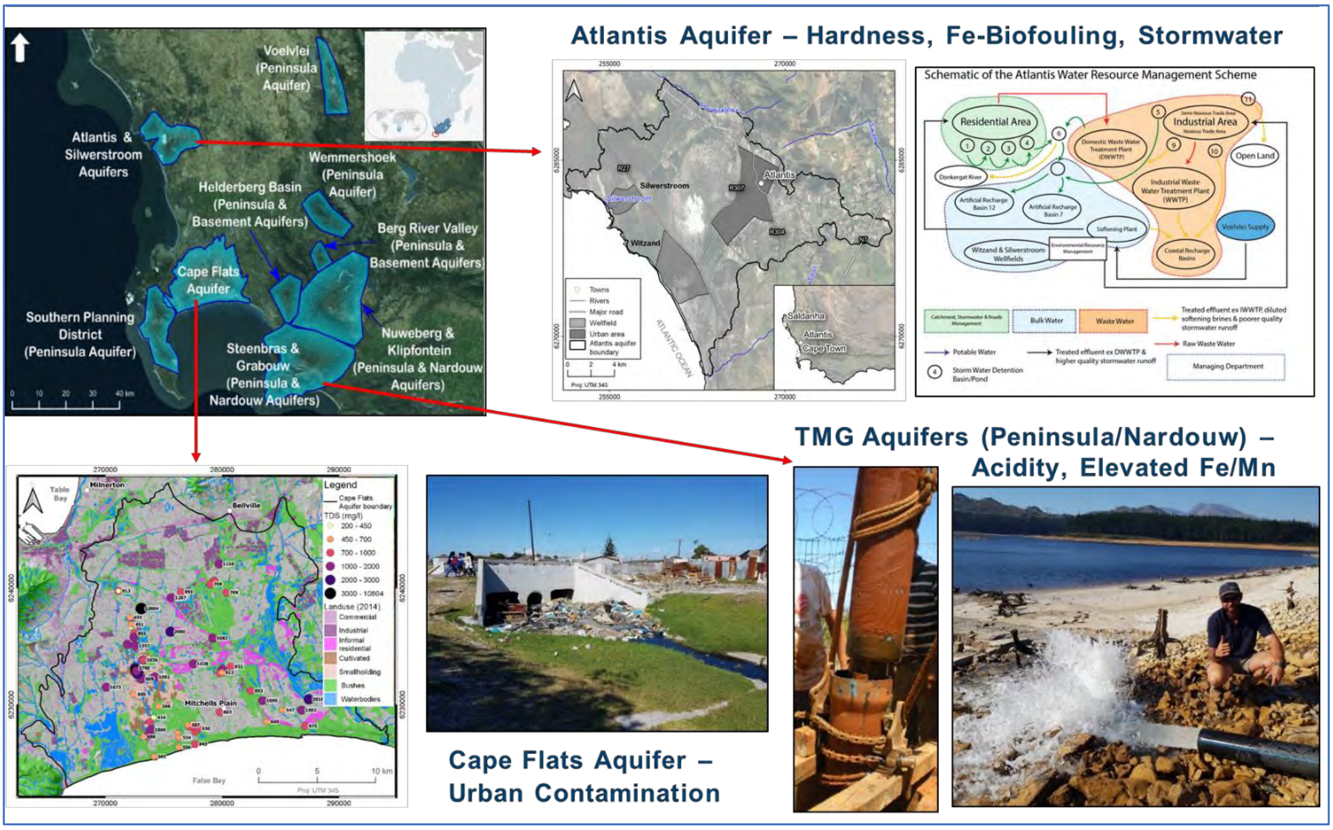
World Water Quality Alliance African Use Case Study Cape Town Aquifers

Deliverable 5: Summary Report

Dr K RIEMANN

World Water Quality Assessment Use Case Study – Cape Town Aquifers

Deliverable 5: Summary Report



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WWQA USE CASE – CAPE TOWN AQUIFERS: SUMMARY REPORT

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Executive Summary

UNEP appointed Dr K Riemann in October 2019 as Water Quality, Management and Groundwater Specialist to facilitate the Cape Town Major Aquifer System Use Case Study. The study structure and methodology for the Cape Town Aquifers Use Case differ slightly from the general structure applied for the other Use Cases in Lake Victoria and Volta basins. This Use Case study consists of three phases with related deliverables and is aligned with the principles and priorities of the City of Cape Town's "Cape Town Water Strategy – Our Shared Water Future" (CCT, 2019).

Aim

The central aim for all three initial use cases is the integration of in-situ measurements, remote sensing-based Earth Observation and water quality modelling data to derive the best possible current state of water quality combined with a multi-stakeholder driven process defining demand for water quality services. The ultimate objective was to provide an evidence base that links water quality hotspots to solutions and investment priorities. The results emanating from this approach are due to be shared widely with the World Water Quality Alliance partners for further consideration and illustration of the approach.

The Cape Town aquifer use case comprises various aquifers in and around Cape Town that are earmarked for water supply to the city. The Cape Flats aquifer underlying most of the city is highly vulnerable to pollution from land-use activities, including small-scale agriculture and sand mining, and from landfill sites, cemeteries, industrial areas and informal settlements without proper sanitation. This has led to salinization of the groundwater and contamination with nutrients, microbiological and industrial contaminants, hydrocarbons and, possibly, contaminants of emerging concern. Extensive in situ monitoring data, remote-sensing (Earth Observation) data, detailing land use and identifying pollution sources, and vulnerability and flow modelling were used in the assessment. Feeding into stakeholder engagement, groundwater protection zones were proposed as a potential assessment product. The high variability of natural groundwater quality and the lack of historic water quality data had prevented assessments of the current state of deterioration. Nonetheless, the findings can be extrapolated to other urban centres with similar geological settings.

The full report of the Cape Town Aquifer summarises the stakeholder engagement process, data assessment and hotspot identification, associated with each of the three aquifer systems investigated, and includes a description of the products developed as part of the study and as discussed with stakeholders and the water quality actions taken or planned by the City of Cape Town. It concludes with recommendations regarding the way forward.

Methodology

Due to the hidden, underground nature of groundwater, the standard remote sensing techniques of the Global Water Quality Assessment (GWQA) are not applicable. Hence, remote sensing was used to map and monitor proxies, such as land use, as indication for the risk of groundwater pollution. This was achieved with high-resolution satellite Sentinel-2, combined with high-resolution aerial imagery.

The modelling approach for this Use Case was different to the other Use Cases in Lake Victoria and Volta Basin, as it comprised not only groundwater flow and transport models to predict groundwater quality under different future scenarios but also GIS-based modelling of aquifer vulnerability and risk to pollution. Thus, modelling was utilised for both the assessment and the product and services development.

One of the success factors for the Cape Town Aquifers Use Case was the ability of the coordination and assessment team of the facilitator Dr K Riemann and the WWQA member Umvoto Africa to integrate the three different data types of the triangle approach, i.e. in-situ measurements, remote sensing data and numerical modelling, on a sub-catchment scale. This required an understanding of the complex surface and groundwater systems and their interaction (flow paths and fluxes) in the urban environment and experience in the different data types. Going forward, there is a need for mapping and modelling the surface – groundwater interaction in terms of flow and contamination under current status and future conditions.

A very comprehensive database of > 30 000 water quality data for the three aquifers has been established through the groundwater development projects by the City of Cape Town and utilized for the use case, including historical data (e.g. since 1970s for Atlantis), groundwater and surface water quality data from national and municipal programmes (e.g. landfills, cemeteries and water treatment works), and recent data collected during the groundwater development projects by the City of Cape Town.

Stakeholder Engagement Process

The success of the Cape Town Use Case was also driven by a robust stakeholder engagement process that drew on an engagement that has developed over many years and included a local stakeholder (communities and institutions) engagement process.

Due to the interest by the public and concerned organisations in the groundwater development by the city, a wide range of stakeholders are involved in project specific meetings, the environmental forum and monitoring committees that meet on a regular basis, representing the municipality, regulatory authorities, environmental action groups, NGOs and academia. The Cape Town Aquifer Use Case built on these existing stakeholder networks and structures, as mentioned above, that were established earlier as part of the groundwater development projects by the City of Cape Town (CCT). Several of these meetings were utilised for the stakeholder engagement to inform stakeholders about the WWQA Use Case and to co-design the proposed products and services that form part of this Use Case.

Hotspots and Demands

<u>Atlantis Aquifer</u>

The Atlantis Aquifer is a Quaternary primary aquifer system comprised primarily of ~30-50 m dune sediment (with some alluvial channels along the basal contact with the older basement rocks of the Malmesbury Group and Cape Granite Suite). Based on the general, trace element and organic chemistry analysis, comparison to drinking water and treatment of Atlantis groundwater and infiltration basins, the following potential contamination sources and hazards have been identified:

- Effluents from the Wesfleur Wastewater Treatment Works (WWTW) have elevated concentrations of multiple parameters, including EC, nitrate, orthophosphate, sodium, chloride, potassium and sulphate, and raises the salinity of surrounding groundwaters.
- Stormwater from the industrial area shows high concentrations of multiple parameters including salinity, total aluminium, iron, dissolved arsenic, ammonia, and nitrate.
- Small scale farming occurs in the northern and north eastern margins of the aquifer and although no farming related nutrient pollution has been observed, herbicides were detected in groundwater samples, and in the treated effluents, related either to their production, use or disposal.
- Lack of adequate sanitation infrastructure in the informal Atlantis settlements can lead to nitrate and faecal contamination of the aquifer. Leaky or faulty sewage systems (septic tanks, pipes and pump stations) in formal settlements can also lead to contaminations.

<u>Cape Flats Aquifer</u>

The urban setting of the Cape Flats Aquifer (CFA) results in salinization and anthropogenic contamination with nutrients, microbiological and industrial contaminants, hydrocarbons and potentially CECs.

- The salinity is highly variable (EC ~120 mS/m) and shows elevated EC values (~300-700 mS/m) in some areas due to natural conditions and agricultural activities, with one borehole close to a stormwater canal having EC of above 200 mS/m due to very high chloride concentrations.
- Nitrates are generally low (i.e. there was no evidence found of diffuse fertilizer contamination within agricultural area), with elevated concentrations linked to point sources such as WWTW and cemeteries. Higher nitrate concentrations are also found in some canals and rivers due to untreated sewage and storm water entering the surface water system.

- Presence of elevated contaminants such as hexavalent chromium and trichloroethylene in CFA groundwater is shown near historical closed industrial areas and landfill sites (e.g. Swartklip area, due to munitions dump/testing).

In essence, CFA groundwater will require extensive treatment via small scale, local treatment works prior to entering the distribution network, as indicated by the exceedances of water quality guideline limits.

TMG Aquifer

The TMG aquifers are located in a pristine environment and do not exhibit any evidence of altered or impacted water quality unlike the other two aquifers included in the use case which are located in urban settings. However, there is a concern of naturally elevated iron and manganese concentrations, especially in the deeper Peninsula Aquifer. Given the pristine and sensitive environment of the TMG Aquifer outcrop areas, this has implications for the risk of discharging of groundwater into the receiving environment, either intentionally or accidentally.

Investigation of these potential impacts has shown that they can be avoided or mitigated against with proper management and establishment of mitigation measures.

Products and Services

Several potential products and services have been identified during the stakeholder engagement process undertaken as part of this Use Case, of which two different products have been developed by Umvoto Africa and The Umvoto Foundation, covering topics of aquifer protection and community engagement, respectively. These products are summarized below and provide examples for solutions to water quality concerns for water practitioners working on groundwater quality including partners of the World Water Quality Alliance.

Aquifer Protection Scheme

Based on the feedback from stakeholders, a Groundwater Protection Scheme for the Cape Flats Aquifer (CFA) was developed in order to ensure the protection of groundwater quality to abstraction boreholes. The Groundwater Protection Scheme is composed of several components, namely Groundwater Protection Zones (GPZ's), vulnerability mapping and ranking, potentially contaminating activities (PCA), and a remediation plan. Currently, the GPZ delineation, vulnerability mapping and PCA identification have been completed. A remediation plan for one of the identified pollution sources has been developed and approved by the regulatory authority for implementation.

Social Engagement and Advocacy

In parallel to the technical and scientific assessment and development of the protection zones, a social engagement process was initiated, which resulted in two initial products that highlight the strength and capacity for the approach for long-lasting and sustainable awareness and solutions.

A collaboration between scientists, engineers, artists and diverse stakeholder and communities led to the development of a concept note on realizing a **Critical Zone Observatory** (CZO) for the Cape Flats Aquifer and surrounding area, incorporating natural processes, socio-economic aspects and art.

The Critical Zone Observatory (CZO) provides the common reference point and platform for bringing various groups of people together, such as scientists studying the physical and social environments, engineers and other practitioners altering the environments, the officials administering them, and – importantly – the communities living in and with these spaces.

The concept and approach, described above, has been implemented in an **Environment and Water Stewardship** course for the local community in one of the collaborative zones, which was prepared and run in November 2019 at the Edith Stephens Nature Reserve in Cape Town. The Edith Stephens Nature Reserve is situated close to the Philippi Horticultural Area and is surrounded by formal and informal settlements, light industry and agricultural land. The Lotus Canal (identified as potential pollution source in the assessment) flows directly pass the Nature Reserve. During high flows, peak flows are diverted into ponds on the Nature Reserve.

Water Quality Action Plan

Due to the fact that there are three very distinct aquifers with different water quality challenges and the involvement of different role players and consulting engineers, it was not achievable to prepare a coherent water quality action plan across the study that covers all three distinct aquifers. However, elements of a water quality action plan for each aquifer haven been developed and the possible solutions listed in the TOR were addressed.

Challenges

The Cape Town Aquifers Use Case differed from the other use cases in its approach and methodology, as its focus was on local to sub-regional aquifers as water resource and was linked to ongoing investigation by the City of Cape Town. Several challenges were encountered:

- The methodology for the Use Case had to be adapted during the study, as the standard approach for surface water quality assessment from the GWQA was not applicable. However, the triangulation approach was successfully adapted and implemented to support the assessment and product development. It is envisaged that this adapted approach can be implemented for other aquifers and upscaled for regional assessments.
- Due to the COVID-19 pandemic and associated restrictions on travel and meetings, the stakeholder engagement was limited to less regular online meetings. This caused a delay in some of the work and deliverables, but was not detrimental to the outcome of the Use Case, as a solid and coherent stakeholder network and engagement structure had been build prior to commencing the study.

Way Forward

Going forward, this stakeholder engagement will be expanded by including different organisations, spanning from household level and communities to municipal and national institutions. This will allow for establishing the appropriate scale for and integration of different groundwater management activities across sectors and tiers of government, thus, requiring different interventions, communication strategies and governance structures.

This continued stakeholder engagement process should also include a continuation of the water and environmental stewardship initiative at a grass-roots level, integrated with government, civil society and private sector initiatives. This could use art/culture/music as a science communication and knowledge exchange tool using an African inspired and adapted 'Renaissance approach' to science-culture-sustainability diplomacy.

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a	-	annum
AA	-	Atlantis Aquifer
AMCOW	-	African Ministerial Committee on Water
AWRMS	-	Atlantis Water Resource Management Scheme
Ca	-	Calcium
CCT	-	City of Cape Town
CEC	-	Chemicals of emerging concern
CFA	-	Cape Flats Aquifer
CFAMS	-	Cape Flats Aquifer Management Scheme
Cl	-	Chloride
CMA	-	Catchment Management Agency
COD	-	Chemical Oxygen Demand
CRB	-	Coastal Recharge Basin
CZO	-	Critical Zone Observatory
DCE	-	Dichloroethylene
DEA&DP	-	Department of Environmental Affairs and Development Planning
DEFF	-	Department of Environmental Affairs, Forestry and Fisheries
DRASTIC	-	**D**epth to water table, net **R**echarge, **A**quifer media, **S**oil media, **T**opography, **I**mpact of the vadose zone, hydraulic **C**onductivity
DSVI	-	DRASTIC Specific Vulnerability Index
DWS	-	Department of Water and Sanitation
e.g.	-	For example
EC	-	Electrical Conductivity
EFG	-	Environmental Focus Group
EO	-	Earth Observation
EP	-	Exit Probability
EPA	-	Environmental Protection Agency
EPH	-	Extractable petroleum compounds
EWG	-	Environmental Working Group
Fe	-	Iron
FFEM	-	Framework for Freshwater Ecosystem Management
FoG	-	Friends of Groundwater
GDE	-	Groundwater dependent ecosystems
GEMS/Water	-	Global Environment Monitoring System for Water
GEMStat	-	Global Environment Monitoring System – Freshwater Quality Database
GPA	-	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
GPNM	-	Global Partnership on Nutrient Management
GPZ	-	Groundwater Protection Zone
GW2I	-	Global Wastewater Initiative
GWD	-	Groundwater Division of the Geological Society of South Africa
GWQA	-	Global Water Quality Assessment
ha	-	Hectare
HCO	-	Hydrocarbonate
IAH	-	International Association of Hydrogeologists
ICU	-	Intensive Collaborative Unit
ICWRGC	-	International Centre for Water Resources and Global Change
IDP	-	Integrated Development Plan
IRF	-	Irrigation Return Flow
IWRM	-	Integrated Water Resource Management
JRC	-	Joint Research Centre of the European Commission
K	-	Hydraulic conductivity

km	-	Kilometre
l/s	-	litres per second
LE	-	Life Expectancy
m	-	Meter
m^3	-	meter cubed
Ma	-	Million years
MAR	-	Management Aquifer Recharge
Mg	-	Magnesium
Ml	-	Mega litres
mm	-	Millimetre
Mn	-	Manganese
mS/m	-	milli Siemens per meter
Na	-	Sodium
NWA	-	National Water Act, Act 36 of 1998
NWP	-	New Water Programme
p.	-	Page
PCA	-	Potentially contaminating activities
PCE	-	Tetrachloroethylene
PHA	-	Philippi Horticultural Area
RS	-	Remote sensing
SANParks	-	South African National Parks
SANS	-	South African National Standard
SDF	-	Spatial Development Framework
SDG	-	Sustainable Development Goals
TCE	-	Trichloroethylene
TDS	-	Total dissolved solids
TMG	-	Table Mountain Group
TMGA	-	Table Mountain Group Aquifer
TOC	-	Total organic carbon
ToR	-	Terms of Reference
UFZ	-	Umweltforschungs Zentrum
UN	-	United Nations
UNEA	-	United Nations Environmental Assembly
UNEP	-	United Nations Environment Programme
WCWSS	-	Western Cape Water Supply System
WMA	-	Water Management Area
WMO	-	World Meteorological Organisation
WSA	-	Water Services Authority
WSDP	-	Water Services Development Plan
WSP	-	Water Services Provider
WSUD	-	Water sensitive urban design
WTW	-	Water Treatment Works
WWQA	-	World Water Quality Alliance
WWTW	-	Wastewater Treatment Works
µg	-	micro gram

Definitions

Alliance	World Water Quality Alliance,
Study	The African Use Case Study for the Cape Town Major Aquifers
Project	Groundwater development projects undertaken by the City of Cape Town for the three aquifers

1. INTRODUCTION

1.1. Global Water Quality Assessment

1.1.1. Background

United Nations Environment Programme (UNEP) has global custodianship of data collection for indicators regarding the Sustainable Development Goals (SDG) targets 6.3, 6.5 and 6.6 (all connected to water quality) and received the mandate (UNEP/EA.3/Res.10 Dec 2017) to investigate water quality globally in depth, including and beyond SDG 6.3 into emerging issues, global trends, nexus focus, protection, governance and services.

A preliminary *Snapshot of the World's Water Quality: Towards a Global Assessment* was published in 2016 (UNEP, 2016) revealing the lack of monitoring data particularly in developing countries, rendering the sole reliance on measured data impossible. The full Global Water Quality Assessment (GWQA) thus needs to employ a data fusion approach combining in-situ monitoring, modelling and remote sensing and is designed to illustrate causal chain cases from drivers to impacts.

The major components of the Global Water Quality Assessment are:

1) Baseline Assessment of worldwide water quality in surface and groundwater bodies,
2) Scenario Analysis of future pathways of water quality in the freshwater system and its compartments, and
3) Mitigation Options, i.e. information on how to protect or restore water quality.

The ambition of the Global Water Quality Assessment is to work at different scales:

1) The global scale to provide a consistent context regarding the state of water quality and to identify the water bodies being at risk;
2) The water body to river basin scale with the engagement of stakeholders to use and to tie the information produced in order to achieve their needs and inform the implementation of the 2030 Agenda for Sustainable Development at relevant scales.

Following UNEA Resolution 3/10 on "Addressing water pollution to protect and restore water-related ecosystems" and building upon the report "A Snapshot of the World's Water Quality" (UNEP, 2016), the United Nations Environment Programme is cooperating with relevant organizations in the World Water Quality Alliance (WWQA, in the following also referred to as "Alliance", see below) to develop a Global Water Quality Assessment (GWQA) for consideration by UNEA 6 in 2023 (marked as UNEA 5 in **Figure 1-1**).

Where relevant and applicable, the GWQA will draw upon UNEP's recent work on harmonizing environmental assessments and the management of freshwater ecosystems, namely the Guidelines for Conducting Integrated Environmental Assessments as well as the Framework for Freshwater Ecosystem Management (FFEM). It also builds on related activities of the Global Environment Monitoring System for Water (GEMS/Water) to enhance the capacity to collect and share water quality monitoring data and of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) and its Global Wastewater Initiative (GW2I) and the Global Partnership on Nutrient Management (GPNM).

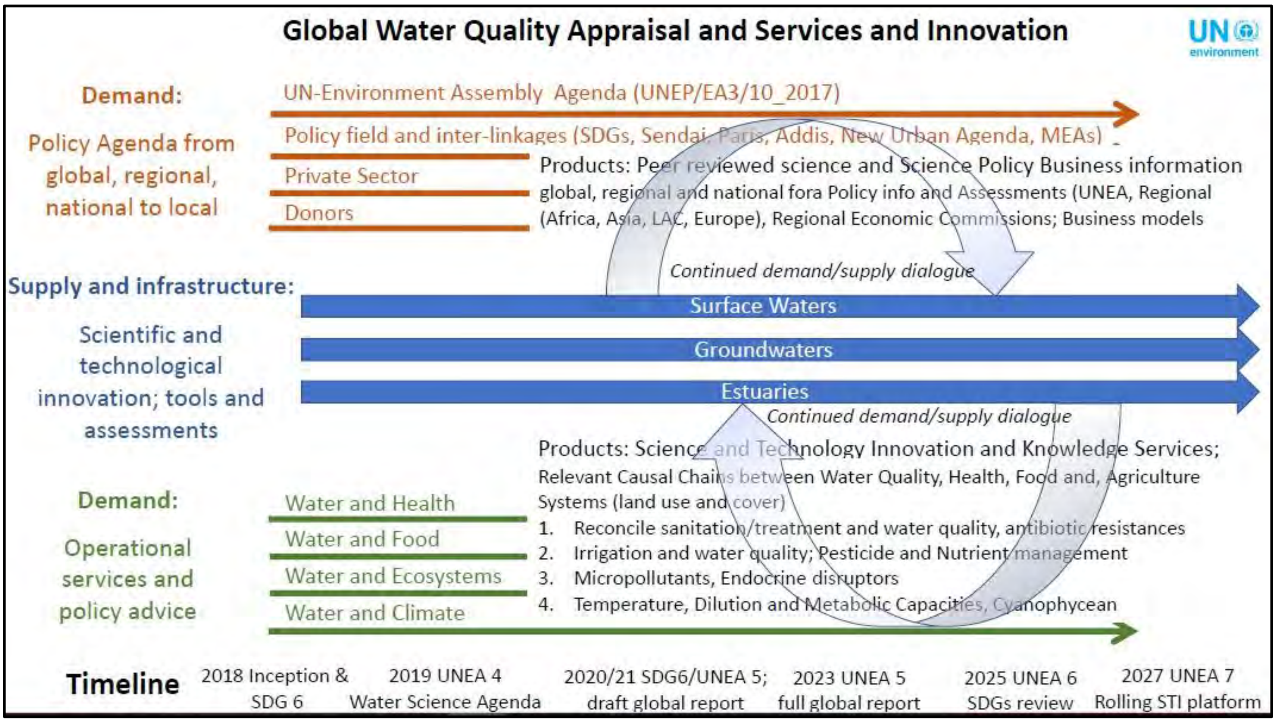


Figure 1-1: Processes and Aspects of Global Water Quality Assessment (Kremer, 2018)

1.1.2. World Water Quality Alliance

To kick off the development of the assessment, UNEP, with support from the World Meteorological Organization (WMO), organized an inception workshop in November 2018. During the workshop, UNEP convened around 50 organizations (UN, research, civil society, private sector), which had expressed interest to engage in the assessment and to also work with UNEP in co-designing agendas and action around emerging issues. This process with strong support from donors marked the emergence of a World Water Quality Alliance as an open community of practice. UNEP, and more specifically the Global Environment Monitoring Unit in Science Division, fulfils the coordination function of the Alliance, through the WWQA Coordination Team.

The World Water Quality Alliance (WWQA) represents a voluntary and flexible global multi-stakeholders network that advocates the central role of freshwater quality in achieving prosperity and sustainability; it explores and communicates water quality risks in global regional, national and local contexts and points towards solutions for maintaining and restoring ecosystem and human health and well-being with an aim to serve countries throughout the lifetime of the 2030 Agenda for Sustainable Development and beyond.

As part of the delivery of this mandate, the WWQA will focus on deliverables on three levels:

1. A global assessment of freshwater quality drawing on science – technology – innovation, including a data fusion approach combining in-situ monitoring, modelling and remote sensing. It will expand to additional sources and illustrate causal chain cases to highlight water quality risks and opportunities, in response to UNEA Resolution 3/10.
2. Horizon scanning, agenda setting and investigating selected priority topics based on a collective prioritization process to identify persistent or emerging water quality issues of key environmental and socio-economic concern and,
3. Following a bottom up-approach, co-designing and operationalization of water quality related services and products, based on a moderated in-country stakeholder driven bottom-up process to identify local demands and needs.

The Alliance was officially launched at the 2nd global meeting at the Joint Research Centre (JRC) of the European Commission in Ispra, Italy on 19 September 2019.

Mission Statement of World Water Quality Alliance:

The World Water Quality Alliance (WWQA) forms an open, global consortium, pooling expertise on water quality science and technology innovation. It aims at providing a participatory platform for water quality assessments and co-design of tailored and demand-driven services. It addresses priority topics relevant to water governance, scalable water solutions and emerging issues in water management.

1.2. WWQA – African Use Cases

During the WWQA Inception Workshop held in November 2018 in Geneva, the Alliance decided to pilot and demonstrate current capabilities and future water quality information services through three case studies in Africa (in the following referred to as Use Cases). These Use Cases provide an initial testbed that puts the quality of surface and ground waters into the context of the local 2030 Agenda and its multiple linkages across the Sustainable Development Goals (SDG). Central in these initial test cases will be the integration of in-situ and remote sensing-based Earth Observation and water quality modelling data to derive the best possible current state of water quality (baseline) with a multi-stakeholder driven process defining demand for water quality services. The ultimate objective is to provide an evidence base that links water quality pollution hotspots to solutions and investment priorities. The results produced by the Use Cases in this two-pronged approach are meant to be shared widely with the World Water Quality Alliance for further consideration.

The Use Cases are funded as a pilot to demonstrate the value added of an Alliance approach to bridge from data to solutions. The Africa Use Case process comprised transdisciplinary engagement with in-country partners through a bottom-up approach aimed at using experience in global problems to support local solutions. They combine data assimilation with transdisciplinary engagement and joint design of water quality products for operational use. Integral to the projects is a moderated, in-country, stakeholder-driven process to identify and address local needs (local solutions to global problems). The co benefit for the assessment originates in the decision to align the Use Case approach to the selection of case studies of the assessment and follow the triangulation approach (see below). In addition, and - different from the assessment - the Use Cases also test out the on-ground stakeholder engagement process towards piloting and testing co-designed products to address key water quality issues at a local level.

1.2.1. Objectives

The project aims are expanded upon within the UNEP/WWQA case studies work package draft:

- Build the “use case” for a Global Water Quality Assessment by means of the piloting and demonstration of current capabilities, future information and services of the World Water Quality Alliance (the “Alliance”) through these three (and other potential) case studies.
- Proof of concept for the WWQA to contribute into the innovation data assimilation platform from different available sources (in-situ, modelling and EO). This work will feed into a broader project under development providing a global water quality baseline, and several more pilots globally that aim to look into causal chain relations and solutions along nexus interactions.
- Provide an evidence base that links water quality hotspots to solutions and investment priorities. Crucial is a multi-stakeholder in-country driven process defining demand for water quality services, with potential stakeholders including government, academia, civil society and (inter)national organisations.

1.2.2. Selection

Based on the objective and aim for use cases and the identified criteria, the participants of the 1st WWQA Workshop in Geneva on 28-29 November 2018 selected three Africa Use Cases comprising different water quality challenges, existing data and information, governance aspects and hydrological conditions.

African Use Cases were selected, as meeting the water challenge in Africa requires the availability of a sufficient quantity and quality of water for health, economic activities, human well-being and ecosystems, while resisting hydrological extremes. Several national, regional and global trends however pose substantial risk:

- Rising water needs and usage by the extension of agricultural irrigation,
- Expansion of industry and mining activities,
- Rapid urbanization: African cities among the fastest growing in the world,
- Expanding extraction of raw materials, with effects on water quantity and quality.

Climate change and mismanagement of water resources increase the risk of water scarcity resulting in changing amount and distribution of water regionally. Deterioration of ambient water quality and of aquatic ecosystems can be attributed to lack of infrastructure for urban and industrial wastewater treatment and increasingly improper use of fertilizers and pesticides in agriculture.Safe drinking water and sanitation is particularly low in rural areas and informal urban settlements in Sub-Saharan Africa with negative consequences for education, health and economic development. The extent of aquatic ecosystems and thus ecosystem resilience is increasingly limited by competing land use affecting river corridors, flow regulation for irrigation, and power generation.

The selected African Use Cases comprise:

- Volta Basin: Transboundary river basin, shared between Burkina Faso, Togo, Mali, Cote D'Ivoire and Ghana; main water quality issue are pathogens
- Lake Victoria: Transboundary lake, shared between Kenya, Tanzania, Uganda, Rwanda and Burundi; main water quality issue is impact on ecosystem health
- Cape Town Main Aquifer Systems: Variety of aquifer systems in and around Cape Town; earmarked for water supply to Cape Town; water quality issues are pollution due to land use activities, geogenic elevated concentrations, impact on surface ecosystems

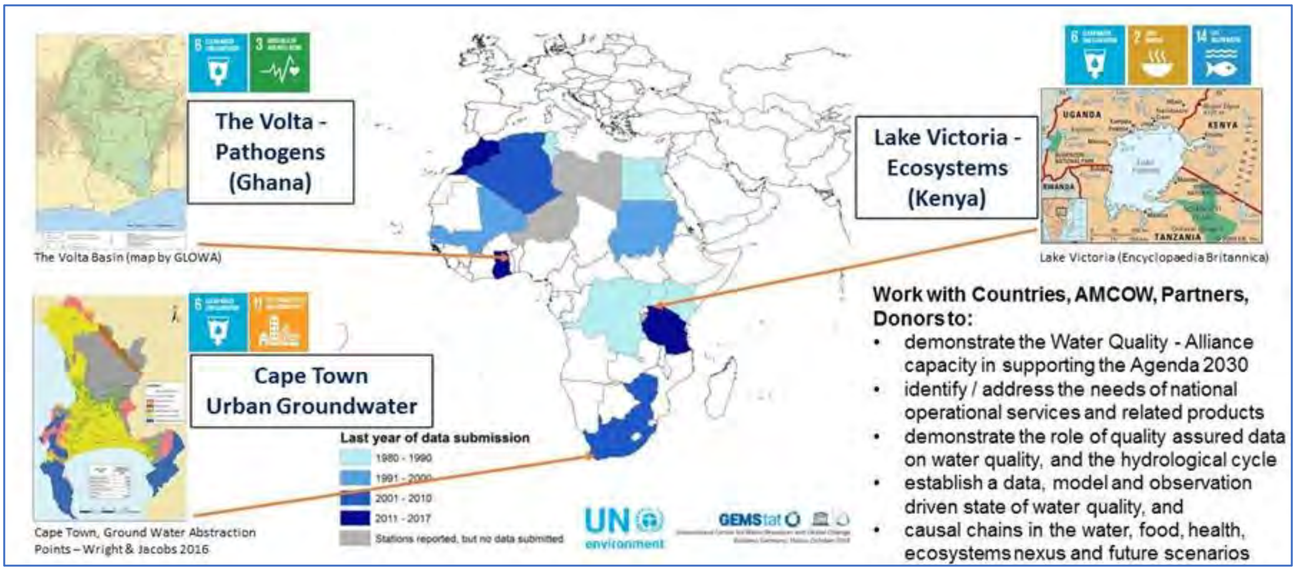


Figure 1-2: Selection of the three African Use Cases (Kremer, 2018)

1.2.3. General Study Process

The use cases follow a three-phase approach, which include assessment of data availability, stakeholder engagement, water quality assessment through a combination in-situ data analysis, earth observation (EO) data and modelling, and final reporting. The process is stakeholder focussed so that products and solutions can be co-designed and co-created between the WWQA partners and the local stakeholders (see **Figure 1.3**).

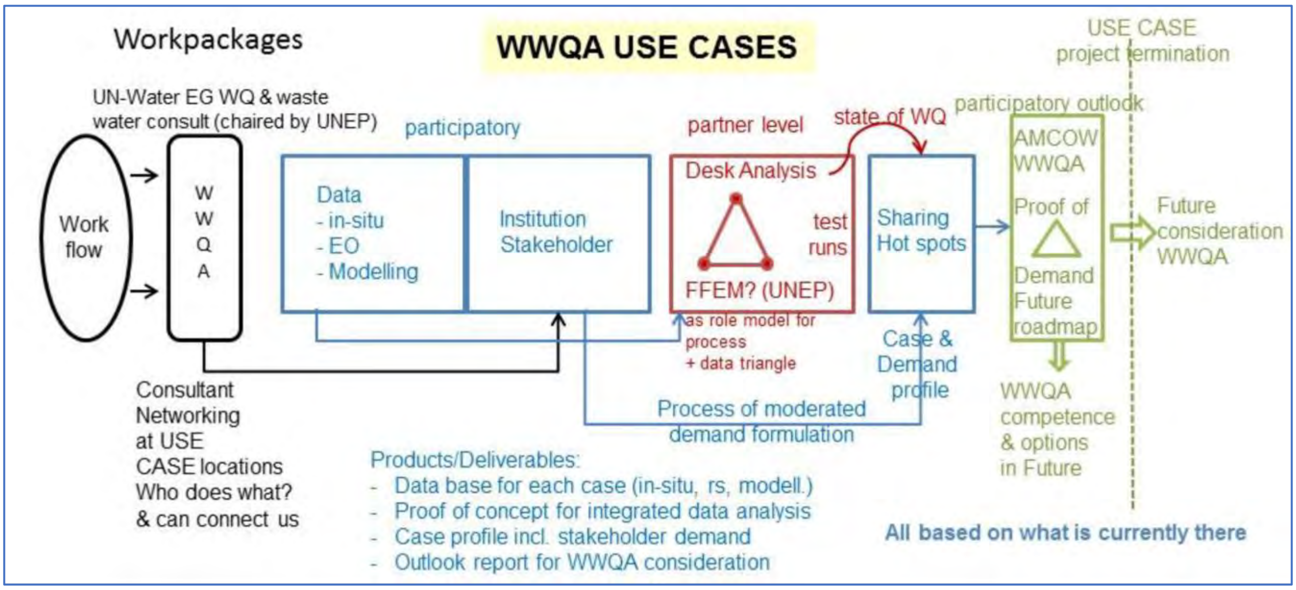


Figure 1-3: Process and Work Packages of Use Cases (Kremer, 2018)

As the use cases are meant to demonstrate the approach and support of the WWQA, it is not envisaged to collect additional data. The process is divided into four work packages (see **Figure 1.4**), resulting in a final report and outlook, originally scheduled for August 2020 for presentation at the annual WWQA meeting and input to submissions for UNEA 5. Due to the Covid-19 pandemic which has restricted travel and movement during the year 2020, the final report timeline delivery had to be adjusted versus the original plan laid out below.

WP1 – Identify Stakeholders and Assess Capacity 1.1 Identify availability of data among WWQ Alliance members 1.2 Identify local Use Case stakeholders 1.3 Assess Use Case capacity	Initiation of process: August 2019 - Data availability - Initial stakeholder engagement Report: December 2019
WP2 – Set Visions and Objectives 2.1 Consult local Use Case stakeholders 2.2 Compile Use Case databases	- Identification of products and services - Database, data repository Report: March 2020
WP3 – Desktop Assessment 3.1 Integrate water quality data 3.2 Assess drivers, pressures & state of water quality 3.3 Develop water quality pilot products and services	- Water quality assessment / model - Develop products and services Report: June 2020
WP4 – Conclusions and Outlook 4.1 Review Results and Compile Outlook	- Summary and outlook Report: August 2020

Figure 1-4: General work packages and original schedule for deliverables for WWQA Use Cases

1.3. Cape Town Aquifer Use Case

1.3.1. Terms of Reference

UNEP appointed Dr K Riemann in October 2019 as Water Quality, Management and Groundwater Specialist to facilitate the Cape Town Major Aquifer System Use Case Study, based on the Terms of Reference (ToR) and proposal call (UNEP, 2019). This appointment was extended until 31 May 2021 by a revised ToR (UNEP, 2021), issued in February 2021.

The study structure for the Cape Town Aquifers Use Case differs slightly from the structure described above for the other use cases, as defined in the original ToR. This use case study consists of three phases with related deliverables and is aligned with the principles and priorities of the City of Cape Town's "Cape Town Water Strategy – Our Shared Water Future" (CCT, 2019). The ToR stated further that the consultant shall be in charge of carrying out the three phases of the study and the related deliverables, under the guidance of the Head of the GEMS/Water Programme of the Science Division, and in consultation with the project partners. The tasks and deliverables are shown in **Table 1-1** below.

Table 1-1 Tasks, activities, schedule and deliverables for Cape Town Aquifer Use Case as per ToR, as amended in 2021

Task	Subtask	Schedule	Deliverables
Phase 1: Initiation	Build Stakeholder Network	Q3 and Q4 of 2019	Deliverable 1: Consultative induction workshop report
	UNEA-4		
	Assessing Capacity		Deliverable 2: Input to the larger capacity assessment report
	Visions and Objectives		
	Capacity Assessment Report		
Phase 2: Identification	Identify Hotspots and Demands	Q4 of 2019 and Q1 of 2020	Deliverable 3: Compilation of use case databases for the Cape Town Aquifers
	Set Aquifer Context		
	Desktop Screening and Assessment		Deliverable 4: Report on Water Quality Assessment and Identification of Pollution Hotspots
Phase 3: Assessment	Integrated Data Analysis	Q1 and Q2 of 2020	
	Proof of Concept Compilation		**Deliverable 5:** Final Use Case study report, including a description of the products developed
	Evaluation and Reporting		

The aim of this Use Case is to demonstrate current capabilities and future water quality information services through the Cape Town Major Aquifer System Use Case Study and will contribute to the larger report on the Use Cases, which will be shared widely with the Alliance for further consideration. The specific deliverables are

(1) Input into larger study capacity assessment report (Deliverable 1 and 2);

(2) Compilation of use case databases for the Atlantis Aquifer, Cape Flats Aquifer and Table Mountain Group Aquifers (Deliverable 3) and

(3) Use case study report (Deliverable 4 and 5).

The aim of the data analysis/modelling will be to provide a use case study report of the three aquifers (see Section 2), including

- State of water quality for each aquifer (including identified hotspots);
- Stakeholder-driven definition of information, future demands, partners and service needs relating to aquifer groundwater quality at present and in the future;
- Solutions-oriented water quality action plan to be tabled for peer discussion in a collective effort between the stakeholders and WWQA members.

The water quality action plan as part of Phase 3 aims to cover one or other of the following solutions:

- Treatment processes specific to each aquifer system, which will provide bulk groundwater supply that meets modern national and international potable domestic standards/limits;
- Wellfield operational and maintenance procedures to reduce iron/manganese precipitation/ biofouling;
- Understanding of potential surface-groundwater hydrochemical mixing impacts with respect to the storage of TMGA groundwater in surface water dams, and potential solutions and operational procedures e.g. pre-treatment of groundwater;
- Restoration of aquifer and wetland ecosystem functions through wetland rehabilitation, biomimicry, water sensitive urban design (WSUD) etc.
- Maintenance of ecosystem functioning through sustainable groundwater abstraction i.e. ensuring the continuation of natural surface-groundwater interaction processes.

