Groundwater Management Framework

Report to the
Water Research Commission

prepared by

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EXECUTIVE SUMMARY

"Resource Management is People Management."

Groundwater has historically been given limited attention and has not been perceived as an important water resource in South Africa. This is reflected in general statistics showing that only 13% of the nation's total water supply originates from groundwater. Public perception that groundwater is not a sustainable resource for bulk domestic supply and cannot be managed properly lingers. Despite this, a growing number of municipalities utilise groundwater on a regular basis, and provide examples of successful management of this resource.

A number of guidelines for groundwater management have been developed internationally and for the South African context. The most relevant for the purpose of this study are the NORAD toolkit (DWAF, 2004), the WRC "Guidelines for the monitoring and management of ground water resources in rural water supply schemes" (Meyer, 2002) and the DWA "Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa" (DWAF, 2008). Other documents include water quality management protocols, minimum standards, the Framework for a National Groundwater Strategy (DWAF, 2007), the National Water Resources Strategy (DWAF 2004), the "Guidelines for Catchment Management Strategies Towards Equity, Sustainability and Efficiency" (DWAF, 2007) and regional groundwater plans, as well as selected national and international articles and publications on groundwater management aspects.

Literature Review and Case Studies of Best Practice

The guidelines and publications were reviewed with respect to the legal framework, completeness of all relevant aspects, feasibility of implementation and functionality. The review concludes with a gap analysis, indicating aspects and management functions that require particular attention:

Comprehensive definition of "groundwater management" and all relevant aspects of it;

Comprehensive definition of the relevant management functions with respect to groundwater management, as defined above;

Mapping of roles and responsibilities of water institutions for the different groundwater management activities, as per comprehensive definition;

Outlining required skills for the different groundwater management activities;

Integrating the different groundwater management guidelines into one document.

Case studies of best practice were prepared for the following towns or municipalities:

Emthanjeni LM (De Aar),

Overstrand LM (Hermanus, Stanford),

Cederberg LM (Elands Bay),

Baviaans LM (Willowmore),

The main factors of success that emanate from the different case studies are:

Appropriate technology for groundwater monitoring and management;

Scientific support from external consultants on request;

Efficient management structure;

Committed staff; and

Adequate funding mechanism.

Groundwater Management Framework

Based on the literature review and case studies, a Groundwater Management Framework is designed to be applicable at local level of responsibilities, i.e. WSA, WSP, WUA. Hence, the assigned responsibilities and available tools to achieve sustainable groundwater management reflect the local level of Water Institutions. However, the principles of the Framework can be applied at all levels and all scales.

Groundwater management includes one or more of the following:

Aquifer protection

Groundwater quality management

Groundwater remediation

Groundwater assessment

Groundwater monitoring

Wellfield planning and design

Wellfield operation and maintenance.

The different aspects of groundwater management relate to two main categories, viz.

Aquifer protection, and

Aquifer utilisation.

In the legal context of South Africa, these relate broadly to Source Directed Measures (SDM) and Resource Directed Measures (RDM), respectively.

Monitoring and data management is a critical part of both categories of groundwater management and has an overarching aspect that requires standardisation of the process. The monitoring and data management category comprises five distinct, but linked tasks:

Development of a Monitoring Protocol

Design and Set-up of a Monitoring Network

Data Collection and Collation

Data Processing

Data Analysis and Evaluation

Data Management.

There are a variety of role players, who are, or should be, responsible for some of the above aspects of groundwater management at different levels:

The Department for Water Affairs

The Department of Environmental Affairs

Catchment Management Agency

Water User Association

Water Services Authority

Water Services Provider

Water Board

Water user

Water polluter.

The Framework describes for each category separately the different aspects, associated tasks and assigned responsibilities of the relevant institutions.

Aquifer Economics

One of the major challenges in valuing aquifers is how to integrate the hydrologic and physical components of groundwater resources into a valuation scheme. An appropriate conceptual basis for valuation identifies service flows as the central link between economic valuation and ground water quality and quantity.

Defining the best long-term management of the resource requires balancing the needs of the present with those of the future. In theory, the balancing is done every day by markets as reflected in the discount rate. The discount rate a water utility employs when valuing aquifers reflects perceptions of risk, returns, and possibly intergenerational equity. A high discount rate implicitly places a low value on the water's value to future generations. A low rate implies the opposite.

The valuation of the range of ecosystem services of an aquifer requires an understanding of geology, geohydrology and ecology of a certain groundwater resource. Hydrological and geohydrological information includes numerous factors such as rainfall, runoff, depth to groundwater, whether the aquifer is confined or unconfined, the groundwater flow rates and direction, type of vadose and water bearing zone materials and water quality associated with different strata.

Implementation in Overstrand Municipality

The Groundwater Management Framework and Aquifer Valuation methodology were tested and implemented as a case study in the Overstrand Municipality for the groundwater supply to Hermanus (targeting the Peninsula Aquifer of the Table Mountain Group) and the supply for Stanford (from the quaternary sands and limestones of the Bredasdorp Group).

The Overstrand Municipality was chosen for this project, as it has separated the WSA and WSP functions within the municipal structures, which is the preferred structure to comply with relevant legislation, i.e. the WSP should not supervise and police itself. This structure enables a clear tracking of roles and responsibilities, as well as required skills for the different functions.

The WSA functions are the responsibility of the water services manager within the Directorate: Infrastructure & Planning.

The WSP functions are the responsibility of the operations managers within the Directorate: Community Services.

The implementation of the Framework confirmed that the split between WSA and WSP is useful, if both parties are fully involved in the groundwater development and wellfield planning. The Aquifer Valuation methodology provides a useful tool for the Local Government to emphasise the value of protecting and utilising the aquifers in a sustainable manner.

Recommendations

The framework has proven to be of high significance for local government to understand their responsibilities and required actions in groundwater management. Hence, it is of utmost importance to introduce municipalities to this framework and train the relevant officials in using the guidelines to achieve sustainable groundwater management.

Furthermore, it is strongly suggested that the Department of Water Affairs adopt this framework as an overarching guideline and incorporates the suite of existing guidelines into this framework.

The following future work is recommended to support the above suggestions and to achieve a successful implementation of the framework:

Roll-out of framework to local government;

Training of municipal officials in elements of the framework and guidelines;

Update DWA Guideline for Assessment and Management to incorporate details of the levels of assessment and planning;

Develop guideline for monitoring data handling, including processing, quality control, storage and sharing of data;

Develop guideline for adaptive management (Monitor – Model – Manage);

Refine valuation methodology to include ecosystems and aquifer characteristics.

Acknowledgements

The Contribution of the Project Reference Group throughout the study and to this report is much appreciated. The Reference Group comprised:

Dr S Adams	*WRC*
Mr E Bertram	*Department of Water Affairs*
Mr P Seward	*Department of Water Affairs*
Ms I Viljoen	*Department of Water Affairs*
Mr S Muller	*Overstrand Municipality*
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Abbreviations

CMA	-	Catchment Management Agency
CMS	-	Catchment Management Strategy
DANIDA	-	Danish International Development Assistance
DWAF	-	Department of Water Affairs and Forestry
DWA	-	Department of Water Affairs
EMF	-	Environmental Management Framework
EU	-	European Union
GRDM	-	Groundwater Resource Directed Measures
GW	-	Groundwater
IWRM	-	Integrated Water Resource Management
IWRMP	-	Integrated Water Resource Management Plan
IWWRM	-	Integrated Water and Waste Resource Management
IWWRMP	-	Integrated Water and Waste Resource Management Plan
KZN	-	KwaZulu-Natal
MSA	-	Municipal Structures Act
NGS	-	National Groundwater Strategy
No	-	Number
NORAD	-	Norwegian Agency for Development Cooperation
NWA	-	National Water Act
NWRS	-	National Water Resource Strategy
O & M	-	Operations and Maintenance
RDM	-	Resource Directed Measures
RQO	-	Resource Quality Objective
SADC	-	Southern Africa Development Community
SMME	-	Small and Medium Enterprises
UN	-	United Nations
USA	-	United States of America
USGS	-	United States Geological Survey
WMA	-	Water Management Area
WRC	-	Water Research Commission
WRM	-	Water Resource Management
WSA	-	Water Services Authority
WSDP	-	Water Services Development Plan
WSP	-	Water Services Provider
WUA	-	Water User Association

1 INTRODUCTION

Over 300 towns, and a far higher number of villages and rural settlements, depend solely on groundwater, but there is little monitoring and management to ensure abstraction does not exceed recharge rates, with the result that many boreholes, and in extreme cases, aquifers, are being over-pumped. In a growing number of settlements, rising demand is leading to borehole failures and severe water shortages.

The primary cause of borehole failure is mismanagement, and with proper management and information, far greater volumes of water can be made available.

Water for Growth and Development (DWAF, 2008)

1.1 Background to Study

Groundwater has historically been given limited attention, and has not been perceived as an important water resource, in South Africa. This is reflected in general statistics showing that only 13% of the nation's total water supply originates from groundwater. Public perception that groundwater is not a sustainable resource for bulk domestic supply and cannot be managed properly lingers. Despite this, a growing number of municipalities utilise groundwater on a regular basis, and provide examples of successful management of this resource.

The guidelines developed, for South Africa, under the NORAD Programme (DWAF, 2004), by the Water Research Commission [WRC] (Meyer, 2002) and recently by the Department of Water Affairs [DWA] (DWAF, 2008) are valuable sources of information in terms of what needs to be done to protect and manage aquifers. Detailed or overall (ground)water management plans are still lacking. In addition to data collection and monitoring there is a need to understand and improve on the management of groundwater resources by equipping the responsible authorities with the required human and capital resources. Local capacity for water management must be explored from the perspective of the institutional environment, the catchment community, and the financial, technical and staff resources of the organisations.

Management functions within the responsible authorities did not receive adequate attention in available management plans. For effective management, these functions must include, among others:

Planning;

Organising;

Directing; and

Controlling and monitoring.

1.2 Aim of the Project

The main aim of this assessment is to define these in terms of groundwater management (groundwater management functions). Within the South African context, these functions would mainly be the responsibility of the Water Services Authorities (WSA; domestic water supplies) and Water User Associations (WUA; irrigation). Groundwater management is ultimately a multistakeholder process wherein competing objectives and differing sets of values and perceptions have to be effectively reconciled. The success of any groundwater management plan depends on the knowledge, skills and effectiveness of the authorities that are responsible. As such these become a prerequisite for integrated water resources management.

In high-performance, team based organisations, the classic functions listed above are replaced by facilitation, coaching and empowering. Sound institutional design and suitable capacity will improve water resource management and the use of adaptive strategies. Linked to the groundwater management functions, a suitable methodology is required to determine the costs involved in operating an efficient management programme within a particular institution. How much should ideally be spent on the management of the resource or well field? Should it be commensurate with the value of the available groundwater resources and scale of abstraction?

1.3 Report Outline

Section 1 provides an introduction to the report and the background to the research study.

Section 2 gives an overview of the structure and content of the groundwater management framework, provides definitions of groundwater management and management functions, and describes the legal context of the Groundwater Management Framework with respect to the municipal requirements (i.e. WSDP, IDP, SDF, IWRMP) and the concept of IWRM in particular.

Section 3 details the aquifer protection aspects of the framework, which are grouped into prevention and remediation.

Section 4 describes the aquifer utilisation aspects of the framework, which deals with groundwater assessment and wellfield management.

Section 5 describes the overarching monitoring aspects of the framework that are required to ensure data consistency and knowledge management.

Section 6 describes the framework and methodology for the valuation of groundwater.

The implementation of the framework in the Overstrand Municipality is documented and discussed in **Section 7**.

Appendix A summarises the initial literature review with respect to water resource management and groundwater management in particular.

The case studies of best practice are contained in **Appendix B**.

2 OVERVIEW OF GROUNDWATER MANAGEMENT FRAMEWORK

> “Management is the art of getting things done through people." – *Mary Parker Follett*.

2.1 Definitions

Management

Management “is the process of leading and directing all or part of an organization through the deployment and application of resources (human, financial, material, intellectual or intangible).” (Wikipedia)

Hence, management in all business and human organization activity is simply the act of getting people together to accomplish desired goals and objectives. Management comprises planning, organizing, staffing, leading or directing, and controlling an organization or effort for the purpose of accomplishing a goal (see Section 2.2).

