PAPER 8

Planning and Implementing Large-Scale Groundwater Supply Schemes

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ABSTRACT

The TMG Aquifer has been under consideration as a potential water supply option for the Cape Town metropolitan area since the early 1990s. Subsequent to a comprehensive water resource planning study for Cape Town and the surrounding metropolitan areas, the TMG Aquifer was studied at feasibility level by the City of Cape Town (CCT) from 2001 to 2013 during the TMG Aquifer Feasibility Study and Pilot Project. This study focussed on determining the potential yield from three main groundwater target areas (namely Theewaterskloof (Nuweberg/Eikenhof), Wemmershoek and Kogelberg-Steenbras). From 2013 onwards, the study continued in the form of an extended Exploratory Phase to also investigate the potential yield from the Groenlandberg/Klipfontein area near Theewaterskloof Dam and to undertake yield tests in the three previously identified main target areas.

When a severe drought occurred in 2017, a National Disaster was declared and the CCT initiated an emergency initiative, called the New Water Programme (NWP), to fast-track the implementation of alternative water supply schemes. The aim was to implement water supply initiatives which would contribute to the drought resilience of the City in future. One of these potential sources was the TMG Aquifer.

The project involves the development of boreholes in the TMG Aquifer in three geographic areas to augment the water supply to Cape Town as part of their water resilience strategy. It includes the drilling of production boreholes with depths greater than 800 m, the mechanical and electrical equipping thereof, as well as the pipelines required to connect to existing dams. The estimated yield from the three wellfields is 50 ML/d in total. The construction of the Steenbras Wellfield is well underway and will be commissioned by the time the paper is presented in November 2021.

The project provided valuable opportunities to test, model and adapt environmental protection measures and aquifer management principles, and some valuable insights were gained. The unusual circumstances of this project resulted in a situation where stakeholders, engineers, contractors and specialists were required to work together to achieve a successful outcome. The authors have endeavoured to provide a roadmap to other municipalities and water services authorities on how to successfully implement and ensure the ongoing sustainability of large-scale groundwater projects.

1. INTRODUCTION

The City of Cape Town (CCT) recently began implementing a large-scale groundwater scheme, namely the Table Mountain Group (TMG) Aquifer scheme. The first part of the scheme: the Steenbras Wellfield, is under construction and will be commissioned by November 2021.

The TMG Aquifer has been under consideration as a potential water supply option for the Cape Town metropolitan area since the early 1990s. Subsequent to a comprehensive water resource planning study for Cape Town and the surrounding metropolitan areas, the TMG Aquifer was studied at feasibility level by the City of Cape Town (CCT) from 2001 to 2013 during the TMG Aquifer Feasibility Study and Pilot Project. This study focussed on determining the potential yield from three main groundwater target areas (namely Theewaterskloof (Nuweberg/Eikenhof), Wemmershoek and Kogelberg-Steenbras).

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The project provided valuable opportunities to test, model and adapt environmental protection measures and aquifer management principles, and some useful insights were gained. This paper seeks to provide a roadmap for other Municipalities and Local Governments authorities on how to successfully implement and ensure the ongoing sustainability of large-scale groundwater projects. The steps provided below must be read against the backdrop of the severe drought faced by the CCT.

2. GETTING STARTED

A water supply scheme is developed to meet a demand for water. In the case of the TMG and the CCT, the TMG Aquifer was one of many potential future water supply schemes being investigated for implementation in the relatively 'far distant' future. The drought that took place in 2017 highlighted that the City was heavily dependent on surface water. In order to make Cape Town's water supply more resilient to the risk of drought, there was a need to bring schemes based on other water sources, such as groundwater, water reuse and desalination, into service as a matter of urgency. The City's NWP was created to make this happen, and one of the consequences was the decision to fast track the TMG Aquifer project as a drought response. Therefore the starting point for implementing the TMG Aquifer project was the drought and the need for non-surface water schemes.