1.3.2. Study Methodology

The approach and methodology for the Cape Town Aquifer Use Case differ from the general methodology applied in the other Use Cases due to the scale of study, available data from recent investigations, difference in water resource and well-established and ongoing stakeholder engagement.

Stakeholder engagement

Due to the current groundwater development projects by the City of Cape Town (CCT), the local stakeholder engagement process and local collaboration (see below) was linked to the stakeholder engagement process by the CCT undertaken for these projects. The engagement with WWQA partners and the UNEP followed the same approach and timeline as for the other Use Cases.

Through a desk-based assessment using feedback through initial consultation of local stakeholders in combination with existing literature, the current monitoring and ongoing project experience by the groundwater consultant Umvoto Africa (Pty) Ltd, capacities are determined around the four components of governance as detailed in the FFEM:

1. **Enabling Environment**: The existence of provisions in government plans, policies and law (elements of Integrated Water Resources Management, IWRM), related to the monitoring and protection of freshwater ecosystems with respect to water quality.
2. **Institutions and Participation**: The institutional and human capacity, from the national level through subnational and basin levels to the local level, to monitor and assess the quality of freshwater ecosystems. The capacity to effectively engage with the private sector and other stakeholder groups is included as well.
3. **Management Instruments**: Existing monitoring programmes and previous assessments, and financial incentives that support measures to protect and restore ecosystems.
4. **Financing**: Financial resources available, including grants and more sustainable revenue streams.

Data collation

A significant focus was on in-situ data collation from the recent investigation and including historical data, groundwater and surface water quality data from national and municipal programmes (e.g. landfills, cemeteries and water treatment works). In addition to water quality data, these included climate data, water use data and water level / flow data.

Due to the hidden, underground nature of groundwater, the standard remote sensing techniques applied in the GWQA are not applicable for the Cape Town Aquifer Use Case. Hence, remote sensing was used to map and monitor proxies to water quality, such as geology and land use, as indication for the risk of groundwater pollution. This was achieved with high-resolution satellite Sentinel-2 in combination with high-resolution aerial imagery.

The modelling approach for the Cape Town Aquifer Use Case differs from the other cases, as it comprised not only groundwater flow and transport models to predict groundwater quality under different future scenarios but also GIS-based modelling of aquifer vulnerability and risk to pollution.

Data analysis and integration

The data analysis with respect to water quality assessment and development of products and services follows the approach of the so-called “magic triangle” of integrating in-situ data, earth observation data and modelled data. However, earth observation does not provide water quality data for groundwater due to the underground nature of groundwater, but it can provide relevant proxy data, such as land use and geological features. The approach followed for the Cape Town Aquifer Use Case is shown in Figure 1-5 below.

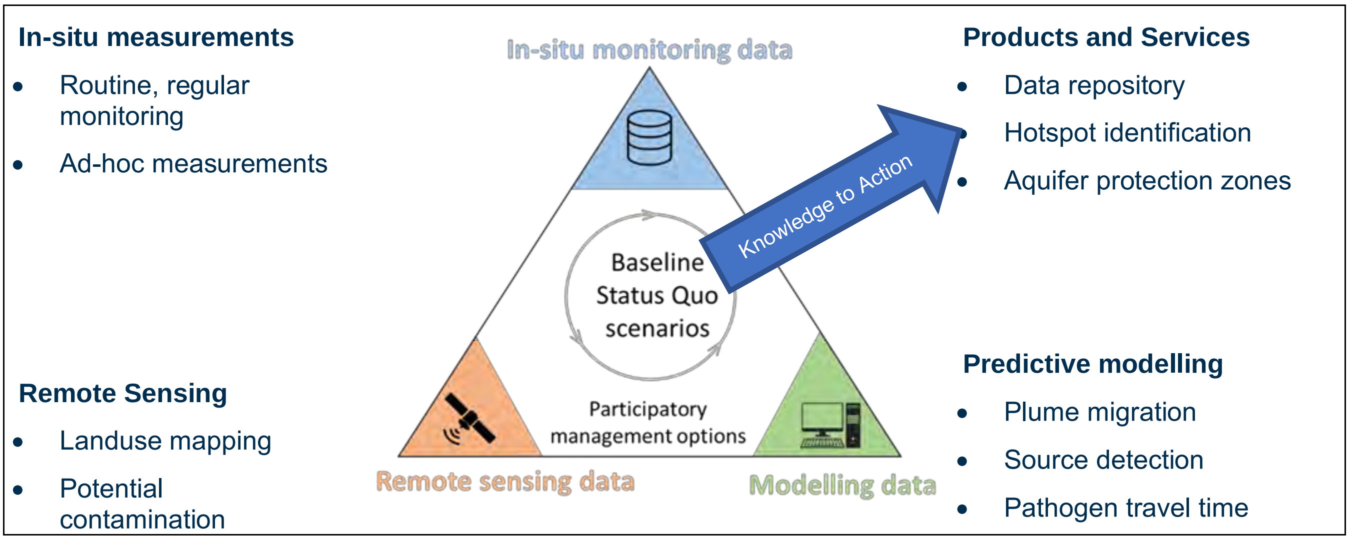


Figure 1-5: Details of the “Magic Triangle” as applied to the Cape Town Aquifer Use Case

1.3.3. Collaborators

The Use Case Study was undertaken in close collaboration with the City of Cape Town, Water and Sanitation Directorate, Bulkwater Branch, which currently is in the process of investigating, designing and developing groundwater schemes for bulk water augmentation in the three major aquifers in the vicinity of Cape Town (see below and Section 2), the appointed consulting engineers for these scheme development, Zutari and iX Engineering, and the appointed groundwater consultant Umvoto Africa.

In addition to the feedback from the CCT projects, Umvoto Africa, as a member of the WWQA, has provided technical input and supported the data analysis.

CCT Project Meetings

Since commencement of the water resilience programme in 2017, the City of Cape Town held regular meetings across all implementation projects to track progress and discuss challenges. These were originally chaired by the Executive Director of Informal Settlements, Water and Sanitation Services and later by the Director of Water & Sanitation. Dr Riemann attended most of these meetings during the study period.

Engagement with the project teams that design and implement the development of the Cape Flats Aquifer Management Scheme, the TMGA Wellfield development and the optimisation and expansion of the Atlantis Water Resource Management Scheme was carried out regularly via attendance of the regular project meetings and team workshops.

Meetings with UNEP and WWQA partners

A close cooperation was observed with the Use Case Study for Lake Victoria and the Volta Basin, as facilitated by Mr Andrew Gemmell. Several meetings were held with the UNEP and WWQA members during the execution of the study:

- 28-29 November 2018, WMO offices, Geneva, Switzerland: WWQA Inception Workshop for the launch of the World Water Quality Alliance, expert mapping & update on latest activities (attended by Dylan Blake in preparation of the Cape Town Aquifer Use Case).
  - Inauguration of the World Water Quality Alliance (WWQA);
  - Decision on African Use Cases to demonstrate potential of the WWQA
- 11-13 September 2019, ICWRGC offices in Koblenz, Germany. Meetings were held between ICWRGC staff, Mr Gemmell and Dr Riemann. The objective was to understand GEMSWater and GEMStat. This included:
  - Understanding the GEMSWater management of data and data providers;
  - Set-up of an online team collaboration page including meeting notes, file folders, etc.;
  - How GEMSWater navigate concerns on intellectual property and licensing;
  - Data quality control procedures; and
  - Product development.
- 16-18 September 2019, Ispra, Italy: WWQA 2nd Global Workshop, attended by Mr Gemmell and Dr Riemann. This was useful towards:
  - Presentation on the Africa Use Case concept and to network with key alliance members;
  - Developing in-country stakeholder network;
  - Water quality data/information/products available (citizen science & in-situ, earth observation and modelling);
  - Face to face meetings with the Africa Use Case team members; and
  - Enhancing the participation of AMCOW and their initiative within the African Development Bank, the Africa Water Facility.
- Meeting with UNEP representatives on 20 and 21 February 2020 at the UNEP offices in Nairobi in the form of project meetings and workshops. The objectives were to outline work to date, and to define the next steps and delivery plan.
- A virtual meeting with WWQA partner UFZ was held on 21 February 2020 together with UNEP representatives to discuss the methodology applied for the Use Case.

- Dr Kornelius Riemann attended the virtual meetings of the WWQA Workstream "Friends of Groundwater" (FoG) during 2020, providing feedback from the Use Case to the work of the FoG and getting input from FoG members on specific aspects of the Cape Town Aquifers Use Case.
- The study outcome has been shared with the WWQA at the 2nd Annual Global Meeting of the WWQA on 27 and 28 January 2021 (see Appendix C) and reported on in the information document for UNEA 5 (UNEP, 2020).

1.4. Report Aims and Objectives

This report constitutes **Deliverable 5: Final Use Case Study Report**.

The report summarises the stakeholder engagement process, data assessment and hotspot identification, and includes a description of the products developed as part of the study and as discussed with stakeholders and the water quality actions taken or planned by the City of Cape Town. It concludes with recommendations regarding the way forward.

Section 1 provides the background the Global Water Quality Assessment and the Use Case study, with special reference to the process followed for the Cape Town Aquifer Use Case.

An overview of the water resources, supply system and future planning for Cape Town is provided in **Section 2**. The overall stakeholder engagement process with the City of Cape Town and other relevant role players is also described here.

The water quality situation and challenges per aquifer are described in **Section 3** to **Section 5**, including definition of water quality hotspots and sources of potential pollution.

Section 6 describes the two products and services that were developed by WWQA partners for this Use Case.

A summary of the findings, challenges and limitations of the process and recommendations for the way forward and possible upscaling are contained in **Section 7**.

2. CAPE TOWN AND CAPE TOWN AQUIFERS

2.1. Location

The City of Cape Town (within the Western Cape Province of South Africa, see **Figure 2-1**) is the most populated coastal city, and second most populated city within South Africa (population of ~4 million people over an area of 2.445 km^2, resulting in a population density of ~1 600 people per km^2). The city is one of the most multi-cultural in the world, and is a major economic, transport, tourist, design and agricultural (in association with surrounding farm regions) hub in South Africa and Africa. The Cape Floristic Kingdom also occurs within the city and surrounding mountain catchments, and despite it being the smallest of the six floral kingdoms of the world, is a biodiversity hotspot with high economic and ecological value.

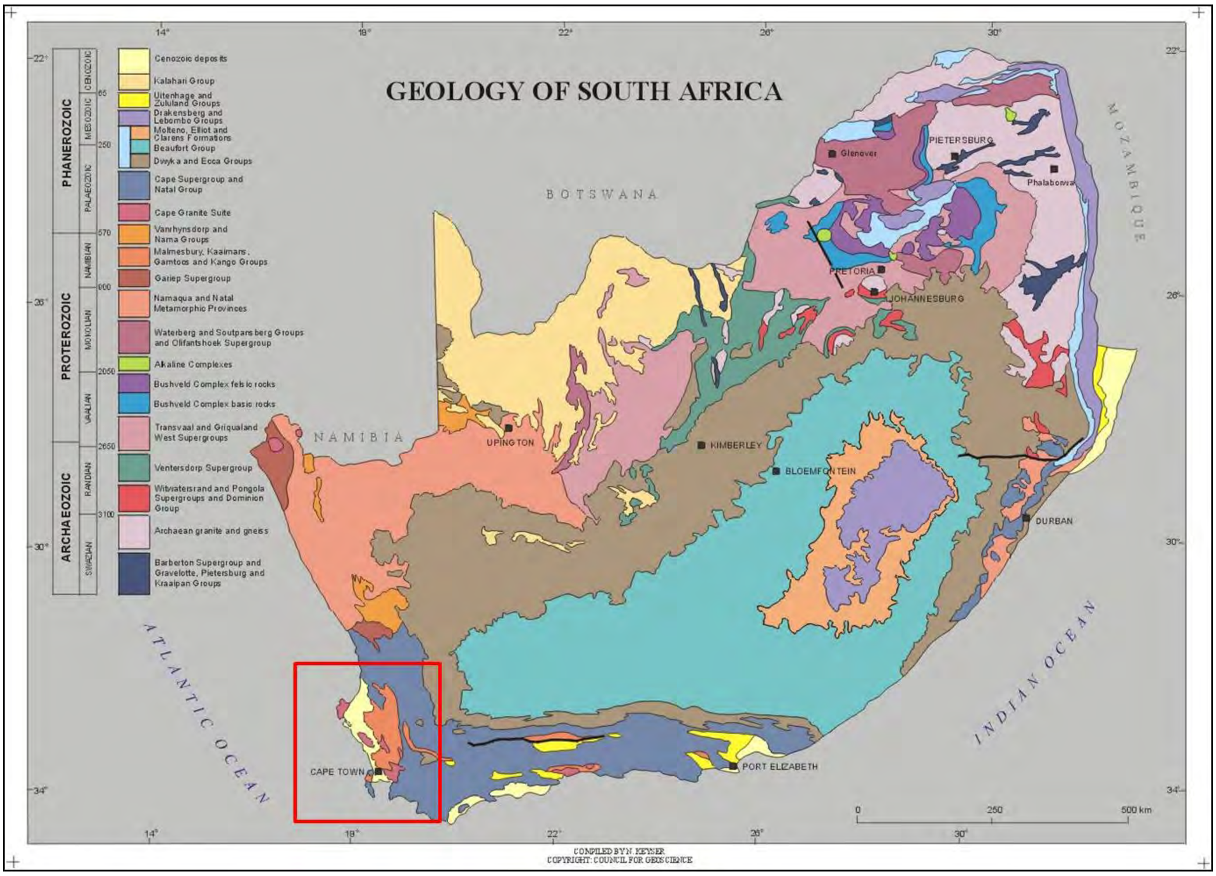


Figure 2-1: Geological Map of South Africa with water supply area for Cape Town in red square. Dark blue arcuate shape is the Cape Supergroup and Cape Fold Belt (within which TMG falls), light yellow units are the coastal sediments (Atlantis and Cape Flats Aquifers). (Council for Geoscience)

The City of Cape Town (as well as urban areas in the Boland and West Coast regions of the Western Cape, and agriculture along Berg River and Riviersonderend catchments) are supplied by surface water stored in the six major dams of the Western Cape Water Supply System (WCWSS; which is currently entirely dependent on winter rainfall from April to September to provide water into the system, see **Figure 2-2**). The WCWSS has a total storage of ~900 million m^3, and an original 98% assurance of supply of 600 million m^3 per annum (~50-60% of which is used by the City of Cape Town, and the remaining ~40-50% used by agriculture/urban users), although storage would only likely supply ~2 years' worth of water during an extended extreme drought (in comparison Sydney has 5 years of storage available).

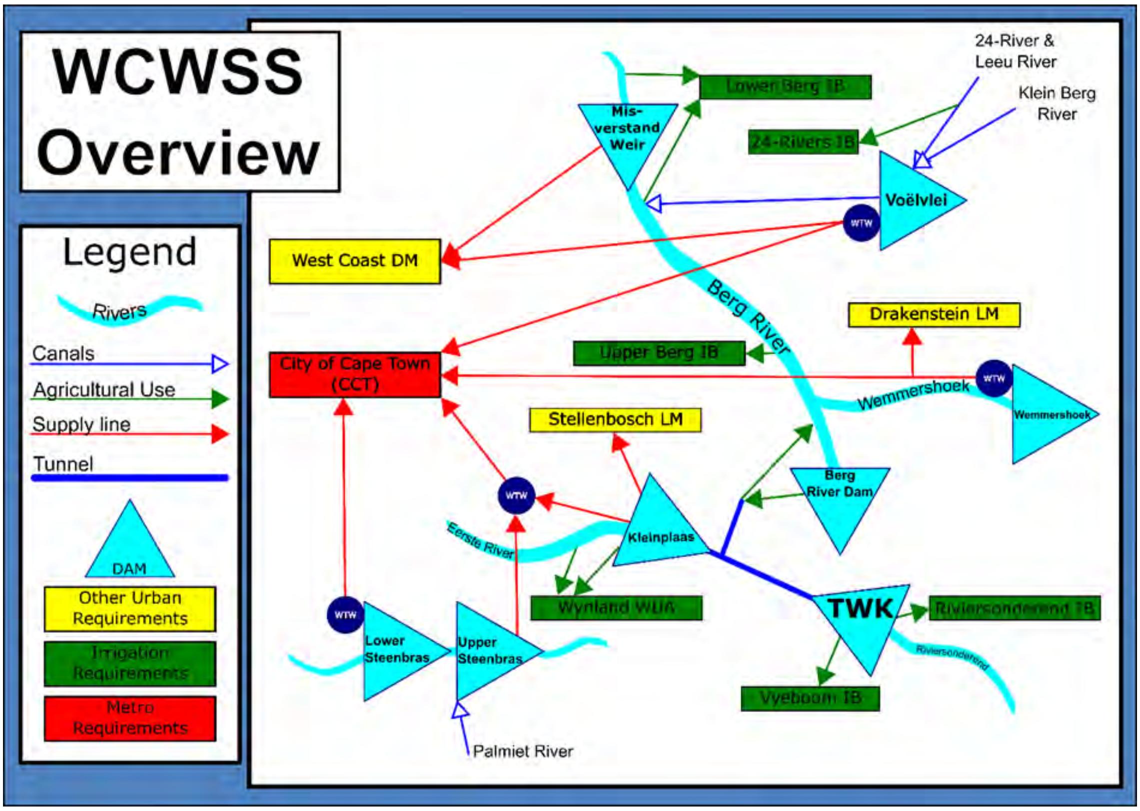


Figure 2-2: System Overview of the Western Cape Water Supply System, supplying Cape Town, surrounding municipalities and agricultural users (DWS, 2016)

An extreme, extended 1:590 year drought in the Western Cape from 2015 to 2017 (although continuing through to present in certain regions of the Western Cape) has put severe strain on the WCWSS to such an extent that the supply system came close to failing in early 2018, even with severe water restrictions and water conservation/water demand measures in place (reducing the city's water demand from ~1 000-1 200 million litres/Megalitres per day [Ml/day] to ~500-600 Ml/day). Consequently, the City of Cape Town was at risk of becoming the first modern day city on Earth to run out of water (as extensively reported nationally and internationally as "Day Zero"), which would have had enormous societal and economic impacts on both a regional and national scale (in addition to drought losses already incurred).

As a result the City of Cape Town initiated its "New Water Programme" in earnest to diversify its water supply to improve its long-term water security and resilience against future droughts (likely to be exacerbated by climate change), by implementing alternative bulk water supply options that the city has been investigating since an earlier drought in 2000-2001. The "New Water Programme" also aims to meet the demand by an ever growing urban population, improving the standard of living of approximately half of the city's population through meeting Sustainable Development Goals (SDG) 6 and 11. Identified alternative bulk water supply options include desalination, water re-use (primarily from wastewater treatment works effluent), and the abstraction of groundwater from three major aquifer systems that the city has access to: the Atlantis Aquifer (AA), Cape Flats Aquifer (CFA), and the Table Mountain Group Aquifers (TMGA; the largest of the three major aquifer systems).

The City of Cape Town contains two major primary sand aquifers within its municipal boundaries, namely the CFA and AA, whereas the major fractured quartzitic sandstone aquifers of the TMG (Peninsula and Nardouw Aquifers) occur within the mountain catchments that surround the city (Steenbras, Grabouw, Nuweberg, Klipfontein, Helderberg, Berg River, Wemmershoek, Voëlvlei and Southern Planning District regions) and incorporate the dams of the WCWSS. The various regional features, and water quality issues that impact the extent to which each aquifer can be utilised, are outlined in the following sections.

2.2. Governance Structure

The legal framework for water resource management, including water quality aspects, is described below. Further details are provided in the Groundwater Management Framework (Riemann et al, 2010).

2.2.1. Water Resource Management Responsibilities

The **South African National Water Act (NWA)**, Act 36 of 1998, provides the legal framework for water resource management. It prescribes the use of the Integrated Water Resource Management (IWRM) approach to ensure that all aspects of water resource management are considered. The National Water Act deals with the water resource. That is rivers, streams, dams, and groundwater. It contains rules about the way the water resource (surface and groundwater) is protected, used, developed, conserved, managed and controlled in an integrated manner. This Act states that water is an indivisible national resource for which national government is the custodian. It further outlines the principles of using and managing this resource.

With the promulgation of the National Water Act in 1998, groundwater lost its previous status of private water and became public water. This has enormous implications for all users and most important benefits for Municipalities as public users. It is now possible for municipalities to exploit groundwater resources even where these can only or best be accessed on private land.

The NWA provides for the establishment of Catchment Management Agencies (CMAs) to manage and regulate all water resources in Water Management Areas (WMAs) as set out in the National Water Resource Strategy. Municipalities also have key responsibilities that impact upon Water Resource Management (WRM):

- Providing municipal water services
- Rural water provision
- Infrastructure provision and management
- Pollution control and water-quality management
- Wastewater treatment and disposal

The **Water Services Act**, Act 108 of 1997, deals mainly with water services or potable (drinkable) water and sanitation services supplied by municipalities to households and other municipal water users. It contains rules about how municipalities should provide water supply and sanitation services. The Act defines the municipal functions of ensuring water services provision and sets out guidelines for Water Services Authorities (WSA) as well as Water Services Providers (WSP).

Paragraph 4 of the Water Services Act sets out the conditions under which a WSP can operate, whereby paragraph 11 describes the duties of the WSA. The roles and responsibilities of the WSA and WSP in terms of water resource management are not explicitly stated but can be inferred from their different roles in the provision of water services.

Water Services Authorities have the following primary responsibilities:

- Realisation of the right to access to basic water services: ensuring progressive realisation of the right to basic water services, subject to available resources (that is, extension of services), the provision of effective and efficient ongoing services (through performance management, by-laws) and sustainability (through financial planning, tariffs, service level choices, environmental monitoring).
- Planning: preparing water services development plans (integrated financial, institutional, social, technical and environmental planning) to progressively ensure efficient, affordable, economical and sustainable access to water.

- Selection of water services providers: selection, procurement and contracting water services providers (including itself).
- Regulation: of water service provision and water services providers (by-laws, contract regulation, monitoring, performance management).
- Communication: consumer education and communication (health and hygiene promotion, water conservation and demand management, information sharing, communication, and consumer charters).

The main duty of water services providers is to provide water services in accordance with the Constitution, the Water Services Act and the by-laws of the water services authority, and in terms of any specific conditions set by the water services authority in a contract.

The key responsibilities of the City of Cape Town as local authority, in terms of the constitution and water legislation that relate to IWRM, include ensuring provision of municipal services, municipal spatial development (land use), infrastructure planning and environmental management, including stormwater management, pollution control and waste management.

Local authority functions, such as environment, water services and air quality, should be dealt with as part of the **Integrated Development Plan (IDP)** process where they are relevant to the local priority issues. The Water Services Development Plan (WSDP) is seen as the water services component of the IDP. In addition, local authorities must set key performance indicators (KPIs) and targets related to their IDPs. The WSDP must be aligned with the Catchment Management Strategy (CMS) of the Catchment Management Agency (CMA), if in existence, or with the Internal Strategic Perspective (ISP) of the National Department of Water and Sanitation (DWS).

The Integrated Waste Management Plans (IWMP) are considered as the waste management component of the IDP. It must include all streams of waste, solid and liquid, and provide for waste reduction, treatment and long-term disposal.

The **Spatial Development Framework (SDF)** deals with the growth and development scenarios of the municipality and the related spatial development and land use. The local SDF's feed into the Provincial Growth and Development Framework and in turn must be aligned with the guiding principles of it.

The legally required sectoral plans, namely Integrated Waste Management Plans (IWMP) and Water Services Development Plans (WSDP) have IWRM gaps, which must be filled if a local authority is to simultaneously comply with its constitutional obligations for sustainable service delivery, socio-economic development and a safe and healthy environment. Hence, the local authority has to develop an Integrated Water Resource Management Plan (IWRMP) to facilitate the water use authorisation application process and local implementation of IWRM.

The responsibilities for water resource management and water supply provision within the City of Cape Town lies with the Water and Sanitation Directorate with the following split of roles between its branches:

- Bulkwater Branch: water resource development and bulk water supply
- Waste Water and Sanitation Branch: sanitation provision and discharge of treated effluent
- Catchment, Stormwater and River Management Branch: surface water resource management within the municipal boundaries

The above aspects are addressed by the City of Cape Town in their relevant by-laws and their Water Strategy (CCT, 2019a).

2.2.2. City of Cape Town Water Strategy

In response to the severe three-year drought that Cape Town experienced from 2015 to 2017, CCT developed a water strategy to ensure water resilience and security for the future. The CCT managed to get through the drought and avoided "Day Zero" by successfully reducing water use by more than 40%, which was a remarkable achievement. The lessons learnt in this process, what works well and what needs to be improved, have informed the strategy.

The strategy provides a roadmap towards a future in which there will be sufficient water for all, and Cape Town will be more resilient to climate and other shocks. It takes into account the important yet complex relationships between water, people, the economy and the environment (CCT, 2019a).

The strategy and action plan are based on five commitments, which are to be achieved by 2040:

- Commitment 1: Safe access to water
- Commitment 2: Wise use
- Commitment 3: Sufficient, reliable water from diverse sources
- Commitment 4: Shared benefits from regional water resources
- Commitment 5: A water sensitive City

> ***Our vision:***
> *By 2040, Cape Town will be a water-sensitive city that optimises and integrates the management of water resources to improve resilience, competitiveness and liveability for the prosperity of its people.*

Groundwater and the urban aquifers play a significant role in achieving the vision. Hence, the CCT embarked on developing several groundwater schemes, which mainly support Commitment 3, as well as Commitment 4 and Commitment 5. Diversification of the water supply is a major change in the water supply system for Cape Town, which until recently relied fully on surface water dams (see Section 2.1). By 2040, 25% of the supplied water shall come from other sources, such as water reuse, desalination and groundwater.

The current groundwater contribution is limited to local springs and the Atlantis Water Resource Management Scheme (AWRMS, see Section 3), which was not producing water at the onset of the drought.

Future groundwater schemes include the Cape Flats Aquifer Management Scheme (CFAMS, see Section 4) and the Table Mountain Group Aquifer (TMGA, see Section 5) wellfields.

Both the AWRMS and CFAMS combine groundwater abstraction for use with managed aquifer recharge (MAR) of treated effluent to enhance storage of water and resilience.

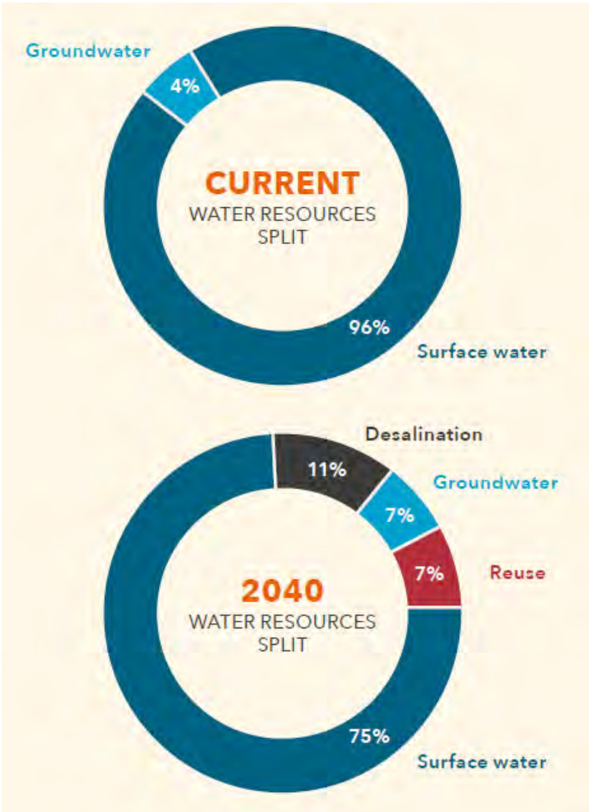
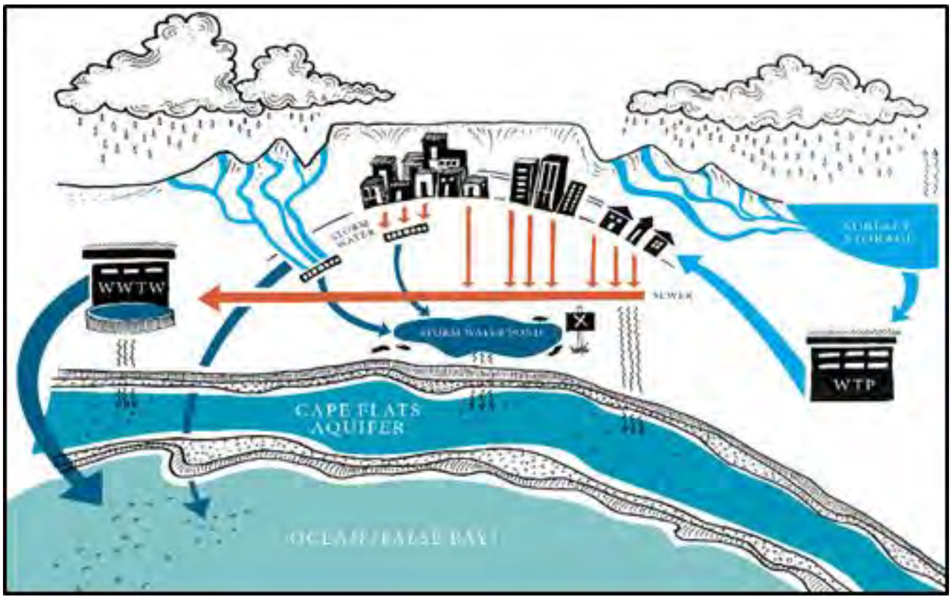


Figure 2-3: Current and future water supply system split (CCT, 2019a)

In addition to the planned groundwater development schemes and the injection of treated effluent for the MAR, the CCT's Water Strategy towards a water resilient city includes (see **Figure 4.3**)

1. the rehabilitation of damaged wetland ecosystems, as well as the development of artificial wetlands along current stormwater drainage canals, in order to improve the quality of stormwater entering the CFA through contaminant removal via biomimicry; and
2. improve the quality of living of residents within informal settlements areas through improved water and sanitation supply, as well as greening the informal settlements (wetland rehabilitation and artificial wetland development, as above).



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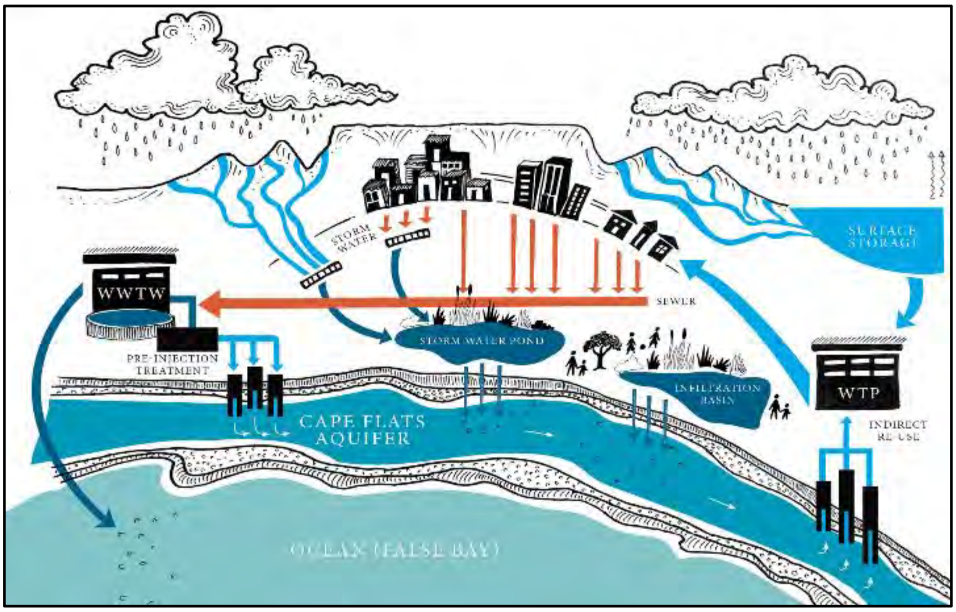


b)

Figure 2-4: Conceptual sketch indicating the change from a) the current CFA situation with uncontrolled groundwater pollution and without MAR, to b) the planned future situation where the MAR scheme with injection of treated effluent and infiltration of stormwater is setup and functional in the CFA (CCT, 2017).

2.3. Aquifers Overview

The Cape Town Aquifers Use Case comprises three aquifers with very distinct and different geological, hydrological, land-use and socio-economic settings, which result in different water quality challenges (see location and summary in Figure 2-3):

- **Atlantis Aquifer:** sedimentary primary aquifer in rural setting, mostly in protected areas; existing wellfield and MAR scheme with risk of pollution through infiltration basin; high risk of biofouling
- **Cape Flats Aquifer:** sedimentary primary aquifer in urban setting; highly vulnerable to pollution from land use activities; known contaminants include nutrients, salts, microbiology and organic compounds
- **TMG Aquifer:** high-yielding fractured-rock aquifer in mostly pristine and natural settings; naturally elevated iron (Fe) and manganese (Mn) concentrations; challenges include possible impact on sensitive environment through groundwater discharge (either naturally via groundwater dependent ecosystems (GDE) or from abstraction and discharge into surface water features)

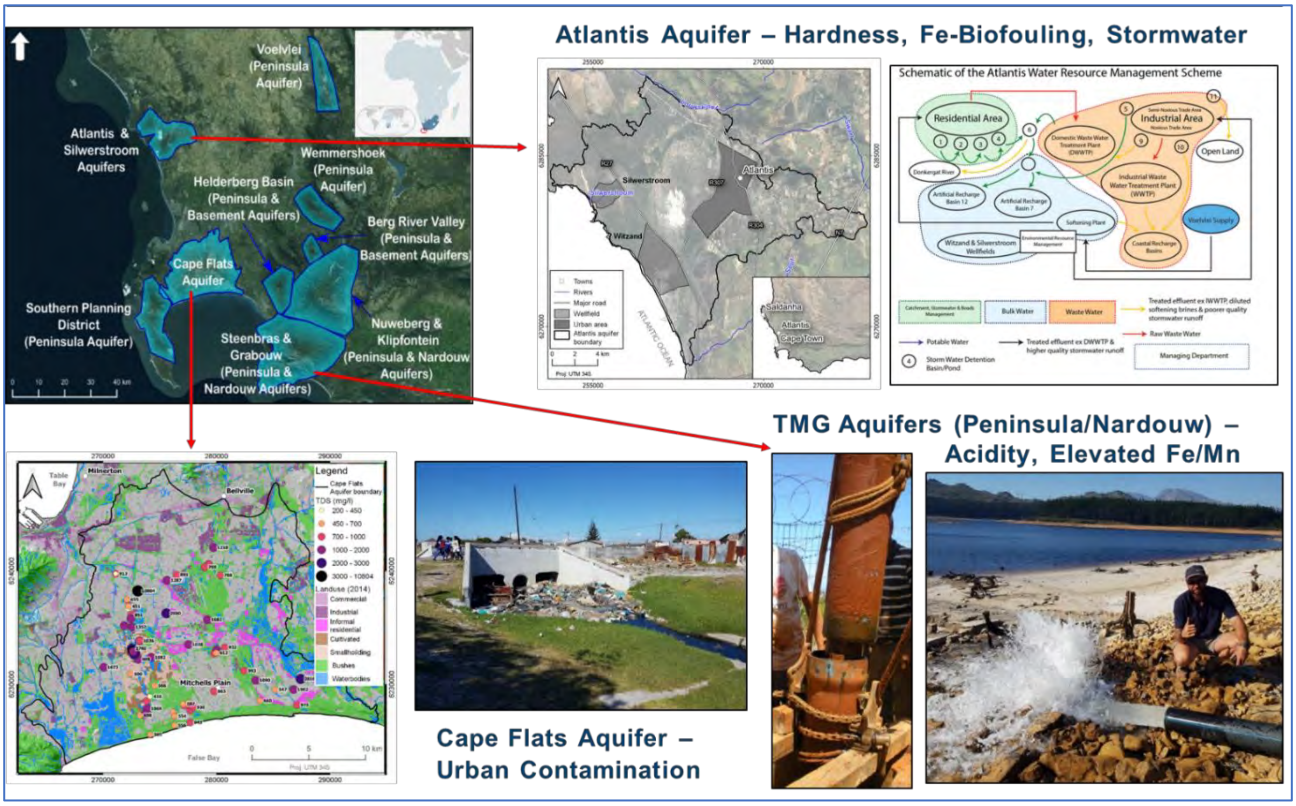


Figure 2-5: Location and Water Quality Aspects of the three Aquifers as part of the CCT Aquifers Use Case; details are provided in Section 3 to 5 (Blake, 2019)

The CCT is currently developing all three aquifers for bulk water supply, details of which are presented in the following sections. The projects are carried out by consulting engineers (iX engineers for Atlantis and CFA; Aurecon for TMGA) with Umvoto Africa as groundwater consultant.

2.4. Stakeholder Engagement

Due to the ongoing projects for all three aquifers, stakeholder engagement is intensive and ongoing. However, there has not been a single meeting with all relevant stakeholders on water quality issues. A summary of the overarching stakeholder engagement and presentations of elements of the use case is given below.

A list of identified stakeholders was provided in the Stakeholder Capacity Assessment Report (Riemann, 2019) with indication of their relevance regarding data provision, access to site for monitoring, impact on water quality (positive or negative) and potential support for solutions. A summary is provided in Appendix A.

2.4.1. Stakeholder identification

There are a number of stakeholders that are applicable across all three aquifers, while others are only relevant to a specific area or aquifer. The relevant stakeholders across all three aquifers and their roles are listed below:

- City of Cape Town (CCT)
    - Water and Sanitation Department (W&S); Water Services Authority (WSA) and Water Services Provider (WSP)
        - Bulk Water Branch,
        - Waste Water and Sanitation Branch,
        - Water Demand Management Branch, and
        - Catchment, Stormwater and River Management Branch
    - Environmental Management Department; managing authority for local protected areas
        - Biodiversity Management Branch, and
        - Environmental Compliance Branch
    - Solid Waste Department; monitoring of landfill sites, disposal of sludge from MAR ponds, WTWs and WWTWs
    - Transport Department – Public Transport Infrastructure; access to sites
    - Human Settlements Directorate; green field development
    - Property Management Department; servitudes and access to private land, reservation of land for development or any new developments
    - Scientific Services; water analysis
    - Ward Councillors; local representation
- Provincial Government of the Western Cape (PGWC)
    - Department of Environmental Affairs and Development Planning (DEA&DP); responsible authority for environmental authorisations
    - Department of Transport and Public Works (DT&PW); land owner for critical infrastructure, such as hospitals
    - Green Cape; research organisations funded by Department of Economic Development,
    - CapeNature; managing protected areas under auspices of the DEA&DP
    - Provincial Disaster Management Centre

- National Government of South Africa
  - Department of Water and Sanitation (DWS), Western Cape Regional Office; responsible authority for water resource management, protection and water use authorisation
  - Department of Environmental Affairs, Forestry and Fisheries (DEFF); managing authority for protected areas
  - South African National Parks (SANParks); managing protected areas under the auspices of the DEA
  - National Disaster Management Centre
- Academia and Research:
  - Water Research Commission
  - University of Stellenbosch
  - University of Cape Town
  - University of the Western Cape

There are various additional stakeholders within the boundaries of the three aquifers that will be discussed further under each aquifer case study.

2.4.2. Atlantis Water Resource Management Scheme

In addition to the general engagement with the City of Cape Town, wider stakeholder engagement specifically around the Atlantis Water Resource Management Scheme (AWRMS) has been undertaken but is only gaining traction in recent months. Meetings and site visits include:

- CCT officials and past role players within the scheme to establish and address major management, design, operational and maintenance shortcomings of the scheme.
- Cape Nature as Managing Authority of land for Silwerstroom
- Eskom as landowner for parts of the wellfield (access agreements) and end user of discharged industrial wastewater and waste from softening plant.
- Groot Springfontyn Development to discuss supplying the new development with water, availability of data from their area and possible access to their land for borehole drilling.
- The Nature Conservancy for potential collaboration of efforts around refurbishment of MAR components.
- Provincial Department of Environmental Affairs and Development Planning to investigate potential for economic use of reed harvests associated with MAR ponds

City of Cape Town Project Team

Engagement with the project teams that design and implement the optimisation and expansion of the Atlantis Water Resource Management Scheme was carried out regularly. This included the engineering consultants appointed for the refurbishment of existing infrastructure and the abstraction and treatment of the groundwater (iX Engineers) and the groundwater specialists appointed for the investigation, optimisation, development, monitoring and management of the aquifer (Umvoto Africa).

