



A CONCISE
GUIDE TO

**DEVELOPING A
GROUNDWATER
SCHEME**

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This booklet provides a summary of the report, K. Pietersen and R. Titus, Guidance document on groundwater scheme development, WRC Report no. TT 903/22. For more detailed information, refer to the full guidance document as well as the list of other helpful guideline documents provided at the end of this booklet.

CONTENTS

Introduction	Page 5
The lifecycle of groundwater scheme development.....	Page 7
Needs assessment	Page 8
Legislative and permitting requirements.....	Page 9
Groundwater exploration.....	Page 11
Borehole drilling, borehole construction and pumping tests.....	Page 13
Implementation	Page 15
Operation and maintenance.....	Page 17
Other useful guides.....	Page 19



INTRODUCTION

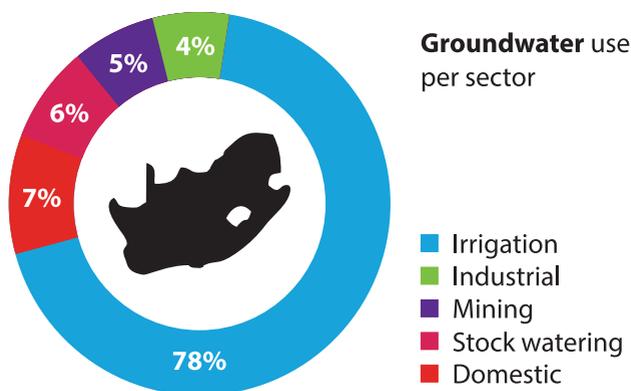
In South Africa groundwater is recognised as a resource of strategic importance. Groundwater forms an essential part of any water management and supply programme, and municipalities have developed many water supply schemes using groundwater as a resource.

Groundwater resources are exploited all over South Africa. The strategic importance of the resource is controlled predominantly by the availability of water supplied from surface water resources. The amount of groundwater available differs according to geological conditions.

Where groundwater management is sustainable, its potential contributions cross multiple dimensions of sustainable development. Sustainable groundwater management can ensure climate-resilient supplies of water needed to help meet goals for food security, energy development and access to drinking water. It can also supply water for sustainable cities and for industrialisation.

Groundwater is a vulnerable resource, and it needs to be protected and well managed. Typical groundwater schemes in South Africa comprise boreholes equipped with pumps or motorised wellfields operated by water agencies or local authorities. In some settings, the boreholes may form part of the water treatment and reticulation system.

Groundwater infrastructure can be considered critical infrastructure as it is socially, economically or operationally essential to the functioning society or community, both in normal circumstances and in the extreme circumstances of an emergency (such as drought). Hence the need to develop guidelines for installing groundwater schemes.



Groundwater use in South Africa per sector

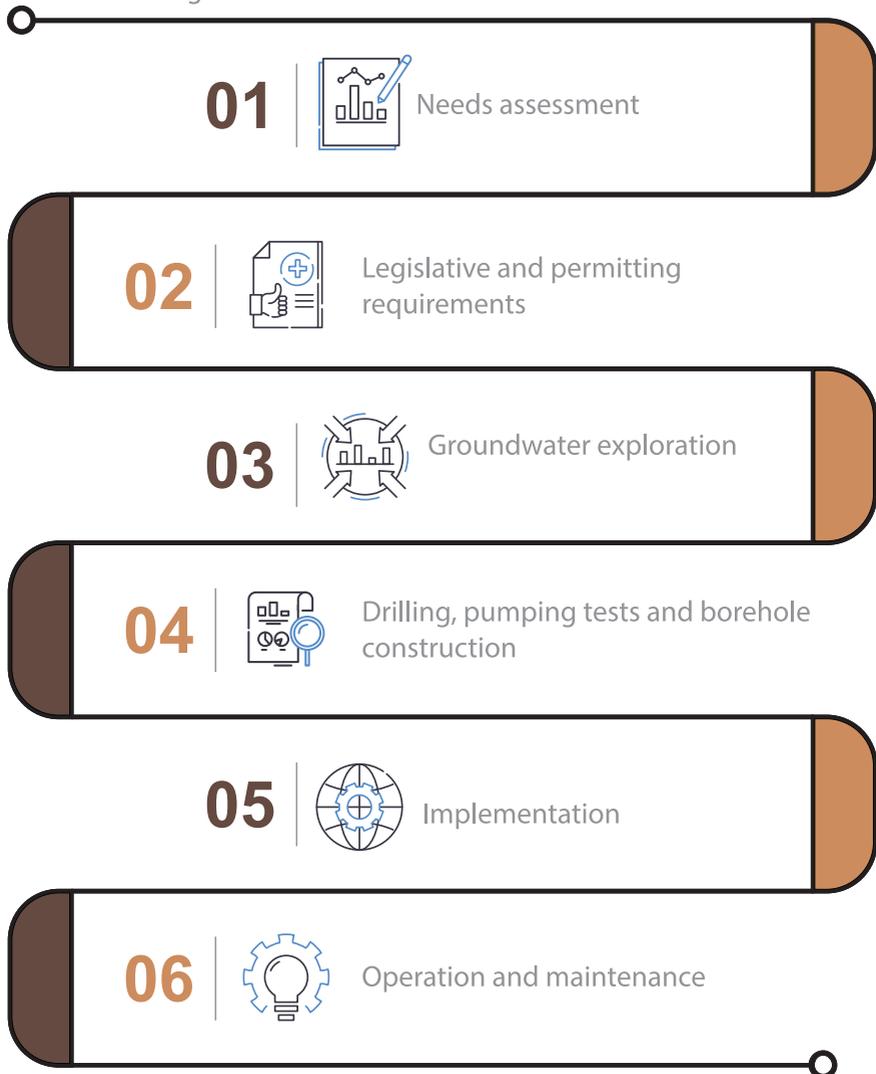
(Source: Groundwater – the myths, the truths, the basics)