Management is usually seen in the business sense of effectively and efficiently achieving the objectives of the business or organisation. The principles of management have been expanded and applied to other forms of organisations, specific areas within a business (e.g. human resource management, risk management, operations management), personal behaviour (e.g. self management, time management), natural resources (e.g. land management, water resource management), etc.

Management System

“A **management system** is the framework of processes and procedures used to ensure that an organization can fulfil all tasks required to achieve its objectives.” (Wikipedia)

This can be summarised as "Plan, Do, Check, Act." A more complete system would include accountability (an assignment of personal responsibility) and a schedule for activities to be completed, as well as auditing tools to implement corrective actions in addition to scheduled activities, creating an upward spiral of continuous improvement.

Some well known management systems are:

Quality Management System, ISO 9000: 2008

Environmental Management System, ISO 14000

Occupational Health and Safety Management System, OHS Act, ISO 18000

Function

“A **function** is frequently interpreted in engineering as a specific process, action or task that a system is designed to perform.” (Wikipedia)

Integrated Water Resource Management

The challenges of sustainable development led to increasing 'integration' requirements, which are well captured in the IWRM definition from the Global Water Partnership:

> *''IWRM is a process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.''*

IWRM discourse often focuses on the integration of the three E's: economic, environment and equity. However, this only considers one of the many integration dimensions of the approach. IWRM also includes integration of several elements such as land and water issues, freshwater and coastal zones, green vs. blue water, water quantity and quality, differing upstream and downstream interests and interactions between surface-water and groundwater resources. Braune and Xu (2008) contend that groundwater, largely because of its hidden and generally poorly understood nature, is seldom properly incorporated into IWRM and national development frameworks.

DWAF (1998) defines IWRM as:

> *"a philosophy, a process and a management strategy to achieve sustainable use of resources by all stakeholders at catchment, regional, national and international levels, while maintaining the characteristics and integrity of water resources at the catchment scale within agreed limits"*

This definition translates in the need for assessment and regulation of all activities that potentially can have a significant impact on the water availability and its distribution within any catchment. This includes not only changes in water use, but applies also to changes in land use, land management and water demand management as well as considering the impact of climate change. IWRM is universally recognized as a people- and environment-focused, holistic paradigm by which to regulate and manage water.

Groundwater Management

The current definitions of "Water Resource Management" and more so "Groundwater Management" vary significantly and are not consistent throughout the legal framework and guidelines. For the development of the Groundwater Management Framework, a comprehensive definition of groundwater management has been applied that includes all of the following aspects:

Aquifer protection

Groundwater quality management

Groundwater remediation

Groundwater assessment

Groundwater monitoring

Wellfield planning and design

Wellfield operation and maintenance

These different aspects of groundwater management relate to two main categories, viz.

Aquifer protection, and

Aquifer utilisation.

In the legal context of South Africa, these are broadly governed by Source Directed Controls (SDC) and Resource Directed Measures (RDM), respectively.

Management Functions

Management operates through various functions. The business management schools normally distinguish between 4 and 7 basic management functions, of which the four most important are planning, organizing, leading/motivating, and controlling:

Planning: Deciding what needs to happen in the future (today, next week, next month, next year, over the next 5 years, etc.) and generating plans for action.

Organizing: (Implementation) making optimum use of the resources required to enable the successful carrying out of plans.

Staffing (Part of Organizing): Job Analyzing, recruitment, and hiring individuals for appropriate jobs.

Leading / Directing: Determining what needs to be done in a situation and getting people to do it.

Motivating (Part of Leading): the process of stimulating an individual to take action that will accomplish a desired goal.

Controlling / Monitoring: checking progress against plans, which may need modification based on feedback.

Planning

Planning is the ongoing process of developing the business' mission and objectives and determining how they will be accomplished. The management function of “Planning” comprises the overarching strategic planning for the organisation, such as

Mission Statement

Defining the objectives

Setting the goals

Plan of Action

The detailed planning of how to get there and its implementation fall under the management function of “Organising”.

Organising

Organising is the management function that usually follows after planning, and involves the assignment of tasks, the grouping of tasks into departments and the assignment of authority and allocation of resources across the organization. In order to reach the objectives outlined in the planning process, structuring the work of the organization is a vital concern.

Part of the “Organising” function is staffing, which involves hiring staff with the required skills and qualification, setting up the training for the employees, where required, acquiring technical resources, and organizing the work group into a productive team.

Leading / Directing

Directing is influencing people's behaviour through motivation, communication, group dynamics, leadership and discipline. The purpose of directing is to channel the behaviour of all personnel to accomplish the organization's mission and objectives while simultaneously helping them accomplish their own career objectives. Those in the leadership role must be able to influence/motivate workers to understand and achieve the overarching goal and follow the duties or responsibilities assigned during the planning process.

These four management functions are the building blocks for all types of management. They form an ongoing cycle of management, as the results of "Controlling" might require changes of the objectives ("Planning"), changes in organisational structure ("Organising"), changes in personnel ("Staffing") or changes in interpersonal relationships ("Directing"), as indicated in **Figure 2-1**. The main elements of the management functions and the responsibilities within the municipal structure are shown in **Table 2-1**.

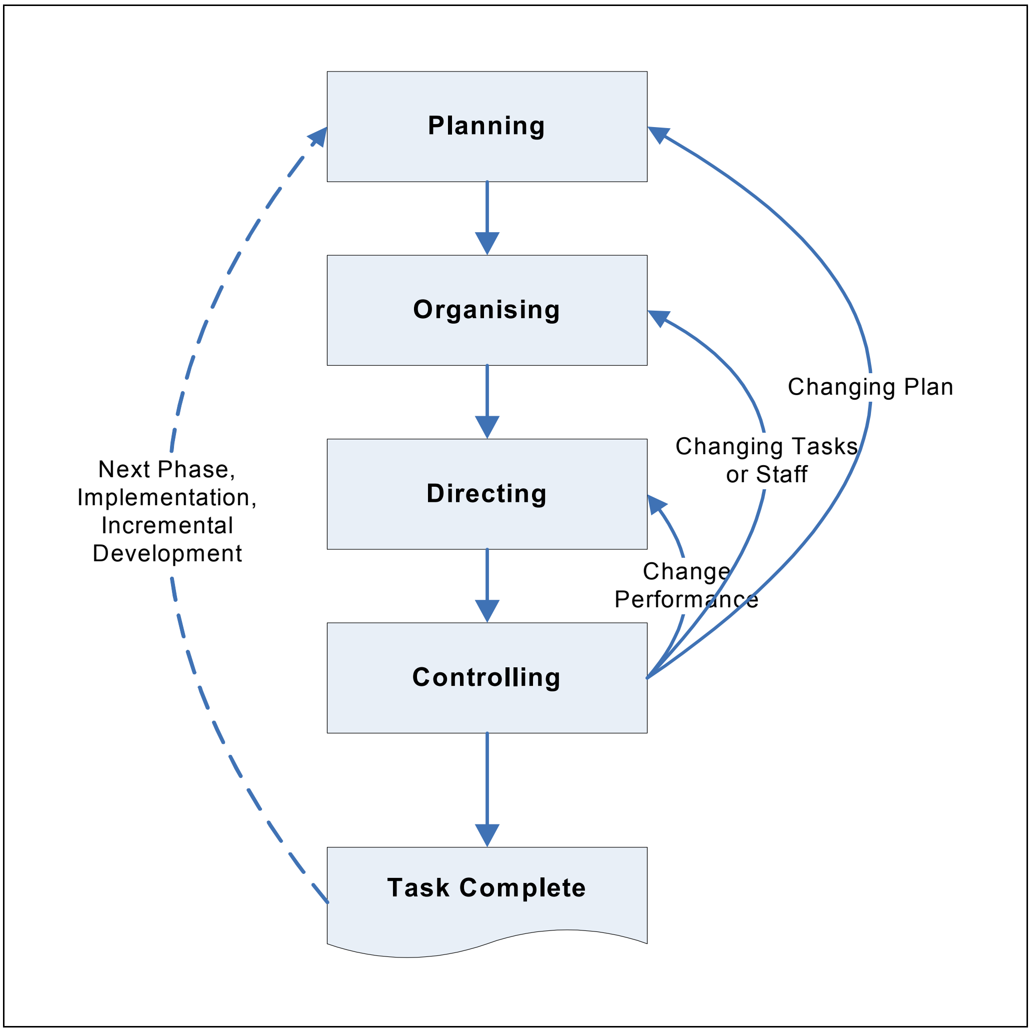


Figure 2-1 Review and Revise Cycle of Management Functions

Table 2-1 Elements of Management Functions with corresponding Responsibilities in Municipal Structure

	Task / Action	Operator	Supervisor	Technical Manager	Head of Department
Planning	Visioning				R
	Define goal				R
	Define objectives				R
Organising	Allocation of authorities and tasks			R	A
	Preparing budget			R	A
	Terms of Reference		S	R	A
	Tender / contracts			R	A
	Hiring qualified staff		S	R	A
	Training of staff		S	R	A
	Allocating time / staff to tasks			R	A
	Appoint external contractor			R	A
	Performance indicators			R	A
Directing	Tasking		S	R	A
	Motivating		S	R	A
	Supervision		S	R	A
	Revision of tasks		S	R	A
Controlling	Data collection	S	R	A	
	Monitoring	S	R	A	
	Data analysis	S	R	A	
	Review			R	A
	Approval of revision = back to P or O			R	A
	Staff performance assessment			R	A

R	Responsible	This role conducts the actual work/owns the problem. There should be only one R.
A	Accountable	This role approves the completed work and is held fully accountable for it.
S	Supportive	This role provides additional resources to conduct the work or plays a supportive role in implementation.

2.2 Legal Context of Groundwater Management

Legal Framework

The **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), as shown in **Figure 2-2**:

Providing municipal water services

Rural water provision

Infrastructure provision and management

Pollution control and water-quality management

Wastewater treatment and disposal

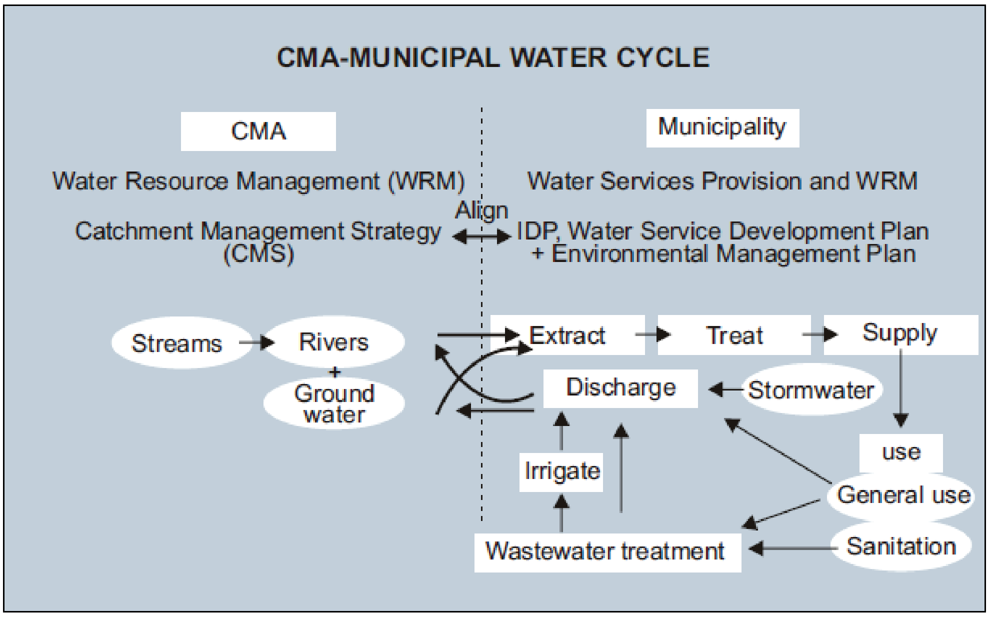


Figure 2-2 Water Resource Management functions between CMA and Municipality (WIN-SA, 2009)

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.

Duties of Water Services Authorities

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).

Duties of Water Services Providers

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. A water services provider must publish a consumer charter which

is consistent with by-laws and other regulations,

is approved by the water services authority, and

includes the duties and responsibilities of both the WSP and the consumer, including conditions of supply of water services and payment conditions.

There are three different municipal structures that need to be considered in this exercise:

Municipality has contracted out the WSP functions

Municipality has separate departments for WSP and WSA functions

Municipality has both WSP and WSA functions in one department

Additional Responsibilities of Local Government

The key responsibilities of the local authorities, 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 DWA.