Atlantis Aquifer Management Team

The re-establishment of the Atlantis Aquifer Management Team comprising numerous CCT departments has been initiated and two meetings were held during the study period.

2.4.3. Cape Flats Aquifer Management Scheme

In addition to the general engagement with the City of Cape Town, wider stakeholder engagement specifically around the Cape Flats Aquifer Management Scheme (CFAMS) has been undertaken. Details are provided in **Appendix A.2**.

City of Cape Town

Since commencement of the water resilience programme in 2017, the City of Cape Town held regular meetings across all implementation projects to track progress and discuss challenges. These were originally chaired by the Executive Director of Informal Settlements, Water and Sanitation Services and later by the Director of Water & Sanitation. The Water Resilience Programme was renamed New Water Programme (NWP), and the meetings are now chaired by the Head of the Bulk Water Branch. Water quality aspects are regularly discussed, as they pertain to costs of scheme implementation and risks to drinking water quality supplied.

The City also instituted an Environmental Monitoring Forum for the water resilience programme to discuss compliance with all legislative requirements. This forum was attended by officials from different responsible authorities; e.g. Department of Environmental Affairs & Development Planning, Department of Water and Sanitation, Heritage Western Cape, Cape Nature, and City of Cape Town departments.

Specific meetings and workshops around the vision for the Cape Flats towards a water resilient city, as stipulated in the CCT Water Strategy, were held with the CCT and other stakeholders. These include:

- Several meetings with CCT officials regarding proposals to implement the Cape Flats Aquifer Management Strategy (DWS, 2015) on aquifer protection and catchment rehabilitation.
- Meetings with CCT officials to develop funding proposal for designing and implementing water resilience catchment management.
- Meeting with Stormwater, Catchment and River Management Branch on 21 November 2019 to discuss support for a pilot study on rehabilitating the Big Lotus Canal (currently a heavily polluted stormwater canal) to near natural conditions.
- Workshop between CCT, Dutch embassy, Deltares, Umvoto Africa and other partners as part of the #CoCreateMyCity event on 21 November 2019 regarding the proposed “liveable urban water ways” project, including pre-event workshops and meetings.

City of Cape Town Project Team

Engagement with the project teams that design and implement the development of the Cape Flats Aquifer Management Scheme was carried out regularly. This included the engineering consultants appointed for the abstraction and treatment of the groundwater (iX Engineers), the engineering consultants appointed for the treatment and reticulation of the treated effluent used for injection into the aquifer (Jeffares & Green, Water & Wastewater Engineering), the groundwater specialists appointed for the investigation, development, monitoring and management of the aquifer (Umvoto Africa), and the water safety specialist appointed for the development of a water safety plan for the aquifer management scheme (Chris Swartz).

Monitoring Committee Meetings

The establishment of a Monitoring Committee is stipulated in the water use licence. Four meetings had been organised by the CCT so far.

Field Visits:

A number of field visits with interested and or affected parties have been undertaken, e.g. with CCT Biodiversity Branch, CCT Environmental Compliance Branch, False Bay Nature Reserve Advisory Group, the South Africa – Denmark Strategic Sector Cooperation.

As part of a workshop on Managed Aquifer Recharge (MAR), organised by the International Association of Hydrogeologists (IAH), South African Chapter and the Groundwater Division (GWD) of the Geological Society of South Africa (GSSA), a field visit to the scheme development area was held with attendees including officials from national Department of Water and Sanitation (DWS) and City of Cape Town, groundwater experts, engineers and scientists.

Local Stakeholder Presentations:

The groundwater development project and or aspects around water quality and aquifer protection have been presented and discussed at several meetings and workshops with farmers in the Philippi Horticultural Area (PHA), land developers and landowners. In addition, a workshop was held with community members from several suburban areas.

2.4.4. Table Mountain Group Aquifer

In addition to the general engagement with the City of Cape Town, wider stakeholder engagement specifically around the development of the TMG Aquifer has been undertaken. Details are provided in **Appendix A.3**.

TMG Environmental Working Group:

The TMG Environmental Working Group (EWG) was initiated by the CCT in response to concerns and criticism expressed publicly by scientists and interested environmental organisations regarding the development of the TMG Aquifer. The purpose of the EWG was to provide a platform to inform the concerned stakeholders about the current investigation and plans, and to discuss the concerns. Three meetings were held, after which the structure of these meetings changed with the introduction of the monitoring committee meetings.

TMG Environmental Focus Group:

The TMG Environmental Focus Group (EFG) was initiated by the project team as a subset of the EWG, specifically to assess and screen proposed field activities, such as borehole drilling and infrastructure development. Several meetings were held, which provided feedback to the project team for consideration in the design and implementation of the groundwater scheme.

TMG Monitoring Committee:

The establishment of a Monitoring Committee is stipulated in the water sue licence. Four meetings had been organised by the CCT so far.

Other stakeholder meetings relevant to the CCT TMGA Project

The groundwater development project and or aspects around water quality and aquifer protection have been presented and discussed at several meetings and workshops with the Kogelberg Biosphere Reserve Company, the Botanical Society of South Africa, SANParks, Vyeboom Irrigation Board farmers and other organisations. Field visits were arranged for the South Africa – Denmark Strategic Sector Cooperation and the Student Field School organised by the Groundwater Division (GWD) of the Geological Society of South Africa (GSSA).

Risk workshops were undertaken for the aquifer development project with several officials of the City of Cape Town.

2.4.5. Visions and Objectives

During the intensive stakeholder engagement process, as outlined above, the Cape Flats Aquifer was considered as essential component of the urban water cycle and crucial element for the successful implementation of the Water Strategy by the City of Cape Town. Hence, the vision for the CFA is tied to the Aquifer Management Strategy (DWS, 2016) and the vision of the Water Strategy (CCT, 2019) in that

The Cape Flats Aquifer and the development of the Managed Aquifer Recharge Scheme are crucial elements towards building a water sensitive City.

Key elements to achieve this vision are:

1. **Mapping all current threats to the water quality of the CFA,**
2. Implementing sustainable wellfield development with respect to other users and the receiving environment,
3. Implementing the Managed Aquifer Recharge scheme, using advanced tertiary treated effluent of high water quality standard (better than the current groundwater quality) to improve water quality and assist with sustainable aquifer management,
4. **Developing and implementing a groundwater management plan that details the underlying strategy and requirements for successfully implementing objectives 2 and 3 above,**
5. **Developing an aquifer protection plan that incorporates protection of the current wellfield development by the CCT, other users of the aquifer and the environment, where ecosystems rely on receiving groundwater from the CFA,**
6. Developing and implementing remediation and rehabilitation plans for known groundwater pollution, including source control,
7. **Developing and implementing rehabilitation plans for surface water features in the CFA catchment area to promote pollution control,**
8. Developing ecological and biodiversity corridors in the CFA catchment area as initial steps towards a water sensitive city.

The stakeholder engagement process identified objectives 1, 4, 5 and 7 as potential products and services for the WWQA Use Case on the CFA. In addition, it was recognized that community engagement and awareness raising are important ingredients for all objectives. Two products have been developed covering objectives 1 and 5, and the community engagement. These products and services are detailed in Section 6.

3. ATLANTIS AQUIFER – WATER QUALITY

3.1. Contextualisation

The Atlantis Aquifer is a Quaternary primary aquifer system comprised primarily of ~30-50 m dune sediment (with some alluvial channels along the basal contact with the older basement rocks of the Malmesbury Group and Cape Granite Suite) – the dune fields (Witzand, Springfontyn and Langebaan Formations of the Sandveld Group) are indicated by the preferentially orientated (due to prevailing wind conditions) green and yellow units on the geological map.

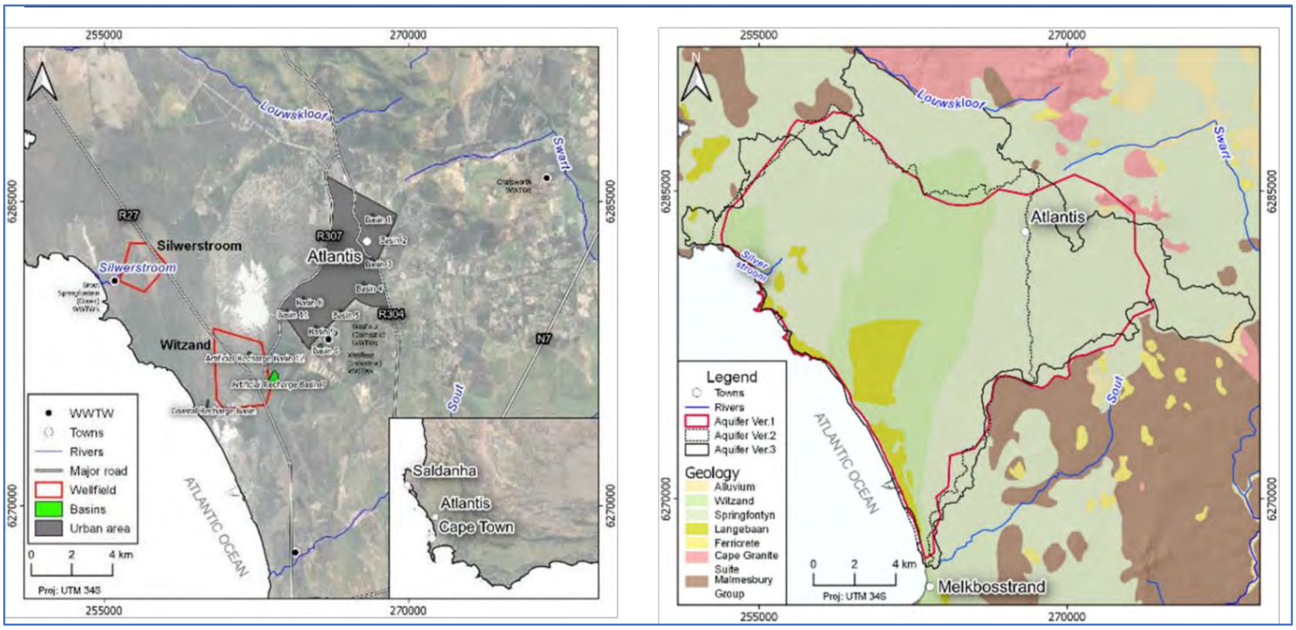


Figure 3-1: Location of AWRMS and Geological Map (after CCT, 2020b)

The Atlantis Water Resource Management Scheme (AWRMS – official name) has been operational since the 1980s and supplies the town and industrial area of Atlantis (and surrounding areas), although the scheme has fallen into a state of disrepair since early 2000s when the CCT installed a pipeline from Voelvlei Dam (one of the major dams of the WCWSS) to the Atlantis area and excess surface water was preferentially used instead of groundwater. The AWRMS comprises of two wellfields – Witzands and Silwerstroom Wellfields produce a combined ~15 Ml/day from 28 existing production boreholes.

In addition to direct rainfall recharge of the aquifer, managed aquifer recharge (MAR) of ~7 Ml/day takes place from a series of infiltration ponds and recharge basins that receive domestic stormwater and treated domestic/industrial effluent.

Due to inherent Fe bacteria present in the aquifer and due to sub-optimal operation and maintenance of wellfield infrastructure, the old existing production boreholes clog rapidly even after cleaning. This is exacerbated, as they are poorly constructed (PVC and bidim, which makes cleaning extremely difficult). Refurbishment and re-drilling of defunct boreholes is in progress, scheduled for completion by end of 2021, using stainless steel and wedge-wire screens. This is expected to increase scheme yield and resilience from 15 Ml/day to 25 Ml/day. Future exploration and expansion of the wellfields is planned to further increase the scheme yield to a total of 40 Ml/day.

However, this requires an increase of the infiltration capacity to ~10-12 Ml/day through refurbishment and optimisation of the MAR basins, which is expected to also improve the infiltration water quality.

Meticulous groundwater and surface water / storm water monitoring is required for both water level and water quality to ensure sustainability of the water resource and supply, especially given the use of storm water run-off and treated waste water for infiltration into the aquifer.

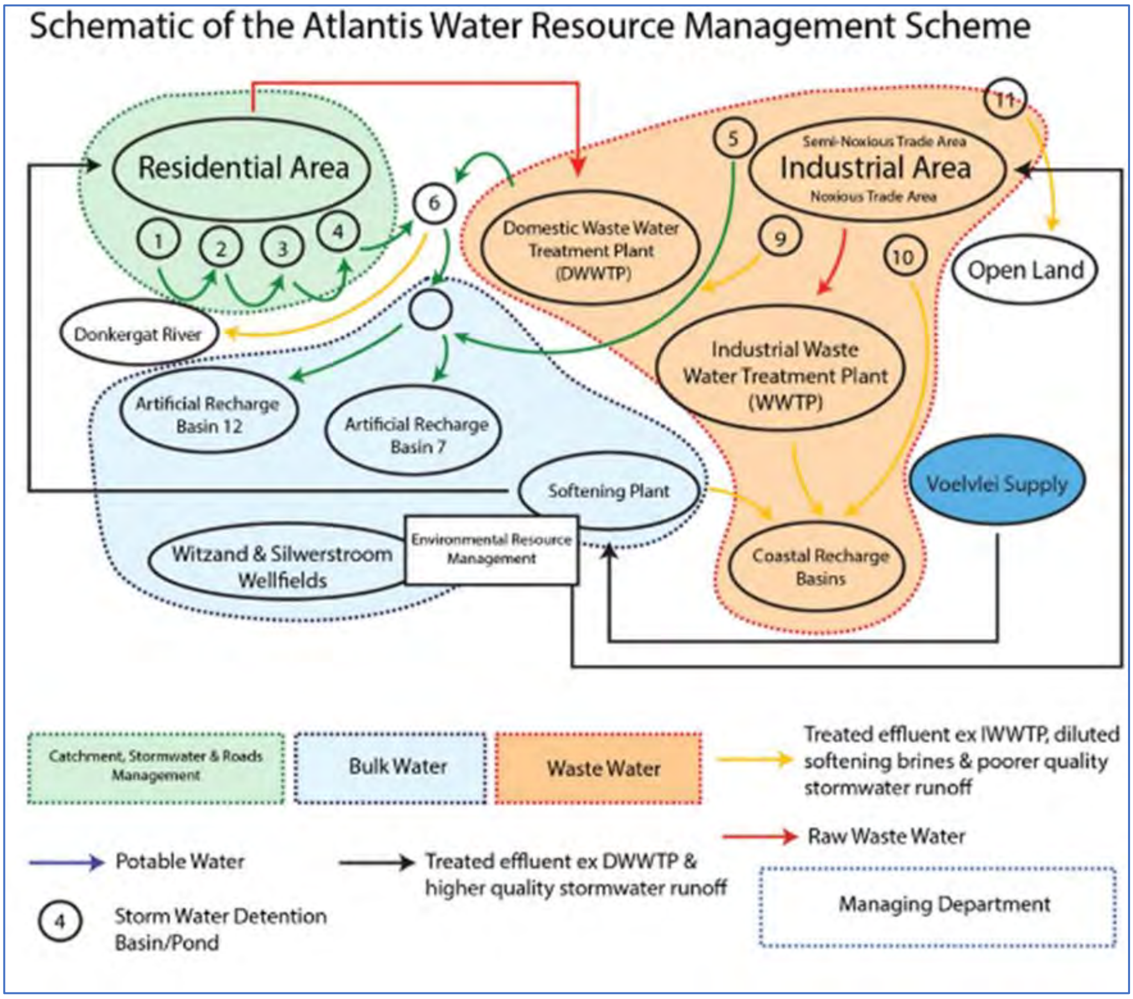


Figure 3-2: Schematic of the AWRMS, highlighting the different responsibilities (CCT, unpublished)

3.2. Data availability

3.2.1. Historic data

The age of the scheme implies there ought to be a comprehensive long term data record ranging from 1980 to present. Due to the scheme's value being overlooked in previous years, large portions of data (which was never kept in a concise and specific database) has been corrupted or lost (transition from manual records to electronic as well as involvement and manipulation of raw data by different role players within CCT and externally) and is often incomplete. The lack of a dedicated monitoring network and team in recent years has resulted in limited data being available for the period since the year 2000. In some instances where data was collected, it has never been interpreted to offer meaningful information to be used in decision making. Previous monitoring programmes / protocols existed but were in some instances never fully implemented and data has been lost through the numerous role players involved in data collection over the scheme's lifespan. Many technical reports are available on the scheme, but raw data is less easily sourced and is often from individual role players that were at one point involved in the scheme.

In summary, the following is available:

- Climate data is sourced from the South African Weather Service (SAWS) at a station located at Wesfleur WWTW and offers a comprehensive record from 1980 to present. This includes parameters such as rainfall, temperature, wind speed, evaporation and evapotranspiration.
- A wealth of groundwater level data is available from 1984 to present. Unfortunately, the data is not continuous throughout the entire monitoring period making long-term water level fluctuations difficult to interpret.
- Abstraction data is available from 1993 to present, with intermittent results throughout the latter parts of the study. A significant decrease was observed from August 1999 onwards due to the connection with the new pipeline as well as the deterioration of the infrastructure, specifically iron-related clogging (Bugan et al., 2014, 2016).
- Effluent volumes from both the domestic and industrial treatment plant were monitored at the Wesfleur WWTW, with data available from January 2003 to February 2013 averaging 2100 ML/a and 1305 ML/a, respectively
- Storm water volumes are not monitored at Atlantis, stormwater rates were therefore estimated as a function of rainfall using the Soil Conservation Service (SCS) Curve Number (CN) as applied by Bugan et al., (2014, 2016).
- Water quality has been more closely monitored (due to MAR components) but has also diminished in frequency over the years. Majority of insights and available data stem from Dr G. Tredoux (lead geochemist during scheme design and inception).

3.2.2. Data repository

The database currently comprises three main datasets that are used for hotspot identification, data analysis, assessment and interpretation – groundwater pump test data, groundwater routine monitoring data, and routine surface water monitoring data, and include historical data sets over the last 4 decades. An excerpt of the data is provided in Appendix B.2.

- 28 730 samples from several sources are recorded for the period 1974 to 2013, while 5 097 samples are recorded for the period 2014 to 2018.
- 59 pump test samples have been taken and analysed, usually taken at the end of 72 hours of pump testing as an once-off sampling, after they have been drilled. Pump testing has been ongoing since January 2018.
- 130 routine groundwater monitoring samples have been taken on a quarterly basis during a sampling campaign. Borehole samples were taken using a DIS device or bailer and analysed for the same parameters as the pump test samples. The first routine monitoring sampling campaign started in April 2019.
- 69 surface water samples have been collected from the Lotus canal and various dams around Philippi and Hanover Park since 2017. These sites have each been sampled once, between 2017 – 2019.
- 29 of the above samples have been analysed for several inorganic and organic pollutants, using a ContamScan.
- 10 additional samples have been taken and analysed for chemicals of emerging concerns (CEC).

Some complimentary data are available in report format and used to support the assessment.

3.3. Water Quality Hotspots

A comprehensive analysis of the hydrochemical data of samples collected during routine monitoring of the Atlantis Aquifer was conducted with the aim of improving the understanding and existing knowledge of the AWRMS, identify potential contamination sources, assess the impact of MAR and other land use activities on the groundwater quality.

A comprehensive analysis of **groundwater** hydrochemical data was conducted. Results showed a distinct zoning in hydrochemical properties of groundwater.

Witzand Wellfield area is characterized by low salinity Ca-HCO_3 water type. Surface water supply from Voëlvlei (via Melkbos reservoirs) is often (standard practise in recent years) blended with abstracted and softened groundwater to lower the salinity and hardness of water supplied. Low salinity in the Witzand area is thus attributed to lower salinity of MAR source water. The ionic dominance seen in the groundwater is due to calcareous, shell rich sands of the Witzand Formation. The abundance of Ca^{2+} and HCO_3^- ions, mobilised from the Witzand Formation into the underlying Springfontein Formation during infiltration and water table fluctuation in the Witzand wellfield, results in the elevated temporary hardness of groundwater. This is a change in water type (based on ionic dominance) between the Witzand Wellfield area and the rest of the aquifer which predominantly shows a Na-Cl ionic dominance. The Na-Cl type of the broader aquifer (excluding Witzand) is likely from continued deposition of marine aerosols on the aquifer surface, influence of peats and clays and the underlying basement rocks. In the industrial area, the Na-Cl water type can also be attributed to the treatment and recycling of effluent and contamination from industry and mining. A zone of transition is observed between the two water types where reverse ion exchange processes result in an Ca-Mg-Cl water type.

Comparison with drinking water standards indicate that groundwater in the industrial and commercial zones of Atlantis is of poorer quality (including elevated *E.coli* and arsenic above guidelines) than the Witzand and Silwerstroom wellfields likely as a result of the mixed urban land use and MAR scheme (unlined and malfunctioning stormwater basins). Iron and manganese were generally elevated at Witzand and Silwerstroom. This aligns with previous observations and continued challenges of borehole clogging due to biofouling by iron reducing bacteria. These bacteria require further investigation. Notable exceedances of the adopted guidelines were observed in Witzand Wellfield for turbidity, and COD, likely related to biofouling in abstraction boreholes and associated equipment. TOC is elevated especially near the Witzand Wellfield and Far Field, likely due to extensive vegetation cover across the aquifer (Bugan et al., 2016) and organic matter in the infiltration basins. This offers hydrochemical motivation to the existing hydrophysical need for cleaning of both basin 7 and basin 12.

Silwerstroom groundwater samples showed notable exceedances of the adopted guidelines for turbidity with exceedances of the SANS-241 operational and aesthetic limits, and the treatment guideline for COD and suspended solids. **Silwerstroom surface water** (spring and weir) results indicated an increase in bacterial count between the Silwerstroom spring and weir

Groundwater samples collected from near the Wesfleur WWTW (WWTW5 and WWTW8) have elevated concentrations of multiple parameters, including EC, nitrate, orthophosphate, TOC, sodium, chloride, potassium, and sulphate. The extent of these elevated constituents should be more finely mapped to assess the reach and impact of the WWTWs.

The sand mining activities present in Atlantis can impact the groundwater quality (EC, sulphate, sodium and chloride content) by promoting evaporation from surface water bodies in hydraulic connection to the aquifer, mobilise fines, metals and contaminants from wash pants and kilns. As a result, these activities need to be assessed and monitored for potential impacts. Compulsory monitoring of groundwater by the mines, with regular supply of data to CoCT is recommended. Likewise, for any and all groundwater users and industrial activities within Atlantis.

MAR source water was sampled and compared to guidelines to assess compliance with conditions of the existing water use license for recharging the aquifer with treated effluent (Section 21e of the National Water Act, Act 36 of 1998). Potential water treatment requirements and how the water quality compares to different standards were also assessed. The CRB flow path and Donkergat River were sampled to assess water quality amidst concerns of contamination from industry and sewerage.

Results obtained for MAR source water indicated the following:

- Elevated salinity of the treated industrial effluent, and resultantly CRB north and south.
- Total suspended solids and associated turbidity was elevated at all surface water locations, except for Basin 6 outlet.
- All surface water samples have elevated *E.coli* and faecal coliforms counts, with the highest *E.coli* counts at Basin 5, 9, 6 inlets, and Basin 10 inlet and outlet.
- Various nutrients (i.e. nitrate, nitrite, ammonia, orthophosphate and Total Organic Carbon) measured in the surface water showed isolated elevated values, predominantly in the CRB flow path (treated effluent, Basin 10 and the CRBs). In addition, there were isolated high values of ammonia at Basin 5 inlet and Basin 6 NW inlet-both receiving stormwater.
- Chemical Oxygen Demand (COD) concentrations were elevated at all sampling locations, particularly in the industrial stormwaters (basin 5, 9, 10 and 11).
- Arsenic was elevated at the inlet and outlet of Basin 10, with further investigations into the poor quality of Basin 10 inputs and its impact on CRB water quality requiring further investigation.
- Dissolved aluminium, manganese and iron were elevated in the industrial stormwaters, with one high iron value at Basin 5 and Basin 9 inlet. Monitoring of these industrial stormwater flow paths is important in preventing contamination of the aquifer and establishing accountability amongst industrial land users. Establishing trends per basin to assess variables related to spikes in certain parameter concentrations and to track the effectiveness of the basins' treatment capacity are important processes in protecting the MAR source water and resultantly the groundwater resource.

The **Donkergat River**, a tributary of the Sout River currently receives treated industrial effluent. To support understanding the Donkergat River status quo and downstream impacts, the Sout River water quality was also considered. Donkergat River is of considerably lower salinity than the Sout River, which has elevated concentrations of multiple constituents - likely due to the geological influence of the wider catchment. In general, the current discharge of treated effluent to the Donkergat improves the water quality of the Sout by lowering the EC downstream of the confluence, but also elevates the nitrate levels of both watercourses, although the Donkergat is ephemeral upstream of the AWRMS discharge location. The effluent has an impact in increasing the dissolved lead in the Donkergat to levels above the aquatic limit. These investigations are preliminary and contributing flows and impacts to Donkergat need further assessment.

Domestic and industrial **effluent** used for aquifer recharge at Witzand and CRBs respectively were tested for CEC's. Most CECs detected are from an anthropogenic source; including artificial sweeteners, antibiotics, prescription drugs and chemicals derived from human metabolism of aspirin and caffeine. The analysis of CEC's showed carbamazepine (an anticonvulsant, analgesic drug) in the domestic effluent and industrial effluent and 1,4-Dioxane (solvent, and a trace contaminant of some chemicals used in household products) in the industrial effluent exceed the adopted guidelines.

3.4. Potential Groundwater Contamination Sources and Hazards

Based on the general chemistry analysis, comparison to drinking water and treatment guidelines, contamscan and CEC analysis of Atlantis groundwater and MAR Basins, the following potential contamination sources and hazards have been identified:

1. **Wesfleur Wastewater Treatment Works (WWTW)**. Groundwater samples collected from the WWTW (WWTW5 and WWTW8) have elevated concentrations of multiple parameters, including EC, nitrate, orthophosphate, TOC, sodium, chloride, potassium and sulphate. The effluents from the WWTW are shown to raise the salinity of surrounding groundwaters, and this is particularly evident in the boreholes around the WWTW, recharge basin 7 and the coastal recharge basins. Power failures at the WWTW pose a minor to moderate threat to the system should untreated sewage be diverted to basin 6 as the impacts would not be observed long term. However, sewage leakage or breakage can have moderate long-term impacts and thus pose a high risk.
2. **Industrial chemical spills and waste discharges**. Industrial wastes can have severe impacts if pollution enters the recycling system via stormwater. Currently, basin 9 receives stormwater from the industrial area and connects to basin 6. Concentrations of parameters, including dissolved iron and total aluminium are on par with observations from basin 10 and the CRBs, poorer water quality streams that are not connected to the main recharge basin. Basin 10 receives stormwater from the noxious trade area and frequent sewage overflows, and multiple parameters including EC, total aluminium, iron, dissolved arsenic, ammonia, and nitrate are observed in high concentrations. Chemical wastes have often been observed in the vicinity of Supapackers Fish Processors along Neil Hare Road.
3. **Petroleum**. Oil spills frequently occur at specific points within the AWRMS. There is also an oil pipeline that passes through the extent of the aquifer which can severely contaminate groundwater. Additionally, atmospheric pollution from combustion of fuels, including the use of diesel at the Ankerlig Eskom Power Station and potential leakages from fuel storage tanks in Atlantis pose a threat to groundwater quality. Although no guideline values are available for extractable petroleum hydrocarbon (EPH) compounds, ContamScan analysis indicates the presence of petroleum compounds in the groundwater across the Witzands Far Field and Witzands Wellfield clusters, as well as in basin 10.
4. **Small-scale farming**. Legal and illegal farming practices can pose a hazard to the system by introducing nutrients and emerging contaminants into the groundwater, through the application of fertilizers and herbicides. Small scale farming occurs in the northern and north eastern margins of the aquifer and although no farming related nutrient pollution has been observed, the herbicides Diuron, Simazine and DIA were detected in groundwater samples from AT-P09 and AT-P32, and in the treated effluents, related either to their production, use or disposal.
5. **Mining activity**. The sand mining activities present in Atlantis can impact the groundwater, including through petroleum spills from mining equipment. Assessment of mine site dams in the Cape Flats Aquifer (*2018-2020 CFA Pump Test and Routine Water Quality*, 2020) have been found to have high EC, sulphate, sodium and chloride content and evaporation from the open dams can further concentrate dissolved ions in the dam waters. Groundwater in the vicinity of the sand mine downgradient of the mine is of the Na-Cl type.
6. **Formal and informal settlements.** Lack of adequate sanitation infrastructure in the informal Atlantis settlements can lead to nitrate and faecal contamination of the aquifer. Leaky or faulty sewage systems (septic tanks, pipes and pump stations) in formal settlements can also lead to contaminations. Recalcitrant CECs were detected in the treated domestic and industrial effluents. Thus, groundwater in the urban residential areas of Atlantis can be contaminated from lack of proper sanitation infrastructure and from faulty systems.

4. CAPE FLATS AQUIFER (CFA) – WATER QUALITY

4.1. Contextualisation

4.1.1. Geology and Hydrogeology

Cape Flats Aquifer (CFA) is a Tertiary-Quaternary primary aquifer, comprised of basal fluvial (in discrete palaeochannel systems incised into the basement Malmesbury Group and Cape Granite Suite rocks) and shallow marine sediments (predominantly along the False Bay coastline portion of the CFA), and upper dune sediments (Witzand, Springfontyn and Langebaan Formations of the Sandveld Group) that dominate the surface outcrop – green and yellow units on the geological map (top right corner image) indicate dune fields with preferential orientation due to prevailing wind directions.

The CFA is ~35-45 m thick, with average borehole yields ranging from ~3-30 l/s – the higher transmissivity and higher yielding aquifer zones are in the vicinity of thicker, coarser grained shallow marine sediment (Varswater Formation, Sandveld Group) and in the vicinity of fluvial palaeochannel gravel deposits (Elandsfontyn Formation, Sandveld Group) (see bottom right image where high hydraulic conductivity zones and boreholes are indicated).

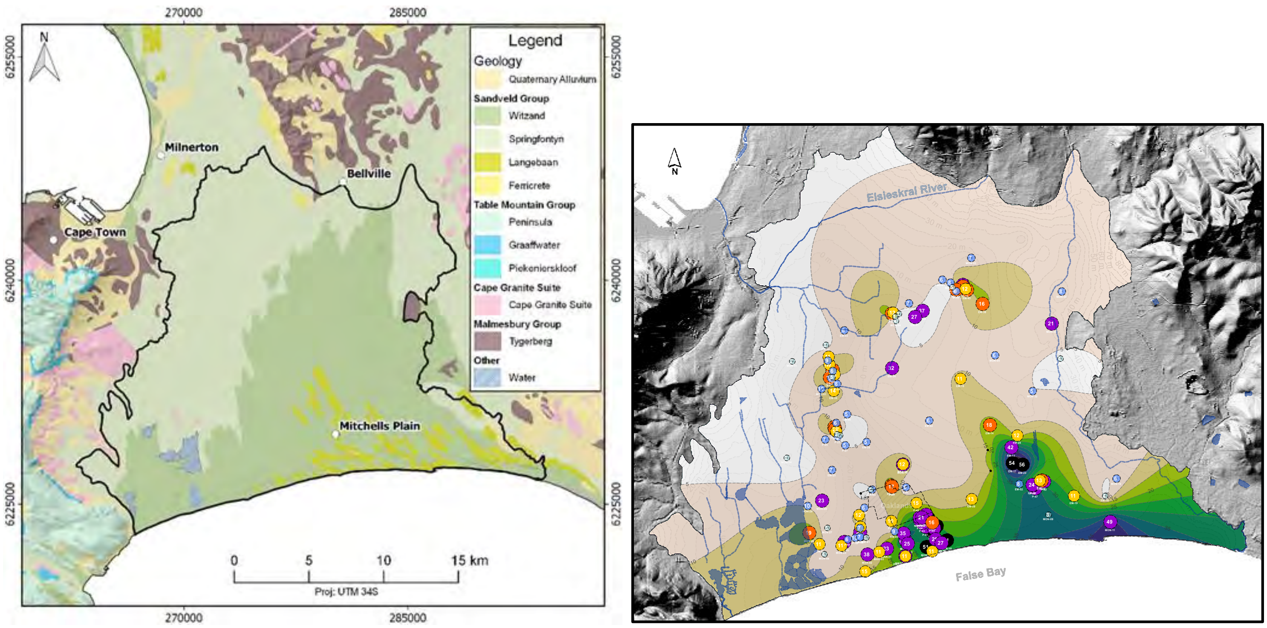


Figure 4-1: Geological Map of the Cape Flats Aquifer (after CCT, 2020a)

The area is termed the Cape Flats because of the very low relief, with the exception of slightly elevated dunes near the False Bay coastline. Elevated and perched groundwater levels result extensive wetland systems (e.g. Zeekoevlei), although because of both controlled suburban/industrial and uncontrolled informal settlement sprawl there is extensive degradation of wetland and surface water systems, as well as the CFA in general.

The CFA is recharged directly by rainfall, as well as indirectly by treated effluent discharge from wastewater treatment works (WWTW) into rivers and canals that are leaking, stormwater runoff and return flow from irrigation within the agricultural area. Hence, an informal MAR system is already in place.

4.1.2. Location and Landuse

The majority of the area is occupied by formal residential areas, which are interspersed with areas of bushes and shrubs. A large number of small-holdings and cultivated land are present in the south east of Cape Town, the Philippi Horticultural Area (PHA). A number of industrial areas are present in the northern and northeastern portion of the CFA. The majority of informal residence are located in a linear pattern from the central to southeastern corner of the CFA along the N2 national highway.

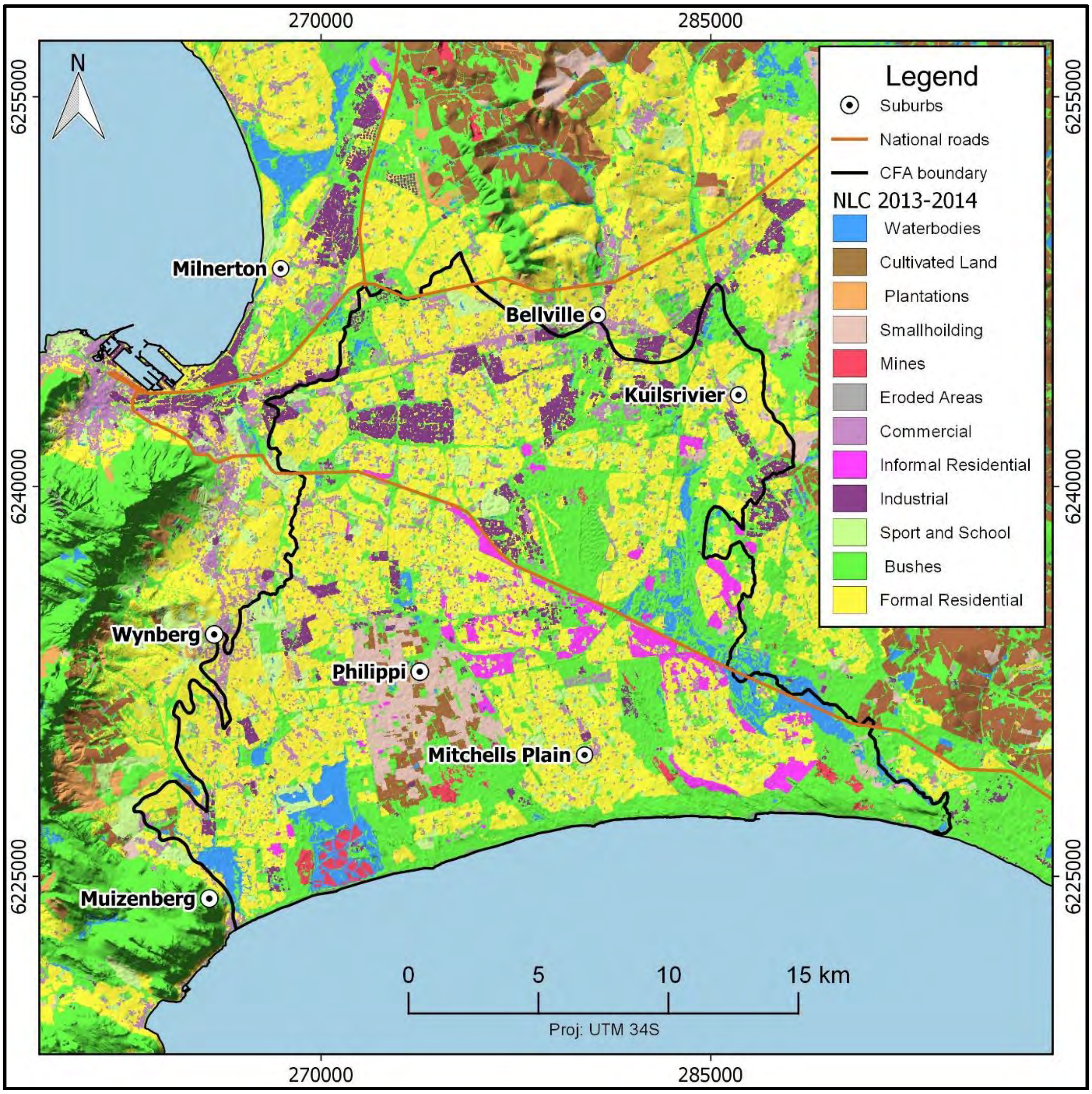


Figure 4-2: Land use distribution map within the CFA (CCT, 2020c).

4.1.3. Current Wellfield Development

The CCT plans to abstract 55 Ml/day from the CFA, as per Phase 1 of the water use licence for the CFA wellfield development, along with the development and implementation of an MAR scheme of 40 Ml/day, injecting treated waste water. The focus of the wellfield development concentrate around the area between Strandfontein along the False Bay coastline and Philippi / Hanover Park, which is mainly under horticultural activities. Potential wellfields outside of this central area might be developed later.

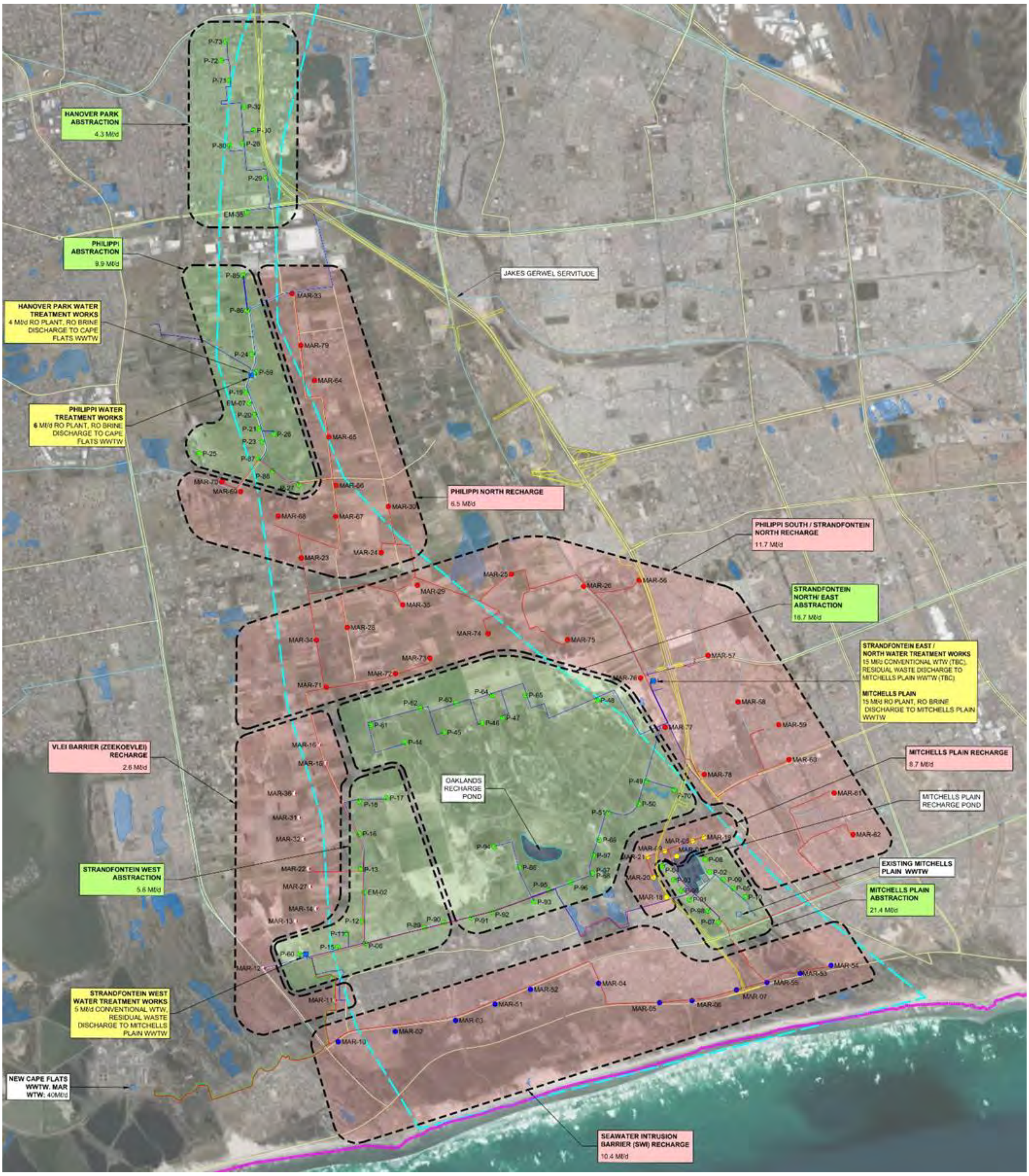


Figure 4-3: Locality Map with proposed wellfield development and monitoring boreholes (after CCT, 2020a)

4.2. Data availability

The majority of available data for the Use Case is derived from the current wellfield development by the City of Cape Town, which is described in more detail in Riemann (2020).

