(indicator bacteria)**	***Clostridium perfringens***	**Phage (indicator virus)**	**Enteric bacteria (e.g., *Campylobacter*)**	**Enteric viruses**	***Giardia lamblia***	***Cryptosporidium parvum***	**Helminths**
Bacteria	X	X	X					
Protozoa and helminths						X	X	X
Viruses			X		X			
Indicative Log Reductions in Various Stages of Wastewater Treatment[1]								
Secondary treatment	1 - 3	0.5 - 1	0.5 - 2.5	1 - 3	0.5 - 2	0.5 - 1.5	0.5 - 1	0 - 2
Dual media filtration[2]	0 - 1	0 - 1	1 - 4	0 - 1	0.5 - 3	1 - 3	1.5 -	2 - 3
Membrane filtration (UF, NF, and RO)[3]	4 - >6	>6	2 - >6	>6	2 - >6	>6	4 - >6	>6
Reservoir storage	1 - 5	N/A	1 - 4	1 - 5	1 - 4	3 - 4	1 - 3.5	1.5 - >3
Ozonation	2 - 6	0 - 0.5	2 - 6	2 - 6	3 - 6	2 - 4	1 - 2	N/A
UV disinfection	2 - >6	N/A	3 - >6	2 - >6	1 ->6	3 - >6	3 - >6	N/A
Advanced oxidation	>6	N/A	>6	>6	>6	>6	>6	N/A
Chlorination	2 - >6	1 - 2	0 - 2.5	2 - >6	1 - 3	0.5 - 1.5	0 - 0.5	0 – 1

(Sources: Bitton, 1999; EPHC, 2008; Mara and Horan, 2003; NRC, 1998; NRC, 2012; Rose et al., 1996; Rose, et al., 2001; EPA, 1999, 2003, 2004; WHO, 1989)

1Reduction rates depend on specific operating conditions, such as retention times, contact times and concentrations of chemicals used, pore size, filter depths, pretreatment, and other factors. Ranges given should not be used as design or regulatory bases—they are meant to show relative comparisons only.
2Including coagulation
3Removal rates vary dramatically depending on the installation and maintenance of the membranes.
N/A = not available

Table 8: Indicative percentage removals of organic chemicals

Treatment	Percent Removal									
	B(a)p	Antibiotics[1]	Pharmaceuticals					Hormones		Fragrance	NDMA
			DZP	CBZ	DCF	IBP	PCT	Steroid[2]	Anabolic[3]		
Secondary (activated sludge)	nd	10–50	nd	–	10–50	>90	nd	>90	nd	50–90	–
Microfiltration	nd	<20	<20	<20	<20	<20	<20	<20	nd	<20	
Ultrafiltration/ powdered activated carbon (PAC)	nd	>90	>90	>90	>90	>90	nd	>90	nd	>90	>90
Nanofiltration	>80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	
Reverse osmosis	>80	>95	>95	>95	>95	>95	>95	>95	>95	>95	25–50
PAC	>80	20–>80	50–80	50–80	20–50	<20	50–80	50–80	50–80	50–80	
Granular activated carbon		>90	>90	>90		>90		>90		>90	>90
Ozonation	>80	>95	50–80	50–80	>95	50–80	>95	>95	>80	50–90	50–90
Advanced oxidation		50–80	50–80	>80	>80	>80	>80	>80	>80	50–80	>90
High-level ultraviolet		20–>80	<20	20–50	>80	20–50	>80	>80	20–50	nd	>90
Chlorination	>80	>80	20–50	–<20	>80	<20	>80	>80	<20	20–>80	–

(Sources: Ternes and Joss, 2006; Snyder et al., 2010)

B(a)p = benz(a)pyrene; CBZ = carbamazepine, DBP = disinfection by-product; DCF = diclofenac; DZP = diazepam; IBP = ibuprofen; NDMA=N-nitrosodimethylamine; nd = no data; PAC = powdered activated carbon; PCT = paracetamol.
1 erythromycin, sulfamethoxazole, triclosan, trimethoprim
2 ethynylestradiol; estrone, estradiol and estriol
3 progesterone, testosterone

2.8 Policy, Regulations and Legislation

2.8.1.1 Department of Water & Sanitation (DWS)

The DWS is the custodian of all water resources in South Africa and provides oversight of all water related activities. The *National Water Services Act (Act 108 of 1997*) and the *National Water Act (Act 36 of 1998)* provide the legislative framework upon which water resources are managed and regulated. These two acts do not explicitly mention potable water reuse and the governing legislation and regulations to manage this water resource. This is primarily because both acts focus on the water sector as a whole, instead of individual resources, and because potable water reuse was still an emerging concept within South Africa. The acts however do impose responsibilities on the relevant Water Service Authority (WSA) to regulate and monitor water activities through local government by-laws.

The Department of Water Affairs (renamed DWS) released the *National Water Resource Strategy – Water for an Equitable and Sustainable Future, 2nd Edition* (2013) which focuses on how South Africa can better manage their water resources to support economic development and ensure they are protected, conserved, managed and controlled in a sustainable and equitable way. This document also contains *Annexure D National Strategy for Water re-use (2011)* which sets out national governments plans for water reuse going forwards. This single document is currently the most up to date strategy put forward by national government and will be used to develop the proposed Stellenbosch DPR scheme to ensure it aligns with national policy.

The *National Strategy for Water re-use (2011)* identifies potable reuse within the municipal sector through IPR and DPR schemes and acknowledges that water reclamation in South Africa will form a larger percentage of the potable water supply in future. The document places specific emphasis on potable reuse schemes in coastal areas whereby wastewater effluent is discharged into the ocean without any opportunity for reuse. The document outlines the following key fundamentals which must be addressed for any potable reuse scheme:

- Water quality and security of supply
- Water treatment technologies
- Costs relative to other water supply alternatives
- Social and cultural perceptions
- Environmental perceptions

The document also acknowledges that there is no definitive water reuse policy within South Africa. The current water policies and regulations are not focused on water reuse projects and therefore the controls that exist between these frameworks can become contradictory when trying to obtain the necessary authorizations and permits. The DWS has set out clear objectives within the document to address these shortcomings in the future by developing clear and practical guidelines for water reuse projects to mitigate the red tape in implementing these types of projects. The document also identifies the need to develop water quality standards and monitoring programmes which are appropriate to the type of reuse implemented.

These objectives can be seen as positive steps in the right direction towards developing a framework for reuse within South Africa. The national governments strategy must promote alternative water resources to augment current water supplies to ensure South Africa becomes more resilient to climate change and urbanisation in future.

2.8.1.2 Stellenbosch Municipality

The Stellenbosch Municipality has outlined direct potable water reuse as a long term intervention in terms of its water reconciliation strategy as part of the *2011/2012 Water Service Development Plan (WSDP).* The Stellenbosch WWTW currently discharges water into the Veldwachters River which is a tributary for the Eerste River. The Eerste River forms part of Lower Eertse River Irrigation Board (LERIB) and is a key water resource for farmers. The LERIB have a water use licence to abstract water from the river for irrigation purposes. This reuse scheme is the only current project which utilises the Stellenbosch WWTW effluent in conjunction with natural run off within the river catchment.

The *WSDP (2011/12)* identified water supply concerns in 5 years due to increased water demand unless alternative water resources could be found. The Stellenbosch Municipality managed to offset these supply concerns by implementing a strict regime of water conservation and demand management (WC/DM) interventions, which are still in place today. These interventions were able to reduce potable water demand by up to 35% at its peak during the 2017/18 drought. It is common knowledge that the water demand will eventually overtake the current water supply within Stellenbosch, irrespective of the WC/DM strategies in place, unless alternative water resources can be found and harnessed.

3. STELLENBOSCH WATER SUPPLY SYSTEM

3.1 Raw and Bulk Supply Infrastructure

Stellenbosch town forms part of the Berg WMA which is managed by the Berg-Olifants CMA which was established by the DWS in 2016. The Stellenbosch Municipality is the Water Services Authority (WSA) in terms of the National Water Act. The responsibility of the WSA is to provide water services within its jurisdiction, which includes bulk treatment and distribution. The Stellenbosch town is supplied with raw water from three main sources which are treated at the Idas Valley WTW and the Paradyskloof WTW. The first source is the Kleinplaas Dam (operated by the DWS) which is situated in the Jonkershoek Mountains on the Eerste River. The Kleinplaas Dam can also be supplemented from the Theewaterskloof Dam through the Jonkershoek tunnel and pipeline. This dam supplies the Idas Valley WTW via a direct pipeline to the facility or via the Idas Valley Dams, which are owned by the Stellenbosch Municipality. The Idas Valley Dams are supplemented with excess raw water from the Kleinplaas Dam, which cannot be treated at the Idas Valley WTW during the winter months. The Paradyskloof WTW is fed via the Stellenboschberg tunnel and pipeline from the Theewaterskloof Dam.

Table 9: Stellenbosch raw water supply system

WTW	Bulk Supply	WMA	CMA	Owner	Abstraction Volume
Idas Valley	Kleinplaas Dam & Idas Valley Dams	Berg	Berg - Olifants	DWS & Stellenbosch Municipality	7.224 Mm^3/a
Paradyskloof	Theewaterskloof Dam	Breede	Breede - Gouritz	DWS	3.0 Mm^3/a

The Idas Valley WTW has a capacity of 28 Mℓ/d but currently only treats on average up to 15 – 20 Mℓ/d depending on the season. The conventional water treatment process consists of aeration, slow sand filtration, stabilisation and disinfection (Figure 14). The Paradyskloof WTW capacity has recently been upgraded from 12 Mℓ/d to 20 Mℓ/d in 2018. The works operates a conventional water treatment process of aeration, flocculation, sedimentation, rapid gravity filtration, stabilisation and disinfection (Figure 16). A high-level raw and bulk water supply infrastructure layout is shown in Figure 15 overleaf and a more detailed layout is attached in Annexure B.

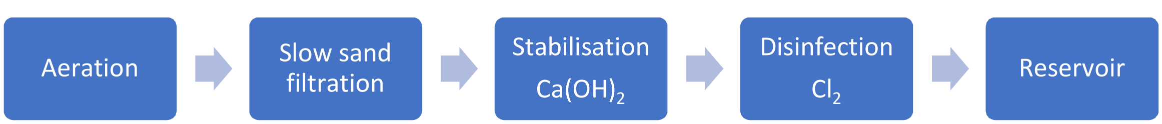

Figure 14: Idas Valley WTW treatment train

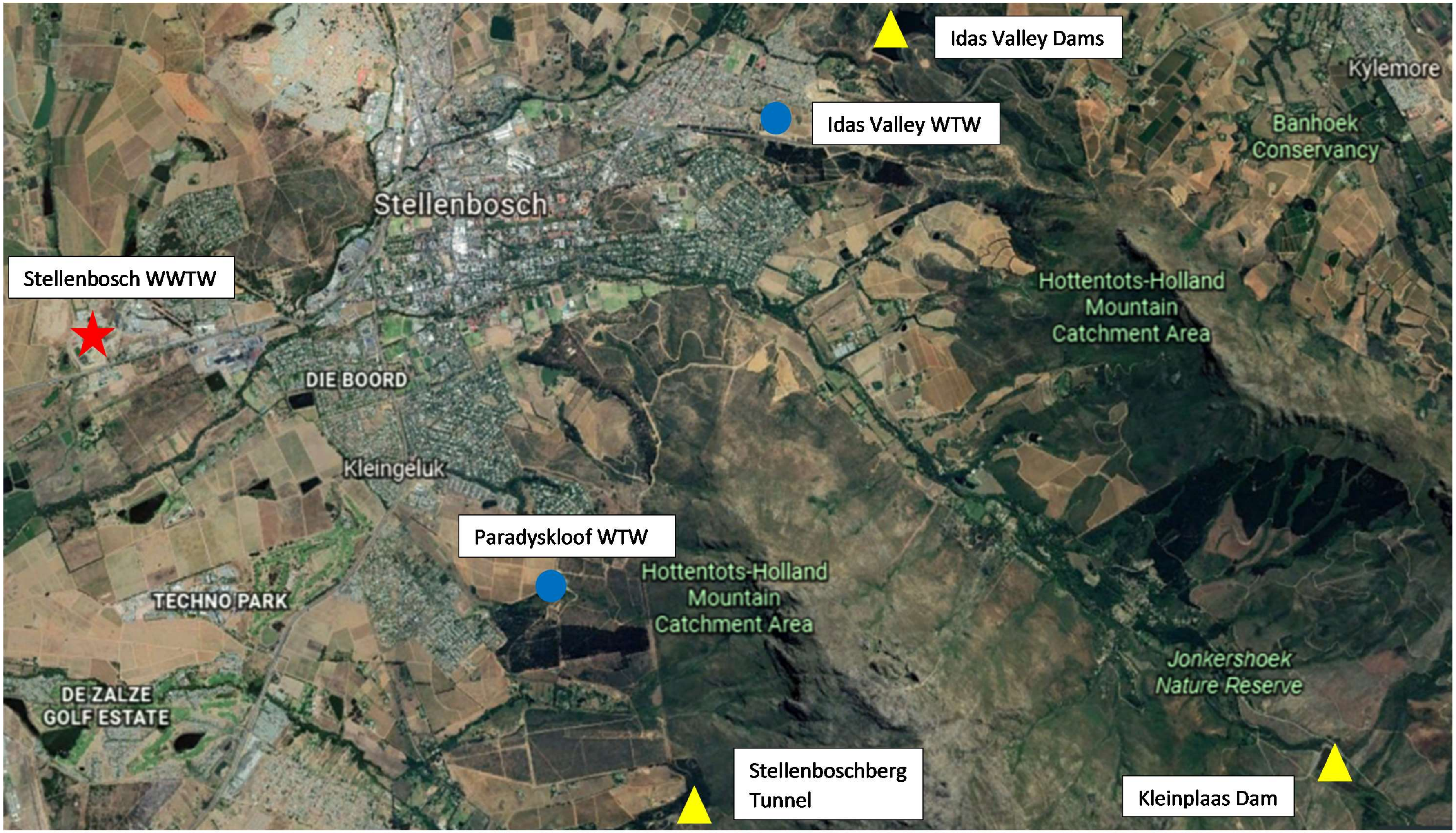

Figure 15: Stellenbosch bulk water supply infrastructure layout (image courtesy of Google Earth 2019)

Figure 16: Paradyskloof WTW treatment train

3.2 Stellenbosch Wastewater Treatment Works

The Stellenbosch WWTW was recently upgraded in 2018 to a capacity of 35 Mℓ/d to cope with the increased hydraulic and organic loading experienced at the plant. The plant was upgraded in two phases to ensure the existing plant remained operational whilst the new lane was constructed. The new lane was then commissioned and the existing lane refurbished. The plant now consists of two lanes, namely a 27 Mℓ/d MBR and 8 Mℓ/d conventional activated sludge (CAS) lane. The two lanes are both operated in a UCT process configuration which provide biological nutrient and excess phosphate removal (BNEPR) upstream of ultrafiltration membranes (MBR lane) and secondary settlement tanks (CAS lane). The two lanes waste activated sludge (WAS) is combined in single sludge treatment train consisting of dissolved air floatation (DAF) thickening, aerobic digestion and mechanical dewatering.

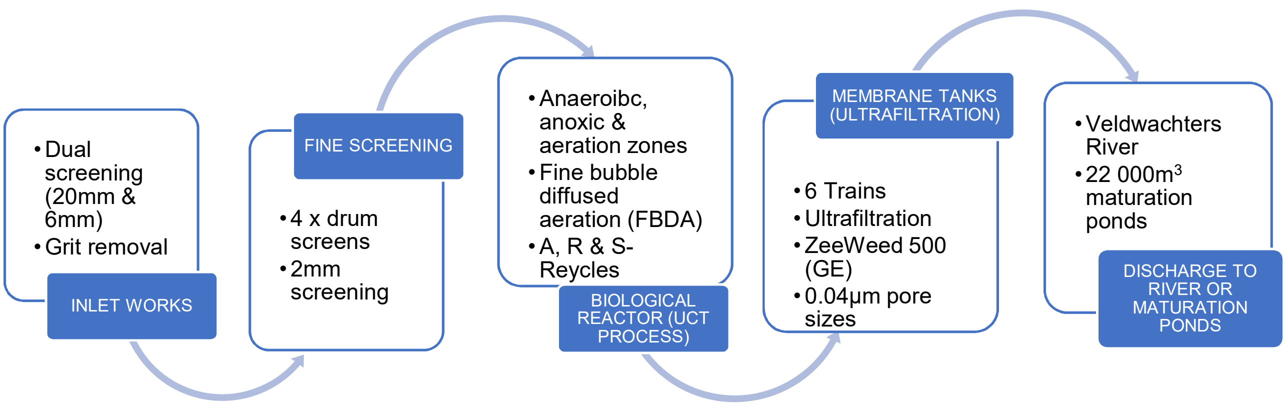

Figure 17: Stellenbosch 27 Mℓ/d MBR lane process train

The high-quality effluent produced by the MBR lane in terms of total suspended solids (TSS), turbidity and pathogenic organisms make it ideal feedwater for a DPR plant over the CAS effluent. This study will only address feedwater from the 27 Mℓ/d MBR lane when developing the technical, environmental and financial considerations for a DPR plant. The MBR lane compromises of six tanks equipped with ZeeWeed 500D submerged hollow fibre membranes supplied General Electric (now Suez). The ultrafiltration membranes have pore sizes of 0.04µm, which provide a physical barrier to most CECs such as pharmaceuticals, PCPs and hormones along with pathogenic microorganism log removals ranging from two to six. The permeate from the membranes is discharged into a concrete tank from which service water is withdrawn for the various process requirements for the mechanical equipment across the site. The rest of the permeate is discharged to the Veldwachters River via the outfall pipeline. The permeate does not undergo any type of disinfection after the membranes as the *E.coli* levels are non-detectable and therefore comply with both the General and Standard Limits for wastewater effluent discharge.

3.3 Current and Future Demands

The Stellenbosch water demands were taken from the Stellenbosch Municipality *Water Master Plan 2017 (2nd Edition)* compiled by GLS Consulting. The current and future demands included an additional 15% for unaccounted-for-water (UAW) which was verified by comparing total water inputs (bulk supply) against total metered water sales. The future water demands took cognisance of existing vacant stands within Stellenbosch which were assumed to become occupied in the future. The master planning was done for a 20-year horizon and the current and future water demands are presented in Table 10 below. The raw water allocation is calculated from the Kleinplaas Dam and Theewaterskloof Dam registered abstraction volumes and does not take into account the natural run off which feeds the Idas Valley Dams.

Table 10: Current and future water demands

Year	Water Demand (Mℓ/d)	WTW Capacity (Mℓ/d)	Surplus / Deficit (Mℓ/d)	Raw Water Allocation (Mℓ/d)	Surplus / Deficit (Mℓ/d)
2017	25.782	48.000	+ 22.218	28.010	+ 2.228
2037	43.030	48.000*	+ 4.970	28.010*	- 15.020*

*The future WTW capacity and raw water allocation has been assumed, for comparative purposes, to remain unchanged over the next 20 years.

The future water demands can be met with the current WTW capacity but issues arise with the abstraction rights from the raw water sources beyond 2020. The future demand creates a deficit of 15.020 Mℓ/d which must be augmented from alternative water resources (see Figure 18). The assumption for this research is that the current water supply will be either augmented by increasing the raw water abstraction rights allocation or a DPR scheme and does not take into account any further WC/DM interventions.

The future water demands were extrapolated to 2039 using the calculated demand growth rate of 2.59% between 2017 and 2037 from the *Water Master Plan 2017 (2nd Edition)*. This was done to predict the water demands for a 20-year horizon for comparative purposes of the lifecycle costing model in Chapter 8. The water supply from the two WTW was assumed to be split proportionately according to each WTW's capacity over the 20-year horizon to be able to isolate the Paradyskloof WTW for analysis. In practice the Stellenbosch Municipality is able to pump up to 12.5 Mℓ/d of treated water between the two WTW to provide flexibility within the water supply network incase of operational issues which could impact on water quality and supply.

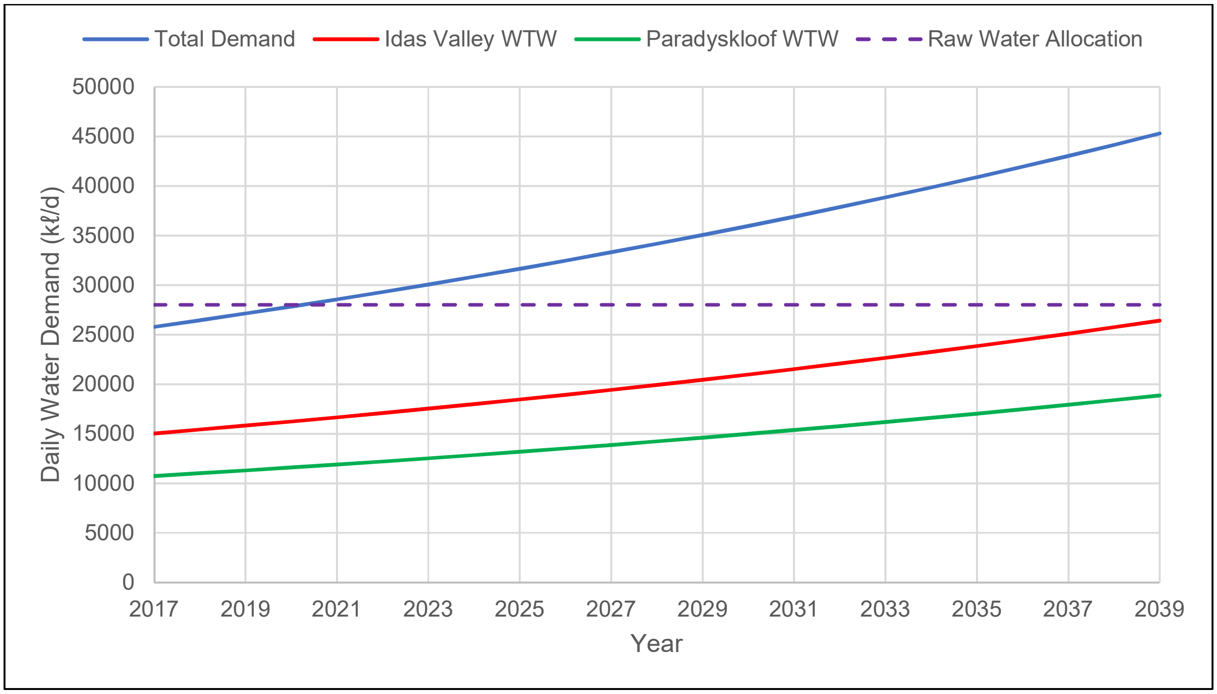

Figure 18: Stellenbosch Daily Water Demand

3.4 Tariffs and Revenue

3.4.1 Raw Water Tariffs

The DWS is the custodian of all water resources, including over 139 raw water supply schemes and other bulk infrastructure within South Africa (DWS, 2015). The department charges tariffs on the supply of raw water to cover the deprecation of assets, cover operational and maintenance costs and finance future water schemes. The tariffs are calculated from an accumulation of 4 different charges levied for the supply of raw water which are dependent on the particular needs of each WMA and CMA. These four types of charges are listed below:

- Water resource management charges
- Water research fund (WRC levy)
- Water resource infrastructure charges (consumptive charges)
- Special water resource infrastructure charges

The Breede – Gouritz CMA, which supplies raw water to the town of Stellenbosch from the Theewaterskloof Dam, set these tariffs in conjunction with the DWS. It is noted that the special water resource infrastructure charge does not apply to this CMA as it does not form part of any Trans Caledon Tunnelling Agency (TCTA) financed projects. The raw water tariffs (excluding VAT) for the past seven years were taken from the DWS database and extrapolated for a 20-year horizon to determine the future tariffs for this research. The average increase in the various raw water charges were determined and used to extrapolate the data represented in Table 11 and

Figure 19. The full data set can be found in **Annexure C**.

Table 11: Raw water tariff breakdown

	Unit	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	Average Increase	2039/40
Water resource management charges[1]	c/m^3	5,46	5,59	3,85	4,35	4,64	4,35	4,35		8.17
% Increase / Decrease	%		2,4%	-31,1%[3]	13,0%	6,7%	-6,3%	0,0%	3.2%	
Consumptive charges[2]	c/m^3	50,09	56,35	60,07	67,88	79,42	91,02	104,13		1203.82
% Increase / Decrease	%		12,5%	6,6%	13,0%	17,0%	14,6%	14,4%	13.0%	
WRC levy	c/m^3	4,7	5,1	5,4	5,7	6,1	6,9	7,5		34.70
% Increase / Decrease	%		9,1%	5,7%	5,2%	7,0%	13,1%	8,0%	8.0%	
Total	c/m^3	60,25	67,07	69,34	77,93	90,16	102,27	114,38		1246.72

[1]Berg-Olifant CMA
[2]Riviersonderend-Berg River (Theewaterskloof Dam and Jonkershoek Tunnel System) - Berg WMA
[3]The large drop in the water resource management charge can be attributed to the consolidation of 19 CMAs into 9 CMAs in 2015/16 financial year by the DWS and has been excluded in the average % increase calculation to avoid skewering the data

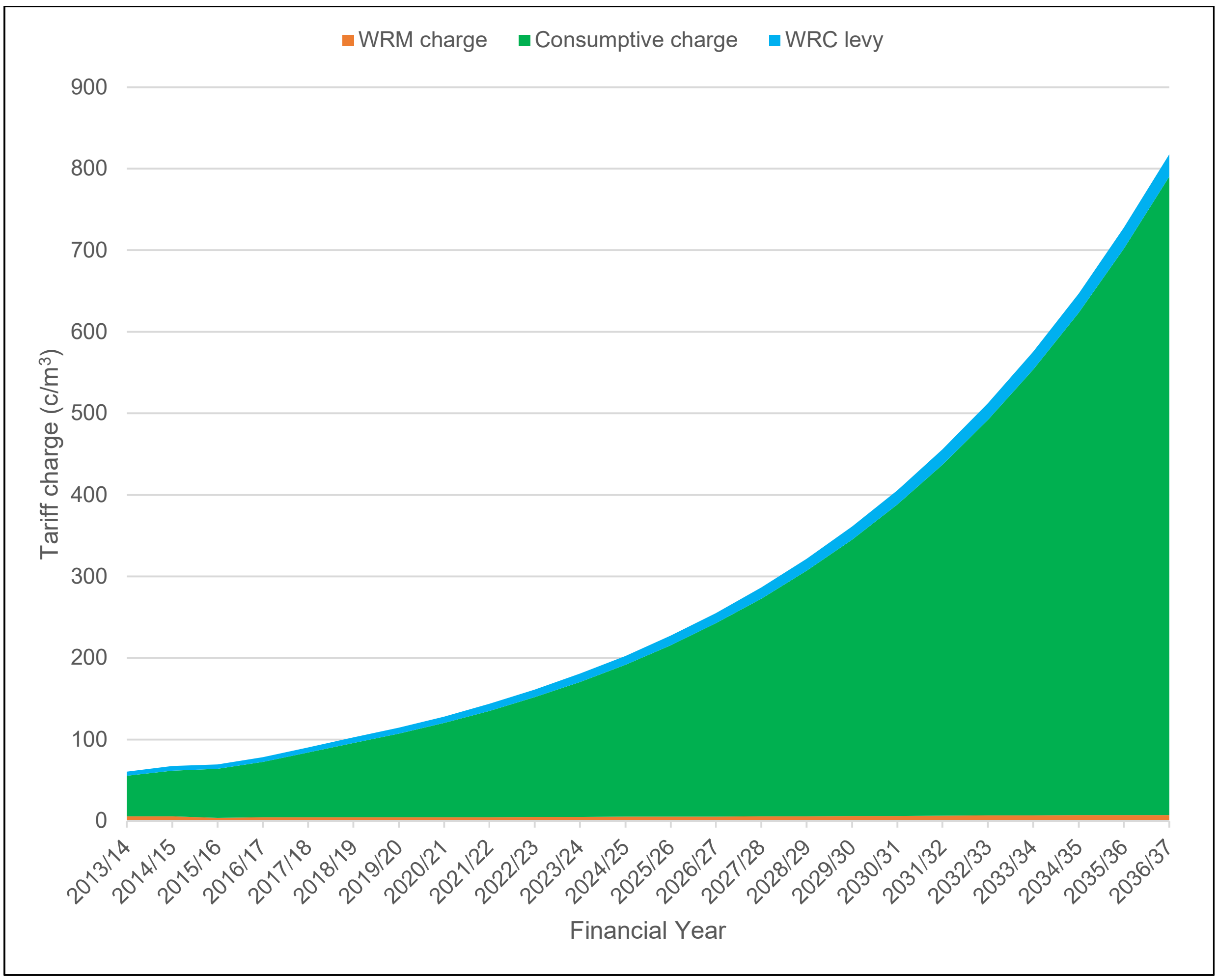

Figure 19: Raw Water Tariff Components

3.4.2 Domestic Water Tariffs

The Stellenbosch Municipality, like most others within South Africa, implements a stepped block tariff structure for domestic water consumption. The tariffs are based on the Municipality's Tariff Policy and Tariff Bylaws which enable them to set the tariffs independently. The tariffs, at the very least, are meant to cover the cost of purchasing of raw water, operation and maintenance of treatment and distribution infrastructure. The tariffs in recent years have fluctuated due to the drought within the Western Cape and the need to balance water demand and supply with water restrictions. This has led to under recovery of costs in providing potable water for domestic consumption in the past. These tariffs can be misleading unless taken within the context of the drought conditions but it must be acknowledged that water consumption behaviours within the Western Cape will not return to pre-2014 levels.

The scope of this research only focusses on the CAPEX and OPEX encountered in purchasing and treatment of raw water through various scenarios and therefore the domestic tariff structure is irrelevant. The higher OPEX required to supply potable water to Stellenbosch would have a knock-on effect on the domestic tariff structure which would have negative consequences for the Municipality and consumers. It is therefore assumed from purely a financial standpoint that increased lifecycle costs for the various scenarios outlined in Chapter 5.1 will render that scenario less favourable than the others. This will be further discussed in Chapter 8.

4. PROCESS DESIGN

4.1 Treatment Objectives

The SANS 241:2015 drinking water quality standards will be used, in the absence of any national potable water reuse guidelines, as the desired DPR product water quality objective to comply with national regulations. The available effluent quality data and subsequent advanced and conventional water treatment process removal efficiencies shall be used to determine the final water quality prior to distribution. Where there was no evidence or research found on the particular removal efficiencies of treatment steps for certain water quality parameters, is was assumed that it remained unchanged throughout the advanced water treatment process and was the same as the feedwater concentration. This will also be compared to the New Goreangab Water Reclamation Plant *Table 2: Treated Water Specification (2001)* which can be found in Annexure A. There are however numerous other indicator parameters for pathogenic microorganisms and CECs which are not measured as part of SANS241:2011, which must be addressed as part of the final water quality objectives.

The log reduction credits for the indicator pathogens for bacteria, viruses and parasites will be compared to the U.S. EPA, California regulations, TWDB and Australian Guidelines. This will provide an indication of where the selected treatment train passes or fails in terms of each of these guidelines for direct potable reuse. The lack of any available data on CECs such as pharmaceuticals, PCPs, hormones, pesticides and herbicides from the Stellenbosch WWTW MBR permeate make it impossible to determine final concentrations and compare these to international maximum thresholds for human consumption. The indicative percentage removal of these CECs however can be determined from previous research undertaken and will form part of the final water quality analysis.

4.2 Water Quality

4.2.1.1 MBR Permeate (Feedwater Quality)

The permeate from the MBR lane is required to meet the specific Water Use Licence (WUL) requirements in terms of the General Authorisation issued by the DWS. The Stellenbosch WWTW effluent discharge must comply with a combination of the General and Special Limits in terms of the licence granted by DWS. A comparison of the available effluent quality data to the WUL is presented in Table 12.

Table 12: Stellenbosch WWTW MBR Effluent Quality (2018/19)

Parameter	Unit	Stellenbosch WUL	MBR Permeate[1]	Pass / Fail
Chemical Oxygen Demand	mg/ℓ	75	23.7	Pass
Faecal Coliforms	per 100 mℓ	1000	6.8	Pass
pH		5.5 – 7.5	6.8	Pass
Ammonia as Nitrogen	mg/ℓ	2	0.2	Pass
Nitrate/Nitrite as Nitrogen	mg/ℓ	5	6.1	Fail
Chlorine as Free Chlorine	mg/ℓ	0	0	Pass
Suspended Solids	mg/ℓ	25	3.5	Pass

Electrical Conductivity (EC)	mS/m	50mS/m above background receiving water, to a maximum of 100mS/m	88.1	Pass
Ortho-phosphate as Phosphorous	mg/ℓ	5	5.3	Fail

[1]Data obtained from the Stellenbosch WWTW on-site laboratory between January 2018 – March 2019

The effluent parameters measured above focus on wastewater discharge to a water resource and do not take into account parameters which are important for potable reuse. The TOC, DOC, TDS and turbidity values are critical parameters for a DPR plant feedwater quality as they will determine the type of advanced water treatment process required. The TDS and turbidity effluent levels have been measured with the other wastewater parameters above by the Stellenbosch WWTW laboratory. The turbidity parameter forms part of the membrane warranty testing regime whilst the TDS was kindly measured for this research between December 2018 to March 2019. There is a direct correlation between electrical conductivity (EC) and TDS in water due to the mineral salt content which forms a large part of the TDS. The more mineral salts dissolved in the wastewater, the higher the EC value. A conversion factor was calculated using the available TDS and EC data, which was then averaged to a value of 4.76. This value is dependent on the type of dissolved metals, minerals and salts in the effluent and hence the most accurate determination for a specific effluent is from actual data recorded. This conversion factor was used to calculate TDS from the EC data prior to December 2018.

The TOC and DOC values are not measured in the wastewater effluent and therefore must be derived from the COD values. The TOC is calculated by dividing the unfiltered COD effluent by a factor of 3 (Equation 1), which is the common COD/TOC ratio found in South Africa wastewaters (Ekama, 2019). The DOC is calculated by assuming that all TSS in the effluent is organic material (i.e. all particulate is volatile suspended solids (VSS)). This is converted to COD by multiplying by the COD/VSS ratio of 1.481. The dissolved COD is then calculated by subtracting the COD in the TSS from the unfiltered COD measured in the laboratory and then dividing by the COD/TOC ratio of 3 (Equation 2). The values were compared to SANS 241:2015 drinking water quality standards to identify any problem parameters which may require a specific type of advanced water treatment technology. It is evident from the results that none of these surrogate parameters should pose any problem for DPR.

$$TOC = \frac{unfiltered\ COD}{3}$$

(Equation 1)

$$DOC = \frac{unfiltered\ COD - 1.481(VSS)}{3}$$

(Equation 2)

Table 13: Stellenbosch WWTW MBR Effluent Quality for Reuse (2018/19)

Parameter	pH	TDS	Turbidity	TOC	DOC
Unit	pH units	mg/ℓ	NTU	mg/ℓ	mg/ℓ
Value	6.8	401.90	0.22	7.91	6.20
SANS 241:2015	5 ≤ pH ≤ 9.7	≤1200	≤1	≤10	<10[1]

[1]Taken from SANS 241:2006

The MBR lane produces on average 27 Mℓ/d of effluent which is discharged directly into the river via an outfall pipeline. A portion of this permeate flow would need to be diverted via an offtake structure to the DPR plant for further advanced water treatment. This offtake structure should be positioned as close to the MBR permeate pumps discharge to point to mitigate the risk of any contamination which may enter the system through the outfall pipeline and manhole structures.

4.2.1.2 Raw Water from Theewaterskloof Dam (Feedwater Quality)

The raw water quality data for the Theewaterskloof Dam was obtained from the Stellenbosch Municipality. The water quality sampling was undertaken by the CSIR, an independent and accredited laboratory, within Stellenbosch. The water samples were taken at the raw water feed sump to the Paradyskloof WTW which is fed directly from the Theewaterskloof Dam via Stellenboschberg Tunnel and pipeline. The raw water quality data was used to determine the effect of blending the DPR Plant final product water prior to the conventional water treatment process at the Paradyskloof WTW. This was done to determine the raw feedwater quality into the Paradyskloof WTW and identify any water quality constituents which cannot be adequately treated in the conventional water treatment process. The important surrogate and indicator parameters have been summarised in Table 14 to measure the impact of blending the DPR plant product water and Theewaterskloof Dam raw water. A full set of the raw water quality results are attached in Annexure D.

Table 14: Theewaterskloof Raw Water Quality (2018/19)

Parameter	pH	TDS	Turbidity	TOC	DOC	Cryptosporidium	Giardia
Unit	pH units	mg/ℓ	NTU	mg/ℓ	mg/ℓ	Count per 1000ml	
Value	6.2	26.0	1.6	3.0	1.8	0	0

4.2.1.3 Paradyskloof WTW (Final Water Quality)

The final water quality results from the Paradyskloof WTW were similarly obtained from the Stellenbosch Municipality in line with SANS 241:2015 sampling requirements for drinking water. These final water quality results were used to determine the final water quality of the DPR product water blended with the Paradyskloof WTW final water. The Paradyskloof WTW received the DWS Blue Drop Certification back in 2014 but has not been graded since then for various reasons owing to the DWS certification programme. The water quality results from CSIR do meet the SANS 241:2015 standards for drinking water and therefore it can be concluded these results have been independently verified and acceptable to use as part of this study. The important surrogate parameters have been summarised in Table 15 below to determine the impact of blending the DPR Plant product water and Paradyskloof WTW final water. A full set of the Paradyskloof WTW final water quality results are attached in Annexure D.

Table 15: Paradyskloof WTW Final Water Quality (2018/19)

Parameter	pH	TDS	Turbidity	TOC	DOC	Cryptosporidium	Giardia
Unit	pH units	mg/ℓ	NTU	mg/ℓ	mg/ℓ	Count per 1000ml	
Value	8.3	45.0	0.7	1.8	1.8	0	0

4.2.1.4 Blending

DPR water must be blended with conventional water sources before reaching the final consumer for drinking. There has been recent research conducted on the impact of blending of reclaimed water with conventional water resources. The recently published *Blending Requirements for Water from Direct Potable Reuse Treatment Facilities* (Salveson *et al*., 2018) looked to address the shortcomings and gaps in previous research to determine the impact of blend ratios and locations for DPR injection on final water quality. DPR product water can be injected into the potable water supply via two different avenues, namely:

1. Injected upstream of the conventional WTW
2. Injected directly into the potable water distribution network

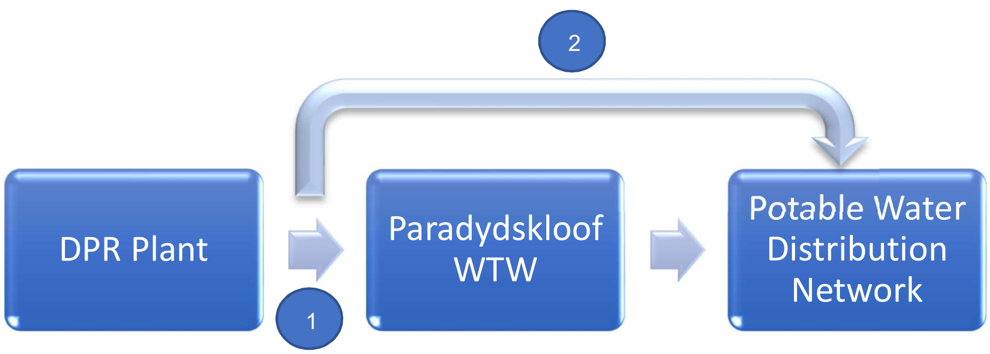

Figure 20: Injection Locations of DPR product water

The blending ratios are dependent on the type of treatment and final product water produced at an advanced water treatment plant. The blend ratio will be determined by final drinking water quality standards as well as social perceptions and risk analysis. The blended water quality results for each scenario developed in Chapter 5 will be compared to the current raw and final water quality results at the Paradyskloof WTW to determine the impact of introducing reclaimed water to Stellenbosch's water supply system. The blend ratio must also take into account social issues such as public acceptance of drinking reclaimed water, where most people would prefer to use the least amount of reclaimed water to augment their potable water supply. The blend ratio also plays a role in the Stellenbosch Municipality's risk mitigation strategy whereby should there be a failure within the DPR Plant, the smaller the percentage of reclaimed water introduced into the system, the lower the risk to human health due to the dilution factor with conventional water resources.

The location of blending the reclaimed water is also important in deciding on the appropriate treatment processes, final water quality, CAPEX, OPEX, monitoring requirements and risk strategy. Reclaimed water being injected upstream of a conventional WTW or directly into potable water distribution network do not require the same level of treatment necessarily. The higher the level of treatment required of reclaimed water will be directly linked to higher CAPEX and OPEX costs. There will also be additional costs should the reclaimed water need to be treated twice, both at the DPR Plant and conventional WTW. The risks of injecting reclaimed water directly into the potable water distribution network are severe should there be a process, operational or monitoring failure at the DPR Plant which can have catastrophic consequences for human health. It is therefore imperative that the monitoring system employed within a DPR scheme accounts for the location of blending the reclaimed water to mitigate contamination risks.

Case studies and literature of IPR and DPR recommend blend ratios between 5 – 50% (Metcalf & Eddy, 2001; U.S. EPA, 2017; Salveson *et al*., 2018) but there have been no adverse findings of increasing this blending ratio in terms of final water quality. There are still the unknown factors such as CECs, EDCs and public perception which have held back these blend ratios to conservative figures to safeguard human health and mitigate risks associated with reclaimed water. The following blend ratios have been chosen for this research to compare what impact these ratios will have on the technical, social and financial aspects of the Stellenbosch DPR scheme.

Table 16: Selected Blending Ratios for Stellenbosch DPR Scheme

Location[1]	Blend Ratio	DPR Plant product water (Mℓ/d)	Raw water (Mℓ/d)	Paradyskloof WTW final water (Mℓ/d)	Total potable water[2] (Mℓ/d)
1	0:1	0.000	20.000	-	20.000
1	1:4	4.000	16.000	-	20.000
1	1:2	6.667	13.333	-	20.000
1	1:1	10.000	10.000	-	20.000
1	1:0	20.000	0.000	-	20.000
2	0:1	0.000	-	20.000	20.000
2	1:4	4.000	-	16.000	20.000
2	1:2	6.667	-	13.333	20.000
2	1:1	10.000	-	10.000	20.000
2	1:0	20.000	-	0.000	20.000

[1]Refer to Figure 20 for location position and number
[2]It is assumed that existing water distribution network will not be upgraded and is therefore capped at 20 Mℓ/d

4.3 Multiple Barrier Approach

The multiple barrier approach was first conceptualised in 1982 after Meiring & Partners published a report on the OGWRP from lessons learnt on the project. The initial focus for the multiple barrier approach was the incorporation of multiple psychical barriers (also called technical barriers) in series to ensure public safety, provide redundancy within the treatment train and prevent the complete plant shutdown should one of the barriers go offline. The focus has in recent years shifted to include operational and management barriers into the multiple barrier approach. These two barriers, although not credited with treatment performance as per technical barriers, can significantly improve treatment, water quality and reliability of the DPR system.

Table 17: Multiple Barrier Approach for DPR

Barrier Type	Description	Objective
Physical	• Wastewater treatment technologies • Advanced water treatment technologies • Conventional water treatment technologies • Source control • Blending	• Removal of contaminants • Produce potable water • Reduce WW influent contaminants • Dilute remaining contaminants
Operational	• Pilot testing and validation • Operational and monitoring procedures • Failure and response plans • Staff training and certification	• Efficient operation • Mitigate operational risks • Improve water quality reliability
Management	• Policy and maintenance plans • Implement monitoring controls	• Provide oversight and guidance on water quality results

The scope of this research will focus more on the physical barriers than the operational and management barriers, although they are just as important in ensuring a reliable and resilient DPR scheme. The design of the physical barriers within treatment configuration will be based on the universally accepted **n+1** approach. This configuration provides redundancy within the system should one the physical barriers go offline for maintenance or emergency shutdown due to failure. The minimum number of physical barriers for each type of contaminant shall be two (2) and therefore the treatment train, in accordance with **n+1** approach, shall have three (3) barriers in series. This will ensure that two barriers are always operational should one of them fail.

4.4 Treatment Train Configuration

There are several advanced water treatment train configurations employed for DPR schemes. The objective of any treatment train configuration is based on, but not limited to, the following key factors during the planning and design phase of the project:

1. Feedwater quality
2. Final water quality
3. Location
4. CAPEX and OPEX
5. Environmental and social considerations

The two most common treatment trains used for DPR are RO and non-RO based configurations. The above factors are critical in deciding on whether to go with a RO or non-RO based configuration. These factors were compared for both type of treatment trains to determine which was most suitable for the Stellenbosch DPR Plant, before being developed further to ensure local and international standards and guidelines for water quality were met.

Table 18: Comparison of RO and non-RO based AWT configurations

Key Factors	Treatment Train Configuration	
	RO based	**Non-RO based**
Feedwater Quality	Biofouling can occur if phosphate levels are above 0.5mg/l Sensitive to chlorine Required for high TDS concentrations (salt & brackish water) Required for high TOC concentrations	Limited exposure to biofouling in treatment train Residual chlorine not an issue Required for low TDS concentrations Required for high TOC concentrations Possible formation of bromate and NDMA during ozonation
Final Water Quality	Removes a wider spectrum of contaminants in a single step TDS removal 90 – 99% (remineralization required to prevent corrosion) Lowest TOC concentrations	Requires more barriers to meet objectives Limited to no TDS removal (except for nanofiltration) Low TOC concentrations depending on GAC / BAC filtration
Location	Better suited to coastal areas where brine can be disposed of via sea outfall Large evapouration ponds or mechanical evapouration required for inland locations	Better suited to inland areas where brine disposal can become a problem
CAPEX & OPEX	Higher CAPEX Higher energy consumption Higher chemical consumption	Lower CAPEX Lower energy consumption Lower chemical consumption
Environmental and social considerations	Brine disposal can be problematic in environmentally sensitive areas Higher level of confidence in final water quality for DPR and IDP	No brine disposal (except for nanofiltration) Used extensively on conventional water treatment but gaining relevance in DPR and IPR

The low TDS, TOC and DOC concentrations within the Stellenbosch WWTW MBR permeate and raw water blend do not constitute the need for RO to meet the SANS 241:2015 standards as shown in Table 12 and Table 14. The ability to remove RO from the treatment train can also mitigate the need to stabilise the final product water through remineralisation. The high TDS (particularly calcium and magnesium) removal efficiencies of RO membranes can lead to final product water with a pH below 6, which can lead to corrosion of concrete structures and metal pipes within the distribution system unless stabilised. The lack of any available water quality data on bromide (which is a precursor to bromate formation during AOP) concentrations in both feedwater qualities and historically reported concentrations in municipal wastewater effluent being well below the threshold for drinking water standards (U.S. EPA and WHO), make non-RO based treatment trains acceptable in the context of Stellenbosch. The disinfection by-product of ozonation, NDMA, is also not of concern due to non-RO based technologies such as GAC and BAC filters having removal efficiencies of up to 90% (Metcalf *et al*., 2014).

The Stellenbosch town is located approximately 21km inland from the nearest coastline and therefore brine disposal would become an issue unless an alternative disposal method could be found. The high capital costs associated with construction of evapouration ponds as found in Metcalf *et.al* (2014) make this method prohibitive. There are other disposal options available such as deep injection wells, surface water disposal and zero liquid discharge technologies available but these have not been investigated as part of this research. The disposal of brine inland where there is no sea outfall conveyance option available can double CAPEX and OPEX of a reclamation facility as reported by Poulson (2010) and Bond & Veerapaneni (2007).

Recent studies have also begun to look at alternative DPR treatment technologies which can provide the same level of treatment as RO based treatment trains. The studies conducted by Schimmoller & Kealy (2014) in association with the WateReuse Research Foundation and Bell *et al*. (2016) have been able to show how ozone-BAC treatment trains can provide similar contaminant removal efficiencies to RO based treatment trains with much lower CAPEX and OPEX required. The studies have looked at the costs of overtreating wastewater effluent to potable standards (both IPR and DPR) and whether or not these costs are necessary against the potential health risks associated with ozone-BAC treatment trains.

The ozone and BAC treatment train combine both chemical and biological oxidation processes which allow for transformation of organic compounds (TOC and DOC) before they are biodegraded within the BAC filter. This occurs as the ozone breaks down longer molecular chains of organic compounds which can be more easily degraded within the BAC filter. The biological growth on the filtration media improves water quality by removing pesticides, herbicides, EDCs, DPB and aesthetic parameters such as colour, odour and taste. Faecal coliforms from MBR permeate were reduced to zero after the ozone dosing stage in pilot studies conducted within South Africa by Metcalf *et al*. (2014) due to the low suspended solids concentrations which enhance the oxidation reaction. The ozone-BAC treatment configuration is not sensitive to phosphate levels above 0.5mg/l, as found within the Stellenbosch MBR permeate, unlike RO membranes which must have chemical precipitation pre-treatment step to prevent biofouling and excessive chemical cleaning regimes.

The New Goreangab WRP in Windhoek is the most relevant DPR example in terms of this research, using ozone-BAC treatment configuration with other pre and post treatment steps. The inland location, municipal feedwater quality, CAPEX, OPEX and required skills to operate and maintain the plant make this treatment train configuration more advantageous than a RO based configuration. The plant final water quality has been monitored independently through research grants and other studies since inception 2002 with no adverse health impacts reported to date. This provides a certain level of credibility to this research in the absence of any laboratory testing and pilot plant. There have been advances in technology since the commissioning of the New Goreangab WRP which would provide improved treatment performance, such as AOP (H_20_2/UV) along with superior source control from the upstream performance at the WWTW (MBR ultrafiltration). The high-quality Stellenbosch MBR permeate is able to simplify the DPR treatment train by omitting the first four and ultrafiltration steps (see Figure 6) from the New Goreangab WRP. Schimmoller & Kealy (2014) recommended a similar treatment configuration in Figure 21 which has also been used to validate the proposed treatment train for Stellenbosch in Figure 22. The omission of the flocculation and sedimentation step from Figure 21 is due to the superior MBR permeate quality from the Stellenbosch WWTW rendering this treatment step obsolete.

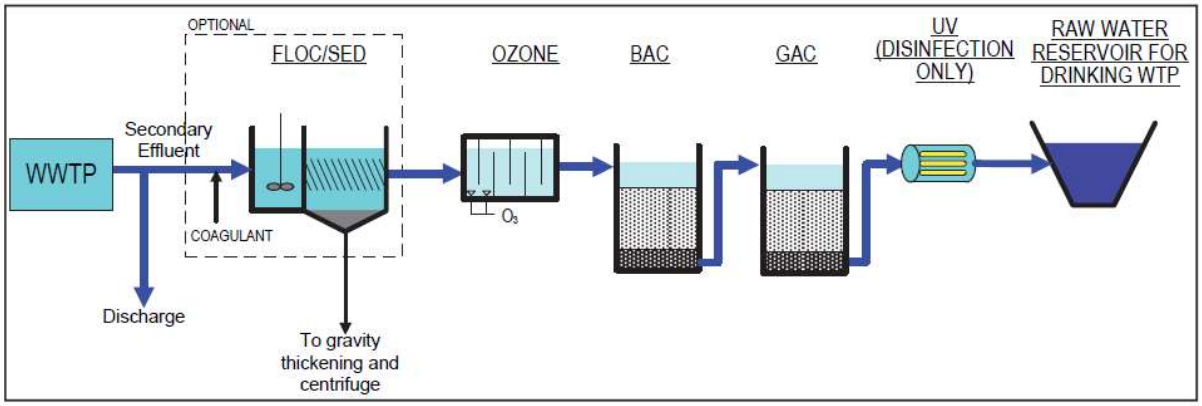

Figure 21: Ozone-BAC Treatment Train (Schimmoller & Kealy, 2014)

Figure 22: Proposed Stellenbosch DPR Treatment Train

Table 19: Stellenbosch DPR Treatment Barriers for Contaminants

Contaminants	Barrier 1	Barrier 2	Barrier 3
Pharmaceuticals	O_3/BAC	GAC	AOP
Pathogens	MBR (UF)	AOP	Cl_2
Pesticides & Herbicides	O_3/BAC	GAC	AOP
DPB	O_3/BAC	GAC	AOP
Organic Matter	MBR (UF)	O_3/BAC	GAC

The selected treatment train meets the requirements **n+1** approach and has three (3) barriers in series for each type of pollutant. This will ensure that there will be at least two barriers for each type of targeted pollutant class even if one of the process steps fails.

4.5 Energy Consumption

Energy is required to transport, treat and distribute water for reuse and can be major operational cost for the utility operating a DPR scheme. The water-energy nexus is the relationship between water supply and energy and must be taken into account when determining the feasibility of any water supply scheme. The energy required to reuse wastewater effluent and treat it to potable standards must be compared to alternative water supply scenarios to get a holistic understanding of the financial, environmental and social costs. The water energy nexus within this research will only analyse the energy consumption between the following two battery limits:

1. Discharge point of the MBR permeate at the Stellenbosch WWTW
2. Discharge point into the water distribution system from the Paradyskloof WTW

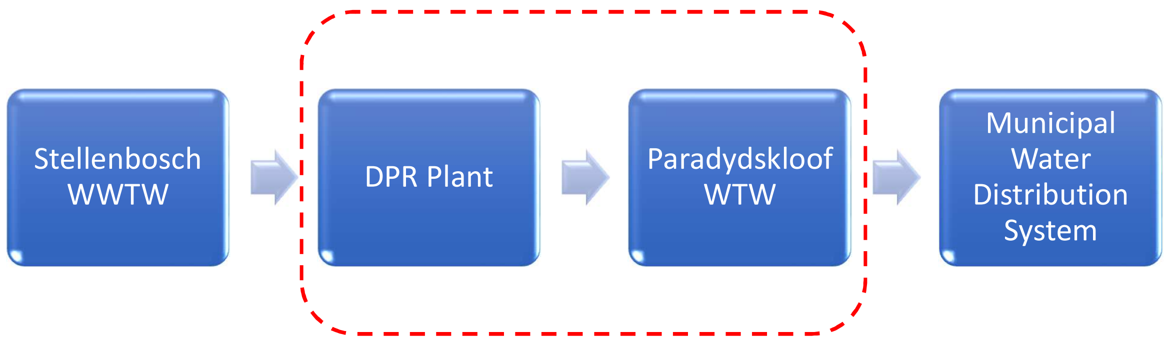

Figure 23: Energy consumption battery limits

The assumption has been made that no further tertiary treatment will be undertaken at the Stellenbosch WWTW prior to the advanced water treatment processes at the DPR Plant. The energy consumptions will therefore remain the same for all scenarios and can be excluded from the energy comparison. The conveyance costs from the DPR Plant to the Paradyskloof WTW will be calculated based on the flow rate, pumping distance and elevation to determine the power consumption for each scenario.