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.

Hence, the Groundwater Management Framework is part of the IWRM framework and must be seen in the context of other relevant guidelines and activities, e.g.:

Catchment management,

Water Conservation and Demand Management (WC/WDM),

Waste management,

Waste water management,

Water resource management,

Water resource planning,

Water service delivery.

DWA Guidelines – Integrated Water Resource Management

A number of guidelines for groundwater management have been developed internationally and for the South African context. The most relevant for the purpose of this study are the NORAD toolkit (DWAF, 2004), the WRC "Guidelines for the monitoring and management of ground water resources in rural water supply schemes" (Meyer, 2002) and the DWA "Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa" (DWAF, 2008). Other documents include water quality management protocols, minimum standards, the Framework for a National Groundwater Strategy (DWAF, 2007), the National Water Resources Strategy (DWAF 2004), the "Guidelines for Catchment Management Strategies Towards Equity, Sustainability and Efficiency" (DWAF, 2007) and regional groundwater plans, as well as selected national and international articles and publications on groundwater management aspects.

The **DANIDA guideline** (DWAF, 2004) outlines the principles of groundwater management in the context of IWRM. The main authorities involved in groundwater management include

Department of Water Affairs – DWA is responsible for national legislation and planning; the development of national groundwater resource policy, regulation and monitoring, and provision of support to other water resource institutions.

Catchment Management Agencies – CMAs are responsible for water resource management within their water management area.

Water User Associations – WUAs are responsible for function at a local level, representing individual water users and providing vehicles for public participation.

The **Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa** (DWAF, 2008) intends to assist in the sustainable development, protection and management of the groundwater resources, and in achieving the overall goal of integrated water resources management (IWRM) within the Department.

Management of groundwater resources relates to the sustainable use and development of these resources. It focuses on the sustainable development of the groundwater resources without compromising resource integrity (quantity and quality). Management thus involves monitoring quantity and quality over a long term period and the use of information to determine compliance against set goals and to assess whether the strategic goals of the department are being met.

The guideline describes the management principles at the national, the CMA and the site specific level. Management of water resources is enabled through water allocation and water use authorization. Management at site-specific level entails, among others, maintenance and control, monitoring and measurement, data management and reporting, auditing and management of impacts. Review of compliance with water use authorization conditions is undertaken at the catchment level, as well as managing the cumulative impacts of the various water user groups on the system. The auditing of compliance with strategic goals and strategic reviews is undertaken at the national level.

Figure 2-3 indicates the proposed institutional framework for the assessment, planning and management of water resources in South Africa. This framework is underpinned by the formation of an Aquifer Management Committee (AMC) in areas where the aquifer(s) span(s) more than one WMA and Catchment Committees for addressing site-specific issues.

The AMC will be an advisory body (not legislated) to provide strategic input to the assessment, planning and management of the groundwater resources in the affected areas. The Catchment Committee will be a legal entity, set up by the Catchment Management Agency (CMA) in accordance with Section 82(5) of the National Water Act.

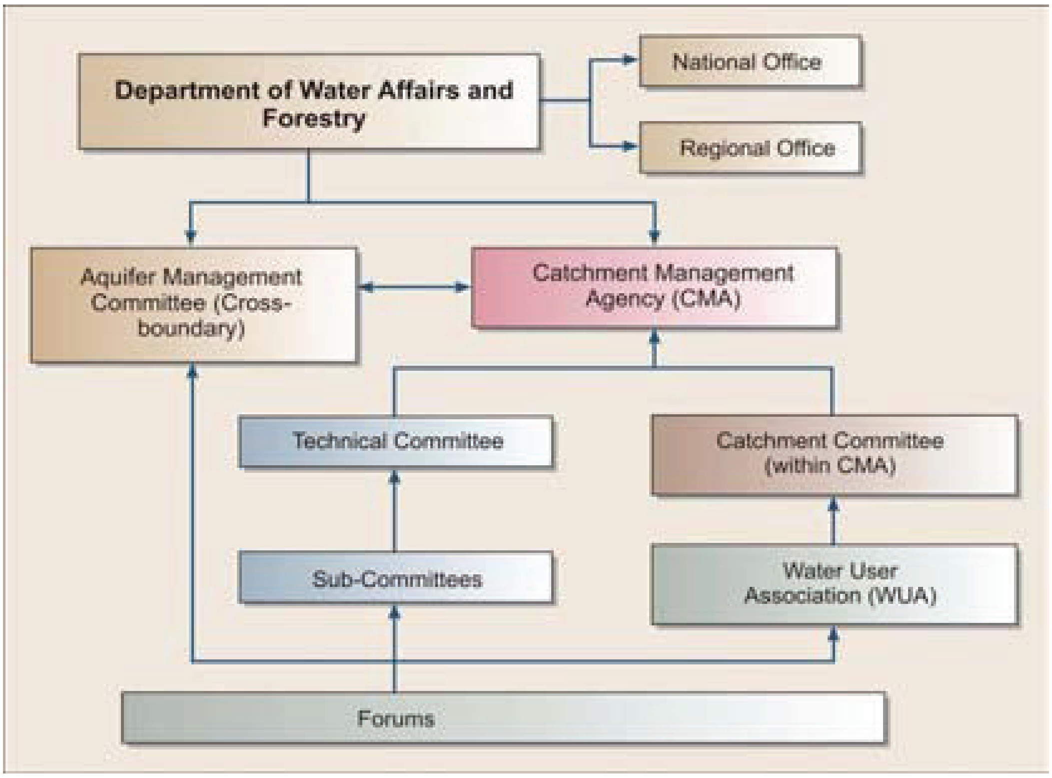


Figure 2-3 Proposed Institutional Framework (DWAF, 2008)

A detailed review of the national and international guidelines and publications with respect to the legal framework, completeness of all relevant aspects, feasibility of implementation and functionality is documented in **Appendix A**. The review concludes with a gap analysis, indicating aspects and management functions that require particular attention:

Comprehensive definition of "groundwater management" and all relevant aspects of it;

Comprehensive definition of the relevant management functions with respect to groundwater management, as defined above;

Mapping of roles and responsibilities of water institutions for the different groundwater management activities, as per comprehensive definition;

Outlining required skills for the different groundwater management activities;

Integrating the different groundwater management guidelines into one document.

These IWRM and groundwater specific strategies, guidelines and frameworks fit into the overarching proposed Groundwater Management Framework, describing specific aspects of the groundwater management. The following guidelines are considered most relevant and become an integral part of the Groundwater Management Framework, as shown in the following sections:

NORAD Toolkit (DWAF, 2004)

Guideline on Assessment, Planning and Management (DWAF, 2008)

WIN-SA Guidelines

DANIDA IWRM Framework

South African Water Quality Guidelines

Minimum Requirements for waste sites

IWRM Plan Guideline

Protection and development of groundwater resources should be achieved in an integrated manner with all components of groundwater management, integrated water resource management and catchment management being taken into account, as formulated in the DANIDA IWRM Framework (see **Figure 2-4**).

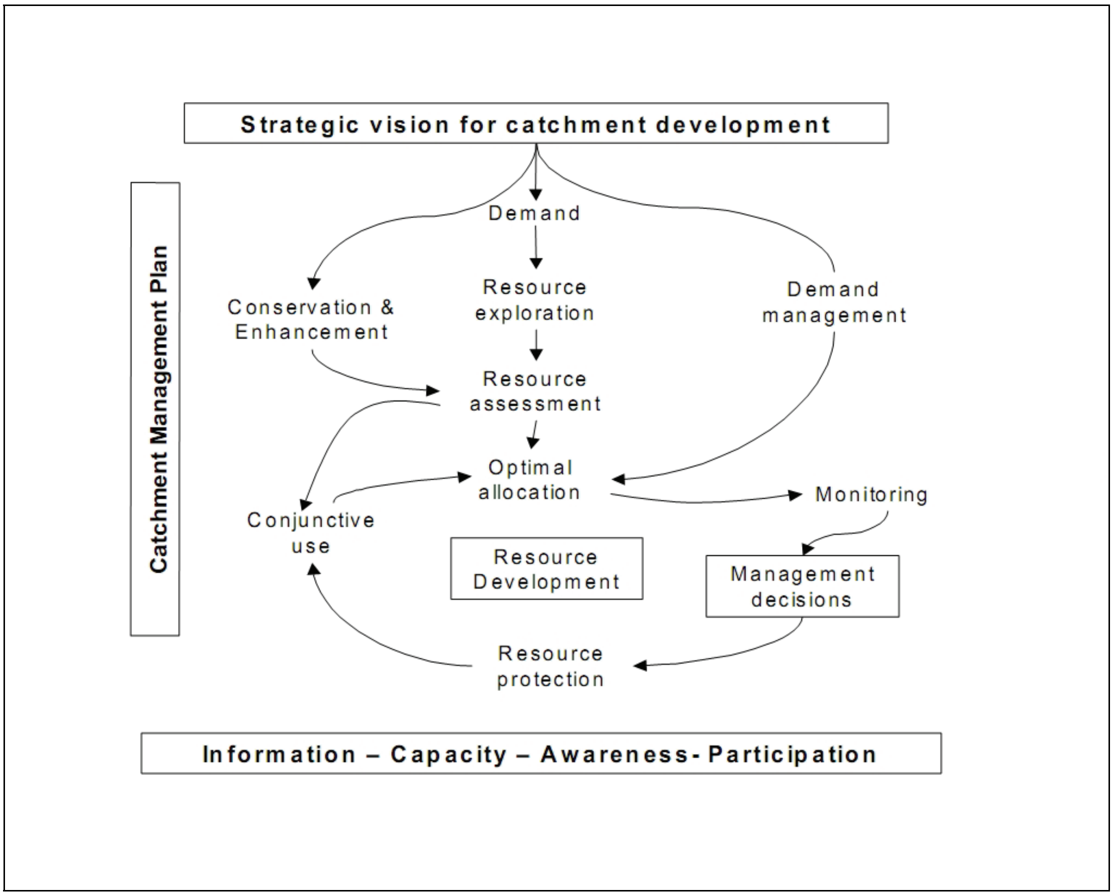


Figure 2-4 Groundwater Management in the context of IWRM and Catchment Management (DWAF, 2006)

2.3 Structure of the Framework

The groundwater management framework provides a guideline for optimal incorporation and integration of the management functions in the municipal structure. The framework is based on the literature review (see **Appendix A**) and an analysis of several case studies of best practice that were prepared for the following towns or municipalities (see **Appendix B** and **Section 7**):

Emthanjeni LM (De Aar),

Overstrand LM (Hermanus, Stanford),

Cederberg LM (Elands Bay),

Baviaans LM (Willowmore).

The case studies are based on available reports, i.e. municipal WSDPs, municipal assessment reports, groundwater assessment reports; and results from a questionnaire that was sent to these municipalities to stimulate interaction and feedback.

In addition to the above mentioned case studies, examples of best practice from the draft report “National Groundwater Strategy: Review of groundwater management examples in South Africa” by J. Cobbing and K. Pietersen (2009) were incorporated into the conclusions.

The main factors of success that emanate from the different case studies are:

Appropriate technology for groundwater monitoring and management;

Scientific support from external consultants on request;

Efficient management structure;

Committed staff; and

Adequate funding mechanism.

The Framework is designed to be applicable at local level of responsibilities, i.e. WSA, WSP, WUA. Hence, the assigned responsibilities and available tools to achieve sustainable groundwater management reflect the local level of Water Institutions. However, the principles of the Framework can be applied at all levels and all scales.

The different aspects of groundwater management, as defined in Section 2.1, relate to two main categories, viz.

Aquifer protection, and

Aquifer utilisation.

In addition, there are two overarching and supporting categories that are relevant for successful groundwater management, viz.

Monitoring, data management and evaluation, and

Valuation of the groundwater source

The overall structure of the Groundwater Management Framework is shown in **Figure 2-5**.

The Framework describes for each category separately the different aspects, associated tasks and assigned responsibilities of the relevant institutions.

The category of “Aquifer Protection” includes all activities to protect the aquifer from deterioration in water quality and reduction in aquifer recharge, and to rehabilitate an aquifer with respect to its water quality, irrespective of whether the aquifer is utilised or not (see **Section 3**). Therefore, the relevant sub-categories are:

Landuse Planning, and

Remediation.