4.2.1. Data repository

The database currently comprises three main datasets that are used for hotspot identification, data analysis, assessment and interpretation – groundwater pump test data, groundwater routine monitoring data, and routine surface water monitoring data. An excerpt of the data is provided in Appendix B.3.

- 241 pump test samples have been taken and analysed, usually taken at the end of 72 hours of pump testing and usually occur once-off for boreholes, after they have been drilled. Pump testing has been ongoing since January 2018.
- 480 routine groundwater monitoring samples have been taken on a quarterly basis during a sampling campaign. Borehole samples were taken using a DIS device and analysed for the same parameters as the pump test samples. The first routine monitoring sampling campaign started in April 2019.
- 22 surface water samples have been collected from the Lotus canal and various dams around Philippi and Hanover Park since 2017. These sites have each been sampled once, between 2017 – 2019.
- 54 of the above samples have been analysed for several inorganic and organic pollutants, using a ContamScan.
- 10 additional samples have been taken and analysed for chemicals of emerging concerns (CEC).

Complimentary data as listed below are available in report format and used to support the assessment.

4.2.2. Additional data sources

Additional data on water quality within the domain of the Cape Flats Aquifer is available from sources outside the wellfield development project; i.e.

- National Groundwater Archive: database of the national Department of Water and Sanitation of boreholes, water levels and water quality
- Department of Transport and Public Works: groundwater development project for securing water supply for critical infrastructure, e.g. hospitals;
- University of the Western Cape: honours and masters projects on the Cape Flats Aquifer;
- University of Cape Town: studies on water sensitive urban design (WSUD);
- CCT Scientific Services: compliance monitoring of water quality at municipal waste sites (leachate and groundwater), waste water treatment plants (effluent), stormwater canals and rivers; selective monitoring of water quality from private boreholes;
- Aerial imagery and remote sensing data, obtained from the National Geographic Institute, Sentinel 2 and Landsat 8, used for detailed mapping of land use and potentially contaminating activities (PCA).

4.3. Identified Water Quality Hotspots

The urban setting of the CFA results in salinization and anthropogenic contamination with nutrients, microbiological and industrial contaminants, hydrocarbons and potentially CECs.

- The salinity is highly variable (EC ~120 mS/m) and shows elevated EC values (~300-700 mS/m) in some areas (see **Figure 4-4**), with one borehole close to a stormwater canal having EC of above 200 mS/m due to very high chloride concentrations.
- Nitrates are generally low (no evidence of diffuse fertilizer contamination within PHA agricultural area), with elevated concentrations linked to point sources such as WWTW (especially the Mitchells Plain WWTW due to unlined sludge ponds, which unfortunately overlies the highest yielding portion of the CFA) and cemeteries. Higher N-concentrations are also found in some canals and rivers.
- Presence of elevated contaminants such as hexavalent chromium and trichloroethylene in CFA groundwater is shown near historical closed industrial areas and landfill sites (e.g. Swartklip area, due to munitions dump/testing).

In essence, CFA groundwater will require extensive treatment via modular treatment works prior to entering the distribution network, as indicated by the exceedances of water quality guideline limits (see **Figure 4-5** for number of exceedances and **Figure 4-6** for maximum percentage of exceedance for acute or chronic health parameters).

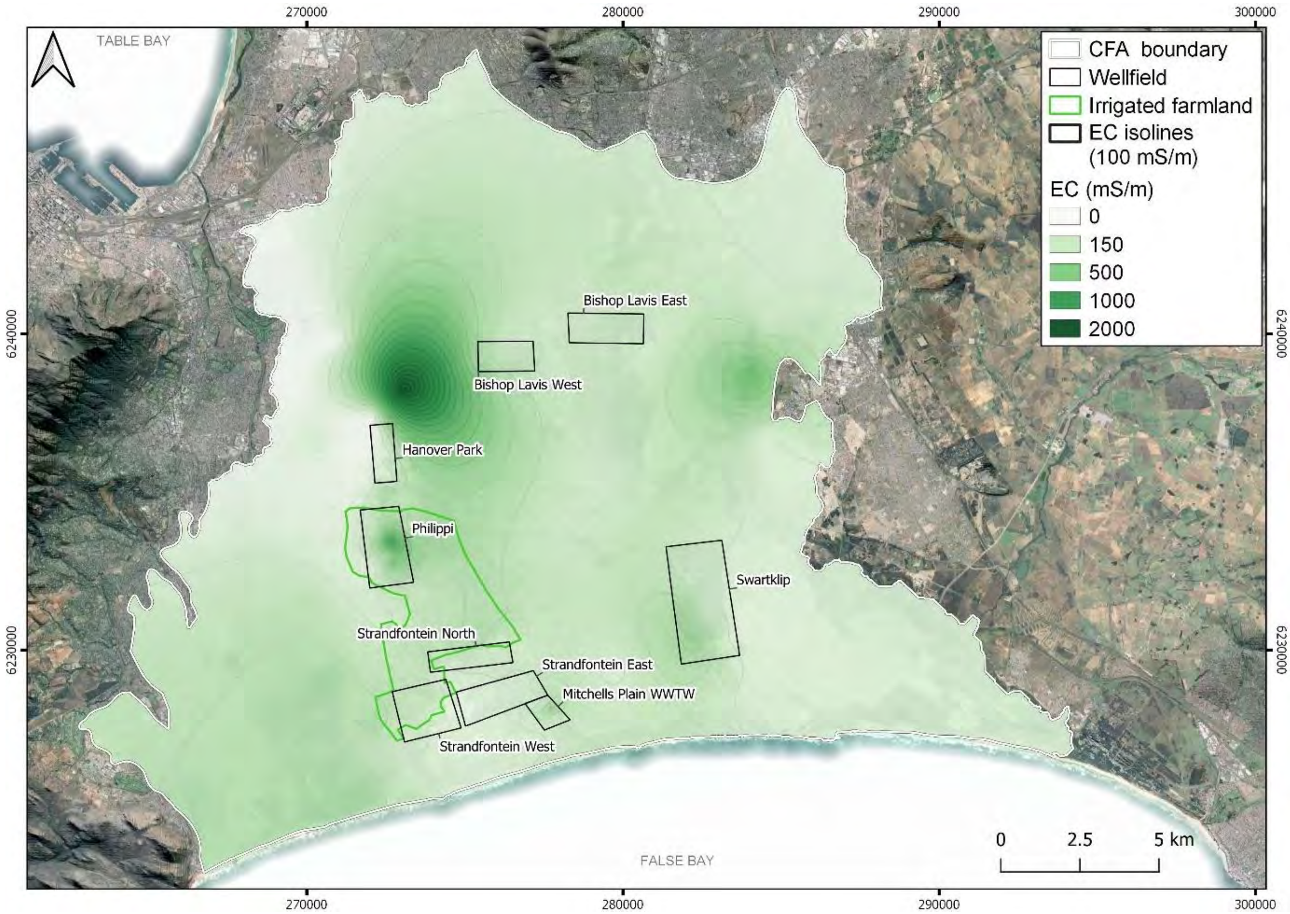


Figure 4-4 EC (mS/m) distribution map across the CFA (after CCT, 2020a).

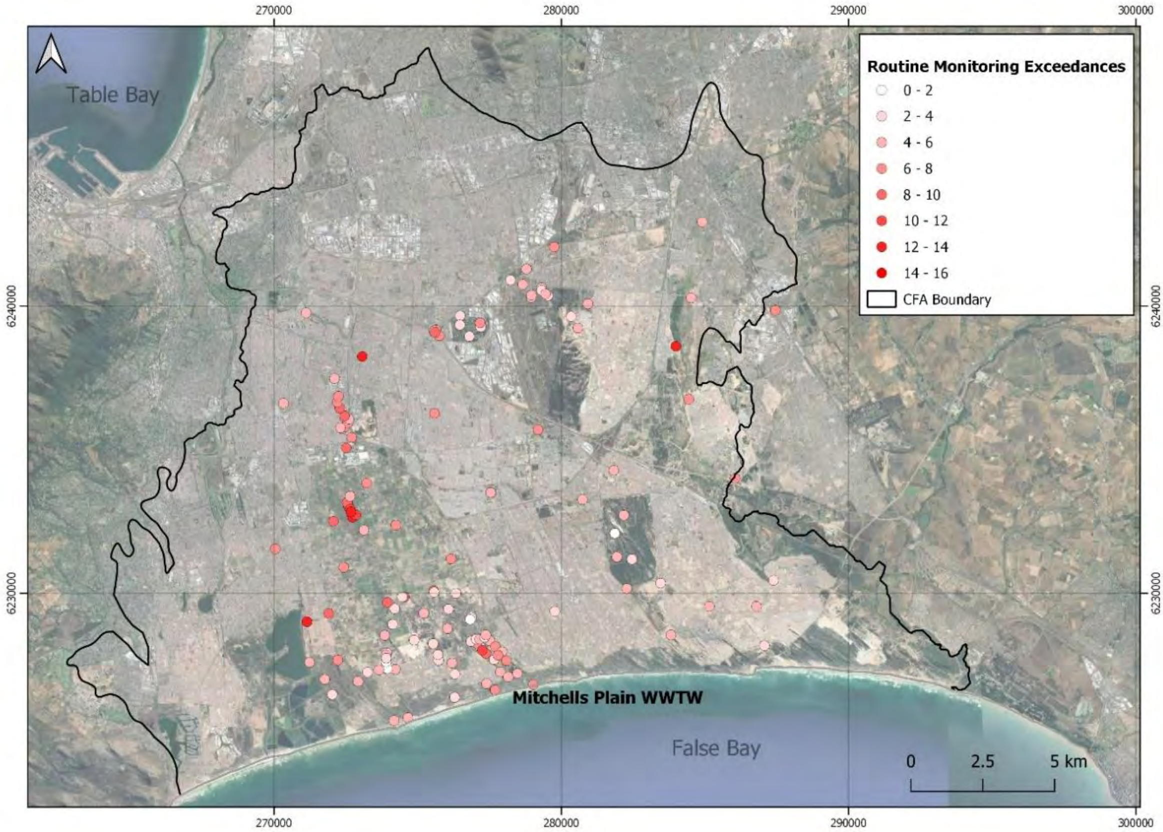


Figure 4-5 Number of exceedances of limits as per SANS 241 Drinking Water Guideline per borehole (CCT, 2020a)

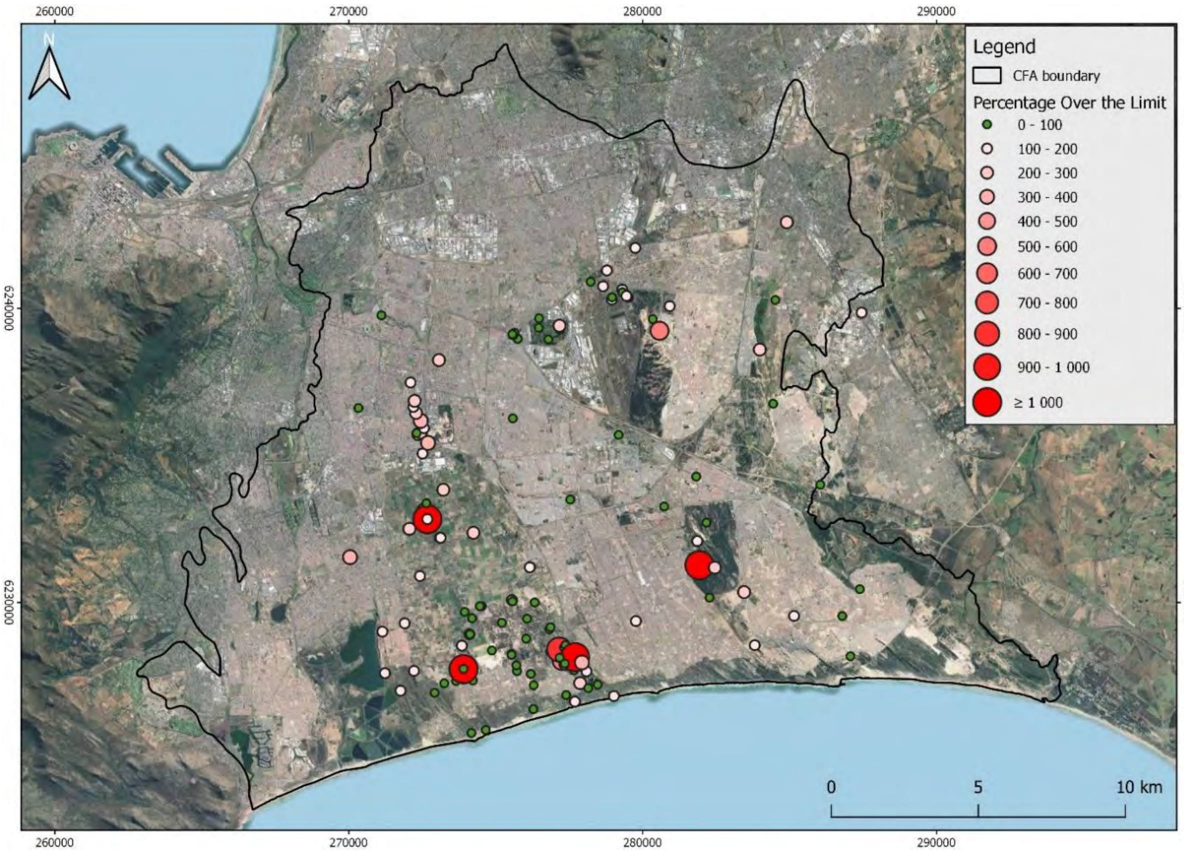


Figure 4-6 Highest percentage of exceedance of acute or chronic health limits (either SANS 241 or EPA guidelines) for any of the analysed parameters per borehole (CCT, 2020a)

4.4. Areas of Concern

4.4.1. Mitchells Plain and Cape Flats WWTW

As listed in **Section 4.1**, the number of exceedances from the test pumping and routine sampling results highlight the Mitchells Plain WWTW as a pollution hotspot. Strandfontein West is also highlighted but the boreholes where the exceedances occur are mainly located alongside the Cape Flats WWTW and Zeekoevlei and form part of the wider monitoring network for the Strandfontein wellfield itself. The exceedances include fluoride, TOC, nitrates, E.coli, arsenic and Ammonia which are likely associated with the unlined sludge and maturation ponds at both WWTWs.

The Cape Flats WWTW contamination plume is deemed less of a risk to the CFAMS, in comparison to the Mitchells Plain WWTW, due to it being downgradient of all production wellfields and the presence of the planned Strandfontein West/Vlei Barrier MAR wellfield, which aims to maintain a hydraulic barrier between the wellfields and the WWTW. A rehabilitation plan has been implemented for the Mitchells Plain WWTW as detailed in CCT (2019).

4.4.2. PHA

The Philippi area was also highlighted as a pollution hotspot in **Section 4.1**, with the highest number of exceedance counts including TOC, nitrates, E.coli, cyanide, EC, chloride, sodium, ammonia and sulphate. The source of the sulphate is likely a combination of the peats found in the area and practices associated with agriculture on land under irrigation within the PHA.

The most concerning of the exceedances is the salinity – high EC, chloride and sodium. Stable isotope and soil samples were analysed to determine if the source of the salinity was natural or anthropogenic, as the area is underlain by clay and peat lenses but is also a vegetable producing area, whereby the crops are intensively irrigated with groundwater. Many farmers have irrigation ponds, whereby they store the abstracted groundwater in surface ponds. The isotope results note that the source of the groundwater within the PHA is from precipitation that has undergone some evaporation prior to infiltration and not from basement upwellings. The soil analysis shows that the peats and clays do have high EC which could contribute to the brackish water found in the area. This however does not fully account for the brackish water, as other areas within the CFA are also underlain by clays and peats. It is therefore presumed that irrigation return flow or the practices involved in agriculture contribute as well.

The quota for groundwater abstraction in the PHA is 22 500 m^3/ha/a (2 250 mm/a). This results in a potential 35.8 million m^3/a of groundwater abstraction for irrigation. As indicated by some farmers, irrigation water is used for half the year (during the dry season), which reduces the potential volume to 17.9 Mm^3/a. It is therefore likely that much of the abstracted water in the PHA is returned to the aquifer directly via infiltration from open surface irrigation dams or irrigation return flow (IRF).

The abstracted groundwater is stored in open surface irrigation dams which undergo high rates of evaporation, resulting in a high concentration of dissolved ions in the water. The water from the irrigation dams is then used to irrigate the crops resulting in the downward percolation of saline water through the soil profile and vadose zone. This results in the soils being leached of their minerals and ions. The effect of irrigation is evident by the high concentration of chloride ions found in the groundwater in these areas. Repeat pumping of the groundwater exacerbates these effects.

A study conducted in 2013 around the Philippi farm area explored the nature and source of salinity (Ruben Aza-Gnandji et al., 2013). The study included a full geochemical analysis of boreholes and irrigation ponds around the area, coupled with environmental isotopes to trace the source of salinity in the area. The study found that samples taken from the irrigation ponds had stable isotope values that showed strong evaporation processes, while the groundwater samples from the boreholes did not show evidence of evaporation processes. This implies that evaporation is not a significant process effecting the ion concentration of groundwater.

The study concluded that the accumulation of salts was mostly due to agricultural activities. Such effects include the application of various fertilizers, manures, insecticides, and fungicides, which contribute to the concentration of soluble salts. In addition to this, evaporation processes.

4.4.3. Surface Water and Lotus Canal

The surface water sampling undertaken by Umvoto Africa and City of Cape Town show how surface water bodies are easily polluted and therefore impact the underlying groundwater quality. Surface water bodies highlight exceedances in EC, ammonia and nitrates (see **Section 4.1**). Results received from samples taken from the Lotus Canal also note the presence of Vibrio Cholera and Clostridium which will continue to be monitored. The pollution of surface water bodies is also confirmed by exceedances observed in boreholes located alongside surface water bodies such as the high EC alongside the Vygieskraal River (outlier in **Figure 4-4**), and high EC, arsenic, ammonia and nitrate in a borehole alongside a stormwater canal discharging into Zeekoevlei.

4.4.4. Swartklip

Due to the significant impacts of groundwater quality at the Swartklip site, this section summarises the site history and the identified contaminants of concern, as well as the potential sources. Historical assessments identified various sources of elevated metals (copper, chromium (VI), lead, cadmium) at the site. Although sources have been remediated by the previous landowner, residual concentrations remain at the site.

Results from the ongoing sampling at the Swartklip site agree with potential contamination hotspots identified in the past reports where spikes in trichloroethylene (TCE), chromium VI, perchlorate and cis-1-2-DCE were noted in some monitoring boreholes. The concentrations of these determinands decreases to the north and south of the Swartklip site in general but remains relatively high to the southeast.

The pathway to the southeast could indicate a contamination plume which is following the local groundwater gradient in that direction. If this is the case it poses a risk to any local groundwater users in the vicinity of the Swartklip site, particularly down gradient. Further assessment is required to assess the spatial extent of the detections, including off-site to the west of the Swartklip property and along the eastern boundary of the property. This will refine the distribution of the contamination plume and the location of the source.

Exceedances of SANS-241 parameters include *E.Coli*, faecal coliforms, ammonia, nitrate and nitrite. These could be from a leaking sewage reticulation network, improper sanitation in the surrounding areas, or animal sources. Ammonia, nitrate and nitrite could also be linked to the historical munitions land-use. Elevated electrical conductivity, total dissolved solids, sodium, chloride and total iron are potentially derived from rock-water interactions and wind-blown salts from the ocean. Elevated organic carbon can be from the leaching of any organic rich (peat) lenses within the aquifer or from leaking sewerage pipelines in the vicinity. Elevated arsenic was only found at EM-24 and could be related to leaking sewerage pipelines or the historical munitions land use.

In order to determine the extent of any contamination plume, samples were taken from schools in the vicinity of Swartklip. Concentrations of various dissolved metals were detected with dissolved iron exceeding the SANS-241 aesthetic guideline (300 mg/l) found in one borehole (639 µg/l).

Tetrachloroethylene (PCE) was measured with a concentration of 33 µg/l at one school's borehole exceeding international limits. Notable is that tetrachloroethylene can be inhaled and absorbed through the skin.

5. TABLE MOUNTAIN GROUP AQUIFER (TMGA) – WATER QUALITY

5.1. Contextualisation

5.1.1. Location and Geology

The Table Mountain Group (TMG) is an extensive (both with respect to areal extent, thickness and volume) Ordovician to Devonian (480-390 Ma) slightly metamorphosed sedimentary package, which was structurally deformed during the Permo-Triassic (~280-230 Ma) Cape Orogeny and Gondwana breakup (~180-110 Ma).

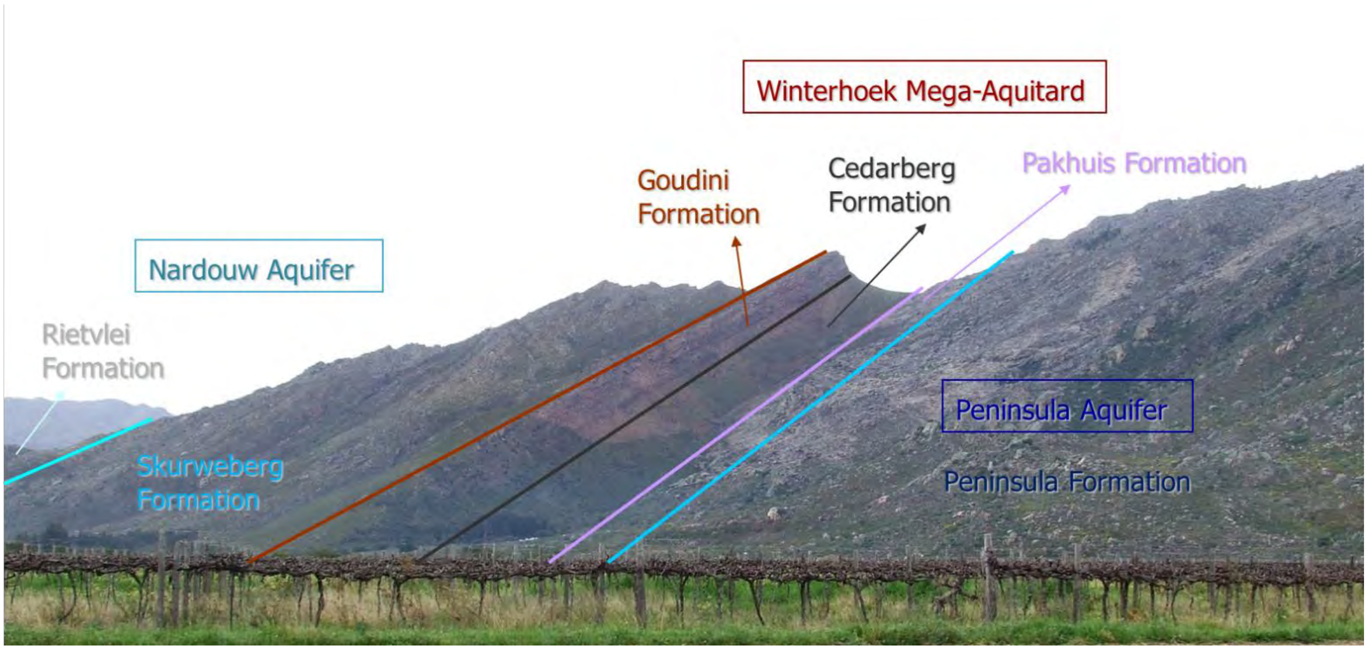


Figure 5-1: Image from opposite Goudini Spa in the Breede River valley northeast of Cape Town, outlining the major formations of the TMG that occur east of Cape Town in the CCT's main TMG groundwater exploration target zones. (Blake, 2019)

The lower Peninsula Aquifer (comprised solely of the Peninsula Formation) and upper Nardouw Aquifer (comprised of the Skurweberg and Rietvlei Formations) form the two major TMG fractured aquifers, which are 700-1200 m thick and 300-400 m thick respectively in the CCT TMG target zones. The Peninsula and Skurweberg Formations are comprised almost entirely of slightly metamorphosed quartzitic sandstone (quartzite), with the Rietvlei Formation being comprised of more feldspathic sandstone and a siltstone/shale layer near the contact with the Skurweberg Formation (informally termed the Verlorenvalley Member, which acts as a local confining unit within the Nardouw Aquifer). The Peninsula and Nardouw Aquifers are separated by the argillaceous (shale-rich) units of the Pakhuis Formation (glacial tillite of ~10-50 m thick), Cedarberg Formation (shale, siltstone and fine sandstone, ~80-100 m thick) and Goudini Formation (iron-rich, reddish sandstone, siltstone and shale, ~150-250 m thick), which combined form the ~250-400 m thick Winterhoek Mega-aquitard.

The TMG was highly deformed (folded and faulted) during the Cape Orogeny, which lead to extensive fracturing of the quartzite formations that comprise the Peninsula and Nardouw Aquifers. Because of the mechanical strength of the quartzites (they form some of the hardest rocks in the world), large regional faults and fractures can be held open to great depths of up to 5-6 km (as proven by numerous hot springs in the Western Cape, which reach temperatures of up to 40-60 degrees Celsius, which would require groundwater flow to these sorts of depths to reach those temperatures).

5.1.2. Existing Study

The Table Mountain Group Aquifer (TMGA) Feasibility Study and Pilot Project commenced in May 2002 with the appointment of the TMGA Alliance by the then Resource and Infrastructure Planning Branch of the Bulk Water Department of the City of Cape Town (CCT). The TMGA project focused on the confined portions of the Peninsula Aquifer located throughout the study area, and where the development of well-fields for bulk water supply to the City may be feasible in terms of existing reticulation infrastructure.

The CCT's Water Strategy aims to develop 50 Ml/day from the TMG aquifers by 2021 from three wellfields – the Steenbras Wellfield (which is in current development and will be outlined in subsequent slides), and the Nuweberg and Klipfontein Wellfields (both within the T/G target zones, with current exploration taking place, and wellfield development following the completion of the Steenbras Wellfield).

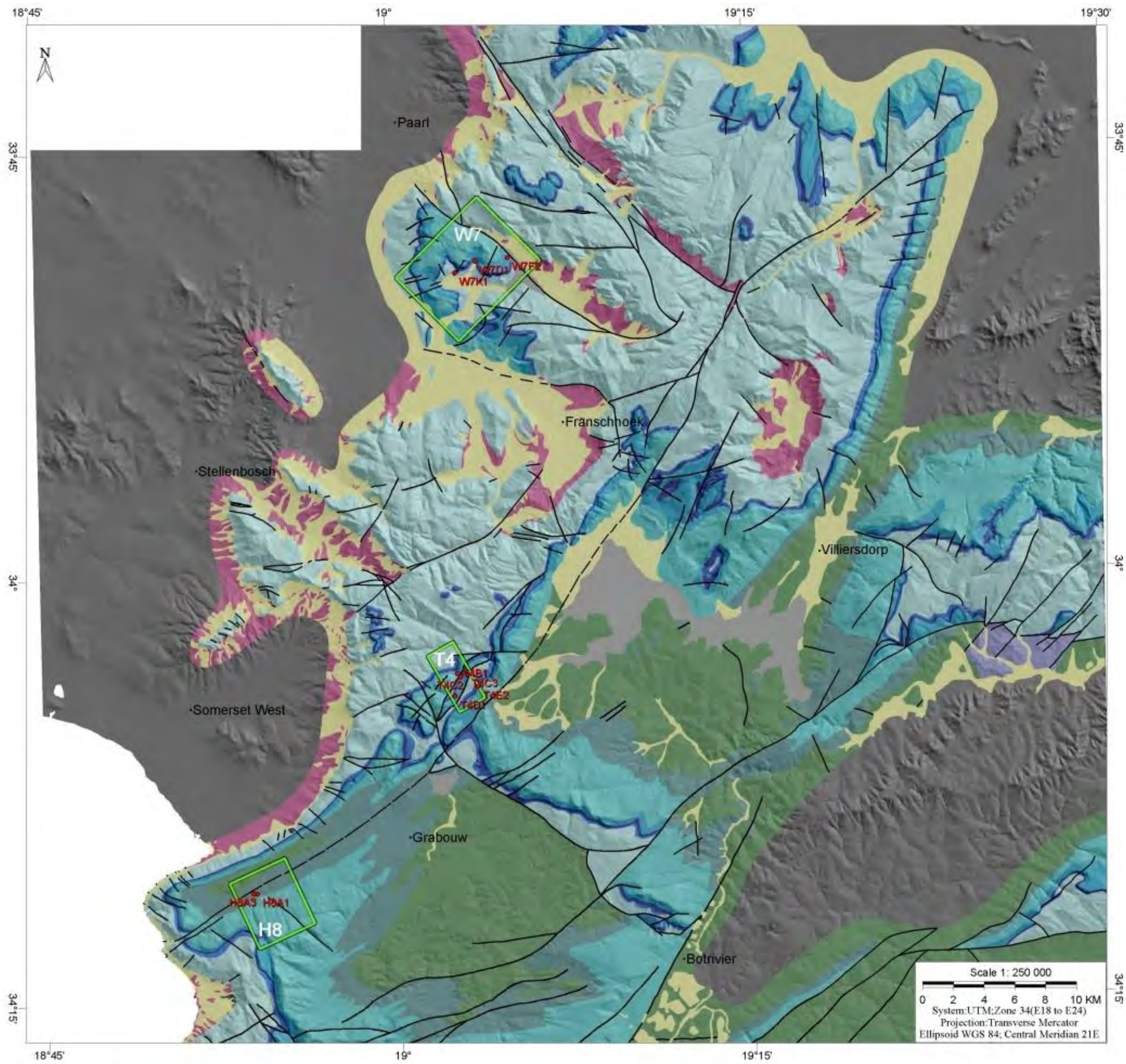


Figure 5-2: Geological Map of the main target areas for the TMG Aquifer development; Steenbras (H8), Nuweberg (T4) and Wemmershoek (W7); other areas not shown on map include Groenlandberg (east of T4), Berg River Dam (south of W7), Helderberg Basin (west of T4), Voëlvlei and Southern Planning District (after CCT, 2012)

The potential yield from the TMG aquifers is much higher than groundwater mix city envisions for 2040 however (potentially up to one third of total bulk water supply could come from the TMG). This further wellfield development will depend on the success of the Steenbras, Nuweberg and Klipfontein Wellfields – if the three wellfields are high yielding and show minimal ecological impacts with respect to the fynbos biome (which extends across the whole TMG, is one of the five floral kingdoms, and is a biodiversity hotspot), then the CCT will likely expand TMG wellfield development to other areas (and increase yield from existing wellfields) to licensed volumes.

5.2. Data availability

5.2.1. Data repository

The database currently comprises three main datasets that are used for hotspot identification, data analysis, assessment and interpretation – groundwater pump test data, groundwater routine monitoring data, and routine surface water monitoring data. An excerpt of the data is provided in Appendix B.4.

- 312 historical routine groundwater samples have been taken across the study area from both the Nardouw and Peninsula Aquifer between 2009 and 2015.
- 77 historical surface water samples have been taken from groundwater discharge points across the study domain between 2009 and 2015.
- 280 groundwater monitoring samples have been taken, either during drilling, from pumping tests or subsequent sampling campaign, since 2017.
- 231 surface water samples have been collected from several potential groundwater discharge points and streams, focusing on the Steenbras wellfield development area and the Nuweberg exploration site, between 2017 – 2019.
- 10 additional samples have been taken and analysed for chemicals of emerging concerns (CEC).

Complimentary data as listed below are available in report and or digital format and used to support the assessment.

5.2.2. Additional data sources

Additional data on water quality within the domain of the Cape Flats Aquifer is available from sources outside the wellfield development project; i.e.

- National Groundwater Archive: database of the national Department of Water and Sanitation of boreholes, water levels and water quality
- WMS database of the national Department of Water and Sanitation: water quality data of surface water bodies
- Department of Transport and Public Works: groundwater development project for securing water supply for critical infrastructure, e.g. hospitals
- University of the Western Cape: honours and masters projects on the TMG Aquifer
- University of Cape Town: studies on isotopic characteristic of groundwater in the TMG
- Aurecon: assessment of the impact of Rotafoam drilling fluid on the environment in Steenbras
- Aurecon: water quality in the Steenbras Dam and assessment of the impact of discharging iron-rich groundwater into the dam
- Aerial imagery and remote sensing data, obtained from the National Geographic Institute, Sentinel 2 and Landsat 8, used for detailed mapping of land use and ecosystems.

5.3. Water Quality Hotspots

The TMG Aquifer is located in a very pristine area, which a large portion of the outcrop and recharge areas being within protected areas such as nature reserves and conservatories. Hence, there is no concern for anthropogenic water quality issues. The available water quality data confirm that.

5.3.1. Geogenic water quality issues

Naturally, groundwater from the TMG Aquifer is similar to rain water, as the geological formations that make the TMG aquifers are mostly comprised of quarzitic sandstones, an inert material. Electric conductivity is mostly below 30 mS/m and the water is slightly acidic to very acidic.

Surface water in the outcrop and recharge areas is usually highly acidic and low in nutrients due to the vegetation cover (fynbos biome), thin topsoil cover and sandy soils. In general, water in this environment has very low salt content (TDS).

Figure 5-3 indicates some similarity between the groundwater and the two surface water monitoring sites. In the case of the Steenbras area, the groundwater samples are from the Nardouw Aquifer, sampled at H8A1 and H8A3, while the groundwater samples in the Nuweberg area come from the deeper Peninsula Aquifer. However, the groundwater quality varies widely and includes Bicarbonate-rich water and increased levels of Calcium. Due to the drilling and construction of these boreholes, viz. small diameter core boreholes with mild steel casings to fractured zone, and the required sampling method via bailer, these results are only indicative. In addition, the low TDS results in small inaccuracies in the lab results creating significant changes in the chemical composition and characteristics.

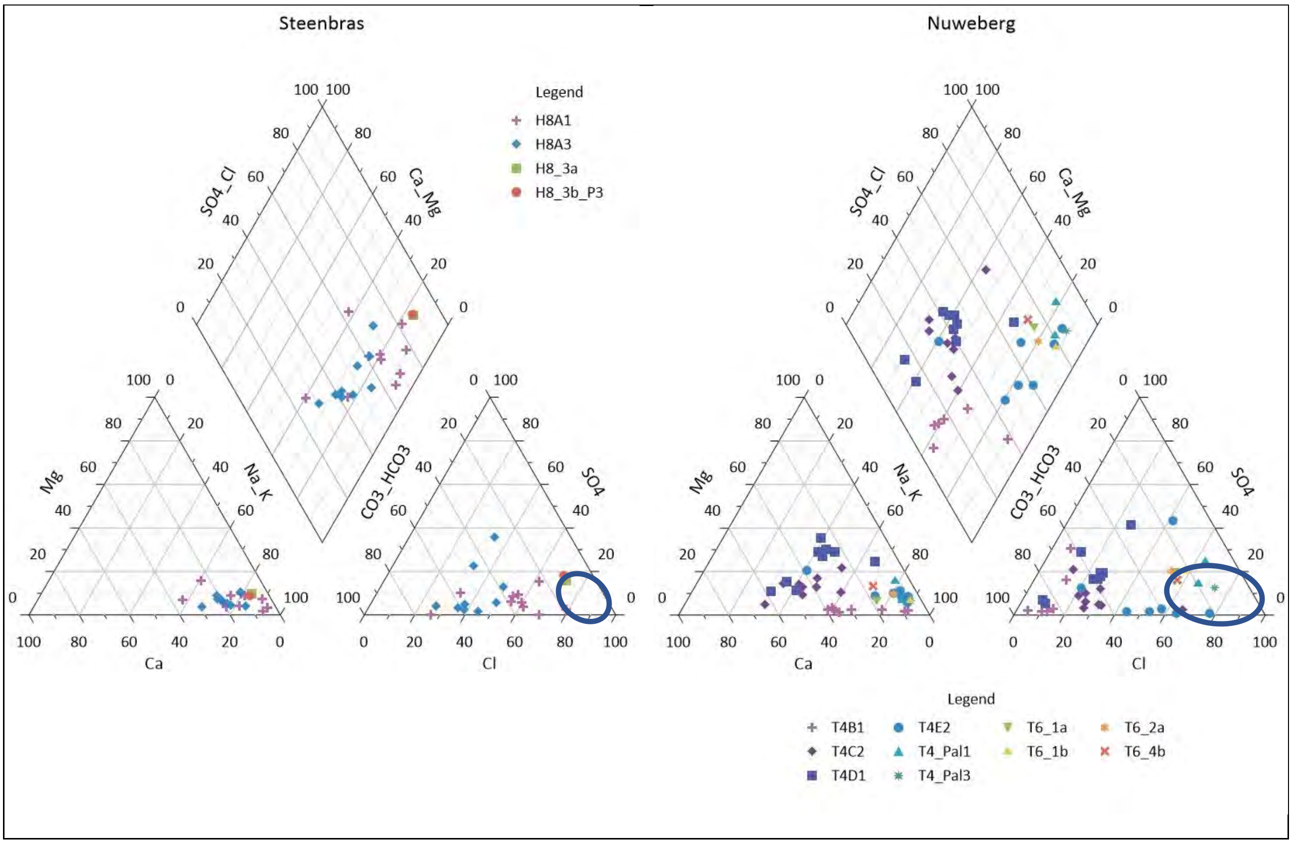


Figure 5-3: Piper diagram of anions and cations measured in the wetlands, streams and boreholes in Steenbras (left) and Nuweberg (right), surface water chemistry shown by blue circle (after CCT, 2019b).

However, groundwater in the TMG Aquifer often is naturally high in Iron (Fe) and Manganese (Mn), which are constituents of concern due to potential impacts on ecosystem health and or treatment requirements. Figure 5-4 shows the elevated Fe concentrations in groundwater samples from new boreholes at the Steenbras Wellfield in comparison to other metal concentrations.