The urgency created by the drought meant that there was insufficient time to go through the usual project development process, as illustrated in Figure 1. There was the need to undertake a number of tasks in parallel, while still moving the scheme forward in a responsible and sustainable manner.

2.1 A good foundation to start from

The CCT initiated the TMG Aquifer Feasibility Study and Pilot Project in 2001 and continued with this project essentially until 2017 when the drought required the fast-tracking thereof. This pro-active approach by

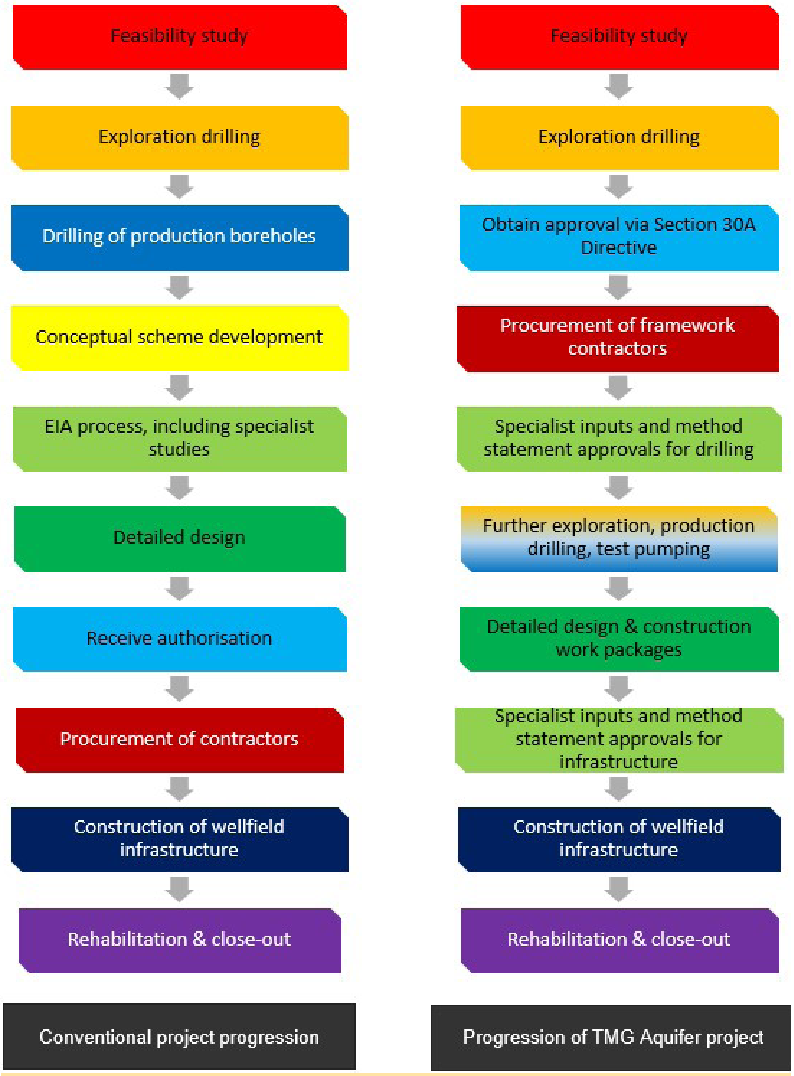

FIGURE 1: Conventional vs emergency project development process (Allpass D. & Larsen J. 2020)

the CCT to study the potential of the TMG Aquifer as a potential resource paid dividends in 2017 as potential areas for production wellfields have already been investigated. In addition, the CCT commenced with regional ecological and hydrogeological monitoring in 2006, resulting in more than 10 years' baseline monitoring data being available.

The lesson learnt was to start early with feasibility studies and investigations even when implementation is only expected to be required in the 'far distant' future. The knowledge gained from these studies and investigations is invaluable when quick decisions, linked with significant financial investment, are required in times of a crisis.