The category of “Aquifer Utilisation” includes all activities to ensure that the groundwater use is sustainable and that impacts from the groundwater use are avoided or mitigated (see **Section 4**). The activities can be grouped into

Groundwater assessment, and

Wellfield operation & maintenance.

All categories and sub-categories require data collection and ongoing monitoring. These activities must be structured and coordinated such that the monitoring data can be utilized for their intended purposes. The monitoring related activities are described in **Section 5** under the following sub-categories:

Monitoring requirements,

Data collection,

Data analysis, and

Data management.

The economic aspect of sustainable groundwater management is of importance for the Local Authority. **Section 6** provides the background and framework for the valuation of the groundwater resource, which feeds into both categories and their sub-categories.

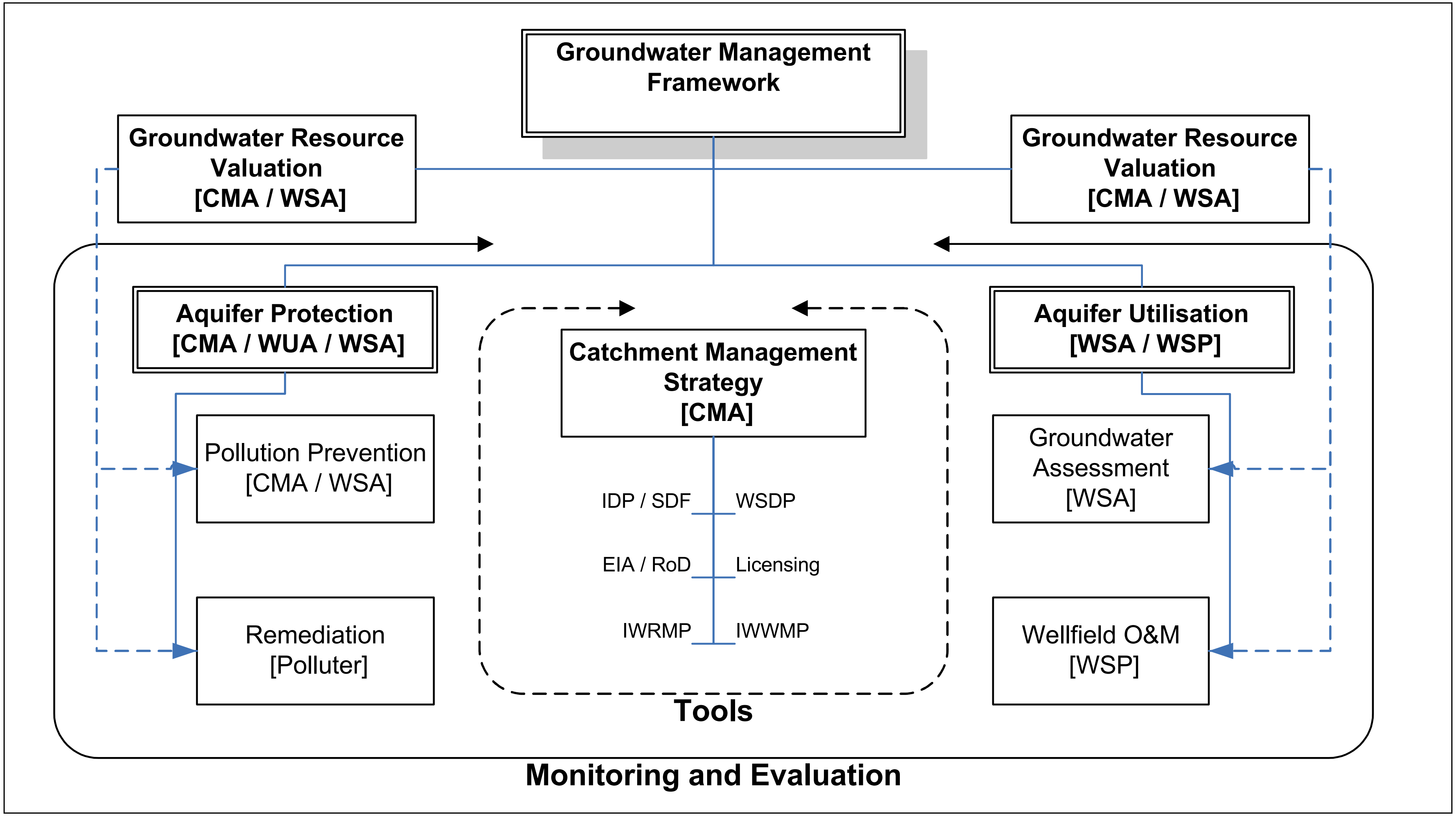


Figure 2-5 Groundwater Management Framework with Categories, Sub-categories and main Tools (Further details are shown on Figure 3-1, Figure 4-1 and Figure 5-2).

2.4 Responsible Water Institutions

There are a variety of role players, who are responsible for some of the above aspects of groundwater management at different levels:

The Department for Water Affairs

The Department of Environmental Affairs

Catchment Management Agency

Water User Association

Local or District Municipality

Water Services Authority

Water Services Provider

Water Board

Water user (e.g. private, company)

Water polluter

Table 2-2 Responsible Water Institutions for Aspects of Groundwater Management

		DWA/ DEA	CMA	LM / DM	WSA	WSP	WUA	Water user / Polluter
Aquifer Protection								
	Landuse planning		X		X		X	
	Waste management	Reg		X				
	Effluent quality management	Reg				X		
	Groundwater remediation	Reg						X
	Groundwater monitoring		X		(X)		X	X
Aquifer Utilisation								
	Groundwater assessment				X			
	Licensing	X			(X)			
	Wellfield planning and design				X	(X)		
	Wellfield operation and maintenance					X		X
	Groundwater monitoring				X	X		X

Reg = Regulator

X = Main responsibility

(X) = Input, partial responsibility

3 AQUIFER PROTECTION

> ”Water is the true wealth in a dry land; without it land is worthless or nearly so. And if you control water, you control the land that depends on it.” Wallace Stegner (1954)

The category of “Aquifer Protection” includes all activities to protect the aquifer from deterioration in water quality and reduction in aquifer recharge, and to rehabilitate an aquifer with respect to its water quality, irrespective of whether the aquifer is utilised or not. Therefore, the relevant sub-categories are:

Pollution Prevention, and

Remediation.

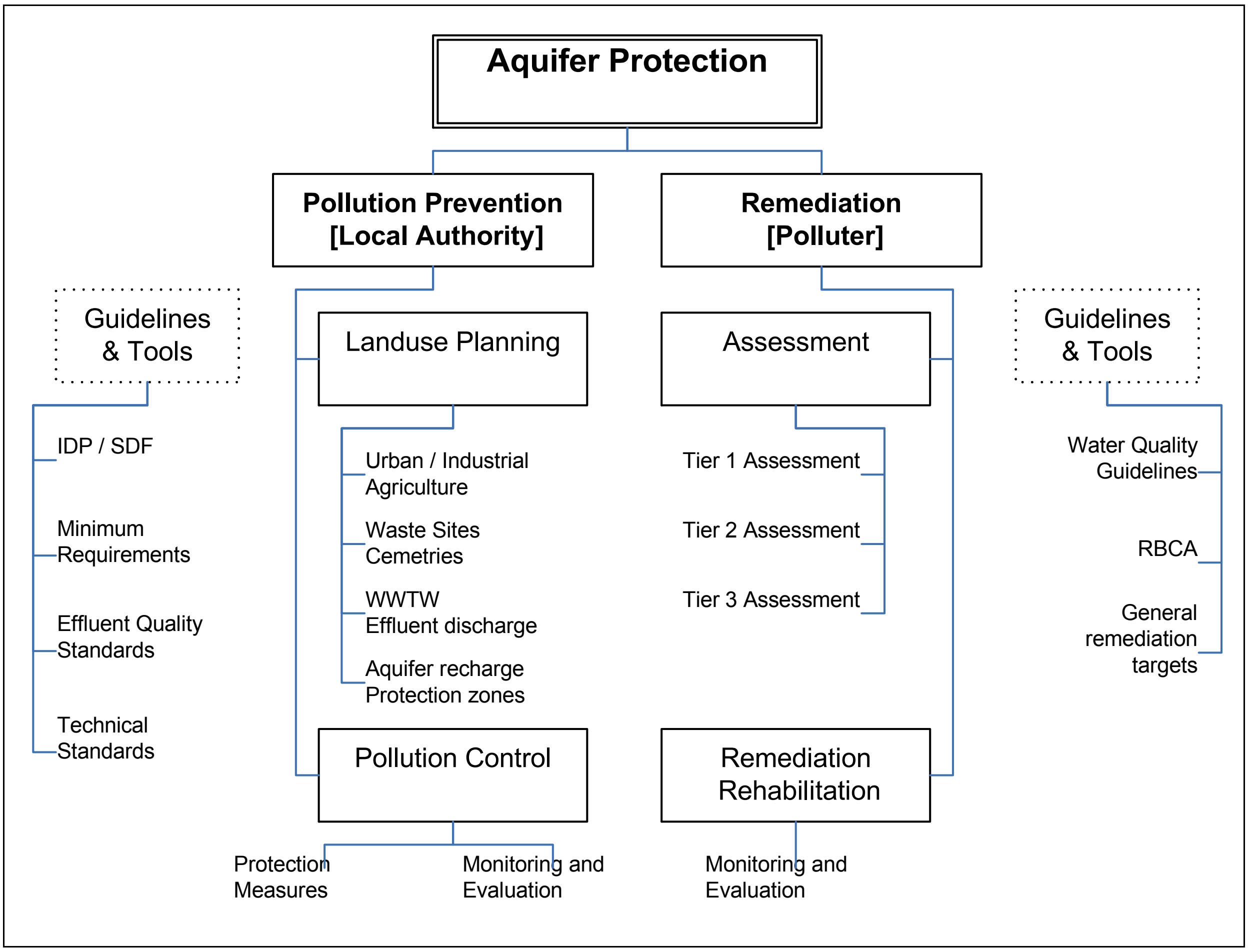


Figure 3-1 Aquifer Protection Category with Sub-categories ‘Pollution Prevention’ and ‘Remediation’, Aspects and details per sub-category and available Guidelines and Tools

3.1 Pollution Prevention

The prevention of aquifer pollution and degradation is achieved on Local Government level with two main tasks; viz. landuse planning and pollution control measures.

The proposed Integrated Water Resource Management Plan Guidelines for Local Authorities (DWAF & WRC, 2006) lists the following objectives of a generic IWRM strategy that are relevant for groundwater protection:

Manage land use effectively for protection of the riparian zone (green corridors) and water resources and maintenance of biodiversity;

Good housekeeping will be maintained to minimise the risk of pollution;

Limit erosion and the consequent degradation of soil and pollution of air and water;

Prevent damage to receiving watercourses from runoff arising from urban drainage;

Prevent damage to groundwater from seepage arising from the Local Authority's activities; and

Promote socio-economic development

The management of groundwater quality requires integrated strategies that take this variety of possible impacts on groundwater quality into account (see **Figure 3-2**).