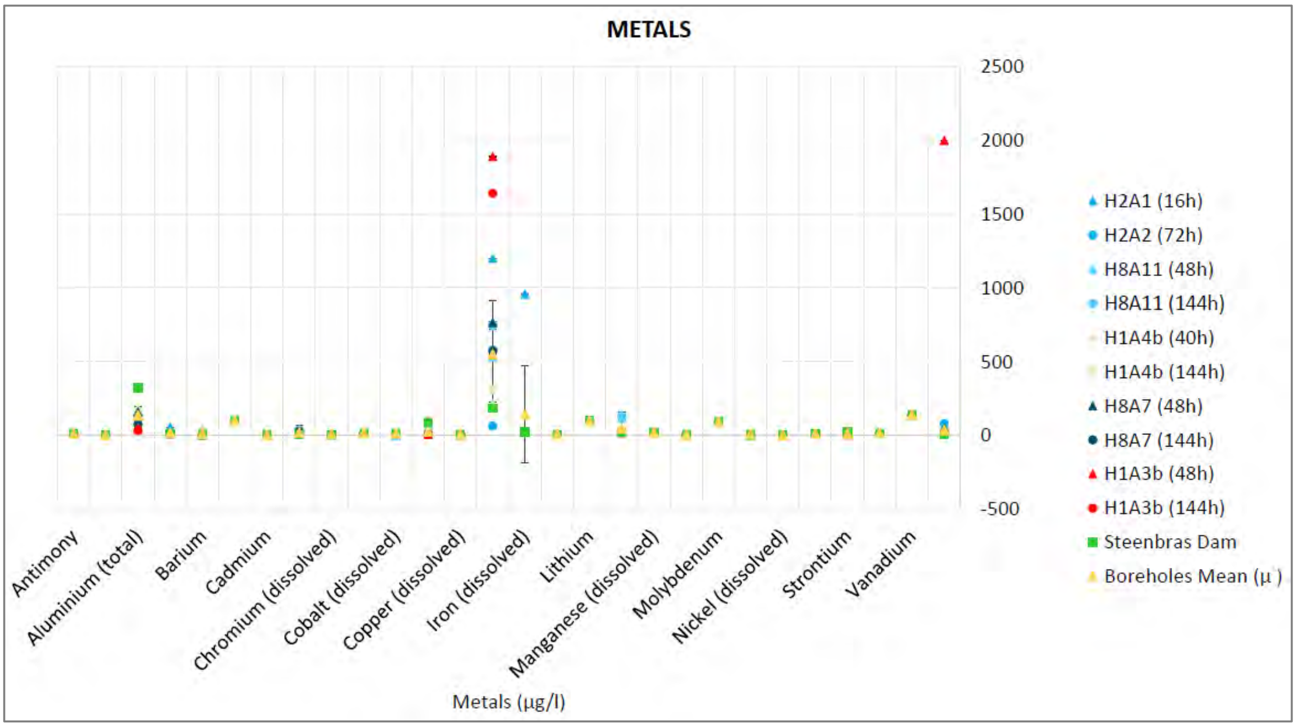


Figure 5-4: Metal concentrations in groundwater from wellfield and surface water dam (Aurecon, 2019b)

Table 5.1: Selected water quality data from the two TMG aquifers in the Steenbras area

Chemical Constituent	SANS 241:2015	Nardouw Aquifer			Peninsula Aquifer		
		Mean	Min	Max	Mean	Min	Max
pH	≥5 to ≤9.7	5.18	4.63	6.01	6.59	5.99	7.19
Conductivitiy (mS/m)	≤170	9.89	7.00	18.50	12.88	10.00	20.00
Turbidity (NTU)	≤1	29.63	0.15	438.00	159.80	5.70	530.00
Macrochemistry (in mg/l)							
Total Dissolved Solids	≤1200	67.83	44.00	158.00	86.88	65.00	127.00
Calcium	-	1.47	0.37	6.10	3.11	1.60	10.30
Magnesium	-	1.71	1.10	6.60	1.51	1.10	2.20
Sodium	≤200	9.45	3.50	21.90	6.66	4.90	9.10
Potassium	-	1.34	0.17	9.00	0.44	0.22	0.67
Chloride	≤300	19.44	13.50	37.80	14.88	13.50	18.40
Sulphate	≤500	3.39	1.50	9.90	1.57	1.40	1.80
Dissolved Silica	-	6.26	0.40	11.60	9.04	3.33	14.17
Total Organic Carbon	≤10	3.91	0.10	13.00	3.56	0.10	12.20
Metals (in µg/l)							
Aluminium (total)	≤300	111.41	23.00	369.00	49.17	12.00	183.00
Aluminium (dissolved)		31.00	17.00	60.00	18.00	18.00	18.00
Iron (total)	≤2000	1258.17	64.00	3572.00	20188.00	12680.00	27650.00
Iron (dissolved)		453.86	28.00	1136.00	3198.14	582.00	8561.00
Manganese (total)	≤400	74.79	20.00	279.00	940.88	509.00	1386.00
Manganese (dissolved)		100.17	53.00	264.00	922.14	374.00	1330.00

Although the general water chemistry between the two aquifers is very similar (see Table 5.1), the Peninsula Aquifer shows much higher concentrations of Fe and Mn. However, there is no spatial correlation between location of the borehole and concentration of Fe, which seem to depend more on stratigraphic formations and lithological contacts intersected, and type of fracture systems encounters.

Given the pristine and sensitive environment of the TMG Aquifer outcrop areas, this has implications for the risk of discharging of groundwater into the receiving environment, either intentionally or accidentally.

5.3.2. Impact investigations

Two investigations have been undertaken by the Consulting Engineers Aurecon, as appointed by the City of Cape Town, to assess the impact of groundwater discharge into surface water bodies due to the varying water quality, specifically the elevated Fe and Mn concentrations.

5.3.2.1. Discharge during drilling and testing

Aurecon investigated the potential environmental impacts of groundwater discharge during the drilling process as part of developing the Steenbras wellfield, which is one of the City's water augmentation projects in response to the 2016-2018 drought. This investigation was initiated by concern that the water quality of the groundwater differ from the surface water quality, and that the use of additives (foaming agent Rotafoam™) during the drilling process could also harm the environment (Aurecon, 2019a).

A compressor blows air into the borehole, and the resulting foam and groundwater from the borehole lift drill cuttings out of the borehole, and towards containment sumps, where the foam subsides, and the water is pumped in a pipeline directly to the dam. In the event of a spill (due to inadequate storage capacity in sumps, or faulty sump pump), water overflows the containment sumps and flows over land (uncontrolled) toward surface water courses (streams), where it mixes with natural surface water. The results of the investigation suggest the following:

- The use of Rotafoam™ significantly increases organic loading compared with the baseline groundwater and surface water samples (by a factor of more than 10) – this could potentially result in deoxygenation of surface water courses in the environment
- While the use of Rotafoam™ significantly increases pH of the groundwater (from 6.01 to 7.15), the groundwater pH (6.01) is itself significantly higher than that of the surface water (pH 4.2)
- The high concentrations of iron and manganese in the Rotafoam™-Mix is due to the presence of these minerals in the water used in preparing the Rotafoam™-Mix, as they are slightly diluted in the Rotafoam-Mix and Groundwater sample
- The groundwater after drilling exhibits higher concentrations of iron and manganese than the baseline surface water quality
- The impacts on the receiving stream of elevated levels of organics in the Rotafoam™ and Groundwater would be within the accepted tolerance margins beyond a 33:1 dilution ratio (< 20% change)

These results suggest that discharge of Rotafoam™ containing water (during drilling) from any of the boreholes would contain elevated pH and elevated levels of Salinity, Organics and Metals when compared with the baseline groundwater.

This implies that Rotafoam™ and or the source water for dilution significantly alters various key groundwater quality components and may alter the receiving surface water quality, resulting in significant impacts to aquatic ecosystems in the event of discharge during drilling.

5.3.2.2. Discharge into dam

Prior to and during the development of production boreholes, chemical tests of the groundwater indicated high iron and manganese concentrations, particularly in the groundwater from the Peninsula aquifer (see above). Concerns were raised about the potential impact of the groundwater when it is pumped into Steenbras Dam, and the impacts it might have on the water quality and biota of the dam. Hence, a report was prepared by Aurecon (2019b) to document an investigation into the concerns about the possible fate of high iron (Fe) and manganese (Mn) groundwater when it is pumped into Steenbras Dam.

In theory, when groundwater rich in iron and manganese is discharged into Upper Steenbras Dam, most of the dissolved iron and manganese would form a precipitate that would settle to the bottom. However, there are a few factors that determine how much of the iron and manganese remains in solution, and if the precipitate is permanently lost from the water column.

The solubility of iron and manganese is a function of pH and Redox Potential. If the pH is neutral to alkaline, and there is oxygen in the water, then most of the Fe and Mn would precipitate out. If the pH is acidic and there is oxygen in the water, then some Fe and Mn may remain in solution.

In-lake water quality monitoring by the CSIR during the summer of 2018/19, found that there was sufficient dissolved oxygen throughout the water column in Upper and Lower Steenbras Dams to maintain healthy ecosystems and to promote the precipitation of dissolved Fe and Mn when it enters the dam. No evidence was found of thermal stratification during the summer months.

Some of the Fe and Mn may stay in solution, bound to organic compounds, particularly humic and fluvic acids, tannic acids, and other lignin derivatives. The waters of Upper and Lower Steenbras Dams are tea-coloured due to the presence of high dissolved organic matter. This may prevent some of the Fe and Mn from forming a precipitate and settling out.

A high-level assessment of the fate of iron rich groundwater discharged into Upper Steenbras was undertaken that considered:

1. An in-lake target for the iron concentration of 0.5 mg/l was assumed to protect aquatic ecosystems.
2. The volume at the end of the dry season, normally about 45% of full supply level.
3. The Fe concentration in the dam at the end of the dry season, 0.27 mg/l in the first year of operation, and 0.5 mg/l (in-lake target) for subsequent years.
4. The Fe concentration in the discharged groundwater determines what volume of groundwater can be pumped into the dam without exceeding the in-lake Fe target of 0.5mg/l.
5. The Fe concentration in the discharged groundwater can be manipulated by blending water from the low Fe Nardouw aquifer with the high Fe Peninsula aquifer.

The primary groundwater source will be the Peninsula Aquifer due to its significant storage volume, high annual recharge and lower environmental impacts associated with drawdown, but this is also the aquifer with the higher Fe concentration. Prior to commissioning of the wellfield, it will be important to commence with in-lake monitoring at the Steenbras Dams to determine the in-lake Fe concentration at the end of the dry season as this will inform the Fe load from the groundwater that can be discharged during the winter months.

It is also evident that the volume of groundwater that can be discharged will need to be limited to most likely 4 - 5 million m^3/a once the Fe concentration in the Steenbras Upper Dam reaches 0.5 mg/l unless a pre-treatment facility is constructed that will remove iron and manganese concentrations to below the current Fe concentration in the dam of 0.27 mg/l. It is therefore proposed that the pre-treatment works be commissioned within two to three years from the commissioning of the entire Steenbras wellfield.

6. PRODUCTS AND SERVICES

As described in Section 3, several potential products and services have been identified during the stakeholder engagement process. Two different products have been developed by Umvoto Africa and The Umvoto Foundation, respectively, covering topics of aquifer protection and community engagement. The development of these products was facilitated under this assignment through engagement with the relevant stakeholders and the technical teams. The description of these products below is reproduced from available reports and documents (CCT, 2020c; Hay & Snyman, 2019; Hay, 2019).

6.1. Aquifer Protection Plan

A Groundwater Protection Scheme for the Cape Flats Aquifer (CFA) was developed by Umvoto Africa in order to ensure the protection of groundwater quality to abstraction boreholes. The Groundwater Protection Scheme is composed of several components, namely Groundwater Protection Zones (GPZ's), vulnerability mapping and ranking, potentially contaminating activities (PCA), and a remediation plan. Currently, the GPZ delineation, vulnerability mapping and PCA identification have been completed. Remediation plans are developed separately for each identified pollution, where required.

The objectives of this section are to document the following:

- Delineate capture zones for each production borehole for 50 days, 100 days and 1 year as stipulated by the water use license (WUL), Clause 11.3.3.
- Delineate four GPZs based on international best practice and the travel time of defined contaminants in groundwater.
- Vulnerability mapping using a modified DRASTIC method to assess the potential risk of groundwater contamination.
- List and map PCAs and their associated risk to groundwater contamination.
- Delineate different protection responses based on GPZ, aquifer vulnerability and PCA risk.

6.1.1. Capture Zones

As per the WUL, capture zones for 50 days, 100 days, and 1 year were calculated using Darcy's Law, which required data on porosity, hydraulic conductivity and groundwater levels. Predicted water levels under the full operation of the scheme were used to determine the hydraulic gradient to the production boreholes. Downhole geophysics has been performed on selected boreholes as part of the CoCT New Water Programme, which have provided values on fluid volume. Results indicate a total porosity between 20% and 30%.

The capture zones were calculated and mapped using the open-source geographical information systems software QGIS. Several assumptions were made, and limitations apply, e.g. the method

- assumes that the nearest production borehole will have the largest hydraulic gradient,
- assumes that the hydraulic conductivity (*K)* of the nearest production borehole is representative of the *K* of the medium between the grid point and the borehole, and
- does not account for private abstraction within the PHA.

This is a preliminary delineation, which need to be updated, once operational water level data and tracer test results are available.

The model results for the 50-day, 100-day and 1-year travel time is displayed in Figure 6-1, Figure 6-2 and Figure 6-3. All three of these travel times are included in the proposed Zone II (2-year travel time) for the CFA Management Scheme GPZ.

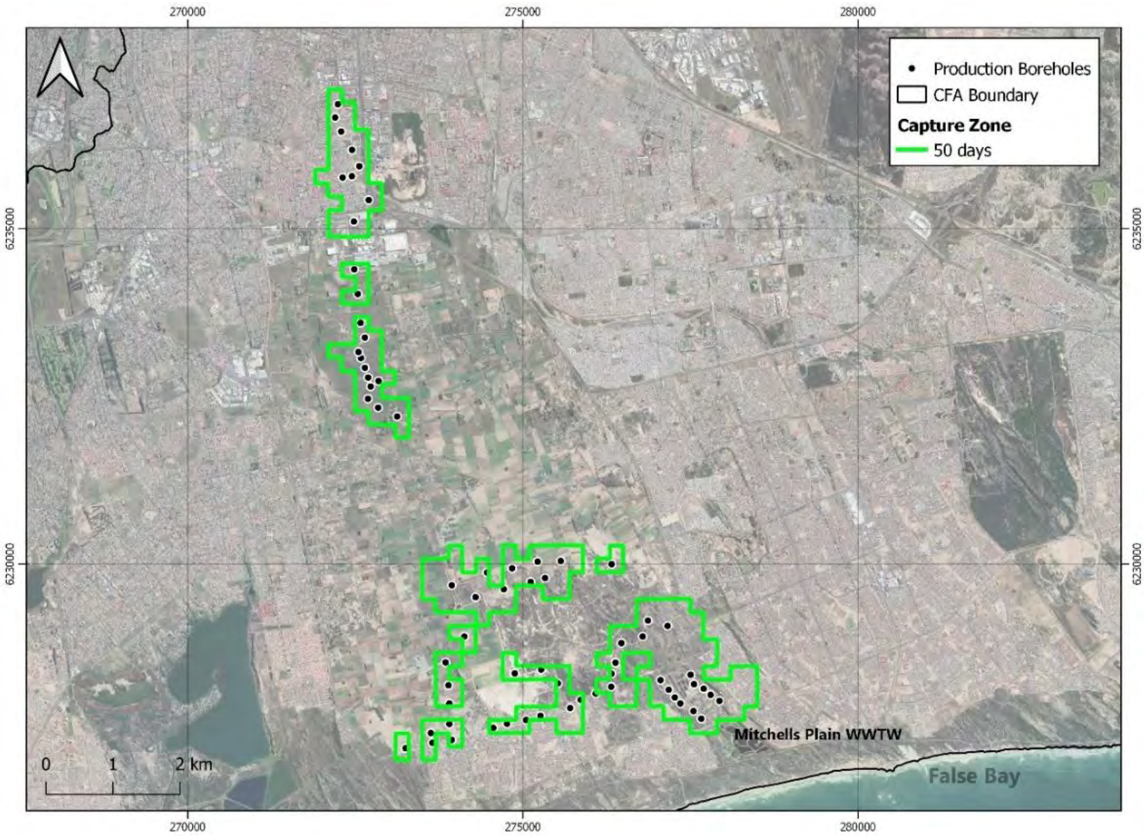


Figure 6-1 Map displaying the production borehole capture zones for a 50-day travel time (CCT, 2020c).

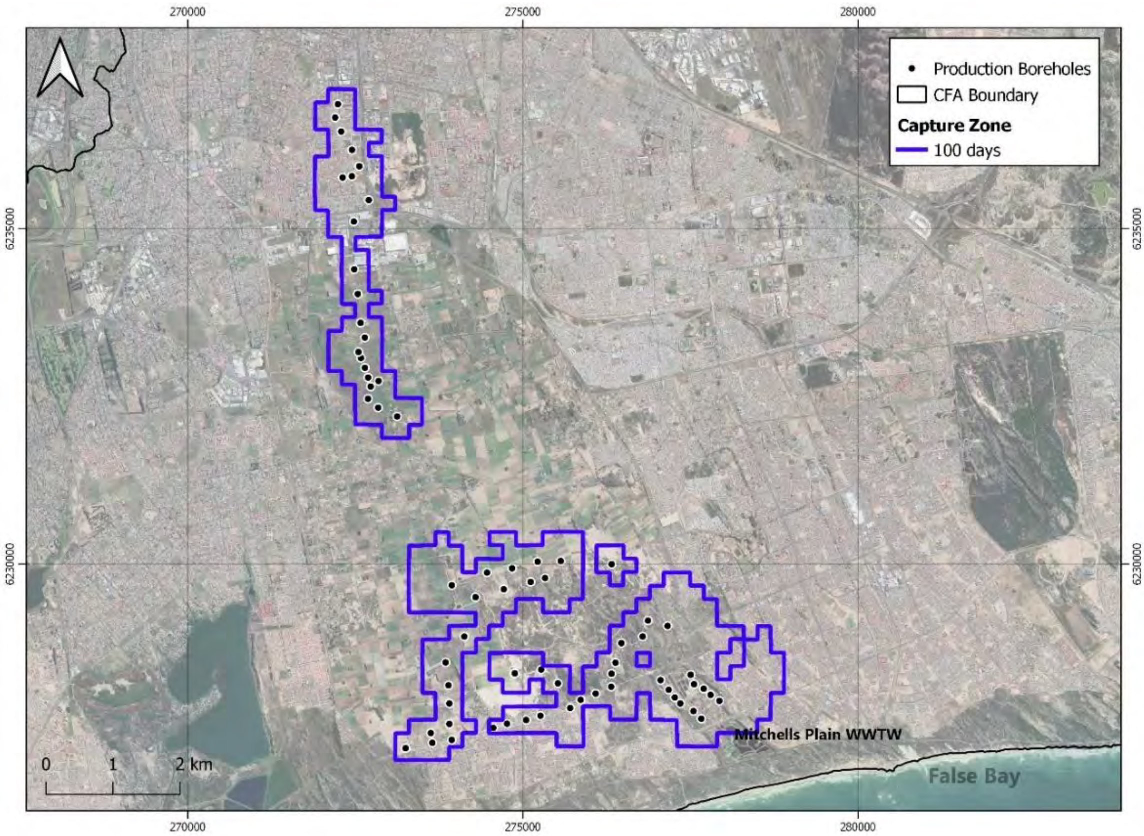


Figure 6-2 Map displaying the production borehole capture zone for a 100-day travel (CCT, 2020c)

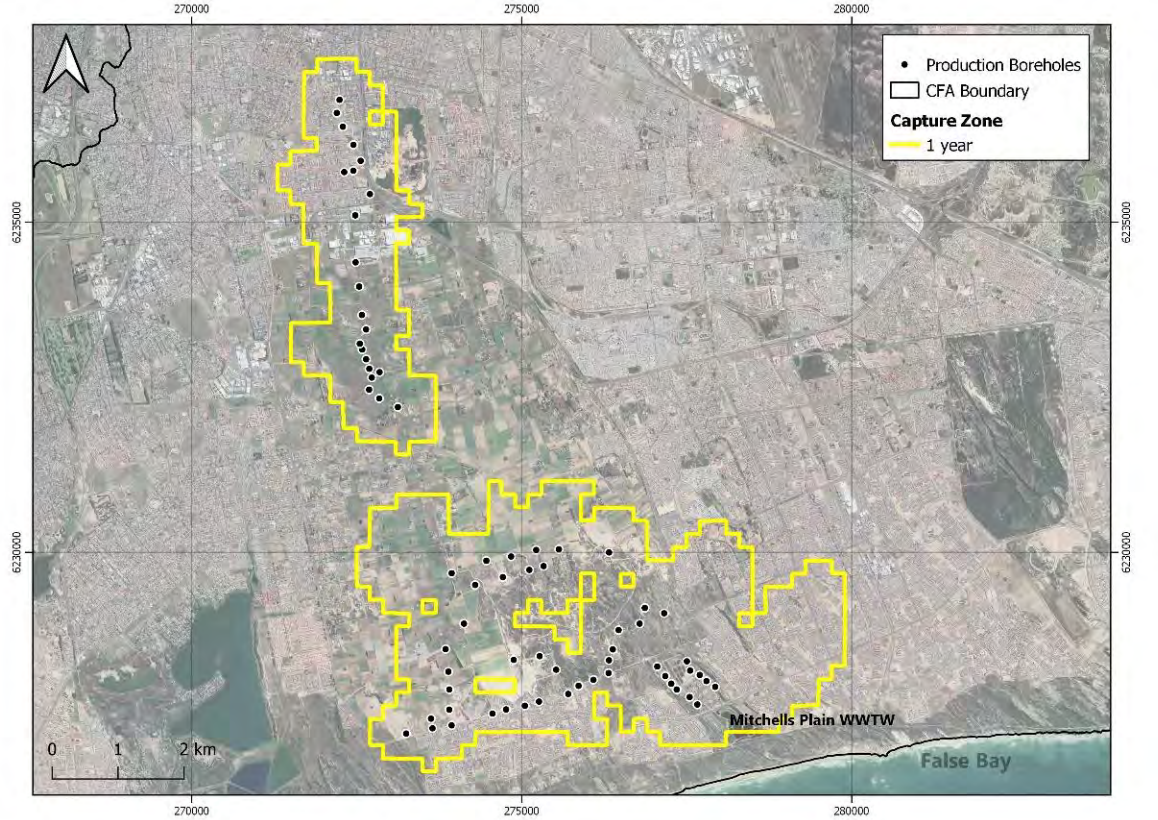


Figure 6-3 Map displaying the production borehole capture zones for a 1-year travel time (CCT, 2020c).

6.1.2. Groundwater Protection Zones

Since South Africa does not have a formal GPZ guideline, GPZ guidelines from the California Environmental Protection Agency, the EU Water Framework Directive and the Portuguese law were used as a reference for the protection zones on the CFA. The first zone is defined by a space function, and the other zones are defined by a travel time function to a water supply borehole. They are listed below:

1. Well-head protection zone/Inner zone (***ZONE I***): 10 m radius around the wellhead. The purpose of this zone is to prevent the rapid ingress of microbial/chemical contaminants. Boreholes have a sanitary seal installed and are covered with a concrete chamber and cage, and access is restricted to the CoCT. No activities of any sorts are allowed in this area, and the land must be routinely cleared and kept clean, with any residues, products or liquid substances cleared out.
2. Middle zone (***ZONE II***): up to two-year travel time. The literature notes that pathogens and bacteria cannot survive in groundwater for more than two years (Division of Drinking Water and Environmental Management, 1999). Hence, activities with risk of chemical and microbial pollution are restricted in this zone, or require special permission.
3. Outer zone (***ZONE III***): up to five-year travel time. To prevent chemical contamination of the water supply, and to protect the drinking water source for the long-term. This zone provides an adequate amount of time to respond to possible chemical spills. Activities with the potential of chemical pollution are restricted or require special permission.
4. Catchment Area (***ZONE IV***): up to 10-year travel time. To prevent chemical contamination of the water supply, and to protect the drinking water source for the long-term. This zone

provides adequate amount of time to respond to possible chemical spills of more persistent chemicals.

5. Full catchment area (***ZONE V***): beyond 10-year travel time.

For Zone I, a fixed arbitrary approach was used, where a radius of 10 m was drawn around each production borehole.

For Zone II, Zone III and Zone IV, numerical modelling methods were applied. The numerical modelling program FEFLOW was used to calculate the travel times for each zone as defined above, using the Exit Probability (EP) Approach. Three scenarios were simulated and are summarized below:

- Scenario 1: assumed all production wellfields were in operation, including private abstraction in the PHA and no MAR.
- Scenario 2: assumed that only the Mitchells Plain, Strandfontein West and Hanover park production wellfields were in operation, including private abstraction in PHA and no MAR.
- Scenario 3: assumed all production wellfields were in operation, including private abstraction in the PHA and MAR available up to 60 million litres per day (Ml/d).

The final GPZ for the CFA Management Scheme is defined by a combination of the three scenarios, as well as considering existing land use and property boundaries where possible, to ensure that all circumstances are covered under the planned phased implementation.

A conservative approach was used to calculate the Life Expectancy (LE) of a parcel of water, since no operational data is currently available. It is recommended that the scenarios are updated once the scheme is in operation, and tracer testing completed. Furthermore, the model assumes constant climatic variability based on historic data and estimates and given the timescales of the LE, the impacts of the interannual variability in rainfall and water demand should be addressed.

A numerical flow model of the CFA had been developed. The flow model simulates steady-state conditions (i.e. long-term averages), accounts for the principal hydrogeological characteristics of the system and is calibrated against hydraulic head data. The impact of model parameter uncertainty on predictive uncertainty is addressed through the use of 118 parameter sets, all of which are able to adequately fit observation data. Parameter uncertainty is considered for spatial distribution of hydraulic conductivity, surface-groundwater interaction, groundwater use and recharge.

For the purposes of delineating Groundwater Protection Zones (GPZs) for the CFA Management Scheme, three (3) scheme operational scenarios are considered:

- Scenario 1: assumed all production wellfields were in operation, including private abstraction in the PHA and no MAR.
- Scenario 2: assumed that only the Mitchells Plain, Strandfontein West and Hanover Park production wellfields were in operation, including private abstraction in PHA and no MAR.
- Scenario 3: assumed all production wellfields were in operation, including private abstraction in the PHA and MAR available up to 60 million litres per day (Ml/d).

In summary, abstraction for the CCT wellfields is simulated using constant head boundary conditions set at planned operating water levels. Thus, no matter the yield, hydraulic head in the wellfields is assumed constant. MAR is simulated using injection and infiltration ponds. These are simulated to add recharge until hydraulic heads reach 2 m below ground level. The spatial distribution of MAR is determined iteratively as part of the model run to maximize MAR within physically reasonable injection and infiltration rates.

Figure 6-4 and **Figure 6-5** present simulated 50% exit probability zones and isochrons for the combined CCT wellfields and abstraction within the PHA under steady-state conditions for the scenarios 2 and 3, as these constitute the extreme positions. Predictions assume that parameters and model setup are representative of the aquifer system and that simulated long-term average conditions are representative of future conditions.

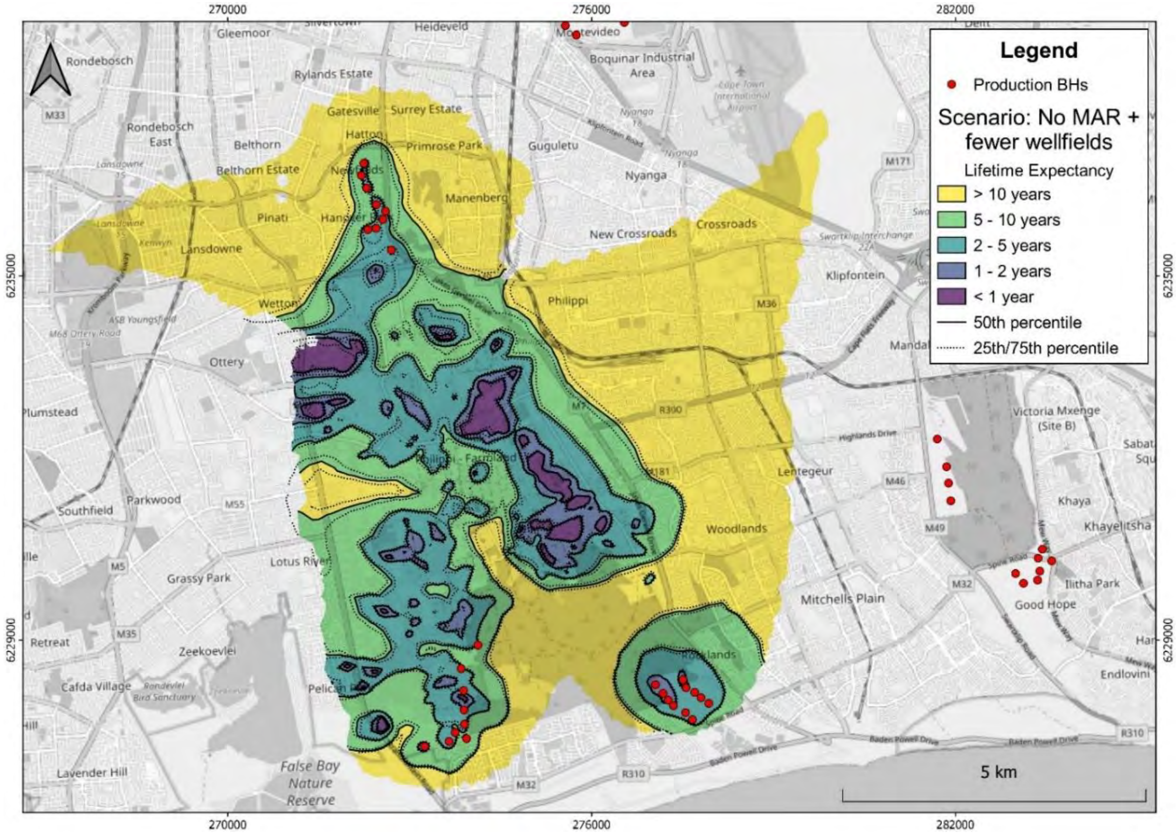


Figure 6-4 Capture zone for the combined CoCT wellfields and private abstraction within the PHA under steady-state conditions, assuming only the Hanover Park, Mitchell's Plain and Strandfontein West wellfields in operation and no MAR (CCT, 2020c).

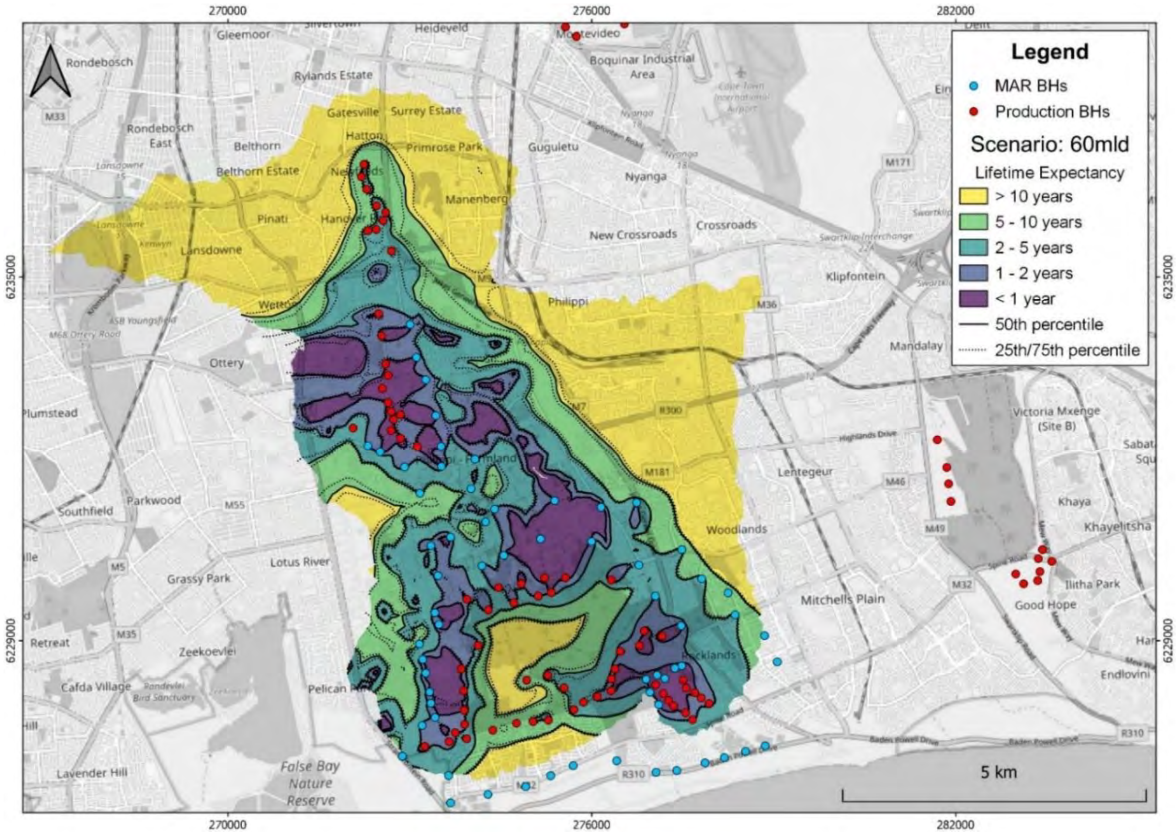


Figure 6-5 Capture zone for the combined CoCT wellfields and private abstraction within the PHA under

steady-state conditions, assuming all wellfields in operation and MAR of 60 Ml/d (CCT, 2020c).

The final GPZ for the CFA Management Scheme is defined by a combination of the three scenarios, as well as considering existing land use and property boundaries where possible, to ensure that all circumstances are covered under the planned phased implementation, e.g. MAR, no MAR and various wellfields in operation (see **Figure 6-6**).

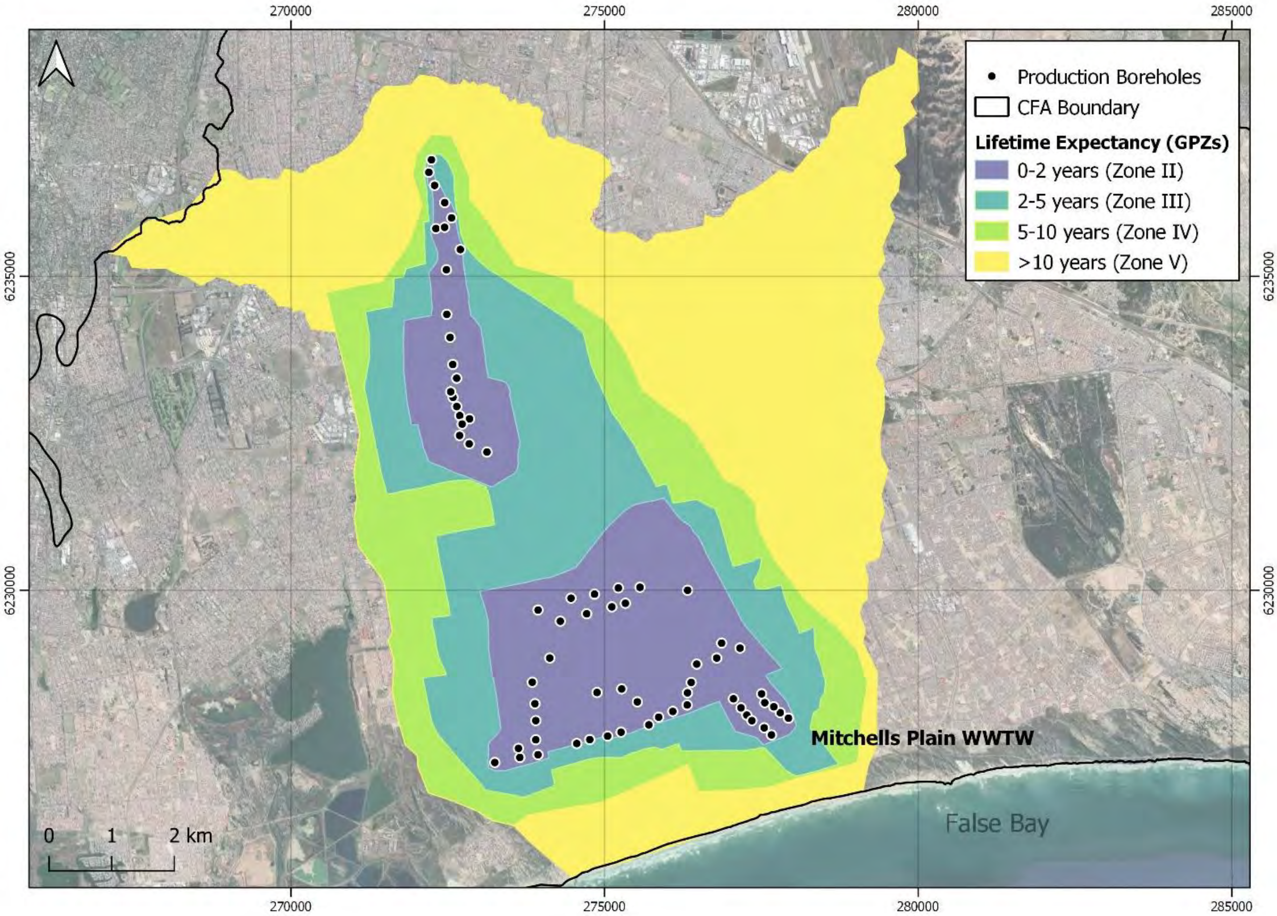


Figure 6-6 Final GPZ's for the CFA Management Scheme based on a combination of the three scenarios listed above, as well as considering land use and property boundaries where possible. Due to the uncertainty and phased implementation of the scheme, the most conservative extent of each zone was selected to ensure that all circumstances are covered (CCT, 2020c).

6.1.3. Vulnerability Mapping

Vulnerability mapping was conducted over the entire area of the aquifer, using a modified DRASTIC index. DRASTIC takes its name from: D = Depth to water table, R = Net recharge, A = Aquifer media, S = Soil media, T = Topography, I = Impact of the vadose zone, C = Hydraulic conductivity. A modified DRASTIC index that includes anthropogenic impacts was developed by Leal and Castillo (2003). Due to the mixed land-use across the whole aquifer, and the influence of human activity on contamination presence or absence, land use is incorporated in the DRASTIC Specific Vulnerability Index (DSVI).

DSVI scores ranged between 121 to 204. These were categorized in different classes based on the level of vulnerability, with 204 representing the most vulnerable and 121 representing the least vulnerable. A risk matrix was derived by combining the GPZ and DSVI class, to form a code. The DSVI score of production boreholes and areas within the bounds of the GPZ's were ranked between 'Very Vulnerable' and 'Extremely Vulnerable'.

Table 6-1 DSVI classes of vulnerability (CCT, 2020c)

DSVI value	Class	
< 79	Extremely Low (EL)	
79 - 100	Very Low (VL)	
100 - 121	Low (L)	
121 - 142	Moderate (M)	
142 - 163	High (H)	
163 - 183	Very High (VH)	
183 - 204	Extremely High (EH)	

Two different sensitivity analyses were performed on the vulnerability map and are described below:

1. Sensitivity analysis 1: to account for variability in recharge, an upper and lower range was set for recharge at 25%. For both the upper and lower range, the difference between the median recharge (of the original DSVI score) was 8. The resulting DSVI score represented only a 4% difference between the original maximum value of 204.
2. Sensitivity analysis 2: the recharge layer was removed and the percentage difference between the original DSVI map and the second sensitivity analysis was 18%, indicating that recharge is a significant factor affecting the DSVI score.

The vulnerability map has several limitations, which are expressed below:

- The contaminant is assumed to be introduced at the ground surface, but this does include sub-surface contamination.
- The contaminant is assigned the mobility of groundwater, assuming that it is transported in the system in the same manner as water.
- The area evaluated by DRASTIC is limited to >0.4 km^2.
- Precipitation features such as duration and intensity are ignored.
- Soil reactivity and anisotropies are ignored.
- Anisotropies in the vadose zone, aquifer media are ignored. *K* values are calculated using test-pumping data, being representative of the screened portion of the deeper aquifer.

- Does not consider the local importance/use of the aquifer. In some areas of the CFA, such as the PHA, groundwater is the sole source of water for irrigation.
- The original DRASTIC equation defined recharge as precipitation only, excluding irrigation return flow (IRF).
- Does not consider groundwater abstraction/managed aquifer recharge of the CFAMS.