Table 1. Advantages and limitations of using groundwater for water supply

Advantages of groundwater	Limitations
Groundwater is often available close to where it is required	Groundwater is not ubiquitous and considerable effort may be needed in some situations to locate suitable sites for boreholes
Groundwater can be developed relatively cheaply and progressively to meet demand with lower capital investment than many surface water schemes	As overall coverage increases, the more difficult areas which are left can become too costly to supply
Groundwater generally has excellent natural quality, and is usually adequate for potable supply with little or not treatment	Natural quality constraints such as high fluoride and nitrate can occur in some areas
Groundwater generally has a protective cover provided by the soil and unsaturated zone	As development increases more rapidly, pollution can exceed the capacity of the soil to attenuate contaminants
Groundwater is generally available during times of surface water drought	As demand for groundwater increases overexploitation of the resource can occur; climate change may reduce recharge in some areas

THE LIFECYCLE OF GROUNDWATER SCHEME DEVELOPMENT

The lifecycle of groundwater supply projects can be divided into six stages:



The lifecycle stages of a water and sanitation development project. Solid arrows indicate the flow of the lifecycle process. (After McConville & Mihelcic, 2007)

Needs assessment

A needs assessment helps the practitioner identify, understand and better address water supply challenges in an area. All relevant stakeholders need to be actively involved in order to best address the problem.

The needs assessment aims to help practitioners understand current levels of groundwater supply coverage, including the existing infrastructure and services, their condition, and what the government must do to meet the minimum standards set by policy or legislation.

The following methodologies can be used to conduct a needs assessment:

- **Background research** – Explore existing publications and data
- **Focus group discussions** – Talk to community members and other stakeholders to ask questions, exchange experiences and comment on each other's point of view
- **Household surveys** – Conduct a survey among households to collect the necessary information about their water supply conditions
- **Site visits and observations** – Observe a particular group in their environment and make recommendations based on these observations
- **Key informant interviews** – Using key informant interviews, practitioners can identify an individual or group's needs.
- **Questionnaires** – These are useful for collecting information from relatively large numbers of people.



Legislative and permitting requirements

South African water law considers groundwater a national resource requiring sustainable management. This means that groundwater sources must be developed in such a way that it prevents pollution and harm to the environment as much as possible.

The country's laws assign different roles to government regarding the delivery of water services. While the national government must manage water resources through various water boards, municipalities are responsible for delivering water and sanitation and drawing up plans for delivery.