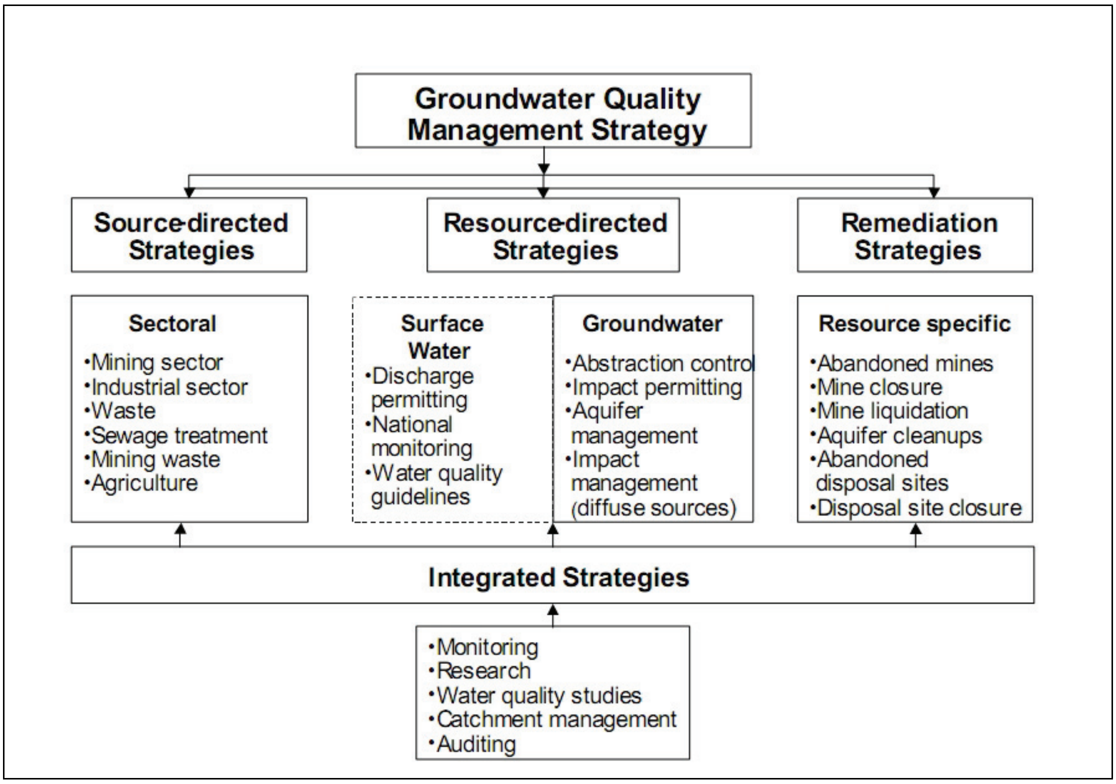


Figure 3-2 Integrated Groundwater Quality Management Strategies (DWAF, 2006)

Landuse Planning

Landuse planning involves the spatial demarcation or zoning of areas for specific use, and the determination of restrictions of land use within these areas. Furthermore, the implementation of the zoning and the effectiveness of the zoning and restrictions with respect to water quality and aquifer recharge needs to be monitored and evaluated regularly.

Special protection is required for aquifer recharge areas, as well as for unconfined aquifers that are vulnerable to contamination. Specific tasks, such as siting and monitoring of landfill sites, cemeteries and WWTWs, location of industrial and agricultural areas and establishment of groundwater protection zones for wellfields fall under this sub-category (see **Figure 3-1**).

Zoning and development is a component of the IDP and must reflect in the municipal SDF. The management of landuse should include the evaluation of zoning, potential restrictions on land use, development and conservation of urban open space and remediation measures, if required.

Pollution Control

While landuse planning is concerned with the general potential impact of activities on the groundwater quality and quantity, the element of pollution control involves direct measures to ensure that the potential impact is reduced further and mitigated against. This element includes activities such as

Leachate collection systems at landfill sites;

Adequate cover measures for landfill sites after closure;

Upgrade of waste water treatment works to ensure good effluent water quality;

All of these pollution control measures require ongoing monitoring to ensure the effective implementation and to allow for improvements of the measures, if negative trends are detected. Hence, the monitoring also acts as early warning system.

An important aspect is the ongoing groundwater monitoring with respect to possible pollution and alteration of aquifer recharge. The monitoring results need to be evaluated with respect to compliance with determined Source Directed Measures (SDM) and general trends of water quality. Similarly, the effect of developments on aquifer recharge needs to be evaluated, based on monitoring data. Negative results could lead to either further policing of the agreed zoning, changing the zoning to better protect the aquifer, corrective and preventative actions at the sources to avoid further deterioration, or remediation of any pollution.

The overarching elements of the monitoring aspect are discussed in Section 5.

3.2 Remediation

Remediation involves the assessment of potential groundwater contamination and the subsequent planning and execution of the remediation to achieve the acceptable and agreed upon water quality indicators. Both are underpinned by ongoing monitoring to assess the water quality and verify the clean-up results.

To develop realistic, cost-effective and site-specific remedial options, it is imperative that the remediation be designed and conducted within the context of an accepted decision making framework such as Risk Based Corrective Action (RBCA).

The *ASTM E1739*-2002 – *Risk Based Corrective Action (RBCA) at Petroleum Release Sites* describes the risk-based corrective action (RBCA) as – ‘a consistent decision making process for the assessment and response to a petroleum release, based on the protection of human health and the environment’. The standard identifies drivers for remediation such as potential (or confirmed) exposure to sensitive receptors. Furthermore the standard facilitates in determining acceptable residual level of contamination which can be incorporated into determining potential clean up target levels. RBCA uses a three-tier approach with different levels of investigation.

Under the RBCA planning process, sites are first classified with regards to the current magnitude and immediacy of human health and environmental risks, using the source – pathway – receptor approach for the assessment. Remedial measures can include one or more of the following:

Removing or treating the source,

Interrupting contaminant transport mechanisms along the pathway,

Controlling activities at the point of exposure (receptor).

Although not legislated, the *ASTM E1739- 2002* represents a consensus standard in the USA, and is internationally accepted.

The levels of responsibility and involvement of staff from the various relevant institutions at different levels for the different aspects are shown in **Table 3-1**. The meaning of the labels is given below:

R	Responsible	This role conducts the actual work/owns the problem. There should be only one R.
A	Accountable	This role approves the completed work and is held fully accountable for it.
S	Supportive	This role provides additional resources to conduct the work or plays a supportive role in implementation.
C	Consulted	This role has the information and/or capability to complete the work. Two-way communication (typically between R and C).
I	Informed	This role is to be informed of progress and results. One-way communication (typically from R to I).

Table 3-1 Responsibility Matrix for aspects of Aquifer Protection

	WSA					WSP / Water Board					DWA / CMA			WUA			DEA			
Aquifer protection (SDM)	Labour	Operator	Supervisor	WR Manager	Head Department	Labour	Operator	Supervisor	Manager	Head Department	Technician	WR Manager	Head Department	Technician	WR Manager	Chairman	Case Officer	Manager	Head Department	Polluter
Landuse																				
Catchment Management Strategy				C								R	A		C	I				
Development / update of IDP / SDF				R	A							I			C	I				
Landuse planning				R	A							R			C	I		I	I	
Waste management									R	A		I			C	I		I	I	
Waste water management				I					R	A		I			C	I		I	I	
Effluent quality management				I		S	R	A	I			I						I	I	
Remediation																				
Groundwater remediation				I								C						I	I	R/A
Monitoring																				
Groundwater monitoring	S	R	A	I								I		S	I	I				
Regional GW Monitoring				I							R	I	A	S	I	I				
GWQ Monitoring (Pollution)				I		S	R	A	I			I		S	I	I		I	I	R
Ecological Monitoring											R	I	A	S	I	I		I	I	

4 AQUIFER UTILISATION

> "Adaptive management shall be thought of as managing the people who interact with the ecosystem, not management of the ecosystem itself." (Lowry, 2002; in Bidwell, 2003)

The category of "Aquifer Utilisation" includes all activities to ensure that the groundwater use is sustainable and that impacts from the groundwater use are avoided or mitigated. The activities can be grouped into

Groundwater assessment, and

Wellfield operation & maintenance.

Both subcategories require ongoing monitoring and evaluation for successful implementation; however, the scale and frequency of monitoring differ between activities and depend on the scale of the investigation.

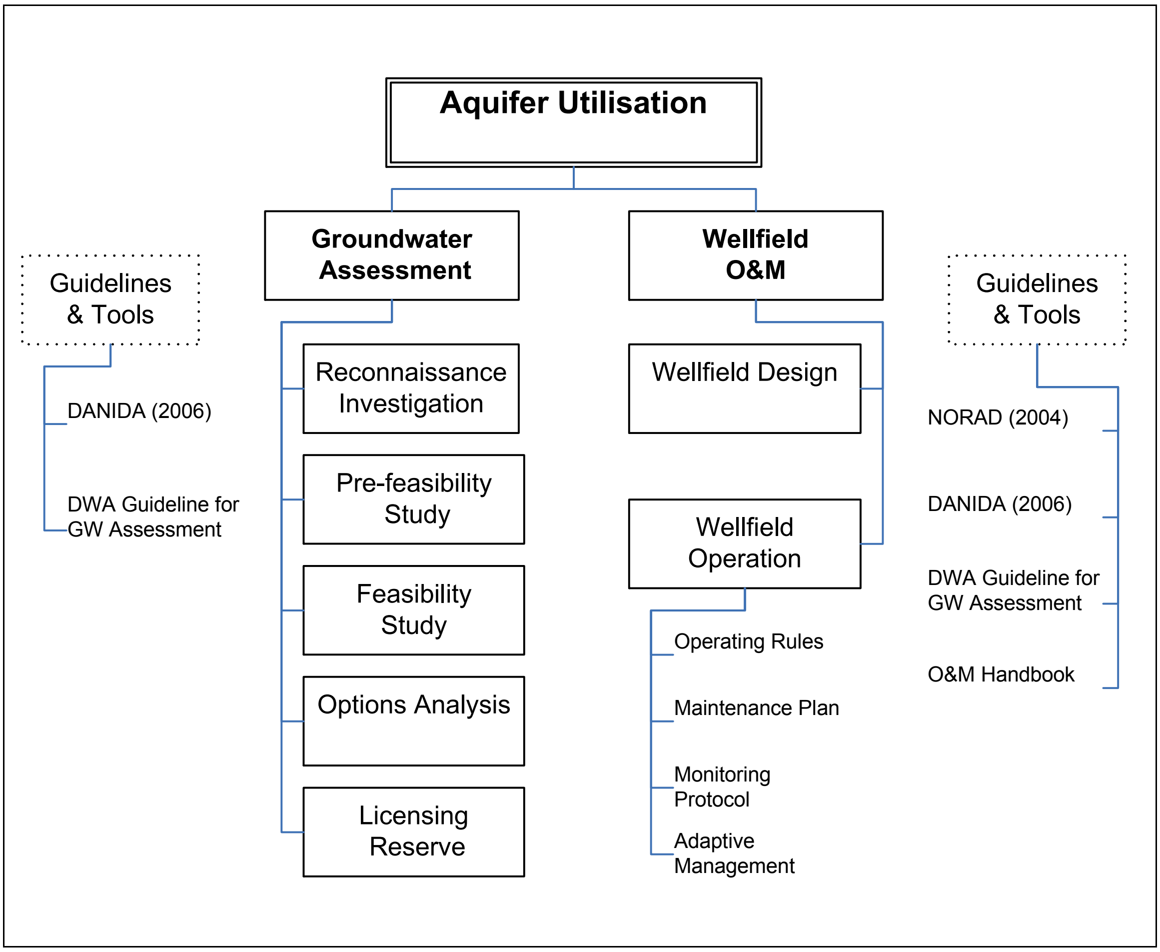


Figure 4-1 Aquifer Utilisation Category with Sub-categories 'Groundwater Assessment' and 'Wellfield O&M', Aspects and details per sub-category and available Guidelines and Tools

4.1 Groundwater Assessment

The development of aquifer schemes and implementation of wellfields should follow a standard project process, which is similar to other infrastructure development. The main elements of this process are shown in **Table 4-1**.

The structure follows the statement of the previous head of DWAF Geohydrology Directorate, J.R. Vegter (2001, p. 38-39): *"Ecologically acceptable and sustainable groundwater exploitation evidently cannot be determined prior to the development of the groundwater resource. It is only through exploratory drilling and testing that the structure of the groundwater system and its spatially variable hydraulic parameters may be determined. <u>Fixing of groundwater's contribution to the ecological reserve before development is not feasible</u> (his emphasis) … Instead of attempting to determine an ecological reserve and a fixed sustainable yield of questionable substance, a flexible open-ended approach in understanding and managing these systems is essential …".* (extract from:"Groundwater Development in South Africa, etc.", Water Research Commission Report TT 134/00.)

Table 4-1 Phases of Groundwater exploration and development

Level of Study	Product / Decision	Data collection	Confidence
Conceptualisation	Inception / Planning Report	Expert evaluation of existing data	50%
Reconnaissance	ID Target Areas Recommendation for and prioritisation of monitoring	Primarily desktop work with limited fieldwork and data collection, as required (e.g. Hydrocensus) 1^{st} order water balance model	60%
Pre-feasibility	Environmental monitoring and assessment ID Target Sites	Geological and ecological mapping Installation of monitoring infrastructure and ongoing monitoring of relevant processes Re-calibrate water balance model	70%
Feasibility	Exploration Yield estimation License & EIA application Feasibility Report	Site survey, borehole siting Drilling and testing of exploration boreholes Regional groundwater modeling Invest in collecting all relevant input for design purposes	80%
Options Analysis	Options Analysis Report	Comparison of different options for water supply, based on feasibility studies	80%
Design *	Wellfield design and implementation Operating rules	Design all components of the scheme Wellfield model	90%
Operation & Maintenance *	Operation & Maintenance	Ongoing monitoring	95%

* Part of the "Wellfield O&M" Category

Since the responsibility changes from the WSA for “Groundwater Assessment” to the WSP for “Wellfield Operation & Maintenance”, it is important to involve the WSP representatives during the “Groundwater Assessment” so that the hand-over of responsibility is facilitated by the regulatory function of the WSA.