2.2 Wellfield selection

A total of eight target areas were considered for production wellfields, as shown in Table 1. First-order yield estimates were undertaken for each of these areas. Wellfields were then prioritised based on several criteria such as: expected yield per borehole (e.g. fewer high-yielding boreholes will reduce the footprint of the wellfield and be more economical), ease of integration into existing bulk water infrastructure, operational flexibility (e.g. the ability to supply multiple water treatment works), ease of operation (e.g. proximity to other infrastructure operated and maintained by the CCT to allow for potential sharing of resources and workshops), availability of power, landownership, time to implement and financial viability.

The Steenbras, Nuweberg and Groenlandberg wellfields were considered the highest priorities based on favourable hydrology and geology and their proximity to existing bulk water infrastructure. The locations of these wellfields are shown in Figure 2.

CCT elected to commence with the Steenbras wellfield, followed by Nuweberg. Nuweberg is essentially an extension to the Steenbras wellfield, as water gravitates from this wellfield towards the Steenbras pre-treatment plant before discharging into the Steenbras Upper Dam. The Groenlandberg wellfield will be developed in parallel with the Nuweberg wellfield.

2.3 Preparing to implement the project

Before construction could commence, a number of preparations had to be made, which are discussed under separate headings below.

Legislation: Environmental and Water Use Licence (WUL) approvals

The Premier of the Western Cape declared the City of Cape Town (CCT) and other areas in the Western Cape as a disaster area in terms of the Disaster Management Act (Act 57 of 2002) in May 2017 due to the severe drought. Certain legal steps were required in order to fast track the TMG Aquifer project, as described below (Wiese J et al. 2021):

- **Issuing of Section 30A Directives**

The first requirement was for the national and regional Environmental departments to issue Directives in terms of Section 30A of the National Environmental Management Act (NEMA) (Act 107 of 1998), as amended. This allowed the CCT to undertake listed activities without the need to undertake an Environmental Impact Assessment (EIA) process, thereby expediting the environmental processes to facilitate an emergency response with clearly defined checks and balances to protect the environment. The CCT applied to the Western Cape Department of Environmental Affairs and Development Planning (DEA&DP) and the National Department of Environment, Forestry and Fisheries (DEFF). These departments issued the Section 30A Directives in terms of NEMA. The conditions of the directives included, amongst others, the requirement for projects to be implemented in terms of an

TABLE 1: Yield estimates and priorities of potential TMG Aquifer production wellfields

Project/Aquifer	Initial (ML/d)	Ultimate (ML/d)	Priority (1 = highest)
Steenbras	33	144	1
Nuweberg	15	230	2
Groenlandberg	12		3
Wemmershoek	5.5	16	4
Berg River Valley	10	30	5
Voëlvlei	8	25	6
Helderberg Basin	10	30	7
Southern Planning District (SPD)	22	58	8

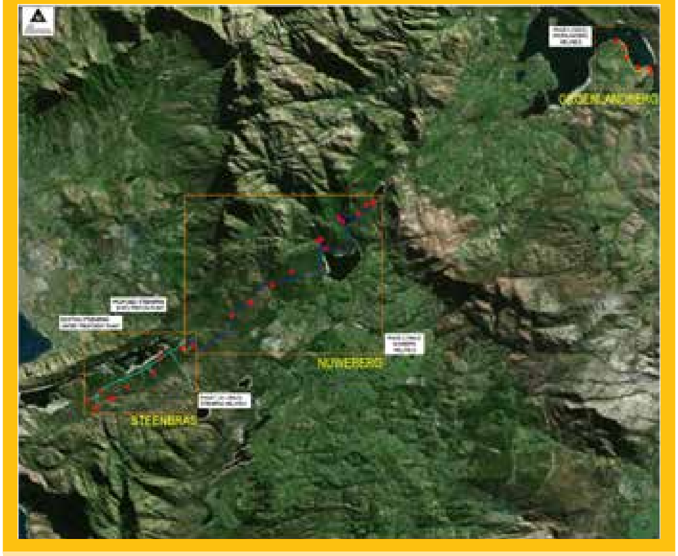

FIGURE 2: Location of the Steenbras, Nuweberg and Groenlandberg wellfields (Kleynhans et al. 2020)

approved generic Environmental Management Programme (EMPr), for approved Environmental Method Statements to be accepted by the DEA&DP or DEFF (depending on environmental competency) prior to commencement, and for regular progress reports and environmental audits to be submitted to the environmental authorities.