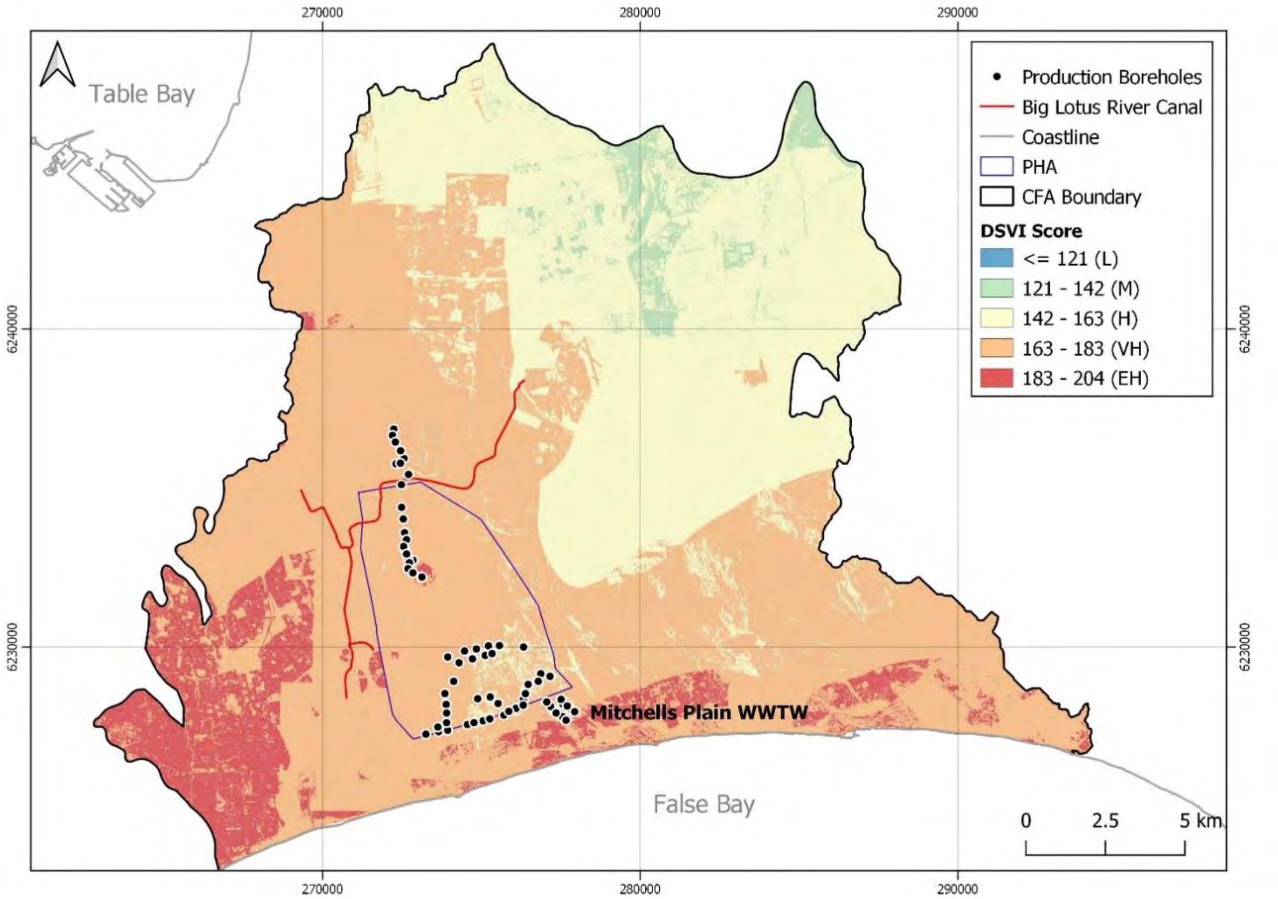


Figure 6-7 DSVI map displaying aquifer vulnerability across the CFA (CCT, 2020c).

6.1.4. Potentially Contaminating Activities

The CFA is a coastal aquifer underlying an urban environment with mixed land use. The majority of the aquifer is covered by formal and informal settlements, whilst the PHA is covered by agricultural land, and areas such as Hanover Park are mixed residential and industrial. Due to the mixed land-use, the sources of groundwater contamination are variable.

Potentially Contaminating Activities (PCA's) are activities that present a threat to the groundwater through contamination. Activities are segmented into commercial/industrial, agricultural/rural, residential/municipal and other. The activities are scored between 1 - 4 depending on the level of risk, with 1 being the lowest risk, and 4 being the highest risk. PCA's within the GPZ's were identified from available shapefiles and local knowledge. Some major sources of contamination to the CFA are listed in **Table 6-2**.

The following impact areas and their associated PCAs were identified:

Table 6-2 Major PCAs across the CFA and their contamination characteristics, partly confirmed by groundwater samples in close proximity that have exceedances in at least one of the contaminant characteristics of the respective PCA (CCT, 2020c).

Feature	Name	Status	Comment	Resulting Contaminant
Waste Site	Swartklip, Coastal Park, Belville South and Athlone	Active	Waste sites only partially lined. Swartklip is fully lined.	Chloride, nitrate, ammonium, EC, TDS, alkalinity, Chemical/Biological Oxygen Demand, sulphate, potassium, Total Organic Carbon and heavy metals
	Numerous, see	Closed	Not known	
WWTW	Mitchells Plain, Cape Flats (Zeekoevlei), Khayelitsha, Bishop Lavis, Athlone and Belville.	Active	Activated sludge	Potassium, ammonia, nitrate, fluoride
Cemeteries	Ottery, Gugulethu, Khayelitsha, Delft and Philippi	Active	No law requiring cemeteries to be lined.	EC, pH, Biological Oxygen Demand, arsenic, formaldehyde, cosmetic pigments, chemical compounds
Industrial Areas	Pineland, Belville, Hanover Park and Cape Town International Airport	Active	-	EC, TDS, pH, Chemical Oxygen Demand, heavy metals, arsenic,
Informal Settlements	Gugulethu, Khayelitsha	Active	-	Potassium, ammonia, nitrate
Agricultural Areas	Philippi	Active	-	EC, TDS, sodium, chloride, nitrate, ammonia, Biological Oxygen Demand, phosphorous, nitrogen, fertilizers, herbicides, pesticides
Surface Water Bodies	Lotus river canal, irrigation dams	-	-	EC, TDS, ammonia, nitrates, major anions, cations

As previously mentioned, GPZ delineation, vulnerability mapping, and detailing existing PCAs are components of a larger Groundwater Protection Scheme. The full scheme needs to include an updated monitoring protocol using the Protection Response number and a remediation plan for sites of confirmed contamination. The inventory of PCA's is limited, and a more comprehensive inventory should be investigated using up-to-date GIS shapefiles and local knowledge. Once tracer testing has been conducted, and the scheme is in operation, the model can be calibrated and the GPZ's refined.

A preliminary inventory of PCAs and their associated Level of Risk found within the GPZs has been constructed. Figure 6-8 displays the distribution of PCA's with their associated Level of Risk. A number of PCA's with level 4 were identified, namely;

- Closed waste site;
- Numerous filling stations;
- Plastic manufacturing;
- Sand mines – around Sand Industria (Hanover Park) and southern Philippi,
- Mitchell's Plain WWTW;

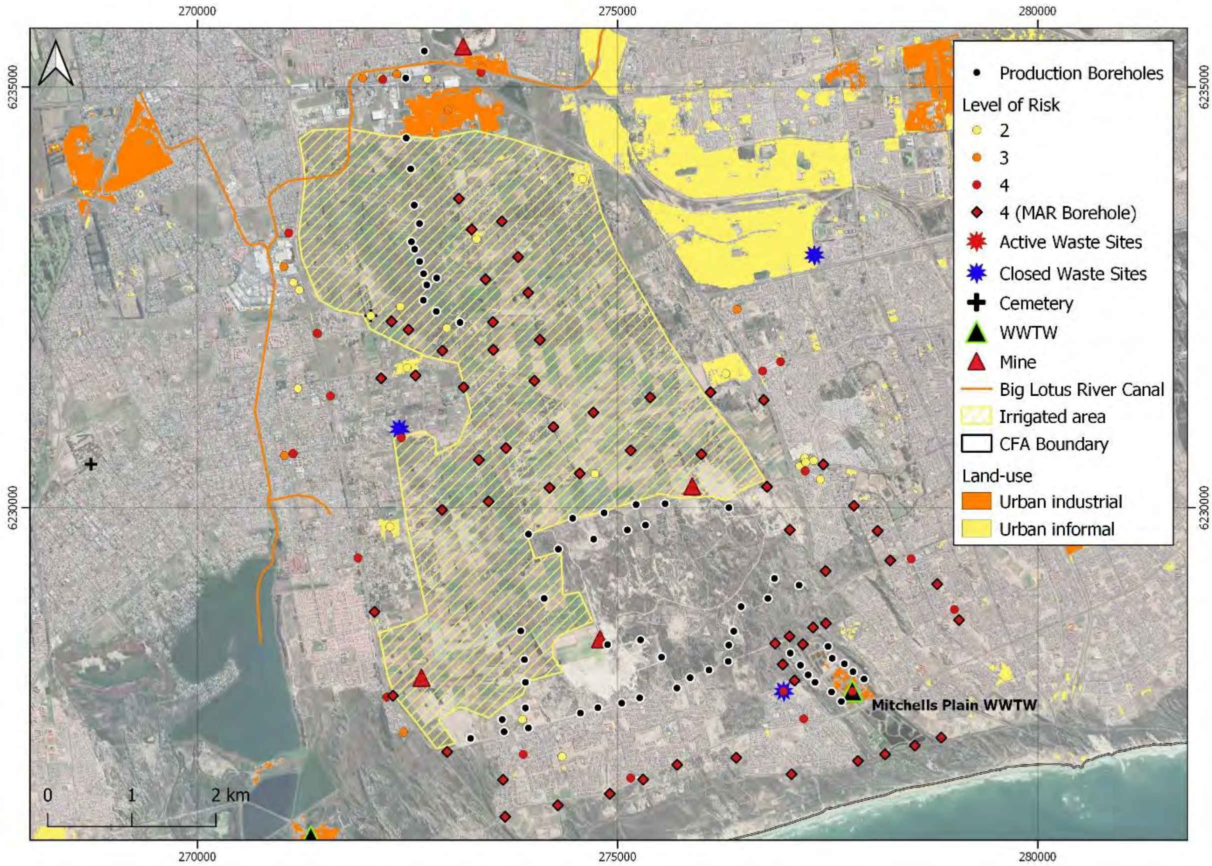


Figure 6-8 Identified PCA's and their associated Level of Risk. The map includes the irrigate areas of the PHA, which has a Level of Risk rating of 2; the Lotus Canal, which has a Level of Risk rating of 3; Informal settlements, which have a Level of Risk rating of 2; Industrial land-use, which has a Level of Risk rating of 3. PCAs with a Level of Risk 1 are not displayed on the map, but can be found in Appendix B, and include schools and reserves. Some major point source PCAs are displayed, including WWTW, waste sites, cemeteries and injection boreholes (MAR). (CCT, 2020c)

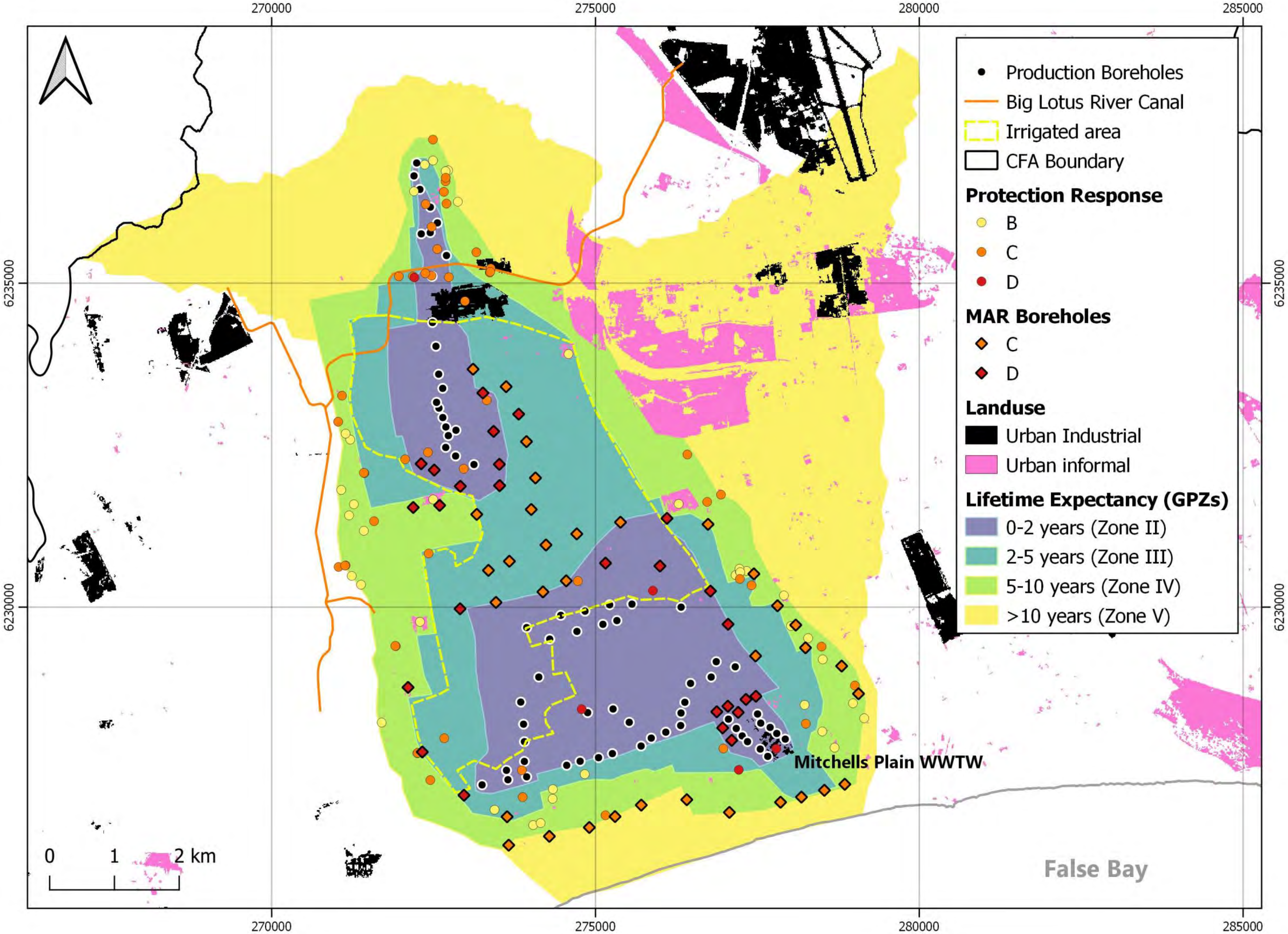


Figure 6-9 Map illustrating the locations of different PCA's with their Protection Response number within the GPZ's. A Protection response number of C and B has been allocated to the Lotus Canal and the irrigated land within the PHA respectively. The vulnerability is not shown but the entire area is defined as Very High Vulnerability (CCT, 2020c).

6.2. Community Engagement and Capacity Development

In parallel to the technical and scientific assessment and development of the protection zones, a stakeholder engagement process was initiated, which resulted in two initial products that highlight the strength and capacity for the approach for long-lasting and sustainable awareness and solutions.

6.2.1. Hoerikwaggo Critical Zone Observatory

A collaboration between scientists, engineers, artists and diverse stakeholder and communities led to the development of a concept note on realizing a Critical Zone Observatory (CZO) for the Cape Flats Aquifer and surrounding area, incorporating natural processes, socio-economic aspects and art.

The Critical Zone is the heterogenous (non-uniform), near surface environment of the Earth within which the natural habitat is regulated and nearly all terrestrial life is sustained. It incorporates the physical land surface, vegetation, rivers, lakes, and shallow seas that extend into the pedosphere (outermost layer of the earth), the unsaturated vadose zone and saturated groundwater zone, and all living organisms inhabiting these spaces, where ongoing and changing interactions occur between air, water, soil, rock and organisms, including humans.

The Critical Zone Observatory (CZO) provides the common reference point and platform for bringing various groups of people together, such as scientists studying the physical and social environments, engineers and other practitioners altering the environments, the officials administering them, and – importantly – the communities living in and with these spaces.

The Cape Flats - Contextualisation

The Cape Flats has a history of residential segregation, poverty and crime. During the apartheid era of residential segregation, particularly from the 1950s, the Cape Flats was earmarked as a relocation area for black communities moved from inner city and suburban areas. This had a devastating and long-term impact. Family cohesion and social networks were destroyed and there are now high levels of unemployment, crime and gangsterism. Despite this social and economic vulnerability there is also evidence of extraordinary resourcefulness and resilience.

The Cape Flats and surrounding areas are now overrun by dense human settlements (formal and informal), with localised agricultural, industrial and mining activities. Formal settlements and agriculture have followed where sand has been mined, flattening the terrain, while informal settlements encroach on the remaining natural dune lands and into the seasonal pan areas and the flood plains of the rivers and the canals. This poses a man-made flood hazard when the winter rains fall, and a pollution threat to open and underground water bodies, with health and other impacts on people, the environment and sustainable clean water supply.

The Cape Flats also include the Philippi Horticultural Area. These small farms, close to the main roads and industrial areas, produce most of Cape Town’s vegetables. Flowers and livestock are also farmed and provide employment for semi-skilled workers. While this area helps ensure food security for the city, parts of it face the threat of development for housing and industry and some farming practices pose a risk to the groundwater quality.

Collaboration and Community Building through Transformative Arts

Key elements are transformative art practice and water supply infrastructure platforms, encouraging collaborative community building, and citizen science networks. Collaboration - even for a common goal and the common good - is difficult, especially in hierarchical and habitually competitive environments. However, collaboration is the mainstay of most creative arts processes, and Transformative Arts Practice has a long track record in South Africa, primarily dealing with individual and shared trauma and injustice.

‘Transformative Arts’ refers to the creative process by which practitioners engage participants in artistic activities to promote change in the lives of all who participate, as well as those who witness what is created.

Cape Flats Aquifer: Collaborative Zones

The first six Collaborative Zones that are envisaged, are based on areas of the CFA watershed that are crucial for the rehabilitation, protection, and development of this water source. Within these Collaborative Zones, multidisciplinary teams, called Intensive Collaborative Units (ICUs), will work together on projects focused on the water flowing through and under those areas.

Figure 6-10 Maps illustrating the 6 Collaborative Zones, the remaining green spaces on the Cape Flats Aquifer and translation into archetypical shapes and art forms (Hay & Snyman, 2019)

The Collaborative Zones will provide the framework, platform, technology, and Transformative Art facilitators for any number of people and disciplines to collaborate, as well as coordinating ICUs across the CFA. ICUs will collaborate with local organisations, schools and community groups around environmental and nature art works, creative interventions and festivals, and any other processes that will ultimately benefit the CFA.

Figure 6-11 Potential transformation of sand mine area after rehabilitation into landscape art, visible from air or space (Hay & Snyman, 2019)

The process and concept have been documented in a brochure and video.

6.2.2. Water Stewardship Workshop

The concept and approach, described above, has been implemented in an environment and water stewardship course for the local community in one of the collaborative zones, which was prepared and run in November 2019 at the Edith Stephens Nature Reserve in Cape Town. The Edith Stephens Nature Reserve is situated close to the Philippi Horticultural Area and is surrounded by formal and informal settlements, light industry and agricultural land. The Lotus Canal (identified as potential pollution source in Section 4 and 5.1, see also Figure 6-12) flows directly pass the Nature Reserve. During high flows, peak flows are diverted into ponds on the Nature Reserve.

Figure 6-12 Section of the Lotus Canal as an example of the pollution and degradation of a previously natural stormwater run-off system (Hay, 2019)

This course was considered and planned as a knowledge exchange between residents, water and environment experts, and local organisations. In the long term, it is envisaged to work together with Communitree, Site Specific Landscape, the Edith Stevens Wetland Park, the City of Cape Town and communities towards improving the Lotus Canal for people and the environment. This course was the first step in this project and shed light on the possibilities and opportunities of working together on the Lotus Canal challenge.

Process

As evident from the course outline (Figure 6-13), the process comprised a combination of teaching, practical learning and art/theater. This approach was important as the participants were from variable background and with different prior knowledge and interest on the subject matter (see Figure 6-14).

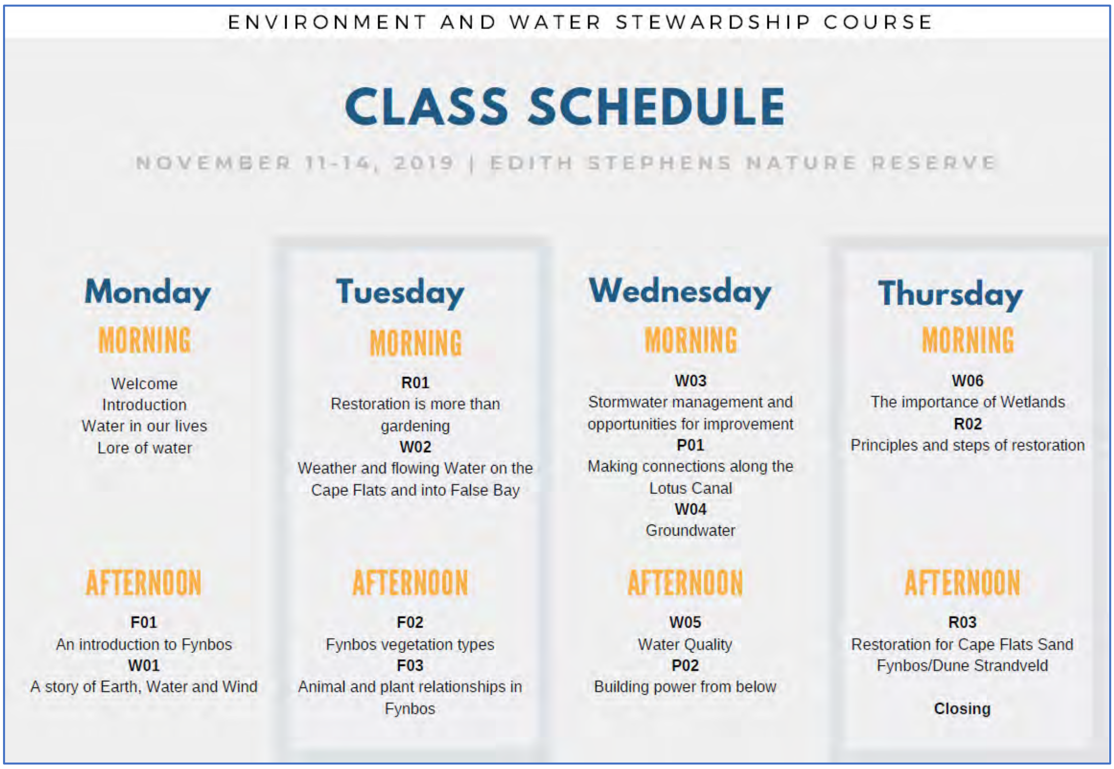


Figure 6-13 Course outline of the Environment and Water Stewardship Course (Hay, 2019)

Figure 6-14 Examples of activities during the course with emphasis on team work and learning by doing (Hay, 2019)

Outcome

Before the course, formal permission from home-owners and the city was obtained to paint five walls that face the Lotus Canal.

A local artist, Seth, painted it during the last day and after the training (see Figure 6-15). In the last session of the training, participants expressed the hope for the canal area to be a place where they can braai, where children can play safely, do not become ill from contaminated water, where people do not dump the litter which is visible in the photos and that people upgradient have formal sanitation so that when it is not raining the canal does not still flow as an open sewer.

Figure 6-15 Graffiti art by Seth1, painted on the back of walls property facing the Lotus Canal (Hay, 2019)

To date, the Edith Stevens Wetland park has agreed to fund regular clean up along a reach of the canal, once the community members have organized in a way that includes conversation with the Ward Councillor, engagement with the various city directorates to support a sustainable initiative. They are advising and supporting in this process. The agreement reached between The Umvoto Foundation, Edith Stevens Nature Reserve and the community is that when this initiative is underway, the artist will be appointed to paint another of the household fences bounding the canal and further engagement between the community and him will be facilitated regarding the remaining two, in celebration of milestones in action being realised. Communitree as project partner will continue to support biodiversity along water ways.

Some of the feedback received from participants is provided below:

Gratitude
Thank you to everyone involved in making the stewardship workshop a huge success
We learnt about water, aquifers, biomes, restorations, fynbos. Diversity, teambuilding, how to read maps on Google Earth, wetlands and stormwater.
Most importantly, we learnt how to take care of our environment and the role we have to play as citizens
To Edith Stephen's nature reserve, Communitree and Umvoto , may Almighty bless you and may you grow from strength to strength Amen
Looking forward to next learning

Evening mama
what a week of learning about Fnybos, different types of water, Lotus river, the ecosystem and how these things are working together it was amazing, the painting next to Lotus river tells us that the river can be home for plants animals like chameleons if we can plant trees and flowers from the plants like sour fig can attract bees and water can be a home for frogs and fishes too and if can kept clean people can also use it in different ways.

Several of the participants got inspired to make changes to their life style and or to their communities after the course, e.g.

CHUKUMISA STREET CLEAN-UP

One participant, Busi, was inspired to start cleaning a street alongside two schools in the Kayelitsha area where they live. It is an entirely grass roots initiative started and led by Busi with a small team of friends, family and neighbours.

They decided to start near the school, and see this as a service to the community and part of creating their sense of place, of greening the pavements, starting a vegetable garden at the school and training school children to care for where they live, to respect and support an environment and be inspired further. They have made progress despite a ward councilor who will not take calls, being sent from pillar to post by persons in solid waste disposal – and they have flourished. Persons in the neighbourhood are coming on board. They have engaged with the persons who empty the dust bins on the pavement rather than waiting for the waste truck to collect. Some people who live on this street are being alerted to inhibit dumping of litter.

Now, when the pavement clean up is done, solid waste send a truck on the same day which empties the skip and collects any black bags remaining. It does not matter how small the steps if each step leads to big success.

7. SUMMARY

7.1. Methodology

One of the success factors for the Cape Town Aquifers Use Case was the ability of the coordination and assessment team of the facilitator Dr K Riemann and the WWQA member Umvoto Africa to integrate the three different data types of the triangle approach, i.e. in-situ measurements, remote sensing data and numerical modelling, on a sub-catchment scale. This required an understanding of the complex surface and groundwater systems and their interaction (flow paths and fluxes) in the urban environment and experience in the different data types. Going forward, there is a need for mapping and modelling the surface – groundwater interaction in terms of flow and contamination under current status and future conditions.

A very comprehensive database of > 30 000 water quality data for the three aquifers has been established, including historical data (e.g. since 1970s for Atlantis), groundwater and surface water quality data from national and municipal programmes (e.g. landfills, cemeteries and water treatment works), and recent data collected during the groundwater development project execution.

Due to the hidden, underground nature of groundwater, the standard remote sensing techniques of the GWQA are not applicable. Hence, remote sensing was used to map and monitor proxies, such as land use, as indication for the risk of groundwater pollution. This was achieved with high-resolution satellite Sentinel-2, combined with high-resolution aerial imagery.

The modelling approach for this Use Case was different to the other Africa Use Cases undertaken, as it comprised not only groundwater flow and transport models to predict groundwater quality under different future scenarios but also GIS-based modelling of aquifer vulnerability and risk to pollution. Thus, modelling was utilised for both the assessment and the product and services development.

7.2. Stakeholder Engagement Process

The success of the Cape Town Use Case was also driven by a robust stakeholder engagement process that has developed over many years and included a local stakeholder (communities and institutions) engagement process.

Due to the interest by the public and concerned organisations in the groundwater development by the city, a wide range of stakeholders are involved in project specific meetings, the environmental forum and monitoring committees that meet on a regular basis, representing the municipality, regulatory authorities, environmental action groups, NGOs and academia. The Cape Town Aquifer Use Case built on these existing stakeholder networks and structures, as mentioned above, that were established earlier as part of the groundwater development projects by the City of Cape Town (CCT). Several of these meetings were utilised for the stakeholder engagement to inform stakeholders about the WWQA Use Case and to co-design the proposed products and services that form part of this Use Case.

The stakeholder capacity for supporting the WWQA objective was evaluated using the four components of governance as detailed in the FFEM, based on current experience with different stakeholders during the groundwater development project (Riemann, 2019).

Enabling Environment

South Africa has sufficient provisions in government plans, policies and law, related to the monitoring and protection of aquifers and freshwater ecosystems with respect to water quality. However, the principles of Integrated Water Resources Management (IWRM) are not fully implemented. The local administrative level (WSAs and WSPs) has limited options for implementing IWRM, as water resource management is the mandate of the national government. The CCT operates well within its mandate and has relevant by-laws and spatial development plans in place that support freshwater ecosystems.

Institutions and Participation

The institutional structure across all tiers of government is well established. However, the institutional and human capacity various between the national level and local level. The national Department of Water and Sanitation, although responsible for monitoring and assessing the quality of water resources and freshwater ecosystems, has currently limited capacity to undertake these tasks at the required spatial and temporal scale. The City of Cape Town has undertaken to monitor several water resources across the three areas for compliance with permits and licences, and as part of the groundwater development project.

It is standard procedure in water resource development projects to have engagement with interested and affected parties. The CCT has implemented this as far as possible as part of an emergency supply intervention. However, the participation of the local level was originally limited, especially the involvement of ward councilors and land owners.

Management Instruments

The CCT has several special monitoring programmes in place for specific compliance issues; i.e. waste sites, waste water discharge sites, cemeteries, stormwater and river flows and quality. There is only limited capacity at private level to undertake monitoring and to implement measures to protect and restore the aquifer and surface ecosystems.

Financing

The biggest constraint to monitoring and managing water resource quality efficiently is the limited availability of funding streams. The CCT increased the tariffs for water supply drastically during the drought, partly to get sufficient revenue for implementing the water augmentation projects.

However, there is limited funding available on national level. The private sector has variable but mostly limited funding available.

Table 7.1 Preliminary Summary of Stakeholder Capacity Assessment for the Cape Town Aquifer Use Case, for the four components of governance; 1 – Enabling environment, 2 – Institutions and participation, 3 – Management instruments, 4 – Financing (Riemann, 2019)

Stakeholder Group	1	2	3	4
City of Cape Town, W&S	Good	Good	Good	Good
City of Cape Town, EMD	Good	Good	Good	Good
City of Cape Town, Ward Councillors	Fair	Fair	Poor	Poor
Other municipalities	Good	Good	Fair	Fair
PGWC, Department of Environmental Affairs and Development Planning (DEA&DP),	Good	Good	Good	Fair
Cape Nature	Good	Good	Fair	Fair
National Department of Environmental Affairs, Forestry and Fisheries (DEFF)	Good	Good	Fair	Fair
National Department of Water and Sanitation (DWS), Western Cape Regional Office	Good	Good	Fair	Fair
Breede-Gouritz Catchment Management Agency	Good	Good	Fair	Poor
Water Users Associations	Fair	Fair	Fair	Poor
PHA farmers (small and commercial)	N/A	Fair	Fair	Poor
Farmers outside Cape Town	N/A	Fair	Fair	Poor
Other land owners	N/A	Fair	Fair	Poor
Parastatal organisations	Good	Fair	Fair	Varied
Academia and Research	N/A	Fair	Fair	Fair
NGOs, CBOs	Fair	Good	Fair	Poor

7.3. Hotspots and Demands

7.3.1. Atlantis Aquifer

Based on the general chemistry analysis, comparison to drinking water and treatment guidelines, contamscan and CEC analysis of Atlantis groundwater and MAR Basins, the following potential contamination sources and hazards have been identified in the Atlantis Aquifer:

- Groundwater samples collected from the Wesfleur Wastewater Treatment Works (WWTW) area have elevated concentrations of multiple parameters, including EC, nitrate, orthophosphate, TOC, sodium, chloride, potassium and sulphate. The effluents from the WWTW are shown to raise the salinity of surrounding groundwaters.
- Currently, basin 9 receives stormwater from the industrial area and connects to basin 6. Basin 10 receives stormwater from the noxious trade area and frequent sewage overflows, and multiple parameters including EC, total aluminium, iron, dissolved arsenic, ammonia, and nitrate are observed in high concentrations.
- There is a bulk oil pipeline that passes through the extent of the aquifer which can severely contaminate groundwater. Additionally, atmospheric pollution from combustion of fuels, including the use of diesel at the Ankerlig Eskom Power Station and potential leakages from fuel storage tanks in Atlantis pose a threat to groundwater quality.
- Small scale farming occurs in the northern and north eastern margins of the aquifer and although no farming related nutrient pollution has been observed, the herbicides Diuron, Simazine and DIA were detected in groundwater samples, and in the treated effluents, related either to their production, use or disposal.
- Lack of adequate sanitation infrastructure in the informal Atlantis settlements can lead to nitrate and faecal contamination of the aquifer. Leaky or faulty sewage systems (septic tanks, pipes and pump stations) in formal settlements can also lead to contaminations. Recalcitrant CECs were detected in the treated domestic and industrial effluents.

7.3.2. Cape Flats Aquifer (CFA)

The urban setting of the CFA results in salinization and anthropogenic contamination with nutrients, microbiological and industrial contaminants, hydrocarbons and potentially CECs.

- The salinity is highly variable (EC ~120 mS/m) and shows elevated EC values (~300-700 mS/m) in some areas, with one borehole close to a stormwater canal having EC of above 200 mS/m due to very high chloride concentrations.
- Nitrates are generally low (no evidence of diffuse fertilizer contamination within PHA agricultural area), with elevated concentrations linked to point sources such as WWTW (especially the Mitchells Plain WWTW due to unlined sludge ponds, which unfortunately overlies the highest yielding portion of the CFA) and cemeteries. Higher N-concentrations are also found in some canals and rivers.
- Presence of elevated contaminants such as hexavalent chromium and trichloroethylene in CFA groundwater is shown near historical closed industrial areas and landfill sites (e.g. Swartklip area, due to munitions dump/testing).

In essence, CFA groundwater will require extensive treatment via modular treatment works prior to entering the distribution network, as indicated by the exceedances of water quality guideline limits.

7.3.3. TMG Aquifer

The TMG aquifers are located in a pristine environment and do not exhibit any evidence of altered or impacted water quality. However, there is a concern of naturally elevated Fe and Mn concentrations, especially in the deeper Peninsula Aquifer. Given the pristine and sensitive environment of the TMG Aquifer outcrop areas, this has implications for the risk of discharging of groundwater into the receiving environment, either intentionally or accidentally.

Investigation of these potential impacts has shown that they can be avoided or mitigated against with proper management and establishment of mitigation measures.

7.4. Products and Services

Several potential products and services have been identified during the stakeholder engagement process. Two different products have been developed by Umvoto Africa and The Umvoto Foundation, covering topics of aquifer protection and community engagement, respectively.

7.4.1. Aquifer Protection Scheme

A Groundwater Protection Scheme for the Cape Flats Aquifer (CFA) was developed in order to ensure the protection of groundwater quality to abstraction boreholes. The Groundwater Protection Scheme is composed of several components, namely Groundwater Protection Zones (GPZ's), vulnerability mapping and ranking, potentially contaminating activities (PCA), and a remediation plan. Currently, the GPZ delineation, vulnerability mapping and PCA identification have been completed. A remediation plan for one of the identified pollution sources has been developed (CCT, 2019c) and approved by the regulatory authority for implementation.

The objectives were to undertake the following:

- Delineate capture zones for each production borehole for 50 days, 100 days and 1 year as stipulated by the water use license.
- Delineate four GPZs based on international best practice and the travel time of defined contaminants in groundwater.
- Vulnerability mapping using a modified DRASTIC method to assess the potential risk of groundwater contamination.
- List and map PCAs and their associated risk to groundwater contamination.
- Delineate different protection responses based on GPZ, aquifer vulnerability and PCA risk.

7.4.2. Social Engagement and Advocacy

In parallel to the technical and scientific assessment and development of the protection zones, a social engagement process was initiated, which resulted in two initial products that highlight the strength and capacity for the approach for long-lasting and sustainable awareness and solutions.

A collaboration between scientists, engineers, artists and diverse stakeholder and communities led to the development of a concept note on realizing a Critical Zone Observatory (CZO) for the Cape Flats Aquifer and surrounding area, incorporating natural processes, socio-economic aspects and art.

The Critical Zone is the heterogenous (non-uniform), near surface environment of the Earth within which the natural habitat is regulated and nearly all terrestrial life is sustained. It incorporates the physical land surface, vegetation, rivers, lakes, and shallow seas that extend into the pedosphere (outermost layer of the earth), the unsaturated vadose zone and saturated groundwater zone, and all living organisms inhabiting these spaces, where ongoing and changing interactions occur between air, water, soil, rock and organisms, including humans.

The Critical Zone Observatory (CZO) provides the common reference point and platform for bringing various groups of people together, such as scientists studying the physical and social environments, engineers and other practitioners altering the environments, the officials administering them, and – importantly – the communities living in and with these spaces.

The concept and approach, described above, has been implemented in an environment and water stewardship course for the local community in one of the collaborative zones, which was prepared and run in November 2019 at the Edith Stephens Nature Reserve in Cape Town. The Edith Stephens Nature Reserve is situated close to the Philippi Horticultural Area and is surrounded by formal and informal settlements, light industry and agricultural land. The Lotus Canal (identified as potential pollution source in the assessment) flows directly pass the Nature Reserve. During high flows, peak flows are diverted into ponds on the Nature Reserve.

This course was planned as a knowledge exchange between residents, water and environment experts, and local organisations. In the long term, it is envisaged to work together with the partners Communitree, Site Specific Landscape, the Edith Stevens Wetland Park, the City of Cape Town and communities towards improving the Lotus Canal for people and the environment. This course was the first step in this project and shed light on the possibilities and opportunities of working together on the Lotus Canal challenge.

7.5. Water Quality Action Plan

Due to the fact that there are three very distinct aquifers with different water quality challenges and the involvement of different role players and consulting engineers, it was not achievable to prepare a coherent water quality action plan across the study. However, the possible solutions listed in te TOR were addressed:

- Treatment processes specific to each aquifer system, which will provide bulk groundwater supply that meets modern national and international potable domestic standards/limits;
    - Addressed in CCT projects via the treatment works design by consulting engineers and in the Water Safety Plan (drafted for the CFA; Swartz, 2020).
- Wellfield operational and maintenance procedures to reduce iron/manganese precipitation/ biofouling;
    - Addressed in CCT projects via standard operational procedures (SOP) and maintenance tender documents.
- Understanding of potential surface-groundwater hydrochemical mixing impacts with respect to the storage of TMGA groundwater in surface water dams, and potential solutions and operational procedures e.g. pre-treatment of groundwater;
    - Investigation carried out by consulting engineers Aurecon (2019b); see **Section 5.3.2**
- Restoration of aquifer and wetland ecosystem functions through wetland rehabilitation, biomimicry, water sensitive urban design (WSUD) etc.
    - Initiated via the Hoerikwaggo Critical Zone Observatory proposal and Water Stewardship Workshop (see **Section 6.2.1** and **6.2.2**). This will be continued as outlined under recommendations below.
- Maintenance of ecosystem functioning through sustainable groundwater abstraction i.e. ensuring the continuation of natural surface-groundwater interaction processes.
    - Addressed as part of the scheme design for the CFA (see **Section 4.1.3**) with the positioning of abstraction boreholes and inclusion of the water injection at strategic locations close to sensitive, groundwater dependent ecosystems.

7.6. Challenges

The Cape Town Aquifers Use Case differed from the other use cases in its approach and methodology, as its focus was on local to sub-regional aquifers as water resource and was linked to ongoing investigation by the City of Cape Town. Several challenges were encountered:

- The methodology for the Use Case had to be adapted during the study, as the standard approach for surface water quality assessment from the GWQA was not applicable. However, the triangulation approach was successfully adapted and implemented to support the assessment and product development. It is envisaged that this adapted approach can be implemented for other aquifers and upscaled for regional assessments.
- Due to the COVID-19 pandemic and associated restrictions on travel and meetings, the stakeholder engagement was limited to less regular online meetings. This caused a delay in some of the work and deliverables, but was not detrimental to the outcome of the Use Case, as a solid and coherent stakeholder network and engagement structure had been build prior to commencing the study.

7.7. Way Forward

Going forward, this stakeholder engagement will be expanded by including different organisations, spanning from household level and communities to municipal and national institutions. This will allow for establishing the appropriate scale for and integration of different groundwater management activities across sectors and tiers of government, thus, requiring different interventions, communication strategies and governance structures.

This continued stakeholder engagement process should also include a continuation of the water and environmental stewardship initiative at a grass-roots level, integrated with government, civil society and private sector initiatives. This could use art/culture/music as a science communication and knowledge exchange tool using an African inspired and adapted ‘Renaissance approach’ to science-culture-sustainability diplomacy.