The energy consumption figures for DPR schemes can vary significantly when reviewing previous case studies on a limited number of plants within Southern Africa and internationally. The energy consumption rates are highly site specific and dependent on the treatment technology employed. The energy costs (excluding conveyance) can account for between 27 – 35% of the OPEX for a DPR plant (Swartz *et al*., 2014). The majority of case studies reviewed as part of this research utilised RO membranes within the treatment train which would give it a distorted view when compared to ozone-BAC treatment train selected for the Stellenbosch DPR Plant. Table 20 provides an overview of the energy consumption figures associated with IPR and DPR schemes. Caution must be exercised when reviewing these figures as they were mostly reported as a single energy consumption figure for the entire plant and not individual treatment processes. These figures could be misleading unless they are taken in context of the technology used and battery limits used to determine the figures. The figures vary depending on three factors:

- Whether the scheme is for IPR or DPR?
- RO technology utilised or not?

- Conveyance energy figures included or not?

Table 20: Energy Consumption for IPR & DPR Plants

	Source	Range (kWh/m^3)			IPR / DPR	RO (Y/N)	Conveyance (Y/N)
		Low	Average	High			
1	NWRI DPR Framework, 2015	0.859	0.950	1.057	DPR	Y	N
2	EPA Potable Reuse Compendium, 2017		1.021		-	Y	N
3	EPA Potable Reuse Compendium, 2017		0.37		-	N	N
4	Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater, 2012	0.106		0.317	-	N	Y
5	San Diego County (Equinox Centre, 2010)	1.255		1.612	IPR	Y	N
6	Beaufort West Water Reclamation Plant (WRC, 2015)		2.07		DPR	Y	N
7	New Goreangab Water Reclamation Plant (WRC, 2015)		0.57		DPR	N	N
8	Potable Reuse of Zandvliet & Macassar Wastewater (Aurecon, 2018)		0.66		DPR	N	N
9	Cooley & Wilkinson (WRRF, 2012)	0.851	1.078	1.253	DPR	Y	N

The Stellenbosch DPR Plant will not be using RO technology and the conveyance energy consumption figures will be calculated separately to improve the accuracy of the figures for local site conditions. This eliminates item 1, 2, 4, 5, 6 and 9 and from this only four sources were used to determine the energy consumption estimates for the Stellenbosch DPR Plant. The U.S. EPA (2017) figure is approximately 35% and 56% lower than both other sources 6 and 7 respectively. The New Goreangab WRP figures were based on the treatment train in Figure 6 which includes additional treatment process not required for the Stellenbosch DPR Plant and can therefore be classified on the high end. The Zandvliet and Macassar report was based on a 70 Mℓ/d plant which can distort energy consumption figures by underestimating them in comparison to smaller plants as discussed in Cooley & Wilkinson (2012). These two figures from Southern Africa therefore contradict one another and is further evidence that energy consumption figures must be taken in context of how they were derived based on location, technology and water quality requirements.

The figures reported within the U.S. EPA (2017) document are closely aligned to the treatment train selected for the Stellenbosch DPR Plant. To avoid underestimating the consumption figures and provide some level of safety in the OPEX calculations, this figure was used as the low-end consumption value. The energy consumption figures of the New Goreangab WRP, the only DPR plant in Southern Africa employing a similar treatment train, will be used as the medium value. The plant has been operating since 2002 and provides the most accurate consumption figures aligned to this research, even if it is on the conservative side. The Zandvliet and Macassar energy consumption is merely an estimate at this stage as the plant is still in the design phase and is yet to be constructed and commissioned. They could therefore be an overestimate at this stage, as can be expected in most preliminary planning reports to allow for a factor of safety, and will be used as the high-end figure. The selected energy consumption figures used for the scenario OPEX comparisons are found in Table 21.

Table 21: Estimated Energy Consumption for the Stellenbosch DPR Plant

Low (kWh/m^3)	Medium (kWh/m^3)	High (kWh/m^3)
0.37	0.57	0.66

The energy consumption figures of conventional water treatment are far more accessible and accurate due to more data being gathered over a longer period and similar treatment processes being adopted. There have been advancements in disinfection systems but the rest of the treatment train consisting of coagulation, sedimentation, filtration and disinfection has remained largely unchanged over the past few decades. The determining factors of energy consumption from conventional water treatment works is down to the capacity of the plant, raw and final water quality requirements (AwwaaRF, 2007). The lack of any recent data on the Paradyskloof WTW energy consumption figures meant that the figures had to be taken from case studies and reports for plants of a similar size.

Table 22: Energy consumption of conventional WTW

Source		Range (kWh/m^3)		
		Low	Average	High
1	NWRI DPR Framework, 2015	0.079	0.100	0.106
2	Cooley & Wilkinson (WRRF, 2012)[1]	0.079	0.198	0.343
3	Cooley & Wilkinson (WRRF, 2012)[2]	0.048	0.148	0.291
4	Opportunities and Economics of Direct Potable Reuse (WRRF, 2015)	0.097	0.101	0.105

[1]Based on a plant capacity between 3.7 – 18.9 Mℓ/d

[2]Based on a plant capacity between 18.9 – 75.7 Mℓ/d

The energy consumption data from item 1 and 4 sources could not be correlated to a plant capacity and therefore made it difficult to assess when comparing to item 2 and 3. The figures from item 1 and 4 sources however closely correlate to one another, particularly the average and high-end consumption figures. The figures from item 2 and 3 fall approximately in the middle of the Paradyskloof WTW capacity of 20 Mℓ/d and therefore the average of these two ranges of data was used to determine the estimated energy consumption figures.

Table 23: Estimated Energy Consumption for the Paradyskloof WTW

Low (kWh/m^3)	Medium (kWh/m^3)	High (kWh/m^3)
0.064	0.173	0.317

4.6 Chemical Consumption

The chemical consumption of each process within the treatment train is important to evaluate the OPEX of the DPR Plant. The volume of chemicals required for the selected advanced water treatment train were determined from the WRC study conducted on MBR permeate (Metcalf *et al*., 2014) calculations where possible. The MBR permeate quality used in this study was similar to that of the Stellenbosch WWTW and was therefore used to calculate the chemical consumption volumes based on the pilot plants that were operated as part of the research.

Ozone

The ozone dosage rate is linked to the TOC concentration within the MBR permeate to oxidise the available particulate and dissolved organic compounds prior to BAC filtration. The ozone process was designed to achieve an ozone dose of 0,7mg/ℓ for every mg of TOC. The ozone contact time was based on 10 minutes within the ozone contact tank to ensure oxidation of micropollutants and disinfection. The ozone transfer efficiency was assumed to be 85% which is typical of ozone generators (Metcalf & Eddy, 2007).

AOP (H_2O_2/UV)

The AOP was based on a H_2O_2 dosage of 7.5mg/ℓ and UV dose of 540mJ/cm^2 which was shown to have the highest micropollutant removal efficiencies in studies conducted by the US Bureau of Reclamation in 2009 (Metcalf *et al*., 2014). These figures are based on a turbidity less than 0.2 NTU and a UVT of 65% or greater which would be expected with MBR permeate. The WRC pilot plant study only tested RO permeate with a H_2O_2/UV process downstream and hence the results obtained could not be used for the selected treatment train for Stellenbosch as the water quality would have been superior to MBR permeate. This could provide misleading information when it comes to H_2O_2 and UV doses and therefore the more conservative figures previously reported by the US Bureau of Reclamation were used.

Chlorine

The chlorine dosing is a final barrier against regrowth of microorganisms within the engineered storage buffer (ESB) and conveyance pipeline to the Paradyskloof WTW. The low levels of iron and manganese within the MBR permeate, which react much quicker than the organic matter with chlorine, do not pose a concern with the chlorine dosage. The process design is also based on the fact that almost all the ammonia has been removed (≤0.1mg/ℓ) via the biological processes within the MBR and therefore all the chlorine is free and available. Ammonia can act as a scavenger and form chloramines should it be found in concentrations above 0.1mg/ℓ. This can reduce the amount of free and available chlorine which is needed to oxidise and degrade organic matter. A dosage rate of 0.5mg/ℓ was selected based on the WHO guidelines (2008) and is commonly used for final disinfection at conventional WTWs.

4.7 Engineered Storage Buffer (ESB)

DPR schemes require engineered storage buffers (ESB) for flow retention and quality assurance for downstream users. These ESB provide final product water from an advanced water treatment plant to be stored to allow for online and offline monitoring and water quality testing to be undertaken to verify the process performance before being discharged. The ESB forms one of the critical control points (CCP) within the DPR scheme to monitor water quality, plant performance and mitigate potential risks from operational failures before they become a hazard to public health.

ESBs are usually constructed from steel or concrete tanks which act as a buffer between the AWTW and the WTW. These tanks are sized based on the failure response time (FRT) of the water quality and plant performance monitoring systems. The FRT is defined as the maximum time it takes from being alerted to a failure in the DPR system until the failure has been rectified so that it does not impact on the final product water quality (Tchobanoglous *et al.*, 2015). The FRT is based on the capabilities of the monitoring systems, skills of the operational staff in identifying and correcting anomalies in the plant performance and factors of safety incorporated into the design. The FRT should allow for both online and offline monitoring water quality testing turnaround times, with the latter being the determining factor due to the time required for laboratory testing. The treatment performance of the plant cannot be verified against the required water quality parameters until it has been measured before being discharged downstream to the WTW or distribution network. The log reduction credits for pathogen removal can only be verified once these water quality test have been conducted and deemed fit for potable reuse.

The design for the ESB for the Stellenbosch DPR Plant will be based on a FRT of 48 hours which allows a two day retention period before the reclaimed water is discharged. The storage tank must be equipped with automated control valves should the final product water from the AWTW not meet the obligatory water quality standards. Chlorine dosing will also be provided to prevent any microbial growth within the tank and conveyance pipeline to the Paradyskloof WTW. The inferior final product quality water can then either be discharged into the Veldwachters River or returned to the head of the AWTW. It is also important to note that an ESB can also be upstream of the AWTW to prevent process disruptions during times of poor effluent quality from the WWTW. The FRT of the MBR UF membranes, should their integrity be severely compromised, would in this case be a matter of seconds due to the rapid online monitoring systems (turbidity) in place at the Stellenbosch WWTW. The design would need to account for an actuated valve between the WWTW and AWTW which would divert poor quality permeate directly to the river or maturation ponds during membrane failure. It is therefore assumed that no ESB will be built upstream of the AWTW.

4.8 Process Monitoring and Control

The reliability of any DPR facility is based upon a robust and comprehensive process monitoring and control system to deliver final product water which is not a hazard to human health. These controls measure, record, monitor and respond to plant performance against a set of performance specifications by using various online and offline tools available to operators and process controllers.

The Hazard Analysis and Critical Control Point (HACCP) is a risk-based assessment approach commonly used in the food industry and can be applied to water reuse also. The method consists of five pre-steps and seven steps whose details could be expanded on in great length. This research will only focus on one of the seven steps which identifies key points in the process whereby if failure occurs, could cause a severe impact on the final product or downstream processes. These are called Critical Control Points (CCPs) and are used to identify controls which can be applied at certain unit processes to mitigate process failure. They also provide a monitoring point to confirm the control is functioning correctly (Tchobanoglous *et al.*, 2015). These individual CCPs are located at the various process units to monitor pathogen and chemical constituents within the treatment train. They importantly provide control to the treatments system but do not necessarily monitor treatment performance of a specific process unit, as is the case for an ESB, whereby pathogen and chemical constituents must be continually monitored although this process unit does not provide any treatment performance. The CCP monitoring sets alert and critical levels for certain parameters which trigger alarms on the Supervisory Control and Data Acquisition (SCADA) system to initiate a response from the operators or process controllers. There are also Critical Operating Points (COPs) which monitor certain requirements to keep the treatment system operating efficiently to maximise performance but are not directly linked to human health (U.S. EPA, 2017). This could be a Clean in Place (CIP) alarms which trigger should the ultrafiltration membranes or UV lamps performance dip below a set threshold to initiate a cleaning cycle.

Process monitoring at CCPs must address human health with regards to acute risks which arise from exposure to pathogens and chronic risks which are from exposure to chemical constituents. These risks are managed immediately through online and offline monitoring tools to measure surrogates at CCPs. They are managed long term by testing and recording all sampling data within a laboratory throughout the plants commissioning and full-time operational stages. The following CCPs for the Stellenbosch DPR Plant have been identified for both pathogen and chemical constituents, as well as the type of control needed.

Table 24: Stellenbosch DPR Plant Critical Control Points

No.	Critical Control Point	Monitor	Performance Target
1	MBR UF	Pressure decay test	Pathogen removal
2	Ozone	Online O_3	Pathogen removal
3	GAC	Online TOC	Chemical constituents' removal
4	AOP	Online intensity sensors	Pathogen / Chemical constituents' removal
5	ESB	Online Cl_2	Pathogen removal

The Stellenbosch DPR Plant will require validation and compliance monitoring programmes once the plant has been constructed and is ready for commissioning. Validation monitoring must be undertaken during commissioning before any of the reclaimed water is injected into the municipal drinking water network. This testing can take between 30 days to 6 months and ensures each treatment step is performing as per specifications. This monitoring programme would take place during the trial and operation period of a typical engineering contract (FIDIC or NEC) and provides a baseline upon which to compare data going forward. Compliance monitoring occurs during full time operation to ensure compliance with the set water quality standards and to verify each treatment train process is performing optimally. This period also helps refine and assess indictors and surrogates upon which performance is tracked against. The results of these monitoring programmes must be made available to the public to ensure confidence within the system and will be dealt with in Chapter 6.

5. TECHNICAL FEASIBILITY

5.1 Development of Scenarios

The feasibility of any reclamation scheme, whether it is IPR or DPR, is the cost of water when compared to alterative water resources. These alternative water resources could be groundwater extraction, surface water, and desalination which should be form part of water reconciliation strategy to determine the most appropriate solution at a local, provincial and national level. These alternative water resources have not been further investigated as part of this research and would have to form part of any water reconciliation strategy for Stellenbosch. This study will only compare various scenarios involving a mix of reclaimed water and current surface water resources to supply the town of Stellenbosch with potable water.

The scenarios developed focused only on the Paradyskloof WTW which supplies the southern part of the town's distribution network. The Idas Valley WTW is approximately 2.0km further from the Stellenbosch WWTW than the Paradyskloof WTW and both are at similar elevations (217m and 227m above sea level). The conveyance costs (due to energy consumption) would be higher to pump water to the Idas Valley WTW than Paradyskloof WTW with this is mind. There were no clear savings in utilising the Idas Valley WTW in term of OPEX as it also receives its raw water from the DWS (Theewaterskloof Dam and Kleinplaas Dam) and therefore the same raw water tariffs would be applicable. The chemical, energy and staff costs per megalitre for each WTW are similar as they both use conventional water treatment processes. The higher capacity of the Idas Valley WTW (28 Mℓ/d) would have been favourable in terms of the CAPEX economics of scale for a larger DPR plant but it was decided to only focus on the Paradyskloof WTW to avoid comparing numerous permutations between different transfer schemes incorporating both WTW.

5.1.1 Scenario A

Scenario A was selected as the 'do-nothing' approach whereby the Stellenbosch Municipality would continue to purchase bulk raw water from the DWS and treat it at the Paradyskloof WTW. In this scenario all of the final effluent from the Stellenbosch WWTW would be discharged into the Veldwachters River and eventually make its way into False Bay. This scenario provides a benchmark with which the DPR Scenario B and C can be compared in order to determine their feasibility.

5.1.2 Scenario B

Scenario B looked at a DPR Plant situated at the Stellenbosch WWTW which treated the MBR permeate and conveyed it to the Paradyskloof WTW. The DPR product water is blended with the raw water from Theewaterskloof Dam upstream of the Paradyskloof WTW inlet sump. The blended water then passes through the conventional water treatment process train before being distributed into the network. The DPR Plant capacity will be in accordance with the blend ratios selected in Chapter 4.2.1.4 of 4, 6.7, 10 and 20 Mℓ/d.

5.1.3 Scenario C

Scenario C also analysed a DPR Plant situated at the Stellenbosch WWTW which treated the MBR permeate and conveyed it to the Paradyskloof WTW. The DPR product water is then blended with the final treated water from the Paradyskloof WTW before being injected directly into distribution the network. The DPR Plant capacities will be identical to Scenario B.

5.2 Final Water Quality

5.2.1 Scenario A

The final water quality of Scenario A would remain as per the latest water quality results in Annexure D, as the raw water source and Paradyskloof WTW treatment process would remain unchanged.

5.2.2 Scenario B

The DPR product water quality was based on the reasonable expectation that water quality can be determined from the selected advanced treatment train processes (Salveson *et al*., 2018). The lack of any data on chemical contaminants within the MBR permeate make it impossible to determine the final concentrations in the DPR product water as they are based on percentage removals associated with each treatment step. The low levels of most chemical constituents detected within wastewater effluents prior to advanced treatments and even lower / non-detectable levels after advanced treatment provide some form of reassurance that advanced water treatment processes do effectively remove these contaminants in the absence of water quality and pilot testing data at Stellenbosch. The product water quality from the DPR Plant for Scenario B and C will be identical due to the same advanced treatment process being used.

Table 25: DPR Product Water Quality (Scenario B & C)

	TOC	COD	TSS	Turbidity	TDS	EC	NH_3	pH	NO_3	NO_2	TP
	mg/ℓ	mg/ℓ	mg/ℓ	NTU	mg/ℓ	mS/m	mg/ℓ		mg/ℓ	mg/ℓ	mg/ℓ
Feedwater Quality	7.9	23.7	3.5	0.2	401.9	88.1	0.2	6.8	6.1	0.1	5.3
Treatment Barrier	AOP + BAC/ GAC	AOP + BAC/ GAC	-	-	-	-	-	-	-	-	-
Removal efficiency	50%[1] 13%[3]	50%[2] 13%[3]	-	-	-	-	-	-	-	-	-
Product Water Quality	**3.4**	**10.3**	**3.5**	**0.2**	**401.9**	**88.1**	**0.2**	**6.8**	**6.1**	**0.1**	**5.3**
SANS 241:2015	10	-	-	1	1200	170	1.5	5 ≤ pH ≤ 9.7	11	0.9	-
Target NGWRP 2002	-**	10	-	0.1	1000	-	N/A	-	Not removed by process		-
Maximum NGWRP 2002	-	15	-	0.2	1200	-	0.1	-	Not removed by process		-

[1]U.S EPA Reuse Compendium (2017) estimates 40 – 60% TOC removal for GAC/BAC from laboratory tests

[2]Direct relationship between COD and TOC defined by the COD/TOC ratio of 3

[3]3 -23% TOC removal by AOP (H_2O_2/UV) reported Lamsal et al., 2011

**Value prescribed is DOC ≤ 3 but no value for TOC. With no information on TSS it is impossible to calculate TOC threshold

The pathogen log removal credits (LRCs) for Scenario B were calculated based on the indicative log removals in Table 7. The table provided a range between two values of pathogen log removals for each advanced water treatment process and from this the mean was determined and used. The total LRCs were then compared to the three international guidelines adopted for this study. It is important to remember that the three LRC methods are measured over different process area boundaries for the three guidelines (see Figure 11 - Figure 13).

Table 26: Log Reduction Credits for Scenario B

	Process Area									
	WWTW	AWTW					WTW		Total	Guidelines minimum
Treatment Barrier	**MBR**	**O_3**	**BAC**	**GAC**	**AOP**	**Cl_2**	**SF[1,2]**	**Cl_2**		
Viruses	2	4.5	0	0	6	1.5	1	1.5	**16.5**	
Cryptosporidium	5	1.5	0	0	6	0.25	1	0.25	**14**	
Giardia	5	3	0	0	6	1	1	1	**17**	
Bacteria	5	4.5	0	0	6	4.5	0.5	4.5	**25**	
NWRI (2015), California GWRS (2011), U.S EPA (2017) & WRRF (2014)										
Viruses	2	4.5	0	0	6	1.5	1	1.5	**16.5**	**12**
Cryptosporidium	5	1.5	0	0	6	0.25	1	0.25	**14**	**10**
Giardia	5	3	0	0	6	1	1	1	**17**	**10**
Bacteria	5	4.5	0	0	6	4.5	0.5	4.5	**25**	**9**
Texas Water Development Board (2015)										
Viruses	-	4.5	0	0	6	1.5	1	1.5	**13.5**	**8**
Cryptosporidium	-	1.5	0	0	6	0.25	1	0.25	**9**	**5.5**
Giardia	-	3	0	0	6	1	1	1	**12**	**6**
Bacteria	-	4.5	0	0	6	4.5	0.5	4.5	**20**	**-**
Australian Reuse Guidelines (2008)										
Viruses	2	4.5	0	0	6	1.5	-	-	**14**	**9.5**
Cryptosporidium	5	1.5	0	0	6	0.25	-	-	**12.75**	**8**
Giardia	5	3	0	0	6	1	-	-	**15**	**8**
Bacteria	5	4.5	0	0	6	4.5	-	-	**20**	**8.1**

[1]Rapid gravity sand filtration with coagulation, flocculation and clarification
[2]Figures were adopted from both Table 7 and Levine *et al.*, 2008

The LRCs achieved for DPR system surpassed all three sets of guideline criteria for pathogen removal. The LRCs compared to the NWRI (2015), California GWRS (2011), U.S EPA (2017) & WRRF (2014) criteria passed by the greatest margin. This can be attributed to the LRC being measured across the entire treatment spectrum from the WWTW to the WTW. The TWDB and Australian Reuse guidelines were also comfortably met, with the protozoa *Cryptosporidium* being met by the smallest margin LRCs of 3.5 and 4.75 respectively. The treatment train is therefore deemed to pass all three guidelines with regard to pathogen removal and deemed acceptable for potable reuse.

The raw water from Theewaterskloof Dam and product water from the DPR Plant are then blended at specific ratios prior to being treated at the Paradyskloof WTW. The table below shows the feedwater quality of these blended water sources. The final water quality after treatment at the Paradyskloof WTW shall meet the SANS 241:2015 and NGWRP (2002) drinking water standards because (1) the DPR product water already meets these standards as shown in Table 25, and (2) the raw water from Theewaterskloof Dam is currently treated to drinking water standards at Paradyskloof WTW without any concerns. The WTW process design and exact final water quality parameters are beyond the scope of this research, mainly due to the fact that is now known that it shall meet the SANS 241:2015 and the NGWRP (2002) drinking water standards.

Table 27: Feedwater Quality into Paradyskloof WTW

	TOC	COD	TSS	Turbidity	TDS	EC	NH_3	pH	NO_3	NO_2	TP
	mg/ℓ	mg/ℓ	mg/ℓ	NTU	mg/ℓ	mS/m	mg/ℓ		mg/ℓ	mg/ℓ	mg/ℓ
Product Water Quality	3.4	10.3	3.5	0.2	401.9	88.1	0.2	6.8	6.1	0.1	5.3
Raw Water Quality	3.0	9.0	N/A	1.6	26	4	0.1	6.2	0.1	0.0	N/A
Blend Ratio											
1:4	3,1	9,3	3,5	1,3	101,2	20,8	0,1	6,3	1,3		0,2
1:3	3,1	9,3	3,5	1,3	120,0	25,0	0,1	6,4	1,6		0,3
1:2	3,1	9,4	3,5	1,1	151,3	32,0	0,1	6,4	2,1		0,3
1:1	3,2	9,7	3,5	0,9	214,0	46,1	0,2	6,5	3,1		0,5
1:0	3.4	10.3	3.5	0.2	401.9	88.1	0.2	6.8	6.1		0.1
SANS 241:2015	10	-	-	1	1200	170	1.5	5 ≤ pH ≤ 9.7	11		0.9
Target NGWRP 2002	-	10	-	0.1	1000	-	N/A	-	Not removed by process		-
Maximum NGWRP 2002	-	15	-	0.2	1200	-	0.1	-	Not removed by process		-

5.2.3 Scenario C

The DPR product water in Scenario C is blended with the treated water from the Paradyskloof WTW, either by direct injection into the outlet pipeline or into Paradyskloof Reservoir No.1. The product water quality from the DPR is assumed to be the same as Scenario B. The pathogen log removal credits (LRCs) for Scenario C were calculated and compared to the three international guidelines adopted for this study.

Table 28: Log Reduction Credits for Scenario C

	Process Area									Guidelines minimum LRC
	WWTW	AWTW					WTW		Total	
Treatment Barrier	MBR	O_3	BAC	GAC	AOP	Cl_2	SF[1,2]	Cl_2		
Viruses	2	4.5	0	0	6	1.5	-	-	**14**	
Cryptosporidium	5	1.5	0	0	6	0.25	-	-	**12.75**	
Giardia	5	3	0	0	6	1	-	-	**15**	
Bacteria	5	4.5	0	0	6	4.5	-	-	**20**	
NWRI (2015), California GWRS (2011), U.S EPA (2017) & WRRF (2014)										
Viruses	2	4.5	0	0	6	1.5	-	-	**14**	**12**
Cryptosporidium	5	1.5	0	0	6	0.25	-	-	**12.75**	**10**
Giardia	5	3	0	0	6	1	-	-	**15**	**10**
Bacteria	5	4.5	0	0	6	4.5	-	-	**20**	**9**
Texas Water Development Board (2015)										
Viruses	-	4.5	0	0	6	1.5	-	-	**12**	**8**
Cryptosporidium	-	1.5	0	0	6	0.25	-	-	**7.75**	**5.5**
Giardia	-	3	0	0	6	1	-	-	**10**	**6**

Bacteria	-	4.5	0	0	6	4.5	-	-	**15**	-
Australian Reuse Guidelines (2008)										
Viruses	2	4.5	0	0	6	1.5	-	-	**14**	**9.5**
Cryptosporidium	5	1.5	0	0	6	0.25	-	-	**12.75**	**8**
Giardia	5	3	0	0	6	1	-	-	**15**	**8**
Bacteria	5	4.5	0	0	6	4.5	-	-	**20**	**8.1**

[1]Rapid gravity sand filtration with coagulation, flocculation and clarification
[2]Figures were adopted from both Table 7 and Levine *et al*., 2008

Scenario C, with the WTW omitted, does achieve lower LRCs than Scenario B as would be expected. The proposed treatment process however does still meet all three guidelines minimum pathogen removal LRCs. The NWRI (2015), California GWRS (2011), U.S EPA (2017) & WRRF (2014) and the Australian Reuse guidelines both achieve the same LRC's as the WTW was omitted from the treatment spectrum leading to both being measured across the same boundaries between the WTWW and the AWTW. The TWDB scores the lowest LRCs for both Scenario B and C and is therefore the most critical in terms of risk to human health.

The product water from the DPR Plant and the treated water from the Paradyskloof WTW are then blended at specific ratios prior to being injected into the distribution network. The table below shows the final water quality of these blended water sources. The final water quality shall meet both SANS 241:2015 and the NGWRP (2002) drinking water standards.

Table 29: Final Water Quality into Distribution Network

	TOC	COD	TSS	Turbidity	TDS	EC	NH_3	pH	NO_3	NO_2	TP
	mg/ℓ	mg/ℓ	mg/ℓ	NTU	mg/ℓ	mS/m	mg/ℓ		mg/ℓ	mg/ℓ	mg/ℓ
Product Water Quality	3.4	10.3	3.5	0.2	401.9	88.1	0.2	6.8	6.1	0.1	5.3
Treated Water Quality	1.8	5.4	N/A	0.7	45	7	0.1	9.4	0.1	0.0	N/A
Blend Ratio											
1:4	2,1	6,4	3,5	0,6	116,4	23,2	0,1	8,9	1,3		0,2
1:3	2,2	6,6	3,5	0,6	134,2	27,3	0,1	8,8	1,6		0,3
1:2	2,3	7,0	3,5	0,5	164,0	34,0	0,1	8,5	2,1		0,3
1:1	2,6	7,9	3,5	0,5	223,5	47,6	0,2	8,1	3,1		0,5
1:0	3,4	10,3	3,5	0,2	401,9	88,1	0,2	6,8	6,1		1,0
SANS 241:2015	10	-	-	1	1200	170	1.5	5 ≤ pH ≤ 9.7	11		0.9
Target NGWRP 2002	-**	10	-	0.1	1000	-	N/A	-	Not removed by process		-
Maximum NGWRP 2002	-	15	-	0.2	1200	-	0.1	-	Not removed by process		-

5.3 Location and Footprint

The spatial constraints at the Paradyskloof WTW site and unfavourable topography, as it sits against the slopes of the Paradyskloof Mountains, do not make it a good location for the DPR Plant. The Stellenbosch WWTW is situated on much flatter topography adjacent to the banks of the Veldwachters River. The close proximity to the river is also an advantage should the DPR Plant need to divert inferior quality feedwater or product water to the river should there be a failure in the WWTW or AWTW treatment trains. The earthworks required for the DPR Plant would lead to higher CAPEX at the Paradyskloof WTW when compared to the Stellenbosch WWTW due to the terrain and required excavations. The Stellenbosch WWTW is also situated closer to the town and main transport routes for chemical deliveries and staffing transport.

The footprint of the DPR Plant was based on high level process calculations of the various advanced treatment technologies. The process units were sized based on the various plant capacities and other empirical calculations which can be found in Annexure E. The Control Building size was based on the required staffing contingent discussed in Chapter 5.5.

Table 30: DPR Plant footprint

Plant Capacity (Mℓ/d)	4.000	6.667	10.000	20.000
Process Unit	**Area (m^2)**			
Ozone Contact Tank	4,27	7,12	10,68	21,37
BAC Filter Beds	23,15	38,58	57,87	115,74
GAC Filter Beds	23,15	38,58	57,87	115,74
AOP	48,00	48,00	48,00	48,00
Cl_2 Dosing	7,00	7,50	8,50	10,50
ESB	1600,00	2666,80	4000,00	8000,00
Control Building	103,78	103,78	121,08	135,08
Total Area	**1809,34**	**2910,36**	**4304,00**	**8446,42**
Available Area	**6200**	**6200**	**6200**	**6200**

The total area of all four plants is relatively small in comparison to the available area at the Stellenbosch WWTW, provided the ESB is excluded from the total area calculation. The 20 Mℓ/d DPR Plant (excluding the ESB) only takes up approximately 450m^2 (7%) of the available 6200m^2 area between the Stellenbosch WWTW southern boundary parallel to Adam Tas Road and the existing maturation ponds in Figure 24. It is evident from the table that the ESB provides the biggest challenge in terms of spatial constraints on the current site. The three smaller DPR Plants would not require any additional land to be procured but the 20 Mℓ/d would most likely require a portion of the ESB to be located off site. The other option would be to reclaim a portion of the area adjacent to the maturation pond but this would impact on the retention period within the ponds which may conflict with the requirements of the Stellenbosch WWTW Water Use Licence.

Figure 24: Proposed DPR Plant Site Location

5.4 Integration with New and Existing Infrastructure

The DPR Plant would need to be integrated with both the Stellenbosch WWTW and Paradyskloof WTW infrastructure to ensure all three plants are interlinked. The hard infrastructure such as MV/LV connections, conduits, valves and pumps would also need to be integrated with electronic and communication instrumentation to ensure the system is fully automated and controlled via a central SCADA system located at the DPR Plant.

The DPR Plant would need to tap into the existing MBR permeate outfall pipeline at one of the manholes prior to the discharge point into the Veldwachters River. The DPR Plant would also be able to be powered from the adjacent mini-sub and emergency back-up power could be supplied from the existing Generator Building which services the Stellenbosch WWTW. The available spare capacity of the existing generators would need to be confirmed prior to the new connection.

The sizing of the pump station and pipeline was done for the four selected DPR Plant capacities to be included the CAPEX and OPEX comparison in Chapter 8. The pipeline route in Annexure F was chosen based on the existing water pipeline routes taken from the *Water Master Plan* (2017) where possible to avoid having to register new servitudes through private land. The pump station and pipeline calculations were based on the following assumptions:

Pipe material: uPVC

Pipe length: 6 288m

Min Suction level: 80.000m

Max Suction level: 85.000m

Discharge level: 227.000m

Minimum Velocity: 1.2m/s

Pump Efficiency: 60%

Safety Factor: 15%

Table 31: DPR Plant Pump Station Design

Plant Capacity (Mℓ/d)		4.000	6.667	10.000	20.000
	Units				
Flow	l/s	46.30	77.16	115.74	231.48
Pipe diameter	mm	200	250	315	450
Velocity	m/s	1.47	1.57	1.48	1.45
Max Head	m	151.85	182.79	171.60	162.92
Pump size	kW	155	265	375	710
Head loss	m	40.62	35.79	24.60	15.92

The DPR Plant product water would need to be pumped to the Paradyskloof WTW for both Scenario B and C. The pump station would either pump into the raw feedwater inlet sump or the Paradyskloof WTW outlet sump/ reservoir. There would be minimal physical and control integration required to connect the new pipeline from the DPR Plant into the raw feedwater inlet sump at the head of the WTW for Scenario B. The physical integration of the pipeline downstream of the WTW would also be fairly straight forward but the control would require more sophisticated programming to ensure the reservoir's capacity is utilised optimally by ensuring it never reaches critical levels or overflows leading to wastage.

5.5 Operation & Maintenance

The performance of the treatment barriers to deliver product water consistently within specification is dependent on operation and maintenance (O&M) of DPR Plant. The performance of these treatment barriers is essential in safeguarding human health by ensuring the process train is operated and monitored in accordance with design specifications. This requires trained and skilled staff to operate and maintain the plant at all times to ensure all treatment steps are operational and performing optimally. The Stellenbosch DPR Plant will require staff with specialist skills, usually not found at WWTW and WTW, due to the advanced process technologies and water quality monitoring programmes.

The process design selected for any reclamation plant must be compatible with the available skills within the workforce. The Stellenbosch DPR Plant process was chosen with this in mind by opting not to include RO or nanofiltration. These technologies require highly skilled operators and maintenance teams to operate efficiently and these would not usually be found within the municipal operations staff contingent. These skills would usually be supplied by the private sector and from part of a Public Private Partnership (PPP) through a concession or separate O&M contract. The BAC and GAC filter beds have the advantage of more conventional operation procedures and monitoring regimes which would suit the available workforce within the Stellenbosch Municipality. The AOP processes require a high degree of skill and knowledge to operate, especially the H_2O_2/UV process. The plant operators must have an in-depth knowledge of the system and know which parameters to monitor on a daily basis to identify when they are not within the performance specifications.

The procurement process of the mechanical and electrical equipment for the advanced water treatment process steps is also linked to successful O&M programmes. The majority of the mechanical and electrical equipment which shall be used in the Stellenbosch DPR Plant will be imported. The impact of slow response times to failures whilst waiting for technical advice or spare parts from overseas can be a major contributor to poor plant reliability. It is therefore paramount that as part of the O&M strategy that all imported equipment is supported by a local agent who can provide technical expertise, routine maintenance inspections and stock critical spares.

The recommended O&M model, which is used at the NGWRP and Beaufort West Reclamation Plant, would be to include a concession as part of a Design-Build-Operate type contract. This concession would see the contractor who designed and built the plant, operate and maintain it for a certain period, usually 20 years, during which time they can charge an agreed tariff to the Municipality for the reclaimed water. This model has the advantage of the contractor being incentivised to provide high quality water, reduce overhead costs and improve efficiencies (energy, chemicals etc.). These private entities are able to tap into a skills base which is not always willing or available to public water utilities like the Stellenbosch Municipality. This model does come with drawbacks in terms of employment opportunities for the local workforce as the private companies employ their own staff. This is currently a hot topic of debate within South Africa’s water infrastructure sector whereby labour unions are opposed to privatisation to protect jobs.

6. PUBLIC ACCEPTANCE

Public acceptance of any reclamation scheme is one of the major obstacles to project implementation (Wilson & Pfaff, 2008; Hurlimann & Dolnicar, 2010; Cain, 2011) and is just as important as the technical and financial factors in determining whether a project will be acceptable to the community. DPR has been stigmatised by the ‘yuck’ factor which deems reclaimed water as dirty and undesirable for drinking. The public perceptions surrounding DPR are based on engrained social and institutional perceptions that stir up emotions which must be addressed through a public awareness programme to engage, educate and address public concerns.

The WRC published a report in 2017 titled *Investigation into institutional and social factors influencing public acceptance of reclaimed water for potable uses in South Africa* which provides and in-depth review of the public perception challenges faced when implementing a potable reuse scheme along with various strategies to counter these challenges. The report focussed on three potable reuse schemes in Beaufort West, Overstrand Municipality and eThekwini Municipality and the public awareness campaigns that were implemented in each. The report underlined the important social and institutional barriers which were encountered in each of the campaigns and provides a framework to address them within the context of South Africa. This research as well as lessons learnt in Australia and the USA potable reuse schemes were summarised and used to formulate a strategy for the Stellenbosch Municipality to successfully engage with all relevant stakeholders.

6.1 Drivers for Acceptance

The drivers for acceptance of potable reuse must be fully understood in order to formulate a strategy to address these concerns. These drivers are both social and institutional aspects which can lead to a negative public perception of potable water reuse and must be dealt with through meaningful outreach and participation (Metcalf & Eddy, 2007). The ability to win public support for potable water reuse is built on the three important pillars of overcoming fear, addressing safety concerns and building trust (Muanda *et.al*, 2017). These fundamental issues are linked to all four stages of a potable reuse project: (1) planning, (2) decision, (3) implementation, and (4) post implementation (Muanda *et.al*, 2017).

6.1.1 Social Drivers

‘Yuck’ factor – most public responses to direct potable reuse is disgust as they see reclaimed water as dirty and contaminated. The emotions which are triggered by the words ‘wastewater reuse’ and ‘toilet to tap’ do not have positive connotations.

Safety – the health concerns associated with drinking water which was been contaminated with sewage can be a difficult obstacle to overcome. The public distrust in advanced water treatment technologies and final water quality must be alleviated through sharing of knowledge, independent studies and sufficient safety measures implemented to ensure public acceptance.

Trust in public institutions – this driver has been shown to be much more prevalent in South Africa than in Australia and the USA. The trust in public institutions has been eroded over time due to poor management and lack of transparency. The public will not trust a water authority to provide clean drinking water from a DPR scheme if it cannot meet current water and wastewater discharge limits from WTW and WWTW respectively. This trust can only be built through the institutional drivers discussed in the next section.

Choice and preference – many people feel that there are alternative choices to reuse such as desalination, ground water or expanding current surface water resources without much knowledge of each type of intervention. The public must be not be made to feel like there is only one choice available to them but rather different options upon which they can provide meaningful input on.

Culture and religion – reuse can be seen as going against cultural and religious beliefs and therefore not acceptable to certain communities. There must be clear understanding of the entire community and their perceptions of potable reuse during planning stages.

Equity – concerns surrounding equity of water users within South Africa is and will be a contentious issue for the foreseeable future. The inequality built along racial lines due to the Apartheid era has led to public perceptions of lower income communities receiving inferior water services to that of high-income communities. This is linked to water quality concerns and preferences for drinking reclaimed water and whether low income areas have a choice on where their water is sourced from.

6.1.2 Institutional Drivers

Public engagement – the public are the end consumers of reclaimed water and therefore they must be part of the decision-making framework. The issues around a misinformed, isolated and sceptical public can render a potable reuse scheme “dead in the water” before it has got past the initial planning phases. The public’s concerns must be heard in public forums and sufficiently addressed by the public authority through consistent communication (U.S. EPA, 2017).

Political support – there must be political support from within the public authority to mobilise public support for potable reuse. These political forces within South Africa hold significant power within communities and must be convinced that potable reuse is a viable option to augment drinking water supply. These political officials can reach communities at their level which is vital in winning support for potable reuse.

Media influence – the relationship between public authorities and the media is of growing importance in the current knowledge and information sharing climate. The ability to convince media platforms through science-based research is important in gaining the public’s trust. It is also important that media coverage moves away from reuse terms which indicate the water quality is inferior or unsafe to drink (Muanda *et.al*, 2017, U.S. EPA, 2017).

6.2 Strategies

6.2.1 Institutional

Institutional strategies to instil public confidence in potable reuse projects must first focus on delivering credible and verified results from the current water and wastewater treatment facilities. The DWS Blue Drop and Green

Drop certification programme must be adhered to as the benchmark for building public confidence in the Stellenbosch Municipality's capacity to operate and maintain water infrastructure in accordance with national standards. The Stellenbosch Municipality should develop an online platform whereby weekly monitoring results are published for public information to begin to develop an open and transparent partnership upon which trust can be built with the public. This platform can then be further developed with monitoring results once the DPR Plant has been commissioned. These results should be independently verified to attach a high level of credibility to the laboratory results.

The Stellenbosch Municipality must also develop in conjunction with specialists, relevant stakeholders and the community reuse guidelines and water quality standards. This document must get approval from national government through the DWS and also be independently reviewed and verified by international experts. This document would provide clear performance and water quality standards which can inform the public of the framework to be adopted for the DPR scheme. This document should clearly outline the public health concerns of exposure to reclaimed water and the multiple barriers in place to prevent disease and long-term health issues.

A comprehensive water reconciliation strategy must be undertaken by the Stellenbosch Municipality to identify all potential water resources to augment the potable water supply. Stellenbosch is currently afforded the luxury of being able to carry out these studies prior to implementing a DPR scheme as there is sufficient water resources available to meet the current demand. This study would help motivate the benefits of potable reuse over other water resources from a technical, financial and environmental standpoint should it be the most viable option. This process will further reinforce the necessity of potable reuse to the public and should be done in consultation with the public.

6.2.2 Public Engagement

Public engagement forms part of both institutional and educational strategies for gaining public acceptance. The ability to consult with the public throughout the four stages of the project mentioned above is imperative. The consultation methodology can be in the form of open workshops whereby the Stellenbosch Municipality, experts in the field of reuse, environmental practioners, relevant stakeholders and the public can discuss aspects of the project and raise their concerns. There are other platforms such as surveys, opinion polls and comment on legislation which can all enhance this public engagement process and reach a wider audience.

The failures of the past in consulting with public have arisen from consultation processes being done after a decision has already been taken. The engagement process has therefore only focussed on addressing the publics objections to the potable reuse scheme (Muanda *et.al*, 2017). The engagement process is therefore initiated too late in the project timeline for it to be meaningful and take consideration of the publics concerns from the beginning. The idea that a decision has already been made by a public authority and the public must abide by it will lead conflict and disputes between the parties.

Public engagement platforms also help the public authority and engineers understand the public's knowledge and very often misconceptions of potable reuse schemes. The consultation process must aim to identify and address these misconceptions through timeous responses and be integrated into educational awareness programmes (Cain, 2011). The use of experts in the water reuse field during the consultation process is highly recommended to build confidence and trust in the Stellenbosch Municipality's potable reuse programme.

6.2.3 Education

Education can help inform the public in the early stages of all the water management options available to Stellenbosch. The idea of water scarcity, urbanisation and climate change can be conveyed to the public in a clear and concise manner through educational awareness (Cain, 2011). This empowers the public to begin to understand the problem of water scarcity and need to augment current water supplies with alternative sources to meet future demands. The public must be made aware of what is at stake in terms of water supply so that they are able to focus on the problem which is being solved through potable reuse (Muanda *et.al*, 2017). The alternative water supply interventions should be classified in terms of the advantages and disadvantages of each so that the public can make up their own mind. This is an extremely powerful tool in being able to convince the public of the benefits of potable reuse (Muanda *et.al*, 2017).

The Stellenbosch Municipality can also create awareness of environmental issues such as climate change and protection of water resources. The development of water as a finite resource in a world with increasing urbanisation and climate change should be at the forefront of educational awareness programmes. The reliance on the Theewaterskloof Dam for raw water and the problems associated with this surface water resource should be used to show the vulnerability within Stellenbosch's water supply system. The protection of the Eerste River and biodiversity which inhabits this ecosystem must also form part of the educational awareness. Contaminants in the form of organics and chemicals being discharged into river bodies without being treated at the WWTW should be highlighted and contrasted with the benefits of removing them at the Stellenbosch DPR Plant.

The educational awareness campaigns can take many different forms ranging from public talks by leading experts, posters, pamphlets, school talks and media releases. The information disseminated to the public must take into account the public engagement process and outcomes from these to be relevant to the wider community. The superior water quality produced by DPR schemes when compared to conventional water treatment works along with the issues surrounding climate change and water resilience should be the main focus of these educational programmes. Building a close relationship with the media will certainly benefit the Stellenbosch Municipality to publish factual evidence and scientific research to persuade the public of the benefits of potable reuse (TDWB, 2015).

7. ENVIRONMENTAL CONSIDERATIONS

7.1 Legislation

The Stellenbosch DPR Plant will be regulated under the *National Water Act (Act 36 of 1998)* to divert effluent discharged from the Stellenbosch WWTW and reclaim it for potable use. In order to understand what impact this will have on the environment with regards to water resource management it is essential to know what the Act is trying to protect. The NWA (1998) prescribes the "*The Reserve*" in Chapter 3, Part 3 which consists of the following two parts:

- Basic human needs reserve – the essential needs of humans for drinking, food preparation and personal hygiene from the water resource
- Ecological reserve – water required to protect aquatic ecosystems within the water resource

The Stellenbosch WWTW effluent is discharged into the Eerste River via the Veldwachters River before flowing into False Bay. The Lower Eerste Irrigation Board (LERIB) holds abstraction rights downstream for irrigation purposes but there are no abstraction rights for any water treatment works. There is a possibility that downstream users in the Macassar area utilise the Eerste River for domestic purposes (Schedule 1 of the NWA, 1998) but it is assumed that all properties are serviced by on-site or communal stand pipes from the municipal potable water network. The impact of the reduction in flow would need to be assessed on these users, as prescribed within Schedule 1 of the NWA, 1998.

The ecological reserve can be impacted in both a positive and negative way by the implementation of the DPR Plant. The water quality within the Eerste River will improve as the wastewater effluent discharge from the Stellenbosch WWTW diminishes which shall be beneficial to the aquatic environment. This is however dependent on the upstream river quality which could either be contaminated by the wastewater effluent if it is of a superior quality, or it could be improved through dilution if it is highly polluted. The Stellenbosch University, in collaboration with the University of Bath, are currently conducting research on the water quality and CECs within the Stellenbosch town to determine the impact of urbanisation, wastewater effluent and agriculture on the rivers and its tributaries. An interview was conducted with one of the researchers, Dr. Edward Archer, in March 2019 whereby initial results had indicated high levels of pollution in the tributaries upstream of the Stellenbosch WWTW. The results of this research are confidential at this time and could not be obtained for this research but initial indications point to the Stellenbosch WWTW effluent being of a higher quality than base river flows emancipating from the town, which would dilute these pollutants and improve downstream water quality.

The current aquatic ecosystem within the Eerste River would also need to be investigated as it may have adapted to the river water quality characteristics when the total Stellenbosch WWTW effluent was discharged into the river. The resultant decline in wastewater effluent discharged into the river and subsequent water quality impacts would need to be further investigated as part of a specialist study to obtain the environmental authorisations from the Western Cape Department of Environmental and Development Planning (DEADP).

The DPR Plant will also be subject to Chapter 4, Part 4: *Stream Flow reduction activities* of the NWA, 1998. The base flow of the Eerste River would need to be determined, if not already known, to determine the impact of diverting wastewater effluent to the DPR Plant. This can have an effect on the downstream aquatic ecosystems as mentioned above as well as the LERIB and their allotted water right allocations. The impact would be most prevalent in the drier summer months when natural flows are at their lowest and the DPR Plant is diverting the maximum wastewater effluent quantity of 20 Mℓ/d.

The *National Environmental Management Act* (NEAM Act 107 of 1998) was passed into law to establish a framework for co-operative governance by establishing principles for decision making on matters which can affect the environment. The Act aims to promote co-ordination between organs of state to administer and enforce environmental legislation to protect the public and surrounding environment from harmful practices. The NEMA (1998) outlines certain 'listed activities' which require environmental authorisation form the relevant authority prior to commencing of any of these 'listed activities'. The environmental authorisation is usually granted after the completion of a Basic Assessment or Scoping and Environmental Impact Report (S&EIR) as set out in the *Environmental Impact Assessment Regulations*, 2014 (Gazette No.38282).

The Stellenbosch DPR Plant will fall under *Listing Notice 1: List of activities and competent authorities identified in terms of Sections 24(2) and 24d, 2010* of the NEMA (1998) for the following 'listed activity':

Activity No.9

The construction of facilities or infrastructure exceeding 1000 metres in length for the bulk transportation of water, sewage or storm water –

(i) with an internal diameter of 0,36 metres or more; or
(ii) with a peak throughput of 120 litres per second or more,

excluding where:

a. such facilities or infrastructure are for bulk transportation of water, sewage or storm water or storm water drainage inside a road reserve; or
b. where such construction will occur within urban areas but further than 32 metres from a watercourse, measured from the edge of the watercourse.

This activity requires a Basic Assessment report to be conducted by a competent environmental assessment practitioner (EAP) and submitted to the DEADP for approval. This application would also need to be supplemented with an Environmental Management Plan (EMP) to be followed during construction and operational phases of the project. The new DPR Plant will be situated on the existing Stellenbosch WWTW site and therefore the existing land use rights will not need to be altered, which could trigger a more prolonged and comprehensive S&IER in terms of NEMA (1998). The Beaufort West Water Reclamation Plant followed the same environmental authorisation process as detailed in the *Final Basic Assessment Report: Reclaimed Water in Beaufort West* (Ninham Shand Consulting Engineers, 2009).

7.2 Energy Consumption

The energy consumption of the DPR Plant will lead to greater environmental implications when compared to a conventional WTW. The DPR Plant will use approximately 70% more energy (see Table 21 & Table 23) than the Paradyskloof WTW which can be converted into certain usage and emission parameters, adapted from Eskom (2011), assuming the power is generated from coal fired power stations. Scenario A has been used as the baseline for comparison purposes with Scenario B and C's energy consumption to produce 20 Mℓ/d of clean drinking water. The minimum and maximum daily energy consumptions for Scenario B and C were calculated depending on the blend ratio between DPR product water, raw water and final treated water.

Table 32: Daily Energy Consumption

	Scenario A	Scenario B		Scenario C	
		Min	Max	Min	Max
Daily Energy Consumption (kWh)	3 460	5 740	14 860	5 048	11 400
% above baseline		66%	329%	46%	229%

Table 33: Environmental impacts of daily energy consumption

			Scenario A	Scenario B		Scenario C	
	per 1kWh	Unit		Min	Max	Min	Max
Coal use	0,53	kg	1834	3042	7876	2675	6042
Water use	1,4	l	4844	8036	20804	7067	15960
Ash produced	0,155	kg	536	890	2303	782	1767
Particulate emissions	0,33	g	1142	1894	4904	1666	3762
CO_2 emissions	0,99	kg	3425	5683	14711	4998	11286
SO_2 emissions	7,75	g	26815	44485	115165	39122	88350
NO_x emissions	4,18	g	14463	23993	62115	21101	47652

The consumption of natural resources, such as coal and water, required for Scenario B and C are much higher than Scenario A. This is to be expected as reclamation is more energy intensive than conventional water treatment. The above tables do not factor in energy requirements for conveyance and can therefore be misleading. The energy required to pump raw water from the Theewaterskloof Dam to the Paradyskloof WTW will have the biggest impact on Scenario A, which only treats raw water from this source. It will also have an impact on the energy consumption of Scenario B and C depending on the blend ratios and portion of raw water to be treated from the Theewaterskloof Dam. The energy consumption figures for the raw water pump station through the Stellenboschberg tunnel and pipeline could not be obtained from the DWS and hence requires further analysis to determine the holistic environmental impact of the three scenarios' chosen.

7.3 Impact on Surface Water Resources

The reclamation of wastewater effluent to potable water will result in a decrease in wastewater effluent discharged from the Stellenbosch WWTW into the surrounding surface water bodies. This will reduce the base flow in the Veldwachters and Eerste River which can have both a positive and negative effect on water quality for aquatic ecosystems and downstream users.

The reduction in wastewater effluent discharge into the river, containing CEC's and other pollutants, can improve the water quality and habitat of aquatic ecosystems. It can also further degrade the river water quality should there be other sources of pollution upstream of the wastewater effluent discharge point. This is because the wastewater effluent previously discharged, aided in diluting the polluted river water from upstream leading to an improvement in the river water quality. The impact of these changes in water quality can have adverse effects on established aquatic ecosystems, which have become used to the composition of the wastewater effluent (NWRI, 2015).

The reduction in baseflow of the river will have an impact on the Lower Eerste River Irrigation Board (LERIB) and the volumes of water farmers can abstract from the river for irrigation purposes. This issue would need to be further investigated to determine the impact on farmers and possible alternative water resources for irrigation. The impact of reduction of baseflow is beyond the scope of this research but would need to be analysed should DPR be considered within Stellenbosch.

8. FINANCIAL FEASIBILITY

A financial analysis was conducted over the three scenarios selected to determine the financial feasibility of each option. The financial feasibility is defined as whether there is the willingness and capability to pay for the project (Metcalf & Eddy, 2007). The feasibility should also determine the appropriate procurement model to finance project over its lifecycle. The financial feasibility must identify all the monetary costs at market prices over the project's lifecycle. These costs can be divided between capital expenditure (CAPEX) and operational expenditure (OPEX) to determine the annual and unit costs over the project lifecycle. The financial analysis can then be developed further to determine the required revenue programme needed to recover these costs to ensure the project is sustainable.