- **Water Use Licence in terms of the National Water Act (Act 36 of 1998) (NWA) from the Department of Water and Sanitation (DWS)**
  The DWS also expedited their Water Use Licencing process to support the CCT's groundwater development projects.

Section 21A Water Use License – abstraction

The CCT applied to secure an allocation in terms of Section 21 (a) ("taking of water") through a Water Use License Application for the Steenbras Wellfield and other proposed wellfields to abstract from the TMG Aquifer as part of the emergency response to the National Disaster declaration in 2017.

The Section 21(a) Water Use Licence was issued to the CCT on 21 December 2017 and authorised the abstraction of groundwater in three phases from the TMG Aquifer. The allocation will be reviewed after five years, thereby allowing abstraction from production boreholes up to a certain volume under emergency situations, but also ensuring that the CCT reassess the volumes required, based on monitoring data feedback during abstraction, for future long-term abstraction.

Section 21 (c) and (i) Water Use Licence – impacts on watercourses

Once exploration and production borehole drilling progressed to a point where a potential wellfield could be designed, the process of applying for the authorisation of Section 21(c) ("impeding or diverting the flow of water in a watercourse") and (i) ("altering the bed, banks, course or characteristics of a watercourse") water uses commenced in 2018. The authorisation process was preceded by workshops attended by environmental specialists who undertook sensitivity analyses of the proposed water pipeline and powerline routes, above- and below-ground water crossings and additional borehole drilling locations. This ensured that optimised solutions were presented for authorisation. A Water Use Licence was issued for Section 21(c) and (i) water uses, for the Steenbras Wellfield Project, on 23 July 2019.

FIGURE 3: Lxploratory core drilling at Steenbras
(photo credit: D Blake of Umvoto)

Stakeholder engagement

Since the abstraction of groundwater was fast-tracked as a result of the drought and national disaster declaration, stakeholder engagement was not done according to Regulation 41 of the 2014 EIA Regulations, as amended (i.e. undertaking a conventional EIA process). Stakeholder engagement on the TMG project commenced as early as March 2018 to pro-actively address concerns raised regarding the environmental impact of large-scale groundwater abstraction from the TMG Aquifer.

Stakeholder engagement included regular working groups, focus groups undertaking screening activities related to proposed infrastructure, monitoring committees focussing on WUL conditions and larger forums for sharing information from all the different projects under the NWP. Engagement also included one-on-one landowner consultations, meetings with Water User Associations, Biosphere Reserves and Municipalities and authority consultations. These consultations aided in collecting extensive local knowledge, identifying environmental sensitivities, awareness of the public's main concerns, sharing ideas, using different skills to undertake screening activities, promoting research topics and improving on-site monitoring and mitigation through information sharing.

An important outcome of the stakeholder engagement process was the refining and optimising of wellfield locations, e.g. the Steenbras wellfield was limited to the utility area, the T4 area was omitted from the Nuweberg wellfield and at the Groenlandberg wellfield, the G2 area was omitted.

Stakeholder engagement is also a critical part of compliance to the Water Use Licences issued to the CCT for the Steenbras Wellfield and other wellfields. Stakeholders have an opportunity to be appointed as members of the Environmental Monitoring Committee which is facilitated by the CCT on a six monthly basis. The aim of these meetings is to monitor compliance to water use license conditions, approve a monitoring protocol for the Steenbras Wellfield and propose additional conditions or mitigation measures, based on the outcome of monitoring data or operational feedback.

Exploration boreholes vs production boreholes

In an ideal situation, exploration drilling (see Figure 3) will be undertaken before commencing with production drilling. The drought, however, required exploration and production drilling to be undertaken at the same time.