The following is recommended for future phases of the study:

- Expansion of the scope of the Use Case
    - Including surface and stormwater systems and their interaction with the aquifer
    - Expand the monitoring network to include additional parameters of concern; e.g. CECs, viruses (including Covid 19)
    - Preparing an implementation plan of GPZs, especially in built-up areas
- Initiation of the Lotus Canal Challenge
    - Rehabilitation plan for degraded stormwater system
    - Water Stewardship & Transformative Art to support behaviour changes
- Roll-out to other urban centres
    - Testing the approach and success factors in different geographical and institutional settings (e.g. environment, water resources, culture, governance, data availability)

8. REFERENCES

8.1. Report References

- Aurecon (2019a). TMG Aquifer - Understanding the impacts of Rotafoam™ spillage. Report prepared on behalf of the City of Cape Town. Reference: 501026
- Aurecon (2019b). TMG Aquifer – Evaluating the impact of iron concentration in groundwater discharged into the Steenbras Dam. Report on behalf of the City of Cape Town. Reference 501026
- Aza-Gnandji, C.D.R., Xu, Y., Raitt, L., Levy, J. (2013). Salinity of irrigation water in the Philippi farming area of the Cape Flats, Cape Town, South Africa. Water SA col. 39 No.2
- Borchardt, C. and Kremer, H. (2018). The World Water Quality Assessment: Three component proposal for a participatory consortium approach (ref Resolution UNEP/EA3/10; Dec 2017) towards a Global Water Quality and Services Platform Project. Position Paper
- Bugan, R., Jovanovic, N., Tredoux, G. and Israel, S., 2014. Provision of professional services for Atlantis Water Supply Scheme: Artificial recharge scientific and operational support. Hydrogeological resource assessment and water balance. Contract No. SCMS, 45, pp.01-11.
- Bugan, R., Jovanovic, N., Israel, S., Tredoux, G., Genthe, B., Steyn, M., Allpass, D., Bishop, R. and Marinus, V., 2016. Four decades of water recycling in Atlantis (Western Cape, South Africa): Past, present and future. Water SA, 42(4), pp.577-594.
- City of Cape Town (unpublished). Schematic of Atlantis Water Resource Management Scheme
- City of Cape Town. (2011). Exploratory Phase: Wellfield Operation. Prepared by the TMG Aquifer Alliance (Authors: K. Riemann, S. Imrie, D. Blake, C. J. H. Hartnady and E. R. Hay of Umvoto Africa (Pty) Ltd) as part of the Exploratory Phase of the Table Mountain Group Aquifer Feasibility Study and Pilot Project.
- City of Cape Town (2012). Exploratory Phase: Hydrogeological Reconnaissance. Prepared by the TMG Aquifer Alliance (Authors: D. Blake, C. J. H. Hartnady and K. Riemann of Umvoto Africa (Pty) Ltd) as part of the Exploratory Phase of the Table Mountain Group Aquifer Feasibility Study and Pilot Project.
- City of Cape Town (CCT) (2017). Five-year Integrated Development Plan 2017-2022. City of Cape Town, Cape Town (South Africa), 149 pp.
- City of Cape Town (2017). Water Resilience – Cape Flats Aquifer: Implementation Plan. Presentation prepared by iX engieneers (Pty) Ltd and Umvoto Africa (Pty Ltd. to the CCT Drought Working Group. 30 September 2017
- City of Cape Town (2018). Numerical Groundwater Model of the Steenbras Table Mountain Group Aquifer System - Progress Report, CCT Water Resilience Plan: TMGA-Steenbras. Prepared by Rui Hugman, Jannie Weitz and Chris Hartnady of Umvoto Africa Pty (Ltd.) on behalf of the City of Cape Town. Report No. 899/07/01.01/2018, pg.41
- City of Cape Town (2019a). Our shared Water Future – Cape Town's Water Strategy
- City of Cape Town (2019b). TMGA Ecological and Hydrogeological Monitoring – Monitoring Report (2007 – 2018) Volume 3: Data Analysis Report. Prepared by S. Jack, K. Riemann, E. Wise and P. Lee of Umvoto Africa, C. Brown, K. Reinecke and A. Joubert of Southern Waters, and C Boucher on behalf of the City of Cape Town

- City of Cape Town (2019c). Rehabilitation Plan for the Groundwater Pollution around the Mitchells Plain Wastewater Treatment Works; CCT New Water Programme: Cape Flats Aquifer. Prepared by A. Gemmell of Umvoto Africa Pty (Ltd.) on behalf of the City of Cape Town, Directorate Water and Sanitation. Report No. 896/07.02/01/2019, 10 pp
- City of Cape Town (CCT). (2020a). New Water Programme – Cape Flats Aquifer Management Scheme: 2018-2020 Hydrochemistry Report. Prepared by Andrew Gemmell, Sabine Henry, David McGibbon, Magen Munnik and Alex Kuhudzai of Umvoto Africa (Pty) Ltd on behalf of the CCT Municipality. Final Draft, Report No.: 896/07/08/2020, October 2020, pg. 97 (excluding Appendices).
- City of Cape Town (CCT). (2020b). New Water Programme - Atlantis Water Resource Management Scheme: AWRMS Hydrochemistry Report. Prepared by Maposholi Mokhethi, Andrew Gemmell, Matthew Misrole, Keanan Woolf, Eddie Wise and Luke Towers of Umvoto Africa (Pty) Ltd on behalf of the CCT Municipality. Draft, Report No.: 897/7.2b/12/2020, September 2020, pg 73 (excluding Appendices).
- City of Cape Town (2020c). New Water Programme: Cape Flats Aquifer Management Scheme - Groundwater Protection Zones and Vulnerability Mapping. Prepared by Henry, SL., Hugman, R., McGibbon, D.C., Kuhudzai, A., E. Wise, E. Van Der Berg and K. Riemann of Umvoto Africa Pty (Ltd.) on behalf of City of Cape Town Municipality. Final Draft; Report No. 896/7.1/13/2020, pg.[51]
- City of Cape Town (2020d). Groundwater Protection Zones and Vulnerability Mapping, New Water Programme – Atlantis Water Resource Management Scheme. Henry, SL., Weitz, J., Kwata, M., Towers, L., of Umvoto Africa Pty (Ltd.) on behalf of City of Cape Town Bulk Water Department. Report No. 897/7.2e/12/2020, 46 pp
- City of Cape Town (2021). City of Cape Town New Water Programme: Table Mountain Group Aquifer. Steenbras-Nuweberg Nardouw Aquifer Conceptual Model Report. Prepared by D. Blake, K. Riemann, C. J. H. Hartnady, E. R. Hay, Z. Rademan, L. Goslin, K. Prinsloo, L. Towers, M. Mokhethi, S. Henry, G. Bluff, D. McGibbon and K. de Bruin of Umvoto Africa Pty (Ltd) on behalf of Zutari (Pty) Ltd for the City of Cape Town: Water and Sanitation Department: Bulk Water Branch: Bulk Water Resource and Infrastructure Planning. Final Draft, Umvoto Report No. 899/07/01/2021, 111pp.
- Council for Geoscience (CGS). Geological Map of South Africa
- Department of Water and Sanitation, South Africa – DWS (2016). Support to the Continuation of the Water Reconciliation Strategy for the Western Cape Water Supply System: Status Report April 2016. Prepared by Umvoto Africa (Pty) Ltd in association with WorleyParsons RSA on behalf of the Directorate : National Water Resource Planning. DWS Report No.
- Department of Water and Sanitation, South Africa – DWS (2015). Support to the Continuation of the Water Reconciliation Strategy for the Western Cape Water Supply System – Cape Flats Aquifer Management Strategy. Prepared by Umvoto Africa (Pty) for the Department of Water and Sanitation, South Africa.
- Hay, R (2019). Environment and Water Stewardship Course; Edith Stephens Nature Reserve. 11 – 14 November 2019
- Hay, R and Snyman, A (2019). Hoerikwaggo Critical Zone Observatory, Cape Flats, Cape Town South Africa
- Kremer, H (2018). World Water Quality Alliance; Assessment – Agenda Setting Services linking the global water quality agenda to the nexus and national local relevance. Presentation at Inception Workshop WMO/Geneva 28/11/2018 & Follow Up, JRC ISPRA21 24/06/2019; World Bank 1 2/04/2019; OECD 06/06/2019

- Riemann, K et al. (2010): Groundwater Management Framework; prepared by K Riemann, N Chimboza and M Fubesi of Umvoto Africa (Pty) Ltd and D Louw of OABS as part of the project "Groundwater Management Functions". Project K5/1917, Water Research Commission, Pretoria. Draft Report, November 2010.
- Riemann, K et al. (2015). Water Governance Framework and Action Plan for Conjunctive Use, Water Governance of Groundwater and Surface Water Resources in South Africa - Deliverable 6. Report to the Water Research Commission South Africa, Pretoria.
- Riemann, K., McGibbon, D.C., Gerstner, K., Scheibert, S., Hoosain, M. and Hay, R. (2017). Water Resource Protection: A review of the state-of-the-art and research and development needs for South Africa – Research Strategy. WRC Report K5/2532/1/17, Water Research Commission, Pretoria South Africa
- Riemann, K (2019). Artificial Recharge for the Cape Flats Aquifer Project. Presentation: Water Resource Management Course, Stellenbosch University, 18 March 2019
- Riemann, K (2019). World Water Quality Alliance Use Case Study – Cape Town Aquifers; Deliverable 1 & 2: Stakeholder Capacity Assessment Report. Prepared for World Water Quality Alliance on behalf of UN Environment Programme. Version 1; Report No. 956/1/1/2019.
- Riemann, K (2020). World Water Quality Alliance Use Case Study – Cape Town Aquifers; Deliverable 3: Data Base Compilation Report. Prepared for World Water Quality Alliance on behalf of UN Environment Programme. Version 1; Report No. 956/2/1/2020.
- Riemann, K (2021). World Water Quality Alliance Use Case Study – Cape Town Aquifers; Deliverable 4: Water Quality Hotspot Report. Prepared for World Water Quality Alliance on behalf of UN Environment Programme. Version 1; Report No. 956/2/2/2020.
- Swartz (2020). Water Safety Plan for the Cape Flats Indirect Potable Reuse (IPR) Water Supply System (including the Strandfontein West Post-Treatment Plant). Third Draft, For Comments. Prepared for City of Cape Town
- UNEP (2016). Snapshot of the World's Water Quality, Towards a Global Assessment. United Nations Environment Programme, Nairobi, Kenya. 162pp. ISBN Number: 978-92-807-3555-0
- UNEA (2017). Addressing water pollution to protect and restore water-related ecosystems. UNEA Resolution 3/10. UNEP/EA.3/Res.10
- UNEP (2019). Terms of Reference for Water Quality, Management and Groundwater Specialist (19-United Nations Environment Programme-121596-Consultant) to undertake the Cape Town Aquifer Use Case
- UNEP (2020). Information on implementation of resolution 3/10 on addressing water pollution to protect and restore water-related ecosystems. Note by Executive Director for submission to UNEA 5. UNEP/EA.5/INF/14
- UNEP (2021). Terms of Reference for Water Quality, Management and Groundwater Specialist (21-United Nations Environment Programme- 148453-Consultant) to continue with the Cape Town Aquifer Use Case

8.2. Conference Presentations

- Blake, D., Kremer, H., Hay, E. R., Christ, K., McGibbon, D. C. and Towers, L. C. (2019). Cape Town's major Aquifer Systems as a Use Case Study for the Global Water Quality Assessment. 2nd Southern African Development Community-Groundwater Management Institute Groundwater Conference, Johannesburg, South Africa, 4-6 September 2019

- Blake, D., Riemann, K., Rademan, Z. and Geldenhuys, P. (2019). Groundwater development of the Table Mountain Group Aquifers as part of the City of Cape Town's New Water Programme. 16th South African Groundwater Division Conference, Port Elizabeth, South Africa, 21-23 October 2019.
- Blake, D., Hartnady, C. J. H., Hay, E. R. and Riemann, K. (2020). Geoethics of bulk groundwater abstraction in ecologically sensitive areas – Geoethics of bulk groundwater abstraction in an ecologically sensitive area - Steenbras Wellfield (Cape Town). Geoethics and Groundwater Management Congress, Porto, Portugal, 18-22 May 2020.
- Hartnady, C. J. H., Hay, E. R., Riemann, K., Blake, D. and Holmes, J. C. (2018). Table Mountain Group aquifers as a long-term resilience buffer against drought and climate change in the Western Cape, South Africa. South African Geocongress 2018, Johannesburg, South Africa, 18-20 July 2018.
- Hay, E. R., Hartnady, C. J. H., Hugman, R., Atkins, F., van Ryneveld, M., Wise, E., McGibbon, D.C. and Holmes, J. C. (2018). Cape Flats Aquifer: 3D geometry and revised hydrostratigraphy based on geomorphological process-domain understanding, new drilling and modelling results. South African Geocongress 2018, Johannesburg, South Africa, 18-20 July 2018.
- Hay, E.R., Snyman, A. and Hartnady, C.J.H. (2020). Transformative Art applied to the social hydrogeology of the Cape Flats, South Africa. Geoethics and Groundwater Management Congress, Porto, Portugal, 18-22 May 2020.
- Holmes, J.C., Hay, A., Coetzee, A., Hugman, R., Flügel, T., Atkins, J.F., Snyman, A. and de Jager, R. (2018). Opportunity in crisis: An interdisciplinary 'learn by doing' approach to resource management of the Cape Flats Aquifer. Presentation at 82nd IMESA Conference, 31 October – 02 November 2018
- McGibbon, D.C., Hugman, R., Towers, L.C., Hartnady, C.H.J., Hay, E.R. and Riemann, K. (2019). Emergency response to drought – the City of Cape Town's groundwater abstraction and MAR scheme (South Africa). International Symposium on Managed Aquifer recharge (ISMAR) 10, Madrid, Spain, 20-24 May 2019.
- McGibbon, D.C., Hugman, R., Towers, L.C., Hartnady, C.H.J., Hay, E.R. and Riemann, K. (2019). Emergency response to drought – the City of Cape Town's groundwater abstraction and MAR scheme (South Africa). 16th South African Groundwater Division Conference, Port Elizabeth, South Africa, 21-23 October 2019.
- McGibbon, D.C., Hugman, R., Towers, L.C., Riemann, K., Hay, E.R. and Hartnady, C.H.J. (2020). Long-term planning during emergency response – a no regrets approach and long-term vision for the development of the Cape Flats Aquifer (Cape Town). Geoethics and Groundwater Management Congress, Porto, Portugal, 18th-22nd May 2020.
- Towers L., Hay R. (2018). The Atlantis Water Resource Management Scheme – Lessons in Resilience and demonstration that "resource management is people management". Presented at the Geological Society of South Africa (GSSA) Geocongress 2018. University of Johannesburg, South Africa.
- Towers L., Riemann K., Weitz J., Hugman, R. (2019). The Atlantis Water Resource Management Scheme – resource management is people management. Presented at the 10th International Symposium for Managed Aquifer Recharge (ISMAR10). Madrid, Spain.
- Towers L., Hugman R. (2021). Cycles of Uncertainty: An Exploration of 40 Years of the Atlantis-Managed Aquifer Recharge Scheme Through a Geoethical Lens. In: Abrunhosa M., Chambel A., Peppoloni S., Chaminé H.I. (eds) Advances in Geoethics and Groundwater Management : Theory and Practice for a Sustainable Development. Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development). Springer, Cham. https://doi.org/10.1007/978-3-030-59320-9_88.

Appendices

Appendix A – Stakeholder Engagement

Appendix A.1: Atlantis Aquifer

A list of identified stakeholders is provided below with indication of their relevance regarding data provision, access to site for monitoring, impact on water quality (positive or negative) and potential support for solutions.

List of identified stakeholders for the Atlantis Aquifer

Stakeholder	Data provider	Access to site	Impact on WQ (+/-)	Support
City of Cape Town				
W&S, Bulk Water Branch	X	X		X
W&S, Waste Water and Sanitation Branch	X	X	X	X
W&S, Water Demand Management Branch				X
W&S, Catchment, Stormwater and River Management		X	X	X
Solid Waste	X		X	
EMD, Biodiversity Management Branch		X		X
EMD, Environmental Compliance Branch		X		X
Pollution Control	X			
Scientific Services	X			
Ward Councillors		X		X
Provincial Government of the Western Cape (PGWC)				
Department of Environmental Affairs and Development Planning (DEA&DP),			X	
Department of Transport and Public Works (DT&PW)	X			
Green Cape	X			X
CapeNature		X	X	
National Government of South Africa				
Department of Water and Sanitation (DWS), Western Cape Regional Office	X	X	X	
Department of Environmental Affairs, Forestry and Fisheries (DEFF)		X	X	
South African National Parks (SANParks)		X		
Landowners				
ESKOM	X	X	X	X
Developer	X	X	X	
Atlantis Foundries	X		X	
Academia and Research:				
Water Research Commission	X			X
University of Cape Town				X
University of the Western Cape	X			
CSIR	X			
Council for Geoscience	X			X
NGOs				
The Nature Conservancy	X			X

In addition to the general engagement with the City of Cape Town, wider stakeholder engagement specifically around the AWRMS has been undertaken but is only gaining traction in recent months.

- Numerous meetings with CCT officials and past role players within the scheme to establish and address major management, design, operational and maintenance shortcomings of scheme.
- Meeting with The Nature Conservancy for potential collaboration of efforts around refurbishment of MAR components on 27 October 2017.
- Meeting on 07 November 2017 and 12 January 2018 with DWS to determine how to approach the WULA for the AWRMS
- Numerous meetings with Eskom as landowner (access agreements) and end user of discharged industrial wastewater and waste from softening plant – initial meeting 22 May 2018.
- Site visits with Cape Nature as Managing Authority of land for Silwerstroom
- Meeting with the Provincial Department of Environmental Affairs and Development Planning on 12 December 2017 to investigate potential for economic use of reed harvests associated with MAR ponds
- Meeting with Groot Springfontyn Development (Bigen Engineers) on 1 August 2018 to discuss supplying the new development with water, availability of data from their area and possible access to their land for borehole drilling.
- Meeting with Disaster Management Centre in Atlantis on 27 June 2019
- Meeting with Pollution Control on 19 November 2018 to discuss spills in Atlantis.
- Meeting with numerous CCT departments to initiate the establishment of the Atlantis Aquifer Management Team held on 21 November 2019.

Appendix A.2: Cape Flats Aquifer

A list of identified stakeholders is provided below with indication of their relevance regarding data provision, access to site for monitoring, impact on water quality (positive or negative) and potential support for solutions.

List of identified stakeholders for the Cape Flats Aquifer

Stakeholder	Data provider	Access to site	Impact on WQ (+/-)	Support
City of Cape Town				
W&S, Bulk Water Branch	X	X		X
W&S, Waste Water and Sanitation Branch	X	X	X	X
W&S, Water Demand Management Branch				X
W&S, Catchment, Stormwater and River Management		X	X	X
EMD, Biodiversity Management Branch		X	X	X
EMD, Environmental Compliance Branch		X	X	X
Scientific Services	X			
Ward Councillors		X	X	X
Provincial Government of the Western Cape (PGWC)				
Department of Environmental Affairs and Development Planning (DEA&DP),			X	X
Department of Transport and Public Works (DT&PW)	X	X		
Green Cape	X			X
CapeNature		X	X	
National Government of South Africa				
Department of Water and Sanitation (DWS), Western Cape Regional Office	X	X	X	X
Department of Environmental Affairs, Forestry and Fisheries (DEFF)		X		
Landowners				
PHA Food and Farming Campaign,				X
PHA farmers (small and commercial),		X	X	X
Consol Glass Mine		X	X	X
Oaklands City Developer	X	X	X	X
Academia and Research:				
Water Research Commission	X			X
University of Stellenbosch				X
University of Cape Town				X
University of the Western Cape	X			
NGOs				
Natural Justice				X
Communitree				X

In addition to the general engagement with the City of Cape Town, wider stakeholder engagement specifically around the Cape Flats Aquifer has been undertaken.

City of Cape Town

Specific meetings and workshops around the vision for the Cape Flats towards a water resilient city, as stipulated in the CCT Water Strategy, were held with the CCT. These include:

- Several meetings with CCT officials regarding proposals to implement the Cape Flats Aquifer Management Strategy (DWS and CCT, 2015) on aquifer protection and catchment rehabilitation.
- Meetings with CCT officials to develop funding proposal for designing and implementing water resilience catchment management.
- Meeting with Stormwater, Catchment and River Management Branch on 21 November 2019 to discuss support for a pilot study on rehabilitating the Big Lotus Canal (currently a heavily polluted stormwater canal) to near natural conditions.
- Workshop between CCT, Dutch embassy, Deltares, Umvoto Africa and other partners as part of the #CoCreateMyCity event on 21 November 2019 regarding the proposed "liveable urban water ways" project, including pre-event workshops and meetings.

Monitoring Committee Meetings

The water use licence for the CFA stipulates the requirement to establish a Monitoring Committee comprising:

- City of Cape Town Municipality
- National Department of Water and Sanitation
- Provincial Department of Environmental Affairs
- Cape Nature
- SANParks
- Local farmers

So far, four meetings were organised by the CCT:

- 10 December 2018 (combined with TMGA Monitoring Committee meeting); focused on providing feedback to relevant stakeholders on the different groundwater development projects by the City and initiating the establishment of the monitoring committee.
- 26 September 2019; focused on officially establishing the monitoring committee for the CFA and providing feedback on current development of the CFA wellfield development and MAR scheme.
- 18 February 2020; feedback on wellfield development progress, monitoring activities and results, allowed for officially introducing the WWQA Use Case and discuss water quality issues.
- 28 January 2021; feedback on wellfield development progress, monitoring activities and results, feedback on the outcome of the WWQA Use Case and the development of specific products and services

Field Visits:

A number of field visits with interested and or affected parties have been undertaken:

- Several on site meetings with CCT Biodiversity Branch, CCT Environmental Compliance Branch, False Bay Nature Reserve Advisory Group, *inter alia*, regarding environmental sensitive sites and authorisation for access to drill boreholes, construct civil works or install monitoring infrastructure.
- MAR field visit 10 April 2019 as part of MAR Workshop, organised by IAH SA and GWD;

attendees included officials from national DWS and City of Cape Town, groundwater experts, engineers and scientists

- DWS (South Africa) - Denmark (MEF) Strategic Sector Cooperation (SSC) Phase 2 – 21 June 2019 Field Visit; attendees included officials from national DWS and Danish Water Ministry
- Auditor General Site Visit – 3 September 2019; attendees included officials from the City of Cape Town, Umvoto Africa, iX Engineers

Local Stakeholder Presentations:

The groundwater development project and or aspects around water quality and aquifer protection have been presented and discussed at several local meetings and workshops:

- PHA Farmers Meeting on 7 February 2019; comprising Umvoto Africa, City of Cape Town, commercial farmers
- PHA Farmers Meeting on 17 October 2019; comprising Umvoto Africa, City of Cape Town, commercial farmers
- PHA Improvement Partnership Forum on 5 November 2019; comprising Umvoto Africa, City of Cape Town, various groups of farmers (subsistence and commercial), PHA Food and Farming Campaign, Consol Glass Mine
- Meeting with Oaklands City developer and planners on 23 July 2019; comprising Umvoto Africa, iX engineers, City of cape Town officials, engineers, groundwater consultant and lawyers for the proposed greenfield development
- Fynbos and Water Stewardship Workshop on 11-14 November 2019; comprising community members from Hanover Park, Athlone and Khayelitsha, Communitree, Umvoto Africa, UCT

Appendix A.3: Table Mountain Group Aquifer

A list of identified stakeholders is provided below with indication of their relevance regarding data provision, access to site for monitoring, impact on water quality (positive or negative) and potential support for solutions.

List of identified stakeholders for the TMG Aquifer

Stakeholder	Data provider	Access to site	Impact on WQ (+/-)	Support
City of Cape Town				
W&S, Bulk Water Branch	X	X		X
W&S, Waste Water and Sanitation Branch	X	X	X	X
W&S, Water Demand Management Branch				X
W&S, Catchment, Stormwater and River Management		X	X	X
EMD, Biodiversity Management Branch		X	X	X
EMD, Environmental Compliance Branch		X	X	X
Scientific Services	X			
Other Municipalities				
Theewaterskloof Local Municipality (LM)		X	X	X
Overberg District Municipality (DM)		X	X	X
Provincial Government of the Western Cape (PGWC)				
Department of Environmental Affairs and Development Planning (DEA&DP)		X	X	X
Department of Transport and Public Works (DT&PW)	X			
CapeNature		X	X	
National Government of South Africa				
Department of Water and Sanitation (DWS), Western Cape Regional Office	X	X	X	
Breede-Gouritz Catchment Management Agency (BGCMA)	X	X	X	
Department of Environmental Affairs (DEA)		X		
South African National Parks (SANParks)		X		
South African National Botanical Institute (SANBI)	X			X
Landowner Representative / Local Stakeholders				
Groenland Water User Association (GWUA)	X	X	X	X
Vyeboom Irrigation Board (VIB)	X	X	X	X
Kogelberg Biosphere Reserve Company (KBR)		X		X
Cape Winelands Biosphere Reserve (CWBR)		X		X
Academia and Research				
Water Research Commission	X			X
University of Cape Town	X			X
University of the Western Cape	X			X
South African Earth Observation Network (SAEON)	X			X
CSIR	X			

In addition to the general engagement with the City of Cape Town, wider stakeholder engagement specifically around the development of the TMG Aquifer has been undertaken.

TMG Environmental Working Group:

The TMG Environmental Working Group (EWG) was initiated by the CCT in response to concerns and criticism expressed publicly by scientists and interested environmental organisations regarding the development of the TMG Aquifer. The purpose of the EWG was to provide a platform to inform the concerned stakeholders about the current investigation and plans, and to discuss the concerns. Three meetings were held, after which the structure of these meetings changed with the introduction of the monitoring committee meetings (see below).

- 20th March 2018 – Introduction to project, work done so far and plans for groundwater development going forward
- 29th May 2018 – Discussion of the purpose and Terms of Reference of the EWG
- 18th September 2018 – Discussion on current and future monitoring activities

TMG Environmental Focus Group:

The TMG Environmental Focus Group (EFG) was initiated by the project team as a subset of the EWG, specifically to assess and screen proposed field activities, such as borehole drilling and infrastructure development. Several meetings were held, which provided feedback to the project team for consideration in the design and implementation of the groundwater scheme.

- 17th September 2018
- 14th March 2019
- 29th May 2019
- 10th September 2019

TMG Monitoring Committee:

The water use licences for the different TMGA wellfield areas stipulate the requirement to establish a Monitoring Committee comprising:

- City of Cape Town Municipality
- National Department of Water and Sanitation
- Provincial Department of Environmental Affairs
- Cape Nature
- SANParks

Four meetings had been organised by the CCT so far:

- 10 December 2018 (combined with CFA Monitoring Committee meeting); focused on providing feedback to relevant stakeholders on the different groundwater development projects by the City and initiating the establishment of the monitoring committee.
- 26 September 2019; focused on officially establishing the monitoring committee for the TMGA and providing feedback on ongoing monitoring and results of data analysis, as well as current progress with the TMGA wellfield development at Steenbras, planned development at Nuweberg and Groenlandberg.
- 17 February 2020; feedback on wellfield development progress, monitoring activities and results, allowed for officially introducing the WWQA Use Case and discuss water quality issues.
- 28 January 2021; feedback on wellfield development progress, monitoring activities and results, feedback on the outcome of the WWQA Use Case

Other stakeholder meetings relevant to the CCT TMGA Project

- Steenbras geology/hydrogeology presentation to the Kogelberg Biosphere Reserve Company – 25 October 2018
- CCT TMG Aquifer presentation to the Botanical Society of South (Kogelberg Branch) – 16 March 2019
- Steenbras Wellfield presentation at CCT Bulk Water Quarterly Operations Workshop – 29 April 2019
- CCT TMG Southern Planning District Groundwater Exploration presentation to SANParks – 21 May 2019
- TMG and CFA site visits and presentations to the South Africa (DWS)-Denmark (MEF) Strategic Sector Cooperation (SSC) Phase 2 – 21 June 2019
- Steenbras Wellfield site visit and presentation to the GWD 2019 Field School – 25 June 2019
- CCT TMG Aquifer presentation to Vyeboom Irrigation Board farmers – 17 July 2019
- TMG Aquifer risk workshops with the CCT – 22 August 2019, 8 October 2019, 28 October 2019, 26 November 2019

Appendix B – Available Data

Appendix B.1: Summary of water quality parameters and data analysis

Parameters

The water quality data focus on

- Parameters from the South African National Standard (SANS) 241: 2015 Drinking Water:
  - Physical: Colour, Conductivity, Total Solids, Turbidity, pH
  - Monochloramine
  - Nitrate, Nitrite, Nitrate & Nitrite, Ammonia
  - Sulphate, Fluoride, Chloride
  - Sodium
  - Metals: Antimony, arsenic, barium, boron, cadmium, total chromium, copper, iron, lead, manganese, mercury, nickel, selenium, uranium, aluminium, zinc,
  - Cyanide
  - Total organic carbon
  - In addition, annually:
    - Phenols
    - Trihalomethanes: chloroform, bromoform, dibromochloromethane, bromodichloromethane, total trihalomethanes.
  - Microbiology: *E. coli*, total coliforms, faecal coliforms.
- Parameters relevant for water treatment requirements:
  - Suspended Solids, Bromide, Orthophosphate,
  - Organic Carbon, Chemical Oxygen Demand
  - Total Metals: Aluminium, iron, manganese
- Parameters to assess geochemistry:
  - Bicarbonate, Total Alkalinity, Total Hardness, Carbonate
  - Calcium, Magnesium, Potassium
- A broad contamination scan ("ContamScan") to assess a wide range of chemicals typically associated with industrial/manufacturing/agriculture processes that could pose a risk to humans and the environment:
  - Volatile organic compounds (VOCs)
  - Pesticides (organochlorine, organophosphorus, nitrogen)
  - Phenols
  - Polycyclic aromatic hydrocarbons
  - Polychlorinated biphenyls
  - Phthalates
  - Other semi volatile organics
  - Metals
  - Hydrocarbons
  - Chromium (VI)
- Chemical of emerging Concerns (CECs) to assess human impact from different land use activities

Analysis

Given that the final use of the abstracted water is for potable use, the analytical results were compared to guidelines specific to drinking water. Hence, analytical results tested for the suite of analyses listed in the SANS 241:2015 drinking water guidelines are compared to the limits specified within the guideline. These guidelines specify limits for each of the determinands based on the following risks:

- **Chronic health:** determinand that poses an unacceptable health risk if ingested over an extended period if present at concentration values exceeding the numerical limits specified in this part of SANS 241
- **Acute health:** determinand that poses an immediate unacceptable health risk if present at concentration values exceeding the numerical limits specified in this part of SANS 241
- **Aesthetic:** determinand that taints water with respect to taste, odour or colour and that does not pose an unacceptable health risk if present at concentration values exceeding the numerical limits specified in this part of SANS 241
- **Operational:** determinand that is essential for assessing the efficient operation of treatment systems and risks to infrastructure

Analytical results tested for the ContamScan suite of analyses were first compared to the SANS 241:2015 drinking water guidelines. Where these were not available, results were compared to the United States Environmental Protection Agency (US EPA) Regional Screening Levels (RSLs). The RSLs are chemical-specific concentrations for individual contaminants in drinking water. In addition to RSLs, the US EPA specifies a Maximum Contaminant Level (MCL), the maximum permissible level of a contaminant in drinking water which is delivered to any user of a public water system. A target hazard quotient (THQ) of 1 was used under the assumption that receptors are only exposed to a single contaminant.

Appendix B.2: Excerpt of Surface Water Quality Data from the MAR System of the Atlantis Scheme

	Determinant	Colour	Electrical Conductivity at 25°C	Total Dissolved Solids at 180°C	Turbidity	pH at 25°C	Mono-chlor-amine	Nitrate	Nitrite	Nitrate / Nitrite	Sulphate	Fluoride	Ammonia	Chloride	Sodium	Total Organic Carbon	E. coli	Total Coliforms	Faecal Coliforms	Hetero-trophic Plate Count
Station Name	Date Sampled	mg Pt-Co/ℓ	mS/m	mg/ℓ	NTU	pH units	mg/ℓ	mg N/ℓ	mg N/ℓ	mg N/ℓ	mg SO_4/ℓ	mg F/ℓ	mg N/ℓ	mg Cl/ℓ	mg Na/ℓ	mg C/ℓ	Count/100ml	Count/100ml	Count/100ml	Count/ml
BASIN 5 INLET	2018/08/22	33	99.5	708	32.2	7.84					93.6	0.52		159	99.6	13.9	>2419	>2419	>2419	
BASIN 5 INLET	2019/05/09	20	139	1028	59	4.4	<3	0.82	0.03	0.85	30.7	0.32	6.6	59	206	660	1	1	1	
BASIN 5 INLET	2019/10/03	89	89	568	45	7.4	<3	0.27	<0.01	0.27	86.1	0.17	0.65	163	158	44	>2419	>2419	>2419	
BASIN 5 INLET	2020/03/04	405	119	748	330	6.7	<3	<0.1	<0.05	<0.1	37.0	0.33	18	238	148	211	>2419	>2419	>2419	>1000
BASIN 5 INLET	2020/05/26	51	36.2	190	36	7.3	<3	0.5	0.05	0.6	18	0.11	0.1	61	35	13	>2419	>2419	>2419	>1000
BASIN 5 OUTLET	2020/05/26	57	33.1	180	4	7.4	<3	1.4	<0,05	1.4	24.8	0.15	0.2	58	31	21	>2419	>2419	>2419	>1000
BASIN 5 OUTLET	2018/08/22	81	40	277	4.1	7.52					39.4	0.18		65.3	39.8	6.2	24	24	>2419	
BASIN 6 Mixed Inflow	2018/08/22	28	86.5	590	1.1	7.47					83.2	0.88		132	88.9	4.9	517	517	>2419	
BASIN 6 Mixed Inflow	2019/10/09	56	80	512	0.7	7.2	<3	6.2	0.61	6.81	45.6	0.14	<0.11	127	108	12	>2419	>2419	>2419	
BASIN 6 NW INLET	2019/05/09	17	81	418	2.1	6.4	<3	4.43	0.36	4.79	72	0.1	2.34	103	114	8.7	>2419	>2419	>2419	
BASIN 6 NW INLET	2020/03/03	50	75.8	536	1.5	6.9	<3	7.7	0.6	8.2	65	0.09	<0.1	120	87	14	>2419	>2419	>2419	>1000
BASIN 6 NW INLET	26/05/2020	101	26.1	142	46	7.2	<3	0.2	<0,05	0.2	17.7	0.08	1.7	36	21	22	>2419	>2419	>2419	>1000
BASIN 6 NE INLET	2019/05/09	24	101	614	0.5	6.9	<3	7.53	<0.01	7.53	96	0.19	0.11	130	162	9.8	13	1120	13	
BASIN 6 NE INLET	2019/10/07	49	77	478	1.3	7.1	<3	5.58	0.47	6.05	44.5	0.25	0.53	127	102	11	>2419	>2419	>2419	
BASIN 6 NE INLET	2020/03/03	36	75.8	472	1.6	7	<3	7.7	0.5	8.2	65	0.09	<0.1	119	87	15	>2419	>2419	>2419	>1000
BASIN 6 NE INLET	26/05/2020	72	90.9	494	0.6	7.2	<3	14	0.2	15	74.7	0.11	0.1	122	101	22	1986	>2419	1986	>1000
BASIN 6 OUTLET	2018/08/22	33	79.5	583	0.46	7.45					81	0.83		118	86.6	1.1	135	>2419	135	
BASIN 6 OUTLET	2019/05/09	20	84	510	0.9	7.1	<3	3.27	<0.01	3.26	76.3	0.17	0.12	114	126	8.8	816	>2419	816	
BASIN 6 OUTLET	2019/10/07	40	68	442	0.7	6.9	<3	<0.04	<0.01	<0.04	36	0.16	0.43	122	86	11	219	>2419	219	
BASIN 6 OUTLET	2020/03/03	41	87.4	450	0.4	6.8	<3	2.9	<0.05	2.9	74.3	0.12	0.1	129	114	15	435	>2419	435	>1000
BASIN 6 OUTLET	26/05/2020	89	36.7	198	13	7.3	<3	2.3	0.1	2.4	28.8	0.09	1	49	34	30	>2419	>2419	>2419	>1000
BASIN 9 INLET	2018/08/22	37	123	853	20.3	6.85					105	0.36		213	117	16.5	>2419	>2419	>2419	
BASIN 9 INLET	2019/05/09	14	99	644	30	6.7	<3	0.08	<0.01	0.08	66	0.2	0.13	129	139	21	>2419	>2419	>2419	
BASIN 9 INLET	2019/10/07	39	104	744	20	6	<3	<0.04	<0.01	<0.04	46.9	0.16	<0.11	202	141	37	>2419	>2419	>2419	
BASIN 9 INLET	2020/03/03	23	98.3	638	8.7	6.9	<3	0.1	<0.05	0.2	75.5	0.86	1.1	132	121	18	>2419	>2419	>2419	>1000
BASIN 9 INLET	2020/05/26	41	90.3	522	39	7.1	<3	1.3	1.5	2.8	72.8	0.13	0.4	150	96	54	>2419	>2419	>2419	>1000
BASIN 9 OUTLET	2018/08/22	33	64	444	3.7	6.96					48.8	<0.10		99.9	65.5	3.1	73	>2419	73	
BASIN 9 OUTLET	2019/05/09	18	83	474	21	6.7	<3	0.14	<0.01	0.14	73.7	0.16	0.17	107	125	9.5	613	>2419	613	
BASIN 9 OUTLET	2019/10/07	39	66	440	2.9	6.6	<3	<0.04	<0.01	<0.04	28	0.19	0.31	118	84	11	2419	>2419	2419	
BASIN 9 OUTLET	2020/03/03	18	79.3	456	2.7	6.9	<3	0.1	<0.05	0.1	78.3	0.11	<0.1	134	102	12	15	>2419	15	>1000
BASIN 9 OUTLET	2020/05/26	21	46.8	270	2.4	7.2	<3	0.2	<0,05	0.2	42	0.13	<0,1	72	48	13	980	>2419	980	>1000
BASIN 10 INLET	2018/08/22	62	215	1568	259	7.23					94.9	1.9		448	249	17.4	>2419	>2419	>2419	
BASIN 10 INLET	2019/05/09	40	230	1254	285	6.8	<3	64.5	0.03	0.1	45.9	0.9	94	214	207	342	>2419	>2419	>2419	
BASIN 10 INLET	2019/10/03	83	216	1290	32	7.2	<3	<0.04	<0.01	<0.04	127	0.16	1.52	522	316	24	113	>2419	113	
BASIN 10 INLET	2020/03/04	109	351	1794	351	7	<3	<0.1	<0.05	<0.1	44	0.19	43	738	560	88	>2419	>2419	>2419	>1000
BASIN 10 INLET	2020/05/26	92	215	1068	26	7.2	<3	<0,1	<0,05	<0,1	79	0.14	35	378	256	70	80	>2419	>2419	>1000
BASIN 10 OUTLET	2019/05/09	57	300	1538	138	7	<3	2.27	<0.01	<0.04	25.3	0.24	69	439	171	122	>2419	>2419	>2419	
BASIN 10 OUTLET	2019/10/03	80	210	1258	199	7.3	<3	2.12	<0.01	2.12	101	0.15	1.49	515	402	21	57	>2419	57	
BASIN 10 OUTLET	2020/03/04	117	344	1724	59	7.2	<3	0.1	<0.05	0.1	58.3	0.18	51	724	539	51	727	>2419	727	>1000
BASIN 10 OUTLET	2020/05/26	127	267	1340	34	7.2	<3	<0,1	<0,05	<0,1	77.8	0.15	46	494	332	72	>2419	>2419	80	>1000
BASIN 11 INLET SOUTH	2018/08/22	10	81	569	1.7	8.18					70.3	0.89		100	59.5	2.9	17	980	17	
BASIN 11 INLET SOUTH	2018/09/18																>2419	>2419	>2419	
BASIN 11 INLET SOUTH	2019/05/09	14	40	256	10	7.2	<3	0.97	0.03	0.57	36	0.65	0.47	41	48	6.5	461	>2419	461	
BASIN 11 INLET SOUTH	2020/03/04	33	170	844	134	7.6	<3	0.4	<0.05	0.4	97.4	0.93	0.3	322	234	17	326	>2419	326	>1000
BASIN 11 INLET SOUTH	26/05/2020	32	19.4	105	79	7.5	<3	0.1	<0,05	0.1	8.72	0.1	1	29	15.5	29	>2419	>2419	>2419	>1000
BASIN 11 INLET SOUTH	26/05/2020	30	47.5	246	21	7.6	<3	0.9	0.1	1	17	0.17	0.4	97	61	13	>2419	>2419	>2419	>1000
BASIN 11 INLET NE	26/05/2020	7	61.9	310	43	7.3	<3	0.8	<0,05	0.8	27.8	0.05	0.4	130	80	13	>2419	>2419	>2419	>1000
SILWERSTROOM WEIR	2019/05/09	10	82	486	1.2	7.9	<3	9.41	<0.01	0.22	55.1	0.19	0.27	160	109	5.4	1733	>2419	1733	
SILWERSTROOM WEIR	2019/10/04	23	73	484	0.5	7.4	<3	1.25	<0.01	1.25	49.4	0.12	<0.11	150	104	5.9	91	>2419	91	
SILWERSTROOM WEIR	2020/02/27	<1	87.7	444	0.5	7.0	<3	0.1	<0.05	0.1	53.0	0.12	<0.1	154	93	7.7	64	>2419	64	