8.1 Procurement Options

The high capital costs associated with establishing a DPR plant mean that public entities may need to secure funding from outside their capital budgets from the private sector and government subsidies. The source of funding and procurement model for a potable reuse project are closely linked. There are numerous procurement options available to finance any potable reuse project and require further investigation to determine the most appropriate based on the individual circumstances for each case. The five preferred procurement models to fund water sector projects are as follows (Turner *et al*., 2015):

1. Public funding
2. Public Private Partnerships (PPP)
3. Concessions
4. Project/Infrastructure Financing Utility
5. Independent Water Utility

The first three procurement options are the most favoured for water reuse projects in Southern Africa and can be implemented together. The Beaufort West Reclamation Plant and the George Water Reclamation Plant were both funded through DWS grants. The Beaufort West Reclamation Plant was to be funded through external loans from the private sector with a capital redemption plan to pay off the costs as part of the annual OPEX. The DWS however, stepped in with emergency funding leading to this model being abandoned which significantly reduced the annual OPEX costs and subsequent unit costs for potable water production. The New Goreangab Water Reclamation Plant was funded through external loans from Europe (95%) and the City of Windhoek's internal capital budget (5%) as reported by Turner *et al*. (2015). The Beaufort West Reclamation Plant and NGWRP projects were both formed and executed on a PPP procurement model and operated and maintained under a 20-year concession. The concession allows the private entity to sell the reclaimed water to the public entity at an agreed price for a 20-year period to recover their costs.

The type of procurement model selected can have a significant impact on the annual and unit costs of DPR plant and therefore must be carefully considered. This research assumes that a PPP model will be chosen whereby the DPR Plant is designed, built and operated by a private company through a 20-year concession. This company would sell the reclaimed water back to the Stellenbosch Municipality through a tariff model to cover their operating costs. This research selected two PPP procurement models for the Stellenbosch DPR Plant which were used to finance the initial CAPEX and annual OPEX.

8.1.1 Procurement Model No.1 (100% public funding)

The first PPP model assumes that the Stellenbosch Municipality will finance the capital costs from government subsidies or their internal capital budget. The DWS currently provides government subsidies in the form of Municipal Infrastructure Grant (MIG) and Regional Bulk Infrastructure Grant (RBIG) for water infrastructure in the public sector. The Stellenbosch Municipality could also fund the project through their own funds generated through internal revenue streams. The advantage of this model is that the capital redemption values which form part of the OPEX are zero resulting in much lower unit costs for producing potable water and therefore lower tariffs for end consumers. The disadvantage is that most DWS subsidies do not cover the full capital costs of a project and most municipalities are already financially strained to meet required shortfall from their internal budgets.

8.1.2 Procurement Model No.2 (100% private funding)

The second PPP procurement model is the most likely in the current economic climate and requires funding from private parties such as banks, contractors or investors for the initial capital costs. These external loans would need to be repaid over the 20-year period as part of the capital redemption costs. The advantage of this model is that the Stellenbosch Municipality would not require any initial capital to implement the project should an emergency situation arise. The disadvantage to this model is that the capital redemption costs to cover the external loan would result in higher unit costs for producing potable water which would be passed onto the municipality and the end user.

8.2 Capital Expenditure (CAPEX)

8.2.1 Scenario A

The Paradyskloof WTW was recently upgraded in 2018 and these capital costs have therefore been excluded from this financial analysis. This initial capital investment can be declared as a sunk cost because the debt obligations will remain regardless of which future scenario is selected (Metcalf & Eddy, 2007). The capital replacement costs however cannot be excluded as the civil, mechanical and electrical equipment will need to be replaced depending on the project duration and expected useful life (see Chapter 8.3.1). The capital replacement costs have been based on the initial capital investment costs of the Paradyskloof WTW in the absence of an asset register for the plant.

The capital costs were calculated based on the DWS (2016) benchmark costs for water services. This document provides a unit capital cost for a conventional WTW based on the scheme size. The entire 20 Mℓ/d capacity was used to determine to the total capital cost of the Paradyskloof WTW in 2019 market prices based on an inflation figure of 5.5% (STATSSA, 10-year mean between 2009 - 2019). The total capital costs were then broken down further under the following assumptions, which are homogenous for Scenario B and C.

Table 34: CAPEX Assumptions

	% Percentage	Source
Preliminary & General	15%	
Contingencies	10%	
Escalation (Civil)	8%	
Escalation (M&E)	3%	
Foreign Exchange (M&E)	5%	
Civil Capital Costs	60%	Swartz et al , 2012
M&E Capital Costs	40%	Swartz et al , 2012
Professional Fees	15%	

8.2.2 Scenario B & C

The capital costs for Scenario B and C was based on the capital costs of the Beaufort West Reclamation Plant and the New Goreangab Water Reclamation Plant. The capital costs reported by Swartz *et al.* (2014) were escalated to 2019 current market prices using an inflation rate of 5.5%. These capital costs were then converted to unit costs based on the plant's capacity and plotted on the graph in Figure 25 below. The two data points fit within the chosen Stellenbosch DPR Plant sizes ranging from 4.0 – 20 Mℓ/d. A logarithmic trendline was then plotted between the two data points in order extrapolate capital costs for various plant sizes. This trendline shows economies of scale achieved through the relationship between the plant capacity and unit costs.

Table 35: Past DPR project capital costs (excl. VAT)

	Beaufort West WRP		New Goreangab WRP	
Capacity (kℓ/d)		2000		21000
Construction Year		2010		2001
Capital Cost	R	23 749 884,00	R	108 556 913,00
Present Year		2019		2019
Present Capital Cost	R	38 453 301,18	R	284 578 285,36
Present Unit Cost (R/kℓ)	**R**	**19 226,65**	**R**	**13 551,35**

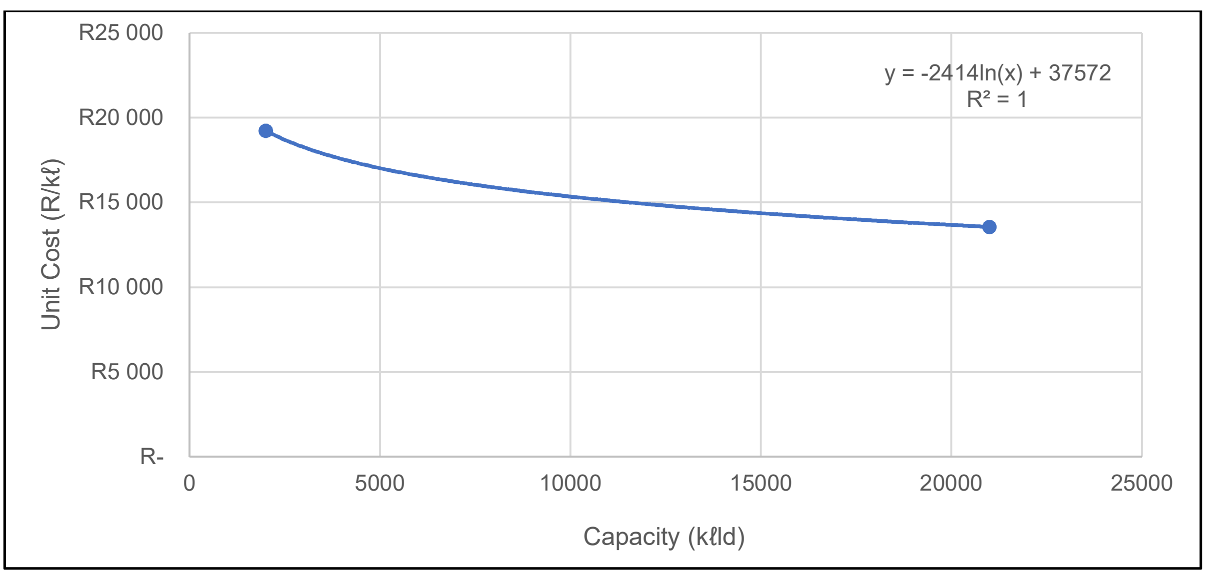

Figure 25: DPR plant capacity and unit costs (excl. VAT)

The capital costs for Scenario B and C do not include the conveyance pipeline from the DPR Plant to the Paradyskloof WTW. The suggested pipeline route and pipe diameters have been determined in Chapter 5.4 for the range of DPR Plant sizes proposed. The costs have been excluded from this study due to the uncertainty surrounding the pipeline route, potential crossings, wayleaves and environmental approvals. These costs would need to be quantified later on to determine the final capital costs.

8.2.3 Summary

Table 36: Capital Costs (R millions)

	Paradyskloof WTW	**Stellenbosch DPR Plant**			
Capacity (Mℓ/d)	**20**	**4**	**6.667**	**10**	**20**
Civil Capital Cost	R 90,212	R 46,778	R 73,732	R 105,553	R 193,872
P&G	R 13,532	R 7,017	R 11,060	R 15,833	R 29,081
Contingencies	R 10,374	R 5,379	R 8,479	R 12,139	R 22,295
Escalation	R 8,559	R 4,438	R 6,995	R 10,014	R 18,394
Total Civil Capital Cost	**R 122,678**	**R 63,612**	**R 100,267**	**R 143,539**	**R 263,641**
M&E Capital Cost	R 60,142	R 31,185	R 49,155	R 70,369	R 129,248
P&G	R 9,021	R 4,678	R 7,373	R 10,555	R 19,387
Contingencies	R 6,916	R 3,586	R 5,653	R 8,092	R 14,863
Escalation	R 2,282	R 1,183	R 1,865	R 2,670	R 4,905
FOREX	R 3,007	R 1,559	R 2,458	R 3,518	R 6,462
Total M&E Capital Cost	**R 81,369**	**R 42,192**	**R 66,504**	**R 95,205**	**R 174,866**
Total Capital Cost (Civil & M&E)	R 204,046	R 105,804	R 166,771	R 238,744	R 438,507
Professional Fees	R 30,607	R 15,871	R 25,016	R 35,812	R 65,776
Total Cost	**R 234,653**	**R 121,674**	**R 191,787**	**R 345,960**	**R 504,283**

8.3 Operational Expenditure (OPEX)

8.3.1 Capital Redemption

A capital redemption plan was setup to break down the capital costs for each scenario into annual payments over the 20-year lifecycle period. It was assumed that the full capital costs would be funded through external loans at an annual interest rate of 6%. The capital replacement costs were also included within these annual payments, with the following expected useful life assumptions made on the assets:

- Civil infrastructure 50 years
- Mechanical equipment 15 years
- Electrical equipment 15 years

The mechanical and electrical equipment would therefore need to be replaced within the 20-year horizon used for this study. It was assumed that the capital replacement costs would amount to 75% of the current mechanical and electrical capital costs, escalated at 5.5% to 2034. This amount would be kept by the

Stellenbosch Municipality in an interest-bearing account matching that of the 5.5% inflation figure for a period of 15 years. The annual capital costs were the determined by adding the capital and capital replacement costs and then using the following formula:

$$\text{Capital redemption} = (\text{Total capital cost} + \text{capital replacement cost}) \times \frac{i(1+i)^n}{(1+i)^n - 1}$$

i = annual interest rate (6%)

n = number of compounding years (20 years)

8.3.2 Raw water tariffs

The raw water demands for each year were calculated using the annual demand and subtracting the volumes being produced by the DPR Plant. The future tariffs were determined from the escalation rates in Table 11 and then multiplied to give the annual cost of purchasing raw water from the Theewaterskloof Dam to feed the Paradyskloof WTW.

8.3.3 Labour

The current staff contingent from the Paradyskloof WTW was obtained from the Stellenbosch Municipality (W De Kock 2019, personal communication, 2 May). The staff salaries could not be obtained for confidentiality reasons and were determined from current market rates and experience.

Table 37: Paradyskloof WTW Labour Costs (2019)

Paradyskloof WTW (Class C Works)					
Staff					
Staff	Class	No	Monthly Salary	Annual Salary	Utilisation
Plant Manager	V	1	R 45 000,00	R 540 000,00	100%
Process Controllers	III	4	R 30 000,00	R 1 440 000,00	100%
Mechanical Technician	n/app	1	R 35 000,00	R 210 000,00	50%
Electrical Technician	n/app	1	R 35 000,00	R 210 000,00	50%
Chemist	n/app	0	R 35 000,00	R -	50%
Laboratory Technician	n/app	0	R 25 000,00	R -	50%
General Workers	n/app	4	R 15 000,00	R 720 000,00	100%
Total		11	R 220 000,00	R 3 120 000,00	

The qualifications of the DPR Plant staff was determined in line with the classification of the plant, as directed by *Government Gazette No.36958, Schedule 1 and 2* (23 October 2013). The DPR Plant was classified as a Class B Works and the salaries were based on the typical process controller and supervisor salaries used in Table 37. The labour costs for both the Paradyskloof WTW and Stellenbosch DPR Plant were escalated at 8% over the project lifecycle to account for inflation, salary increases and bonuses.

Table 38: Stellenbosch DPR Plant Labour Costs (2019)

Stellenbosch DPR Plant (Class B Works)						
Staff						
Staff	Class	No*	Monthly Salary		Annual Salary	Utilisation
Plant Manager	V	1	R	45 000,00	R 540 000,00	100%
Process Controllers	IV	2	R	30 000,00	R 720 000,00	100%
Mechanical Technician	n/app	1	R	35 000,00	R 105 000,00	25%
Electrical Technician	n/app	1	R	35 000,00	R 105 000,00	25%
Chemist	n/app	1	R	35 000,00	R 105 000,00	25%
Laboratory Technician	n/app	1	R	25 000,00	R 75 000,00	25%
General Workers	n/app	2	R	15 000,00	R 360 000,00	100%
Total		9	R	220 000,00	R 2 010 000,00	

*The number of staff increased for the 10Ml/d and 20Ml/d DPR Plants and can be found in Annexure E.

8.3.4 Energy

The electricity pricing was obtained from the latest Stellenbosch Municipality *2018/2019 Tariffs (Appendix 3)*. These costs included daily consumption charges, fixed monthly charges and Max. Consumption (MC). The daily consumption charges were broken done into off-peak, standard and peak rates. The off peak, standard and peak times were obtained from the Eskom *2019/20 Schedule of Standard Prices for Eskom Tariffs* and converted to the number of days per year. An annual allowance of 8.28% for electricity price increases was included which was calculated from the average electricity price increases over the past 7 years from Eskom's published tariffs. The medium energy consumption figures reported in Table 21 and Table 23 were used for the costing calculations.

Table 39: Electricity Pricing (excl. VAT)

ELECTRICITY PRICING ASSUMPTIONS			
Low Demand	273	days	Eskom 2019/20
High Demand	92	days	Eskom 2019/20
Off-peak	176	days	Eskom 2019/20
Standard	135	days	Eskom 2019/20
Peak	54	days	Eskom 2019/20
Off-peak rate (OR)	0,611	R/kWh	Stellenbosch Municipality Tariffs 2018/19
Standard rate (SR)	0,815	R/kWh	Stellenbosch Municipality Tariffs 2018/19
Peak rate (PR)	1,247	R/kWh	Stellenbosch Municipality Tariffs 2018/19
Fixed Monthly Charge	5512,6	R/month	Stellenbosch Municipality Tariffs 2018/19
Max Consumption (MC)	39,04	R/kVA	Stellenbosch Municipality Tariffs 2018/19
Annual Price Increase	8,28%		Eskom average increases (2012 -2019)
kW to kVA conversion factor	1,25		

8.3.5 Chemical

Calcium hydroxide (lime)

The Paradyskloof WTW uses lime to increase the alkalinity of the raw feedwater from the Theewaterskloof Dam by removing calcium and magnesium. This raised alkalinity and pH enhances the chemical precipitation reactions during the coagulation / flocculation stages. The average dosing rates were obtained from Stellenbosch Municipality's historical records over the past two years (W De Kock 2019, personal communication, 16 April). It is noted that the WTW does not re carbonate their final product quality water to lower pH below 8.0 (J Beukes 2019, personal communication, 24 July)

Sodium Aluminate

Sodium Aluminate is used during coagulation to destabilise and join together the suspended particles within the raw water before settlement in the clarifiers. The average dosing rates and prices were obtained from Stellenbosch Municipality's historical records over the past two years (W De Kock 2019, personal communication, 16 April).

Chlorine

Chlorine is used for final disinfection at both the Paradyskloof WTW and Stellenbosch DPR Plant. The average dosing rates were obtained from Stellenbosch Municipality's historical records over the past two years (W De Kock 2019, personal communication, 16 April). The Stellenbosch DPR Plant's dosing rates are in accordance with process design selected in Chapter 4.6. Chlorine prices were obtained from Protea Chemicals who are suppliers to water and wastewater treatment works within the Western Cape.

Ozone

Ozone can be produced from clean air or pure oxygen. The two methods vary in the amount of ozone produced as a percentage of the gas stream injected into the water. Pure oxygen is between two and four times more efficient than using clean air (U.S.EPA, 1999) but comes at the additional expense of constantly providing pure oxygen to the ozone generator. It was assumed for this study that the ozone generator would convert clean air into ozone and therefore would not require any additional chemical consumption requirements. Allowance was made in the OPEX model to adjust this cost should pure oxygen be required to produce ozone.

Hydrogen peroxide

Hydrogen peroxide (50% concentration) pricing was obtained from Blendwell Chemicals (Pty) Ltd.

Granular activated carbon

GAC pricing was received from Water Icon Industrial Water Treatment Solutions based on a media with an apparent density of 0.36g/cm^3. This apparent density was converted to a bed density within the GAC and BAC filters by multiplying it by a factor of 0.91, commonly used for these type of filter beds. GAC is usually regenerated off-site with a regeneration efficiency between 77- 90% (Metcalf & Eddy, 2007; Clements & Haarhof, 2006) to account for losses in the handling, regeneration and reactivation steps. The frequency of the regeneration process is dependent on the absorption capacity of the media, contaminants present in the feedwater, backwash cycles frequency and a number of other operational factors. This study has assumed the carbon will be regenerated once a year with a regeneration efficiency of 80%. This does not take into account losses during backwash cycles which have been assumed to be zero in this research. It must be noted that carbon regeneration is not always recommended for water reuse because of the residual constituents not removed in the regeneration process which could desorb and contaminate the feedwater (Metcalf & Eddy, 2007).

Summary

The chemical costs and consumption figures are presented in Table 40 below. An allowance of 5.5% per annum was included for chemical price increases to coincide with the selected inflation rate.

Table 40: Chemical pricing assumptions (excl. VAT)

Chemicals	Dose	Unit	Price	Unit
$Ca(OH)_2$ (lime)	0,0075	kg/m³	R 7 980,00	R/t
Sodium	0,0078	kg/m³	R 13 646,79	R/t
Aluminate	0,021	kg/m³	R 2 102,96	R/t
Chlorine (WTW)	0,841	mg/l	R 28 700,00	R/t
Chlorine (AWTW)	0,500	mg/l	R 28 700,00	R/t
Ozone	5,530	mg/l	R -	R/t
Hydrogen Peroxide	7,500	mg/l	R 26,38	R/l
GAC	n/appl		R 14 086,80	R/m³

8.3.6 Maintenance

The annual maintenance costs for the Paradyskloof WTW were not available and therefore assumptions had to be made for both plants. It was assumed that the civil maintenance costs would be 0.5% of the civil capital costs whilst the mechanical and electrical maintenance costs accounted for 1.5% of the mechanical and electrical maintenance costs. An allowance of 5.5% per annum was included to meet price increases of materials, consumables and external service providers to coincide with the selected inflation rate.

8.4 Results and Discussions

The unit costs represented in the figures below are of the entire potable water scheme for each scenario. They are calculated by adding the total annual costs for the Paradyskloof WTW and Stellenbosch DPR Plant and dividing these costs by the total amount of potable water injected into the municipal water distribution system each year. The unit costs would be the minimum tariffs each year which must be charged for the project to be financially sustainable. A full lifecycle cost breakdown for each scenario is provided in Annexure G.

8.4.1 Augmentation with 4.0 Mℓ/d DPR Plant

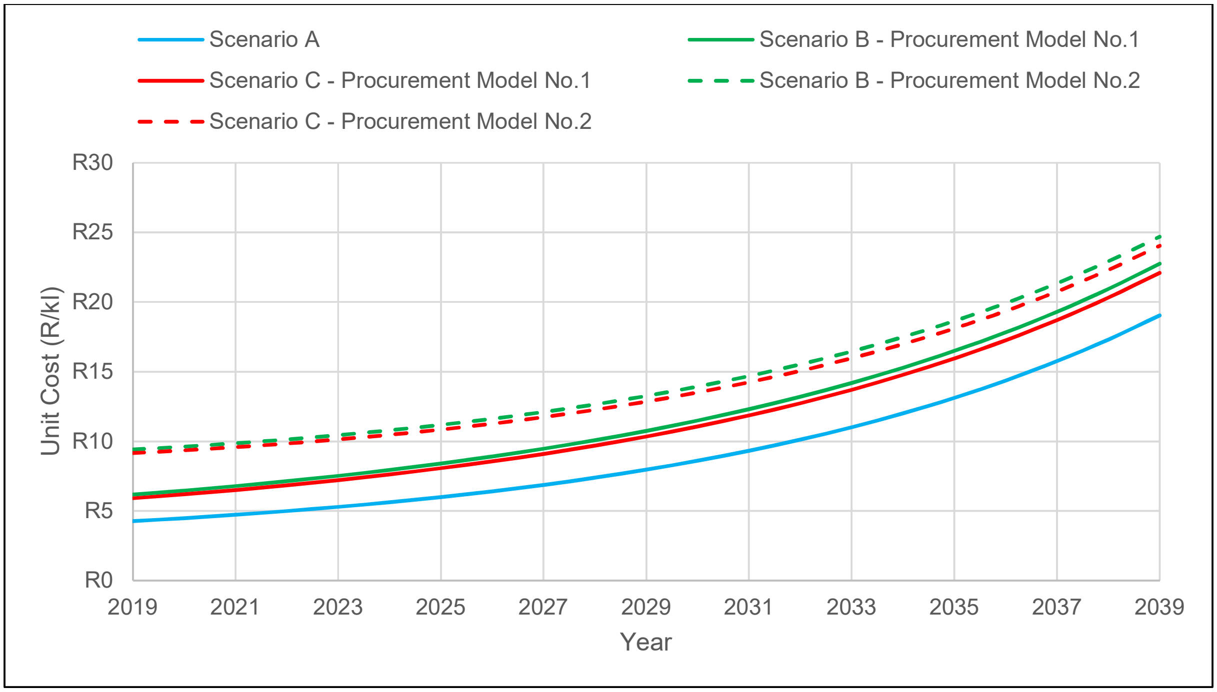

Figure 26: Augmentation with 4.0 Mℓ/d Reclaimed Water Unit Costs

The graph above shows that Scenario A is able to produce the equivalent amount of potable water at much lower unit costs than both Scenario B and C over the project lifecycle. Scenario C has the lowest unit costs between the two DPR Plant options, which is to be expected as the reclaimed water does not have to be treated again at the Paradyskloof WTW. The lowest unit costs are achieved using Procurement Model No.1 as the capital redemption costs are not factored into the annual OPEX which results in a saving of R3.24/kℓ in 2019 down to a saving of R1.95/kℓ in 2039 for both Scenario B and C.

The percentage difference between the unit costs of Scenario B and C for both procurement models begin to diverge as the project continues into the future even though the graphs seem to move away from each other. This can be attributed to the diverging unit costs of the Paradyskloof WTW over time as the Stellenbosch DPR Plant unit costs remain equal for Scenario B and C.

8.4.2 Augmentation with 6.667 Mℓ/d DPR Plant

The unit costs of Scenario A are again lower than both Scenario B and C, irrespective of the procurement model selected. The difference in unit costs between Scenario A and both Scenario B and C has now increased when compared to the 4.0 Mℓ/d DPR augmentation scheme. This shows that the unit costs are increasing as the Stellenbosch DPR Plant capacity increases from 4.0 Mℓ/d to 6.667 Mℓ/d. The lowest unit costs are again achieved using Procurement Model No.1 with a saving of R5.10/kℓ in 2019 and R3.06/kℓ in 2039 for both Scenario B and C.

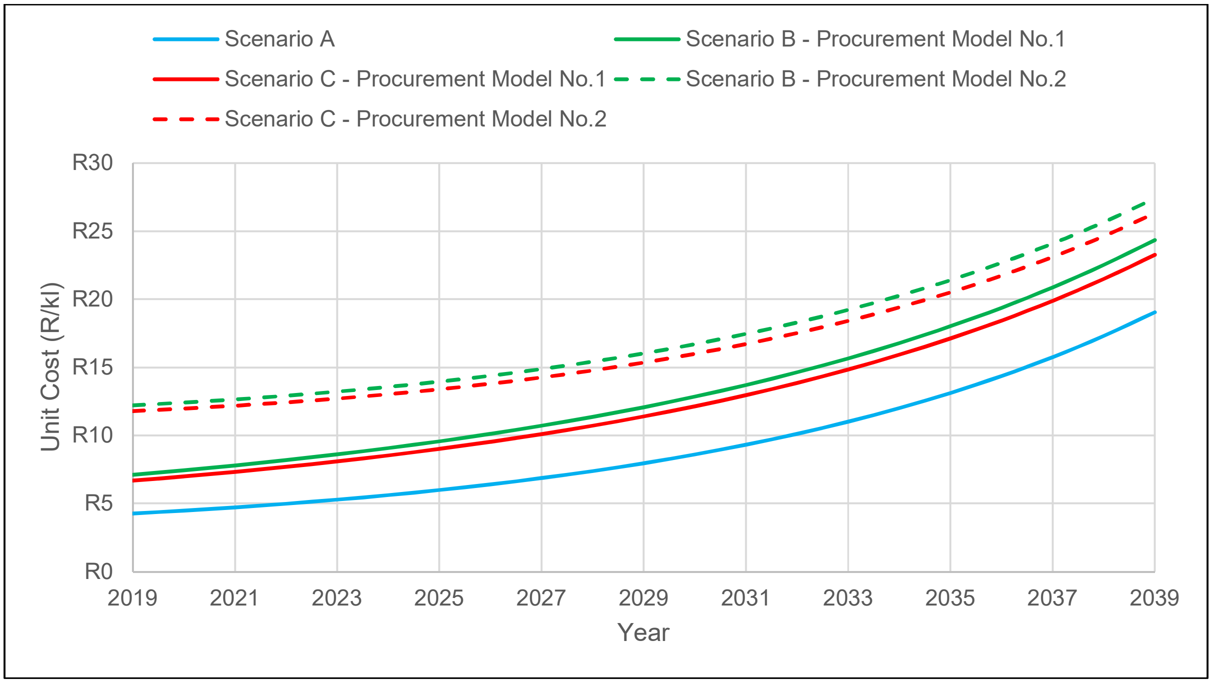

Figure 27: Augmentation with 6.667 Mℓ/d Reclaimed Water Unit Costs

8.4.3 Augmentation with 10.0 Mℓ/d DPR Plant

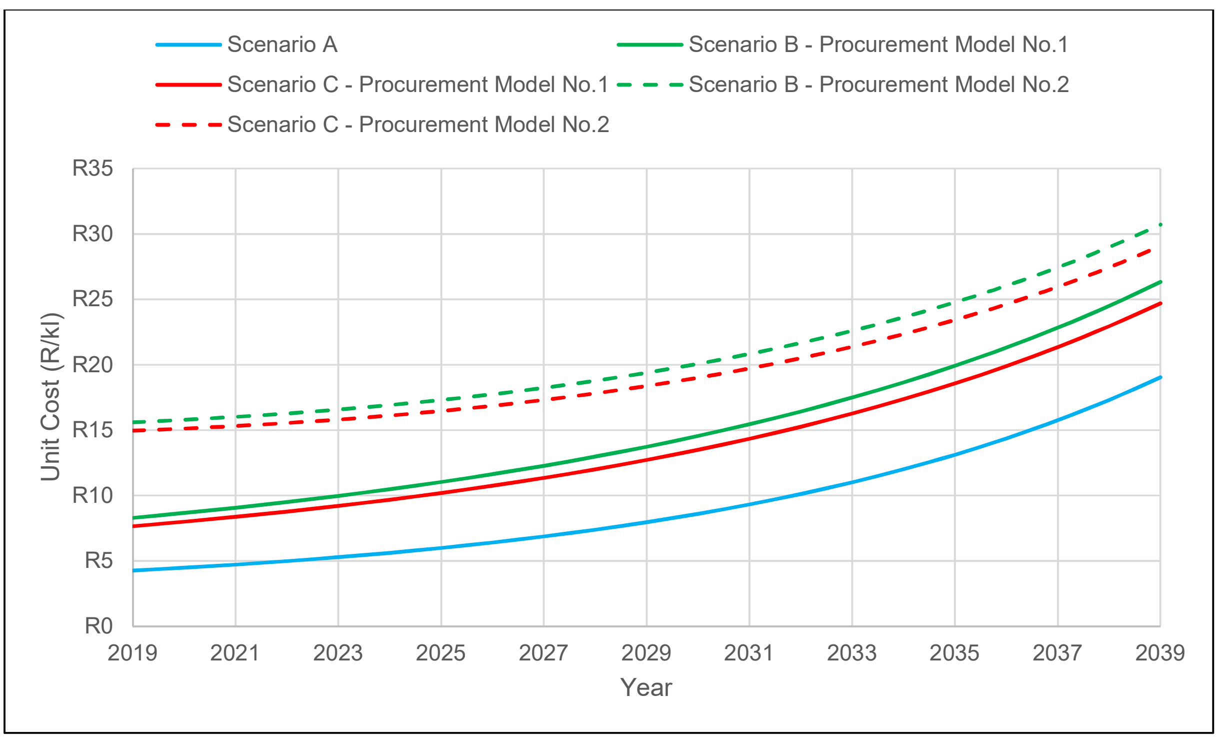

Figure 28: Augmentation with 10.0 Mℓ/d Reclaimed Water Unit Costs

The unit costs for producing potable water continue to increase as the DPR Plant supplements the municipal supply with more reclaimed water. The unit costs for Scenario B and C are approximately 94% and 80% more than Scenario A for Procurement Model No.1 and 265% and 250% more for Procurement Model No.2 respectively.

8.4.4 Augmentation with 20.0 Mℓ/d DPR Plant

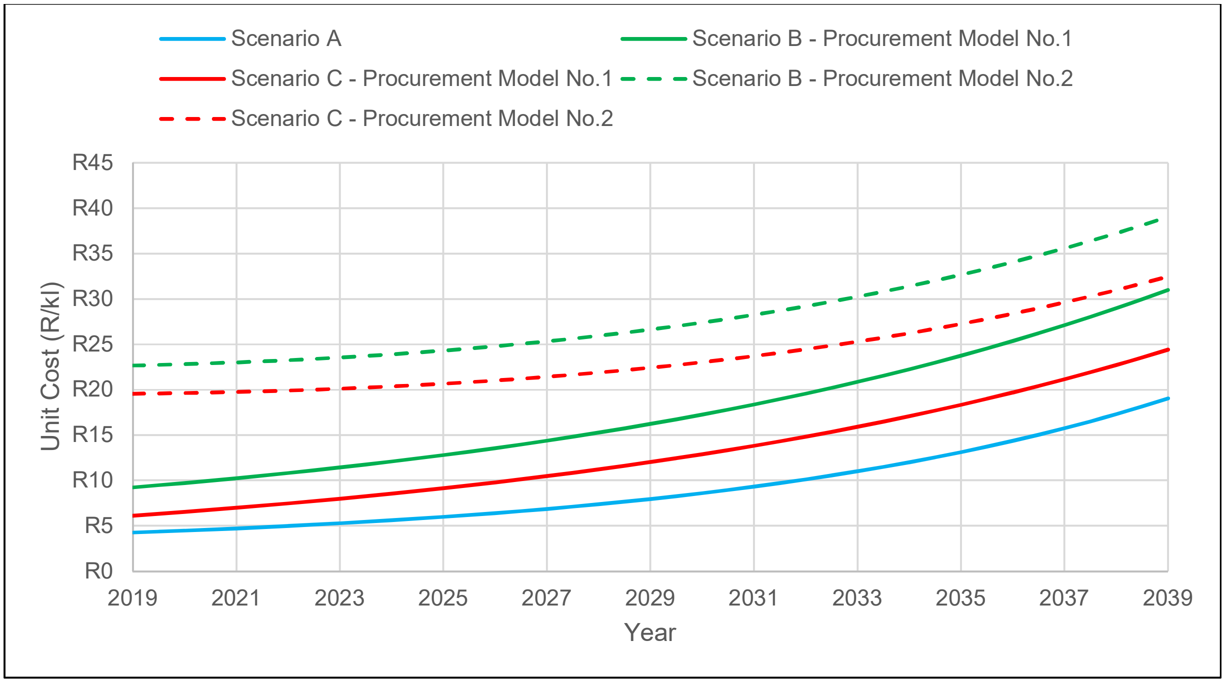

Figure 29: Augmentation with 20.0 Mℓ/d Reclaimed Water Unit Costs

The 20Mℓ/d DPR Plant in Scenario C (Procurement Model No.1) would lead to the lowest unit costs out of Scenario B and C for the various plant capacities. This is because the Paradyskloof WTW would not be utilised and could effectively be mothballed due to sufficient capacity at the DPR Plant to meet the demands over the next 20 years. The unit costs however would still be higher than Scenario A which remains the most cost-effective option out of the three scenarios.

8.4.5 Present Value Unit Costs

The present value unit costs were calculated by dividing the total OPEX costs by the total volume of potable water injected into the municipal water distribution system over the 20-year lifecycle. The individual components of the total OPEX costs were also broken down into their unit costs to clearly show the contribution of each to the total unit costs. These figures included inflation and other market related price increases to give a present value unit cost for each scheme as summarised in the graphs below. These present value unit costs differ from the unit costs shown in the above graphs, as the present value unit cost does not change over time but remains constant over the 20-year lifecycle. These present unit value costs allow us to compare the various scenarios and analyse which scheme is the most cost effective for each procurement model.

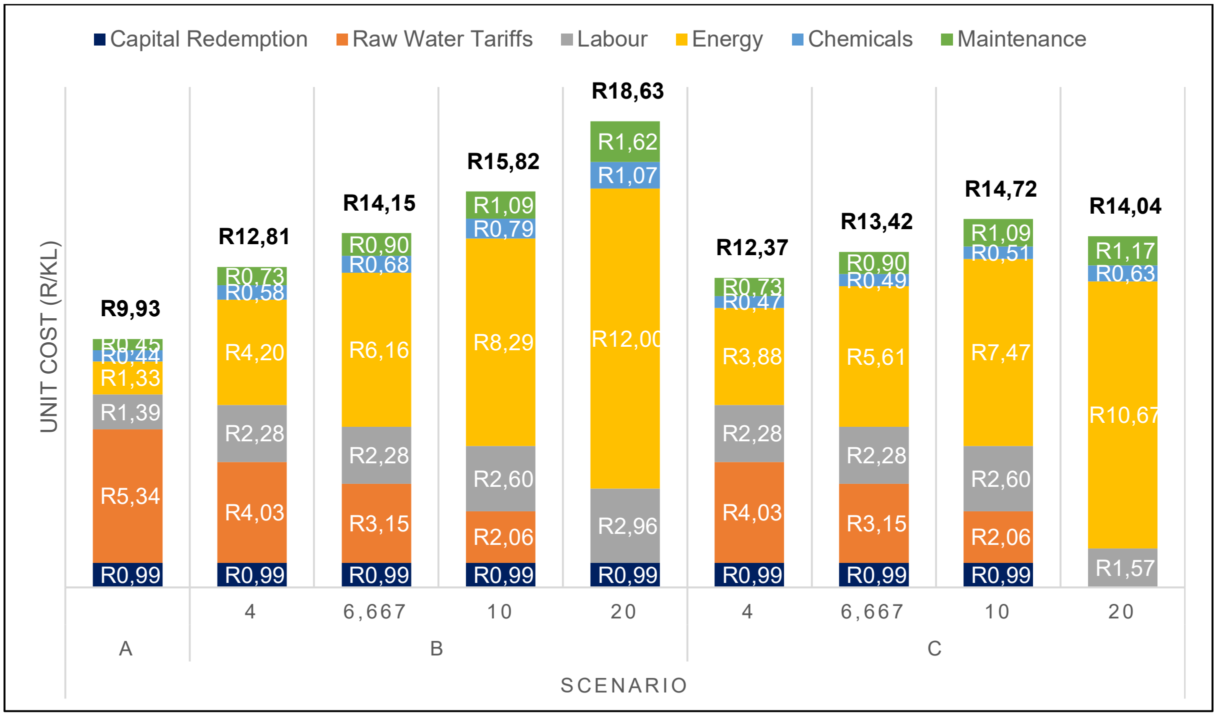

Figure 30: Present Value Unit Costs (Procurement Model No.1)

In Figure 30 Scenario A has lowest total present value unit costs for potable water supply without any water reclamation taking place. The 4.0Mℓ/d DPR Plant generates the next lowest total present value unit costs for Scenario B and C, which are R2,98/kℓ and R2,44/kℓ respectively, more expensive than Scenario A. When comparing the present value unit costs between Scenario B and C for the same DPR Plant capacity it is clear to see that Scenario C is more cost effective. This is due to a combination of lower chemical and energy costs in Scenario C due to the reclaimed water not having to be treated again at the Paradyskloof WTW. The additional costs of Scenario B make it less favourable from a financial perspective but this is offset by the lower risk associated with treating the reclaimed water twice.

Scenario B present unit value costs increase as the size of DPR Plant increases. The reduction in raw water tariffs as the DPR Plant size increases is offset by the higher labour, chemical, maintenance and energy costs. It is also important to note that the 20Mℓ/d DPR Plant will not reach its ultimate capacity over the next 20 years as the demand only reaches 18.8Mℓ/d by 2039. The present unit costs are therefore underestimated for a 20Mℓ/d DPR Plant operating at full capacity.

Scenario C follows a similar trend to Scenario B with the present unit costs increasing as the DPR Plant capacity increases up to 10Mℓ/d. The present value unit costs however then drop for the 20Mℓ/d DPR Plant to below those of the 10Mℓ/d DPR Plant. The reason for this is due to the Paradyskloof WTW becoming redundant as the DPR Plant can supply the entire potable water demand. This means that the Paradyskloof WTW can effectively be decommissioned and all OPEX associated with the works can be omitted from the model. The reality of this occurring is highly unlikely as the Stellenbosch Municipality has recently upgraded and refurbished the Paradyskloof WTW and it would be seen as wasteful expenditure. This scenario would also mean that all potable water supplied to this area of Stellenbosch would be from the DPR Plant without any blending with water from other sources or emergency back-up should the DPR Plant fail.

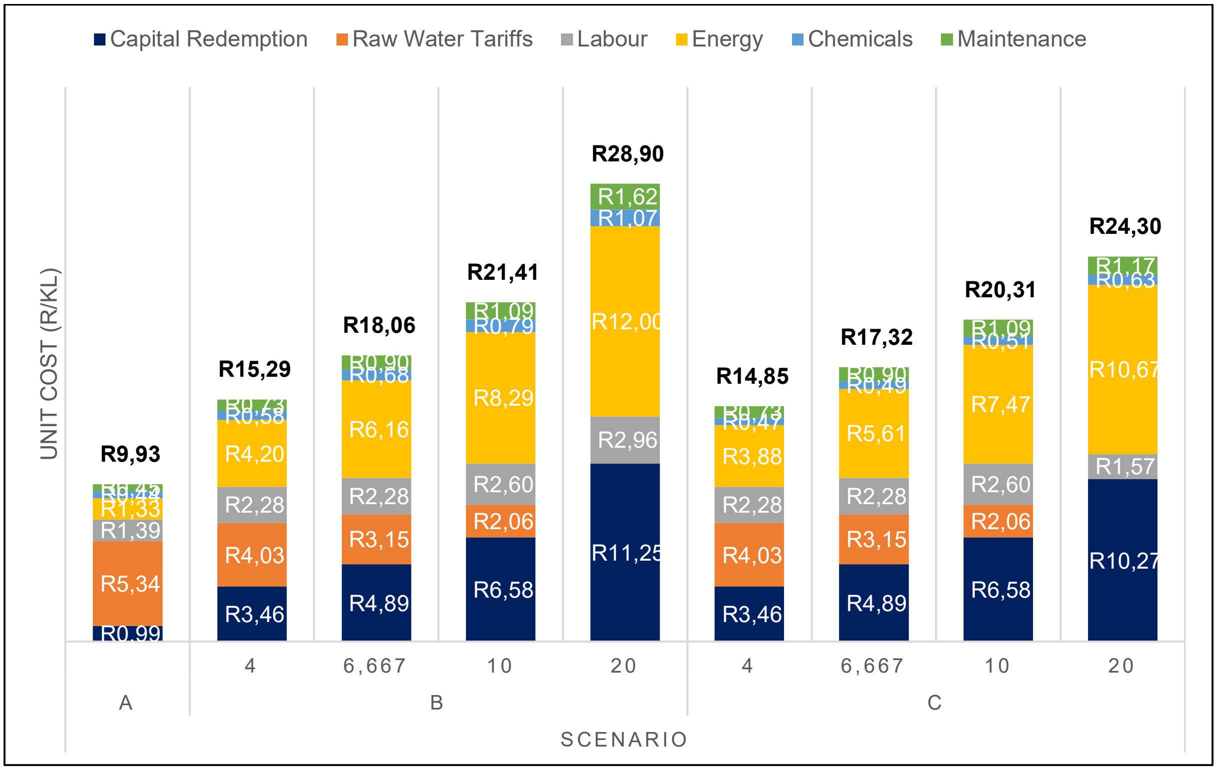

Figure 31: Present Value Unit Costs (Procurement Model No.2)

Scenario A again has the lowest present value unit costs out of all the scenarios in Figure 31. The present value unit costs are higher than in Figure 30 due to the capital redemption costs being included in this procurement model. The present value unit costs in Figure 31 follow a similar trend to those in Figure 30 as they increase along with the DPR Plant capacity for Scenario B and C. The 4.0Mℓ/d DPR Plant achieves the lowest present value unit costs for Scenario B and C but these are still well above the present value unit costs of Scenario A.

It is evident from the bar charts above that the energy consumption for Scenario B and C make up the majority of the OPEX costs when compared to that of a Scenario A. This is due to the higher energy consumption figures associated with DPR Plants which is to be expected. The energy consumption accounts for approximately 14% of the total OPEX for Scenario A compared to 27 – 76% for Scenario B and C. The annual energy price increase (8.78%) over the 20-year lifecycle is higher than inflation (5.5%) and therefore consumes a larger portion of the OPEX over time when compared to the other contributors such as chemicals and labour. These high energy consumption costs are one of the main reasons for the DPR Plants present value unit costs being higher than the Paradyskloof WTW present value unit costs.

8.4.6 Consumer Tariffs

It is evident from the financial analysis that no matter which DPR Plant capacity and procurement model is chosen, the unit costs of producing potable water to meet the demand in any given year will be higher than the current water supply scheme. The Stellenbosch Municipality would need to increase their potable water tariffs charged to consumers to ensure their operational costs of the DPR scheme are covered. It is difficult to quantify the exact required increase in the water tariffs due to the current stepped tariff structure in place in Stellenbosch. The stepped tariff structure is based on the principle of the more water consumed, the higher the tariff charged. The tariff structure also makes an allowance for the first 6kℓ to be provided for free to households classified as indigent. This consumption information would need to be analysed to determine the amount of potable water in the various stepped consumption blocks which is liable to a consumption tariff. The proposed tariff structure, should Scenario B or C be implemented, would need to be accurately determined to ascertain the public's willingness and acceptance to pay higher tariffs for a DPR Plant.

It is noted that the costs presented above are close order estimates from the available information derived from two operational DPR Plants in Southern Africa. A detailed CAPEX and OPEX should be done once the preliminary and detailed designs are complete to give a more accurate lifecycle cost estimate. It is however clear from the cost information presented above that the current water supply scheme would be more cost effective than introducing a DPR Plant to augment the potable water supply in Stellenbosch.

9. CONCLUSION AND RECOMMENDATIONS

The role of potable reuse in South Africa and internationally will continue to grow as part of the water cycle, due to the growing constraints on current resources. The New Goreangab Water Reclamation Plant and Beaufort West Reclamation Plant are good examples of successfully implemented DPR projects in Southern Africa which were introduced in the face of severe droughts. These projects were able to show that DPR was feasible under the local conditions to supplement the existing potable water supply without posing a risk to human health.

The pollutants found in wastewater effluent have been characterised in more detail over the past two decades as potable reuse grows in popularity globally. Australia and the U.S.A have led the way in research of CECs to the extent where they have prescribed guidelines for these contaminants and concentrations which are safe for human consumption. South Africa has begun its own research on classifying local wastewater effluent pollutants but has stopped short of publishing its own guidelines at this stage, rather relying on international best practice when determining final water quality parameters for DPR. This approach should be followed with extreme caution and emphasis should be placed on local conditions which are pertinent to the population which generates the wastewater from which the DPR scheme is fed.

The town of Stellenbosch will need to increase their raw water allocation by 2020 from the Theewaterskloof Dam to meet future demands. The town has enough capacity to treat the daily demand volumes at their current water treatment works but this is solely dependent on finding new water resources. This would have to be investigated further to determine alternative water resources through a reconciliation strategy study. There is however sufficient high-quality wastewater effluent from the Stellenbosch WWTW MBR facility to augment this alternative water resource mix in future via DPR.

The advanced water treatment technologies available on the market make it feasible to implement DPR from domestic wastewater effluent. Case studies and research have pointed to reclaimed water being of a higher quality than conventionally treated water. The multiple barrier approach has been successfully employed in many DPR and IPR schemes to ensure the water meets stringent health standards and mitigate the risk of contamination during the treatment process. The Stellenbosch WWTW effluent and location of the town make it more viable for a non-RO advanced water treatment process train for DPR. This is because of the low TDS within the wastewater effluent, the complications associated with brine disposal inland and high energy costs. The advanced water treatment process train selected using ozone, BAC filtration, GAC filtration and AOP met the treatment objectives and final water quality requirements prescribed internationally.

The Stellenbosch DPR Plant would be most likely need to be located on the same site as the Stellenbosch WWTW to reduce costs associated with purchasing land and time delays in getting the required zoning rights and approvals. The Stellenbosch WWTW does have sufficient space to accommodate the DPR Plant but would require a detailed space optimisation analysis for the 20Mℓ/d plant once final process sizing has been completed. The proposed DPR Plant location would also be in close proximity to key existing infrastructure including the final effluent pipeline, electricity substation and Generator Building.

The effective and efficient operation and maintenance of any DPR Plant is essential in meeting the desired water quality targets consistently. The selection of the reuse technology and monitoring programmes must be compatible with the skills available and should always have local support. The DPR Plant at Stellenbosch would most likely need to be operated through a concession within a PPP, due to the high level of skills needed to operate and maintain a plant with sophisticated equipment. A DPR Plant with a capacity below 5.0Ml/d could potentially be operated by trained municipal staff with an external service provider remotely monitoring the system, as is the case at the Beaufort West Reclamation Plant.

Public acceptance of potable reuse is a key facet of the feasibility of any reuse plant and must be carefully addressed by the Stellenbosch Municipality. There seems to be a clear correlation between public acceptance of potable reuse and trust in public institutions which needs to be built up over time through transparent and good management. It is of vital importance that public engagement takes place throughout the project lifecycle to address stakeholders’ concerns and ensure support for potable reuse. The growing influence of social media and politicians must be harnessed by the Stellenbosch Municipality to engage all levels of society to educate and inform them of the benefits of potable reuse. The Stellenbosch Municipality should approach potable reuse as a method to secure future water supply for all residents and weave this into the fabric of their public acceptance campaign.

The current legislation governing potable water reuse in South Africa has not been clearly defined from national government, in particular the Department of Water and Sanitation. This is in light of water reuse being given high priority in water supply strategies to augment current resources. The lack of clear legislation for DPR will provide red tape at national and provincial government level but these obstacles can be overcome, as was the case in Beaufort West. Stellenbosch Municipality, in conjunction with the relevant authorities, will need to monitor the downstream waterbodies to determine the environmental impacts on the ecosystems and downstream users. The reduction in wastewater effluent into receiving waterbodies can improve downstream water quality but it can also further pollute them. The impact on the Veldwachters and Eerste River water quality due to a DPR plant requires further research to understand the consequences of reducing the baseflow.

The potable water produced by the DPR Plant will come at a higher present value unit cost than the current conventional water treatment system in place in Stellenbosch, regardless of the treatment train arrangement or procurement model used. The high capital and energy costs associated with DPR outweigh the savings generated by reducing spending on raw water tariffs from the Theewaterskloof Dam. The unit costs for labour, maintenance and chemicals are also higher for a water supply system which incorporates a DPR Plant, as is evident from the present value unit cost graphs. The higher unit costs would be passed onto the consumers through consumption tariffs unless the Stellenbosch Municipality is willing and able to subsidise a portion of these tariffs.

The monetarised costs of DPR are far easier to quantify than the on non-monetarised costs such as the environment, water security and resilience. We can measure the unit costs of potable reuse as those costs needed to recover the operational costs for the plant but we cannot easily measure the impact the plant will have on the surrounding environment or ability to secure future water supply. The price of water is therefore not a true reflection of its value within the marketplace and therefore cannot be the underlying factor when making a decision on choosing between various water supply interventions. Water has been treated as a basic right within South Africa over the past two decades where it should be treated as a finite resource and therefore a commodity in the market. Once this mindset change has occurred the true value of potable water will be better understood and will result in a rise in DPR systems within South Africa and globally.

This research shows that the Stellenbosch DPR Plant can form part of the future Stellenbosch water supply to improve security and resilience against external factors beyond the Stellenbosch Municipality's control such as urbanisation and climate change. The implementation of a DPR Plant has been shown to be a feasible option but this should form part of a larger study which encompasses all alternative water resources. This would enable the Stellenbosch Municipality to evaluate each of the various water supply interventions from a technical, environmental, social and financial standing to develop a sustainable future water supply scheme.

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ANNEXURE A – NGWRP RAW & FINAL WATER QUALITY GUIDELINES

ANNEXURE 3: WATER QUALITY PROVISIONS

PART 1: Water Quality Specifications

1.0 RAW WATER SPECIFICATION

Raw Water Sources

1.1 Raw Water comprises a varying blend of waters from various component sources, being principally Dam Water from Goreangab Dam and Wastewater from the Gammams Water Care Works. Other sources of component water include various return process and washdown waters salvaged from Plant operations.

1.2 Raw Water comes into existence only when water from one or more of the component sources is mixed in the Raw Water/Recycle/PAC Sump. For the purposes of this Agreement, Raw Water quality is measured at the Sampling Point nominated in Part 1 of Annexure 9.

1.3 Title and ownership of Raw Water and all of its various component sources remains with the Council at all times.

Raw Water Mixing

1.4 The Developer shall blend Raw Water from its various component sources according to the following hierarchy:

(i) Salvage all available process return waters;

(ii) Reclaim all available Wastewater, then;

(iii) Subject to Section 1.5, draw-off of Dam Water as needed

1.5 Dam Water shall only be drawn off by the Developer:

(a) Where there is insufficient water available from other component waters to meet the projected demand for Treated Water for that day; or

(b) Where the Raw Water quality would otherwise fall outside the Raw Water Design Values (as detailed in Table 1). In such case, the Developer is authorised to draw off only such volumes of Dam Water as are sufficient to ensure that Raw Water complies with the Raw Water Design Values; or

(c) Where so directed by the Council in its own discretion for whatever reason; or

(d) Where, in the absolute discretion of the Council, so authorised by the Council in response to a specific and reasoned request from the Developer.

1.6 The Developer shall record the daily, monthly and annual water volumes of Wastewater and Dam Water entering the Plant and will notify the Council of these volumes on a weekly basis.

1.7 Where the Developer identifies a benefit in changing the Dam Water draw-off level at Goreangab Dam by using the existing infrastructure, the Developer may submit a formal proposal to the Council, which will be actioned by the Council within twenty-four (24) hours of receipt of the Developer's proposal.

1.8 Where the Developer identifies a benefit in changing the Dam Water draw-off level at Goreangab Dam by installing new infrastructure, the Developer may submit a proposal to the Council for installation of such infrastructure as a proposed Modification for consideration by the Council. The Council may accept or reject such a proposal in its sole discretion and the Developer shall have no basis of claim on the Council's acceptance or rejection of any such proposed Modification.

Raw Water Quality

1.9 The Council does not warrant the quality of Raw Water. The Developer shall make its own assessment of the likely quality of the Raw Water over the duration of the Agreement and cannot assume that Raw Water quality will not vary significantly from available historical records.

1.10 The Developer will be obliged to treat all Raw Water that is within the Raw Water Design Values to produce Treated Water at up to the Treated Water Maximum Demand.

1.11 Where the Raw Water blended by the Developer falls outside the Raw Water Design Values and the Developer believes it cannot adjust its blending ratios to produce Raw Water lying within the Raw Water Design Values, the Developer will immediately notify the Council.

1.12 The Developer may elect to treat Raw Water that lies outside the Raw Water Design Values where it considers that it can produce compliant Treated Water. If the Developer elects to treat such Raw Water then the Developer will be paid the Raw Water Surcharge as detailed in Part 2 of Annexure 11. For payment purposes, the volume of Raw Water that does not meet the Raw Water Design Values and which the Developer elects to treat will be determined separately by the Developer.

1.13 The parties acknowledge that the Developer's obligation to provide Treated Water that complies with the Treated Water Specification will not be relaxed notwithstanding that Raw Water may lie outside the Raw Water Design Values.

1.14 Where the Developer elects not to treat Raw Water that lies outside the Raw Water Design Values, then the Developer is permitted to cease supply of Treated Water and shall advise the Council forthwith. In such an event the Developer will be entitled to payment as stated in Annexure 11.

1.15 In the event the Developer ceases supply of Treated Water to the Council on the basis that the Developer is unable to achieve Raw Water which lies within the Raw Water Design Values, the latest hourly samples of water taken from the inlet pipes to the Plant for Dam Water and Wastewater shall be used to validate or otherwise the Developer's contention that it was not possible to achieve Raw Water which lies within the Raw Water Design Values.

1.16 In the event that Raw Water does not lie within the Raw Water Design Values, the Council may elect in its own discretion to procure potable water from other available sources. In such event the Availability Toll remains payable at the rate described in Annexure 11.

2.0 TREATED WATER SPECIFICATION

Treated Water Quality

2.1 Treated Water supplied to the Council by the Developer shall comply with the Treated Water Specification as contained in Table 2 of this Annexure.

2.2 Title and ownership of Treated Water will remain with the Council at all times.

Minimum Requirements for Treated Water

2.3 The Developer shall supply Treated Water to the Treated Water Delivery Point identified as Point G in Attachment 1 to Part 2 of Annexure 1.

2.4 The Plant is to be available for production of Treated Water up to the Treated Water Maximum Demand at all times. Notwithstanding this requirement, the Developer is permitted to schedule major maintenance or repair/replacement activities during anticipated periods of low Treated Water demand, with the prior written agreement of the Council which may not be unreasonably withheld.