Extensive field work and mapping was conducted by the groundwater specialists in order to site the boreholes. High yielding fractures were targeted, determined from extensive field mapping of fault structures. Aerial magnetic survey (airborne geophysics) was used to provide more information where afforestation obscured the ground level geological investigations.

FIGURE 4: The Steenbras Wellfield (Kleynhans et al. 2020)

Proposed borehole positions were screened on-site by the environmental specialists, refinements made, and mitigation measures agreed upon before finalising the positions of the exploration, monitoring and production boreholes.

Infrastructure design

Adaptive infrastructure designs were developed while awaiting borehole positions and yields. These designs were finalised once the borehole positions and yields were available, thus shortening the overall time required.

Procurement of contractors

An adaptive procurement strategy was required for drilling the boreholes and construction of the infrastructure. Groundwater projects typically follow a process whereby exploration and production boreholes are drilled, and firm borehole yields are determined. This is followed by the infrastructure design, based on confirmed borehole yields and an environmental approval process, whereafter construction commences. Due to the drought crisis, the drilling of exploration and production boreholes and the infrastructure design and construction all had to take place within the shortest possible timeframe.

In order to provide flexibility, yet abide by very tight timeframes, contractors were appointed on Framework Contracts, which allowed for the City to issue works projects as and when designs were finalised. The construction scope was handled under three Framework Contracts, i.e. drilling, civil works, and mechanical and electrical works. More than one contractor could be appointed per Framework Contract, which provided further flexibility to accelerate construction. This approach therefore ensured that construction could commence literally within a few weeks from completing the designs.

3. IMPLEMENTATION

The Steenbras wellfield (see Figure 4) comprises:

- 12 production boreholes drilled to depths of up to 1000 m and 17 monitoring boreholes
- 12 pumphouse structures housing the pumpsets, switchgear, ring main units and transformers
- 11 500 m of pipelines with diameters ranging from DN160 to DN560
- 14 300 m of medium voltage (MV) cables
- A pre-treatment works

The specific design selections made to meet the requirements detailed above are described in the sections below.

FIGURE 5: Production borehole drilling in progress showing sumps (a series of containers) and temporary pipelines

3.1 Borehole drilling methods

Water from the boreholes was high in sediment, iron and manganese and had a high pH compared to the water quality of the rivers and streams within the Steenbras catchment area. It was therefore not desirable that this water be discharged into the natural vegetation. Extensive mitigation measures were used to contain drilling water (for example sumps, berms, plastic sheeting etc.). Temporary pipelines were installed from the boreholes to discharge drilling water directly into the Steenbras dam (Figure 5).

Additional drilling methods such as flood reverse circulation and water hammer were used to supplement traditional rotary air percussion drilling. This reduced the chance of spilling drilling water and sediment while drilling.

3.2 Positive displacement pumps

Positive displacement pumps, installed at depths from 80 m to 150 m, were considered the best technical solution to deal with the varying pumping heads due to water-level fluctuation in the boreholes, which could vary by up to 100 m, and changing frictional losses in the pumping mains (e.g. depending on the number of operational boreholes, the flows in some pipelines will vary).

The groundwater also has very high concentrations of iron and manganese, which required the careful selection of equipment and instrumentation to mitigate the risk of failure or malfunctioning due to the precipitation of iron. This also limited the flow control mechanisms that could be considered should submersible centrifugal pumps be used.

A constant discharge test is undertaken for each production borehole to determine the safe yield and informs the pump duty. The safe yields, however, need to be adjusted once all boreholes are operated simultaneously, which requires flexibility to change the flow rate at each borehole to match the ultimate sustainable yield. The positive displacement pumps are belt-driven, which means that flows could be easily adjusted by strategic selection of pulley size (diameter). The motors are fitted with variable speed drives to further vary the flows to match the conjunctive use yield target set for the wellfield as well as the water level limitations within the aquifer.