The Guideline for the Assessment, Planning and Management of Groundwater resources in South Africa (DWAF, 2008) distinguish between “Assessment” and “Planning” rather than the level of study.

Assessment determines the status quo (in terms of both water quantity and quality) of the groundwater resources in a particular area, and defines the geographic extent of the aquifer system(s). Assessment includes the determination of the aquifer resource capability with respect not only to sustainable, economic and technically feasible abstraction but also to the impact of such abstraction on spring and river flow (i.e. ecological requirements). Assessment also summarises existing water requirements for all sector users, taking into account demographic and socio-economic changes.

The steps required to assess the groundwater resources and to prepare inputs for the subsequent planning phases are similar irrespective of the scale and level of detail. The process includes such aspects as existing use, development potential as a bulk or local water supply, importance of springs and baseflow, dependence of ecology and identifying potential impacts. The application of this methodology will vary for the different levels of studies due to the scale and/or spatial intensity of the investigations.

Planning within IWRM is a process of matching water availability with water requirements. Planning typically involves the investigation of development options to meet water requirements through a predetermined sequence of increasingly detailed phases. Planning generally follows an assessment during which the various water development options (including groundwater options) are identified. Planning ensures that the information is made clear to the decision-maker.

Reconnaissance level assessment includes a desk study to obtain information on water availability and requirements over various catchments/ compartments. Depending on the amount and nature of the date available it might be necessary to undertake the collation of information from boreholes and springs. The main outcome is the identification of potential target areas and determination of monitoring requirements.

Pre-feasibility level assessment has its focus on one or more aquifers in a catchment. The aim is to determine the parameters of the target aquifer(s) in sufficient detail from existing boreholes and to establish a monitoring network for baseline data collection.

The **feasibility level** planning is preceded by a detailed assessment of the feasible options at the site-specific level. The assessment will include siting, drilling and testing of boreholes, and then using this information to derive a conceptual hydrogeological and, if necessary and applicable, a numerical model of the aquifer. The study includes a detailed assessment of the target area to determine the ability of the aquifer in that area to support the requirements on a sustainable basis.

The feasibility level planning study is an intensive investigation and optimisation of the most beneficial layout of the scheme under investigation, resulting in the best layout of the scheme and its major dimensions and final specifications. This study will provide sufficient information to enable detailed design of the preferred scheme.

At the end of the feasibility study, an application for a **water use licence** in terms of the NWA as may be required from the Department of Water Affairs or the CMA and for **environmental authorization** in terms of the National Environmental Management Act (NEMA) (Act No. 107 of 1998) should be submitted to the relevant authorities. Although not a legal requirement, it is recommended that the WSA appoint their hydrogeological consultant to undertake the Reserve Determination Study.

Options analysis involves the undertaking of sufficient pre-feasibility level or feasibility level design and costing to be in a position to assess the various water use options. Each option should be assessed on the basis of:

a) social considerations,

b) potential environmental impact,

c) economic and financial viability,

d) technical feasibility,

e) long-term land use, and

f) regulatory considerations.

The water use options need to be ranked using the results of the options analysis.

4.2 Wellfield Operation & Maintenance

The design and implementation of a wellfield, as well as the ongoing operation of the wellfield is grouped under this Category, as these are strongly linked in terms of sustainable groundwater management. The management options during the operation need to be considered during the design and construction phase.

Wellfield Management

Management of groundwater resources relates to the sustainable use and development of these resources. It focuses on the sustainable development of the groundwater resources without compromising resource integrity (quantity and quality). Management thus involves monitoring quantity and quality over a long-term period and the use of this information to determine compliance against set goals and to assess whether the strategic goals of the Department are being met.

Management is generally an iterative process that has two components:

Setting management objectives, including strategic objectives set at a national level, the catchment management strategy (CMS) and management plans set at catchment and site-specific levels, and

Monitoring and reporting against these objectives, as well as updating the strategies and management plans on an ongoing basis.

Monitoring and reporting will provide information to assess the operations against the strategic goals and objectives (compliance assessment). The results of the compliance auditing will be used to devise action plans and update the strategic goals, if required.

The guiding principles for groundwater management are defined in the NORAD Toolkit (DWAF, 2004) as:

Integration of monitoring activities with O&M activities (Operation and maintenance) of the WSA or WSP.

Groundwater monitoring should be part of a monitoring scheme that includes all aspects of a schemes operation.

Processing only data necessary for groundwater management.

Integrate with other WRM institutions.

Wellfield management for water supply purposes requires maintaining a groundwater management system and integrating it into O&M activities (see below). Different institutions need to contribute to the operation of the system. Their responsibilities will include one or more of the following:

Responsibility for data collection.

Responsibility for ensuring that the data is analysed by an experienced groundwater professional (which includes payment for this service if consultants are used).

Responsibility for ensuring that the data is passed on to relevant authorities, such as DWA and CMAs.

Responsibility for ensuring that the management recommendations are heeded.

The proposed institutional model for groundwater management that is based on existing legal requirements and the guiding principles (see above) is outlined below:

The CMA is responsible for setting up the groundwater management system to allow for evaluation of compliance with licence conditions.

The WSA is the local groundwater manager, because groundwater management and O&M (ultimately, a WSA responsibility) are closely linked.

The WSA may delegate some or all of the groundwater management responsibilities to WSPs. If so, this would be incorporated into the water services provision contract (WSPC). The nature of the responsibilities that can be delegated would depend on the capacity of the particular WSP.

The WSP will collect relevant groundwater data and pass it on to the WSA. This should be included in the WSP contract, together with scheduling O&M activities and monitoring scheme performance. The additional tasks involved with groundwater monitoring are small in comparison to the necessary tasks required for on-going O&M and scheme performance assessment. By including groundwater monitoring scheduling in the WSP contract a comprehensive O&M monitoring plan can be developed.

The WSA will analyse the data and inform the WSP of operational improvements that should be made such as modifying pumping schedules.

The WSA will provide the CMA and DWA with a summary report on groundwater use, water quality, water levels and compliance.

Where the WSA also fulfils the role of the WSP, all the roles and functions of groundwater monitoring would be retained by the WSA. The WSA can enter into service contracts with external organizations to assist them with specific tasks and this could include some of the functions of groundwater monitoring and reporting. The different staff functions required for the groundwater management system are:

Pump operator.

Pump operator supervisor.

Data capture clerk.

Technical manager.

Health manager.

Groundwater management involves the management of data collection, transfer and analysis and implementation requirements (see **Figure 4-2**). Key to success of this is provision of training to pump attendants, administrators in local government and water service institutions to collect reliable and accurate data.

It is only possible to manage a resource on a sustainable basis, if the system and the factors influencing the resource are understood and monitored. The collection of data and information improves the knowledge and understanding of the resource and helps to predict the impacts of changes to the resource. Based on the prediction (i.e. model) the changes to the resource are managed and the impacts are monitored, which in turn provides relevant information to improve the understanding of the resource and the prediction of impacts. This approach is called Adaptive Management and follows the motto: Monitor – Model – Manage (Hay et al., 2006).

What is most notable about adaptive management is its emphasis on monitoring programs and the assimilation of monitoring results into analytical or numerical models for testing a working hypothesis, or preferably multiple working hypotheses, about aquifer responses. Models are then developed in an iterative way as new data and insight becomes available. The new information should be used to review and revise the conceptual model prior to any revisions to the numerical model. If this is done the model results will improve. This is using a model in management mode. The updated predictions of the revised model are then translated into operational rules, which once implemented changes the operation and management of the resource. Then the cycle of monitor – model – manage starts again (see **Figure 4-2** and **Figure 4-3**).

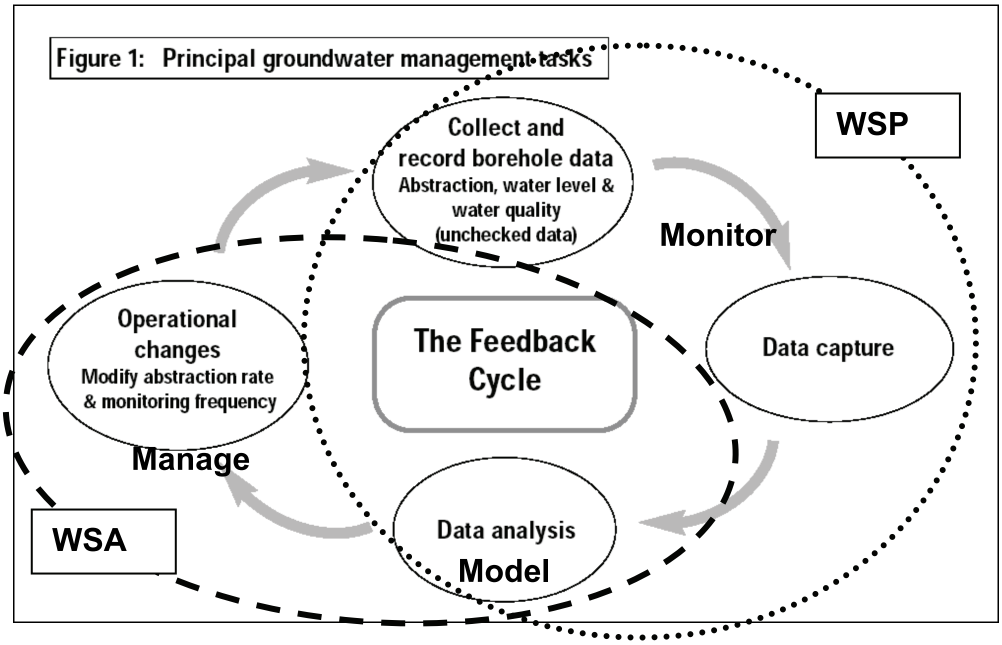


Figure 4-2 The Feedback Cycle of Groundwater Management (adapted from DWAF, 2004)

O&M activities and schedules

Possibly the most important element of groundwater management is day to day operation and maintenance (O&M). O&M refers to the mainly routine tasks that should be carried out in the course of operating a groundwater supply scheme. A groundwater supply scheme might be as simple as a single borehole with a hand pump, although schemes usually involve more than one borehole, pipe-work, electrical control systems, treatment systems, etc. O&M tasks include maintaining infrastructure (cleaning and descaling pipes, replacing worn out components, cleaning of boreholes, checking the operation of switchgear, etc.) as well as the monitoring of groundwater levels, groundwater quality, water demand, etc.

O&M tasks can be thought of as necessary for asset management. In contrast to data collection and “resource management”, there is very little information in the literature regarding O&M, yet in most cases it is a failure of O&M rather than a failure of the regional groundwater resource that leads to groundwater scheme disruption and failure.

The regular operation and maintenance activities include checking, cleaning and eventually replacement of:

Borehole underground conditions, e.g. casing, gravel pack,

Borehole equipment, i.e. pump, rising main,

Pump house and pump installations above ground,

Borehole yard, manhole cover, pipelines, joints and valves,

Measurement devices and telemetry system,

Electrical installations.

Technical Managers must enforce both an electrical and mechanical scheduled maintenance routine. Maintenance personnel must carry out these simple tasks whether a system is broken or not. Basic first-line maintenance is an absolute necessity for sustainable operation of any borehole and plant and should be conducted conscientiously. The O&M activities and schedules must adhere to the maintenance requirements specified by manufactures of pumps and equipment.

There are many factors that determine the quality of O&M. The main ones are quality of staff, access to dedicated O&M funds, and the quality of records and analysis of information. This requires resources like motivated staff, necessary tools, equipment, consumables, transport – and careful planning. It is the responsibility of the WSA and or their consultant to provide an O&M Manual for each borehole separately and for the complete wellfield.

Monitoring and Evaluation

The ongoing monitoring and evaluation of data underpins both the groundwater assessment to increase the confidence in yield estimations and the wellfield O&M to allow for adaptive management. Depending upon the level of investigation and the management options during operation, the scale, frequency, parameters and sophistication of equipment will vary widely. However, it is pertinent to adopt the appropriate level of monitoring and data evaluation.