2.5 Table 2 includes both Target Values and Absolute Values for the final Treated Water quality to be delivered to the Treated Water Delivery Point. The Developer is expected to consistently achieve all these values.

2.6 A limited number of the Treated Water parameters described in Table 2 of this Annexure are continuously monitored at the Plant via on-line equipment whilst the remaining parameters are monitored by a sampling and testing regime described in Annexure 9. The Developer is to ensure that the Council retains continuous remote access to the signal output from on-line monitoring equipment at the Plant and that the Treated Water sampling regime described in Annexure 9 is duly followed.

2.7 Treated Water that does not meet the Absolute Values will be considered to be Non-Compliant Water.

2.8 If the Developer does not achieve the Absolute or Target Values for Treated Water then the Developer's entitlements to payment will be subject to the Toll payment reduction regime as detailed in Part 1 of Annexure 11.

2.9 If there is a risk that the Treated Water will not meet the Treated Water Specification or may be otherwise unsuitable for use, then the Developer will immediately notify the Council.

2.10 Where on-line monitoring equipment indicates the production of Non-Compliant Water the Developer shall take immediate corrective action to prevent release of such waters into the Council's distribution system. In the alternative, the Developer may offer the supply of such Non-Compliant Water to the Council, subject to the Toll payment reduction regime as set out in Part 1 of Annexure 11. The Council may in its sole discretion either accept or reject Non-Compliant Water.

If Non-Compliant Water is rejected by the Council, the Developer may:

- Return the Non-Compliant Water to the head of the Plant (if technically possible);
- Return the Non-Compliant Water to the head of any treatment process (if technically possible);
- Send the Non-Compliant Water to waste;

- Use or dispose of the Non-Compliant Water in any other way approved by the Council; or
- Shutdown the Plant.

2.11 For those parameters which are not continuously monitored and for which the Council may have already received Non-Compliant Water into its distribution system, the Developer will be subject to the Toll payment reduction regime as detailed in Part 1 of Annexure 11 and shall have such further liability as may be provided for in the Agreement. The Developer is further obliged to investigate the cause of production of Non-Compliant Water as a nonconformance under its Quality Assurance System.

Treatment Processes

2.12 The Plant has been designed to operate a multiple barrier system comprising a sequence of treatment processes in the production of potable water. The Developer shall operate the Plant so that under normal operation, all installed treatment processes are fully functional and operating in accordance with the Operations and Maintenance Manual for the Plant.

2.13 In the event that one or more of the treatment processes is scheduled to be taken out of operation for any reason, the Developer shall obtain the Council's consent to such a proposal and also propose an interim monitoring program to ensure that Treated Water continues to meet the Treated Water Specification. In its sole discretion, the Council may elect to purchase potable water from alternative sources rather than allow Plant operation whilst the full multiple barrier system is not in operation.

2.14 Compliance with Intermediate Water Quality Criteria detailed in Table 3 is monitored downstream of the nominated treatment processes.

2.15 The Developer is required to achieve the Target Values for the Intermediate Water Quality Criteria for each treatment process as detailed in Table 3 of this Annexure.

2.16 The Developer is expected to achieve the Absolute Values for Intermediate Water Quality Criteria as a hundred percentile (100%) outcome.

2.17 The Toll payment reduction regime to apply where the Developer fails to achieve the Target Values and/or Absolute Values for Intermediate Water Quality Criteria is detailed in Section 5.5 of Part 1 of Annexure 11.

Accumulation of Critical Substances

2.18 To the extent that the design of the Plant permits from a technical point of view, the Developer shall ensure that the Plant, and especially the backwash water recycling system, is not operated or maintained in a manner that produces or promotes a systematic accumulation of protozoan cysts and/or other deleterious substances during operation of the Plant.

Disinfection

2.19 In the absence of any specific directions from the Council, the chlorine content of the Treated Water as measured at the final sampling point before delivery to the Treated Water Delivery Point shall be within the range 1-2 mg/l.

2.20 The Council may direct the Developer at any time to increase or decrease the chlorine dosage. The Treated Water Toll will only be adjusted if the Council directs that the chlorine dosage be increased by more than 20% of the amount set out in Section 2.19 above for more than 3 days per month.

2.21 In the event the Council directs that the chlorine content of the Treated Water be greater than 2 mg/l, the Developer is excused from complying with the Treated Water Specification in respect only of Trihalomethanes and only as a direct consequence of the Council's direction.

Corrosion Protection

2.22 In the absence of any specific directions from the Council, the Calcium Carbonate Precipitation Potential of the Treated Water as measured at the final sampling point before delivery to the Treated Water Delivery Point is to pursue an average value of 4 mg/l $CaCO_3$ whilst the Absolute Value is to be in accordance with the requirements listed in Table 2 of this Annexure.

2.23 As the Treated Water is to be mixed with potable water from other sources the Council may direct the Developer to increase or decrease the Calcium Carbonate Precipitation Potential of the Treated Water for the continuing protection of the Council's distribution network.

2.24 The Treated Water Toll will only be adjusted if the annual chemical consumption resulting from a direction from the Council to increase the Calcium Carbonate Precipitation Potential is more than 10% higher than the annual consumption based on achieving a CCPP value of 4.

3.0 DEVELOPER'S INFORMATION

3.1 Part 2 of this Annexure is the Developer's Water Quality Submission, detailing its response to the Council's Raw Water Specification and Treated Water Specification described in this Part 1.

3.2 Nothing in Part 2 of this Annexure shall limit or exclude the Developer's obligations or liabilities under this Part 1.

Table 1: Raw Water Design Values

Physical and Organoleptic Constituents	Units	Average Value (See Note 2)	Raw Water Design Value (See Note 3) (Maxima UNO)
Chemical Oxygen Demand	mg/l	33.70	43.32
Colour	mg/l Pt	37.50	71.88
Dissolved Organic Carbon	mg/l	10.43	15.10
Turbidity	NTU	10.23	52.96
Alkalinity	mg/l	162.7	217.7
Total Trihalomethane Formation Potential	µg/l	121.50	168.75
UV_{254}	abs/cm	0.24	0.36
Macro Elements	**Units**		
Aluminium	Al mg/l	0.26	1.29
Ammonia	N mg/l	0.37	2.30
Chloride	Cl mg/l	72.62	98.47
Fluorine	F mg/l	0.35	0.89
Iron	Fe mg/l	0.47	2.84
Manganese	Mn mg/l	0.17	0.90
Nitrate & Nitrite	N mg/l	3.27	7.71
Nitrite	N mg/l	0.04	0.27
Sulfate	SO_4 mg/l	55.92	75.71
Microbiological Indicators	**Units**		
Heterotrophic Plate Count	per 1 ml	9,900	332,150
Total Coliforms	Per 100 ml	1,375	245,125
Faecal Coliforms	Per 100 ml	202	22,292
E. Coli	Per 100 ml	123	20,347
Coliphage	Per 100 ml	1.00	24.35
Clostridium Spores	Per 100 ml	154.00	11,085
Clostridium Viable Cells	Per 100 ml	407.50	3,942.50
Biological Indicators	**Units**		
Chlorophyll *a*	µg/l	9.22	35.485
Giardia	per 100 l	0.00	214.25
Cryptosporidium	per 100 l	0.00	334.00

Notes:

1. UNO = Unless Noted Otherwise
2. The Average Values column indicates the historical average for Raw Water quality for mixed Dam Water and Wastewater received at the existing water reclamation plant over a three year range.
3. The Raw Water Design Values represent the Raw Water parameters upon which the Plant was designed and for which the Turnkey Contractor has provided its Performance Guarantees.

Table 2: Treated Water Specification

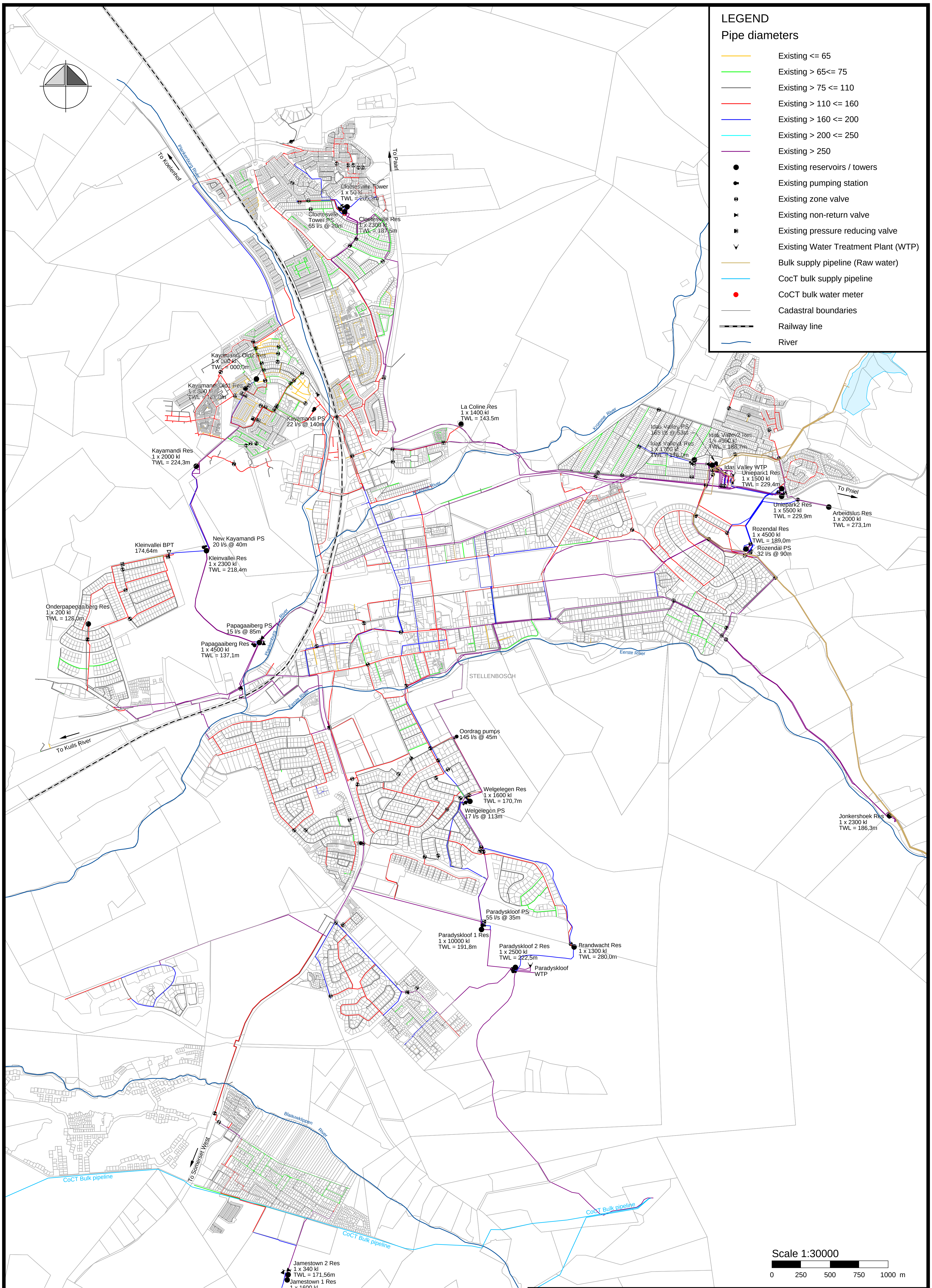
Physical and Organoleptic Constituents	Units	Target Values (Maximum UNO)	Absolute Values (Maximum UNO)
Calcium Carbonate Precipitation Potential	$CaCO_3$ mg/l	N/A	Must lie in range 0 to 8
Chemical Oxygen Demand	.mg/l	10	15
Colour	.mg/l Pt	8	10
Dissolved Organic Carbon	.mg/l	3	5
Total Dissolved Solids	.mg/l	Greater of 1000 or 200 above Raw Water	Greater of 1200 or 250 above Raw Water
Turbidity	NTU	0.1	0.2
UV_{254}	Abs/cm	N/A	0.06
Macro Elements	**Units**		
Aluminium	Al mg/l	N/A	0.15
Ammonia	N mg/l	N/A	0.10
Chloride	Cl mg/l	Not removed by process	
Iron	Fe mg/l	0.05	0.1
Manganese	Mn mg/l	0.0025	0.005
Nitrate & Nitrite	N mg/l	Not removed by process	
Nitrite	N mg/l	Not removed by process	
Sulfate	SO_4 mg/l	Not removed by process	
Microbiological Indicators	**Units**		
Heterotrophic Plate Count	Per 1 ml	80	100
Total Coliforms	Per 100 ml	N/A	0
Faecal Coliforms	Per 100 ml	N/A	0
E. Coli	Per 100 ml	N/A	0
Coliphage	Per 100 ml	N/A	0
Enteric Viruses	Per 10 l	N/A	Greater of 0 per 10 l or a 4 log removal
Faecal Streptococci	Per 100 ml	N/A	0
Clostridium Spores	Per 100 ml	N/A	0
Clostridium Viable Cells	per 100 ml	N/A	0
Disinfection By-products	**Units**		
Total Trihalomethanes	µg/l	20	40
Biological Indicators	**Units**		
Chlorophyll *a*	µg/l	N/A	1
Giardia	per 100 l	Greater of 0 per 100 l or a 6 log removal	Greater of 0 per 100 l or a 5 log removal
Cryptosporidium	per 100 l	Greater of 0 per 100 l or a 6 log removal	Greater of 0 per 100 l or a 5 log removal

Note: Other parameters that are not included in Table 2 will be required to comply with the Rand Water Standards (RSA) for potable water as valid at the Effective Date. The Treated Water will not exceed the lower of the RSA limits or the background concentration for those parameters as found in the Raw Water.

Table 3: Intermediate Treated Water Criteria

1. Treatment Process / Parameters	2. Units	3. Target Values (Maximum UNO)	4. Target Values (Maximum UNO) (Refer Clause 5.5.5 of Part 1 of Annexure 11)	5. Absolute Values (Maximum UNO)
After DAF				
Turbidity	NTU	1.5 (exceeded by no more than eight readings in one day - readings are taken at 15 minute intervals) 5.0 (exceeded by no more than four readings in one day - readings are taken at 15 minute intervals)	5.0 (exceeded by no more than four readings in one day – readings are taken at 15 minute intervals)	8.0 (absolute maximum peak as registered by on-line measuring equipment)
After Rapid Sand Filters				
Turbidity	NTU	0.2 (exceeded by no more than four readings in one day - readings are taken at 15 minute intervals)	0.35 (exceeded by no more than four readings in one day – readings are taken at 15 minute intervals)	0.5 (absolute maximum peak as registered by on-line measuring equipment)
Manganese	mg/l	0.03	0.05	N/A
Iron	mg/l	0.05	0.05	N/A
After Ozonation				
Ozone concentration	mg/l			0.1 minimum (absolute minimum trough as registered by on-line measuring equipment)
COD	mg/l	25	25	N/A
DOC	mg/l	15	15	N/A
Microbiological, disinfection by-products and biological quality		According to Treated Water Specification (Table 2)		N/A
After GAC Filters				
DOC	mg/l	5 (exceeded by no more than four readings - readings are taken at 15 minute intervals)	5 (exceeded by no more than four readings in one day – readings are taken at 15 minute intervals)	8 (absolute maximum peak as registered by on-line measuring equipment)

ANNEXURE B – STELLENBOSCH WATER SUPPLY NETWORK



June 2017

STELLENBOSCH WATER MASTER PLAN

gls consulting
an EOH company

Figure SW 2.1a

Existing water system layout - Stellenbosch

ANNEXURE C – RAW WATER TARIFFS

	Unit	Financial Year 2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Water resource management charges*	c/m3	5,46	5,59	3,85	4,35	4,64	4,35	4,35	4,49	4,63	4,78	4,93
% Increase / Decrease	%		2,4%	-31,1%	13,0%	6,7%	-6,3%	0,0%	3,2%	3,2%	3,2%	3,2%
Consumptive charges**	c/m3	50,09	56,35	60,07	67,88	79,42	91,02	102,58	115,61	130,29	146,84	165,48
% Increase / Decrease	%		12,5%	6,6%	13,0%	17,0%	14,6%	12,7%	12,7%	12,7%	12,7%	12,7%
WRC levy	c/m3	4,7	5,1	5,4	5,7	6,1	6,9	7,5	8,0	8,7	9,4	10,1
% Increase / Decrease	%		9,1%	5,7%	5,2%	7,0%	13,1%	8,0%	8,0%	8,0%	8,0%	8,0%
Total	c/m3	60,25	67,07	69,34	77,93	90,16	102,27	114,38	128,14	143,61	161,00	180,56
% Increase / Decrease	%		11,3%	3,4%	12,4%	15,7%	13,4%	11,8%	12,0%	12,1%	12,1%	12,1%

		Financial Year 2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34	2034/35	2035/36	2036/37	
Water resource management charges*	Unit	5,09	5,25	5,42	5,60	5,78	5,96	6,15	6,35	6,55	6,76	6,98	7,20	7,43	0,91%
% Increase / Decrease	c/m3	3,2%	3,2%	3,2%	3,2%	3,2%	3,2%	3,2%	3,2%	3,2%	3,2%	3,2%	3,2%	3,2%	
Consumptive charges**	%	186,50	210,19	236,88	266,96	300,87	339,08	382,14	430,67	485,37	547,01	616,48	694,77	783,01	95,72%
% Increase / Decrease	c/m3	12,7%	12,7%	12,7%	12,7%	12,7%	12,7%	12,7%	12,7%	12,7%	12,7%	12,7%	12,7%	12,7%	
WRC levy	%	10,9	11,8	12,8	13,8	14,9	16,1	17,4	18,8	20,3	21,9	23,6	25,5	27,6	3,37%
% Increase / Decrease	c/m3	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	8,0%	
Total	%	202,54	227,27	255,07	286,35	321,54	361,13	405,67	455,79	512,19	575,66	647,10	727,50	818,01	
% Increase / Decrease	c/m3	12,2%	12,2%	12,2%	12,3%	12,3%	12,3%	12,3%	12,4%	12,4%	12,4%	12,4%	12,4%	12,4%	
	%														

ANNEXURE D – STELLENBOSCH RAW & FINAL WATER QUALITY RESULTS

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Chemistry Laboratory - Stellenbosch

Certificate of Analysis

Report NO:	SAL-2019-14139	Sample Description:	Freshwater samples in 250ml plastic bottles with white caps
Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	21
		Sample Condition:	Room Temperature
		Date Received:	12-Mar-2019
Contact:	Dewald van Staden	Date Completed:	14-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	TBA
Email:	dewald@metsi.co.za		

Sample Disposal	a) Liquid Sample One Month - After issuing of final Certificate of Analysis	b) Solid Sample Three Months - After issuing of final Certificate of Analysis

Lab No / Sample Date / Sample ID / Analysis	Unit	1914139-92710FW 12-Mar-2019 WBSM FR-032 Franschoek WTW	1914139-92711FW 12-Mar-2019 WBSM JD-001 Johannesdal Reservoir #1	1914139-92712FW 12-Mar-2019 WBSM KM-002 Kylemore Reservoir #2	1914139-92713FW 12-Mar-2019 WBSM PN-002 Pniel Scheme Reservoir	1914139-92714FW 12-Mar-2019 WBSM ST-001 Paradyskloof WTW
Sodium as Na Dissolved	mg/l	3.6	3.8	3.8	3.9	5.8
Calcium as Ca Dissolved	mg/l	0.6	7.9	9.2	8.3	1.7
Magnesium as Mg Dissolved	mg/l	0.6	0.6	0.5	0.5	1.1
Sulphate as SO4 Dissolved	mg/l	0.5	3.3	3.7	3.4	2.8
Alkalinity as CaCO3	mg/l	<2.5	16	19	16	3.5
Electrical Conductivity	mS/m (25°C)	3	7	8	7	5
pH (Lab) (20°C)		5.7	7.8	9.5	7.7	6.2
Turbidity *	NTU	1.2	0.7	0.5	0.4	16
Colour (filtered) *	mg Pt/L	9	<5	<5	<5	60
Aluminium as Al Dissolved	mg/l	0.05	0.06	0.11	0.06	0.27
Iron as Fe Dissolved	mg/l	0.09	0.01	<0.01	<0.01	0.23

Remarks: * Method is not SANAS accredited and is not included in the SANAS Schedule of accreditation for this laboratory.
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Certificate of Analysis

Report NO:	SAL-2019-14139	Sample Description:	Freshwater samples in 250ml plastic bottles with white caps
Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	21
		Sample Condition:	Room Temperature
		Date Received:	12-Mar-2019
Contact:	Dewald van Staden	Date Completed:	14-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	TBA
Email:	dewald@metsi.co.za		

Lab No		1914139-92715FW	1914139-92716FW	1914139-92717FW	1914139-92718FW	1914139-92719FW
Sample Date		12-Mar-2019	12-Mar-2019	12-Mar-2019	12-Mar-2019	12-Mar-2019
Sample ID		WBSM ST-003 Idas Valley Dam	WBSM ST-004 Jonkershoek Weir	WBSM ST-011 Idas Valley Reservoir #1	WBSM ST-012 Idas Valley Reservoir #2	WBSM ST-017 Welgelegen Reservoir
Analysis	**Unit**					
Sodium as Na Dissolved	mg/l	9.4	6.3	5.4	5.4	5.6
Calcium as Ca Dissolved	mg/l	2.9	2.4	3.4	4.6	3.9
Magnesium as Mg Dissolved	mg/l	2.2	1.4	0.8	0.9	0.7
Sulphate as SO4 Dissolved	mg/l	2.0	2.7	1.2	1.3	1.2
Alkalinity as CaCO3	mg/l	15	6.6	9.0	9.7	9.1
Electrical Conductivity	mS/m (25°C)	8	6	5	6	6
pH (Lab) (20°C)		7.3	6.7	7.2	7.2	7.2
Turbidity *	NTU	1.6	29	0.6	0.7	0.3
Colour (filtered) *	mg Pt/L	6	56	42	47	<5
Aluminium as Al Dissolved	mg/l	0.01	0.19	0.08	0.12	0.03
Iron as Fe Dissolved	mg/l	0.06	0.26	0.06	0.07	0.03

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Report NO:	SAL-2019-14139	Sample Description:	Freshwater samples in 250ml plastic bottles with white caps
Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	21
		Sample Condition:	Room Temperature
		Date Received:	12-Mar-2019
Contact:	Dewald van Staden	Date Completed:	14-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	TBA
Email:	dewald@metsi.co.za		

Lab No **Sample Date** **Sample ID** **Analysis**	**Unit**	1914139-92720FW 12-Mar-2019 WBSM ST-018 Paradyskloof Reservoir #1	1914139-92721FW 12-Mar-2019 WBSM ST-025 Technopark	1914139-92722FW 12-Mar-2019 WBSM ST-028 Die Boord	1914139-92723FW 12-Mar-2019 WBSM ST-032 Cloetesville	1914139-92724FW 12-Mar-2019 WBSM ST-034 Stellenbosch Hospital
Sodium as Na Dissolved	mg/l	9.3	9.2	13	5.8	5.1
Calcium as Ca Dissolved	mg/l	6.9	7.8	7.9	3.9	4.4
Magnesium as Mg Dissolved	mg/l	1.6	1.4	2.1	0.8	0.6
Sulphate as SO4 Dissolved	mg/l	8.7	8.6	9.1	1.4	1.2
Alkalinity as CaCO3	mg/l	14	16	22	9.7	13
Electrical Conductivity	mS/m (25°C)	11	11	13	6	6
pH (Lab) (20°C)		9.5	9.6	7.8	7.2	7.2
Turbidity *	NTU	0.6	0.4	0.8	0.3	0.2
Colour (filtered) *	mg Pt/L	<5	<5	<5	6	<5
Aluminium as Al Dissolved	mg/l	0.13	0.08	0.08	0.03	<0.01
Iron as Fe Dissolved	mg/l	0.01	0.02	0.03	0.04	0.04

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Report NO:	SAL-2019-14139	Sample Description:	Freshwater samples in 250ml plastic bottles with white caps
Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	21
		Sample Condition:	Room Temperature
		Date Received:	12-Mar-2019
Contact:	Dewald van Staden	Date Completed:	14-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	TBA
Email:	dewald@metsi.co.za		

Lab No / Sample Date / Sample ID		1914139-92725FW	1914139-92726FW	1914139-92727FW	1914139-92728FW	1914139-92729FW
		12-Mar-2019	12-Mar-2019	12-Mar-2019	12-Mar-2019	12-Mar-2019
		WBSM ST-041 Kayamandi	WBSM ST-042 Onder Papegaaiberg	WBSM ST-043 Plankenburg	WBSM ST-046 Mosterdrift	WBSM ST-095 Paradyskloof WTW
Analysis	**Unit**					
Sodium as Na Dissolved	mg/l	9.0	9.8	9.4	5.6	5.6
Calcium as Ca Dissolved	mg/l	7.6	7.1	7.8	3.6	1.5
Magnesium as Mg Dissolved	mg/l	1.5	1.6	1.5	0.8	0.9
Sulphate as SO4 Dissolved	mg/l	7.6	8.2	8.1	1.4	1.2
Alkalinity as CaCO3	mg/l	17	16	16	9.3	4.1
Electrical Conductivity	mS/m (25°C)	11	11	12	6	5
pH (Lab) (20°C)		9.1	9.1	9.6	7.2	6.6
Turbidity *	NTU	0.9	0.4	0.6	0.9	0.6
Colour (filtered) *	mg Pt/L	5	<5	<5	19	16
Aluminium as Al Dissolved	mg/l	0.18	0.10	0.09	0.04	0.04
Iron as Fe Dissolved	mg/l	0.04	0.02	0.02	0.04	0.23

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Report NO:	SAL-2019-14139	Sample Description:	Freshwater samples in 250ml plastic bottles with white caps
Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	21
		Sample Condition:	Room Temperature
		Date Received:	12-Mar-2019
Contact:	Dewald van Staden	Date Completed:	14-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	TBA
Email:	dewald@metsi.co.za		

Lab No Sample Date Sample ID		1914139-92730FW 12-Mar-2019 WBSM WV-001 Welgevonden
Analysis	**Unit**	
Sodium as Na Dissolved	mg/l	5.5
Calcium as Ca Dissolved	mg/l	3.7
Magnesium as Mg Dissolved	mg/l	0.7
Sulphate as SO4 Dissolved	mg/l	1.1
Alkalinity as CaCO3	mg/l	9.7
Electrical Conductivity	mS/m (25°C)	6
pH (Lab) (20°C)		7.2
Turbidity *	NTU	0.3
Colour (filtered) *	mg Pt/L	<5
Aluminium as Al Dissolved	mg/l	0.02
Iron as Fe Dissolved	mg/l	0.04

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Testing Laboratory T0093

Certificate of Analysis

Report NO: SAL-2019-14167
Customer: Stellenbosch Municipality
Address: P O Box 17
STELLENBOSCH 7600

Contact: Dewald van Staden
Phone: 021 808 8267 Fax: 021 886 5623
Email: dewald@metsi.co.za

Sample Description: Freshwater samples in 250ml plastic bottles with white caps
No of Samples 17
Sample Condition: Room Temperature
Date Received: 18-Mar-2019
Date Completed: 26-Mar-19
Order No: TBA

Sample Disposal
a) Liquid Sample — One Month - After issuing of final Certificate of Analysis
b) Solid Sample — Three Months - After issuing of final Certificate of Analysis

Lab No / Sample Date / Sample ID		1914167-92857FW	1914167-92858FW	1914167-92859FW	1914167-92860FW	1914167-92861FW
		WBSM DV - 006 Devon Valley, JC le Roux	WBSM DV - 007 Devon Valley	WBSM EB - 002 JJ Rhode Primary School	WBSM FR - 003 Franschoek Pass, Raw	WBSM FR - 007 Franschoek, Police Station
Analysis	**Unit**					
Sodium as Na Dissolved	mg/l	40	4.2	3.3	2.6	5.1
Calcium as Ca Dissolved	mg/l	4.6	7.2	6.7	0.8	0.7
Magnesium as Mg Dissolved	mg/l	5.8	0.7	0.6	0.3	0.5
Sulphate as SO4 Dissolved	mg/l	17	3.8	3.2	0.5	0.4
Alkalinity as CaCO3	mg/l	38	20	18	2.9	5.0
Electrical Conductivity	mS/m (25°C)	33	8	8	3	5
pH (Lab) (20°C)		6.7	9.5	9.3	6.0	6.6
Turbidity *	NTU	0.4	0.6	1.1	0.5	1.5
Colour (filtered) *	mg Pt/L	<5	<5	<5	5	<5
Aluminium as Al Dissolved	mg/l	<0.01	0.17	0.07	0.02	0.02
Iron as Fe Dissolved	mg/l	<0.01	0.02	0.02	0.07	0.07

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Certificate of Analysis

Report NO: SAL-2019-14167
Customer: Stellenbosch Municipality
Address: P O Box 17
STELLENBOSCH 7600

Contact: Dewald van Staden
Phone: 021 808 8267 Fax: 021 886 5623
Email: dewald@metsi.co.za

Sample Description: Freshwater samples in 250ml plastic bottles with white caps
No of Samples: 17
Sample Condition: Room Temperature
Date Received: 18-Mar-2019
Date Completed: 26-Mar-19
Order No: TBA

Lab No / **Sample Date** / **Sample ID** / **Analysis**	**Unit**	1914167-92862FW WBSM FR - 012 Franschoek, Pick n Pay Centre	1914167-92863FW WBSM FR - 013 Franschoek, La Petite Provence	1914167-92864FW WBSM FR - 017 Franschoek, Groendal Primary	1914167-92865FW WBSM FR - 032 Franschoek WTW, Final	1914167-92866FW WBSM KL - 005 Klapmuts Primary School
Sodium as Na Dissolved	mg/l	4.5	3.1	4.0	6.8	4.1
Calcium as Ca Dissolved	mg/l	1.7	5.1	6.9	1.0	6.7
Magnesium as Mg Dissolved	mg/l	0.4	0.5	0.5	0.4	0.6
Sulphate as SO4 Dissolved	mg/l	0.9	2.8	2.9	0.5	2.7
Alkalinity as CaCO3	mg/l	6.5	14	15	3.5	14
Electrical Conductivity	mS/m (25°C)	5	6	7	4	6
pH (Lab) (20°C)		7.1	7.6	7.6	6.4	7.7
Turbidity *	NTU	0.6	0.6	0.5	0.7	0.7
Colour (filtered) *	mg Pt/L	9	<5	<5	<5	<5
Aluminium as Al Dissolved	mg/l	0.06	0.07	0.07	0.03	0.07
Iron as Fe Dissolved	mg/l	0.06	<0.01	<0.01	0.05	<0.01

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Certificate of Analysis

Report NO: SAL-2019-14167
Customer: Stellenbosch Municipality
Address: P O Box 17
STELLENBOSCH 7600

Contact: Dewald van Staden
Phone: 021 808 8267 Fax: 021 886 5623
Email: dewald@metsi.co.za

Sample Description: Freshwater samples in 250ml plastic bottles with white caps
No of Samples 17
Sample Condition: Room Temperature
Date Received: 18-Mar-2019
Date Completed: 26-Mar-19
Order No: TBA

Lab No / Sample Date / Sample ID		1914167-92867FW	1914167-92868FW	1914167-92869FW	1914167-92870FW	1914167-92871FW
		WBSM RB - 002 Raithby Reservoir	WBSM RB - 003 Faure Pumpstation	WBSM ST - 012 Idas Valley Reservoir #2	WBSM ST - 018 Paradyskloof Reservoir #1	WBSM ST - 024 Jamestown Reservoir
Analysis	**Unit**					
Sodium as Na Dissolved	mg/l	9.5	13	5.1	8.9	8.8
Calcium as Ca Dissolved	mg/l	10	23	4.0	6.1	5.8
Magnesium as Mg Dissolved	mg/l	1.3	1.9	0.6	1.5	1.4
Sulphate as SO4 Dissolved	mg/l	11	36	2.5	8.7	8.9
Alkalinity as CaCO3	mg/l	17	25	7.7	14	12
Electrical Conductivity	mS/m (25°C)	12	23	5	11	10
pH (Lab) (20°C)		9.3	9.2	7.0	9.7	7.5
Turbidity *	NTU	1.4	0.6	5.6	0.8	0.8
Colour (filtered) *	mg Pt/L	<5	<5	13	<5	<5
Aluminium as Al Dissolved	mg/l	0.22	0.07	0.05	0.05	0.10
Iron as Fe Dissolved	mg/l	0.07	0.01	0.03	0.01	0.02

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Certificate of Analysis

Report NO:	SAL-2019-14167	Sample Description:	Freshwater samples in 250ml plastic bottles with white caps
Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	17
		Sample Condition:	Room Temperature
		Date Received:	18-Mar-2019
Contact:	Dewald van Staden	Date Completed:	26-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	TBA
Email:	dewald@metsi.co.za		

Lab No **Sample Date** **Sample ID** **Analysis**	**Unit**	1914167-92872FW WBSM VB - 001 van Rhyn	1914167-92873FW WBSM WH - 001 Wemmershoek Pump Station, Main Meter
Sodium as Na Dissolved	mg/l	7.5	3.8
Calcium as Ca Dissolved	mg/l	13	6.2
Magnesium as Mg Dissolved	mg/l	1.6	0.6
Sulphate as SO4 Dissolved	mg/l	12	3.0
Alkalinity as CaCO3	mg/l	22	13
Electrical Conductivity	mS/m (25°C)	13	6
pH (Lab) (20°C)		7.9	7.5
Turbidity *	NTU	0.6	0.5
Colour (filtered) *	mg Pt/L	<5	<5
Aluminium as Al Dissolved	mg/l	0.10	0.04
Iron as Fe Dissolved	mg/l	<0.01	<0.01

Remarks: * Method is not SANAS accredited and is not included in the SANAS Schedule of accreditation for this laboratory.
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Stellenbosch, 7600
P O Box 320
Stellenbosch, 7599

Chemistry Laboratory - Stellenbosch

Certificate of Analysis

Report NO:	SAL-2019-14198	Sample Description:	Freshwater samples in 250ml plastic bottles with white caps
Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	18
		Sample Condition:	Room Temperature
		Date Received:	26-Mar-2019
Contact:	Dewald van Staden	Date Completed:	29-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	Tender
Email:	dewald@metsi.co.za		

Sample Disposal	a) Liquid Sample One Month - After issuing of final Certificate of Analysis	b) Solid Sample Three Months - After issuing of final Certificate of Analysis

Lab No / **Sample Date** / **Sample ID** / **Analysis**	**Unit**	1914198-93018FW 26-Mar-2019 WBSM FR-032 Franschoek WTW	1914198-93019FW 26-Mar-2019 WBSM JD-001 Johannesdal Reservoir #1	1914198-93020FW 26-Mar-2019 WBSM KM-002 Kylemore Reservoir #2	1914198-93021FW 26-Mar-2019 WBSM PN-002 Pniel Scheme Reservoir	1914198-93022FW 26-Mar-2019 WBSM ST-011 Idas Valley Reservoir #1
Sodium as Na Dissolved	mg/l	3.1	3.9	3.9	4.0	5.5
Calcium as Ca Dissolved	mg/l	0.2	6.6	7.9	7.2	3.7
Magnesium as Mg Dissolved	mg/l	0.3	0.5	0.5	0.5	0.6
Sulphate as SO4 Dissolved	mg/l	0.3	2.5	3.0	2.6	1.1
Alkalinity as CaCO3	mg/l	<2.5	14	17	15	8.9
Electrical Conductivity	mS/m (25°C)	3	7	7	7	6
pH (Lab) (20°C)		5.5	8.7	9.1	8.3	7.1
Turbidity *	NTU	0.8	0.8	0.5	0.5	0.4
Colour (filtered) *	mg Pt/L	6	<5	<5	<5	5
Aluminium as Al Dissolved	mg/l	0.02	0.06	0.07	0.06	0.03
Iron as Fe Dissolved	mg/l	0.07	<0.01	<0.01	<0.01	0.03

Remarks: * Method is not SANAS accredited and is not included in the SANAS Schedule of accreditation for this laboratory.
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Efraim Fieland - Technical Signatory

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		Sample Condition:	Room Temperature
		Date Received:	26-Mar-2019
Contact:	Dewald van Staden	Date Completed:	29-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	Tender
Email:	dewald@metsi.co.za		

Lab No		1914198-93023FW	1914198-93024FW	1914198-93025FW	1914198-93026FW	1914198-93027FW
Sample Date		26-Mar-2019	26-Mar-2019	26-Mar-2019	26-Mar-2019	26-Mar-2019
Sample ID		WBSM ST-012 Idas Valley Reservoir #2	WBSM ST-017 Welgelegen Reservoir	WBSM ST-018 Paradyskloof Reservoir #1	WBSM ST-025 Technopark	WBSM ST-028 Die Boord
Analysis	**Unit**					
Sodium as Na Dissolved	mg/l	5.5	5.4	9.2	9.2	29
Calcium as Ca Dissolved	mg/l	3.4	3.1	2.1	6.1	12
Magnesium as Mg Dissolved	mg/l	0.7	0.6	1.4	1.2	5.8
Sulphate as SO4 Dissolved	mg/l	1.0	1.0	8.4	8.2	17
Alkalinity as CaCO3	mg/l	8.3	7.3	3.4	14	57
Electrical Conductivity	mS/m (25°C)	6	6	8	10	27
pH (Lab) (20°C)		7.0	7.0	6.4	9.5	7.8
Turbidity *	NTU	0.6	1.1	0.4	1.8	0.5
Colour (filtered) *	mg Pt/L	<5	7	<5	<5	<5
Aluminium as Al Dissolved	mg/l	0.02	0.03	0.02	0.07	0.02
Iron as Fe Dissolved	mg/l	0.02	0.03	<0.01	0.02	0.01

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Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	18
		Sample Condition:	Room Temperature
		Date Received:	26-Mar-2019
Contact:	Dewald van Staden	Date Completed:	29-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	Tender
Email:	dewald@metsi.co.za		

Lab No / **Sample Date** / **Sample ID**		1914198-93028FW 26-Mar-2019 WBSM ST-032 Cloetesville	1914198-93029FW 26-Mar-2019 WBSM ST-034 Stellenbosch Hospital	1914198-93030FW 26-Mar-2019 WBSM ST-041 Kayamandi	1914198-93031FW 26-Mar-2019 WBSM ST-042 Onder Papegaaiberg	1914198-93032FW 26-Mar-2019 WBSM ST-043 Plankenburg
Analysis	**Unit**					
Sodium as Na Dissolved	mg/l	6.4	5.3	9.3	9.5	9.4
Calcium as Ca Dissolved	mg/l	4.1	4.1	6.5	6.4	6.6
Magnesium as Mg Dissolved	mg/l	0.9	0.7	1.4	1.4	1.4
Sulphate as SO4 Dissolved	mg/l	1.6	1.1	8.4	9.0	9.1
Alkalinity as CaCO3	mg/l	9.4	12	13	13	13
Electrical Conductivity	mS/m (25°C)	6	6	10	11	11
pH (Lab) (20°C)		7.1	7.2	9.3	9.3	9.6
Turbidity *	NTU	0.4	0.4	0.7	0.6	0.7
Colour (filtered) *	mg Pt/L	<5	<5	<5	<5	<5
Aluminium as Al Dissolved	mg/l	0.03	0.01	0.10	0.10	0.06
Iron as Fe Dissolved	mg/l	0.03	0.03	0.03	0.03	0.01

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Report NO:	SAL-2019-14198	Sample Description:	Freshwater samples in 250ml plastic bottles with white caps
Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	18
		Sample Condition:	Room Temperature
		Date Received:	26-Mar-2019
Contact:	Dewald van Staden	Date Completed:	29-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	Tender
Email:	dewald@metsi.co.za		

Lab No / Sample Date / Sample ID		1914198-93033FW 26-Mar-2019 WBSM ST-046 Mosterdrift	1914198-93034FW 26-Mar-2019 WBSM ST-095 Paradyskloof WTW	1914198-93035FW 26-Mar-2019 WBSM WV-001 Welgevonden
Analysis	**Unit**			
Sodium as Na Dissolved	mg/l	5.7	5.8	5.7
Calcium as Ca Dissolved	mg/l	4.1	1.3	3.8
Magnesium as Mg Dissolved	mg/l	0.7	0.8	0.6
Sulphate as SO4 Dissolved	mg/l	1.3	1.0	1.0
Alkalinity as CaCO3	mg/l	10	2.8	8.8
Electrical Conductivity	mS/m (25°C)	6	5	6
pH (Lab) (20°C)		7.2	6.1	7.1
Turbidity *	NTU	0.4	0.4	0.5
Colour (filtered) *	mg Pt/L	<5	<5	6
Aluminium as Al Dissolved	mg/l	0.01	0.02	0.03
Iron as Fe Dissolved	mg/l	0.02	0.04	0.03

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Testing Laboratory T0093

Certificate of Analysis

Report NO: SAL-2018-12691
Customer: Stellenbosch Municipality
Address: P O Box 17
STELLENBOSCH 7600

Contact: Dewald van Staden
Phone: 021 808 8267 Fax: 021 886 5623
Email: dewald@metsi.co.za

Sample Description: SANS241 water samples in 8x25L & 8x5L plastic bottles
No of Samples 8
Sample Condition: Room Temperature
Date Received: 17-May-2018
Date Completed: 18-Jun-18
Order No: 342861

Sample Disposal
a) Liquid Sample
One Month - After issuing of final Certificate of Analysis
b) Solid Sample
Three Months - After issuing of final Certificate of Analysis

Lab No				1812691-84763FW	1812691-84764FW	1812691-84765FW	1812691-84766FW
Sample Date				2018-05-17	2018-05-17	2018-05-17	2018-05-17
Sample ID				WBSM DV - 006 Devon Valley, JC le Roux	WBSM RB - 003 Faure Pumpstation	WBSM ST - 001 Paradyskloof WTW, Raw	WBSM ST - 004 Jonkershoek Weir
Analysis	**Unit**	% Uncertainty	SANS241:2015				
Potassium as K Dissolved	mg/l	8.1	NA	3.4	1.8	0.4	0.4
Sodium as Na Dissolved	mg/l	6.9	≤200	52	17	4.0	4.4
Calcium as Ca Dissolved	mg/l	6.1	NA	7.6	21	1.8	2.1
Magnesium as Mg Dissolved	mg/l	5.2	NA	7.4	3.1	0.6	0.7
Ammonia as N	mg/l	8.1	≤1.5	<0.10	<0.10	<0.10	<0.10
Sulphate as SO4 Dissolved	mg/l	4.0	≤500	17	38	1.9	3.1
Chloride as Cl Dissolved	mg/l	5.9	≤300	63	31	7.7	8.1
Alkalinity as CaCO3	mg/l	2.9	NA	45	23	4.0	4.0
Nitrate + Nitrite as N *	mg/l	8.4	≤11	1.6	0.5	0.1	0.1
Nitrite as N *	mg/L	8.4	≤0.9	<0.1	<0.1	<0.1	<0.1
Fluoride as F *	mg/l	8.9	≤1.5	0.5	<0.1	<0.1	<0.1
Total Organic Carbon	mg/l	7.6	≤10	<0.5	3.1	3.0	3.7
Electrical Conductivity	mS/m (25°C)	6.2	≤170	35	26	4	4
pH (Lab) (20°C)		0.7	≥5 to ≤9.7	7.2	7.9	6.2	6.2
Total dissolved salts (Calc) *	mg/l	NA	≤1200	224	166	26	26
Turbidity *	NTU	14.0	≤1	0.3	1.2	1.6	2.6
Colour (filtered) *	mg Pt/L	11.8	≤15	<5	<5	27	30
% Difference (Standard Method) *		NA	NA	2.5	1.7	2.9	2.0
CATIONS meq/L *		NA	NA	3.3	2.1	0.3	0.4

Subcontracted Analysis

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Certificate of Analysis

Report NO:	SAL-2018-12691	Sample Description:	SANS241 water samples in 8x25L & 8x5L plastic bottles
Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	8
		Sample Condition:	Room Temperature
		Date Received:	17-May-2018
Contact:	Dewald van Staden	Date Completed:	18-Jun-18
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	342861
Email:	dewald@metsi.co.za		

				1812691-84763FW 2018-05-17 WBSM DV - 006 Devon Valley, JC le Roux	1812691-84764FW 2018-05-17 WBSM RB - 003 Faure Pumpstation	1812691-84765FW 2018-05-17 WBSM ST - 001 Paradyskloof WTW, Raw	1812691-84766FW 2018-05-17 WBSM ST - 004 Jonkershoek Weir
ANIONS meq/L *		NA	NA	3.2	2.2	0.3	0.4
Abs Difference *		NA	NA	-0.17	0.07	0.02	0.01
Aluminium as Al Dissolved	mg/l	13.3	≤0.3	<0.01	0.02	0.07	0.06
Barium as Ba Dissolved	mg/l	6.6	≤0.7	<0.01	<0.01	<0.01	<0.01
Boron as B Dissolved	mg/l	12.5	≤2.4	<0.02	<0.02	<0.02	<0.02
Antimony as Sb Dissolved	µg/L	16.0	≤20	<0.5	<0.5	<0.5	<0.5
Arsenic as As Dissolved	µg/L	13.3	≤10	0.9	<0.5	<0.5	<0.5
Cadmium as Cd Dissolved	µg/L	14.3	≤3	<0.5	<0.5	<0.5	<0.5
Chromium as Cr Dissolved	mg/l	11.2	≤0.05	<0.01	<0.01	<0.01	<0.01
Copper as Cu Dissolved	mg/l	8.8	≤2	<0.01	<0.01	<0.01	<0.01
Cyanide as CN *	mg/l	NA	≤0.2	<0.05	<0.05	<0.05	<0.05
Iron as Fe Dissolved	mg/l	10.9	≤0.3	<0.01	0.05	0.05	0.07
Lead as Pb Dissolved	µg/l	16.5	≤10	<0.5	<0.5	<0.5	<0.5
Manganese as Mn Dissolved	mg/l	12.9	≤0.1	<0.01	<0.01	<0.01	0.01
Mercury as Hg Dissolved	µg/L	24.2	≤6	<1	<1	<1	<1
Nickel as Ni Dissolved	mg/l	9.6	≤0.07	<0.01	<0.01	<0.01	<0.01
Selenium as Se Dissolved	µg/L	14.5	≤40	<0.5	<0.5	<0.5	<0.5
Uranium as U Dissolved	µg/L	14.1	≤30	1.5	<0.5	<0.5	<0.5
Zinc as Zn Dissolved	mg/l	9.3	≤5	<0.01	<0.01	<0.01	<0.01
Cryptosporidium oocysts * #	count per 10L		Not Detected	0	0	0	0

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				1812691-84763FW 2018-05-17 WBSM DV - 006 Devon Valley, JC le Roux	1812691-84764FW 2018-05-17 WBSM RB - 003 Faure Pumpstation	1812691-84765FW 2018-05-17 WBSM ST - 001 Paradyskloof WTW, Raw	1812691-84766FW 2018-05-17 WBSM ST - 004 Jonkershoek Weir
Gardia cysts * #	count per 10L		Not Detected	0	0	0	0
Phenols * #	mg/l	11.8	≤0.01	<0.01	<0.01	<0.01	<0.01
Somatic Coliphages * #	count per 10ml	30	Not Detected	<1	<1	<1	<1
bromodichloromethane * #	µg/l	30.0	<60	<1	24	<1	<1
bromoform * #	µg/l	30.0	<100	<1	<1	<1	<1
chloroform * #	µg/l	30.0	<300	<1	77	<1	<1
dibromochloromethane * #	µg/l	30.0	<100	<1	10	<1	<1
Total THM * #	µg/l	30	<560	<1	111	<1	<1

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Lab No / Sample Date / Sample ID				1812691-84767FW 2018-05-17 WBSM ST - 012 Idas Valley Reservoir #2	1812691-84768FW 2018-05-17 WBSM ST - 018 Paradyskloof Reservoir #1	1812691-84769FW 2018-05-17 WBSM ST - 034 Stellenbosch Hospital	1812691-84770FW 2018-05-17 WBSM VB - 001 van Rhyn
Analysis	**Unit**	% Uncertainty	SANS241:2015				
Potassium as K Dissolved	mg/l	8.1	NA	0.3	0.3	0.3	0.4
Sodium as Na Dissolved	mg/l	6.9	≤200	4.8	5.4	4.8	4.5
Calcium as Ca Dissolved	mg/l	6.1	NA	1.8	4.4	2.5	13
Magnesium as Mg Dissolved	mg/l	5.2	NA	0.7	0.6	0.6	0.9
Ammonia as N	mg/l	8.1	≤1.5	<0.10	<0.10	<0.10	<0.10
Sulphate as SO4 Dissolved	mg/l	4.0	≤500	1.3	3.6	1.2	11
Chloride as Cl Dissolved	mg/l	5.9	≤300	11	9.4	12	12
Alkalinity as CaCO3	mg/l	2.9	NA	5.6	13	5.6	26
Nitrate + Nitrite as N *	mg/l	8.4	≤11	<0.1	<0.1	<0.1	0.2
Nitrite as N *	mg/L	8.4	≤0.9	<0.1	<0.1	<0.1	<0.1
Fluoride as F *	mg/l	8.9	≤1.5	<0.1	<0.1	<0.1	<0.1
Total Organic Carbon	mg/l	7.6	≤10	1.8	1.8	3.0	1.4
Electrical Conductivity	mS/m (25°C)	6.2	≤170	5	7	5	12
pH (Lab) (20°C)		0.7	≥5 to ≤9.7	6.7	9.4	6.7	7.9
Total dissolved salts (Calc) *	mg/l	NA	≤1200	32	45	32	77
Turbidity *	NTU	14.0	≤1	0.9	0.7	0.9	0.6
Colour (filtered) *	mg Pt/L	11.8	≤15	8	7	22	<5
% Difference (Standard Method) *		NA	NA	10.5	8.0	9.7	8.5
CATIONS meq/L *		NA	NA	0.4	0.5	0.4	0.9
ANIONS meq/L *		NA	NA	0.5	0.6	0.5	1.1

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		Sample Condition:	Room Temperature
		Date Received:	17-May-2018
Contact:	Dewald van Staden	Date Completed:	18-Jun-18
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	342861
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				1812691-84767FW 2018-05-17 WBSM ST - 012 Idas Valley Reservoir #2	1812691-84768FW 2018-05-17 WBSM ST - 018 Paradyskloof Reservoir #1	1812691-84769FW 2018-05-17 WBSM ST - 034 Stellenbosch Hospital	1812691-84770FW 2018-05-17 WBSM VB - 001 van Rhyn
Abs Difference *		NA	NA	0.09	0.09	0.08	0.17
Aluminium as Al Dissolved	mg/l	13.3	≤0.3	0.20	0.07	0.05	0.04
Barium as Ba Dissolved	mg/l	6.6	≤0.7	<0.01	<0.01	<0.01	<0.01
Boron as B Dissolved	mg/l	12.5	≤2.4	<0.02	<0.02	<0.02	<0.02
Antimony as Sb Dissolved	µg/L	16.0	≤20	<0.5	<0.5	<0.5	<0.5
Arsenic as As Dissolved	µg/L	13.3	≤10	<0.5	<0.5	<0.5	<0.5
Cadmium as Cd Dissolved	µg/L	14.3	≤3	<0.5	<0.5	<0.5	<0.5
Chromium as Cr Dissolved	mg/l	11.2	≤0.05	<0.01	<0.01	<0.01	<0.01
Copper as Cu Dissolved	mg/l	8.8	≤2	<0.01	<0.01	0.07	<0.01
Cyanide as CN *	mg/l	NA	≤0.2	<0.05	<0.05	<0.05	<0.05
Iron as Fe Dissolved	mg/l	10.9	≤0.3	<0.01	<0.01	0.06	<0.01
Lead as Pb Dissolved	µg/l	16.5	≤10	<0.5	<0.5	<0.5	<0.5
Manganese as Mn Dissolved	mg/l	12.9	≤0.1	<0.01	<0.01	<0.01	<0.01
Mercury as Hg Dissolved	µg/L	24.2	≤6	<1	<1	<1	<1
Nickel as Ni Dissolved	mg/l	9.6	≤0.07	<0.01	<0.01	<0.01	<0.01
Selenium as Se Dissolved	µg/L	14.5	≤40	<0.5	<0.5	<0.5	<0.5
Uranium as U Dissolved	µg/L	14.1	≤30	<0.5	<0.5	<0.5	<0.5
Zinc as Zn Dissolved	mg/l	9.3	≤5	<0.01	<0.01	0.45	0.03
Cryptosporidium oocysts * #	count per 10L		Not Detected	0	0	0	0
Gardia cysts * #	count per 10L		Not Detected	0	0	0	0

Subcontracted Analysis

Remarks: * Method is not SANAS accredited and is not included in the SANAS Schedule of accreditation for this laboratory.
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Efraim Fieland - Technical Signatory

Signature Removed

Sebastian Brown - Technical Manager

Date Printed
18-Jun-2018

CSIR Implementation Unit
Jan Celliers Street
Stellenbosch, 7600
P O Box 320
Stellenbosch, 7599

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Chemistry Laboratory - Stellenbosch

Tel: (+27) 21 888 2400/2433
Fax: (+27) 21 888 2630

Certificate of Analysis

Report NO:	SAL-2018-12691
Customer:	Stellenbosch Municipality
Address:	P O Box 17 STELLENBOSCH 7600
Contact:	Dewald van Staden
Phone:	021 808 8267
Fax:	021 886 5623
Email:	dewald@metsi.co.za
Sample Description:	SANS241 water samples in 8x25L & 8x5L plastic bottles
No of Samples	8
Sample Condition:	Room Temperature
Date Received:	17-May-2018
Date Completed:	18-Jun-18
Order No:	342861

				1812691-84767FW 2018-05-17 WBSM ST - 012 Idas Valley Reservoir #2	1812691-84768FW 2018-05-17 WBSM ST - 018 Paradyskloof Reservoir #1	1812691-84769FW 2018-05-17 WBSM ST - 034 Stellenbosch Hospital	1812691-84770FW 2018-05-17 WBSM VB - 001 van Rhyn
Phenols * #	mg/l	11.8	≤0.01	<0.01	<0.01	<0.01	<0.01
Somatic Coliphages * #	count per 10ml	30	Not Detected	<1	<1	<1	<1
bromodichloromethane * #	µg/l	30.0	<60	4	<1	3	8
bromoform * #	µg/l	30.0	<100	<1	<1	<1	<1
chloroform * #	µg/l	30.0	<300	19	<1	36	60
dibromochloromethane * #	µg/l	30.0	<100	<1	<1	<1	<1
Total THM * #	µg/l	30	<560	23	<1	39	70