The laws that govern groundwater use and management in South Africa

Constitution of South Africa (Act 108 of 1996)

National Water Act (Act 36 of 1998)

Water Services Act (Act 37 of 1997)

Water use authorisations

Municipalities need to take note of the various water use authorisations for groundwater and surface water recognised and issued in South Africa. This includes:

- **Existing lawful water use:** This covers groundwater that was abstracted after 1 October 1996 and before 1 October 1998.
- **General authorisation:** Groundwater abstractions under General Authorisations are limited, and are mainly for domestic watering, stock watering, non-commercial irrigation purposes, and small-scale exploration purposes.
- **Groundwater use licensing:** Groundwater abstractions exceeding the General Authorisation limits form part of groundwater use licences. This includes, for example, groundwater abstractions for bulk water supply, mine dewatering, and irrigation schemes, among others.
- **Controlled activities:** According to the National Water Act, controlled activities include, for example, the irrigation of any land with waste or water containing waste generated by a water treatment works or any industry; activities that can modify the atmospheric precipitation, a power generation activity that alters the flow of a water resource, recharging an aquifer with waste or water containing waste; artificial recharge and hydraulic fracturing.

National standards for the provision of water services

There are several minimum standards and indicators for water services in South Africa relevant to groundwater.

The minimum standard for basic water supply is:

- A minimum quantity of potable water of 25 litres per person per day or 6 kl per household per month:
 - At a minimum flow rate of not less than 10 litres per minute
 - Within 200 metres of a household
 - With effectiveness such that no consumer is without a supply for more than seven full days in any year

Drinking water must meet SANS 241 – Specifications for drinking water or the South African Water Quality Guidelines published by the Department of Water and Sanitation. It is important that regular water samples are taken as part of a water quality sampling programme to ensure that drinking water consistently meets water quality guidelines.

Every water services authority has to prepare a water services development plan. Such development plans must be developed in consultation with consumers, who have a right to comment and to have their comments considered before the plan is adopted. Further, every water services authority must draft bylaws to provide water services.



Groundwater exploration

Most South African aquifer systems occur in fractured geological environments. Hydrogeologists require a multidisciplinary approach to improve the borehole success rate in these terrains, sustain groundwater resources, and meet water services standards.

There are several steps towards undertaking successful groundwater exploration:

Step 1: Hydrocensus

The aim of a hydrocensus is to characterise a region in terms of the physical and economic feasibility of meeting water demands through groundwater. This is done by looking at aspects such as expected borehole yields, historic drilling success, the proximity of boreholes to geological structures and their yield, depth to water strikes, static water levels, groundwater chemistry and potential hydrogeological targets.

Hydrogeologists conduct a hydrocensus by collecting data from the national groundwater databases, previous groundwater investigations and field surveys.

Step 2: Tectonics and geodynamics

Geodynamic investigations require solving the tectonic history of the target area. The aim is to define a chronologically expected pattern to explain observed faulting by strain analysis.

Step 3: Structural analysis

A structural analysis aims to identify strain conditions in rocks by identifying compressional and tensional orientations by mapping the strike and dip of joints and plotting the data on stereonet.

Step 4: Remote sensing

The aim of using remote sensing methods is to identify structures that may be of hydrological significance, are not noticeable in the field or have not already been mapped.

Step 5: Modelling

Developing a groundwater model of an aquifer system enables the quantification of groundwater and evaluation of groundwater dynamics. This includes quantifying and evaluating groundwater inflow (recharge from rainfall and lateral inflow), groundwater flow through the aquifer and groundwater outflow (subsurface drainage, seepage, evapotranspiration and abstractions).

Step 6: Field verification investigations

Field proofing investigations are required to identify the nature of target lineaments to determine their nature and origin and to pinpoint the lineaments in the field using observation or geophysics, with due consideration given to constraints on siting. The aim is to identify drilling sites with structural features of hydrogeological significance at locations where drilling and water abstraction are physically, economically, socially and legally acceptable.



Borehole drilling, borehole construction and pumping tests

Poor borehole drilling impacts construction and operations and maintenance (O&M). Borehole drilling is a specialised area that requires specialised drilling equipment and skilled personnel. The technical specifications for borehole drilling need to be drawn up by qualified and experienced personnel who should plug all possible loopholes that contractors could use to compromise quality works. Supervision of the drilling works requires equally qualified and experienced personnel.

Rotary drilling techniques are primarily applied in South Africa as the method allows the construction of deeper boreholes. The drillers use circulating fluids to cool and lubricate the cutting tools and remove debris from the hole. The circulating fluids are compressed air, pumped water with additives and drilling muds or foams.