3.3 Bedding / locally sourced material

The environmental specialists required that the bedding material used in the pipe installation have the same chemical composition as the natural fynbos environment. This proved challenging, because the natural pH was extremely low (i.e. a pH of 5.6) and the soil was low in nutrients. In comparison, sand available from commercial quarries had a pH of 9.0

and higher, and had much higher nutrient concentrations. A crusher dust material from a nearby commercial quarry was found to be a suitable bedding material. In addition, the need to import fill for backfilling trenches was reduced wherever possible. On-site crushing and screening of material obtained from drilling operations and trench excavations were undertaken. Road maintenance also made use of local crushed material.

3.4 Trench dewatering

Water from trench excavations could not be discharged into the natural fynbos environment due to the sediment in the water. Various dewatering options were tested (e.g. using geotextile bags to trap sediment) but ultimately a network of temporary pipelines, which also convey water from drilling operations, was installed to discharge the water to the dam.

The pipelines also intersected numerous wetland areas, which posed a risk as the wetlands could be dewatered into the pipe trenches. Impermeable walls had to be constructed in the pipe trenches to ensure that the water tables of the wetland areas are not impacted.

3.5 Choice of pipe material

Pipeline diameters vary from DN 160 to DN 560. The pipe material chosen was HDPE, based on the acidic nature of the water (a pH as low as 4.0), the very restricted working widths varying from 6 m to 10 m (i.e. HDPE pipes can be welded outside the trench and then installed), and the need to limit joints (i.e. the pipeline working width is rehabilitated with fynbos, and the risk of roots penetrating the joints and causing leaks had to be minimised). Furthermore, continuously butt-welded HDPE pipelines did not require concrete thrust and anchor blocks to be installed.

3.6 Stream crossings

A total of nine stream crossings were identified by the environmental specialists, where they recommended above-ground stream crossings to avoid disturbing the streambeds. The pipes had to be installed above the 1:100-year flood levels and no pipe supports were allowed in the flow path of the streams, requiring the pipes to span lengths up to 20 m. The spans up to 13 m were designed such that the pipes could span the entire length of the crossing, but pipe bridges had to be constructed for the longer spans. The above-ground piping was manufactured from stainless steel with a suitable coating and lining to protect it from the low pH of the groundwater. Stainless steel, however, has a much lower yield strength compared to mild steel, requiring careful design to optimise the wall thicknesses required against the distances to be spanned.

FIGURE 6: Completed pumphouse structure clad with natural stone to reduce visual impact

3.7 Pumphouse structures

The pumphouse structures comprise four rooms to house the pump motor, low voltage and control equipment, transformer and ring main units respectively. Due to the environmental sensitivity of the area, the structures were manufactured off-site as precast units and then erected on-site. This reduced the risk of environmental degradation due to concrete spills and also drastically shortened the construction time on-site. To further mitigate the visual appearance of these rather large structures, visualisation specialists were appointed to provide advice about mitigation measures. The final solution was to clad the structures in stone, as shown in Figure 6.

3.8 Buried MV cable

Due to the environmental sensitivity of the area, and the risk of damage by natural fire cycles in fynbos, the medium-voltage power cables were buried in the same trenches as the pipelines. Fibre optic cables, feeding all the data from the respective boreholes to the centralised SCADA, were also installed in the pipeline trench.

3.9 Pre-treatment works

A detailed study was carried out on the fate of the iron and manganese when discharged into the Upper Steenbras Dam. The in-lake dissolved iron concentration is 0.27 mg/L, compared to 2.5 mg/L in groundwater from the Peninsula Aquifer. Furthermore, total iron concentrations in the Peninsula Aquifer greater than 20 mg/L had been found at some of the boreholes. Based on water-quality guidelines, the in-lake target dissolved iron concentration in the Upper Steenbras Dam should be kept below 0.5 mg/L to protect aquatic ecosystems. The study showed that it would be possible to discharge untreated groundwater directly into the Upper Steenbras Dam for a period of approximately three years (based on full production) before a pre-treatment plant should become operational. The design of a pre-treatment plant, which will reduce the iron and manganese concentrations, is currently underway, with construction likely to commence by late-2022.