Subcontracted Analysis

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Stellenbosch, 7599

Chemistry Laboratory - Stellenbosch

Certificate of Analysis

Report NO: SAL-2019-14099
Customer: Stellenbosch Municipality
Address: P O Box 17
STELLENBOSCH 7600
Contact: Dewald van Staden
Phone: 021 808 8267 Fax: 021 886 5623
Email: dewald@metsi.co.za

Sample Description: Freshwater samples in 250ml plastic bottles with white caps
No of Samples: 18
Sample Condition: Room Temperature
Date Received: 05-Mar-2019
Date Completed: 8-Mar-19
Order No: TBA

Sample Disposal
a) Liquid Sample — One Month - After issuing of final Certificate of Analysis
b) Solid Sample — Three Months - After issuing of final Certificate of Analysis

Lab No / Sample Date / Sample ID		1914099-92571FW	1914099-92572FW	1914099-92573FW	1914099-92574FW	1914099-92575FW
		WBSM DV - 006 Devon Valley, JC le Roux	WBSM DV - 007 Devon Valley	WBSM EB - 002 JJ Rhode Primary School	WBSM FR - 001 Franschoek Pass, Raw	WBSM FR - 003 Franschoek Pass, Raw
Analysis	**Unit**					
Sodium as Na Dissolved	mg/l	48	5.8	3.7	2.8	3.2
Calcium as Ca Dissolved	mg/l	6.2	9.4	8.6	0.6	0.3
Magnesium as Mg Dissolved	mg/l	6.4	0.7	0.5	0.4	0.3
Sulphate as SO4 Dissolved	mg/l	16	3.6	3.6	0.5	0.4
Alkalinity as CaCO3	mg/l	41	20	17	<2.5	<2.5
Electrical Conductivity	mS/m (25°C)	35	8	7	2	3
pH (Lab) (20°C)		7.1	9.5	9.3	5.5	6.2
Turbidity *	NTU	0.3	0.4	0.4	0.7	0.5
Colour (filtered) *	mg Pt/L	<5	<5	<5	<5	8
Aluminium as Al Dissolved	mg/l	<0.01	0.24	0.09	0.01	0.02
Iron as Fe Dissolved	mg/l	<0.01	0.02	0.02	<0.01	0.08

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Stellenbosch, 7600
P O Box 320
Stellenbosch, 7599

Chemistry Laboratory - Stellenbosch

Certificate of Analysis

Report NO:	SAL-2019-14099	Sample Description:	Freshwater samples in 250ml plastic bottles with white caps
Customer:	Stellenbosch Municipality		
Address:	P O Box 17 STELLENBOSCH 7600	No of Samples	18
		Sample Condition:	Room Temperature
		Date Received:	05-Mar-2019
Contact:	Dewald van Staden	Date Completed:	8-Mar-19
Phone:	021 808 8267 Fax: 021 886 5623	Order No:	TBA
Email:	dewald@metsi.co.za		

Lab No / Sample Date / Sample ID		1914099-92576FW	1914099-92577FW	1914099-92578FW	1914099-92579FW	1914099-92580FW
		WBSM FR - 007 Franschoek, Police Station	WBSM FR - 012 Franschoek, Pick n Pay Centre	WBSM FR - 013 Franschoek, La Petite Provence	WBSM FR - 017 Franschoek, Groendal Primary	WBSM FR - 032 Franschoek WTW, Final
Analysis	**Unit**					
Sodium as Na Dissolved	mg/l	3.4	4.3	4.1	4.3	2.8
Calcium as Ca Dissolved	mg/l	0.5	6.0	7.9	9.6	0.7
Magnesium as Mg Dissolved	mg/l	0.4	0.6	0.6	0.6	0.3
Sulphate as SO4 Dissolved	mg/l	0.5	4.0	3.8	4.0	0.4
Alkalinity as CaCO3	mg/l	4.0	15	18	23	<2.5
Electrical Conductivity	mS/m (25°C)	3	7	7	9	2
pH (Lab) (20°C)		6.7	7.7	7.8	9.6	5.8
Turbidity *	NTU	0.7	0.4	0.5	0.6	0.6
Colour (filtered) *	mg Pt/L	6	<5	<5	<5	6
Aluminium as Al Dissolved	mg/l	0.01	0.05	0.08	0.09	0.02
Iron as Fe Dissolved	mg/l	0.08	<0.01	<0.01	<0.01	0.08

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Certificate of Analysis

Report NO: SAL-2019-14099
Customer: Stellenbosch Municipality
Address: P O Box 17
STELLENBOSCH 7600

Contact: Dewald van Staden
Phone: 021 808 8267 Fax: 021 886 5623
Email: dewald@metsi.co.za

Sample Description: Freshwater samples in 250ml plastic bottles with white caps
No of Samples: 18
Sample Condition: Room Temperature
Date Received: 05-Mar-2019
Date Completed: 8-Mar-19
Order No: TBA

Lab No / Sample Date / Sample ID		1914099-92581FW	1914099-92582FW	1914099-92583FW	1914099-92584FW	1914099-92585FW
Analysis	**Unit**	WBSM KL - 005 Klapmuts Primary School	WBSM RB - 002 Raithby Reservoir	WBSM RB - 003 Faure Pumpstation	WBSM ST - 012 Idas Valley Reservoir #2	WBSM ST - 018 Paradyskloof Reservoir #1
Sodium as Na Dissolved	mg/l	3.8	14	14	5.5	8.7
Calcium as Ca Dissolved	mg/l	7.1	26	27	3.4	2.4
Magnesium as Mg Dissolved	mg/l	0.5	1.9	2.0	0.6	1.4
Sulphate as SO4 Dissolved	mg/l	3.6	39	41	1.1	6.3
Alkalinity as CaCO3	mg/l	15	27	26	9.1	5.3
Electrical Conductivity	mS/m (25°C)	7	25	25	6	8
pH (Lab) (20°C)		8.9	9.0	9.1	7.3	6.8
Turbidity *	NTU	0.4	0.3	0.4	0.6	0.7
Colour (filtered) *	mg Pt/L	<5	<5	<5	<5	<5
Aluminium as Al Dissolved	mg/l	0.05	0.05	0.06	0.02	0.04
Iron as Fe Dissolved	mg/l	<0.01	<0.01	0.01	0.02	<0.01

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Stellenbosch, 7599

Chemistry Laboratory - Stellenbosch

Certificate of Analysis

Report NO: SAL-2019-14099
Customer: Stellenbosch Municipality
Address: P O Box 17
STELLENBOSCH 7600

Contact: Dewald van Staden
Phone: 021 808 8267 Fax: 021 886 5623
Email: dewald@metsi.co.za

Sample Description: Freshwater samples in 250ml plastic bottles with white caps
No of Samples: 18
Sample Condition: Room Temperature
Date Received: 05-Mar-2019
Date Completed: 8-Mar-19
Order No: TBA

Lab No / **Sample Date** / **Sample ID**		1914099-92586FW	1914099-92587FW	1914099-92588FW
				05-Mar-2019
		WBSM ST - 024 Jamestown Reservoir	WBSM VB - 001 van Rhyn	WBSM WH - 001 Wemmershoek Pump Station, Main Meter
Analysis	**Unit**			
Sodium as Na Dissolved	mg/l	9.4	7.6	3.8
Calcium as Ca Dissolved	mg/l	6.6	14	8.0
Magnesium as Mg Dissolved	mg/l	1.4	1.5	0.5
Sulphate as SO4 Dissolved	mg/l	7.3	13	3.8
Alkalinity as CaCO3	mg/l	15	23	16
Electrical Conductivity	mS/m (25°C)	11	13	7
pH (Lab) (20°C)		9.6	8.4	8.6
Turbidity *	NTU	1.3	0.7	0.7
Colour (filtered) *	mg Pt/L	6	<5	<5
Aluminium as Al Dissolved	mg/l	0.27	0.13	0.04
Iron as Fe Dissolved	mg/l	0.07	0.02	<0.01

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ANNEXURE E – PROCESS UNIT SIZING CALCULATIONS

INPUTS

Capacity	4,000	Ml/d	TOC	7,9	mg/l
Flow Rate	0,046	m3/s			

OZONE DOSING

Ozone Dosing rate	0	mg/l	
Transfer Efficiency	85%	%	
Mass required	0	kg/day	
Contact Time	10	mins	
Flow rate	0,000	m3/s	
Tank Volume	0	m3	
Depth	6,5	m	
Area	0,00	m2	
Width : Length	2		3
Width	0,0	m	
Length	0,0	m	
No. of Tanks	2		

BIOLOGICAL ACTIVATED CARBON FILTRATION

			Typical Values		
	Value	Unit	Min	Max	Source
Empty Bed Contact Time (EBCT)	15	mins			
Flow Rate	0,046	m3/s			
Flow Rate	166,667	m3/hr	50	400	Metcalf & Eddy, 2007
Volume Required	41,66667	m3			
No. of Beds	3				
Volume of each Bed	13,88889	m3	10	50	Metcalf & Eddy, 2007
Depth of Media	1,8	m	1,8	4	Metcalf & Eddy, 2007
Total Area	23,15	m2			
Radia	1,567	m			
Diameter	3,134	m			
Cross sectional area	7,716	m2	5	30	Metcalf & Eddy, 2007

GRANULAR ACTIVATED CARBON FILTRATION

			Typical Values		
	Value	Unit	Min	Max	Source
Empty Bed Contact Time (EBCT)	15	mins			
Flow Rate	0,046	m3/s			
Flow Rate	166,667	m3/hr	50	400	Metcalf & Eddy, 2007
Volume Required	41,66667	m3			
No. of Beds	3				
Volume of each Bed	13,88889	m3	10	50	Metcalf & Eddy, 2007
Depth of Media	1,8		1,8	4	Metcalf & Eddy, 2007
Total Area	23,15	m2			
Radia	1,567	m			
Diameter	3,134	m			
Cross sectional area	7,716	m2	5	30	Metcalf & Eddy, 2007

ADVANCED OXIDATION PROCESSES

UV

UV Dose	540	mJ/cm2	Metcalf, 2014 - highest pollutant removal efficincies for most contaminants
Effluent Turbidity	0,2	NTU	The effluent turbidity shall be equal to or less than 0.2 ntu 95 percent of the time, not to exceed 0.5 ntu. The filtered effluent UV transmittance shall be 65 percent or greater at 254 nm.

H2O2

Dose	7,5	mg/l	Metcalf, 2014 - highest pollutant removal efficincies for most contaminants
Flow Rate	0,000	m3/s	
Mass	0	kg/d	
Density @20°C	1,069	kg/l	
Volume	0,000	l/day	
Area	48	m2	
Width	6	m	
Breadth	8	m	

CHLORINE DOSING

Chlorine residual dosing

Dose	0,5	mg/l	Assume all ammonia degraded in biological process (<0,1mg/l) therefore all chlorine is free and available. pH below 8. Iron and manganese not present
Flow Rate	0,046	m3/s	
Mass	2,000	kg/d	
Storage Capacity	60	days	
No. of 70kg Cyclinders	2		
Area Required	7,00	m2	

ENGINEERED STORAGE BUFFER

Retention Time	48	hours
Volume Required	8000	m3
Depth	5	m
Area	1600	m2
No. Tanks	2	
Radius	16,0	m
Diameter	31,9	m

STAFF

Plant Manager	1	No
Process Controllers	2	No
Chemist	1	No
Laboratory Staff	1	No
General Workers	2	No
Total	7	

CONTROL BUILDING

	Area	
Laboratory	40	m2
Offices	36	m2
Toilets	3,3	m2
Showers	2,475	m2
Changerooms	6	m2
Kitchenette and Pause Area	16	m2
Total Area	103,78	m2

Plant Capacity (Mℓ/d)	4.000
Process Unit	**Area (m^2)**
Ozone Contact Tank	4,27
BAC Filter Beds	23,15
GAC Filter Beds	23,15
AOP	48,00
Cl_2 Dosing	7,00
ESB	1600,00
Control Building	103,78
Total Area	1809,34

INPUTS

Capacity	6,667	Ml/d	TOC	7,9	mg/l
Flow Rate	0,077	m3/s			

OZONE DOSING

Ozone Dosing rate	5,53	mg/l
Transfer Efficiency	85%	%
Mass required	42,39879	kg/day
Contact Time	10	mins
Flow rate	0,077	m3/s
Tank Volume	46	m3
Depth	6,5	m
Area	7,12	m2
Width : Length	2	3
Width	2,2	m
Length	3,3	m
No. of Tanks	2	

BIOLOGICAL ACTIVATED CARBON FILTRATION

			Typical Values		
	Value	Unit	Min	Max	Source
Empty Bed Contact Time (EBCT)	15	mins			
Flow Rate	0,077	m3/s			
Flow Rate	277,792	m3/hr	50	400	Metcalf & Eddy, 2007
Volume Required	69,44792	m3			
No. of Beds	5				
Volume of each Bed	13,88958	m3	10	50	Metcalf & Eddy, 2007
Depth of Media	1,8	m	1,8	4	Metcalf & Eddy, 2007
Total Area	38,58	m2			
Radia	1,567	m			
Diameter	3,134	m			
Cross sectional area	7,716	m2	5	30	Metcalf & Eddy, 2007

GRANULAR ACTIVATED CARBON FILTRATION

			Typical Values		
	Value	Unit	Min	Max	Source
Empty Bed Contact Time (EBCT)	15	mins			
Flow Rate	0,077	m3/s			
Flow Rate	277,792	m3/hr	50	400	Metcalf & Eddy, 2007
Volume Required	69,44792	m3			
No. of Beds	5				
Volume of each Bed	13,88958	m3	10	50	Metcalf & Eddy, 2007
Depth of Media	1,8		1,8	4	Metcalf & Eddy, 2007
Total Area	38,58	m2			
Radia	1,567	m			
Diameter	3,134	m			
Cross sectional area	7,716	m2	5	30	Metcalf & Eddy, 2007

ADVANCED OXIDATION PROCESSES

UV

UV Dose	540	mJ/cm2	Metcalf, 2014 - highest pollutant removal efficincies for most contaminants
Effluent Turbidity	0,2	NTU	The effluent turbidity shall be equal to or less than 0.2 ntu 95 percent of the time, not to exceed 0.5 ntu. The filtered effluent UV transmittance shall be 65 percent or greater at 254 nm.

H2O2

Dose	7,5	mg/l	Metcalf, 2014 - highest pollutant removal efficincies for most contaminants
Flow Rate	0,077	m3/s	
Mass	50,0025	kg/d	
Density @20°C	1,069	kg/l	
Volume	46,775	l/day	
Area	48	m2	
Width	6	m	
Breadth	8	m	

CHLORINE DOSING

Chlorine residual dosing			
Dose	0,5	mg/l	Assume all ammonia degraded in biological process (<0,1mg/l) therefore all chlorine is free and available. pH below 8. Iron and manganese not present
Flow Rate	0,077	m3/s	
Mass	3,334	kg/d	
Storage Capacity	60	days	
No. of 70kg Cyclinders	3		
Area Required	7,50	m2	

ENGINEERED STORAGE BUFFER

Retention Time	48	hours
Volume Required	13334	m3
Depth	5	m
Area	2666,8	m2
No. Tanks	4	
Radius	14,6	m
Diameter	29,1	m

STAFF

Plant Manager	1	No
Process Controllers	2	No
Chemist	1	No
Laboratory Staff	1	No
General Workers	2	No
Total	7	

CONTROL BUILDING

	Area	
Laboratory	40	m2
Offices	36	m2
Toilets	3,3	m2
Showers	2,475	m2
Changerooms	6	m2
Kitchenette and Pause Area	16	m2
Total Area	103,78	m2

Plant Capacity (Mℓ/d)	6.667
Process Unit	**Area (m^2)**
Ozone Contact Tank	7,12
BAC Filter Beds	38,58
GAC Filter Beds	38,58
AOP	48,00
Cl_2 Dosing	7,50
ESB	2666,80
Control Building	103,78
Total Area	2910,36

INPUTS

Capacity	10,000	Ml/d	TOC	7,9	mg/l
Flow Rate	0,116	m3/s			

OZONE DOSING

Ozone Dosing rate	5,53	mg/l	
Transfer Efficiency	85%	%	
Mass required	63,595	kg/day	
Contact Time	10	mins	
Flow rate	0,116	m3/s	
Tank Volume	69	m3	
Depth	6,5	m	
Area	10,68	m2	
Width : Length	2		3
Width	2,7	m	
Length	4,0	m	
No. of Tanks	2		

BIOLOGICAL ACTIVATED CARBON FILTRATION

			Typical Values		
	Value	Unit	Min	Max	Source
Empty Bed Contact Time (EBCT)	15	mins			
Flow Rate	0,116	m3/s			
Flow Rate	416,667	m3/hr	50	400	Metcalf & Eddy, 2007
Volume Required	104,1667	m3			
No. of Beds	8				
Volume of each Bed	13,02083	m3	10	50	Metcalf & Eddy, 2007
Depth of Media	1,8	m	1,8	4	Metcalf & Eddy, 2007
Total Area	57,87	m2			
Radia	1,517	m			
Diameter	3,035	m			
Cross sectional area	7,234	m2	5	30	Metcalf & Eddy, 2007

GRANULAR ACTIVATED CARBON FILTRATION

			Typical Values		
	Value	Unit	Min	Max	Source
Empty Bed Contact Time (EBCT)	15	mins			
Flow Rate	0,116	m3/s			
Flow Rate	416,667	m3/hr	50	400	Metcalf & Eddy, 2007
Volume Required	104,1667	m3			
No. of Beds	8				
Volume of each Bed	13,02083	m3	10	50	Metcalf & Eddy, 2007
Depth of Media	1,8		1,8	4	Metcalf & Eddy, 2007
Total Area	57,87	m2			
Radia	1,517	m			
Diameter	3,035	m			
Cross sectional area	7,234	m2	5	30	Metcalf & Eddy, 2007

ADVANCED OXIDATION PROCESSES

UV

UV Dose	540	mJ/cm2	Metcalf, 2014 - highest pollutant removal efficincies for most contaminants
Effluent Turbidity	0,2	NTU	The effluent turbidity shall be equal to or less than 0.2 ntu 95 percent of the time, not to exceed 0.5 ntu. The filtered effluent UV transmittance shall be 65 percent or greater at 254 nm.

H2O2

Dose	7,5	mg/l	Metcalf, 2014 - highest pollutant removal efficincies for most contaminants
Flow Rate	0,116	m3/s	
Mass	75	kg/d	
Density @20°C	1,069	kg/l	
Volume	70,159	l/day	
Area	48	m2	
Width	6	m	
Breadth	8	m	

CHLORINE DOSING

Chlorine residual dosing			
Dose	0,5	mg/l	Assume all ammonia degraded in biological process (<0,1mg/l) therefore all chlorine is free and available. pH below 8. Iron and manganese not present
Flow Rate	0,116	m3/s	
Mass	5,000	kg/d	
Storage Capacity	60	days	
No. of 70kg Cyclinders	5		
Area Required	8,50	m2	

ENGINEERED STORAGE BUFFER

Retention Time	48	hours
Volume Required	20000	m3
Depth	5	m
Area	4000	m2
No. Tanks	6	
Radius	14,6	m
Diameter	29,1	m

STAFF

Plant Manager	1	No
Process Controllers	3	No
Chemist	1	No
Laboratory Staff	1	No
General Workers	4	No
Total	10	

CONTROL BUILDING

	Area	
Laboratory	40	m2
Offices	48	m2
Toilets	6,6	m2
Showers	2,475	m2
Changerooms	8	m2
Kitchenette and Pause Area	16	m2
Total Area	121,08	m2

Plant Capacity (Mℓ/d)	10
Process Unit	Area (m^2)
Ozone Contact Tank	10,68
BAC Filter Beds	57,87
GAC Filter Beds	57,87
AOP	48,00
Cl_2 Dosing	8,50
ESB	4000,00
Control Building	121,08
Total Area	4304,00

INPUTS

Capacity	20,000	Ml/d	TOC	7,9	mg/l
Flow Rate	0,231	m3/s			

OZONE DOSING

Ozone Dosing rate	5,53	mg/l	
Transfer Efficiency	85%	%	
Mass required	127,19	kg/day	
Contact Time	10	mins	
Flow rate	0,231	m3/s	
Tank Volume	139	m3	
Depth	6,5	m	
Area	21,37	m2	
Width : Length	2		3
Width	3,8	m	
Length	5,7	m	
No. of Tanks	2		

BIOLOGICAL ACTIVATED CARBON FILTRATION

			Typical Values		
	Value	Unit	Min	Max	Source
Empty Bed Contact Time (EBCT)	15	mins			
Flow Rate	0,231	m3/s			
Flow Rate	833,333	m3/hr	50	400	Metcalf & Eddy, 2007
Volume Required	208,3333	m3			
No. of Beds	16				
Volume of each Bed	13,02083	m3	10	50	Metcalf & Eddy, 2007
Depth of Media	1,8	m	1,8	4	Metcalf & Eddy, 2007
Total Area	115,74	m2			
Radia	1,517	m			
Diameter	3,035	m			
Cross sectional area	7,234	m2	5	30	Metcalf & Eddy, 2007

GRANULAR ACTIVATED CARBON FILTRATION

			Typical Values		
	Value	Unit	Min	Max	Source
Empty Bed Contact Time (EBCT)	15	mins			
Flow Rate	0,231	m3/s			
Flow Rate	833,333	m3/hr	50	400	Metcalf & Eddy, 2007
Volume Required	208,3333	m3			
No. of Beds	16				
Volume of each Bed	13,02083	m3	10	50	Metcalf & Eddy, 2007
Depth of Media	1,8		1,8	4	Metcalf & Eddy, 2007
Total Area	115,74	m2			
Radia	1,517	m			
Diameter	3,035	m			
Cross sectional area	7,234	m2	5	30	Metcalf & Eddy, 2007

ADVANCED OXIDATION PROCESSES

UV

UV Dose	540	mJ/cm2	Metcalf, 2014 - highest pollutant removal efficincies for most contaminants
Effluent Turbidity	0,2	NTU	The effluent turbidity shall be equal to or less than 0.2 ntu 95 percent of the time, not to exceed 0.5 ntu. The filtered effluent UV transmittance shall be 65 percent or greater at 254 nm.

H_2O_2

Dose	7,5	mg/l	Metcalf, 2014 - highest pollutant removal efficincies for most contaminants
Flow Rate	0,231	m3/s	
Mass	150	kg/d	
Density @20°C	1,069	kg/l	
Volume	140,318	l/day	
Area	48	m2	
Width	6	m	
Breadth	8	m	

CHLORINE DOSING

Chlorine residual dosing

Dose	0,5	mg/l	Assume all ammonia degraded in biological process (<0,1mg/l) therefore all chlorine is free and available. pH below 8. Iron and manganese not present
Flow Rate	0,231	m3/s	
Mass	10,000	kg/d	
Storage Capacity	60	days	
No. of 70kg Cyclinders	9		
Area Required	10,50	m2	

ENGINEERED STORAGE BUFFER

Retention Time	48	hours
Volume Required	40000	m3
Depth	5	m
Area	8000	m2
No. Tanks	6	
Radius	20,6	m
Diameter	41,2	m

STAFF

Plant Manager	1	No
Process Controllers	4	No
Chemist	1	No
Laboratory Staff	2	No
General Workers	6	No
Total	14	

CONTROL BUILDING

	Area	
Laboratory	40	m2
Offices	60	m2
Toilets	6,6	m2
Showers	2,475	m2
Changerooms	10	m2
Kitchenette and Pause Area	16	m2
Total Area	135,08	m2

Plant Capacity (Mℓ/d)	20
Process Unit	Area (m^2)
Ozone Contact Tank	21,37
BAC Filter Beds	115,74
GAC Filter Beds	115,74
AOP	48,00
Cl_2 Dosing	10,50
ESB	8000,00
Control Building	135,08
Total Area	8446,42

ANNEXURE F – CONVEYANCE PIPELINE ROUTE

Google Earth 9.2.81.1. 2019. *Stellenbosch area 33°58'49"S, 18°52'03"E, elevation 128m.* 2D map, viewed 01 April 2019. < https://earth.google.com/web >.

ANNEXURE B – STELLENBOSCH WATER SUPPLY NETWORK

INFLATION ASSUMPTIONS

Consumer Price Index	5,50%	Stats SA (2009 -2019)
Interest Rates	6,00%	
Salary Increase	8,00%	
Chemical Increase	5,50%	

CAPEX & OPEX ASSUMPTIONS

Prelimary & General	15%		
Contingencies	10%		
Escalation (Civil)	8%		
Escalation (M&E)	3%		
Forex	5%		
Civil Capital Costs	60%	Swartz et al , 2012	
M&E Capital Costs	40%	Swartz et al , 2012	
Professional Fees	15%		
Annual Civil Maintenance	0,50%		
Annual M&E Maintenance	1,50%		
Loan Payback Period	20	years	
Funding from external loans	0%		
M&E Capital Replacement Costs	75%		
M&E Capital Replacement Period	15	years	
GAC Replacement period	1	year	Metcalf & Eddy
GAC Recovery	80,00%		Clements & Haarhof, 2006 - 78,7%
			Metcalf & Eddy, 2006 - 77 - 90%

ELECTRICITY PRICING ASSUMPTIONS

Base Date	2018/2019		
Low Demand	273	days	
High Demand	92	days	
Off-peak	176	days	
Standard	135	days	
Peak	54	days	
Off-peak rate (OR)	0,611	R/kWh	Stellenbosch Municipality Tariffs 2018/19
Standard rate (SR)	0,815	R/kWh	Stellenbosch Municipality Tariffs 2018/19
Peak rate (PR)	1,247	R/kWh	Stellenbosch Municipality Tariffs 2018/19
Fixed Monthly Charge	5512,6	R/month	Stellenbosch Municipality Tariffs 2018/19
Max Consumption (MC)	39,04	R/kVA	Stellenbosch Municipality Tariffs 2018/19
Annual Price Increase	8,28%		Eskom average increase (2012 -2019)
kW to kVA conversion factor	1,25		

ENERGY CONSUMPTION

WTW		
Low	0,064	kWh/m^3
Medium	0,173	kWh/m^3
High	0,317	kWh/m^3
AWTW		
Low	0,370	kWh/m^3
Medium	0,570	kWh/m^3
High	0,660	kWh/m^3
Transfer Pump Size	156	kW

CHEMICAL PRICES

$Ca(OH)_2$ (lime)	R	7 980,00	R/t	Stellenbosch Municipality
Sodium	R	13 646,79	R/t	Stellenbosch Municipality
Alum	R	2 102,96	R/t	Stellenbosch Municipality
Chlorine	R	28 700,00	R/t	Protea Chemicals
Ozone	R	-	R/t	
Hydrogen Peroxide	R	26,38	R/l	Blendwell Chemicals
GAC	R	14 086,80	R/m^3	Water Icon

CHEMICAL USAGE

$Ca(OH)_2$ (lime)	0,0075	kg/m^3	Stellenbosch Municipality (2018 - 2019)
Sodium	0,0078	kg/m^3	Stellenbosch Municipality (2018 - 2019)
Alum	0,021	kg/m^3	Stellenbosch Municipality (2018 - 2019)
Chlorine (WTW)	0,841	mg/l	Stellenbosch Municipality (2018 - 2019)
Chlorine (AWTW)	0,500	mg/l	
Ozone	5,530	mg/l	
Hydrogen Peroxide	7,500	mg/l	
GAC Filters	41,667	m^3	
BAC Filters	41,667	m^3	

CHEMICAL PROPERTIES

Density @ 20°C		
Hydrogen Peroxide	1,069	kg/l
Transfer Efficiency		
Ozone	85%	

DEMOGRAPHICS

Population	19068	2011	Census 2011
Population	40756	2039	
Growth Rate	2,75%		

CAPITAL COSTS WTW (excl. fees, P&G's and VAT)

Capital cost	R	6 402 180,00	R/Ml	Cost benchmarks for water services, DWS 2016
Base Date		2016		
Current Date		2019		
Capital cost	R	7 517 704,65	R/Ml	Escalated to 2019
WTW Capacity		20,00	Ml	Paradyskloof WTW
Total Capital Cost	R	150 354 092,92		
Civil Capital cost	R	90 212 455,75		
M&E Capital Cost	R	60 141 637,17		

Stellenbosch DPR Plant

Capacity	4	Ml/d

Scenario A

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	11307	R 5 320 565,84	R 4 784 615,35	R 3 120 000,00	R 2 075 627,05	R 968 189,28	R 1 353 186,84	R 17 622 184,35	R 4,27	R 1,16	R 0,76	R 0,50	R 0,23	R 0,33
2020	11600	R 5 320 565,84	R 5 513 858,26	R 3 369 600,00	R 2 303 934,77	R 1 047 937,71	R 1 427 612,11	R 18 983 508,69	R 4,48	R 1,30	R 0,80	R 0,54	R 0,25	R 0,34
2021	11901	R 5 320 565,84	R 6 356 644,53	R 3 639 168,00	R 2 557 405,63	R 1 134 254,90	R 1 506 130,78	R 20 514 169,68	R 4,72	R 1,46	R 0,84	R 0,59	R 0,26	R 0,35
2022	12210	R 5 320 565,84	R 7 330 837,47	R 3 930 301,44	R 2 838 817,23	R 1 227 681,93	R 1 588 967,97	R 22 237 171,88	R 4,99	R 1,64	R 0,88	R 0,64	R 0,28	R 0,36
2023	12527	R 5 320 565,84	R 8 457 126,02	R 4 244 725,56	R 3 151 254,13	R 1 328 804,40	R 1 676 361,21	R 24 178 837,15	R 5,29	R 1,85	R 0,93	R 0,69	R 0,29	R 0,37
2024	12852	R 5 320 565,84	R 9 759 473,07	R 4 584 303,60	R 3 498 141,76	R 1 438 256,20	R 1 768 561,08	R 26 369 301,55	R 5,62	R 2,08	R 0,98	R 0,75	R 0,31	R 0,38
2025	13185	R 5 320 565,84	R 11 265 635,07	R 4 951 047,89	R 3 883 284,20	R 1 556 723,39	R 1 865 831,94	R 28 843 088,32	R 5,99	R 2,34	R 1,03	R 0,81	R 0,32	R 0,39
2026	13527	R 5 320 565,84	R 13 007 764,18	R 5 347 131,72	R 4 310 906,00	R 1 684 948,57	R 1 968 452,69	R 31 639 769,00	R 6,41	R 2,63	R 1,08	R 0,87	R 0,34	R 0,40
2027	13878	R 5 320 565,84	R 15 023 106,28	R 5 774 902,26	R 4 785 698,73	R 1 823 735,47	R 2 076 717,59	R 34 804 726,17	R 6,87	R 2,97	R 1,14	R 0,94	R 0,36	R 0,41
2028	14238	R 5 320 565,84	R 17 354 809,84	R 6 236 894,44	R 5 312 872,63	R 1 973 954,06	R 2 190 937,06	R 38 390 033,87	R 7,39	R 3,34	R 1,20	R 1,02	R 0,38	R 0,42
2029	14608	R 5 320 565,84	R 20 052 863,56	R 6 735 845,99	R 5 898 214,01	R 2 136 545,96	R 2 311 438,60	R 42 455 473,95	R 7,96	R 3,76	R 1,26	R 1,11	R 0,40	R 0,43
2030	14987	R 5 320 565,84	R 23 175 183,11	R 7 274 713,67	R 6 548 148,96	R 2 312 530,32	R 2 438 567,72	R 47 069 709,62	R 8,60	R 4,24	R 1,33	R 1,20	R 0,42	R 0,45
2031	15375	R 5 320 565,84	R 26 788 870,76	R 7 856 690,76	R 7 269 814,21	R 2 503 010,27	R 2 572 688,94	R 52 311 640,79	R 9,32	R 4,77	R 1,40	R 1,30	R 0,45	R 0,46
2032	15774	R 5 320 565,84	R 30 971 675,44	R 8 485 226,03	R 8 071 135,68	R 2 709 179,80	R 2 714 186,83	R 58 271 969,62	R 10,12	R 5,38	R 1,47	R 1,40	R 0,47	R 0,47
2033	16183	R 5 320 565,84	R 35 813 685,12	R 9 164 044,11	R 8 960 915,87	R 2 932 331,23	R 2 863 467,11	R 65 055 009,28	R 11,01	R 6,06	R 1,55	R 1,52	R 0,50	R 0,48
2034	16603	R 5 320 565,84	R 41 419 288,54	R 9 897 167,64	R 9 948 930,86	R 3 173 863,33	R 3 020 957,80	R 72 780 774,01	R 12,01	R 6,83	R 1,63	R 1,64	R 0,52	R 0,50
2035	17034	R 5 320 565,84	R 47 909 449,15	R 10 688 941,05	R 11 046 038,06	R 3 435 290,11	R 3 187 110,48	R 81 587 394,69	R 13,12	R 7,71	R 1,72	R 1,78	R 0,55	R 0,51
2036	17476	R 5 320 565,84	R 55 424 341,06	R 11 544 056,33	R 12 264 295,88	R 3 718 250,25	R 3 362 401,56	R 91 633 910,92	R 14,37	R 8,69	R 1,81	R 1,92	R 0,58	R 0,53
2037	17929	R 5 320 565,84	R 64 126 404,51	R 12 467 580,84	R 13 617 096,69	R 4 024 517,43	R 3 547 333,64	R 103 103 498,95	R 15,76	R 9,80	R 1,91	R 2,08	R 0,61	R 0,54
2038	18394	R 5 320 565,84	R 74 203 887,90	R 13 464 987,30	R 15 119 314,43	R 4 356 011,41	R 3 742 436,99	R 116 207 203,88	R 17,31	R 11,05	R 2,01	R 2,25	R 0,65	R 0,56
2039	18871	R 5 320 565,84	R 85 874 953,69	R 14 542 186,29	R 16 787 468,67	R 4 714 810,10	R 3 948 271,03	R 131 188 255,62	R 19,05	R 12,47	R 2,11	R 2,44	R 0,68	R 0,57
	113318373							R 1 125 247 631,98	R 9,93					

Paradyskloof WTW		
Amoritzed Capital Cost	R	0,99
Raw Water Tariffs	R	5,34
Labour	R	1,39
Energy	R	1,33
Chemicals	R	0,44
Maintenance	R	0,45
Unit Cost	R	9,93
Check	R	9,93

Scenario B - 4,0ML/D (Procurement Model No.1)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	11307	R 5 320 565,84	R 3 092 008,15	R 3 120 000,00	R 2 075 627,05	R 968 189,28	R 1 353 186,84	R 15 929 577,15	R 3,86	R 0,75	R 0,76	R 0,50	R 0,23	R 0,33
2020	11600	R 5 320 565,84	R 3 612 596,05	R 3 369 600,00	R 2 303 934,77	R 1 047 937,71	R 1 427 612,11	R 17 082 246,48	R 4,03	R 0,85	R 0,80	R 0,54	R 0,25	R 0,34
2021	11901	R 5 320 565,84	R 4 220 200,07	R 3 639 168,00	R 2 557 405,63	R 1 134 254,90	R 1 506 130,78	R 18 377 725,22	R 4,23	R 0,97	R 0,84	R 0,59	R 0,26	R 0,35
2022	12210	R 5 320 565,84	R 4 929 271,42	R 3 930 301,44	R 2 838 817,23	R 1 227 681,93	R 1 588 967,97	R 19 835 605,83	R 4,45	R 1,11	R 0,88	R 0,64	R 0,28	R 0,36
2023	12527	R 5 320 565,84	R 5 756 645,75	R 4 244 725,56	R 3 151 254,13	R 1 328 804,40	R 1 676 361,21	R 21 478 356,88	R 4,70	R 1,26	R 0,93	R 0,69	R 0,29	R 0,37
2024	12852	R 5 320 565,84	R 6 721 934,23	R 4 584 303,60	R 3 498 141,76	R 1 438 256,20	R 1 768 561,08	R 23 331 762,71	R 4,97	R 1,43	R 0,98	R 0,75	R 0,31	R 0,38
2025	13185	R 5 320 565,84	R 7 847 978,56	R 4 951 047,89	R 3 883 284,20	R 1 556 723,39	R 1 865 831,94	R 25 425 431,82	R 5,28	R 1,63	R 1,03	R 0,81	R 0,32	R 0,39
2026	13527	R 5 320 565,84	R 9 161 380,09	R 5 347 131,72	R 4 310 906,00	R 1 684 948,57	R 1 968 452,69	R 27 793 384,90	R 5,63	R 1,86	R 1,08	R 0,87	R 0,34	R 0,40
2027	13878	R 5 320 565,84	R 10 693 115,24	R 5 774 902,26	R 4 785 698,73	R 1 823 735,47	R 2 076 717,59	R 30 474 735,13	R 6,02	R 2,11	R 1,14	R 0,94	R 0,36	R 0,41
2028	14238	R 5 320 565,84	R 12 479 251,24	R 6 236 894,44	R 5 312 872,63	R 1 973 954,06	R 2 190 937,06	R 33 514 475,27	R 6,45	R 2,40	R 1,20	R 1,02	R 0,38	R 0,42
2029	14608	R 5 320 565,84	R 14 561 778,35	R 6 735 845,99	R 5 898 214,01	R 2 136 545,96	R 2 311 438,60	R 36 964 388,74	R 6,93	R 2,73	R 1,26	R 1,11	R 0,40	R 0,43
2030	14987	R 5 320 565,84	R 16 989 577,57	R 7 274 713,67	R 6 548 148,96	R 2 312 530,32	R 2 438 567,72	R 40 884 104,08	R 7,47	R 3,11	R 1,33	R 1,20	R 0,42	R 0,45
2031	15375	R 5 320 565,84	R 19 819 545,77	R 7 856 690,76	R 7 269 814,21	R 2 503 010,27	R 2 572 688,94	R 45 342 315,80	R 8,08	R 3,53	R 1,40	R 1,30	R 0,45	R 0,46
2032	15774	R 5 320 565,84	R 23 117 903,74	R 8 485 226,03	R 8 071 135,68	R 2 709 179,80	R 2 714 186,83	R 50 418 197,92	R 8,76	R 4,02	R 1,47	R 1,40	R 0,47	R 0,47
2033	16183	R 5 320 565,84	R 26 961 716,88	R 9 164 044,11	R 8 960 915,87	R 2 932 331,23	R 2 863 467,11	R 56 203 041,04	R 9,51	R 4,56	R 1,55	R 1,52	R 0,50	R 0,48
2034	16603	R 5 320 565,84	R 31 440 662,81	R 9 897 167,64	R 9 948 930,86	R 3 173 863,33	R 3 020 957,80	R 62 802 148,28	R 10,36	R 5,19	R 1,63	R 1,64	R 0,52	R 0,50
2035	17034	R 5 320 565,84	R 36 659 086,05	R 10 688 941,05	R 11 046 038,06	R 3 435 290,11	R 3 187 110,48	R 70 337 031,58	R 11,31	R 5,90	R 1,72	R 1,78	R 0,55	R 0,51
2036	17476	R 5 320 565,84	R 42 738 386,15	R 11 544 056,33	R 12 264 295,88	R 3 718 250,25	R 3 362 401,56	R 78 947 956,01	R 12,38	R 6,70	R 1,81	R 1,92	R 0,58	R 0,53
2037	17929	R 5 320 565,84	R 49 819 793,20	R 12 467 580,84	R 13 617 096,69	R 4 024 517,43	R 3 547 333,64	R 88 796 887,64	R 13,57	R 7,61	R 1,91	R 2,08	R 0,61	R 0,54
2038	18394	R 5 320 565,84	R 58 067 593,40	R 13 464 987,30	R 15 119 314,43	R 4 356 011,41	R 3 742 436,99	R 100 070 909,38	R 14,91	R 8,65	R 2,01	R 2,25	R 0,65	R 0,56
2039	18871	R 5 320 565,84	R 67 672 877,43	R 14 542 186,29	R 16 787 468,67	R 4 714 810,10	R 3 948 271,03	R 112 986 179,36	R 16,40	R 9,82	R 2,11	R 2,44	R 0,68	R 0,57
	113318373							R 976 996 461,21	R 8,62					

Stellenbosch DPR Plant

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs Annual Cost Rands	Combined Costs Unit Cost R/kl
2019	4000	R0,00	R 2 010 000,00	R 6 254 443,43	R 419 453,81	R 845 689,09	R 9 529 586,33	R 6,53	R 1,38	R 4,28	R 0,29	R 0,58	R 25 459 163,49	R 6,17
2020	4000	R0,00	R 2 170 800,00	R 6 772 311,35	R 442 523,77	R 892 201,99	R 10 277 837,11	R 7,04	R 1,49	R 4,64	R 0,30	R 0,61	R 27 360 083,59	R 6,46
2021	4000	R0,00	R 2 344 464,00	R 7 333 058,72	R 466 862,58	R 941 273,10	R 11 085 658,41	R 7,59	R 1,61	R 5,02	R 0,32	R 0,64	R 29 463 383,63	R 6,78
2022	4000	R0,00	R 2 532 021,12	R 7 940 235,99	R 492 540,02	R 993 043,12	R 11 957 840,25	R 8,19	R 1,73	R 5,44	R 0,34	R 0,68	R 31 793 446,08	R 7,13
2023	4000	R0,00	R 2 734 582,81	R 8 597 687,53	R 519 629,72	R 1 047 660,50	R 12 899 560,55	R 8,84	R 1,87	R 5,89	R 0,36	R 0,72	R 34 377 917,43	R 7,52
2024	4000	R0,00	R 2 953 349,43	R 9 309 576,05	R 548 209,36	R 1 105 281,82	R 13 916 416,67	R 9,53	R 2,02	R 6,38	R 0,38	R 0,76	R 37 248 179,38	R 7,94
2025	4000	R0,00	R 3 189 617,39	R 10 080 408,95	R 578 360,87	R 1 166 072,32	R 15 014 459,53	R 10,28	R 2,18	R 6,90	R 0,40	R 0,80	R 40 439 891,35	R 8,40
2026	4000	R0,00	R 3 444 786,78	R 10 915 066,81	R 610 170,72	R 1 230 206,30	R 16 200 230,61	R 11,10	R 2,36	R 7,48	R 0,42	R 0,84	R 43 993 615,52	R 8,91
2027	4000	R0,00	R 3 720 369,72	R 11 818 834,34	R 643 730,11	R 1 297 867,65	R 17 480 801,82	R 11,97	R 2,55	R 8,10	R 0,44	R 0,89	R 47 955 536,95	R 9,47
2028	4000	R0,00	R 4 017 999,30	R 12 797 433,83	R 679 135,26	R 1 369 250,37	R 18 863 818,76	R 12,92	R 2,75	R 8,77	R 0,47	R 0,94	R 52 378 294,03	R 10,08
2029	4000	R0,00	R 4 339 439,24	R 13 857 061,35	R 716 487,70	R 1 444 559,14	R 20 357 547,44	R 13,94	R 2,97	R 9,49	R 0,49	R 0,99	R 57 321 936,17	R 10,75
2030	4000	R0,00	R 4 686 594,38	R 15 004 426,03	R 755 894,53	R 1 524 009,89	R 21 970 924,83	R 15,05	R 3,21	R 10,28	R 0,52	R 1,04	R 62 855 028,91	R 11,49
2031	4000	R0,00	R 5 061 521,93	R 16 246 792,50	R 797 468,72	R 1 607 830,44	R 23 713 613,60	R 16,24	R 3,47	R 11,13	R 0,55	R 1,10	R 69 055 929,40	R 12,31
2032	4000	R0,00	R 5 466 443,69	R 17 592 026,92	R 841 329,50	R 1 696 261,11	R 25 596 061,23	R 17,53	R 3,74	R 12,05	R 0,58	R 1,16	R 76 014 259,15	R 13,20
2033	4000	R0,00	R 5 903 759,18	R 19 048 646,75	R 887 602,63	R 1 789 555,47	R 27 629 564,04	R 18,92	R 4,04	R 13,05	R 0,61	R 1,23	R 83 832 605,07	R 14,19
2034	4000	R0,00	R 6 376 059,92	R 20 625 874,70	R 936 420,77	R 1 887 981,02	R 29 826 336,42	R 20,43	R 4,37	R 14,13	R 0,64	R 1,29	R 92 628 484,70	R 15,28
2035	4000	R0,00	R 6 886 144,71	R 22 333 697,13	R 987 923,91	R 1 991 819,98	R 32 199 585,74	R 22,05	R 4,72	R 15,30	R 0,68	R 1,36	R 102 536 617,32	R 16,49
2036	4000	R0,00	R 7 437 036,29	R 24 182 927,25	R 1 042 259,73	R 2 101 370,08	R 34 763 593,35	R 23,81	R 5,09	R 16,56	R 0,71	R 1,44	R 113 711 549,36	R 17,83
2037	4000	R0,00	R 8 031 999,19	R 26 185 273,63	R 1 099 584,01	R 2 216 945,43	R 37 533 802,27	R 25,71	R 5,50	R 17,94	R 0,75	R 1,52	R 126 330 689,90	R 19,30
2038	4000	R0,00	R 8 674 559,13	R 28 353 414,28	R 1 160 061,14	R 2 338 877,43	R 40 526 911,98	R 27,76	R 5,94	R 19,42	R 0,79	R 1,60	R 140 597 821,36	R 20,94
2039	4000	R0,00	R 9 368 523,86	R 30 701 076,99	R 1 223 864,50	R 2 467 515,69	R 43 760 981,03	R 29,97	R 6,42	R 21,03	R 0,84	R 1,69	R 156 747 160,39	R 22,76
	30660000						R 475 105 131,97	R 15,50					R 1 452 101 593,17	R 12,81

Paradyskloof WTW		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	4,03
Labour	R	1,39
Energy	R	1,33
Chemicals	R	0,44
Maintenance	R	0,45
Unit Cost	R	8,62
Check	R	8,62
Stellenbosch DPR Plant		
Amortized Capital Cost	R	-
Labour	R	3,31
Energy	R	10,63
Chemicals	R	0,52
Maintenance	R	1,04
Unit Cost	R	15,50
Check	R	15,50
Total		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	4,03
Labour	R	2,28
Energy	R	4,20
Chemicals	R	0,58
Maintenance	R	0,73
Unit Cost	R	12,81
Check	R	12,81

Scenario B - 4,0ML/D (Procurement Model No.2)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	11307	R 5 320 565,84	R 3 092 008,15	R 3 120 000,00	R 2 075 627,05	R 968 189,28	R 1 353 186,84	R 15 929 577,15	R 3,86	R 0,75	R 0,76	R 0,50	R 0,23	R 0,33
2020	11600	R 5 320 565,84	R 3 612 596,05	R 3 369 600,00	R 2 303 934,77	R 1 047 937,71	R 1 427 612,11	R 17 082 246,48	R 4,03	R 0,85	R 0,80	R 0,54	R 0,25	R 0,34
2021	11901	R 5 320 565,84	R 4 220 200,07	R 3 639 168,00	R 2 557 405,63	R 1 134 254,90	R 1 506 130,78	R 18 377 725,22	R 4,23	R 0,97	R 0,84	R 0,59	R 0,26	R 0,35
2022	12210	R 5 320 565,84	R 4 929 271,42	R 3 930 301,44	R 2 838 817,23	R 1 227 681,93	R 1 588 967,97	R 19 835 605,83	R 4,45	R 1,11	R 0,88	R 0,64	R 0,28	R 0,36
2023	12527	R 5 320 565,84	R 5 756 645,75	R 4 244 725,56	R 3 151 254,13	R 1 328 804,40	R 1 676 361,21	R 21 478 356,88	R 4,70	R 1,26	R 0,93	R 0,69	R 0,29	R 0,37
2024	12852	R 5 320 565,84	R 6 721 934,23	R 4 584 303,60	R 3 498 141,76	R 1 438 256,20	R 1 768 561,08	R 23 331 762,71	R 4,97	R 1,43	R 0,98	R 0,75	R 0,31	R 0,38
2025	13185	R 5 320 565,84	R 7 847 978,56	R 4 951 047,89	R 3 883 284,20	R 1 556 723,39	R 1 865 831,94	R 25 425 431,82	R 5,28	R 1,63	R 1,03	R 0,81	R 0,32	R 0,39
2026	13527	R 5 320 565,84	R 9 161 380,09	R 5 347 131,72	R 4 310 906,00	R 1 684 948,57	R 1 968 452,69	R 27 793 384,90	R 5,63	R 1,86	R 1,08	R 0,87	R 0,34	R 0,40
2027	13878	R 5 320 565,84	R 10 693 115,24	R 5 774 902,26	R 4 785 698,73	R 1 823 735,47	R 2 076 717,59	R 30 474 735,13	R 6,02	R 2,11	R 1,14	R 0,94	R 0,36	R 0,41
2028	14238	R 5 320 565,84	R 12 479 251,24	R 6 236 894,44	R 5 312 872,63	R 1 973 954,06	R 2 190 937,06	R 33 514 475,27	R 6,45	R 2,40	R 1,20	R 1,02	R 0,38	R 0,42
2029	14608	R 5 320 565,84	R 14 561 778,35	R 6 735 845,99	R 5 898 214,01	R 2 136 545,96	R 2 311 438,60	R 36 964 388,74	R 6,93	R 2,73	R 1,26	R 1,11	R 0,40	R 0,43
2030	14987	R 5 320 565,84	R 16 989 577,57	R 7 274 713,67	R 6 548 148,96	R 2 312 530,32	R 2 438 567,72	R 40 884 104,08	R 7,47	R 3,11	R 1,33	R 1,20	R 0,42	R 0,45
2031	15375	R 5 320 565,84	R 19 819 545,77	R 7 856 690,76	R 7 269 814,21	R 2 503 010,27	R 2 572 688,94	R 45 342 315,80	R 8,08	R 3,53	R 1,40	R 1,30	R 0,45	R 0,46
2032	15774	R 5 320 565,84	R 23 117 903,74	R 8 485 226,03	R 8 071 135,68	R 2 709 179,80	R 2 714 186,83	R 50 418 197,92	R 8,76	R 4,02	R 1,47	R 1,40	R 0,47	R 0,47
2033	16183	R 5 320 565,84	R 26 961 716,88	R 9 164 044,11	R 8 960 915,87	R 2 932 331,23	R 2 863 467,11	R 56 203 041,04	R 9,51	R 4,56	R 1,55	R 1,52	R 0,50	R 0,48
2034	16603	R 5 320 565,84	R 31 440 662,81	R 9 897 167,64	R 9 948 930,86	R 3 173 863,33	R 3 020 957,80	R 62 802 148,28	R 10,36	R 5,19	R 1,63	R 1,64	R 0,52	R 0,50
2035	17034	R 5 320 565,84	R 36 659 086,05	R 10 688 941,05	R 11 046 038,06	R 3 435 290,11	R 3 187 110,48	R 70 337 031,58	R 11,31	R 5,90	R 1,72	R 1,78	R 0,55	R 0,51
2036	17476	R 5 320 565,84	R 42 738 386,15	R 11 544 056,33	R 12 264 295,88	R 3 718 250,25	R 3 362 401,56	R 78 947 956,01	R 12,38	R 6,70	R 1,81	R 1,92	R 0,58	R 0,53
2037	17929	R 5 320 565,84	R 49 819 793,20	R 12 467 580,84	R 13 617 096,69	R 4 024 517,43	R 3 547 333,64	R 88 796 887,64	R 13,57	R 7,61	R 1,91	R 2,08	R 0,61	R 0,54
2038	18394	R 5 320 565,84	R 58 067 593,40	R 13 464 987,30	R 15 119 314,43	R 4 356 011,41	R 3 742 436,99	R 100 070 909,38	R 14,91	R 8,65	R 2,01	R 2,25	R 0,65	R 0,56
2039	18871	R 5 320 565,84	R 67 672 877,43	R 14 542 186,29	R 16 787 468,67	R 4 714 810,10	R 3 948 271,03	R 112 986 179,36	R 16,40	R 9,82	R 2,11	R 2,44	R 0,68	R 0,57
	113318373							R 976 996 461,21	R 8,62					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs: Annual Cost Rands	Combined Costs: Unit Cost R/kl
2019	4000	R13 366 998,69	R 2 010 000,00	R 6 254 443,43	R 419 453,81	R 845 689,09	R 22 896 585,02	R 15,68	R 1,38	R 4,28	R 0,29	R 0,58	R 38 826 162,18	R 9,41
2020	4000	R13 366 998,69	R 2 170 800,00	R 6 772 311,35	R 442 523,77	R 892 201,99	R 23 644 835,80	R 16,20	R 1,49	R 4,64	R 0,30	R 0,61	R 40 727 082,28	R 9,62
2021	4000	R13 366 998,69	R 2 344 464,00	R 7 333 058,72	R 466 862,58	R 941 273,10	R 24 452 657,10	R 16,75	R 1,61	R 5,02	R 0,32	R 0,64	R 42 830 382,32	R 9,86
2022	4000	R13 366 998,69	R 2 532 021,12	R 7 940 235,99	R 492 540,02	R 993 043,12	R 25 324 838,94	R 17,35	R 1,73	R 5,44	R 0,34	R 0,68	R 45 160 444,77	R 10,13
2023	4000	R13 366 998,69	R 2 734 582,81	R 8 597 687,53	R 519 629,72	R 1 047 660,50	R 26 266 559,24	R 17,99	R 1,87	R 5,89	R 0,36	R 0,72	R 47 744 916,12	R 10,44
2024	4000	R13 366 998,69	R 2 953 349,43	R 9 309 576,05	R 548 209,36	R 1 105 281,82	R 27 283 415,36	R 18,69	R 2,02	R 6,38	R 0,38	R 0,76	R 50 615 178,06	R 10,79
2025	4000	R13 366 998,69	R 3 189 617,39	R 10 080 408,95	R 578 360,87	R 1 166 072,32	R 28 381 458,22	R 19,44	R 2,18	R 6,90	R 0,40	R 0,80	R 53 806 890,04	R 11,18
2026	4000	R13 366 998,69	R 3 444 786,78	R 10 915 066,81	R 610 170,72	R 1 230 206,30	R 29 567 229,30	R 20,25	R 2,36	R 7,48	R 0,42	R 0,84	R 57 360 614,21	R 11,62
2027	4000	R13 366 998,69	R 3 720 369,72	R 11 818 834,34	R 643 730,11	R 1 297 867,65	R 30 847 800,51	R 21,13	R 2,55	R 8,10	R 0,44	R 0,89	R 61 322 535,64	R 12,11
2028	4000	R13 366 998,69	R 4 017 999,30	R 12 797 433,83	R 679 135,26	R 1 369 250,37	R 32 230 817,45	R 22,08	R 2,75	R 8,77	R 0,47	R 0,94	R 65 745 292,72	R 12,65
2029	4000	R13 366 998,69	R 4 339 439,24	R 13 857 061,35	R 716 487,70	R 1 444 559,14	R 33 724 546,12	R 23,10	R 2,97	R 9,49	R 0,49	R 0,99	R 70 688 934,86	R 13,26
2030	4000	R13 366 998,69	R 4 686 594,38	R 15 004 426,03	R 755 894,53	R 1 524 009,89	R 35 337 923,52	R 24,20	R 3,21	R 10,28	R 0,52	R 1,04	R 76 222 027,60	R 13,93
2031	4000	R13 366 998,69	R 5 061 521,93	R 16 246 792,50	R 797 468,72	R 1 607 830,44	R 37 080 612,29	R 25,40	R 3,47	R 11,13	R 0,55	R 1,10	R 82 422 928,08	R 14,69
2032	4000	R13 366 998,69	R 5 466 443,69	R 17 592 026,92	R 841 329,50	R 1 696 261,11	R 38 963 059,92	R 26,69	R 3,74	R 12,05	R 0,58	R 1,16	R 89 381 257,84	R 15,52
2033	4000	R13 366 998,69	R 5 903 759,18	R 19 048 646,75	R 887 602,63	R 1 789 555,47	R 40 996 562,73	R 28,08	R 4,04	R 13,05	R 0,61	R 1,23	R 97 199 603,76	R 16,46
2034	4000	R13 366 998,69	R 6 376 059,92	R 20 625 874,70	R 936 420,77	R 1 887 981,02	R 43 193 335,11	R 29,58	R 4,37	R 14,13	R 0,64	R 1,29	R 105 995 483,39	R 17,49
2035	4000	R13 366 998,69	R 6 886 144,71	R 22 333 697,13	R 987 923,91	R 1 991 819,98	R 45 566 584,42	R 31,21	R 4,72	R 15,30	R 0,68	R 1,36	R 115 903 616,01	R 18,64
2036	4000	R13 366 998,69	R 7 437 036,29	R 24 182 927,25	R 1 042 259,73	R 2 101 370,08	R 48 130 592,04	R 32,97	R 5,09	R 16,56	R 0,71	R 1,44	R 127 078 548,05	R 19,92
2037	4000	R13 366 998,69	R 8 031 999,19	R 26 185 273,63	R 1 099 584,01	R 2 216 945,43	R 50 900 800,96	R 34,86	R 5,50	R 17,94	R 0,75	R 1,52	R 139 697 688,59	R 21,35
2038	4000	R13 366 998,69	R 8 674 559,13	R 28 353 414,28	R 1 160 061,14	R 2 338 877,43	R 53 893 910,67	R 36,91	R 5,94	R 19,42	R 0,79	R 1,60	R 153 964 820,05	R 22,93
2039	4000	R13 366 998,69	R 9 368 523,86	R 30 701 076,99	R 1 223 864,50	R 2 467 515,69	R 57 127 979,72	R 39,13	R 6,42	R 21,03	R 0,84	R 1,69	R 170 114 159,08	R 24,70
	30660000						R 755 812 104,44	R 24,65					R 1 732 808 565,65	R 15,29