Borehole construction

The hydrogeologist designs the borehole construction to match the characteristics of the aquifer. Technical considerations include:

- **Borehole screens** – The hydrogeologist selects the borehole screens after conducting a sieve analysis of the aquifer material obtained during drilling or from prior knowledge of the aquifer.
- **Placement of borehole screens** – The hydrogeologist places the screens against the aquifers (water-yielding formations). In confined aquifers (aquifers in which the water level rises above the aquifer), hydrogeologists screen 80-90% of the thickness of the aquifer, and the best results are obtained by centring the screen section in the aquifer. For unconfined aquifers (aquifers in which the water level may be roughly the same level as the water strike), maximum yield is obtained by using the longest screen possible. Screen design is a critical factor for the efficiency of a successful borehole.
- **Gravel/filter pack** – Gravel pack helps in filtration, stabilising of the aquifer, preventing the collapse of the formation, which would lead to low abstraction volumes (low yields), minimising sand pumping, which would damage the pump, reducing the groundwater flow velocity to levels preventing screen encrustation or wear, and reduction in head losses.

- **Location of the pump in the borehole:** The pump should ideally not be placed within the borehole screens. It should instead be placed within a plain or unperforated casing, commonly referred to as a pumping chamber. Ideally, pumping should be carried out in confined aquifers at levels above the top of the aquifer to avoid agitating the filter pack and aquifer material.

During drilling, mud and borehole cuttings can plug the aquifer. The driller must thoroughly remove the material through the borehole development process.

Borehole disinfection

The purpose of disinfection is to cleanse the borehole of any bacteria, particularly coliform bacteria, introduced during the rehabilitation or testing operations. Disinfection can be accomplished by injecting chlorine (or chlorine-yielding compounds) into the borehole in quantities.

Site finishing

Upon completion of the rehabilitation and pumping test, all the debris from a construction, such as unsuitable or rejected materials, spillage and cuttings, must be removed. The site of the work must be cleaned of all rubbish, excess materials, false works, temporary structural installations and abandoned equipment. All resulting construction scars from these works should be treated to blend with the contour and vegetation of the surroundings.

Pumping tests

The pumping test is one of the most valuable tools for evaluating groundwater resources. It is a method of assessing the performance of a borehole, the borehole yield, the zone of influence of the borehole and aquifer characteristics (i.e. the aquifer's ability to store and transmit water, aquifer extent, presence of boundary conditions and possible hydraulic connection to surface water)

A pumping test consists of pumping groundwater from a borehole, measuring water levels in the pumped borehole, and observing boreholes (if present) during and after pumping. The hydrogeologist uses the data to plot drawdown and recovery. How the water levels respond to the pumping is analysed to derive information about borehole efficiencies and the hydraulic parameters of the aquifer system. Thus, it becomes critical that hydrogeologists oversee pumping tests properly. (For a detailed description of all the procedures accompanying pumping tests, refer to the full guideline)

Implementation

This phase comprises the installation of the groundwater infrastructure. In South Africa, there are numerous groundwater schemes and technologies. The groundwater schemes range from simple spring protections to mechanised boreholes.

Multi-borehole schemes with storage buffers and extensive reticulation serving large areas with complex O&M characteristics are at the upper level of complexity. In a few cases, groundwater use evolved as part of planned urban water-supply development, e.g. Atlantis. However, it occurred more often in response to water shortage or service deficiency and through private initiatives.

Infrastructure that brings water to communities must always be kept functional. The responsibility of the groundwater infrastructure lies with the engineer.

Table 2. Types of groundwater schemes

Standalone scheme	<ul style="list-style-type: none"> • A spring, borehole or well equipped with a pump. Typically, many standalone schemes only have one water source without a backup in the case of failure • Rising main pipeline from the borehole to the storage reservoir • Water treatment and disinfection and disinfected water storage reservoir. Many schemes supply groundwater without treatment or disinfection • Distribution pipelines to communal tap stands or private connections
Group scheme	<ul style="list-style-type: none"> • More than one groundwater source (spring, borehole or well equipped with a pump) • Rising main pipeline from the borehole to a central storage reservoir • Water treatment and disinfection and disinfected water storage reservoir Some schemes supply groundwater without treatment or disinfection • Distribution pipelines to reservoirs at the individual settlements that may be supplied by gravity or pumped • Distribution pipelines to communal tap stands or private connections

Regional scheme	<ul style="list-style-type: none"> • Multiple groundwater sources or wellfields • Raw water pipelines, pump stations and reservoirs • Water treatment and disinfection facilities • Treated water pipelines, pump stations and reservoirs • Reticulation networks
Private supply	Private supply schemes could range from a borehole or well with a hand pump in the yard to a sophisticated system integrated with a fully plumbed house or institution, including complex water treatment, storage, and a booster pump station.