3.10 Construction supervision

Involving the environmental team throughout construction had numerous benefits, as described below:

- Two Environmental Control Officers were employed on site full-time to monitor and actively measure compliance and initiate incident responses during borehole drilling and construction activities.
- Weekly coordination meetings took place between the CCT's ECO, Environmental Control Officers, contractors, engineers and the CCT's Environmental Management Department.
- For all new activities, Environmental Method Statements were drafted through input from specialists and were approved by the Environmental Control Officers, CCT Biodiversity Management Branch and CCT ECO (and accepted by the DEFF or DEA&DP, where activities triggered NEMA EIA listed activities). In this way, site-specific mitigation measures could be recommended, implemented and audited, with an opportunity to apply any lessons learnt through the implementation of the mitigation measures when future Environmental Method Statements are compiled and approved.
- During construction the specialists had the opportunity to be involved in the recommendation of immediate incident responses, ecological monitoring and implementation of additional mitigation measures depending on the site-specific conditions. This ensured that they could

FIGURE 7: Screenshots of SCADA system used to monitor and control the Steenbras Wellfield

pro-actively initiate erosion control measures, flood detention measures and prevent potential contamination from construction activities.

- An incident response procedure was developed, which defined the collection of water and soil samples, undertaking site assessments with specialists, analysing the sampling data and submitting reports on incidents and potential long- or short-term impacts to stakeholders and relevant authorities.
- The lessons and data collected can be applied to the planning of future wellfields, thereby limiting adverse environmental impacts in future wellfields.

3.11 Ongoing inputs from environmental specialists

All wellfields under consideration are located in environmentally sensitive areas and thus the environmental component of the project was substantial, influencing every aspect of the design and construction of the wellfield, requiring a hands-on approach from the City's Environmental Management Department, environmental specialists, stakeholders and regulatory authorities. The approach followed was to appoint environmental experts, namely a botanist and freshwater ecologist who frequently visited the sites to monitor construction activities and to provide advice on mitigation measures.

3.12 Rehabilitation specialist

Rehabilitation of vegetation was planned for by employing a rehabilitation specialist contractor for the duration of the project.

- Specific plants and seeds were actively harvested prior to clearing sites for drilling and construction activities These plants and seeds were labelled and housed in an on-site nursery, and were replanted/sown back in the area of collection to maintain genetic integrity.
- Alien vegetation has been cleared for 20 m on either side of the linear infrastructure to reduce recolonization by alien plants. This will increase the success of vegetative rehabilitation.
- Topsoil removal and stockpiling for all works has been overseen by the terrestrial ecologists or rehabilitation specialist to aid post-construction rehabilitation.
- Drilling footprints and the working widths for linear infrastructure have been reduced in areas of high environmental sensitivity to reduce the area of vegetation that needed to be cleared. For example, the working widths for DN 560 pipelines varied from 6 m to 10 m, which included the existing road width of 3.5 m.
- Sandbag barriers (trench collars) are being installed in the trenches to match the historical hydrological movement through wetland areas.

4. LONG TERM SUSTAINABILITY

4.1 Offsets

When a project will result in unavoidable residual environmental impacts, these can be compensated for by implementing positive environmental impacts at another location. These are referred to as ecological offsets. One of the license conditions as part of authorising Section 21 (c) and (i) water uses, is the requirement to calculate a wetland offset and implement an offset plan.

Due to the environmental sensitivity of the Steenbras Nature Reserve and ecological changes along the infrastructure routes from wetland to dryland, DWS replaced the need for a wetland offset by a combined biodiversity offset. This combined offset was aimed at including both wet- and dryland residual impacts to determine a suitable offset accounting for construction related impacts, as well as long-term abstraction related impacts. This is the first time that offsets due to long-term groundwater abstraction on this scale have been implemented within the South African context. Offset specialists have been appointed to provide guidance regarding construction and abstraction-related offset requirements. DWS has agreed that offsets be determined in parallel to the Section 21 c) and i) application process.