Paradyskloof WTW		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	4,03
Labour	R	1,39
Energy	R	1,33
Chemicals	R	0,44
Maintenance	R	0,45
Unit Cost	R	8,62
Check	R	8,62
Stellenbosch DPR Plant		
Amortized Capital Cost	R	9,16
Labour	R	3,31
Energy	R	10,63
Chemicals	R	0,52
Maintenance	R	1,04
Unit Cost	R	24,65
Check	R	24,65
Total		
Amortized Capital Cost	R	3,46
Raw Water Tariffs	R	4,03
Labour	R	2,28
Energy	R	4,20
Chemicals	R	0,58
Maintenance	R	0,73
Unit Cost	R	15,29
Check	R	15,29

Scenario B - 6,667ML/D (Procurement Model No.1)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	11307	R 5 320 565,84	R 1 963 462,30	R 3 120 000,00	R 2 075 627,05	R 968 189,28	R 1 353 186,84	R 14 801 031,30	R 3,59	R 0,48	R 0,76	R 0,50	R 0,23	R 0,33
2020	11600	R 5 320 565,84	R 2 344 929,48	R 3 369 600,00	R 2 303 934,77	R 1 047 937,71	R 1 427 612,11	R 15 814 579,90	R 3,74	R 0,55	R 0,80	R 0,54	R 0,25	R 0,34
2021	11901	R 5 320 565,84	R 2 795 725,73	R 3 639 168,00	R 2 557 405,63	R 1 134 254,90	R 1 506 130,78	R 16 953 250,88	R 3,90	R 0,64	R 0,84	R 0,59	R 0,26	R 0,35
2022	12210	R 5 320 565,84	R 3 328 027,26	R 3 930 301,44	R 2 838 817,23	R 1 227 681,93	R 1 588 967,97	R 18 234 361,67	R 4,09	R 0,75	R 0,88	R 0,64	R 0,28	R 0,36
2023	12527	R 5 320 565,84	R 3 956 100,53	R 4 244 725,56	R 3 151 254,13	R 1 328 804,40	R 1 676 361,21	R 19 677 811,66	R 4,30	R 0,87	R 0,93	R 0,69	R 0,29	R 0,37
2024	12852	R 5 320 565,84	R 4 696 655,21	R 4 584 303,60	R 3 498 141,76	R 1 438 256,20	R 1 768 561,08	R 21 306 483,69	R 4,54	R 1,00	R 0,98	R 0,75	R 0,31	R 0,38
2025	13185	R 5 320 565,84	R 5 569 256,09	R 4 951 047,89	R 3 883 284,20	R 1 556 723,39	R 1 865 831,94	R 23 146 709,34	R 4,81	R 1,16	R 1,03	R 0,81	R 0,32	R 0,39
2026	13527	R 5 320 565,84	R 6 596 803,49	R 5 347 131,72	R 4 310 906,00	R 1 684 948,57	R 1 968 452,69	R 25 228 808,31	R 5,11	R 1,34	R 1,08	R 0,87	R 0,34	R 0,40
2027	13878	R 5 320 565,84	R 7 806 093,71	R 5 774 902,26	R 4 785 698,73	R 1 823 735,47	R 2 076 717,59	R 27 587 713,60	R 5,45	R 1,54	R 1,14	R 0,94	R 0,36	R 0,41
2028	14238	R 5 320 565,84	R 9 228 472,54	R 6 236 894,44	R 5 312 872,63	R 1 973 954,06	R 2 190 937,06	R 30 263 696,57	R 5,82	R 1,78	R 1,20	R 1,02	R 0,38	R 0,42
2029	14608	R 5 320 565,84	R 10 900 597,28	R 6 735 845,99	R 5 898 214,01	R 2 136 545,96	R 2 311 438,60	R 33 303 207,67	R 6,25	R 2,04	R 1,26	R 1,11	R 0,40	R 0,43
2030	14987	R 5 320 565,84	R 12 865 325,07	R 7 274 713,67	R 6 548 148,96	R 2 312 530,32	R 2 438 567,72	R 36 759 851,58	R 6,72	R 2,35	R 1,33	R 1,20	R 0,42	R 0,45
2031	15375	R 5 320 565,84	R 15 172 748,32	R 7 856 690,76	R 7 269 814,21	R 2 503 010,27	R 2 572 688,94	R 40 695 518,35	R 7,25	R 2,70	R 1,40	R 1,30	R 0,45	R 0,46
2032	15774	R 5 320 565,84	R 17 881 401,46	R 8 485 226,03	R 8 071 135,68	R 2 709 179,80	R 2 714 186,83	R 45 181 695,64	R 7,85	R 3,11	R 1,47	R 1,40	R 0,47	R 0,47
2033	16183	R 5 320 565,84	R 21 059 667,06	R 9 164 044,11	R 8 960 915,87	R 2 932 331,23	R 2 863 467,11	R 50 300 991,21	R 8,52	R 3,57	R 1,55	R 1,52	R 0,50	R 0,48
2034	16603	R 5 320 565,84	R 24 787 414,10	R 9 897 167,64	R 9 948 930,86	R 3 173 863,33	R 3 020 957,80	R 56 148 899,57	R 9,27	R 4,09	R 1,63	R 1,64	R 0,52	R 0,50
2035	17034	R 5 320 565,84	R 29 157 906,45	R 10 688 941,05	R 11 046 038,06	R 3 435 290,11	R 3 187 110,48	R 62 835 851,98	R 10,11	R 4,69	R 1,72	R 1,78	R 0,55	R 0,51
2036	17476	R 5 320 565,84	R 34 280 025,72	R 11 544 056,33	R 12 264 295,88	R 3 718 250,25	R 3 362 401,56	R 70 489 595,57	R 11,05	R 5,37	R 1,81	R 1,92	R 0,58	R 0,53
2037	17929	R 5 320 565,84	R 40 280 860,11	R 12 467 580,84	R 13 617 096,69	R 4 024 517,43	R 3 547 333,64	R 79 257 954,55	R 12,11	R 6,16	R 1,91	R 2,08	R 0,61	R 0,54
2038	18394	R 5 320 565,84	R 47 308 719,04	R 13 464 987,30	R 15 119 314,43	R 4 356 011,41	R 3 742 436,99	R 89 312 035,02	R 13,30	R 7,05	R 2,01	R 2,25	R 0,65	R 0,56
2039	18871	R 5 320 565,84	R 55 536 643,08	R 14 542 186,29	R 16 787 468,67	R 4 714 810,10	R 3 948 271,03	R 100 849 945,01	R 14,64	R 8,06	R 2,11	R 2,44	R 0,68	R 0,57
	113318373							R 878 149 993,10	R 7,75					

Stellenbosch DPR Plant

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs Annual Cost Rands	Combined Costs Unit Cost R/kl
2019	6667	R0,00	R 2 010 000,00	R 10 503 439,52	R 699 121,51	R 1 333 000,03	R 14 545 561,06	R 5,98	R 0,83	R 4,32	R 0,29	R 0,55	R 29 346 592,36	R 7,11
2020	6667	R0,00	R 2 170 800,00	R 11 373 124,31	R 737 573,19	R 1 406 315,04	R 15 687 812,54	R 6,45	R 0,89	R 4,67	R 0,30	R 0,58	R 31 502 392,44	R 7,44
2021	6667	R0,00	R 2 344 464,00	R 12 314 819,00	R 778 139,72	R 1 483 662,36	R 16 921 085,08	R 6,95	R 0,96	R 5,06	R 0,32	R 0,61	R 33 874 335,96	R 7,80
2022	6667	R0,00	R 2 532 021,12	R 13 334 486,02	R 820 937,40	R 1 565 263,79	R 18 252 708,33	R 7,50	R 1,04	R 5,48	R 0,34	R 0,64	R 36 487 070,00	R 8,19
2023	6667	R0,00	R 2 734 582,81	R 14 438 581,46	R 866 088,96	R 1 651 353,30	R 19 690 606,53	R 8,09	R 1,12	R 5,93	R 0,36	R 0,68	R 39 368 418,19	R 8,61
2024	6667	R0,00	R 2 953 349,43	R 15 634 096,00	R 913 723,85	R 1 742 177,73	R 21 243 347,02	R 8,73	R 1,21	R 6,42	R 0,38	R 0,72	R 42 549 830,71	R 9,07
2025	6667	R0,00	R 3 189 617,39	R 16 928 599,15	R 963 978,66	R 1 837 997,51	R 22 920 192,71	R 9,42	R 1,31	R 6,96	R 0,40	R 0,76	R 46 066 902,06	R 9,57
2026	6667	R0,00	R 3 444 786,78	R 18 330 287,16	R 1 016 997,49	R 1 939 087,37	R 24 731 158,80	R 10,16	R 1,42	R 7,53	R 0,42	R 0,80	R 49 959 967,11	R 10,12
2027	6667	R0,00	R 3 720 369,72	R 19 848 034,94	R 1 072 932,35	R 2 045 737,18	R 26 687 074,19	R 10,97	R 1,53	R 8,16	R 0,44	R 0,84	R 54 274 787,79	R 10,71
2028	6667	R0,00	R 4 017 999,30	R 21 491 452,23	R 1 131 943,63	R 2 158 252,72	R 28 799 647,88	R 11,83	R 1,65	R 8,83	R 0,47	R 0,89	R 59 063 344,45	R 11,37
2029	6667	R0,00	R 4 339 439,24	R 23 270 944,48	R 1 194 200,53	R 2 276 956,62	R 31 081 540,87	R 12,77	R 1,78	R 9,56	R 0,49	R 0,94	R 64 384 748,54	R 12,08
2030	6667	R0,00	R 4 686 594,38	R 25 197 778,68	R 1 259 880,66	R 2 402 189,23	R 33 546 443,86	R 13,79	R 1,93	R 10,35	R 0,52	R 0,99	R 70 306 295,44	R 12,85
2031	6667	R0,00	R 5 061 521,93	R 27 284 154,75	R 1 329 175,05	R 2 534 309,64	R 36 209 161,38	R 14,88	R 2,08	R 11,21	R 0,55	R 1,04	R 76 904 679,73	R 13,70
2032	6667	R0,00	R 5 466 443,69	R 29 543 282,77	R 1 402 279,67	R 2 673 696,67	R 39 085 702,80	R 16,06	R 2,25	R 12,14	R 0,58	R 1,10	R 84 267 398,44	R 14,64
2033	6667	R0,00	R 5 903 759,18	R 31 989 466,58	R 1 479 405,05	R 2 820 749,99	R 42 193 380,81	R 17,34	R 2,43	R 13,15	R 0,61	R 1,16	R 92 494 372,02	R 15,66
2034	6667	R0,00	R 6 376 059,92	R 34 638 194,41	R 1 560 772,33	R 2 975 891,24	R 45 550 917,90	R 18,72	R 2,62	R 14,23	R 0,64	R 1,22	R 101 699 817,48	R 16,78
2035	6667	R0,00	R 6 886 144,71	R 37 506 236,91	R 1 646 614,81	R 3 139 565,26	R 49 178 561,69	R 20,21	R 2,83	R 15,41	R 0,68	R 1,29	R 112 014 413,68	R 18,02
2036	6667	R0,00	R 7 437 036,29	R 40 611 753,33	R 1 737 178,63	R 3 312 241,35	R 53 098 209,59	R 21,82	R 3,06	R 16,69	R 0,71	R 1,36	R 123 587 805,16	R 19,38
2037	6667	R0,00	R 8 031 999,19	R 43 974 406,50	R 1 832 723,45	R 3 494 414,62	R 57 333 543,77	R 23,56	R 3,30	R 18,07	R 0,75	R 1,44	R 136 591 498,31	R 20,87
2038	6667	R0,00	R 8 674 559,13	R 47 615 487,36	R 1 933 523,24	R 3 686 607,43	R 61 910 177,15	R 25,44	R 3,56	R 19,57	R 0,79	R 1,51	R 151 222 212,18	R 22,52
2039	6667	R0,00	R 9 368 523,86	R 51 558 049,71	R 2 039 867,02	R 3 889 370,83	R 66 855 811,42	R 27,47	R 3,85	R 21,19	R 0,84	R 1,60	R 167 705 756,43	R 24,35
	51102555						R 725 522 645,39	R 14,20					R 1 603 672 638,49	R 14,15

Paradyskloof WTW		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	3,15
Labour	R	1,39
Energy	R	1,33
Chemicals	R	0,44
Maintenance	R	0,45
Unit Cost	R	7,75
Check	R	7,75
Stellenbosch DPR Plant		
Amortized Capital Cost	R	-
Labour	R	1,98
Energy	R	10,71
Chemicals	R	0,52
Maintenance	R	0,99
Unit Cost	R	14,20
Check	R	14,20
Total		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	3,15
Labour	R	2,28
Energy	R	6,16
Chemicals	R	0,68
Maintenance	R	0,90
Unit Cost	R	14,15
Check	R	14,15

Scenario B - 6,667ML/D (Procurement Model No.2)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	11307	R 5 320 565,84	R 1 963 462,30	R 3 120 000,00	R 2 075 627,05	R 968 189,28	R 1 353 186,84	R 14 801 031,30	R 3,59	R 0,48	R 0,76	R 0,50	R 0,23	R 0,33
2020	11600	R 5 320 565,84	R 2 344 929,48	R 3 369 600,00	R 2 303 934,77	R 1 047 937,71	R 1 427 612,11	R 15 814 579,90	R 3,74	R 0,55	R 0,80	R 0,54	R 0,25	R 0,34
2021	11901	R 5 320 565,84	R 2 795 725,73	R 3 639 168,00	R 2 557 405,63	R 1 134 254,90	R 1 506 130,78	R 16 953 250,88	R 3,90	R 0,64	R 0,84	R 0,59	R 0,26	R 0,35
2022	12210	R 5 320 565,84	R 3 328 027,26	R 3 930 301,44	R 2 838 817,23	R 1 227 681,93	R 1 588 967,97	R 18 234 361,67	R 4,09	R 0,75	R 0,88	R 0,64	R 0,28	R 0,36
2023	12527	R 5 320 565,84	R 3 956 100,53	R 4 244 725,56	R 3 151 254,13	R 1 328 804,40	R 1 676 361,21	R 19 677 811,66	R 4,30	R 0,87	R 0,93	R 0,69	R 0,29	R 0,37
2024	12852	R 5 320 565,84	R 4 696 655,21	R 4 584 303,60	R 3 498 141,76	R 1 438 256,20	R 1 768 561,08	R 21 306 483,69	R 4,54	R 1,00	R 0,98	R 0,75	R 0,31	R 0,38
2025	13185	R 5 320 565,84	R 5 569 256,09	R 4 951 047,89	R 3 883 284,20	R 1 556 723,39	R 1 865 831,94	R 23 146 709,34	R 4,81	R 1,16	R 1,03	R 0,81	R 0,32	R 0,39
2026	13527	R 5 320 565,84	R 6 596 803,49	R 5 347 131,72	R 4 310 906,00	R 1 684 948,57	R 1 968 452,69	R 25 228 808,31	R 5,11	R 1,34	R 1,08	R 0,87	R 0,34	R 0,40
2027	13878	R 5 320 565,84	R 7 806 093,71	R 5 774 902,26	R 4 785 698,73	R 1 823 735,47	R 2 076 717,59	R 27 587 713,60	R 5,45	R 1,54	R 1,14	R 0,94	R 0,36	R 0,41
2028	14238	R 5 320 565,84	R 9 228 472,54	R 6 236 894,44	R 5 312 872,63	R 1 973 954,06	R 2 190 937,06	R 30 263 696,57	R 5,82	R 1,78	R 1,20	R 1,02	R 0,38	R 0,42
2029	14608	R 5 320 565,84	R 10 900 597,28	R 6 735 845,99	R 5 898 214,01	R 2 136 545,96	R 2 311 438,60	R 33 303 207,67	R 6,25	R 2,04	R 1,26	R 1,11	R 0,40	R 0,43
2030	14987	R 5 320 565,84	R 12 865 325,07	R 7 274 713,67	R 6 548 148,96	R 2 312 530,32	R 2 438 567,72	R 36 759 851,58	R 6,72	R 2,35	R 1,33	R 1,20	R 0,42	R 0,45
2031	15375	R 5 320 565,84	R 15 172 748,32	R 7 856 690,76	R 7 269 814,21	R 2 503 010,27	R 2 572 688,94	R 40 695 518,35	R 7,25	R 2,70	R 1,40	R 1,30	R 0,45	R 0,46
2032	15774	R 5 320 565,84	R 17 881 401,46	R 8 485 226,03	R 8 071 135,68	R 2 709 179,80	R 2 714 186,83	R 45 181 695,64	R 7,85	R 3,11	R 1,47	R 1,40	R 0,47	R 0,47
2033	16183	R 5 320 565,84	R 21 059 667,06	R 9 164 044,11	R 8 960 915,87	R 2 932 331,23	R 2 863 467,11	R 50 300 991,21	R 8,52	R 3,57	R 1,55	R 1,52	R 0,50	R 0,48
2034	16603	R 5 320 565,84	R 24 787 414,10	R 9 897 167,64	R 9 948 930,86	R 3 173 863,33	R 3 020 957,80	R 56 148 899,57	R 9,27	R 4,09	R 1,63	R 1,64	R 0,52	R 0,50
2035	17034	R 5 320 565,84	R 29 157 906,45	R 10 688 941,05	R 11 046 038,06	R 3 435 290,11	R 3 187 110,48	R 62 835 851,98	R 10,11	R 4,69	R 1,72	R 1,78	R 0,55	R 0,51
2036	17476	R 5 320 565,84	R 34 280 025,72	R 11 544 056,33	R 12 264 295,88	R 3 718 250,25	R 3 362 401,56	R 70 489 595,57	R 11,05	R 5,37	R 1,81	R 1,92	R 0,58	R 0,53
2037	17929	R 5 320 565,84	R 40 280 860,11	R 12 467 580,84	R 13 617 096,69	R 4 024 517,43	R 3 547 333,64	R 79 257 954,55	R 12,11	R 6,16	R 1,91	R 2,08	R 0,61	R 0,54
2038	18394	R 5 320 565,84	R 47 308 719,04	R 13 464 987,30	R 15 119 314,43	R 4 356 011,41	R 3 742 436,99	R 89 312 035,02	R 13,30	R 7,05	R 2,01	R 2,25	R 0,65	R 0,56
2039	18871	R 5 320 565,84	R 55 536 643,08	R 14 542 186,29	R 16 787 468,67	R 4 714 810,10	R 3 948 271,03	R 100 849 945,01	R 14,64	R 8,06	R 2,11	R 2,44	R 0,68	R 0,57
	113318373							R 878 149 993,10	R 7,75					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs Annual Cost Rands	Combined Costs Unit Cost R/kl
2019	6667	R21 069 456,65	R 2 010 000,00	R 10 503 439,52	R 699 121,51	R 1 333 000,03	R 35 615 017,71	R 14,64	R 0,83	R 4,32	R 0,29	R 0,55	R 50 416 049,01	R 12,22
2020	6667	R21 069 456,65	R 2 170 800,00	R 11 373 124,31	R 737 573,19	R 1 406 315,04	R 36 757 269,18	R 15,10	R 0,89	R 4,67	R 0,30	R 0,58	R 52 571 849,08	R 12,42
2021	6667	R21 069 456,65	R 2 344 464,00	R 12 314 819,00	R 778 139,72	R 1 483 662,36	R 37 990 541,73	R 15,61	R 0,96	R 5,06	R 0,32	R 0,61	R 54 943 792,61	R 12,65
2022	6667	R21 069 456,65	R 2 532 021,12	R 13 334 486,02	R 820 937,40	R 1 565 263,79	R 39 322 164,98	R 16,16	R 1,04	R 5,48	R 0,34	R 0,64	R 57 556 526,65	R 12,91
2023	6667	R21 069 456,65	R 2 734 582,81	R 14 438 581,46	R 866 088,96	R 1 651 353,30	R 40 760 063,17	R 16,75	R 1,12	R 5,93	R 0,36	R 0,68	R 60 437 874,83	R 13,22
2024	6667	R21 069 456,65	R 2 953 349,43	R 15 634 096,00	R 913 723,85	R 1 742 177,73	R 42 312 803,67	R 17,39	R 1,21	R 6,42	R 0,38	R 0,72	R 63 619 287,35	R 13,56
2025	6667	R21 069 456,65	R 3 189 617,39	R 16 928 599,15	R 963 978,66	R 1 837 997,51	R 43 989 649,36	R 18,08	R 1,31	R 6,96	R 0,40	R 0,76	R 67 136 358,70	R 13,95
2026	6667	R21 069 456,65	R 3 444 786,78	R 18 330 287,16	R 1 016 997,49	R 1 939 087,37	R 45 800 615,45	R 18,82	R 1,42	R 7,53	R 0,42	R 0,80	R 71 029 423,75	R 14,39
2027	6667	R21 069 456,65	R 3 720 369,72	R 19 848 034,94	R 1 072 932,35	R 2 045 737,18	R 47 756 530,83	R 19,62	R 1,53	R 8,16	R 0,44	R 0,84	R 75 344 244,43	R 14,87
2028	6667	R21 069 456,65	R 4 017 999,30	R 21 491 452,23	R 1 131 943,63	R 2 158 252,72	R 49 869 104,53	R 20,49	R 1,65	R 8,83	R 0,47	R 0,89	R 80 132 801,10	R 15,42
2029	6667	R21 069 456,65	R 4 339 439,24	R 23 270 944,48	R 1 194 200,53	R 2 276 956,62	R 52 150 997,52	R 21,43	R 1,78	R 9,56	R 0,49	R 0,94	R 85 454 205,19	R 16,03
2030	6667	R21 069 456,65	R 4 686 594,38	R 25 197 778,68	R 1 259 881,56	R 2 402 189,23	R 54 615 900,50	R 22,44	R 1,93	R 10,35	R 0,52	R 0,99	R 91 375 752,09	R 16,70
2031	6667	R21 069 456,65	R 5 061 521,93	R 27 284 154,75	R 1 329 175,05	R 2 534 309,64	R 57 278 618,02	R 23,54	R 2,08	R 11,21	R 0,55	R 1,04	R 97 974 136,37	R 17,46
2032	6667	R21 069 456,65	R 5 466 443,69	R 29 543 282,77	R 1 402 279,67	R 2 673 696,67	R 60 155 159,45	R 24,72	R 2,25	R 12,14	R 0,58	R 1,10	R 105 336 855,09	R 18,30
2033	6667	R21 069 456,65	R 5 903 759,18	R 31 989 466,58	R 1 479 405,05	R 2 820 749,99	R 63 262 837,46	R 26,00	R 2,43	R 13,15	R 0,61	R 1,16	R 113 563 828,67	R 19,23
2034	6667	R21 069 456,65	R 6 376 059,92	R 34 638 194,41	R 1 560 772,33	R 2 975 891,24	R 66 620 374,55	R 27,38	R 2,62	R 14,23	R 0,64	R 1,22	R 122 769 274,12	R 20,26
2035	6667	R21 069 456,65	R 6 886 144,71	R 37 506 236,91	R 1 646 614,81	R 3 139 565,26	R 70 248 018,34	R 28,87	R 2,83	R 15,41	R 0,68	R 1,29	R 133 083 870,32	R 21,41
2036	6667	R21 069 456,65	R 7 437 036,29	R 40 611 753,33	R 1 737 178,63	R 3 312 241,35	R 74 167 666,23	R 30,48	R 3,06	R 16,69	R 0,71	R 1,36	R 144 657 261,81	R 22,68
2037	6667	R21 069 456,65	R 8 031 999,19	R 43 974 406,50	R 1 832 723,45	R 3 494 414,62	R 78 403 000,41	R 32,22	R 3,30	R 18,07	R 0,75	R 1,44	R 157 660 954,96	R 24,09
2038	6667	R21 069 456,65	R 8 674 559,13	R 47 615 487,36	R 1 933 523,24	R 3 686 607,43	R 82 979 633,80	R 34,10	R 3,56	R 19,57	R 0,79	R 1,51	R 172 291 668,82	R 25,66
2039	6667	R21 069 456,65	R 9 368 523,86	R 51 558 049,71	R 2 039 867,02	R 3 889 370,83	R 87 925 268,07	R 36,13	R 3,85	R 21,19	R 0,84	R 1,60	R 188 775 213,08	R 27,41
	51102555						R 1 167 981 234,94	R 22,86					R 2 046 131 228,04	R 18,06

Paradyskloof WTW		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	3,15
Labour	R	1,39
Energy	R	1,33
Chemicals	R	0,44
Maintenance	R	0,45
Unit Cost	R	7,75
Check	R	7,75
Stellenbosch DPR Plant		
Amortized Capital Cost	R	8,66
Labour	R	1,98
Energy	R	10,71
Chemicals	R	0,52
Maintenance	R	0,99
Unit Cost	R	22,86
Check	R	22,86
Total		
Amortized Capital Cost	R	4,89
Raw Water Tariffs	R	3,15
Labour	R	2,28
Energy	R	6,16
Chemicals	R	0,68
Maintenance	R	0,90
Unit Cost	R	18,06
Check	R	18,06

Scenario B - 10ML/D (Procurement Model No.1)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	11307	R 5 320 565,84	R 553 097,35	R 3 120 000,00	R 2 075 627,05	R 968 189,28	R 1 353 186,84	R 13 390 666,35	R 3,24	R 0,13	R 0,76	R 0,50	R 0,23	R 0,33
2020	11600	R 5 320 565,84	R 760 702,74	R 3 369 600,00	R 2 303 934,77	R 1 047 937,71	R 1 427 612,11	R 14 230 353,17	R 3,36	R 0,18	R 0,80	R 0,54	R 0,25	R 0,34
2021	11901	R 5 320 565,84	R 1 015 533,39	R 3 639 168,00	R 2 557 405,63	R 1 134 254,90	R 1 506 130,78	R 15 173 058,54	R 3,49	R 0,23	R 0,84	R 0,59	R 0,26	R 0,35
2022	12210	R 5 320 565,84	R 1 326 922,36	R 3 930 301,44	R 2 838 817,23	R 1 227 681,93	R 1 588 967,97	R 16 233 256,76	R 3,64	R 0,30	R 0,88	R 0,64	R 0,28	R 0,36
2023	12527	R 5 320 565,84	R 1 705 925,34	R 4 244 725,56	R 3 151 254,13	R 1 328 804,40	R 1 676 361,21	R 17 427 636,48	R 3,81	R 0,37	R 0,93	R 0,69	R 0,29	R 0,37
2024	12852	R 5 320 565,84	R 2 165 625,97	R 4 584 303,60	R 3 498 141,76	R 1 438 256,20	R 1 768 561,08	R 18 775 454,45	R 4,00	R 0,46	R 0,98	R 0,75	R 0,31	R 0,38
2025	13185	R 5 320 565,84	R 2 721 493,80	R 4 951 047,89	R 3 883 284,20	R 1 556 723,39	R 1 865 831,94	R 20 298 947,06	R 4,22	R 0,57	R 1,03	R 0,81	R 0,32	R 0,39
2026	13527	R 5 320 565,84	R 3 391 803,94	R 5 347 131,72	R 4 310 906,00	R 1 684 948,57	R 1 968 452,69	R 22 023 808,76	R 4,46	R 0,69	R 1,08	R 0,87	R 0,34	R 0,40
2027	13878	R 5 320 565,84	R 4 198 128,67	R 5 774 902,26	R 4 785 698,73	R 1 823 735,47	R 2 076 717,59	R 23 979 748,56	R 4,73	R 0,83	R 1,14	R 0,94	R 0,36	R 0,41
2028	14238	R 5 320 565,84	R 5 165 913,34	R 6 236 894,44	R 5 312 872,63	R 1 973 954,06	R 2 190 937,06	R 26 201 137,36	R 5,04	R 0,99	R 1,20	R 1,02	R 0,38	R 0,42
2029	14608	R 5 320 565,84	R 6 325 150,53	R 6 735 845,99	R 5 898 214,01	R 2 136 545,96	R 2 311 438,60	R 28 727 760,92	R 5,39	R 1,19	R 1,26	R 1,11	R 0,40	R 0,43
2030	14987	R 5 320 565,84	R 7 711 169,25	R 7 274 713,67	R 6 548 148,96	R 2 312 530,32	R 2 438 567,72	R 31 605 695,77	R 5,78	R 1,41	R 1,33	R 1,20	R 0,42	R 0,45
2031	15375	R 5 320 565,84	R 9 365 558,27	R 7 856 690,76	R 7 269 814,21	R 2 503 010,27	R 2 572 688,94	R 34 888 328,30	R 6,22	R 1,67	R 1,40	R 1,30	R 0,45	R 0,46
2032	15774	R 5 320 565,84	R 11 337 246,19	R 8 485 226,03	R 8 071 135,68	R 2 709 179,80	R 2 714 186,83	R 38 637 540,37	R 6,71	R 1,97	R 1,47	R 1,40	R 0,47	R 0,47
2033	16183	R 5 320 565,84	R 13 683 764,52	R 9 164 044,11	R 8 960 915,87	R 2 932 331,23	R 2 863 467,11	R 42 925 088,68	R 7,27	R 2,32	R 1,55	R 1,52	R 0,50	R 0,48
2034	16603	R 5 320 565,84	R 16 472 724,22	R 9 897 167,64	R 9 948 930,86	R 3 173 863,33	R 3 020 957,80	R 47 834 209,69	R 7,89	R 2,72	R 1,63	R 1,64	R 0,52	R 0,50
2035	17034	R 5 320 565,84	R 19 783 541,39	R 10 688 941,05	R 11 046 038,06	R 3 435 290,11	R 3 187 110,48	R 53 461 486,93	R 8,60	R 3,18	R 1,72	R 1,78	R 0,55	R 0,51
2036	17476	R 5 320 565,84	R 23 709 453,79	R 11 544 056,33	R 12 264 295,88	R 3 718 250,25	R 3 362 401,56	R 59 919 023,65	R 9,39	R 3,72	R 1,81	R 1,92	R 0,58	R 0,53
2037	17929	R 5 320 565,84	R 28 359 876,24	R 12 467 580,84	R 13 617 096,69	R 4 024 517,43	R 3 547 333,64	R 67 336 970,67	R 10,29	R 4,33	R 1,91	R 2,08	R 0,61	R 0,54
2038	18394	R 5 320 565,84	R 33 863 151,65	R 13 464 987,30	R 15 119 314,43	R 4 356 011,41	R 3 742 436,99	R 75 866 467,63	R 11,30	R 5,04	R 2,01	R 2,25	R 0,65	R 0,56
2039	18871	R 5 320 565,84	R 40 369 763,04	R 14 542 186,29	R 16 787 468,67	R 4 714 810,10	R 3 948 271,03	R 85 683 064,96	R 12,44	R 5,86	R 2,11	R 2,44	R 0,68	R 0,57
	113318373							R 754 619 705,05	R 6,66					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs: Annual Cost Rands	Combined Costs: Unit Cost R/kl
2019	10000	R0,00	R 2 730 000,00	R 15 142 408,96	R 1 048 629,83	R 1 908 280,37	R 20 829 319,16	R 5,71	R 0,75	R 4,15	R 0,29	R 0,52	R 34 219 985,52	R 8,29
2020	10000	R0,00	R 2 948 400,00	R 16 396 200,42	R 1 106 304,47	R 2 013 235,79	R 22 464 140,69	R 6,15	R 0,81	R 4,49	R 0,30	R 0,55	R 36 694 493,85	R 8,67
2021	10000	R0,00	R 3 184 272,00	R 17 753 805,82	R 1 167 151,22	R 2 123 963,76	R 24 229 192,80	R 6,64	R 0,87	R 4,86	R 0,32	R 0,58	R 39 402 251,33	R 9,07
2022	10000	R0,00	R 3 439 013,76	R 19 223 820,94	R 1 231 344,53	R 2 240 781,77	R 26 134 961,00	R 7,16	R 0,94	R 5,27	R 0,34	R 0,61	R 42 368 217,77	R 9,51
2023	10000	R0,00	R 3 714 134,86	R 20 815 553,31	R 1 299 068,48	R 2 364 024,76	R 28 192 781,42	R 7,72	R 1,02	R 5,70	R 0,36	R 0,65	R 45 620 417,90	R 9,98
2024	10000	R0,00	R 4 011 265,65	R 22 539 081,13	R 1 370 517,25	R 2 494 046,12	R 30 414 910,15	R 8,33	R 1,10	R 6,18	R 0,38	R 0,68	R 49 190 364,60	R 10,49
2025	10000	R0,00	R 4 332 166,90	R 24 405 317,05	R 1 445 895,70	R 2 631 218,66	R 32 814 598,31	R 8,99	R 1,19	R 6,69	R 0,40	R 0,72	R 53 113 545,37	R 11,04
2026	10000	R0,00	R 4 678 740,25	R 26 426 077,30	R 1 525 419,96	R 2 775 935,69	R 35 406 173,20	R 9,70	R 1,28	R 7,24	R 0,42	R 0,76	R 57 429 981,96	R 11,63
2027	10000	R0,00	R 5 053 039,47	R 28 614 156,50	R 1 609 318,06	R 2 928 612,15	R 38 205 126,18	R 10,47	R 1,38	R 7,84	R 0,44	R 0,80	R 62 184 874,74	R 12,28
2028	10000	R0,00	R 5 457 282,63	R 30 983 408,66	R 1 697 830,55	R 3 089 685,82	R 41 228 207,66	R 11,30	R 1,50	R 8,49	R 0,47	R 0,85	R 67 429 345,03	R 12,97
2029	10000	R0,00	R 5 893 865,24	R 33 548 834,89	R 1 791 211,24	R 3 259 618,54	R 44 493 529,91	R 12,19	R 1,61	R 9,19	R 0,49	R 0,89	R 73 221 290,83	R 13,73
2030	10000	R0,00	R 6 365 374,46	R 36 326 678,42	R 1 889 727,85	R 3 438 897,56	R 48 020 678,30	R 13,16	R 1,74	R 9,95	R 0,52	R 0,94	R 79 626 374,06	R 14,56
2031	10000	R0,00	R 6 874 604,42	R 39 334 527,40	R 1 993 662,88	R 3 628 036,92	R 51 830 831,62	R 14,20	R 1,88	R 10,78	R 0,55	R 0,99	R 86 719 159,92	R 15,45
2032	10000	R0,00	R 7 424 572,77	R 42 591 426,26	R 2 103 314,34	R 3 827 578,95	R 55 946 892,33	R 15,33	R 2,03	R 11,67	R 0,58	R 1,05	R 94 584 432,70	R 16,43
2033	10000	R0,00	R 8 018 538,59	R 46 117 996,36	R 2 218 996,63	R 4 038 095,80	R 60 393 627,38	R 16,55	R 2,20	R 12,64	R 0,61	R 1,11	R 103 318 716,06	R 17,49
2034	10000	R0,00	R 8 660 021,68	R 49 936 566,46	R 2 341 041,45	R 4 260 191,07	R 65 197 820,65	R 17,86	R 2,37	R 13,68	R 0,64	R 1,17	R 113 032 030,34	R 18,65
2035	10000	R0,00	R 9 352 823,42	R 54 071 314,16	R 2 469 798,70	R 4 494 501,57	R 70 388 437,88	R 19,28	R 2,56	R 14,81	R 0,68	R 1,23	R 123 849 924,80	R 19,92
2036	10000	R0,00	R 10 101 049,29	R 58 548 418,97	R 2 605 637,66	R 4 741 699,16	R 75 996 805,08	R 20,82	R 2,77	R 16,04	R 0,71	R 1,30	R 135 915 828,73	R 21,31
2037	10000	R0,00	R 10 909 133,23	R 63 396 228,06	R 2 748 947,73	R 5 002 492,61	R 82 056 801,64	R 22,48	R 2,99	R 17,37	R 0,75	R 1,37	R 149 393 772,31	R 22,83
2038	10000	R0,00	R 11 781 863,89	R 68 645 435,75	R 2 900 139,85	R 5 277 629,71	R 88 605 069,20	R 24,28	R 3,23	R 18,81	R 0,79	R 1,45	R 164 471 536,83	R 24,50
2039	10000	R0,00	R 12 724 413,00	R 74 329 277,83	R 3 059 647,55	R 5 567 899,34	R 95 681 237,72	R 26,21	R 3,49	R 20,36	R 0,84	R 1,53	R 181 364 302,68	R 26,33
	76650000						R 1 038 531 142,28	R 13,55					R 1 793 150 847,34	R 15,82

Paradyskloof WTW		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	2,06
Labour	R	1,39
Energy	R	1,33
Chemicals	R	0,44
Maintenance	R	0,45
Unit Cost	R	6,66
Check	R	6,66
Stellenbosch DPR Plant		
Amortized Capital Cost	R	-
Labour	R	1,80
Energy	R	10,30
Chemicals	R	0,52
Maintenance	R	0,94
Unit Cost	R	13,55
Check	R	13,55
Total		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	2,06
Labour	R	2,60
Energy	R	8,29
Chemicals	R	0,79
Maintenance	R	1,09
Unit Cost	R	15,82
Check	R	15,82

Scenario B - 10ML/D (Procurement Model No.2)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	11307	R 5 320 565,84	R 553 097,35	R 3 120 000,00	R 2 075 627,05	R 968 189,28	R 1 353 186,84	R 13 390 666,35	R 3,24	R 0,13	R 0,76	R 0,50	R 0,23	R 0,33
2020	11600	R 5 320 565,84	R 760 702,74	R 3 369 600,00	R 2 303 934,77	R 1 047 937,71	R 1 427 612,11	R 14 230 353,17	R 3,36	R 0,18	R 0,80	R 0,54	R 0,25	R 0,34
2021	11901	R 5 320 565,84	R 1 015 533,39	R 3 639 168,00	R 2 557 405,63	R 1 134 254,90	R 1 506 130,78	R 15 173 058,54	R 3,49	R 0,23	R 0,84	R 0,59	R 0,26	R 0,35
2022	12210	R 5 320 565,84	R 1 326 922,36	R 3 930 301,44	R 2 838 817,23	R 1 227 681,93	R 1 588 967,97	R 16 233 256,76	R 3,64	R 0,30	R 0,88	R 0,64	R 0,28	R 0,36
2023	12527	R 5 320 565,84	R 1 705 925,34	R 4 244 725,56	R 3 151 254,13	R 1 328 804,40	R 1 676 361,21	R 17 427 636,48	R 3,81	R 0,37	R 0,93	R 0,69	R 0,29	R 0,37
2024	12852	R 5 320 565,84	R 2 165 625,97	R 4 584 303,60	R 3 498 141,76	R 1 438 256,20	R 1 768 561,08	R 18 775 454,45	R 4,00	R 0,46	R 0,98	R 0,75	R 0,31	R 0,38
2025	13185	R 5 320 565,84	R 2 721 493,80	R 4 951 047,89	R 3 883 284,20	R 1 556 723,39	R 1 865 831,94	R 20 298 947,06	R 4,22	R 0,57	R 1,03	R 0,81	R 0,32	R 0,39
2026	13527	R 5 320 565,84	R 3 391 803,94	R 5 347 131,72	R 4 310 906,00	R 1 684 948,57	R 1 968 452,69	R 22 023 808,76	R 4,46	R 0,69	R 1,08	R 0,87	R 0,34	R 0,40
2027	13878	R 5 320 565,84	R 4 198 128,67	R 5 774 902,26	R 4 785 698,73	R 1 823 735,47	R 2 076 717,59	R 23 979 748,56	R 4,73	R 0,83	R 1,14	R 0,94	R 0,36	R 0,41
2028	14238	R 5 320 565,84	R 5 165 913,34	R 6 236 894,44	R 5 312 872,63	R 1 973 954,06	R 2 190 937,06	R 26 201 137,36	R 5,04	R 0,99	R 1,20	R 1,02	R 0,38	R 0,42
2029	14608	R 5 320 565,84	R 6 325 150,53	R 6 735 845,99	R 5 898 214,01	R 2 136 545,96	R 2 311 438,60	R 28 727 760,92	R 5,39	R 1,19	R 1,26	R 1,11	R 0,40	R 0,43
2030	14987	R 5 320 565,84	R 7 711 169,25	R 7 274 713,67	R 6 548 148,96	R 2 312 530,32	R 2 438 567,72	R 31 605 695,77	R 5,78	R 1,41	R 1,33	R 1,20	R 0,42	R 0,45
2031	15375	R 5 320 565,84	R 9 365 558,27	R 7 856 690,76	R 7 269 814,21	R 2 503 010,27	R 2 572 688,94	R 34 888 328,30	R 6,22	R 1,67	R 1,40	R 1,30	R 0,45	R 0,46
2032	15774	R 5 320 565,84	R 11 337 246,19	R 8 485 226,03	R 8 071 135,68	R 2 709 179,80	R 2 714 186,83	R 38 637 540,37	R 6,71	R 1,97	R 1,47	R 1,40	R 0,47	R 0,47
2033	16183	R 5 320 565,84	R 13 683 764,52	R 9 164 044,11	R 8 960 915,87	R 2 932 331,23	R 2 863 467,11	R 42 925 088,68	R 7,27	R 2,32	R 1,55	R 1,52	R 0,50	R 0,48
2034	16603	R 5 320 565,84	R 16 472 724,22	R 9 897 167,64	R 9 948 930,86	R 3 173 863,33	R 3 020 957,80	R 47 834 209,69	R 7,89	R 2,72	R 1,63	R 1,64	R 0,52	R 0,50
2035	17034	R 5 320 565,84	R 19 783 541,39	R 10 688 941,05	R 11 046 038,06	R 3 435 290,11	R 3 187 110,48	R 53 461 486,93	R 8,60	R 3,18	R 1,72	R 1,78	R 0,55	R 0,51
2036	17476	R 5 320 565,84	R 23 709 453,79	R 11 544 056,33	R 12 264 295,88	R 3 718 250,25	R 3 362 401,56	R 59 919 023,65	R 9,39	R 3,72	R 1,81	R 1,92	R 0,58	R 0,53
2037	17929	R 5 320 565,84	R 28 359 876,24	R 12 467 580,84	R 13 617 096,69	R 4 024 517,43	R 3 547 333,64	R 67 336 970,67	R 10,29	R 4,33	R 1,91	R 2,08	R 0,61	R 0,54
2038	18394	R 5 320 565,84	R 33 863 151,65	R 13 464 987,30	R 15 119 314,43	R 4 356 011,41	R 3 742 436,99	R 75 866 467,63	R 11,30	R 5,04	R 2,01	R 2,25	R 0,65	R 0,56
2039	18871	R 5 320 565,84	R 40 369 763,04	R 14 542 186,29	R 16 787 468,67	R 4 714 810,10	R 3 948 271,03	R 85 683 064,96	R 12,44	R 5,86	R 2,11	R 2,44	R 0,68	R 0,57
	113318373							R 754 619 705,05	R 6,66					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs Annual Cost Rands	Combined Costs Unit Cost R/kl
2019	10000	R30 162 362,71	R 2 730 000,00	R 15 142 408,96	R 1 048 629,83	R 1 908 280,37	R 50 991 681,88	R 13,97	R 0,75	R 4,15	R 0,29	R 0,52	R 64 382 348,23	R 15,60
2020	10000	R30 162 362,71	R 2 948 400,00	R 16 396 200,42	R 1 106 304,47	R 2 013 235,79	R 52 626 503,40	R 14,42	R 0,81	R 4,49	R 0,30	R 0,55	R 66 856 856,57	R 15,79
2021	10000	R30 162 362,71	R 3 184 272,00	R 17 753 805,82	R 1 167 151,22	R 2 123 963,76	R 54 391 555,51	R 14,90	R 0,87	R 4,86	R 0,32	R 0,58	R 69 564 614,04	R 16,01
2022	10000	R30 162 362,71	R 3 439 013,76	R 19 223 820,94	R 1 231 344,53	R 2 240 781,77	R 56 297 323,71	R 15,42	R 0,94	R 5,27	R 0,34	R 0,61	R 72 530 580,48	R 16,27
2023	10000	R30 162 362,71	R 3 714 134,86	R 20 815 553,31	R 1 299 068,48	R 2 364 024,76	R 58 355 144,13	R 15,99	R 1,02	R 5,70	R 0,36	R 0,65	R 75 782 780,61	R 16,57
2024	10000	R30 162 362,71	R 4 011 265,65	R 22 539 081,13	R 1 370 517,25	R 2 494 046,12	R 60 577 272,87	R 16,60	R 1,10	R 6,18	R 0,38	R 0,68	R 79 352 727,32	R 16,92
2025	10000	R30 162 362,71	R 4 332 166,90	R 24 405 317,05	R 1 445 895,70	R 2 631 218,66	R 62 976 961,02	R 17,25	R 1,19	R 6,69	R 0,40	R 0,72	R 83 275 908,08	R 17,30
2026	10000	R30 162 362,71	R 4 678 740,25	R 26 426 077,30	R 1 525 419,96	R 2 775 935,69	R 65 568 535,92	R 17,96	R 1,28	R 7,24	R 0,42	R 0,76	R 87 592 344,67	R 17,74
2027	10000	R30 162 362,71	R 5 053 039,47	R 28 614 156,50	R 1 609 318,06	R 2 928 612,15	R 68 367 488,90	R 18,73	R 1,38	R 7,84	R 0,44	R 0,80	R 92 347 237,46	R 18,23
2028	10000	R30 162 362,71	R 5 457 282,63	R 30 983 408,66	R 1 697 830,55	R 3 089 685,82	R 71 390 570,37	R 19,56	R 1,50	R 8,49	R 0,47	R 0,85	R 97 591 707,74	R 18,78
2029	10000	R30 162 362,71	R 5 893 865,24	R 33 548 834,89	R 1 791 211,24	R 3 259 618,54	R 74 655 892,62	R 20,45	R 1,61	R 9,19	R 0,49	R 0,89	R 103 383 653,54	R 19,39
2030	10000	R30 162 362,71	R 6 365 374,46	R 36 326 678,42	R 1 889 727,85	R 3 438 897,56	R 78 183 041,01	R 21,42	R 1,74	R 9,95	R 0,52	R 0,94	R 109 788 736,77	R 20,07
2031	10000	R30 162 362,71	R 6 874 604,42	R 39 334 527,40	R 1 993 662,88	R 3 628 036,92	R 81 993 194,34	R 22,46	R 1,88	R 10,78	R 0,55	R 0,99	R 116 881 522,63	R 20,83
2032	10000	R30 162 362,71	R 7 424 572,77	R 42 591 426,26	R 2 103 314,34	R 3 827 578,95	R 86 109 255,05	R 23,59	R 2,03	R 11,67	R 0,58	R 1,05	R 124 746 795,42	R 21,67
2033	10000	R30 162 362,71	R 8 018 538,59	R 46 117 996,36	R 2 218 996,63	R 4 038 095,80	R 90 555 990,10	R 24,81	R 2,20	R 12,64	R 0,61	R 1,11	R 133 481 078,77	R 22,60
2034	10000	R30 162 362,71	R 8 660 021,68	R 49 936 566,46	R 2 341 041,45	R 4 260 191,07	R 95 360 183,36	R 26,13	R 2,37	R 13,68	R 0,64	R 1,17	R 143 194 393,05	R 23,63
2035	10000	R30 162 362,71	R 9 352 823,42	R 54 071 314,16	R 2 469 798,73	R 4 494 501,57	R 100 550 800,59	R 27,55	R 2,56	R 14,81	R 0,68	R 1,23	R 154 012 287,52	R 24,77
2036	10000	R30 162 362,71	R 10 101 049,29	R 58 548 418,97	R 2 605 637,66	R 4 741 699,16	R 106 159 167,79	R 29,08	R 2,77	R 16,04	R 0,71	R 1,30	R 166 078 191,44	R 26,04
2037	10000	R30 162 362,71	R 10 909 133,23	R 63 396 228,06	R 2 748 947,73	R 5 002 492,61	R 112 219 164,35	R 30,74	R 2,99	R 17,37	R 0,75	R 1,37	R 179 556 135,03	R 27,44
2038	10000	R30 162 362,71	R 11 781 863,89	R 68 645 435,75	R 2 900 139,85	R 5 277 629,71	R 118 767 431,91	R 32,54	R 3,23	R 18,81	R 0,79	R 1,45	R 194 633 899,54	R 28,99
2039	10000	R30 162 362,71	R 12 724 413,00	R 74 329 277,83	R 3 059 647,55	R 5 567 899,34	R 125 843 600,43	R 34,48	R 3,49	R 20,36	R 0,84	R 1,53	R 211 526 665,39	R 30,71
	76650000						R 1 671 940 759,25	R 21,81					R 2 426 560 464,31	R 21,41

Paradyskloof WTW		
Amoritzed Capital Cost	R	0,99
Raw Water Tariffs	R	2,06
Labour	R	1,39
Energy	R	1,33
Chemicals	R	0,44
Maintenance	R	0,45
Unit Cost	R	6,66
Check	R	6,66
Stellenbosch DPR Plant		
Amoritzed Capital Cost	R	8,26
Labour	R	1,80
Energy	R	10,30
Chemicals	R	0,52
Maintenance	R	0,94
Unit Cost	R	21,81
Check	R	21,81
Total		
Amoritzed Capital Cost	R	6,58
Raw Water Tariffs	R	2,06
Labour	R	2,60
Energy	R	8,29
Chemicals	R	0,79
Maintenance	R	1,09
Unit Cost	R	21,41
Check	R	21,41