Since the evaluation of monitoring data must provide sufficient detail to allow for changing management options and operating rules, a crucial part of the evaluation process is seen as predictive modelling. The activities of data collection, data evaluation and changing operating rules are assigned different responsibilities, hence, the feedback cycle between these steps must be set as part of institutional arrangements.

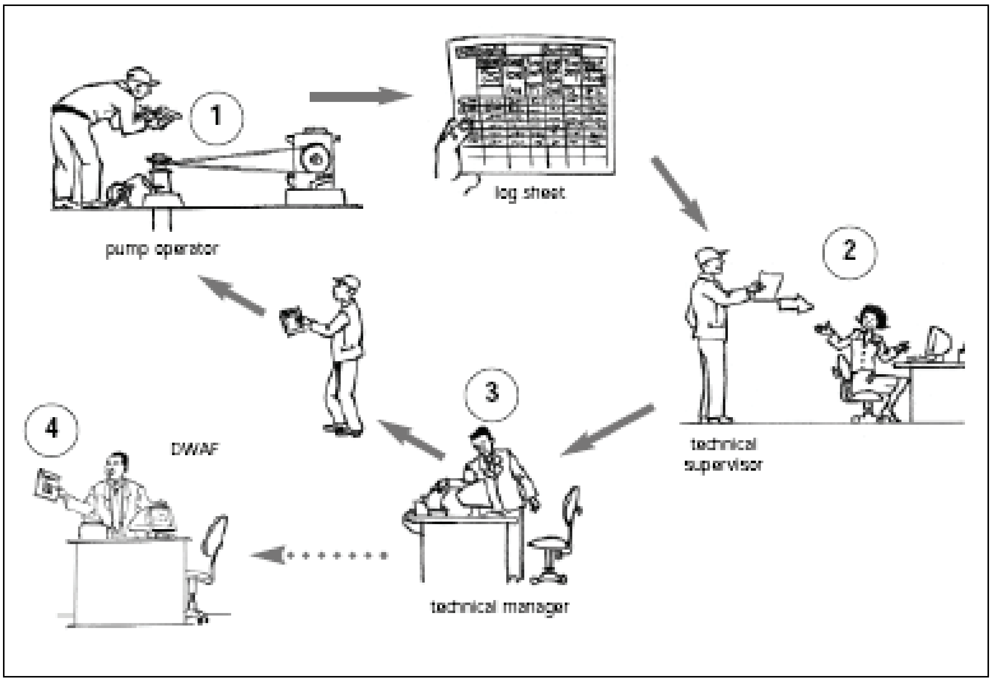


Figure 4-3 Groundwater Monitoring Feedback Cycle (DWAF, 2004)

The levels of responsibility and involvement of staff from the various relevant institutions at different levels for the different aspects are shown in **Table 3-1**. The meaning of the labels is given below:

R	Responsible	This role conducts the actual work/owns the problem. There should be only one R.
A	Accountable	This role approves the completed work and is held fully accountable for it.
S	Supportive	This role provides additional resources to conduct the work or plays a supportive role in implementation.
C	Consulted	This role has the information and/or capability to complete the work. Two-way communication (typically between R and C).
I	Informed	This role is to be informed of progress and results. One-way communication (typically from R to I).

Table 4-2 Responsibility Matrix for aspects of Aquifer Utilisation

	WSA					WSP / Water Board					DWA / CMA			WUA			DEA		
Groundwater development (RDM)	Labour	Operator	Supervisor	WR Manager	Head Department	Labour	Operator	Supervisor	Manager	Head Department	Technician	WR Manager	Head Department	Technician	WR Manager	Chairman	Case Officer	Manager	Head Department
Groundwater Assessment																			
Reconnaissance Study				R	A				I	I		C			I	I			
Pre-feasibility Study				R	A				I	I		C			I	I			
Feasibility Study				R	A				I	I		C			I	I			
Options Analysis				R	A				I	I		C			I	I			
License application				R	A				C	I		C			C	I			
Reserve Determination				C	I				C	I	S	R	A		C	I			
EIA / RoD				C	I				C	I		C			C		R	C	A
Licensing				C	I				C	I		R	A		C	I		C	
Wellfield O&M																			
Wellfield planning and design				I					R	A		I						I	
Wellfield development				I				S	R	A		I						I	
Wellfield operation and maintenance				I		S	R	C	A		S	I		S				I	
Monitoring																			
Groundwater baseline monitoring	S	R	C	I	A						S	I		S	I			I	
Groundwater compliance monitoring				I		S	R	C	I	A		I			I			I	

5 MONITORING, DATA MANAGEMENT AND EVALUATION

"Monitoring may be defined as repeated measurement of a series of defined variables. Monitoring allows for assessing changes in the environment over time. Where baseline data are not available, monitoring activities can help establish them and assess changes from that point forward. It is inherently a long-term activity, since annual fluctuations may not be meaningful but over many years important trends may clearly emerge. The point of monitoring is to gather information in order to accomplish specific goals, e.g., to develop policies and best practices for conservation and sustainable development. It can provide scientists with biological and environmental data. It can also identify trends and discriminate between natural, anthropogenic, and climatic changes. The results can be used at local, regional and global levels for a variety of specific purposes."

(UNESCO, 2001)

An integral part of all aspects of groundwater management is the ongoing monitoring and evaluation to ensure that the implemented measures are effective and the groundwater development is sustainable. The details of the monitoring activities, monitoring parameters, etc. vary depending upon the purpose of monitoring (see descriptions in Section 3 and 4) and the local circumstances. Since monitoring is a crucial aspect of aquifer management, the implementation of an overarching approach to monitoring is important to ensure that the relevant data are collected at the right place and right time, the data are analysed regularly and to a standard that allows for management decisions to be taken.

The National Water Act [NWA] (Act 36 of 1998) stipulates in Chapter 14 the need for monitoring as part of water resource management:

> *Monitoring, recording, assessing and disseminating information on water resources is critically important for achieving the objects of the Act. Part 1 of this Chapter places a duty on the Minister, as soon as it is practicable to do so, to establish national monitoring systems. The purpose of the systems will be to facilitate the continued and co-ordinated monitoring of various aspects of water resources by collecting relevant information and data, through established procedures and mechanisms, from a variety of sources including organs of state, water management institutions and water users.*

Although the Minister has the duty to establish a **national monitoring system**, which "*must provide for the collection of appropriate data and information*" (Section 137 (2)), there is no requirement in the Act that the DWA must undertake the monitoring itself. The data collection can and often is undertaken by water management institutions and water users.

The information gathered during investigation and monitoring needs to be provided to the DWA, if it is required for "*the management and protection of water resources.*" (Section 141 (b)). Information contained in the monitoring information system is then made available to the public (Section 142).

The DWA recognises four main purposes for groundwater monitoring (DWAF, 2004):

Reference (natural or background conditions),

Regulatory or compliance monitoring,

Site specific monitoring, and

Early warning and surveillance monitoring

The roles and responsibilities of water management institutions for groundwater monitoring are given in **Figure 5-1**:

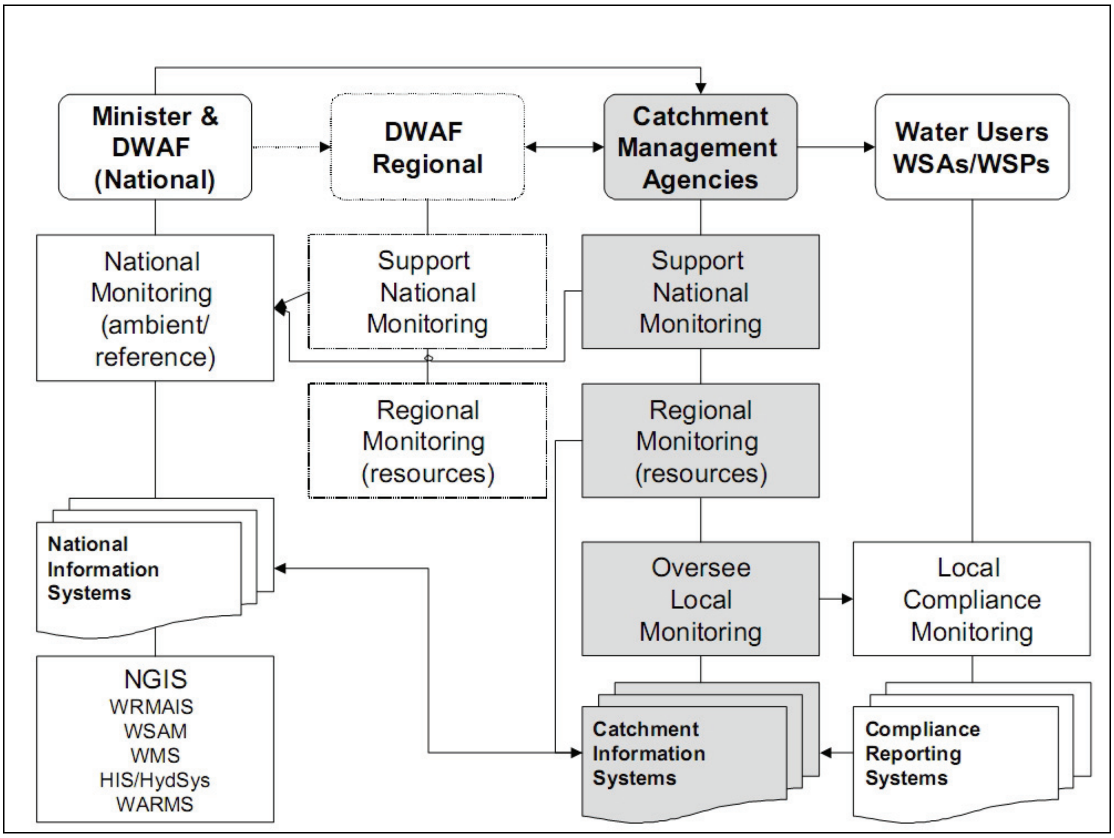


Figure 5-1 Responsibilities for Groundwater Monitoring (from DANIDA Guideline, DWAF 2004)

The monitoring and data management category comprises five distinct, but linked tasks (see **Figure 5-2**) that are described below:

Development of a Monitoring Protocol

Design and Set-up of a Monitoring Network

Data Collection and Collation

Data Processing

Data Analysis and Evaluation

Data Management

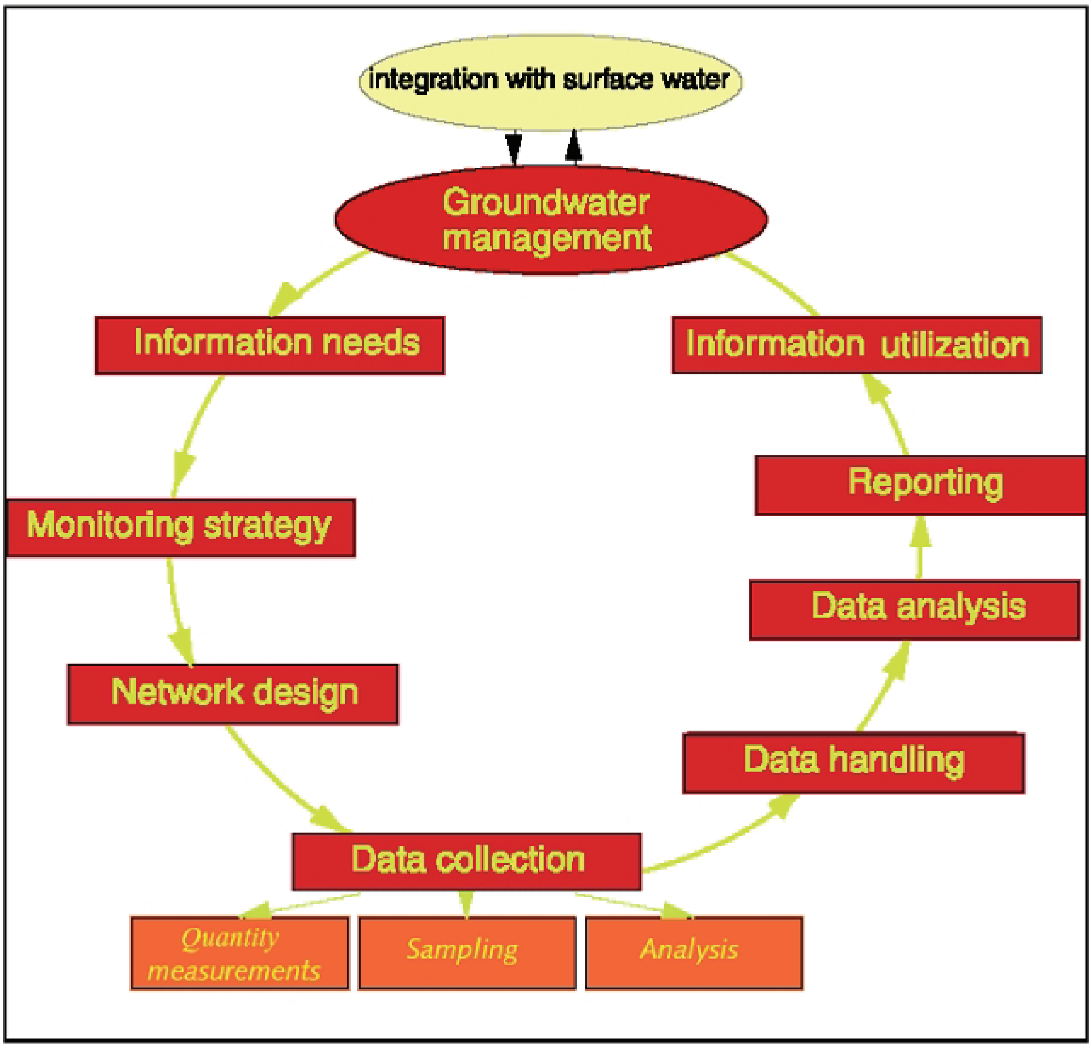


Figure 5-2 The elements of the monitoring cycle in the context of Groundwater Management (ACSAD-BGR, 2004)

5.1 Monitoring Requirements

Monitoring Protocol

The first step in any monitoring activity is the development of a monitoring protocol and the physical set-up of the monitoring network. The purpose and expected outcome of the monitoring need to be clarified before commencing with data collection to ensure that the data can be used for testing the hypothesis.