Appendix B.3: Excerpt of Water Quality Data from the Cape Flats Aquifer

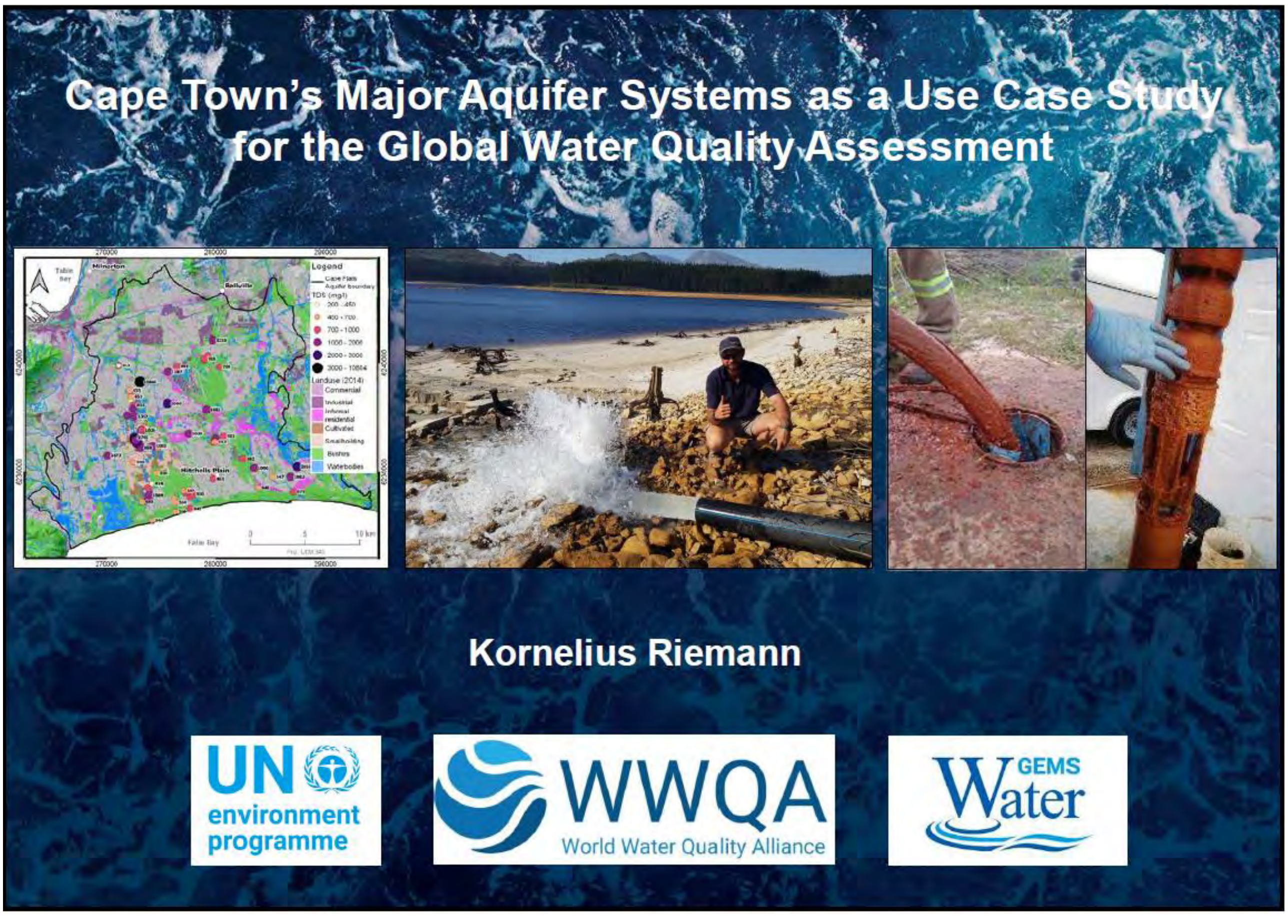
Physical and Aesthetic Determinants						Macro-determinants (in mg/l)									Organics	Total Metals (in µg/l)			Microbiological Determinants		
Borehole Name	Colour	Electrical Conductivity at 25°C (mS/m)	Total Dissolved Solids at 180°C (mg/l)	Turbidity (NTU)	pH at 25°C	Mono-chlor-amine	Nitrate	Nitrite	Nitrate + Nitrite	Sulphate	Fluoride	Ammonia	Chloride	Sodium	Total Organic Carbon	Total Aluminium	Total Iron	Total Manganese	E. coli	Total Coliforms	Faecal Coliforms
	mg Pt-Co/ℓ	mS/m	mg/ℓ	NTU	pH units	mg/ℓ	mg N/ℓ	mg N/ℓ	mg N/ℓ	mg SO_4/ℓ	mg F/ℓ	mg N/ℓ	mg Cl/ℓ	mg Na/ℓ	mg C/ℓ	µg Al/ℓ	µg Fe/ℓ	µg Mn/ℓ	(count per 100 ml)		
EM-18	6	69	428	130	7.5	<3	1.1	0.05	1.15	6.52	0.52	1.07	42	25	5.5	82	27347	11.1	1	11	1
EM-18	10	73	458	432	7.1	<3	0.28	0.02	0.3	18.3	0.45	1.15	64	32	7.7	35	65379	15.7	<1	326	<1
EM-18	24	81.7	436	98	7.6	<3	0.33	<0,01	0.33	23.2	0.54	1.35	71	39	7.3	21	13800	6.606	<1	36	<1
EM-19	<1	88	584	855	7.6	<3	9.04	0.15	9.18	101	0.5	<0.11	78	59	6.3	68	2309	7.4	<1	517	<1
EM-19	23	92	576	>1000	7	<3	10.9	<0.01	10.9	93.3	0.41	0.28	76	58	18	914	663269	84	<1	1986	<1
EM-19	<1	69.8	348	854	7.8	<3	1.93	<0,01	1.93	73	0.56	<0,11	62	42	3.3	108	76740	10.45	<1	36	<1
MON-09	1	78	510	18	7.2	<3	9.47	0.1	9.57	39.3	0.18	0.67	46	29	1.5	241	1261	8.2	<1	127	<1
MON-09	<1	81	498	5.4	7.6	<3	11.6	<0.01	11.6	39	0.2	0.1	43	28	<1.0	52	753	6.15	<1	>2419	<1
MON-09	<1	84.4	526	1.4	6.8	<3	11.3	<0.01	11.3	39.6	0.87	<0.11	47	31	1	160	407	5.44	<1	165	<1
MON-09	<1	85.7	480	3.9	7.4	<3	9.74	<0,01	9.74	37.6	0.26	<0,11	47	29	1.1	52	275	3.91	<1	31	<1
MON-09																			<1	5	<1
MON-10	<1	103	616	1.3	6.7	<3	8.44	<0.01	8.44	65.8	0.3	0.25	128	95	3.4	114	548	41	<1	613	<1
MON-10	<1	94.8	470	2.3	7.6	<3	6.84	<0,01	6.84	60	0.34	<0,11	100	88	3.8	34	200	48	<1	20	<1
MON-11	<1	97	644	6.9	7.3	<3	1.73	0.04	1.77	123	0.32	<0.11	54	53	2.1	49	881	18.8	<1	7	<1
MON-11	<1	96	588	4.5	6.9	<3	4.04	0.11	4.14	123	0.24	0.2	54	57	<1.0	68	3198	18.4	<1	816	<1
MON-11	<1	99.7	574	35	7.6	<3	3.82	0.07	3.9	127	0.28	<0,11	53	50	3.4	38	7417	16.13	<1	67	<1
EM-14	6	158	942	253	7.4	<3	0.65	0.94	1.79	9.83	0.32	<0.11	679	170	12	446	6268	69	<1	11	<1
EM-14	<1	169	926	127	6.8	<3	<0.04	<0.01	<0.04	0.21	0.33	0.87	276	178	3	44	8092	75	<1	22	<1
EM-14																			<1	11	<1
EM-15	35	121	728	5.8	7.4	<3	12.4	<0.01	12.4	103	0.36	1.48	101	42	11	18.7	885	11.4	<1	26	<1
EM-15	23	82.8	420	0.5	6.9	<3	3.27	0.25	3.52	35.8	0.46	17.4	28	23	7	48	366	12.8	<1	45	<1
EM-15																			<1	816	<1
EM-22	<1	65	434	8.8	7.9	<3	<0.04	<0.01	<0.04	116	0.31	0.2	129	46	1.6	107	301	2.77	<1	11	<1
EM-22	<1	170	900	10	6.8	<3	<0.04	<0.01	<0.04	52.7	1.19	<0.11	314	219	1.7	37	1246	9.6	<1	35	<1
EM-22																			<1	135	<1
EM-29	<1	69	428	2.6	7.7	<3	12.8	<0.01	12.8	36.3	0.14	<0.11	46	28	2	49	237	4.41	<1	3	<1
EM-29	1	71	464	1.2	8	<3	14.5	<0.01	14.5	84.4	0.34	<0.11	135	46	1.9	25	41	1.54	<1	13	<1
EM-29	<1	71	450	1.6	7.1	<3	14.8	<0.01	14.8	40.4	0.14	0.2	50	29	1.5	17	214	4.82	<1	1733	<1
EM-29	<1	73.2	460	1.9	6.9	<3	13	<0.01	13	38.6	0.66	<0.11	51	32	1.4	29	201	4.69	<1	46	<1
EM-29	<1	76	430	1	7.8	<3	17.7	<0,01	17.7	37.8	0.14	<0,11	55	33	2.1	132	930	2.302	<1	2	<1
EM-29																			<1	78	<1
EM-34	7	391	2364	77	7.3	<3	0.2	<0.01	0.2	626	0.15	<0.11	2779	1005	6.9	29	4009	44	<1	4	<1
EM-34	10	413	2510	59	6.7	<3	<0.04	<0.01	<0.04	242	0.29	<0.11	978	608	5	61	4175	42	<1	31	<1
EM-34																			<1	11	<1
P-01	6	137	838	41	7.8	<3	0.51	<0.01	0.5	103	0.28	14.9	102	87	9.7	21	3623	35	<1	2	<1
P-03	<1	95	574	13	7.3	<3	0.11	<0.01	0.1	19.5	0.19	5.47	104	66	5.1	30	2050	10.5	<1	3	<1
P-04	19	84	568	17	7.2	<3	4.36	0.01	4.37	38.8	0.12	0.54	122	65	2.3	47	1809	12.9	<1	11	<1
P-07	1	96	588	25	7.1	<3	<0.04	<0.01	<0.04	5.66	0.25	2.06	105	75	2.6	39	2367	21	<1	2	<1
P-07																					
P-07	11	92	604	26	7.2	<3	0.52	<0.01	0.52	5.48	0.18	2.12	110	74	2.8	21	2436	22	<1	172	<1
P-08	<1	96	608	21	7.4	<3	0.16	<0.01	0.15	39.7	0.19	3.63	105	65	4.7	25	2922	14.4	<1	72	<1
P-08	42	101	608	45	7.1	<3	<0.04	<0.01	<0.04	96.1	0.11	5.32	94	64	4.5	17.4	4406	9.95	<1	248	<1
P-09	25	349	2982	0.6	7.3	<3	168	0.04	168	615	0.11	<0.11	114	82	36	33	269	24	<1	166	<1
P-10	4	183	1226	0.5	6.9	<3	40.7	<0.01	40.7	276	0.13	7.8	98	82	28	35	154	9.72	<1	<1	<1
P-10	14	162	1046	3.8	6.9	<3	29.7	<0.01	29.7	225	0.19	4.5	92	63	3.2	35	161	12.2	<1	980	<1
PIEZO-01-Deep	28	182	1264	10	7	<3	58	<0.01	57	177	0.21	8.9	94	81	8.4	75	2163	34	21	55	21
PIEZO-01-Deep																			<1	10	<1
S-08	<1	108	680	9	7	<3	5.63	<0.01	5.58	13.9	0.13	0.16	160	117	2.4	124	4067	73	<1	4	<1
S-08	6	91.4	572	7.6	6.8	<3	0.11	<0.01	0.11	38.9	0.22	0.19	88	59	2.8	214	370	51	<1	67	<1
S-08																			<1	3	<1

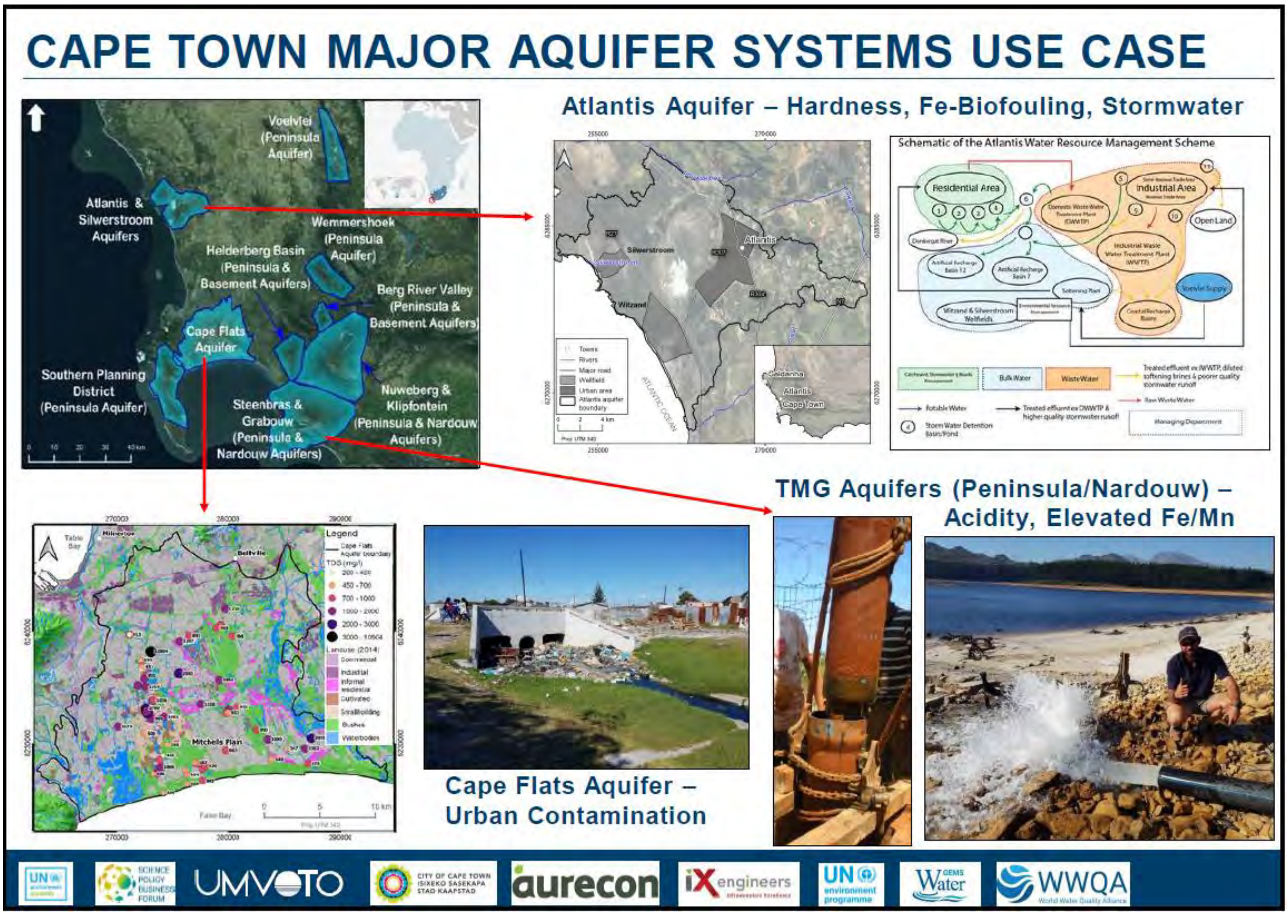
Appendix B.4: Excerpt of Water Quality Data from the Table Mountain Group Aquifer

Chemical Constituent	H8A1										
	2010-06-10	2010-06-22	2011-04-18	2011-10-03	2012-04-16	2012-10-01	2013-04-25	2013-11-04	2014-04-23	2017-04-13	2018-10-25
Field Parameters											
Water Temperature (°C)	-	-	21.50	-	18.50	15.90	19.80	20.60	16.40	-	
Air Temperature (°C)	-	-		-	-	-	-	-	-	-	
pH	-	-	6.02	-	6.31	7.10	8.61	7.28	5.91	-	
Conductivitiy (mS/m)	-	-	8.68	-	12.15	11.92	9.00	6.82	7.12	-	
Total Dissolved Solids (TDS)											
Salinity (ppm)											
ORP (mV)	-	-	16.00	-	29.00	-18.00	-	-	-	-	
Dissolved Oxygen (mg/L)											
Laboratory Parameters											
pH	6.75	6.60	6.10	6.60	6.31	7.10	8.61	7.28	5.84	7.10	6.09
Conductivitiy (mS/m)	17.35	5.32	7.00	6.00	12.15	11.92	9.00	6.82	13.63	2.00	13.00
Turbidity (NTU)	-	-	-	-	-	-	-	-	-	-	5.70
Colour (Pt/Co)	-	-	-	-	-	-	-	-	-	-	175.00
ORP (mV)	14.00	-	-	-	-	-	-	-	-	-	61.00
Dissolved Oxygen (mg/L)											2.40
Macrochemistry (mg/L)											
Total Dissolved Solids (TDS)	-	-	-	-	-	-	-	-	-	102.00	120.00
Total Alkalinity	-	30.12	6.00	7.80	9.00	7.00	7.00	3.00	8.50	24.00	37.90
Total Hardness	-	-	-	-	-	-	-	-	-	22.00	15.00
Bicarbonate	-	-	-	-	-	-	-	-	-	24.00	46.20
Calcium	-	2.60	0.50	1.10	1.20	1.20	0.80	1.00	0.40	6.70	2.90
Magnesium	-	0.50	1.10	1.00	1.10	0.70	0.20	0.30	0.40	1.30	1.90
Sodium	-	9.63	13.20		9.00	6.00	10.00	5.40	9.80	10.00	6.70
Potassium	-	0.59	-	9.10	-	-	1.80	0.30	1.00	0.90	0.67
Chloride	-	17.62	16.40	13.40	15.00	10.00	16.00	13.00	15.00	36.00	13.70
Fluoride	-	-	-	-	-	-	-	-	-	0.18	0.30
Bromide	-	-	-	-	-	-	1.00	-	-	-	0.32
Sulphate	-	5.40	4.10	1.30	2.50	1.10	0.01	0.40	0.90	5.66	<0,1
Orthophosphate	-	-	0.02	0.00	0.18	0.04	0.14		0.09	0.02	0.29
Ammonia	-	12.10	0.01	0.06	0.15	0.02	0.00	0.09	0.07	0.59	<0,1
Ammonium											
Nitrate	-	3.66	0.01	0.12	0.01	-	-	0.02	-	0.05	
Nitrite	-	-	-	-	-	-	-	-	-	0.05	
Inorganic Nitrogen	-	-	-	-	-	-	-	-	-	-	1.00
Nitrite-N											<0,2
Nitrate-N											<0,2
Ammonia - N											<0,1
Ammonium - N											
Orthophosphate - P											0.29
Orthosilicate	-	-	-	-	-	-	-	-	-	-	
DOC	-	-	-	-	-	-	-	-	-	2.00	1.30
TOC	-	-	-	-	-	-	-	-	-		1.70
COD	-	-	-	-	-	-	-	-	-	16.00	11.60
BOD											
Silica	-	-	-	-	-	-	-	-	-	-	3.33
Total Iron	-	0.77	0.43	0.31	0.98	1.50	3.10	2.40	0.20	2.47	12.68
Total Manganese	-	0.04	0.16	0.30	0.23	0.07	0.07	0.32	0.07	0.70	0.56

Chemical Constituent	H8A3										
	2010-06-10	2010-06-22	2011-04-18	2011-10-03	2012-04-16	2012-10-01	2013-04-25	2013-11-04	2014-04-23	2017-04-13	2018-03-19
Field Parameters											
Water Temperature (°C)	-	-	20.30	-	18.00	14.80	20.90	18.70	17.10	-	-
Air Temperature (°C)	-	-	-	-	-	-	-	-	-	-	-
pH	-	-	5.70	-	5.71	6.94	6.70	7.01	5.84	-	-
Conductivitiy (mS/m)	-	-	8.79	-	7.89	24.20	22.10	16.69	13.63	-	-
Total Dissolved Solids (TDS)											
Salinity (ppm)											
ORP (mV)	-	-	32.00	-	62.00	-9.00	-	-	-	-	-
Dissolved Oxygen (mg/L)											
Laboratory Parameters											
pH	7.22	6.80	6.60	6.70	5.71	6.94	6.70	7.01	5.91	6.40	6.32
Conductivitiy (mS/m)	23.20	13.43	9.00	10.00	7.89	24.20	22.10	16.69	7.12	11.00	11.50
Turbidity (NTU)	-	-	-	-	-	-	-	-	-	-	-
Colour (Pt/Co)	-	-	-	-	-	-	-	-	-	-	-
ORP (mV)	-	-	-	-	-	-	-	-	-	-	-
Dissolved Oxygen (mg/L)											
Macrochemistry (mg/L)											
Total Dissolved Solids (TDS)	-	-	-	-	-	-	-	-	-	104.00	100.00
Total Alkalinity	-	53.21	16.00	21.00	11.00	29.00	23.00	23.00	24.00	15.00	-
Total Hardness	-	-	-	-	-	-	-	-	-	13.00	-
Bicarbonate	-	-	-	-	-	-	-	-	-	15.00	-
Calcium	-	7.41	2.20	3.60	2.40	3.30	3.40	3.00	3.30	3.00	1.36
Magnesium	-	0.97	0.80	0.90	0.70	1.10	1.20	0.90	1.10	1.30	1.38
Sodium	-	12.53	15.90	2.10	8.00	11.00	11.00	10.00	11.00	9.50	9.72
Potassium	-	4.45		14.10	2.00		1.40	1.30	1.20	0.70	0.47
Chloride	-	20.27	17.70	17.20	14.00	17.00	15.00	15.00	17.00	17.00	17.40
Fluoride	-	-	-	-	-	-	-	-	-	0.11	0.07
Bromide	-	-	-	-	-	-	-	-	-	-	-
Sulphate	-	3.30	2.00	0.70	3.70	1.60	1.90	0.90	12.00	17.70	8.17
Orthophosphate	-		0.00	0.00	0.00	0.01	0.00		0.02	0.02	0.01
Ammonia	-	12.22	0.18	0.19	0.01	0.10	0.14	0.11	0.15	0.11	-
Ammonium											
Nitrate	-	2.60	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.05	<0.13
Nitrite	-	-	-	-	-	-	-	-	-	0.05	<0.001
Inorganic Nitrogen	-	-	-	-	-	-	-	-	-	-	-
Nitrite-N											
Nitrate-N											
Ammonia - N											
Ammonium - N											
Orthophosphate - P											
Orthosilicate	-	-	-	-	-	-	-	-	-	-	-
DOC	-	-	-	-	-	-	-	-	-	2.20	-
TOC	-	-	-	-	-	-	-	-	-	-	-
COD	-	-	-	-	-	-	-	-	-	56.00	18.00
BOD											
Silica	-	-	-	-	-	-	-	-	-	-	-
Total Iron	-	21.32	0.12	2.36	0.51	2.40	0.96	6.60	8.00	5.27	0.02
Total Manganese	-	0.93	0.05	0.41	0.03	0.41	1.10	0.35	0.17	0.26	<0.0003

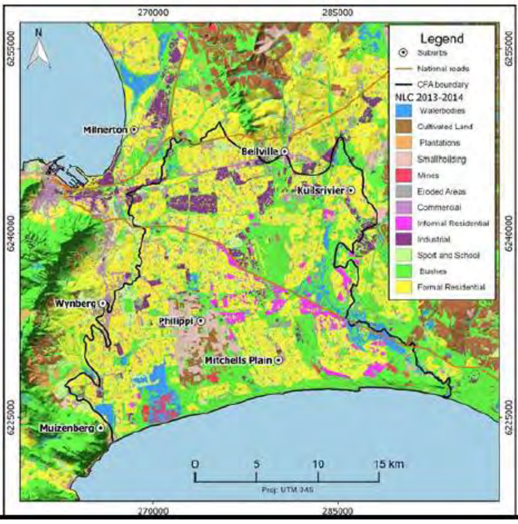
Appendix C – Presentation at WWQA 2nd Global Meeting

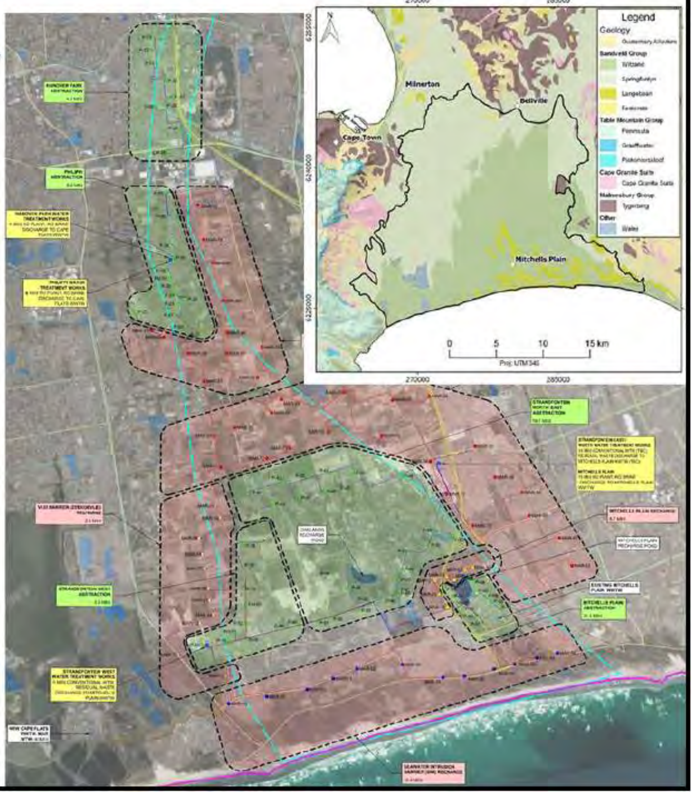

Cape Town's Major Aquifer Systems as a Use Case Study for the Global Water Quality Assessment
Kornelius Riemann
UN environment programme
WWQA
World Water Quality Alliance
GEMS Water


CAPE TOWN MAJOR AQUIFER SYSTEMS USE CASE
Atlantis Aquifer – Hardness, Fe-Biofouling, Stormwater
Voelvlei (Peninsula Aquifer)
Atlantis & Silwerstroom Aquifers
Wemmershoek (Peninsula Aquifer)
Helderberg Basin (Peninsula & Basement Aquifers)
Berg River Valley (Peninsula & Basement Aquifers)
Cape Flats Aquifer
Southern Planning District (Peninsula Aquifer)
Steenbras & Grabouw (Peninsula & Nardouw Aquifers)
Nuweberg & Klipfontein (Peninsula & Nardouw Aquifers)
Schematic of the Atlantis Water Resource Management Scheme
TMG Aquifers (Peninsula/Nardouw) – Acidity, Elevated Fe/Mn
Cape Flats Aquifer – Urban Contamination
UMVOTO
aurecon
iX engineers
WWQA

CAPE FLATS AQUIFER – CONTEXTUALISATION

- Sedimentary aquifer in urban setting, prone to pollution
- Intensively used for irrigation in agricultural area
- Groundwater scheme development by City of Cape Town



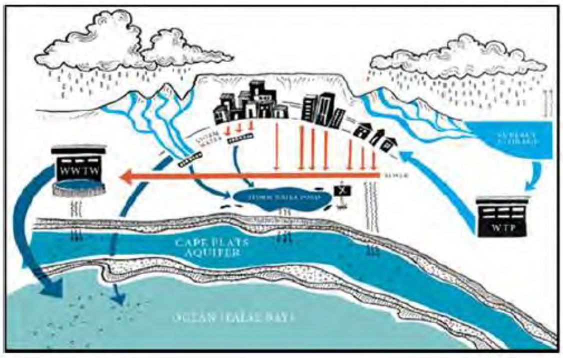


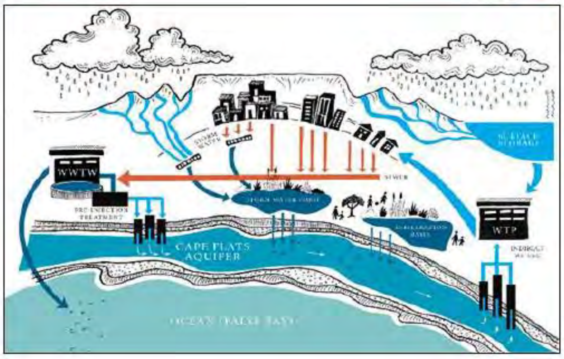
CAPE FLATS AQUIFER – STAKEHOLDERS

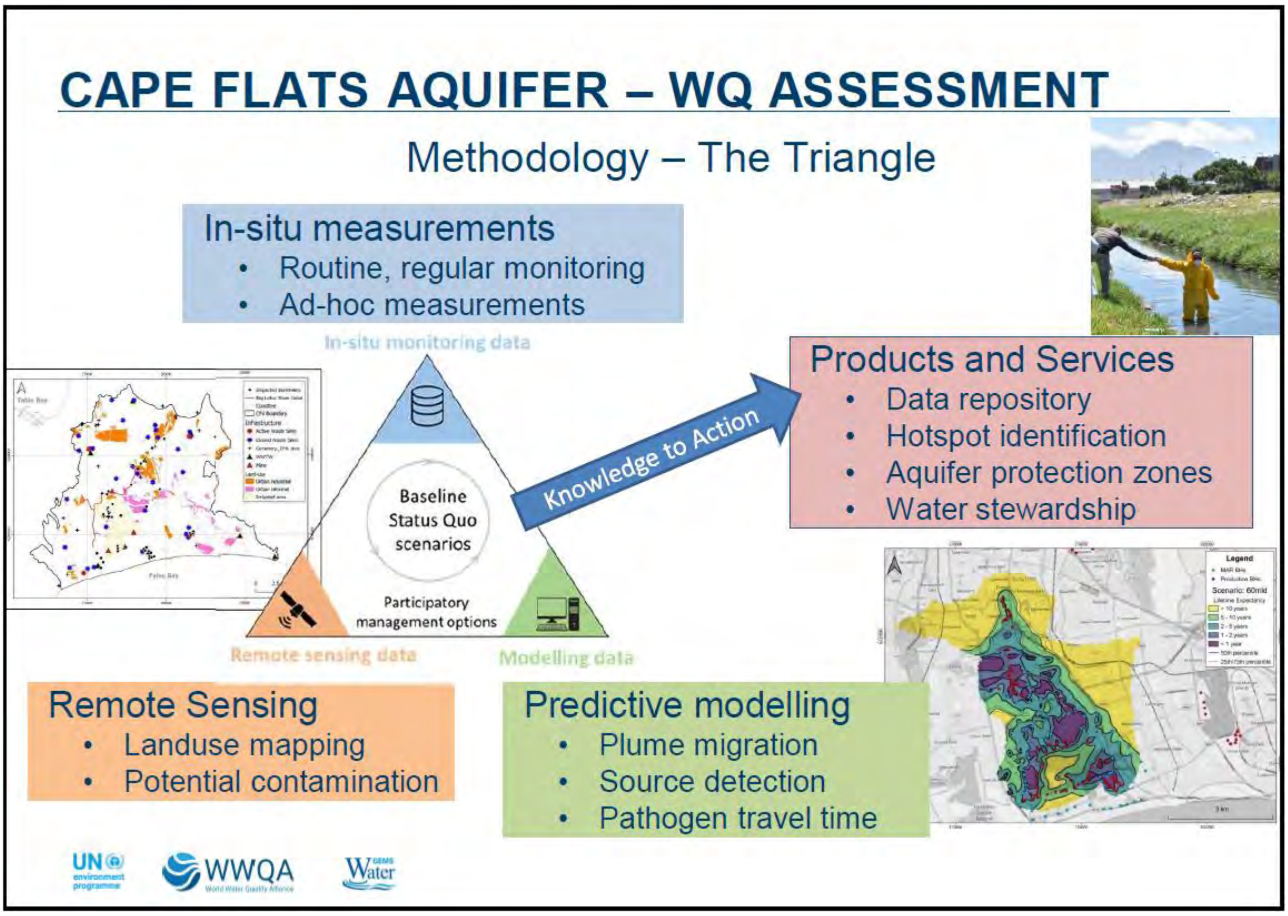
Engagement Process

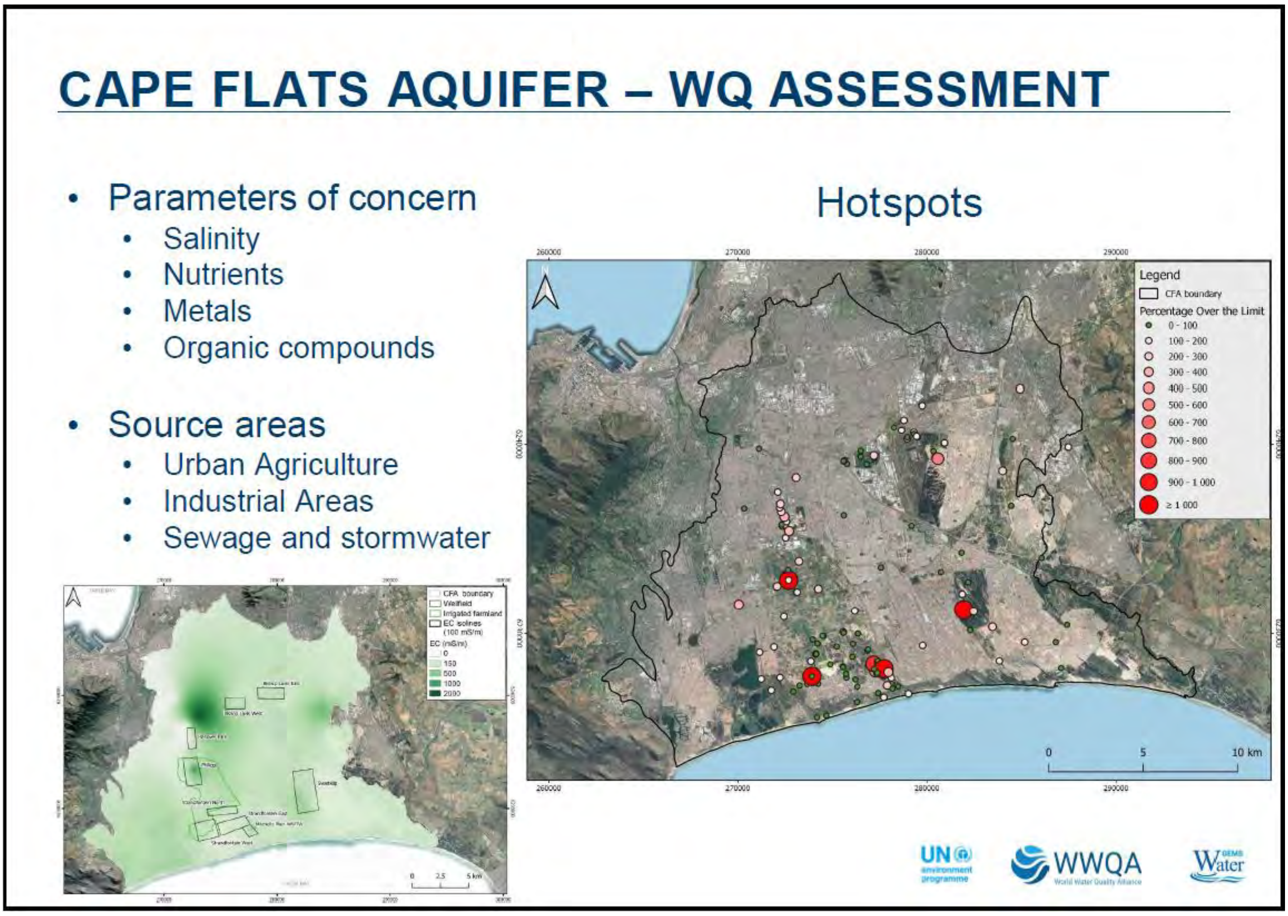
- Formal
  - City of Cape Town officials (regularly)
  - Project engineers (monthly)
  - Environmental Monitoring Committee (bi-annual)
- Other Stakeholders
  - Farmers Forum
  - Landowners
- Communities
  - Informal while on site
  - Stewardship Initiative

Vision: Water Sensitive City by 2040





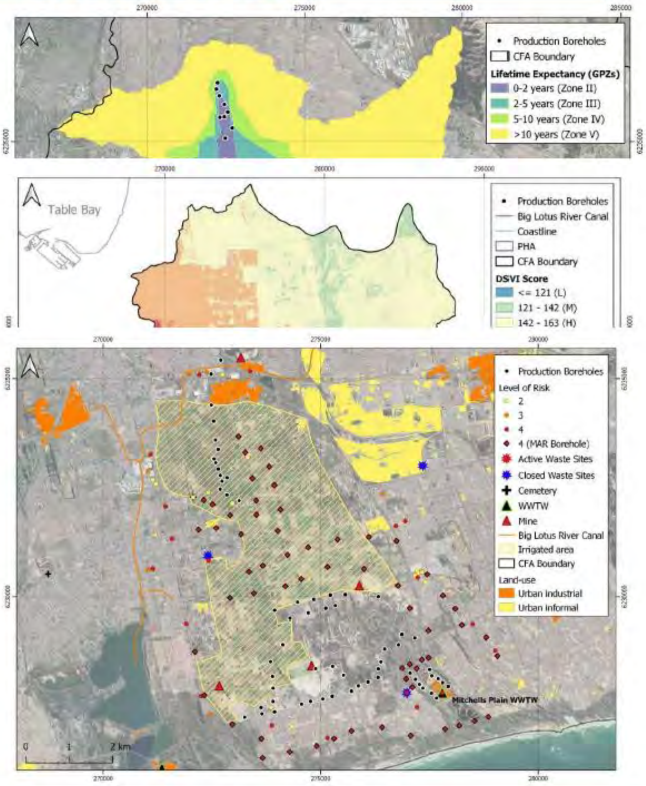

CAPE FLATS AQUIFER – WQ ASSESSMENT
Methodology – The Triangle
In-situ measurements
• Routine, regular monitoring
• Ad-hoc measurements
In-situ monitoring data
Baseline
Status Quo
scenarios
Participatory
management options
Knowledge to Action
Remote sensing data
Modelling data
Products and Services
• Data repository
• Hotspot identification
• Aquifer protection zones
• Water stewardship
Remote Sensing
• Landuse mapping
• Potential contamination
Predictive modelling
• Plume migration
• Source detection
• Pathogen travel time


CAPE FLATS AQUIFER – WQ ASSESSMENT
• Parameters of concern
• Salinity
• Nutrients
• Metals
• Organic compounds
• Source areas
• Urban Agriculture
• Industrial Areas
• Sewage and stormwater
Hotspots
Legend
CFA boundary
Percentage Over the Limit
0 - 100
100 - 200
200 - 300
300 - 400
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1 000
≥ 1 000
0
5
10 km
260000
270000
280000
290000

CAPE FLATS AQUIFER – PRODUCTS

Aquifer Protection Scheme

- Capture Zones
  - 50-day, 100-day, 1-year travel
- Groundwater Protection Zones
  - Zone I to V, based on traveltime
- Vulnerability mapping
  - Highly vulnerable to pollution
- Potentially contaminating areas
  - Agriculture, industry, sewage, stormwater, cemeteries
- Risk assessment
  - Source – pathway - receptor
- Rehabilitation plans
  - Site-specific



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CAPE FLATS AQUIFER – PRODUCTS

Water Stewardship

- Critical Zone Observatory
- Transformative Art
- Stewardship Workshop

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CAPE FLATS AQUIFER – WAY FORWARD

Success factors

- Integration of the triangle
  - System understanding
  - Team interactions
- Social engagement process
  - Established formal platform
  - Wide range of stakeholders
  - Community involvement
  - Quadruple/Quintuple Helix
- Detailed, recent in-situ data
  - Historical data sets
  - Current investigation by City
  - Current monitoring programmes

Next Steps

- Expansion of scope
  - Including surface & stormwater
  - Additional parameters
  - Implementation of GPZs
- Lotus Canal Challenge
  - Rehabilitation plan for degraded stormwater system
  - Water Stewardship & Transformative Art
- Roll-out to other urban centres
  - Testing approach in different settings (e.g. environment, water resources, culture, governance, data availability)

THANK YOU