Scenario B - 20ML/D (Procurement Model No.1)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	11307	R 5 320 565,84	R -	R 3 120 000,00	R 2 075 627,05	R 968 189,28	R 1 353 186,84	R 12 837 569,01	R 3,11	R -	R 0,76	R 0,50	R 0,23	R 0,33
2020	11600	R 5 320 565,84	R -	R 3 369 600,00	R 2 303 934,77	R 1 047 937,71	R 1 427 612,11	R 13 469 650,43	R 3,18	R -	R 0,80	R 0,54	R 0,25	R 0,34
2021	11901	R 5 320 565,84	R -	R 3 639 168,00	R 2 557 405,63	R 1 134 254,90	R 1 506 130,78	R 14 157 525,15	R 3,26	R -	R 0,84	R 0,59	R 0,26	R 0,35
2022	12210	R 5 320 565,84	R -	R 3 930 301,44	R 2 838 817,23	R 1 227 681,93	R 1 588 967,97	R 14 906 334,41	R 3,34	R -	R 0,88	R 0,64	R 0,28	R 0,36
2023	12527	R 5 320 565,84	R -	R 4 244 725,56	R 3 151 254,13	R 1 328 804,40	R 1 676 361,21	R 15 721 711,13	R 3,44	R -	R 0,93	R 0,69	R 0,29	R 0,37
2024	12852	R 5 320 565,84	R -	R 4 584 303,60	R 3 498 141,76	R 1 438 256,20	R 1 768 561,08	R 16 609 828,48	R 3,54	R -	R 0,98	R 0,75	R 0,31	R 0,38
2025	13185	R 5 320 565,84	R -	R 4 951 047,89	R 3 883 284,20	R 1 556 723,39	R 1 865 831,94	R 17 577 453,26	R 3,65	R -	R 1,03	R 0,81	R 0,32	R 0,39
2026	13527	R 5 320 565,84	R -	R 5 347 131,72	R 4 310 906,00	R 1 684 948,57	R 1 968 452,69	R 18 632 004,82	R 3,77	R -	R 1,08	R 0,87	R 0,34	R 0,40
2027	13878	R 5 320 565,84	R -	R 5 774 902,26	R 4 785 698,73	R 1 823 735,47	R 2 076 717,59	R 19 781 619,89	R 3,91	R -	R 1,14	R 0,94	R 0,36	R 0,41
2028	14238	R 5 320 565,84	R -	R 6 236 894,44	R 5 312 872,63	R 1 973 954,06	R 2 190 937,06	R 21 035 224,03	R 4,05	R -	R 1,20	R 1,02	R 0,38	R 0,42
2029	14608	R 5 320 565,84	R -	R 6 735 845,99	R 5 898 214,01	R 2 136 545,96	R 2 311 438,60	R 22 402 610,39	R 4,20	R -	R 1,26	R 1,11	R 0,40	R 0,43
2030	14987	R 5 320 565,84	R -	R 7 274 713,67	R 6 548 148,96	R 2 312 530,32	R 2 438 567,72	R 23 894 526,51	R 4,37	R -	R 1,33	R 1,20	R 0,42	R 0,45
2031	15375	R 5 320 565,84	R -	R 7 856 690,76	R 7 269 814,21	R 2 503 010,27	R 2 572 688,94	R 25 522 770,03	R 4,55	R -	R 1,40	R 1,30	R 0,45	R 0,46
2032	15774	R 5 320 565,84	R -	R 8 485 226,03	R 8 071 135,68	R 2 709 179,80	R 2 714 186,83	R 27 300 294,18	R 4,74	R -	R 1,47	R 1,40	R 0,47	R 0,47
2033	16183	R 5 320 565,84	R -	R 9 164 044,11	R 8 960 915,87	R 2 932 331,23	R 2 863 467,11	R 29 241 324,15	R 4,95	R -	R 1,55	R 1,52	R 0,50	R 0,48
2034	16603	R 5 320 565,84	R -	R 9 897 167,64	R 9 948 930,86	R 3 173 863,33	R 3 020 957,80	R 31 361 485,47	R 5,18	R -	R 1,63	R 1,64	R 0,52	R 0,50
2035	17034	R 5 320 565,84	R -	R 10 688 941,05	R 11 046 038,06	R 3 435 290,11	R 3 187 110,48	R 33 677 945,53	R 5,42	R -	R 1,72	R 1,78	R 0,55	R 0,51
2036	17476	R 5 320 565,84	R -	R 11 544 056,33	R 12 264 295,88	R 3 718 250,25	R 3 362 401,56	R 36 209 569,86	R 5,68	R -	R 1,81	R 1,92	R 0,58	R 0,53
2037	17929	R 5 320 565,84	R -	R 12 467 580,84	R 13 617 096,69	R 4 024 517,43	R 3 547 333,64	R 38 977 094,43	R 5,96	R -	R 1,91	R 2,08	R 0,61	R 0,54
2038	18394	R 5 320 565,84	R -	R 13 464 987,30	R 15 119 314,43	R 4 356 011,41	R 3 742 436,99	R 42 003 315,98	R 6,26	R -	R 2,01	R 2,25	R 0,65	R 0,56
2039	18871	R 5 320 565,84	R -	R 14 542 186,29	R 16 787 468,67	R 4 714 810,10	R 3 948 271,03	R 45 313 301,93	R 6,58	R -	R 2,11	R 2,44	R 0,68	R 0,57
	113318373							R 520 633 159,06	R 4,59					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs: Annual Cost Rands	Combined Costs: Unit Cost R/kl
2019	11307	R0,00	R 3 525 000,00	R 16 569 407,17	R 1 695 925,53	R 3 504 981,97	R 25 295 314,67	R 6,13	R 0,85	R 4,01	R 0,41	R 0,85	R 38 132 883,67	R 9,24
2020	11600	R0,00	R 3 807 000,00	R 18 404 927,46	R 1 803 488,55	R 3 697 755,98	R 27 713 171,99	R 6,55	R 0,92	R 4,46	R 0,44	R 0,90	R 41 182 822,42	R 9,73
2021	11901	R0,00	R 4 111 560,00	R 20 443 834,39	R 1 918 144,36	R 3 901 132,56	R 30 374 671,30	R 6,99	R 1,00	R 4,95	R 0,46	R 0,95	R 44 532 196,45	R 10,25
2022	12210	R0,00	R 4 440 484,80	R 22 708 668,73	R 2 040 379,97	R 4 115 694,85	R 33 305 228,35	R 7,47	R 1,08	R 5,50	R 0,49	R 1,00	R 48 211 562,75	R 10,82
2023	12527	R0,00	R 4 795 723,58	R 25 224 469,73	R 2 170 717,21	R 4 342 058,06	R 36 532 968,59	R 7,99	R 1,16	R 6,11	R 0,53	R 1,05	R 52 254 679,72	R 11,43
2024	12852	R0,00	R 5 179 381,47	R 28 019 052,11	R 2 309 715,21	R 4 580 871,26	R 40 089 020,05	R 8,55	R 1,25	R 6,79	R 0,56	R 1,11	R 56 698 848,53	R 12,09
2025	13185	R0,00	R 5 593 731,99	R 31 123 313,71	R 2 457 973,23	R 4 832 819,17	R 44 007 838,10	R 9,14	R 1,36	R 7,54	R 0,60	R 1,17	R 61 585 291,36	R 12,80
2026	13527	R0,00	R 6 041 230,55	R 34 571 577,28	R 2 616 133,61	R 5 098 624,23	R 48 327 565,67	R 9,79	R 1,46	R 8,38	R 0,63	R 1,24	R 66 959 570,49	R 13,56
2027	13878	R0,00	R 6 524 528,99	R 38 401 970,18	R 2 784 884,97	R 5 379 048,56	R 53 090 432,70	R 10,48	R 1,58	R 9,30	R 0,67	R 1,30	R 72 872 052,59	R 14,39
2028	14238	R0,00	R 7 046 491,31	R 42 656 846,13	R 2 964 965,67	R 5 674 896,23	R 58 343 199,33	R 11,23	R 1,71	R 10,34	R 0,72	R 1,38	R 79 378 423,36	R 15,27
2029	14608	R0,00	R 7 610 210,62	R 47 383 253,73	R 3 157 167,51	R 5 987 015,53	R 64 137 647,38	R 12,03	R 1,84	R 11,48	R 0,76	R 1,45	R 86 540 257,77	R 16,23
2030	14987	R0,00	R 8 219 027,46	R 52 633 456,98	R 3 362 339,75	R 6 316 301,38	R 70 531 125,57	R 12,89	R 1,99	R 12,75	R 0,81	R 1,53	R 94 425 652,08	R 17,26
2031	15375	R0,00	R 8 876 549,66	R 58 465 513,40	R 3 581 393,38	R 6 663 697,96	R 77 587 154,39	R 13,83	R 2,15	R 14,17	R 0,87	R 1,61	R 103 109 924,42	R 18,37
2032	15774	R0,00	R 9 586 673,63	R 64 943 916,36	R 3 815 305,78	R 7 030 201,34	R 85 376 097,12	R 14,83	R 2,32	R 15,74	R 0,92	R 1,70	R 112 676 391,30	R 19,57
2033	16183	R0,00	R 10 353 607,53	R 72 140 308,55	R 4 065 125,72	R 7 416 862,42	R 93 975 904,21	R 15,91	R 2,51	R 17,48	R 0,98	R 1,80	R 123 217 228,37	R 20,86
2034	16603	R0,00	R 11 181 896,13	R 80 134 274,57	R 4 331 978,70	R 7 824 789,85	R 103 472 939,24	R 17,07	R 2,71	R 19,42	R 1,05	R 1,90	R 134 834 424,71	R 22,25
2035	17034	R0,00	R 12 076 447,82	R 89 014 221,39	R 4 617 072,76	R 8 255 153,29	R 113 962 895,26	R 18,33	R 2,93	R 21,57	R 1,12	R 2,00	R 147 640 840,79	R 23,75
2036	17476	R0,00	R 13 042 563,64	R 98 878 356,46	R 4 921 704,76	R 8 709 186,72	R 125 551 811,59	R 19,68	R 3,16	R 23,96	R 1,19	R 2,11	R 161 761 381,44	R 25,36
2037	17929	R0,00	R 14 085 968,73	R 109 835 774,23	R 5 247 267,03	R 9 188 191,99	R 138 357 201,98	R 21,14	R 3,41	R 26,61	R 1,27	R 2,23	R 177 334 296,41	R 27,10
2038	18394	R0,00	R 15 212 846,23	R 122 007 663,10	R 5 595 254,66	R 9 693 542,55	R 152 509 306,55	R 22,72	R 3,69	R 29,56	R 1,36	R 2,35	R 194 512 622,53	R 28,97
2039	18871	R0,00	R 16 429 873,93	R 135 528 646,31	R 5 967 273,33	R 10 226 687,39	R 168 152 480,96	R 24,41	R 3,98	R 32,84	R 1,45	R 2,48	R 213 465 782,89	R 30,99
	113318373						R 1 590 693 974,99	R 14,04					R 2 111 327 134,04	R 18,63

Paradyskloof WTW		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	-
Labour	R	1,39
Energy	R	1,33
Chemicals	R	0,44
Maintenance	R	0,45
Unit Cost	R	4,59
Check	R	4,59
Stellenbosch DPR Plant		
Amortized Capital Cost	R	-
Labour	R	1,57
Energy	R	10,67
Chemicals	R	0,63
Maintenance	R	1,17
Unit Cost	R	14,04
Check	R	14,04
Total		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	-
Labour	R	2,96
Energy	R	12,00
Chemicals	R	1,07
Maintenance	R	1,62
Unit Cost	R	18,63
Check	R	18,63

Scenario B - 20ML/D (Procurement Model No.2)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	11307	R 5 320 565,84	R -	R 3 120 000,00	R 2 075 627,05	R 968 189,28	R 1 353 186,84	R 12 837 569,01	R 3,11	R -	R 0,76	R 0,50	R 0,23	R 0,33
2020	11600	R 5 320 565,84	R -	R 3 369 600,00	R 2 303 934,77	R 1 047 937,71	R 1 427 612,11	R 13 469 650,43	R 3,18	R -	R 0,80	R 0,54	R 0,25	R 0,34
2021	11901	R 5 320 565,84	R -	R 3 639 168,00	R 2 557 405,63	R 1 134 254,90	R 1 506 130,78	R 14 157 525,15	R 3,26	R -	R 0,84	R 0,59	R 0,26	R 0,35
2022	12210	R 5 320 565,84	R -	R 3 930 301,44	R 2 838 817,23	R 1 227 681,93	R 1 588 967,97	R 14 906 334,41	R 3,34	R -	R 0,88	R 0,64	R 0,28	R 0,36
2023	12527	R 5 320 565,84	R -	R 4 244 725,56	R 3 151 254,13	R 1 328 804,40	R 1 676 361,21	R 15 721 711,13	R 3,44	R -	R 0,93	R 0,69	R 0,29	R 0,37
2024	12852	R 5 320 565,84	R -	R 4 584 303,60	R 3 498 141,76	R 1 438 256,20	R 1 768 561,08	R 16 609 828,48	R 3,54	R -	R 0,98	R 0,75	R 0,31	R 0,38
2025	13185	R 5 320 565,84	R -	R 4 951 047,89	R 3 883 284,20	R 1 556 723,39	R 1 865 831,94	R 17 577 453,26	R 3,65	R -	R 1,03	R 0,81	R 0,32	R 0,39
2026	13527	R 5 320 565,84	R -	R 5 347 131,72	R 4 310 906,00	R 1 684 948,57	R 1 968 452,69	R 18 632 004,82	R 3,77	R -	R 1,08	R 0,87	R 0,34	R 0,40
2027	13878	R 5 320 565,84	R -	R 5 774 902,26	R 4 785 698,73	R 1 823 735,47	R 2 076 717,59	R 19 781 619,89	R 3,91	R -	R 1,14	R 0,94	R 0,36	R 0,41
2028	14238	R 5 320 565,84	R -	R 6 236 894,44	R 5 312 872,63	R 1 973 954,06	R 2 190 937,06	R 21 035 224,03	R 4,05	R -	R 1,20	R 1,02	R 0,38	R 0,42
2029	14608	R 5 320 565,84	R -	R 6 735 845,99	R 5 898 214,01	R 2 136 545,96	R 2 311 438,60	R 22 402 610,39	R 4,20	R -	R 1,26	R 1,11	R 0,40	R 0,43
2030	14987	R 5 320 565,84	R -	R 7 274 713,67	R 6 548 148,96	R 2 312 530,32	R 2 438 567,72	R 23 894 526,51	R 4,37	R -	R 1,33	R 1,20	R 0,42	R 0,45
2031	15375	R 5 320 565,84	R -	R 7 856 690,76	R 7 269 814,21	R 2 503 010,27	R 2 572 688,94	R 25 522 770,03	R 4,55	R -	R 1,40	R 1,30	R 0,45	R 0,46
2032	15774	R 5 320 565,84	R -	R 8 485 226,03	R 8 071 135,68	R 2 709 179,80	R 2 714 186,83	R 27 300 294,18	R 4,74	R -	R 1,47	R 1,40	R 0,47	R 0,47
2033	16183	R 5 320 565,84	R -	R 9 164 044,11	R 8 960 915,87	R 2 932 331,23	R 2 863 467,11	R 29 241 324,15	R 4,95	R -	R 1,55	R 1,52	R 0,50	R 0,48
2034	16603	R 5 320 565,84	R -	R 9 897 167,64	R 9 948 930,86	R 3 173 863,33	R 3 020 957,80	R 31 361 485,47	R 5,18	R -	R 1,63	R 1,64	R 0,52	R 0,50
2035	17034	R 5 320 565,84	R -	R 10 688 941,05	R 11 046 038,06	R 3 435 290,11	R 3 187 110,48	R 33 677 945,53	R 5,42	R -	R 1,72	R 1,78	R 0,55	R 0,51
2036	17476	R 5 320 565,84	R -	R 11 544 056,33	R 12 264 295,88	R 3 718 250,25	R 3 362 401,56	R 36 209 569,86	R 5,68	R -	R 1,81	R 1,92	R 0,58	R 0,53
2037	17929	R 5 320 565,84	R -	R 12 467 580,84	R 13 617 096,69	R 4 024 517,43	R 3 547 333,64	R 38 977 094,43	R 5,96	R -	R 1,91	R 2,08	R 0,61	R 0,54
2038	18394	R 5 320 565,84	R -	R 13 464 987,30	R 15 119 314,43	R 4 356 011,41	R 3 742 436,99	R 42 003 315,98	R 6,26	R -	R 2,01	R 2,25	R 0,65	R 0,56
2039	18871	R 5 320 565,84	R -	R 14 542 186,29	R 16 787 468,67	R 4 714 810,10	R 3 948 271,03	R 45 313 301,93	R 6,58	R -	R 2,11	R 2,44	R 0,68	R 0,57
	113318373							R 520 633 159,06	R 4,59					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs: Annual Cost Rands	Combined Costs: Unit Cost R/kl
2019	11307	R55 399 897,79	R 3 525 000,00	R 16 569 407,17	R 1 695 925,53	R 3 504 981,97	R 80 695 212,45	R 19,55	R 0,85	R 4,01	R 0,41	R 0,85	R 93 532 781,46	R 22,66
2020	11600	R55 399 897,79	R 3 807 000,00	R 18 404 927,46	R 1 803 488,55	R 3 697 755,98	R 83 113 069,77	R 19,63	R 0,92	R 4,46	R 0,44	R 0,90	R 96 582 720,20	R 22,81
2021	11901	R55 399 897,79	R 4 111 560,00	R 20 443 834,39	R 1 918 144,36	R 3 901 132,56	R 85 774 569,08	R 19,75	R 1,00	R 4,95	R 0,46	R 0,95	R 99 932 094,23	R 23,00
2022	12210	R55 399 897,79	R 4 440 484,80	R 22 708 668,73	R 2 040 379,97	R 4 115 694,85	R 88 705 126,13	R 19,90	R 1,08	R 5,50	R 0,49	R 1,00	R 103 611 460,54	R 23,25
2023	12527	R55 399 897,79	R 4 795 723,58	R 25 224 469,73	R 2 170 717,21	R 4 342 058,06	R 91 932 866,37	R 20,11	R 1,16	R 6,11	R 0,53	R 1,05	R 107 654 577,51	R 23,54
2024	12852	R55 399 897,79	R 5 179 381,47	R 28 019 052,11	R 2 309 715,21	R 4 580 871,26	R 95 488 917,83	R 20,36	R 1,25	R 6,79	R 0,56	R 1,11	R 112 098 746,31	R 23,90
2025	13185	R55 399 897,79	R 5 593 731,99	R 31 123 313,71	R 2 457 973,23	R 4 832 819,17	R 99 407 735,89	R 20,66	R 1,36	R 7,54	R 0,60	R 1,17	R 116 985 189,15	R 24,31
2026	13527	R55 399 897,79	R 6 041 230,55	R 34 571 577,28	R 2 616 133,61	R 5 098 624,23	R 103 727 463,45	R 21,01	R 1,46	R 8,38	R 0,63	R 1,24	R 122 359 468,27	R 24,78
2027	13878	R55 399 897,79	R 6 524 528,99	R 38 401 970,18	R 2 784 884,97	R 5 379 048,56	R 108 490 330,49	R 21,42	R 1,58	R 9,30	R 0,67	R 1,30	R 128 271 950,38	R 25,32
2028	14238	R55 399 897,79	R 7 046 491,31	R 42 656 846,13	R 2 964 965,67	R 5 674 896,23	R 113 743 097,12	R 21,89	R 1,71	R 10,34	R 0,72	R 1,38	R 134 778 321,15	R 25,93
2029	14608	R55 399 897,79	R 7 610 210,62	R 47 383 253,73	R 3 157 167,51	R 5 987 015,53	R 119 537 545,16	R 22,42	R 1,84	R 11,48	R 0,76	R 1,45	R 141 940 155,55	R 26,62
2030	14987	R55 399 897,79	R 8 219 027,46	R 52 633 456,98	R 3 362 339,75	R 6 316 301,38	R 125 931 023,35	R 23,02	R 1,99	R 12,75	R 0,81	R 1,53	R 149 825 549,86	R 27,39
2031	15375	R55 399 897,79	R 8 876 549,66	R 58 465 513,40	R 3 581 393,38	R 6 663 697,96	R 132 987 052,18	R 23,70	R 2,15	R 14,17	R 0,87	R 1,61	R 158 509 822,21	R 28,24
2032	15774	R55 399 897,79	R 9 586 673,63	R 64 943 916,36	R 3 815 305,78	R 7 030 201,34	R 140 775 994,91	R 24,45	R 2,32	R 15,74	R 0,92	R 1,70	R 168 076 289,08	R 29,19
2033	16183	R55 399 897,79	R 10 353 607,53	R 72 140 308,55	R 4 065 125,72	R 7 416 862,42	R 149 375 802,00	R 25,29	R 2,51	R 17,48	R 0,98	R 1,80	R 178 617 126,15	R 30,24
2034	16603	R55 399 897,79	R 11 181 896,13	R 80 134 274,57	R 4 331 978,70	R 7 824 789,85	R 158 872 837,03	R 26,22	R 2,71	R 19,42	R 1,05	R 1,90	R 190 234 322,50	R 31,39
2035	17034	R55 399 897,79	R 12 076 447,82	R 89 014 221,39	R 4 617 072,76	R 8 255 153,29	R 169 362 793,05	R 27,24	R 2,93	R 21,57	R 1,12	R 2,00	R 203 040 738,58	R 32,66
2036	17476	R55 399 897,79	R 13 042 563,64	R 98 878 356,46	R 4 921 704,76	R 8 709 186,72	R 180 951 709,37	R 28,37	R 3,16	R 23,96	R 1,19	R 2,11	R 217 161 279,23	R 34,04
2037	17929	R55 399 897,79	R 14 085 968,73	R 109 835 774,23	R 5 247 267,03	R 9 188 191,99	R 193 757 099,76	R 29,61	R 3,41	R 26,61	R 1,27	R 2,23	R 232 734 194,20	R 35,56
2038	18394	R55 399 897,79	R 15 212 846,23	R 122 007 663,10	R 5 595 254,66	R 9 693 542,55	R 207 909 204,34	R 30,97	R 3,69	R 29,56	R 1,36	R 2,35	R 249 912 520,32	R 37,22
2039	18871	R55 399 897,79	R 16 429 873,93	R 135 528 646,31	R 5 967 273,33	R 10 226 687,39	R 223 552 378,75	R 32,45	R 3,98	R 32,84	R 1,45	R 2,48	R 268 865 680,67	R 39,03
	113318373						R 2 754 091 828,48	R 24,30					R 3 274 724 987,54	R 28,90

Paradyskloof WTW		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	-
Labour	R	1,39
Energy	R	1,33
Chemicals	R	0,44
Maintenance	R	0,45
Unit Cost	R	4,59
Check	R	4,59
Stellenbosch DPR Plant		
Amoritzed Capital Cost	R	10,27
Labour	R	1,57
Energy	R	10,67
Chemicals	R	0,63
Maintenance	R	1,17
Unit Cost	R	24,30
Check	R	24,30
Total		
Amortized Capital Cost	R	11,25
Raw Water Tariffs	R	-
Labour	R	2,96
Energy	R	12,00
Chemicals	R	1,07
Maintenance	R	1,62
Unit Cost	R	28,90
Check	R	28,90

Scenario C - 4ML/D (Procurement Model No.1)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	7307	R 5 320 565,84	R 3 092 008,15	R 3 120 000,00	R 1 364 754,17	R 625 682,30	R 1 353 186,84	R 14 876 197,30	R 5,58	R 1,16	R 1,17	R 0,51	R 0,23	R 0,51
2020	7600	R 5 320 565,84	R 3 612 596,05	R 3 369 600,00	R 1 534 201,61	R 686 592,85	R 1 427 612,11	R 15 951 168,46	R 5,75	R 1,30	R 1,21	R 0,55	R 0,25	R 0,51
2021	7901	R 5 320 565,84	R 4 220 200,07	R 3 639 168,00	R 1 723 938,57	R 753 036,07	R 1 506 130,78	R 17 163 039,33	R 5,95	R 1,46	R 1,26	R 0,60	R 0,26	R 0,52
2022	8210	R 5 320 565,84	R 4 929 271,42	R 3 930 301,44	R 1 936 339,10	R 825 496,06	R 1 588 967,97	R 18 530 941,83	R 6,18	R 1,64	R 1,31	R 0,65	R 0,28	R 0,53
2023	8527	R 5 320 565,84	R 5 756 645,75	R 4 244 725,56	R 2 174 050,81	R 904 498,31	R 1 676 361,21	R 20 076 847,47	R 6,45	R 1,85	R 1,36	R 0,70	R 0,29	R 0,54
2024	8852	R 5 320 565,84	R 6 721 934,23	R 4 584 303,60	R 2 440 026,01	R 990 613,28	R 1 768 561,08	R 21 826 004,03	R 6,76	R 2,08	R 1,42	R 0,76	R 0,31	R 0,55
2025	9185	R 5 320 565,84	R 7 847 978,56	R 4 951 047,89	R 2 737 556,46	R 1 084 460,11	R 1 865 831,94	R 23 807 440,79	R 7,10	R 2,34	R 1,48	R 0,82	R 0,32	R 0,56
2026	9527	R 5 320 565,84	R 9 161 380,09	R 5 347 131,72	R 3 070 312,01	R 1 186 710,80	R 1 968 452,69	R 26 054 553,14	R 7,49	R 2,63	R 1,54	R 0,88	R 0,34	R 0,57
2027	9878	R 5 320 565,84	R 10 693 115,24	R 5 774 902,26	R 3 442 383,55	R 1 298 094,63	R 2 076 717,59	R 28 605 779,10	R 7,93	R 2,97	R 1,60	R 0,95	R 0,36	R 0,58
2028	10238	R 5 320 565,84	R 12 479 251,24	R 6 236 894,44	R 3 858 330,95	R 1 419 402,97	R 2 190 937,06	R 31 505 382,50	R 8,43	R 3,34	R 1,67	R 1,03	R 0,38	R 0,59
2029	10608	R 5 320 565,84	R 14 561 778,35	R 6 735 845,99	R 4 323 236,28	R 1 551 494,56	R 2 311 438,60	R 34 804 359,61	R 8,99	R 3,76	R 1,74	R 1,12	R 0,40	R 0,60
2030	10987	R 5 320 565,84	R 16 989 577,57	R 7 274 713,67	R 4 842 763,08	R 1 695 301,09	R 2 438 567,72	R 38 561 488,97	R 9,62	R 4,24	R 1,81	R 1,21	R 0,42	R 0,61
2031	11375	R 5 320 565,84	R 19 819 545,77	R 7 856 690,76	R 5 423 222,38	R 1 851 833,44	R 2 572 688,94	R 42 844 547,13	R 10,32	R 4,77	R 1,89	R 1,31	R 0,45	R 0,62
2032	11774	R 5 320 565,84	R 23 117 903,74	R 8 485 226,03	R 6 071 646,04	R 2 022 188,24	R 2 714 186,83	R 47 731 716,72	R 11,11	R 5,38	R 1,97	R 1,41	R 0,47	R 0,63
2033	12183	R 5 320 565,84	R 26 961 716,88	R 9 164 044,11	R 6 795 868,49	R 2 207 555,13	R 2 863 467,11	R 53 313 217,56	R 11,99	R 6,06	R 2,06	R 1,53	R 0,50	R 0,64
2034	12603	R 5 320 565,84	R 31 440 662,81	R 9 897 167,64	R 7 604 617,56	R 2 409 224,55	R 3 020 957,80	R 59 693 196,20	R 12,98	R 6,83	R 2,15	R 1,65	R 0,52	R 0,66
2035	13034	R 5 320 565,84	R 36 659 086,05	R 10 688 941,05	R 8 507 615,62	R 2 628 596,19	R 3 187 110,48	R 66 991 915,23	R 14,08	R 7,71	R 2,25	R 1,79	R 0,55	R 0,67
2036	13476	R 5 320 565,84	R 42 738 386,15	R 11 544 056,33	R 9 515 692,06	R 2 867 188,17	R 3 362 401,56	R 75 348 290,11	R 15,32	R 8,69	R 2,35	R 1,93	R 0,58	R 0,68
2037	13929	R 5 320 565,84	R 49 819 793,20	R 12 467 580,84	R 10 640 908,47	R 3 126 646,93	R 3 547 333,64	R 84 922 828,92	R 16,70	R 9,80	R 2,45	R 2,09	R 0,61	R 0,70
2038	14394	R 5 320 565,84	R 58 067 593,40	R 13 464 987,30	R 11 896 697,83	R 3 408 758,04	R 3 742 436,99	R 95 901 039,41	R 18,25	R 11,05	R 2,56	R 2,26	R 0,65	R 0,71
2039	14871	R 5 320 565,84	R 67 672 877,43	R 14 542 186,29	R 13 298 019,41	R 3 715 457,80	R 3 948 271,03	R 108 497 377,79	R 19,99	R 12,47	R 2,68	R 2,45	R 0,68	R 0,73
	82658373							R 927 007 331,60	R 11,21					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs: Annual Cost Rands	Combined Costs: Unit Cost R/kl
2019	4000	R0,00	R 2 010 000,00	R 6 254 443,43	R 419 453,81	R 845 689,09	R 9 529 586,33	R 6,53	R 1,38	R 4,28	R 0,29	R 0,58	R 24 405 783,63	R 5,91
2020	4000	R0,00	R 2 170 800,00	R 6 772 311,35	R 442 523,77	R 892 201,99	R 10 277 837,11	R 7,04	R 1,49	R 4,64	R 0,30	R 0,61	R 26 229 005,57	R 6,19
2021	4000	R0,00	R 2 344 464,00	R 7 333 058,72	R 466 862,58	R 941 273,10	R 11 085 658,41	R 7,59	R 1,61	R 5,02	R 0,32	R 0,64	R 28 248 697,74	R 6,50
2022	4000	R0,00	R 2 532 021,12	R 7 940 235,99	R 492 540,02	R 993 043,12	R 11 957 840,25	R 8,19	R 1,73	R 5,44	R 0,34	R 0,68	R 30 488 782,09	R 6,84
2023	4000	R0,00	R 2 734 582,81	R 8 597 687,53	R 519 629,72	R 1 047 660,50	R 12 899 560,55	R 8,84	R 1,87	R 5,89	R 0,36	R 0,72	R 32 976 408,02	R 7,21
2024	4000	R0,00	R 2 953 349,43	R 9 309 576,05	R 548 209,36	R 1 105 281,82	R 13 916 416,67	R 9,53	R 2,02	R 6,38	R 0,38	R 0,76	R 35 742 420,70	R 7,62
2025	4000	R0,00	R 3 189 617,39	R 10 080 408,95	R 578 360,87	R 1 166 072,32	R 15 014 459,53	R 10,28	R 2,18	R 6,90	R 0,40	R 0,80	R 38 821 900,33	R 8,07
2026	4000	R0,00	R 3 444 786,78	R 10 915 066,81	R 610 170,72	R 1 230 206,30	R 16 200 230,61	R 11,10	R 2,36	R 7,48	R 0,42	R 0,84	R 42 254 783,75	R 8,56
2027	4000	R0,00	R 3 720 369,72	R 11 818 834,34	R 643 730,11	R 1 297 867,65	R 17 480 801,82	R 11,97	R 2,55	R 8,10	R 0,44	R 0,89	R 46 086 580,93	R 9,10
2028	4000	R0,00	R 4 017 999,30	R 12 797 433,83	R 679 135,26	R 1 369 250,37	R 18 863 818,76	R 12,92	R 2,75	R 8,77	R 0,47	R 0,94	R 50 369 201,26	R 9,69
2029	4000	R0,00	R 4 339 439,24	R 13 857 061,35	R 716 487,70	R 1 444 559,14	R 20 357 547,44	R 13,94	R 2,97	R 9,49	R 0,49	R 0,99	R 55 161 907,04	R 10,35
2030	4000	R0,00	R 4 686 594,38	R 15 004 426,03	R 755 894,53	R 1 524 009,89	R 21 970 924,83	R 15,05	R 3,21	R 10,28	R 0,52	R 1,04	R 60 532 413,80	R 11,07
2031	4000	R0,00	R 5 061 521,93	R 16 246 792,50	R 797 468,72	R 1 607 830,44	R 23 713 613,60	R 16,24	R 3,47	R 11,13	R 0,55	R 1,10	R 66 558 160,73	R 11,86
2032	4000	R0,00	R 5 466 443,69	R 17 592 026,92	R 841 329,50	R 1 696 261,11	R 25 596 061,23	R 17,53	R 3,74	R 12,05	R 0,58	R 1,16	R 73 327 777,95	R 12,74
2033	4000	R0,00	R 5 903 759,18	R 19 048 646,75	R 887 602,63	R 1 789 555,47	R 27 629 564,04	R 18,92	R 4,04	R 13,05	R 0,61	R 1,23	R 80 942 781,60	R 13,70
2034	4000	R0,00	R 6 376 059,92	R 20 625 874,70	R 936 420,77	R 1 887 981,02	R 29 826 336,42	R 20,43	R 4,37	R 14,13	R 0,64	R 1,29	R 89 519 532,61	R 14,77
2035	4000	R0,00	R 6 886 144,71	R 22 333 697,13	R 987 923,91	R 1 991 819,98	R 32 199 585,74	R 22,05	R 4,72	R 15,30	R 0,68	R 1,36	R 99 191 500,96	R 15,95
2036	4000	R0,00	R 7 437 036,29	R 24 182 927,25	R 1 042 259,73	R 2 101 370,08	R 34 763 593,35	R 23,81	R 5,09	R 16,56	R 0,71	R 1,44	R 110 111 883,46	R 17,26
2037	4000	R0,00	R 8 031 999,19	R 26 185 273,63	R 1 099 584,01	R 2 216 945,43	R 37 533 802,27	R 25,71	R 5,50	R 17,94	R 0,75	R 1,52	R 122 456 631,19	R 18,71
2038	4000	R0,00	R 8 674 559,13	R 28 353 414,28	R 1 160 061,14	R 2 338 877,43	R 40 526 911,98	R 27,76	R 5,94	R 19,42	R 0,79	R 1,60	R 136 427 951,38	R 20,32
2039	4000	R0,00	R 9 368 523,86	R 30 701 076,99	R 1 223 864,50	R 2 467 515,69	R 43 760 981,03	R 29,97	R 6,42	R 21,03	R 0,84	R 1,69	R 152 258 358,83	R 22,10
	30660000						R 475 105 131,97	R 15,50					R 1 402 112 463,57	R 12,37

Paradyskloof WTW		
Amortized Capital Cost	R	1,35
Raw Water Tariffs	R	5,52
Labour	R	1,90
Energy	R	1,37
Chemicals	R	0,45
Maintenance	R	0,62
Unit Cost	R	11,21
Check	R	11,21
Stellenbosch DPR Plant		
Amortized Capital Cost	R	-
Labour	R	3,31
Energy	R	10,63
Chemicals	R	0,52
Maintenance	R	1,04
Unit Cost	R	15,50
Check	R	15,50
Total		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	4,03
Labour	R	2,28
Energy	R	3,88
Chemicals	R	0,47
Maintenance	R	0,73
Unit Cost	R	12,37
Check	R	12,37

Scenario C - 4ML/D (Procurement Model No.2)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	7307	R 5 320 565,84	R 3 092 008,15	R 3 120 000,00	R 1 364 754,17	R 625 682,30	R 1 353 186,84	R 14 876 197,30	R 5,58	R 1,16	R 1,17	R 0,51	R 0,23	R 0,51
2020	7600	R 5 320 565,84	R 3 612 596,05	R 3 369 600,00	R 1 534 201,61	R 686 592,85	R 1 427 612,11	R 15 951 168,46	R 5,75	R 1,30	R 1,21	R 0,55	R 0,25	R 0,51
2021	7901	R 5 320 565,84	R 4 220 200,07	R 3 639 168,00	R 1 723 938,57	R 753 036,07	R 1 506 130,78	R 17 163 039,33	R 5,95	R 1,46	R 1,26	R 0,60	R 0,26	R 0,52
2022	8210	R 5 320 565,84	R 4 929 271,42	R 3 930 301,44	R 1 936 339,10	R 825 496,06	R 1 588 967,97	R 18 530 941,83	R 6,18	R 1,64	R 1,31	R 0,65	R 0,28	R 0,53
2023	8527	R 5 320 565,84	R 5 756 645,75	R 4 244 725,56	R 2 174 050,81	R 904 498,31	R 1 676 361,21	R 20 076 847,47	R 6,45	R 1,85	R 1,36	R 0,70	R 0,29	R 0,54
2024	8852	R 5 320 565,84	R 6 721 934,23	R 4 584 303,60	R 2 440 026,01	R 990 613,28	R 1 768 561,08	R 21 826 004,03	R 6,76	R 2,08	R 1,42	R 0,76	R 0,31	R 0,55
2025	9185	R 5 320 565,84	R 7 847 978,56	R 4 951 047,89	R 2 737 556,46	R 1 084 460,11	R 1 865 831,94	R 23 807 440,79	R 7,10	R 2,34	R 1,48	R 0,82	R 0,32	R 0,56
2026	9527	R 5 320 565,84	R 9 161 380,09	R 5 347 131,72	R 3 070 312,01	R 1 186 710,80	R 1 968 452,69	R 26 054 553,14	R 7,49	R 2,63	R 1,54	R 0,88	R 0,34	R 0,57
2027	9878	R 5 320 565,84	R 10 693 115,24	R 5 774 902,26	R 3 442 383,55	R 1 298 094,63	R 2 076 717,59	R 28 605 779,10	R 7,93	R 2,97	R 1,60	R 0,95	R 0,36	R 0,58
2028	10238	R 5 320 565,84	R 12 479 251,24	R 6 236 894,44	R 3 858 330,95	R 1 419 402,97	R 2 190 937,06	R 31 505 382,50	R 8,43	R 3,34	R 1,67	R 1,03	R 0,38	R 0,59
2029	10608	R 5 320 565,84	R 14 561 778,35	R 6 735 845,99	R 4 323 236,28	R 1 551 494,56	R 2 311 438,60	R 34 804 359,61	R 8,99	R 3,76	R 1,74	R 1,12	R 0,40	R 0,60
2030	10987	R 5 320 565,84	R 16 989 577,57	R 7 274 713,67	R 4 842 763,08	R 1 695 301,09	R 2 438 567,72	R 38 561 488,97	R 9,62	R 4,24	R 1,81	R 1,21	R 0,42	R 0,61
2031	11375	R 5 320 565,84	R 19 819 545,77	R 7 856 690,76	R 5 423 222,38	R 1 851 833,44	R 2 572 688,94	R 42 844 547,13	R 10,32	R 4,77	R 1,89	R 1,31	R 0,45	R 0,62
2032	11774	R 5 320 565,84	R 23 117 903,74	R 8 485 226,03	R 6 071 646,04	R 2 022 188,24	R 2 714 186,83	R 47 731 716,72	R 11,11	R 5,38	R 1,97	R 1,41	R 0,47	R 0,63
2033	12183	R 5 320 565,84	R 26 961 716,88	R 9 164 044,11	R 6 795 868,49	R 2 207 555,13	R 2 863 467,11	R 53 313 217,56	R 11,99	R 6,06	R 2,06	R 1,53	R 0,50	R 0,64
2034	12603	R 5 320 565,84	R 31 440 662,81	R 9 897 167,64	R 7 604 617,56	R 2 409 224,55	R 3 020 957,80	R 59 693 196,20	R 12,98	R 6,83	R 2,15	R 1,65	R 0,52	R 0,66
2035	13034	R 5 320 565,84	R 36 659 086,05	R 10 688 941,05	R 8 507 615,62	R 2 628 596,19	R 3 187 110,48	R 66 991 915,23	R 14,08	R 7,71	R 2,25	R 1,79	R 0,55	R 0,67
2036	13476	R 5 320 565,84	R 42 738 386,15	R 11 544 056,33	R 9 515 692,06	R 2 867 188,17	R 3 362 401,56	R 75 348 290,11	R 15,32	R 8,69	R 2,35	R 1,93	R 0,58	R 0,68
2037	13929	R 5 320 565,84	R 49 819 793,20	R 12 467 580,84	R 10 640 908,47	R 3 126 646,93	R 3 547 333,64	R 84 922 828,92	R 16,70	R 9,80	R 2,45	R 2,09	R 0,61	R 0,70
2038	14394	R 5 320 565,84	R 58 067 593,40	R 13 464 987,30	R 11 896 697,83	R 3 408 758,04	R 3 742 436,99	R 95 901 039,41	R 18,25	R 11,05	R 2,56	R 2,26	R 0,65	R 0,71
2039	14871	R 5 320 565,84	R 67 672 877,43	R 14 542 186,29	R 13 298 019,41	R 3 715 457,80	R 3 948 271,03	R 108 497 377,79	R 19,99	R 12,47	R 2,68	R 2,45	R 0,68	R 0,73
	82658373,03							R 927 007 331,60	R 11,21					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs Annual Cost Rands	Combined Costs Unit Cost R/kl
2019	4000	R13 366 998,69	R 2 010 000,00	R 6 254 443,43	R 419 453,81	R 845 689,09	R 22 896 585,02	R 15,68	R 1,38	R 4,28	R 0,29	R 0,58	R 37 772 782,32	R 9,15
2020	4000	R13 366 998,69	R 2 170 800,00	R 6 772 311,35	R 442 523,77	R 892 201,99	R 23 644 835,80	R 16,20	R 1,49	R 4,64	R 0,30	R 0,61	R 39 596 004,26	R 9,35
2021	4000	R13 366 998,69	R 2 344 464,00	R 7 333 058,72	R 466 862,58	R 941 273,10	R 24 452 657,10	R 16,75	R 1,61	R 5,02	R 0,32	R 0,64	R 41 615 696,43	R 9,58
2022	4000	R13 366 998,69	R 2 532 021,12	R 7 940 235,99	R 492 540,02	R 993 043,12	R 25 324 838,94	R 17,35	R 1,73	R 5,44	R 0,34	R 0,68	R 43 855 780,77	R 9,84
2023	4000	R13 366 998,69	R 2 734 582,81	R 8 597 687,53	R 519 629,72	R 1 047 660,50	R 26 266 559,24	R 17,99	R 1,87	R 5,89	R 0,36	R 0,72	R 46 343 406,71	R 10,14
2024	4000	R13 366 998,69	R 2 953 349,43	R 9 309 576,05	R 548 209,36	R 1 105 281,82	R 27 283 415,36	R 18,69	R 2,02	R 6,38	R 0,38	R 0,76	R 49 109 419,38	R 10,47
2025	4000	R13 366 998,69	R 3 189 617,39	R 10 080 408,95	R 578 360,87	R 1 166 072,32	R 28 381 458,22	R 19,44	R 2,18	R 6,90	R 0,40	R 0,80	R 52 188 899,02	R 10,84
2026	4000	R13 366 998,69	R 3 444 786,78	R 10 915 066,81	R 610 170,72	R 1 230 206,30	R 29 567 229,30	R 20,25	R 2,36	R 7,48	R 0,42	R 0,84	R 55 621 782,44	R 11,27
2027	4000	R13 366 998,69	R 3 720 369,72	R 11 818 834,34	R 643 730,11	R 1 297 867,65	R 30 847 800,51	R 21,13	R 2,55	R 8,10	R 0,44	R 0,89	R 59 453 579,61	R 11,74
2028	4000	R13 366 998,69	R 4 017 999,30	R 12 797 433,83	R 679 135,26	R 1 369 250,37	R 32 230 817,45	R 22,08	R 2,75	R 8,77	R 0,47	R 0,94	R 63 736 199,95	R 12,26
2029	4000	R13 366 998,69	R 4 339 439,24	R 13 857 061,35	R 716 487,70	R 1 444 559,14	R 33 724 546,12	R 23,10	R 2,97	R 9,49	R 0,49	R 0,99	R 68 528 905,73	R 12,85
2030	4000	R13 366 998,69	R 4 686 594,38	R 15 004 426,03	R 755 894,53	R 1 524 009,89	R 35 337 923,52	R 24,20	R 3,21	R 10,28	R 0,52	R 1,04	R 73 899 412,49	R 13,51
2031	4000	R13 366 998,69	R 5 061 521,93	R 16 246 792,50	R 797 468,72	R 1 607 830,44	R 37 080 612,29	R 25,40	R 3,47	R 11,13	R 0,55	R 1,10	R 79 925 159,42	R 14,24
2032	4000	R13 366 998,69	R 5 466 443,69	R 17 592 026,91	R 841 329,50	R 1 696 261,11	R 38 963 059,92	R 26,69	R 3,74	R 12,05	R 0,58	R 1,16	R 86 694 776,64	R 15,06
2033	4000	R13 366 998,69	R 5 903 759,18	R 19 048 646,75	R 887 602,63	R 1 789 555,47	R 40 996 562,73	R 28,08	R 4,04	R 13,05	R 0,61	R 1,23	R 94 309 780,29	R 15,97
2034	4000	R13 366 998,69	R 6 376 059,92	R 20 625 874,70	R 936 420,77	R 1 887 981,02	R 43 193 335,11	R 29,58	R 4,37	R 14,13	R 0,64	R 1,29	R 102 886 531,30	R 16,98
2035	4000	R13 366 998,69	R 6 886 144,71	R 22 333 697,13	R 987 923,91	R 1 991 819,98	R 45 566 584,42	R 31,21	R 4,72	R 15,30	R 0,68	R 1,36	R 112 558 499,65	R 18,10
2036	4000	R13 366 998,69	R 7 437 036,29	R 24 182 927,25	R 1 042 259,73	R 2 101 370,08	R 48 130 592,04	R 32,97	R 5,09	R 16,56	R 0,71	R 1,44	R 123 478 882,15	R 19,36
2037	4000	R13 366 998,69	R 8 031 999,19	R 26 185 273,63	R 1 099 584,01	R 2 216 945,43	R 50 900 800,96	R 34,86	R 5,50	R 17,94	R 0,75	R 1,52	R 135 823 629,88	R 20,75
2038	4000	R13 366 998,69	R 8 674 559,13	R 28 353 414,28	R 1 160 061,14	R 2 338 877,43	R 53 893 910,67	R 36,91	R 5,94	R 19,42	R 0,79	R 1,60	R 149 794 950,07	R 22,31
2039	4000	R13 366 998,69	R 9 368 523,86	R 30 701 076,99	R 1 223 864,50	R 2 467 515,69	R 57 127 979,72	R 39,13	R 6,42	R 21,03	R 0,84	R 1,69	R 165 625 357,52	R 24,05
	30660000						R 755 812 104,44	R 24,65					R 1 682 819 436,04	R 14,85

Paradyskloof WTW	
Amoritzed Capital Cost	R1,35
Raw Water Tariffs	R5,52
Labour	R1,90
Energy	R1,37
Chemicals	R0,45
Maintenance	R0,62
Unit Cost	R11,21
Check	R11,21
Stellenbosch DPR Plant	
Amoritzed Capital Cost	R9,16
Labour	R3,31
Energy	R10,63
Chemicals	R0,52
Maintenance	R1,04
Unit Cost	R24,65
Check	R24,65
Total	
Amoritzed Capital Cost	R3,46
Raw Water Tariffs	R4,03
Labour	R2,28
Energy	R3,88
Chemicals	R0,47
Maintenance	R0,73
Unit Cost	R14,85
Check	R14,85

Scenario C - 6,667ML/D (Procurement Model No.1)

Paradyskloof WTW

Year	Capacity (kl/d)	Amoritised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	4640	R 5 320 565,84	R 1 963 462,30	R 3 120 000,00	R 890 779,68	R 397 315,78	R 1 353 186,84	R 13 045 310,42	R 7,70	R 1,16	R 1,84	R 0,53	R 0,23	R 0,80
2020	4933	R 5 320 565,84	R 2 344 929,48	R 3 369 600,00	R 1 020 982,03	R 445 666,16	R 1 427 612,11	R 13 929 355,62	R 7,74	R 1,30	R 1,87	R 0,57	R 0,25	R 0,79
2021	5234	R 5 320 565,84	R 2 795 725,73	R 3 639 168,00	R 1 168 224,41	R 498 858,42	R 1 506 130,78	R 14 928 673,17	R 7,81	R 1,46	R 1,90	R 0,61	R 0,26	R 0,79
2022	5543	R 5 320 565,84	R 3 328 027,26	R 3 930 301,44	R 1 334 611,81	R 557 338,63	R 1 588 967,97	R 16 059 812,95	R 7,94	R 1,64	R 1,94	R 0,66	R 0,28	R 0,79
2023	5860	R 5 320 565,84	R 3 956 100,53	R 4 244 725,56	R 1 522 500,49	R 621 592,23	R 1 676 361,21	R 17 341 845,85	R 8,11	R 1,85	R 1,98	R 0,71	R 0,29	R 0,78
2024	6185	R 5 320 565,84	R 4 696 655,21	R 4 584 303,60	R 1 734 527,33	R 692 147,36	R 1 768 561,08	R 18 796 760,41	R 8,33	R 2,08	R 2,03	R 0,77	R 0,31	R 0,78
2025	6518	R 5 320 565,84	R 5 569 256,09	R 4 951 047,89	R 1 973 642,49	R 769 578,56	R 1 865 831,94	R 20 449 922,80	R 8,60	R 2,34	R 2,08	R 0,83	R 0,32	R 0,78
2026	6860	R 5 320 565,84	R 6 596 803,49	R 5 347 131,72	R 2 243 145,96	R 854 510,77	R 1 968 452,69	R 22 330 610,47	R 8,92	R 2,63	R 2,14	R 0,90	R 0,34	R 0,79
2027	7211	R 5 320 565,84	R 7 806 093,71	R 5 774 902,26	R 2 546 728,16	R 947 623,60	R 2 076 717,59	R 24 472 631,15	R 9,30	R 2,97	R 2,19	R 0,97	R 0,36	R 0,79
2028	7571	R 5 320 565,84	R 9 228 472,54	R 6 236 894,44	R 2 888 515,29	R 1 049 656,03	R 2 190 937,06	R 26 915 041,20	R 9,74	R 3,34	R 2,26	R 1,05	R 0,38	R 0,79
2029	7941	R 5 320 565,84	R 10 900 597,28	R 6 735 845,99	R 3 273 119,88	R 1 161 411,53	R 2 311 438,60	R 29 702 979,12	R 10,25	R 3,76	R 2,32	R 1,13	R 0,40	R 0,80
2030	8320	R 5 320 565,84	R 12 865 325,07	R 7 274 713,67	R 3 705 697,05	R 1 283 763,50	R 2 438 567,72	R 32 888 632,85	R 10,83	R 4,24	R 2,40	R 1,22	R 0,42	R 0,80
2031	8708	R 5 320 565,84	R 15 172 748,32	R 7 856 690,76	R 4 192 007,27	R 1 417 661,28	R 2 572 688,94	R 36 532 362,43	R 11,49	R 4,77	R 2,47	R 1,32	R 0,45	R 0,81
2032	9107	R 5 320 565,84	R 17 881 401,46	R 8 485 226,03	R 4 738 486,33	R 1 564 136,62	R 2 714 186,83	R 40 704 003,10	R 12,25	R 5,38	R 2,55	R 1,43	R 0,47	R 0,82
2033	9516	R 5 320 565,84	R 21 059 667,06	R 9 164 044,11	R 5 352 323,15	R 1 724 310,67	R 2 863 467,11	R 45 484 377,93	R 13,09	R 6,06	R 2,64	R 1,54	R 0,50	R 0,82
2034	9936	R 5 320 565,84	R 24 787 414,10	R 9 897 167,64	R 6 041 546,66	R 1 899 401,64	R 3 020 957,80	R 50 967 053,69	R 14,05	R 6,83	R 2,73	R 1,67	R 0,52	R 0,83
2035	10367	R 5 320 565,84	R 29 157 906,45	R 10 688 941,05	R 6 815 122,45	R 2 090 733,03	R 3 187 110,48	R 57 260 379,29	R 15,13	R 7,71	R 2,82	R 1,80	R 0,55	R 0,84
2036	10809	R 5 320 565,84	R 34 280 025,72	R 11 544 056,33	R 7 683 060,46	R 2 299 742,53	R 3 362 401,56	R 64 489 852,43	R 16,35	R 8,69	R 2,93	R 1,95	R 0,58	R 0,85
2037	11262	R 5 320 565,84	R 40 280 860,11	R 12 467 580,84	R 8 656 534,97	R 2 527 991,78	R 3 547 333,64	R 72 800 867,19	R 17,71	R 9,80	R 3,03	R 2,11	R 0,61	R 0,86
2038	11727	R 5 320 565,84	R 47 308 719,04	R 13 464 987,30	R 9 748 018,21	R 2 777 176,86	R 3 742 436,99	R 82 361 904,24	R 19,24	R 11,05	R 3,15	R 2,28	R 0,65	R 0,87
2039	12204	R 5 320 565,84	R 55 536 643,08	R 14 542 186,29	R 10 971 429,12	R 3 049 139,65	R 3 948 271,03	R 93 368 235,00	R 20,96	R 12,47	R 3,26	R 2,46	R 0,68	R 0,89
	62215818,03							R 794 830 611,32	R 12,78					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs: Annual Cost Rands	Combined Costs: Unit Cost R/kl
2019	6667	R0,00	R 2 010 000,00	R 10 503 439,52	R 699 121,51	R 1 333 000,03	R 14 545 561,06	R 5,98	R 0,83	R 4,32	R 0,29	R 0,55	R 27 590 871,48	R 6,69
2020	6667	R0,00	R 2 170 800,00	R 11 373 124,31	R 737 573,19	R 1 406 315,04	R 15 687 812,54	R 6,45	R 0,89	R 4,67	R 0,30	R 0,58	R 29 617 168,15	R 6,99
2021	6667	R0,00	R 2 344 464,00	R 12 314 819,00	R 778 139,72	R 1 483 662,36	R 16 921 085,08	R 6,95	R 0,96	R 5,06	R 0,32	R 0,61	R 31 849 758,26	R 7,33
2022	6667	R0,00	R 2 532 021,12	R 13 334 486,02	R 820 937,40	R 1 565 263,79	R 18 252 708,33	R 7,50	R 1,04	R 5,48	R 0,34	R 0,64	R 34 312 521,28	R 7,70
2023	6667	R0,00	R 2 734 582,81	R 14 438 581,46	R 866 088,96	R 1 651 353,30	R 19 690 606,53	R 8,09	R 1,12	R 5,93	R 0,36	R 0,68	R 37 032 452,38	R 8,10
2024	6667	R0,00	R 2 953 349,43	R 15 634 096,00	R 913 723,85	R 1 742 177,73	R 21 243 347,02	R 8,73	R 1,21	R 6,42	R 0,38	R 0,72	R 40 040 107,43	R 8,54
2025	6667	R0,00	R 3 189 617,39	R 16 928 599,15	R 963 978,66	R 1 837 997,51	R 22 920 192,71	R 9,42	R 1,31	R 6,96	R 0,40	R 0,76	R 43 370 115,52	R 9,01
2026	6667	R0,00	R 3 444 786,78	R 18 330 287,16	R 1 016 997,49	R 1 939 087,37	R 24 731 158,80	R 10,16	R 1,42	R 7,53	R 0,42	R 0,80	R 47 061 769,27	R 9,53
2027	6667	R0,00	R 3 720 369,72	R 19 848 034,94	R 1 072 932,35	R 2 045 737,18	R 26 687 074,19	R 10,97	R 1,53	R 8,16	R 0,44	R 0,84	R 51 159 705,33	R 10,10
2028	6667	R0,00	R 4 017 999,30	R 21 491 452,23	R 1 131 943,63	R 2 158 252,72	R 28 799 647,88	R 11,83	R 1,65	R 8,83	R 0,47	R 0,89	R 55 714 689,08	R 10,72
2029	6667	R0,00	R 4 339 439,24	R 23 270 944,48	R 1 194 200,53	R 2 276 956,62	R 31 081 540,87	R 12,77	R 1,78	R 9,56	R 0,49	R 0,94	R 60 784 520,00	R 11,40
2030	6667	R0,00	R 4 686 594,38	R 25 197 778,68	R 1 259 881,56	R 2 402 189,23	R 33 546 443,86	R 13,79	R 1,93	R 10,35	R 0,52	R 0,99	R 66 435 076,71	R 12,15
2031	6667	R0,00	R 5 061 521,93	R 27 284 154,75	R 1 329 175,05	R 2 534 309,64	R 36 209 161,38	R 14,88	R 2,08	R 11,21	R 0,55	R 1,04	R 72 741 523,80	R 12,96
2032	6667	R0,00	R 5 466 443,69	R 29 543 282,77	R 1 402 279,67	R 2 673 696,67	R 39 085 702,80	R 16,06	R 2,25	R 12,14	R 0,58	R 1,10	R 79 789 705,90	R 13,86
2033	6667	R0,00	R 5 903 759,18	R 31 989 466,58	R 1 479 405,05	R 2 820 749,99	R 42 193 380,81	R 17,34	R 2,43	R 13,15	R 0,61	R 1,16	R 87 677 758,74	R 14,84
2034	6667	R0,00	R 6 376 059,92	R 34 638 194,41	R 1 560 772,33	R 2 975 891,24	R 45 550 917,90	R 18,72	R 2,62	R 14,23	R 0,64	R 1,22	R 96 517 971,59	R 15,93
2035	6667	R0,00	R 6 886 144,71	R 37 506 236,91	R 1 646 614,81	R 3 139 565,26	R 49 178 561,69	R 20,21	R 2,83	R 15,41	R 0,68	R 1,29	R 106 438 940,99	R 17,12
2036	6667	R0,00	R 7 437 036,29	R 40 611 753,33	R 1 737 178,63	R 3 312 241,35	R 53 098 209,59	R 21,82	R 3,06	R 16,69	R 0,71	R 1,36	R 117 588 062,02	R 18,43
2037	6667	R0,00	R 8 031 999,19	R 43 974 406,50	R 1 832 723,45	R 3 494 414,62	R 57 333 543,77	R 23,56	R 3,30	R 18,07	R 0,75	R 1,44	R 130 134 410,95	R 19,89
2038	6667	R0,00	R 8 674 559,13	R 47 615 487,36	R 1 933 523,24	R 3 686 607,43	R 61 910 177,15	R 25,44	R 3,56	R 19,57	R 0,79	R 1,51	R 144 272 081,40	R 21,49
2039	6667	R0,00	R 9 368 523,86	R 51 558 049,71	R 2 039 867,02	R 3 889 370,83	R 66 855 811,42	R 27,47	R 3,85	R 21,19	R 0,84	R 1,60	R 160 224 046,43	R 23,26
	51102555						R 725 522 645,39	R 14,20					R 1 520 353 256,72	R 13,42