Responsibility for operation and maintenance

Municipalities are the responsible institution for groundwater supply in South Africa. Organisational responsibility for water and sanitation operation and maintenance includes a range of functions and requires a multidisciplinary team to staff the institution.

Managing large complex regional water-supply schemes requires sophisticated management and a skilled staff complement that can adequately fulfil all the physical and administrative functions required. In dispersed rural communities, especially where there are many standalone schemes, individual handpumps, and spring protections, communities can play an influential role in the scheme operation, doing essential maintenance and communicating and reporting to the responsible authority. In some cases, communities cover the cost of these services and their contribution to their water supply, while the local operation, maintenance and monitoring is remunerated by the responsible authority elsewhere.

The maintenance of handpumps and smaller standalone schemes from boreholes and springs require less technical skilled input. The difficulties associated with access and the fact that the schemes are dispersed over large areas give rise to additional logistical challenges and associated costs for the type of schemes.



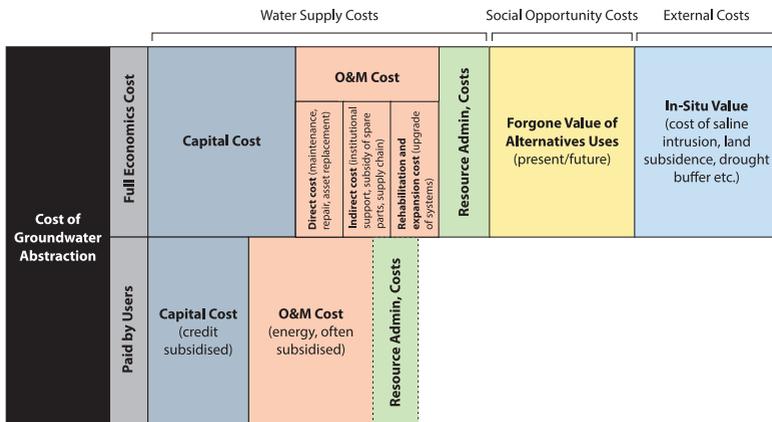
Operation and maintenance

There are many challenges to implementing infrastructure sustainably, ranging from inadequate funding to poor governance. For groundwater infrastructure to be sustainable and resilient, its lifespan must be ensured through proper O&M, as this is the main cause of infrastructure breakdown.

Factors undermining groundwater infrastructure sustainability and resilience:

- The project was poorly conceived (e.g., a project that only increased the number of water points, or sanitation facilities, as a way of improving accessibility to these services, without considering the broader range of factors needed to sustain the benefits)
- There was minimal or no community involvement and participation in the project; hence, the communities did not have a sense of project ownership. Demand and community involvement (of both men and women) are critical to generating long-term community commitment to improved services and sustaining the services. Community involvement and participation also make the community members responsible for the choice of technology and make community members aware of the financial, managerial, and technical implications of their choice, including future O&M tasks associated with the technology
- The performance of the project facilities was either not assessed or was insufficiently monitored during the O&M phase of the project cycle (ineffective or non-existent O&M)

Typical cost structure of groundwater schemes



Costs associated with groundwater abstraction (Harvey, 2007; Smith et al., 2016)

Pumping groundwater requires energy, and potential energy sources include solar, diesel, and grid-connected. Energy costs can make up anything from 5% to 50% of the annual costs of running a groundwater scheme, depending on the energy source and extent of pumping required.

Solar has minimal running costs, but the capital costs are high, as well as the susceptibility to vandalism and the reliance on sunlight. Diesel, while very common for small, rural schemes, is the most expensive to run and maintain, with grid-connected systems generally being 50% to 70% of the running cost of diesel systems.

There are other benefits to grid-connected systems, such as the improved ability to automate electric motors, the potential to install a smaller capacity pump (since an electric pump can run continuously whereas a diesel pump generally operates for 8 hours a day), and the ability to install switches that require electricity such as no flow switches, cut off probes and pressure switches.



Other useful guides for groundwater development and management

- DWAf, A framework for groundwater management of community water supply, 2004, <https://bit.ly/46w5vw2>
- K. Danert, Manual drilling compendium, 2015, <https://bit.ly/46As0jg>
- R. Meyer, Guidelines for the monitoring and management of groundwater resources in rural water supply schemes, 2002, <https://bit.ly/46xUtpZ>
- A. van der Wal, Understanding groundwater and wells in manual drilling, 2010, <https://bit.ly/3PWJHnP>
- R. Vuik et al, 2010, Technical training handbook on affordable well drilling, <https://bit.ly/46h0s2Q>





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