4.2 Wellfield control system and philosophy

The boreholes are connected by a fibre optic cable network (rather than a telemetry system, which is more conventional). The control room is located in a temporary structure. It will be incorporated into the pre-treatment plant building once that is complete. A SCADA system enables the automated control and operation of the wellfield. Figure 7 shows two screenshots of the type of control mechanisms that are in place.

The operation of the wellfield can be controlled automatically in one of two modes to ensure that sustainable yields are extracted from the aquifers. The two modes are level control or flow mode.

Level control is mainly used during the commissioning phase of the wellfield. Boreholes are pumped at the safe yields determined from the individual pump tests with drawdown limited to a pre-determined level. Once the water level reaches this maximum permissible drawdown level, the pump speed will be reduced to a flow rate where this water level is maintained. The level mode therefore allows for the safe yield of the boreholes to be refined once the entire wellfield is operational.

The CCT can, through their various planning and system models, determine the additional flow required from the wellfields to augment their surface water sources. As such, flow mode allows the operator at the pre-treatment plant to specify the desired flow rate, whereafter pumps will be started automatically until the required flow rate is delivered to the pre-treatment plant. In flow mode, a priority and safe yield is assigned to each of the boreholes. The priority determines the starting sequence, and the safe yields of the individual boreholes will determine the number of boreholes to be started. Preference is given to those boreholes abstracting from the deeper Peninsula Aquifer before utilising any of the boreholes abstracting from the shallower Nardouw Aquifer.

4.3 Wellfield monitoring and modelling

All data from the SCADA system on the Steenbras wellfield site will be fed through to the CCT's data system and will form inputs to their Decision Support System (DSS), currently being developed. This DSS will allow the CCT to monitor all major water sources in real time, and adjust their abstraction from the different water sources to manage the system optimally and sustainably.

An extensive monitoring programme is being developed in parallel with the project implementation. This includes a detailed groundwater model that will use the data from the SCADA to model potential long-term abstraction impacts on the environment. The calibrated model could also be used to model various abstraction scenarios and their likely impacts – which will inform the offset requirements related to abstraction impacts.

4.4 Ecological and hydrogeological monitoring

Ongoing monitoring of the groundwater and environmental impacts will continue as part of the implementation and operational phases of the Steenbras wellfield. This includes on-going baseline monitoring undertaken at a regional scale as well as wellfield-specific abstraction impact monitoring. The results from these monitoring activities are evaluated and reviewed by the Groundwater Monitoring Committee (part of the WUL conditions) who provides on-going advice on sustainable yields and monitoring requirements.

4.5 Water Quality

The potential impact of discharging treated and untreated groundwater into Steenbras Dam on the water quality in the dam was investigated, i.e. it was important to demonstrate that the addition of water from the TMG Aquifer would not negatively impact the water quality and ecology of the dam. A water quality model was set up using actual inflows to the dam (i.e. natural run-off and transfers from Palmiet) and water demands obtained from the system modelling.

5. CONCLUSIONS

The authors have endeavoured to provide a roadmap to other municipalities and water services authorities on how to successfully implement and ensure the ongoing sustainability of large-scale groundwater projects. Implementing a large-scale groundwater project under emergency conditions, in a sustainable way within a sensitive environment, was unchartered territory with valuable insights gained along the way viz;

- Lay a strong foundation – get the research done.
- Get a head start – don't wait for crises before commencing.
- Journey with seasoned travellers – engage engineers and specialists that have comparable experience to avoid pitfalls and dead-ends.
- Co-operative governance - collaboration with all tiers of government regulators must be secured in advance.
- Teamwork wins the day – robust interaction between all role-players must be maintained throughout.
- Build trust – Maintain a high duty of care through instilling a culture of compliance.
- Plan for a marathon and not a sprint – adopt a paced approach to the project by setting realistic timelines.
- Flexible Funding mechanism – fund the project not the financial year.
- Expect the unexpected – adopt an adaptive management approach to project deliverables.

The authors have shared their insights gained from the process in the express wish that other municipalities and water services authorities located elsewhere in South Africa, can benefit from their experience.

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