Paradyskloof WTW		
Amortized Capital Cost	R	1,80
Raw Water Tariffs	R	5,75
Labour	R	2,53
Energy	R	1,42
Chemicals	R	0,46
Maintenance	R	0,82
Unit Cost	R	12,78
Check	R	12,78
Stellenbosch DPR Plant		
Amortized Capital Cost	R	-
Labour	R	1,98
Energy	R	10,71
Chemicals	R	0,52
Maintenance	R	0,99
Unit Cost	R	14,20
Check	R	14,20
Total		
Amortized Capital Cost	R	0,99
Raw Water Tariffs	R	3,15
Labour	R	2,28
Energy	R	5,61
Chemicals	R	0,49
Maintenance	R	0,90
Unit Cost	R	13,42
Check	R	13,42

Scenario C - 6,667ML/D (Procurement Model No.2)

Paradyskloof WTW

Year	Capacity (kl/d)	Amoritised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	4640	R 5 320 565,84	R 1 963 462,30	R 3 120 000,00	R 890 779,68	R 397 315,78	R 1 353 186,84	R 13 045 310,42	R 7,70	R 1,16	R 1,84	R 0,53	R 0,23	R 0,80
2020	4933	R 5 320 565,84	R 2 344 929,48	R 3 369 600,00	R 1 020 982,03	R 445 666,16	R 1 427 612,11	R 13 929 355,62	R 7,74	R 1,30	R 1,87	R 0,57	R 0,25	R 0,79
2021	5234	R 5 320 565,84	R 2 795 725,73	R 3 639 168,00	R 1 168 224,41	R 498 858,42	R 1 506 130,78	R 14 928 673,17	R 7,81	R 1,46	R 1,90	R 0,61	R 0,26	R 0,79
2022	5543	R 5 320 565,84	R 3 328 027,26	R 3 930 301,44	R 1 334 611,81	R 557 338,63	R 1 588 967,97	R 16 059 812,95	R 7,94	R 1,64	R 1,94	R 0,66	R 0,28	R 0,79
2023	5860	R 5 320 565,84	R 3 956 100,53	R 4 244 725,56	R 1 522 500,49	R 621 592,23	R 1 676 361,21	R 17 341 845,85	R 8,11	R 1,85	R 1,98	R 0,71	R 0,29	R 0,78
2024	6185	R 5 320 565,84	R 4 696 655,21	R 4 584 303,60	R 1 734 527,33	R 692 147,36	R 1 768 561,08	R 18 796 760,41	R 8,33	R 2,08	R 2,03	R 0,77	R 0,31	R 0,78
2025	6518	R 5 320 565,84	R 5 569 256,09	R 4 951 047,89	R 1 973 642,49	R 769 578,56	R 1 865 831,94	R 20 449 922,80	R 8,60	R 2,34	R 2,08	R 0,83	R 0,32	R 0,78
2026	6860	R 5 320 565,84	R 6 596 803,49	R 5 347 131,72	R 2 243 145,96	R 854 510,77	R 1 968 452,69	R 22 330 610,47	R 8,92	R 2,63	R 2,14	R 0,90	R 0,34	R 0,79
2027	7211	R 5 320 565,84	R 7 806 093,71	R 5 774 902,26	R 2 546 728,16	R 947 623,60	R 2 076 717,59	R 24 472 631,15	R 9,30	R 2,97	R 2,19	R 0,97	R 0,36	R 0,79
2028	7571	R 5 320 565,84	R 9 228 472,54	R 6 236 894,44	R 2 888 515,29	R 1 049 656,03	R 2 190 937,06	R 26 915 041,20	R 9,74	R 3,34	R 2,26	R 1,05	R 0,38	R 0,79
2029	7941	R 5 320 565,84	R 10 900 597,28	R 6 735 845,99	R 3 273 119,88	R 1 161 411,53	R 2 311 438,60	R 29 702 979,12	R 10,25	R 3,76	R 2,32	R 1,13	R 0,40	R 0,80
2030	8320	R 5 320 565,84	R 12 865 325,07	R 7 274 713,67	R 3 705 697,05	R 1 283 763,50	R 2 438 567,72	R 32 888 632,85	R 10,83	R 4,24	R 2,40	R 1,22	R 0,42	R 0,80
2031	8708	R 5 320 565,84	R 15 172 748,32	R 7 856 690,76	R 4 192 007,27	R 1 417 661,28	R 2 572 688,94	R 36 532 362,43	R 11,49	R 4,77	R 2,47	R 1,32	R 0,45	R 0,81
2032	9107	R 5 320 565,84	R 17 881 401,46	R 8 485 226,03	R 4 738 486,33	R 1 564 136,62	R 2 714 186,83	R 40 704 003,10	R 12,25	R 5,38	R 2,55	R 1,43	R 0,47	R 0,82
2033	9516	R 5 320 565,84	R 21 059 667,06	R 9 164 044,11	R 5 352 323,15	R 1 724 310,67	R 2 863 467,11	R 45 484 377,93	R 13,09	R 6,06	R 2,64	R 1,54	R 0,50	R 0,82
2034	9936	R 5 320 565,84	R 24 787 414,10	R 9 897 167,64	R 6 041 546,66	R 1 899 401,64	R 3 020 957,80	R 50 967 053,69	R 14,05	R 6,83	R 2,73	R 1,67	R 0,52	R 0,83
2035	10367	R 5 320 565,84	R 29 157 906,45	R 10 688 941,05	R 6 815 122,45	R 2 090 733,03	R 3 187 110,48	R 57 260 379,29	R 15,13	R 7,71	R 2,82	R 1,80	R 0,55	R 0,84
2036	10809	R 5 320 565,84	R 34 280 025,72	R 11 544 056,33	R 7 683 060,46	R 2 299 742,53	R 3 362 401,56	R 64 489 852,43	R 16,35	R 8,69	R 2,93	R 1,95	R 0,58	R 0,85
2037	11262	R 5 320 565,84	R 40 280 860,11	R 12 467 580,84	R 8 656 534,97	R 2 527 991,78	R 3 547 333,64	R 72 800 867,19	R 17,71	R 9,80	R 3,03	R 2,11	R 0,61	R 0,86
2038	11727	R 5 320 565,84	R 47 308 719,04	R 13 464 987,30	R 9 748 018,21	R 2 777 176,86	R 3 742 436,99	R 82 361 904,24	R 19,24	R 11,05	R 3,15	R 2,28	R 0,65	R 0,87
2039	12204	R 5 320 565,84	R 55 536 643,08	R 14 542 186,29	R 10 971 429,12	R 3 049 139,65	R 3 948 271,03	R 93 368 235,00	R 20,96	R 12,47	R 3,26	R 2,46	R 0,68	R 0,89
	62215818							R 794 830 611,32	R 12,78					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs Annual Cost Rands	Combined Costs Unit Cost R/kl
2019	6667	R21 069 456,65	R 2 010 000,00	R 10 503 439,52	R 699 121,51	R 1 333 000,03	R 35 615 017,71	R 14,64	R 0,83	R 4,32	R 0,29	R 0,55	R 48 660 328,13	R 11,79
2020	6667	R21 069 456,65	R 2 170 800,00	R 11 373 124,31	R 737 573,19	R 1 406 315,04	R 36 757 269,18	R 15,10	R 0,89	R 4,67	R 0,30	R 0,58	R 50 686 624,80	R 11,97
2021	6667	R21 069 456,65	R 2 344 464,00	R 12 314 819,00	R 778 139,72	R 1 483 662,36	R 37 990 541,73	R 15,61	R 0,96	R 5,06	R 0,32	R 0,61	R 52 919 214,90	R 12,18
2022	6667	R21 069 456,65	R 2 532 021,12	R 13 334 486,02	R 820 937,40	R 1 565 263,79	R 39 322 164,98	R 16,16	R 1,04	R 5,48	R 0,34	R 0,64	R 55 381 977,93	R 12,43
2023	6667	R21 069 456,65	R 2 734 582,81	R 14 438 581,46	R 866 088,96	R 1 651 353,30	R 40 760 063,17	R 16,75	R 1,12	R 5,93	R 0,36	R 0,68	R 58 101 909,02	R 12,71
2024	6667	R21 069 456,65	R 2 953 349,43	R 15 634 096,00	R 913 723,85	R 1 742 177,73	R 42 312 803,67	R 17,39	R 1,21	R 6,42	R 0,38	R 0,72	R 61 109 564,07	R 13,03
2025	6667	R21 069 456,65	R 3 189 617,39	R 16 928 599,15	R 963 978,66	R 1 837 997,51	R 43 989 649,36	R 18,08	R 1,31	R 6,96	R 0,40	R 0,76	R 64 439 572,16	R 13,39
2026	6667	R21 069 456,65	R 3 444 786,78	R 18 330 287,16	R 1 016 997,49	R 1 939 087,37	R 45 800 615,45	R 18,82	R 1,42	R 7,53	R 0,42	R 0,80	R 68 131 225,91	R 13,80
2027	6667	R21 069 456,65	R 3 720 369,72	R 19 848 034,94	R 1 072 932,35	R 2 045 737,18	R 47 756 530,83	R 19,62	R 1,53	R 8,16	R 0,44	R 0,84	R 72 229 161,98	R 14,26
2028	6667	R21 069 456,65	R 4 017 999,30	R 21 491 452,23	R 1 131 943,63	R 2 158 252,72	R 49 869 104,53	R 20,49	R 1,65	R 8,83	R 0,47	R 0,89	R 76 784 145,73	R 14,77
2029	6667	R21 069 456,65	R 4 339 439,24	R 23 270 944,48	R 1 194 200,53	R 2 276 956,62	R 52 150 997,52	R 21,43	R 1,78	R 9,56	R 0,49	R 0,94	R 81 853 976,64	R 15,35
2030	6667	R21 069 456,65	R 4 686 594,38	R 25 197 778,68	R 1 259 881,56	R 2 402 189,23	R 54 615 900,50	R 22,44	R 1,93	R 10,35	R 0,52	R 0,99	R 87 504 533,35	R 16,00
2031	6667	R21 069 456,65	R 5 061 521,93	R 27 284 154,75	R 1 329 175,05	R 2 534 309,64	R 57 278 618,02	R 23,54	R 2,08	R 11,21	R 0,55	R 1,04	R 93 810 980,45	R 16,72
2032	6667	R21 069 456,65	R 5 466 443,69	R 29 543 282,77	R 1 402 279,67	R 2 673 696,67	R 60 155 159,45	R 24,72	R 2,25	R 12,14	R 0,58	R 1,10	R 100 859 162,55	R 17,52
2033	6667	R21 069 456,65	R 5 903 759,18	R 31 989 466,58	R 1 479 405,05	R 2 820 749,99	R 63 262 837,46	R 26,00	R 2,43	R 13,15	R 0,61	R 1,16	R 108 747 215,39	R 18,41
2034	6667	R21 069 456,65	R 6 376 059,92	R 34 638 194,41	R 1 560 772,33	R 2 975 891,24	R 66 620 374,55	R 27,38	R 2,62	R 14,23	R 0,64	R 1,22	R 117 587 428,24	R 19,40
2035	6667	R21 069 456,65	R 6 886 144,71	R 37 506 236,91	R 1 646 614,81	R 3 139 565,26	R 70 248 018,34	R 28,87	R 2,83	R 15,41	R 0,68	R 1,29	R 127 508 397,63	R 20,51
2036	6667	R21 069 456,65	R 7 437 036,29	R 40 611 753,33	R 1 737 178,63	R 3 312 241,35	R 74 167 666,23	R 30,48	R 3,06	R 16,69	R 0,71	R 1,36	R 138 657 518,67	R 21,74
2037	6667	R21 069 456,65	R 8 031 999,19	R 43 974 406,50	R 1 832 723,45	R 3 494 414,62	R 78 403 000,41	R 32,22	R 3,30	R 18,07	R 0,75	R 1,44	R 151 203 867,60	R 23,11
2038	6667	R21 069 456,65	R 8 674 559,13	R 47 615 487,36	R 1 933 523,24	R 3 686 607,43	R 82 979 633,80	R 34,10	R 3,56	R 19,57	R 0,79	R 1,51	R 165 341 538,04	R 24,63
2039	6667	R21 069 456,65	R 9 368 523,86	R 51 558 049,71	R 2 039 867,02	R 3 889 370,83	R 87 925 268,07						R 181 293 503,07	R 26,32
	51102555						R 1 167 981 234,94	R 22,86					R 1 962 811 846,27	R 17,32

Paradyskloof WTW		
Amortized Capital Cost	R	1,80
Raw Water Tariffs	R	5,75
Labour	R	2,53
Energy	R	1,42
Chemicals	R	0,46
Maintenance	R	0,82
Unit Cost	R	12,78
Check	R	12,78
Stellenbosch DPR Plant		
Amortized Capital Cost	R	8,66
Labour	R	1,98
Energy	R	10,71
Chemicals	R	0,52
Maintenance	R	0,99
Unit Cost	R	22,86
Check	R	22,86
Total		
Amortized Capital Cost	R	4,89
Raw Water Tariffs	R	3,15
Labour	R	2,28
Energy	R	5,61
Chemicals	R	0,49
Maintenance	R	0,90
Unit Cost	R	17,32
Check	R	17,32

Scenario C - 10ML/D (Procurement Model No.1)

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
							Paradyskloof WTW							
2019	1307	R 5 320 565,84	R 553 097,35	R 3 120 000,00	R 298 444,85	R 111 921,83	R 1 353 186,84	R 10 757 216,71	R 22,55	R 1,16	R 6,54	R 0,63	R 0,23	R 2,84
2020	1600	R 5 320 565,84	R 760 702,74	R 3 369 600,00	R 379 601,88	R 144 575,55	R 1 427 612,11	R 11 402 658,12	R 19,52	R 1,30	R 5,77	R 0,65	R 0,25	R 2,44
2021	1901	R 5 320 565,84	R 1 015 533,39	R 3 639 168,00	R 473 737,98	R 181 207,82	R 1 506 130,78	R 12 136 343,81	R 17,49	R 1,46	R 5,24	R 0,68	R 0,26	R 2,17
2022	2210	R 5 320 565,84	R 1 326 922,36	R 3 930 301,44	R 582 621,91	R 222 217,26	R 1 588 967,97	R 12 971 596,77	R 16,08	R 1,64	R 4,87	R 0,72	R 0,28	R 1,97
2023	2527	R 5 320 565,84	R 1 705 925,34	R 4 244 725,56	R 708 245,83	R 268 039,18	R 1 676 361,21	R 13 923 862,95	R 15,10	R 1,85	R 4,60	R 0,77	R 0,29	R 1,82
2024	2852	R 5 320 565,84	R 2 165 625,97	R 4 584 303,60	R 852 852,37	R 319 148,89	R 1 768 561,08	R 15 011 057,75	R 14,42	R 2,08	R 4,40	R 0,82	R 0,31	R 1,70
2025	3185	R 5 320 565,84	R 2 721 493,80	R 4 951 047,89	R 1 018 964,85	R 376 065,18	R 1 865 831,94	R 16 253 969,50	R 13,98	R 2,34	R 4,26	R 0,88	R 0,32	R 1,60
2026	3527	R 5 320 565,84	R 3 391 803,94	R 5 347 131,72	R 1 209 421,01	R 439 354,15	R 1 968 452,69	R 17 676 729,35	R 13,73	R 2,63	R 4,15	R 0,94	R 0,34	R 1,53
2027	3878	R 5 320 565,84	R 4 198 128,67	R 5 774 902,26	R 1 427 410,78	R 509 633,36	R 2 076 717,59	R 19 307 358,50	R 13,64	R 2,97	R 4,08	R 1,01	R 0,36	R 1,47
2028	4238	R 5 320 565,84	R 5 165 913,34	R 6 236 894,44	R 1 676 518,44	R 587 576,34	R 2 190 937,06	R 21 178 405,45	R 13,69	R 3,34	R 4,03	R 1,08	R 0,38	R 1,42
2029	4608	R 5 320 565,84	R 6 325 150,53	R 6 735 845,99	R 1 960 769,69	R 673 917,46	R 2 311 438,60	R 23 327 688,10	R 13,87	R 3,76	R 4,01	R 1,17	R 0,40	R 1,37
2030	4987	R 5 320 565,84	R 7 711 169,25	R 7 274 713,67	R 2 284 684,26	R 769 457,25	R 2 438 567,72	R 25 799 157,99	R 14,17	R 4,24	R 4,00	R 1,26	R 0,42	R 1,34
2031	5375	R 5 320 565,84	R 9 365 558,27	R 7 856 690,76	R 2 653 334,63	R 875 068,19	R 2 572 688,94	R 28 643 906,63	R 14,60	R 4,77	R 4,00	R 1,35	R 0,45	R 1,31
2032	5774	R 5 320 565,84	R 11 337 246,19	R 8 485 226,03	R 3 072 411,58	R 991 700,90	R 2 714 186,83	R 31 921 337,37	R 15,15	R 5,38	R 4,03	R 1,46	R 0,47	R 1,29
2033	6183	R 5 320 565,84	R 13 683 764,52	R 9 164 044,11	R 3 548 297,42	R 1 120 390,99	R 2 863 467,11	R 35 700 529,99	R 15,82	R 6,06	R 4,06	R 1,57	R 0,50	R 1,27
2034	6603	R 5 320 565,84	R 16 472 724,22	R 9 897 167,64	R 4 088 147,60	R 1 262 266,38	R 3 020 957,80	R 40 061 829,48	R 16,62	R 6,83	R 4,11	R 1,70	R 0,52	R 1,25
2035	7034	R 5 320 565,84	R 19 783 541,39	R 10 688 941,05	R 4 699 981,95	R 1 418 555,32	R 3 187 110,48	R 45 098 696,03	R 17,57	R 7,71	R 4,16	R 1,83	R 0,55	R 1,24
2036	7476	R 5 320 565,84	R 23 709 453,79	R 11 544 056,33	R 5 392 786,33	R 1 590 595,05	R 3 362 401,56	R 50 919 858,89	R 18,66	R 8,69	R 4,23	R 1,98	R 0,58	R 1,23
2037	7929	R 5 320 565,84	R 28 359 876,24	R 12 467 580,84	R 6 176 626,14	R 1 779 841,19	R 3 547 333,64	R 57 651 823,89	R 19,92	R 9,80	R 4,31	R 2,13	R 0,61	R 1,23
2038	8394	R 5 320 565,84	R 33 863 151,65	R 13 464 987,30	R 7 062 772,92	R 1 987 877,98	R 3 742 436,99	R 65 441 792,69	R 21,36	R 11,05	R 4,39	R 2,31	R 0,65	R 1,22
2039	8871	R 5 320 565,84	R 40 369 763,04	R 14 542 186,29	R 8 063 845,52	R 2 216 429,34	R 3 948 271,03	R 74 461 061,05	R 23,00	R 12,47	R 4,49	R 2,49	R 0,68	R 1,22
	36668373							R 629 646 881,03	R 17,17					

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs: Annual Cost Rands	Combined Costs: Unit Cost R/kl
					Stellenbosch DPR Plant									
2019	10000	R0,00	R 2 730 000,00	R 15 142 408,96	R 1 048 629,83	R 1 908 280,37	R 20 829 319,16	R 5,71	R 0,75	R 4,15	R 0,29	R 0,52	R 31 586 535,87	R 7,65
2020	10000	R0,00	R 2 948 400,00	R 16 396 200,42	R 1 106 304,47	R 2 013 235,79	R 22 464 140,69	R 6,15	R 0,81	R 4,49	R 0,30	R 0,55	R 33 866 798,81	R 8,00
2021	10000	R0,00	R 3 184 272,00	R 17 753 805,82	R 1 167 151,22	R 2 123 963,76	R 24 229 192,80	R 6,64	R 0,87	R 4,86	R 0,32	R 0,58	R 36 365 536,61	R 8,37
2022	10000	R0,00	R 3 439 013,76	R 19 223 820,94	R 1 231 344,53	R 2 240 781,77	R 26 134 961,00	R 7,16	R 0,94	R 5,27	R 0,34	R 0,61	R 39 106 557,77	R 8,77
2023	10000	R0,00	R 3 714 134,86	R 20 815 553,31	R 1 299 068,48	R 2 364 024,76	R 28 192 781,42	R 7,72	R 1,02	R 5,70	R 0,36	R 0,65	R 42 116 644,37	R 9,21
2024	10000	R0,00	R 4 011 265,65	R 22 539 081,13	R 1 370 517,25	R 2 494 046,12	R 30 414 910,15	R 8,33	R 1,10	R 6,18	R 0,38	R 0,68	R 45 425 967,90	R 9,68
2025	10000	R0,00	R 4 332 166,90	R 24 405 317,05	R 1 445 895,70	R 2 631 218,66	R 32 814 598,31	R 8,99	R 1,19	R 6,69	R 0,40	R 0,72	R 49 068 567,81	R 10,20
2026	10000	R0,00	R 4 678 740,25	R 26 426 077,30	R 1 525 419,96	R 2 775 935,69	R 35 406 173,20	R 9,70	R 1,28	R 7,24	R 0,42	R 0,76	R 53 082 902,55	R 10,75
2027	10000	R0,00	R 5 053 039,47	R 28 614 156,50	R 1 609 318,06	R 2 928 612,15	R 38 205 126,18	R 10,47	R 1,38	R 7,84	R 0,44	R 0,80	R 57 512 484,69	R 11,35
2028	10000	R0,00	R 5 457 282,63	R 30 983 408,66	R 1 697 830,55	R 3 089 685,82	R 41 228 207,66	R 11,30	R 1,50	R 8,49	R 0,47	R 0,85	R 62 406 613,11	R 12,01
2029	10000	R0,00	R 5 893 865,24	R 33 548 834,89	R 1 791 211,24	R 3 259 618,54	R 44 493 529,91	R 12,19	R 1,61	R 9,19	R 0,49	R 0,89	R 67 821 218,01	R 12,72
2030	10000	R0,00	R 6 365 374,46	R 36 326 678,42	R 1 889 727,85	R 3 438 897,56	R 48 020 678,30	R 13,16	R 1,74	R 9,95	R 0,52	R 0,94	R 73 819 836,29	R 13,50
2031	10000	R0,00	R 6 874 604,42	R 39 334 527,40	R 1 993 662,88	R 3 628 036,92	R 51 830 831,62	R 14,20	R 1,88	R 10,78	R 0,55	R 0,99	R 80 474 738,25	R 14,34
2032	10000	R0,00	R 7 424 572,77	R 42 591 426,26	R 2 103 314,34	R 3 827 578,95	R 55 946 892,33	R 15,33	R 2,03	R 11,67	R 0,58	R 1,05	R 87 868 229,71	R 15,26
2033	10000	R0,00	R 8 018 538,59	R 46 117 996,36	R 2 218 996,63	R 4 038 095,80	R 60 393 627,38	R 16,55	R 2,20	R 12,64	R 0,61	R 1,11	R 96 094 157,37	R 16,27
2034	10000	R0,00	R 8 660 021,68	R 49 936 566,46	R 2 341 041,45	R 4 260 191,07	R 65 197 820,65	R 17,86	R 2,37	R 13,68	R 0,64	R 1,17	R 105 259 650,13	R 17,37
2035	10000	R0,00	R 9 352 823,42	R 54 071 314,16	R 2 469 798,73	R 4 494 501,57	R 70 388 437,88	R 19,28	R 2,56	R 14,81	R 0,68	R 1,23	R 115 487 133,91	R 18,57
2036	10000	R0,00	R 10 101 049,29	R 58 548 418,97	R 2 605 637,66	R 4 741 699,16	R 75 996 805,08	R 20,82	R 2,77	R 16,04	R 0,71	R 1,30	R 126 916 663,97	R 19,90
2037	10000	R0,00	R 10 909 133,23	R 63 396 228,06	R 2 748 947,73	R 5 002 492,61	R 82 056 801,64	R 22,48	R 2,99	R 17,37	R 0,75	R 1,37	R 139 708 625,53	R 21,35
2038	10000	R0,00	R 11 781 863,89	R 68 645 435,75	R 2 900 139,85	R 5 277 629,71	R 88 605 069,20	R 24,28	R 3,23	R 18,81	R 0,79	R 1,45	R 154 046 861,89	R 22,94
2039	10000	R0,00	R 12 724 413,00	R 74 329 277,83	R 3 059 647,55	R 5 567 899,34	R 95 681 237,72	R 26,21	R 3,49	R 20,36	R 0,84	R 1,53	R 170 142 298,77	R 24,70
	76650000						R 1 038 531 142,28	R 13,55					R 1 668 178 023,32	R 14,72

Paradyskloof WTW		
Amoritzed Capital Cost	R	3,05
Raw Water Tariffs	R	6,38
Labour	R	4,29
Energy	R	1,57
Chemicals	R	0,49
Maintenance	R	1,39
Unit Cost	R	17,17
Check	R	17,17
Stellenbosch DPR Plant		
Amoritzed Capital Cost	R	-
Labour	R	1,80
Energy	R	10,30
Chemicals	R	0,52
Maintenance	R	0,94
Unit Cost	R	13,55
Check	R	13,55
Total		
Amoritzed Capital Cost	R	0,99
Raw Water Tariffs	R	2,06
Labour	R	2,60
Energy	R	7,47
Chemicals	R	0,51
Maintenance	R	1,09
Unit Cost	R	14,72
Check	R	14,72

Scenario C - 10ML/D (Procurement Model No.2)

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
						Paradyskloof WTW								
2019	1307	R 5 320 565,84	R 553 097,35	R 3 120 000,00	R 298 444,85	R 111 921,83	R 1 353 186,84	R 10 757 216,71	R 22,55	R 1,16	R 6,54	R 0,63	R 0,23	R 2,84
2020	1600	R 5 320 565,84	R 760 702,74	R 3 369 600,00	R 379 601,88	R 144 575,55	R 1 427 612,11	R 11 402 658,12	R 19,52	R 1,30	R 5,77	R 0,65	R 0,25	R 2,44
2021	1901	R 5 320 565,84	R 1 015 533,39	R 3 639 168,00	R 473 737,98	R 181 207,82	R 1 506 130,78	R 12 136 343,81	R 17,49	R 1,46	R 5,24	R 0,68	R 0,26	R 2,17
2022	2210	R 5 320 565,84	R 1 326 922,36	R 3 930 301,44	R 582 621,91	R 222 217,26	R 1 588 967,97	R 12 971 596,77	R 16,08	R 1,64	R 4,87	R 0,72	R 0,28	R 1,97
2023	2527	R 5 320 565,84	R 1 705 925,34	R 4 244 725,56	R 708 245,83	R 268 039,18	R 1 676 361,21	R 13 923 862,95	R 15,10	R 1,85	R 4,60	R 0,77	R 0,29	R 1,82
2024	2852	R 5 320 565,84	R 2 165 625,97	R 4 584 303,60	R 852 852,37	R 319 148,89	R 1 768 561,08	R 15 011 057,75	R 14,42	R 2,08	R 4,40	R 0,82	R 0,31	R 1,70
2025	3185	R 5 320 565,84	R 2 721 493,80	R 4 951 047,89	R 1 018 964,85	R 376 065,18	R 1 865 831,94	R 16 253 969,50	R 13,98	R 2,34	R 4,26	R 0,88	R 0,32	R 1,60
2026	3527	R 5 320 565,84	R 3 391 803,94	R 5 347 131,72	R 1 209 421,01	R 439 354,15	R 1 968 452,69	R 17 676 729,35	R 13,73	R 2,63	R 4,15	R 0,94	R 0,34	R 1,53
2027	3878	R 5 320 565,84	R 4 198 128,67	R 5 774 902,26	R 1 427 410,78	R 509 633,36	R 2 076 717,59	R 19 307 358,50	R 13,64	R 2,97	R 4,08	R 1,01	R 0,36	R 1,47
2028	4238	R 5 320 565,84	R 5 165 913,34	R 6 236 894,44	R 1 676 518,44	R 587 576,34	R 2 190 937,06	R 21 178 405,45	R 13,69	R 3,34	R 4,03	R 1,08	R 0,38	R 1,42
2029	4608	R 5 320 565,84	R 6 325 150,53	R 6 735 845,99	R 1 960 769,69	R 673 917,46	R 2 311 438,60	R 23 327 688,10	R 13,87	R 3,76	R 4,01	R 1,17	R 0,40	R 1,37
2030	4987	R 5 320 565,84	R 7 711 169,25	R 7 274 713,67	R 2 284 684,26	R 769 457,25	R 2 438 567,72	R 25 799 157,99	R 14,17	R 4,24	R 4,00	R 1,26	R 0,42	R 1,34
2031	5375	R 5 320 565,84	R 9 365 558,27	R 7 856 690,76	R 2 653 334,63	R 875 068,19	R 2 572 688,94	R 28 643 906,63	R 14,60	R 4,77	R 4,00	R 1,35	R 0,45	R 1,31
2032	5774	R 5 320 565,84	R 11 337 246,19	R 8 485 226,03	R 3 072 411,58	R 991 700,90	R 2 714 186,83	R 31 921 337,37	R 15,15	R 5,38	R 4,03	R 1,46	R 0,47	R 1,29
2033	6183	R 5 320 565,84	R 13 683 764,52	R 9 164 044,11	R 3 548 297,42	R 1 120 390,99	R 2 863 467,11	R 35 700 529,99	R 15,82	R 6,06	R 4,06	R 1,57	R 0,50	R 1,27
2034	6603	R 5 320 565,84	R 16 472 724,22	R 9 897 167,64	R 4 088 147,60	R 1 262 266,38	R 3 020 957,80	R 40 061 829,48	R 16,62	R 6,83	R 4,11	R 1,70	R 0,52	R 1,25
2035	7034	R 5 320 565,84	R 19 783 541,39	R 10 688 941,05	R 4 699 981,95	R 1 418 555,32	R 3 187 110,48	R 45 098 696,03	R 17,57	R 7,71	R 4,16	R 1,83	R 0,55	R 1,24
2036	7476	R 5 320 565,84	R 23 709 453,79	R 11 544 056,33	R 5 392 786,33	R 1 590 595,05	R 3 362 401,56	R 50 919 858,89	R 18,66	R 8,69	R 4,23	R 1,98	R 0,58	R 1,23
2037	7929	R 5 320 565,84	R 28 359 876,24	R 12 467 580,84	R 6 176 626,14	R 1 779 841,19	R 3 547 333,64	R 57 651 823,89	R 19,92	R 9,80	R 4,31	R 2,13	R 0,61	R 1,23
2038	8394	R 5 320 565,84	R 33 863 151,65	R 13 464 987,30	R 7 062 772,92	R 1 987 877,98	R 3 742 436,99	R 65 441 792,69	R 21,36	R 11,05	R 4,39	R 2,31	R 0,65	R 1,22
2039	8871	R 5 320 565,84	R 40 369 763,04	R 14 542 186,29	R 8 063 845,52	R 2 216 429,34	R 3 948 271,03	R 74 461 061,05	R 23,00	R 12,47	R 4,49	R 2,49	R 0,68	R 1,22
	36668373,03							R 629 646 881,03	R 17,17					

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs: Annual Cost Rands	Combined Costs: Unit Cost R/kl
						Stellenbosch DPR Plant								
2019	10000	R30 162 362,71	R 2 730 000,00	R 15 142 408,96	R 1 048 629,83	R 1 908 280,37	R 50 991 681,88	R 13,97	R 0,75	R 4,15	R 0,29	R 0,52	R 61 748 898,58	R 14,96
2020	10000	R30 162 362,71	R 2 948 400,00	R 16 396 200,42	R 1 106 304,47	R 2 013 235,79	R 52 626 503,40	R 14,42	R 0,81	R 4,49	R 0,30	R 0,55	R 64 029 161,52	R 15,12
2021	10000	R30 162 362,71	R 3 184 272,00	R 17 753 805,82	R 1 167 151,22	R 2 123 963,76	R 54 391 555,51	R 14,90	R 0,87	R 4,86	R 0,32	R 0,58	R 66 527 899,32	R 15,31
2022	10000	R30 162 362,71	R 3 439 013,76	R 19 223 820,94	R 1 231 344,53	R 2 240 781,77	R 56 297 323,71	R 15,42	R 0,94	R 5,27	R 0,34	R 0,61	R 69 268 920,48	R 15,54
2023	10000	R30 162 362,71	R 3 714 134,86	R 20 815 553,31	R 1 299 068,48	R 2 364 024,76	R 58 355 144,13	R 15,99	R 1,02	R 5,70	R 0,36	R 0,65	R 72 279 007,09	R 15,81
2024	10000	R30 162 362,71	R 4 011 265,65	R 22 539 081,13	R 1 370 517,25	R 2 494 046,12	R 60 577 272,87	R 16,60	R 1,10	R 6,18	R 0,38	R 0,68	R 75 588 330,62	R 16,11
2025	10000	R30 162 362,71	R 4 332 166,90	R 24 405 317,05	R 1 445 895,70	R 2 631 218,66	R 62 976 961,02	R 17,25	R 1,19	R 6,69	R 0,40	R 0,72	R 79 230 930,52	R 16,46
2026	10000	R30 162 362,71	R 4 678 740,25	R 26 426 077,30	R 1 525 419,96	R 2 775 935,69	R 65 568 535,92	R 17,96	R 1,28	R 7,24	R 0,42	R 0,76	R 83 245 265,27	R 16,86
2027	10000	R30 162 362,71	R 5 053 039,47	R 28 614 156,50	R 1 609 318,06	R 2 928 612,15	R 68 367 488,90	R 18,73	R 1,38	R 7,84	R 0,44	R 0,80	R 87 674 847,40	R 17,31
2028	10000	R30 162 362,71	R 5 457 282,63	R 30 983 408,66	R 1 697 830,55	R 3 089 685,82	R 71 390 570,37	R 19,56	R 1,50	R 8,49	R 0,47	R 0,85	R 92 568 975,82	R 17,81
2029	10000	R30 162 362,71	R 5 893 865,24	R 33 548 834,89	R 1 791 211,24	R 3 259 618,54	R 74 655 892,62	R 20,45	R 1,61	R 9,19	R 0,49	R 0,89	R 97 983 580,72	R 18,38
2030	10000	R30 162 362,71	R 6 365 374,46	R 36 326 678,42	R 1 889 727,85	R 3 438 897,56	R 78 183 041,01	R 21,42	R 1,74	R 9,95	R 0,52	R 0,94	R 103 982 199,00	R 19,01
2031	10000	R30 162 362,71	R 6 874 604,42	R 39 334 527,40	R 1 993 662,88	R 3 628 036,92	R 81 993 194,34	R 22,46	R 1,88	R 10,78	R 0,55	R 0,99	R 110 637 100,96	R 19,71
2032	10000	R30 162 362,71	R 7 424 572,77	R 42 591 426,26	R 2 103 314,34	R 3 827 578,95	R 86 109 255,05	R 23,59	R 2,03	R 11,67	R 0,58	R 1,05	R 118 030 592,42	R 20,50
2033	10000	R30 162 362,71	R 8 018 538,59	R 46 117 996,36	R 2 218 996,63	R 4 038 095,80	R 90 555 990,10	R 24,81	R 2,20	R 12,64	R 0,61	R 1,11	R 126 256 520,08	R 21,37
2034	10000	R30 162 362,71	R 8 660 021,68	R 49 936 566,46	R 2 341 041,45	R 4 260 191,07	R 95 360 183,36	R 26,13	R 2,37	R 13,68	R 0,64	R 1,17	R 135 422 012,84	R 22,35
2035	10000	R30 162 362,71	R 9 352 823,42	R 54 071 314,16	R 2 469 798,73	R 4 494 501,57	R 100 550 800,59	R 27,55	R 2,56	R 14,81	R 0,68	R 1,23	R 145 649 496,62	R 23,43
2036	10000	R30 162 362,71	R 10 101 049,29	R 58 548 418,97	R 2 605 637,66	R 4 741 699,16	R 106 159 167,79	R 29,08	R 2,77	R 16,04	R 0,71	R 1,30	R 157 079 026,68	R 24,63
2037	10000	R30 162 362,71	R 10 909 133,23	R 63 396 228,06	R 2 748 947,73	R 5 002 492,61	R 112 219 164,35	R 30,74	R 2,99	R 17,37	R 0,75	R 1,37	R 169 870 988,24	R 25,96
2038	10000	R30 162 362,71	R 11 781 863,89	R 68 645 435,75	R 2 900 139,85	R 5 277 629,71	R 118 767 431,91	R 32,54	R 3,23	R 18,81	R 0,79	R 1,45	R 184 209 224,61	R 27,44
2039	10000	R30 162 362,71	R 12 724 413,00	R 74 329 277,83	R 3 059 647,55	R 5 567 899,34	R 125 843 600,43	R 34,48	R 3,49	R 20,36	R 0,84	R 1,53	R 200 304 661,48	R 29,08
	76650000						R 1 671 940 759,25	R 21,81					R 2 301 587 640,29	R 20,31

Paradyskloof WTW		
Amortized Capital Cost	R	3,05
Raw Water Tariffs	R	6,38
Labour	R	4,29
Energy	R	1,57
Chemicals	R	0,49
Maintenance	R	1,39
Unit Cost	R	17,17
Check	R	17,17
Stellenbosch DPR Plant		
Amortized Capital Cost	R	8,26
Labour	R	1,80
Energy	R	10,30
Chemicals	R	0,52
Maintenance	R	0,94
Unit Cost	R	21,81
Check	R	21,81
Total		
Amortized Capital Cost	R	6,58
Raw Water Tariffs	R	2,06
Labour	R	2,60
Energy	R	7,47
Chemicals	R	0,51
Maintenance	R	1,09
Unit Cost	R	20,31
Check	R	20,31

Scenario C - 20ML/D (Procurement Model No.1)

Paradyskloof WTW

Year	Capacity (kl/d)	Amoritised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2020	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2021	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2022	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2023	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2024	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2025	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2026	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2027	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2028	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2029	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2030	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2031	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2032	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2033	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2034	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2035	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2036	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2037	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2038	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2039	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	0							R -	#DIV/0!					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amoritized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs: Annual Cost Rands	Combined Costs: Unit Cost R/kl
2019	11307	R0,00	R 3 525 000,00	R 16 569 407,17	R 1 695 925,53	R 3 504 981,97	R 25 295 314,67	R 6,13	R 0,85	R 4,01	R 0,41	R 0,85	R 25 295 314,67	R 6,13
2020	11600	R0,00	R 3 807 000,00	R 18 404 927,46	R 1 803 488,55	R 3 697 755,98	R 27 713 171,99	R 6,55	R 0,92	R 4,46	R 0,44	R 0,90	R 27 713 171,99	R 6,55
2021	11901	R0,00	R 4 111 560,00	R 20 443 834,39	R 1 918 144,36	R 3 901 132,56	R 30 374 671,30	R 6,99	R 1,00	R 4,95	R 0,46	R 0,95	R 30 374 671,30	R 6,99
2022	12210	R0,00	R 4 440 484,80	R 22 708 668,73	R 2 040 379,97	R 4 115 694,85	R 33 305 228,35	R 7,47	R 1,08	R 5,50	R 0,49	R 1,00	R 33 305 228,35	R 7,47
2023	12527	R0,00	R 4 795 723,58	R 25 224 469,73	R 2 170 717,21	R 4 342 058,06	R 36 532 968,59	R 7,99	R 1,16	R 6,11	R 0,53	R 1,05	R 36 532 968,59	R 7,99
2024	12852	R0,00	R 5 179 381,47	R 28 019 052,11	R 2 309 715,21	R 4 580 871,26	R 40 089 020,05	R 8,55	R 1,25	R 6,79	R 0,56	R 1,11	R 40 089 020,05	R 8,55
2025	13185	R0,00	R 5 593 731,99	R 31 123 313,71	R 2 457 973,23	R 4 832 819,17	R 44 007 838,10	R 9,14	R 1,36	R 7,54	R 0,60	R 1,17	R 44 007 838,10	R 9,14
2026	13527	R0,00	R 6 041 230,55	R 34 571 577,28	R 2 616 133,61	R 5 098 624,23	R 48 327 565,67	R 9,79	R 1,46	R 8,38	R 0,63	R 1,24	R 48 327 565,67	R 9,79
2027	13878	R0,00	R 6 524 528,99	R 38 401 970,18	R 2 784 884,97	R 5 379 048,56	R 53 090 432,70	R 10,48	R 1,58	R 9,30	R 0,67	R 1,30	R 53 090 432,70	R 10,48
2028	14238	R0,00	R 7 046 491,31	R 42 656 846,13	R 2 964 965,67	R 5 674 896,23	R 58 343 199,33	R 11,23	R 1,71	R 10,34	R 0,72	R 1,38	R 58 343 199,33	R 11,23
2029	14608	R0,00	R 7 610 210,62	R 47 383 253,73	R 3 157 167,51	R 5 987 015,53	R 64 137 647,38	R 12,03	R 1,84	R 11,48	R 0,76	R 1,45	R 64 137 647,38	R 12,03
2030	14987	R0,00	R 8 219 027,46	R 52 633 456,98	R 3 362 339,75	R 6 316 301,38	R 70 531 125,57	R 12,89	R 1,99	R 12,75	R 0,81	R 1,53	R 70 531 125,57	R 12,89
2031	15375	R0,00	R 8 876 549,66	R 58 465 513,40	R 3 581 393,38	R 6 663 697,96	R 77 587 154,39	R 13,83	R 2,15	R 14,17	R 0,87	R 1,61	R 77 587 154,39	R 13,83
2032	15774	R0,00	R 9 586 673,63	R 64 943 916,36	R 3 815 305,78	R 7 030 201,34	R 85 376 097,12	R 14,83	R 2,32	R 15,74	R 0,92	R 1,70	R 85 376 097,12	R 14,83
2033	16183	R0,00	R 10 353 607,53	R 72 140 308,55	R 4 065 125,72	R 7 416 862,42	R 93 975 904,21	R 15,91	R 2,51	R 17,48	R 0,98	R 1,80	R 93 975 904,21	R 15,91
2034	16603	R0,00	R 11 181 896,13	R 80 134 274,57	R 4 331 978,70	R 7 824 789,85	R 103 472 939,24	R 17,07	R 2,71	R 19,42	R 1,05	R 1,90	R 103 472 939,24	R 17,07
2035	17034	R0,00	R 12 076 447,82	R 89 014 221,39	R 4 617 072,76	R 8 255 153,29	R 113 962 895,26	R 18,33	R 2,93	R 21,57	R 1,12	R 2,00	R 113 962 895,26	R 18,33
2036	17476	R0,00	R 13 042 563,64	R 98 878 356,46	R 4 921 704,76	R 8 709 186,72	R 125 551 811,59	R 19,68	R 3,16	R 23,96	R 1,19	R 2,11	R 125 551 811,59	R 19,68
2037	17929	R0,00	R 14 085 968,73	R 109 835 774,23	R 5 247 267,03	R 9 188 191,99	R 138 357 201,98	R 21,14	R 3,41	R 26,61	R 1,27	R 2,23	R 138 357 201,98	R 21,14
2038	18394	R0,00	R 15 212 846,23	R 122 007 663,10	R 5 595 254,66	R 9 693 542,55	R 152 509 306,55	R 22,72	R 3,69	R 29,56	R 1,36	R 2,35	R 152 509 306,55	R 22,72
2039	18871	R0,00	R 16 429 873,93	R 135 528 646,31	R 5 967 273,33	R 10 226 687,39	R 168 152 480,96	R 24,41	R 3,98	R 32,84	R 1,45	R 2,48	R 168 152 480,96	R 24,41
	113318373						R 1 590 693 974,99	R 14,04					R 1 590 693 974,99	R 14,04

Paradyskloof WTW		
Amortized Capital Cost		0
Raw Water Tariffs		0
Labour		0
Energy		0
Chemicals		0
Maintenance		R0,00
Unit Cost		0
Check		R0,00
Stellenbosch DPR Plant		
Amoritized Capital Cost	R	-
Labour	R	1,57
Energy	R	10,67
Chemicals	R	0,63
Maintenance	R	1,17
Unit Cost	R	14,04
Check	R	14,04
Total		
Amortized Capital Cost	R	-
Raw Water Tariffs	R	-
Labour	R	1,57
Energy	R	10,67
Chemicals	R	0,63
Maintenance	R	1,17
Unit Cost	R	14,04
Check	R	14,04

Scenario C - 20ML/D (Procurement Model No.2)

Paradyskloof WTW

Year	Capacity (kl/d)	Amortised Capital Cost	Raw Water Tariffs Rands	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Raw Water Tariffs R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl
2019	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2020	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2021	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2022	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2023	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2024	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2025	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2026	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2027	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2028	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2029	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2030	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2031	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2032	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2033	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2034	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2035	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2036	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2037	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2038	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2039	0	R -	R -	R -	R -	R -	R -	R -	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	0							R -	#DIV/0!					

Stellenbosch DPR Plant / Combined Costs

Year	Capacity (kl/d)	Amortized Capital Cost	Labour Rands	Energy Rands	Chemicals Rands	Maintenance Rands	Annual Cost Rands	Unit Cost R/kl	Labour R/kl	Energy R/kl	Chemicals R/kl	Maintenance R/kl	Combined Costs: Annual Cost Rands	Combined Costs: Unit Cost R/kl
2019	11307	R55 399 897,79	R 3 525 000,00	R 16 569 407,17	R 1 695 925,53	R 3 504 981,97	R 80 695 212,45	R 19,55	R 0,85	R 4,01	R 0,41	R 0,85	R 80 695 212,45	R 19,55
2020	11600	R55 399 897,79	R 3 807 000,00	R 18 404 927,46	R 1 803 488,55	R 3 697 755,98	R 83 113 069,77	R 19,63	R 0,92	R 4,46	R 0,44	R 0,90	R 83 113 069,77	R 19,63
2021	11901	R55 399 897,79	R 4 111 560,00	R 20 443 834,39	R 1 918 144,36	R 3 901 132,56	R 85 774 569,08	R 19,75	R 1,00	R 4,95	R 0,46	R 0,95	R 85 774 569,08	R 19,75
2022	12210	R55 399 897,79	R 4 440 484,80	R 22 708 668,73	R 2 040 379,97	R 4 115 694,85	R 88 705 126,13	R 19,90	R 1,08	R 5,50	R 0,49	R 1,00	R 88 705 126,13	R 19,90
2023	12527	R55 399 897,79	R 4 795 723,58	R 25 224 469,73	R 2 170 717,21	R 4 342 058,06	R 91 932 866,37	R 20,11	R 1,16	R 6,11	R 0,53	R 1,05	R 91 932 866,37	R 20,11
2024	12852	R55 399 897,79	R 5 179 381,47	R 28 019 052,11	R 2 309 715,21	R 4 580 871,26	R 95 488 917,83	R 20,36	R 1,25	R 6,79	R 0,56	R 1,11	R 95 488 917,83	R 20,36
2025	13185	R55 399 897,79	R 5 593 731,99	R 31 123 313,71	R 2 457 973,23	R 4 832 819,17	R 99 407 735,89	R 20,66	R 1,36	R 7,54	R 0,60	R 1,17	R 99 407 735,89	R 20,66
2026	13527	R55 399 897,79	R 6 041 230,55	R 34 571 577,28	R 2 616 133,61	R 5 098 624,23	R 103 727 463,45	R 21,01	R 1,46	R 8,38	R 0,63	R 1,24	R 103 727 463,45	R 21,01
2027	13878	R55 399 897,79	R 6 524 528,99	R 38 401 970,18	R 2 784 884,97	R 5 379 048,56	R 108 490 330,49	R 21,42	R 1,58	R 9,30	R 0,67	R 1,30	R 108 490 330,49	R 21,42
2028	14238	R55 399 897,79	R 7 046 491,31	R 42 656 846,13	R 2 964 965,67	R 5 674 896,23	R 113 743 097,12	R 21,89	R 1,71	R 10,34	R 0,72	R 1,38	R 113 743 097,12	R 21,89
2029	14608	R55 399 897,79	R 7 610 210,62	R 47 383 253,73	R 3 157 167,51	R 5 987 015,53	R 119 537 545,16	R 22,42	R 1,84	R 11,48	R 0,76	R 1,45	R 119 537 545,16	R 22,42
2030	14987	R55 399 897,79	R 8 219 027,46	R 52 633 456,98	R 3 362 339,75	R 6 316 301,38	R 125 931 023,35	R 23,02	R 1,99	R 12,75	R 0,81	R 1,53	R 125 931 023,35	R 23,02
2031	15375	R55 399 897,79	R 8 876 549,66	R 58 465 513,40	R 3 581 393,38	R 6 663 697,96	R 132 987 052,18	R 23,70	R 2,15	R 14,17	R 0,87	R 1,61	R 132 987 052,18	R 23,70
2032	15774	R55 399 897,79	R 9 586 673,63	R 64 943 916,36	R 3 815 305,78	R 7 030 201,34	R 140 775 994,91	R 24,45	R 2,32	R 15,74	R 0,92	R 1,70	R 140 775 994,91	R 24,45
2033	16183	R55 399 897,79	R 10 353 607,53	R 72 140 308,55	R 4 065 125,72	R 7 416 862,42	R 149 375 802,00	R 25,29	R 2,51	R 17,48	R 0,98	R 1,80	R 149 375 802,00	R 25,29
2034	16603	R55 399 897,79	R 11 181 896,13	R 80 134 274,57	R 4 331 978,70	R 7 824 789,85	R 158 872 837,03	R 26,22	R 2,71	R 19,42	R 1,05	R 1,90	R 158 872 837,03	R 26,22
2035	17034	R55 399 897,79	R 12 076 447,82	R 89 014 221,39	R 4 617 072,76	R 8 255 153,29	R 169 362 793,05	R 27,24	R 2,93	R 21,57	R 1,12	R 2,00	R 169 362 793,05	R 27,24
2036	17476	R55 399 897,79	R 13 042 563,64	R 98 878 356,46	R 4 921 704,76	R 8 709 186,72	R 180 951 709,37	R 28,37	R 3,16	R 23,96	R 1,19	R 2,11	R 180 951 709,37	R 28,37
2037	17929	R55 399 897,79	R 14 085 968,73	R 109 835 774,23	R 5 247 267,03	R 9 188 191,99	R 193 757 099,76	R 29,61	R 3,41	R 26,61	R 1,27	R 2,23	R 193 757 099,76	R 29,61
2038	18394	R55 399 897,79	R 15 212 846,23	R 122 007 663,10	R 5 595 254,66	R 9 693 542,55	R 207 909 204,34	R 30,97	R 3,69	R 29,56	R 1,36	R 2,35	R 207 909 204,34	R 30,97
2039	18871	R55 399 897,79	R 16 429 873,93	R 135 528 646,31	R 5 967 273,33	R 10 226 687,39	R 223 552 378,75	R 32,45	R 3,98	R 32,84	R 1,45	R 2,48	R 223 552 378,75	R 32,45
	113318373						R 2 754 091 828,48	R 24,30					R 2 754 091 828,48	R 24,30

Paradyskloof WTW		
Amoritzed Capital Cost	R	-
Raw Water Tariffs	R	-
Labour	R	-
Energy	R	-
Chemicals	R	-
Maintenance	R	-
Unit Cost	R	-
Check	R	-
Stellenbosch DPR Plant		
Amoritzed Capital Cost	R	10,27
Labour	R	1,57
Energy	R	10,67
Chemicals	R	0,63
Maintenance	R	1,17
Unit Cost	R	24,30
Check	R	24,30
Total		
Amoritzed Capital Cost	R	10,27
Raw Water Tariffs	R	-
Labour	R	1,57
Energy	R	10,67
Chemicals	R	0,63
Maintenance	R	1,17
Unit Cost	R	24,30
Check	R	24,30