The approach to developing the monitoring protocol and designing the monitoring network is summarised as:

There are distinct stages of monitoring, from data collection to interpretation and decision making;

The monitoring activities are related to the purpose of data collection and level of study;

The monitoring will take place in different locations, which can be divided into zones;

The required monitoring activities can relate to:

- The water cycle (i.e. rain, surface water, groundwater);
- The life cycle (i.e. aquatic and terrestrial ecosystems);

The protocol is not a static document and will undergo revisions, once new data, information and insight are available.

To the extent possible a water resource monitoring protocol needs to indicate:

- parameters to be observed;
- locations to be monitored;
- methods of data collection;
- timing and scheduling of data collection;
- frequency of measurements;
- personnel requirements (in terms of trained personnel);
- equipment requirements;
- methods for analysis of the data collected;
- data access;
- data dissemination;
- revision policy.

The monitoring protocol is considered the technical specifications for the monitoring activities, which must be aligned with the proposed data analysis methods and data management approach.

Design and Set-up of a Monitoring Network

Most of the parameters identified in the monitoring protocol require the permanent installation of monitoring infrastructure and equipment. The design of the monitoring network must take cognisance of the aquifer characteristics and the purpose of monitoring. Guidelines for monitoring networks for waste sites and groundwater pollution sites are given in the Minimum Requirements, EPA guidelines, etc. The same principles can be applied for the design of monitoring networks for groundwater assessment and aquifer management. The network should at least comprise monitoring sites, as defined by DWAF (2004), for

Reference (natural or background conditions),

Regulatory or compliance monitoring, and

Early warning and surveillance monitoring,

The main monitoring infrastructure and equipment includes:

Monitoring boreholes / piezometers for aquifer specific and or depth specific measurements and sampling;

Monitoring and production boreholes equipped with flow meters, pressure gauges and or water level recorders;

V-notches or weirs for determining flow rates in rivers and streams; and

Weather stations.

Some or all of the following steps are required for the set-up of the monitoring network:

Design of monitoring network in alignment with monitoring protocol;

Drilling of dedicated monitoring boreholes;

Installation of piezometers;

Installation of monitoring equipment in existing boreholes;

Calibration of monitoring equipment.

It is important that the WSA prepares an infrastructure asset register that contains all relevant information about the monitoring site and installed equipment. This allows for recording all changes to the equipment and for following-up on the routine O&M tasks.

5.2 Monitoring and Data Analysis

Data Collection and Collation

A series of complementary datasets comprising measurements of different biophysical elements collected at different spatial and temporal scales are considered necessary for comprehensive IWRM monitoring of groundwater resources. **Table 5-1** provides an example of the variety of monitoring parameters.

Table 5-1 Examples of possible datasets for monitoring (after CCT, 2006)

Location	Water Cycle	Chemistry	Aquatic Ecology	Terrestrial Ecology
Boreholes	Geology Water level Pressure (if artesian) Abstraction rate	Macro chemistry Trace elements Isotopes	N/a	N/a
Springs, seeps and wetlands	Geology, Discharge, Soil moisture	Macro chemistry Trace elements Isotopes	Species composition for: Macroinvertebrates, Diatoms, SASS	Vegetation Community Structure
Rivers, Streams	Discharge	Macro chemistry Trace elements Isotopes	Species composition for: Macroinvertebrates, Diatoms, SASS	Vegetation Community Structure
Lakes, Dams	Dam level	Macro chemistry Trace elements	N/a	N/a
Weather Station	Rainfall, Temperature, Wind Speed and Direction, Evaporation	Macro chemistry Trace elements Isotopes	N/a	N/a

The procedures and methodologies for data collection, sampling and analysis must be based ISO or SABS standards, where available, or an internal QA system to ensure that the monitoring is undertaken consistently. It becomes cumbersome, if not impossible, to compare data that are based on different methodologies.

All measurements, sampling, etc. must be recorded in field sheets, which includes a range of ancillary information that determine the conditions on site and in the wider area prior and during the data collection. These are called 'metadata'.

If external data are collated and utilized, the attached metadata must form part of the data set to ensure that the source and context of the monitoring data is available for queries during the data processing and data analysis processes.

Data Processing

Each team tasked with data collection or data collation is responsible for its own data pre-processing to provide digital data to the Monitoring Task. Data pre-processing involves

- transfer of manual records in hardcopy onto digital format, as specified below;
- quality check and verification of data transfer;
- saving collated data into files of specified format.

The kind of parameters differ in different categories depending upon the kind of measurements, e.g. for a hydrocensus data sheet the parameters would be water level, water flow, EC, pH, temperature. Basic information about a monitoring point, such as coordinates, geological and topographic setting, and type of monitoring, need to be stored in a single file, following the same structure as above.

The data structure for the different data sets depends upon the structure of the regional or national database, into which the data need to be integrated. Data that are collated from existing databases will not be changed in their structure in this process. Additional field data will be captured according to the field sheets and the national databases, if they exist.

All monitoring data have to be checked for correctness and relevance before they are stored in the monitoring database. The process to be followed comprises of at least the following steps, which are outlined below:

Checking of raw data for completeness and correctness

Checking of raw data against other measurements

Correcting of raw data

Validation of corrected data

Storing of validated data

The quality control should finally result in data verification. Data that are found to be questionable or not plausible are marked as such in the database and discarded from further data analysis. This process will be used to supervise and manage the contractor responsible for data collection.

Data Analysis and Evaluation

It is generally recommended that the data analysis procedures that are to be employed once the data have been collected should be determined first, and only thereafter should the data collection procedure be designed. Therefore, data analysis techniques that should be employed depending upon the purpose of the monitoring and the available monitoring data are listed below in general terms.

Types of data analysis, e.g.

Estimating aquifer parameters

- Transmissivity and Storativity,
- Sustainable yield
- Recharge rates
- Water use
- Groundwater flow directions and gradient

Chemical characterization

Trend analysis

Compliance with

- licence conditions,
- DWQ guidelines,
- clean up targets, etc.

Predictions

Available Tools, e.g.

Statistical analysis programs

Plotting programs

Spatial analysis models

Analytical models

Numerical models

5.3 Data Management

It is important that the collected data (hardcopy field sheets and electronic version) are stored safely so that they can be retrieved at any time for further analysis. Any relevant metadata must be stored together with the actual monitoring data to ensure data integrity and to keep the context of the monitoring data available for the data analysis process.

The structure and format of the data storage must allow for easy data sharing between the different authorities. Hence, the database structure of national databases, such as NGA and WMS, must be considered for the monitoring database design. All raw data must be captured electronically.

The monitoring data are translated into information through the data processing and data analysis process. With increased analysis across projects, areas and disciplines, the information is translated into knowledge. This process and the outcomes must be documented in report format, which can then be disseminated to the relevant authorities and involved stakeholders.

6 AQUIFER ECONOMICS

> The need to treat water as an economic good has been recognised as an essential component of sustainable water management. Integrated Water Resources Management (IWRM), a globally endorsed concept for water management, identifies maximising economic value from the use of water and from investments in the water sector as one of the key objectives along with equity and environmental sustainability (Global Water Partnership 2000). This principle was reconfirmed at the 2002 World Summit on Sustainable Development in Johannesburg, the 2003 Third World Water Forum in Tokyo, and the 2005 Millennium Project Report to the UN. The prices charged for water recorded in the national accounts often do not reflect its full economic value.
>
> Source: UNSD 2006.

6.1 Background to Aquifer Valuation

Water is often wasted because it is underpriced. Direct and indirect subsidies are still common in both developed and developing countries. Removing such subsidies and allowing water prices to rise can provide incentives for conservation and for the investment needed to develop more efficient technologies. It is important to recognise that water provides many values not traditionally assigned a monetary value, such as the value that a good or service has to society in general, from an environmental and social perspective. People are willing to pay for sufficient quantity and quality of water.

New principles were incorporated in the National Water Act to facilitate sustainable water resource management based on the three pillars of social, economic and environmental principles. A national water pricing strategy was established to enable full cost recovery, setting various charges to:

Fund costs associated with managing the quality and quantity of water resource;

Fund costs associated with development and operating of water supply schemes.

Surface water vs. groundwater

However, the standard costing and valuation methodologies that are used for surface water resources are not directly applicable to groundwater and aquifers.

The basic principles for aquifer valuation are:

Groundwater is both stock and flux;

Groundwater is natural asset, whether used or not;

Groundwater in storage is like “money in the bank”, available when required.

A three-fold problem has to be addressed for the economics of aquifers:

(a) the size and importance of the groundwater economy have to be estimated;

(b) individual aquifers have to be managed as valuable ecosystem assets (akin to mineral reserves); and

(c) adequate management instruments must be developed for optimal (sustainable) management of individual aquifers.

The strategic importance of aquifers in the water economy of South Africa will not be recognized until these aspects are addresses. In 2008, Statistics South Africa (StatsSA) published a draft Water Resource Account for South Africa, which estimated the size of the groundwater economy in South Africa at approximately R620 million per year (expressed in terms of contribution to Gross Domestic Product (GDP)). The StatsSA data was based on groundwater harvesting data obtained from the National Water Resources Strategy (1 088 million m^3/a), from which GDP can be inferred using Water Sector GDP data collected annually by StatsSA. This is, however, a gross under-estimation of the value of groundwater, for a number of reasons.

First, the NWRS harvesting data is clearly outdated.

Second, average GDP component of the water sector does not apply (accurately) to groundwater supply.

Thirdly, the groundwater from primary, secondary and dolomitic aquifers is, in many urban and rural local economies in South Africa, the only source of their sustainable water supply.

Finally, national GDP type data do not have the ability to adequately capture the asset value of aquifers.

For any case to be made for the importance of aquifers in the economy, this under-estimation must first be corrected.

Closely related to the above is the treatment of aquifers, at a management level, as ecosystem assets. A common failure in many groundwater management approaches is to view an aquifer merely as a source of groundwater, in other words the provision of water is regarded as the sole benefit derived from the aquifer. This is however not true, as aquifers play important supporting and regulating roles in supplying a range of ecosystem services to the economy of South Africa. Examples include its role in maintaining baseflow, especially during low flow seasons, or supplying soil water in support of evapo-transpiration processes. Sustainable management of aquifers require managers, investors and the wider public to appreciate the extent and importance of individual aquifers as assets which have to be managed sustainably.

Cost vs. Value

The category of 'Aquifer Economics' comprises two sub-categories, the first dealing with the costs of groundwater development and the second with the valuation of the aquifer (see **Figure 6-1**). The value of an aquifer is not equal its development costs. Hence, both aspects must be clearly separated and established independently.

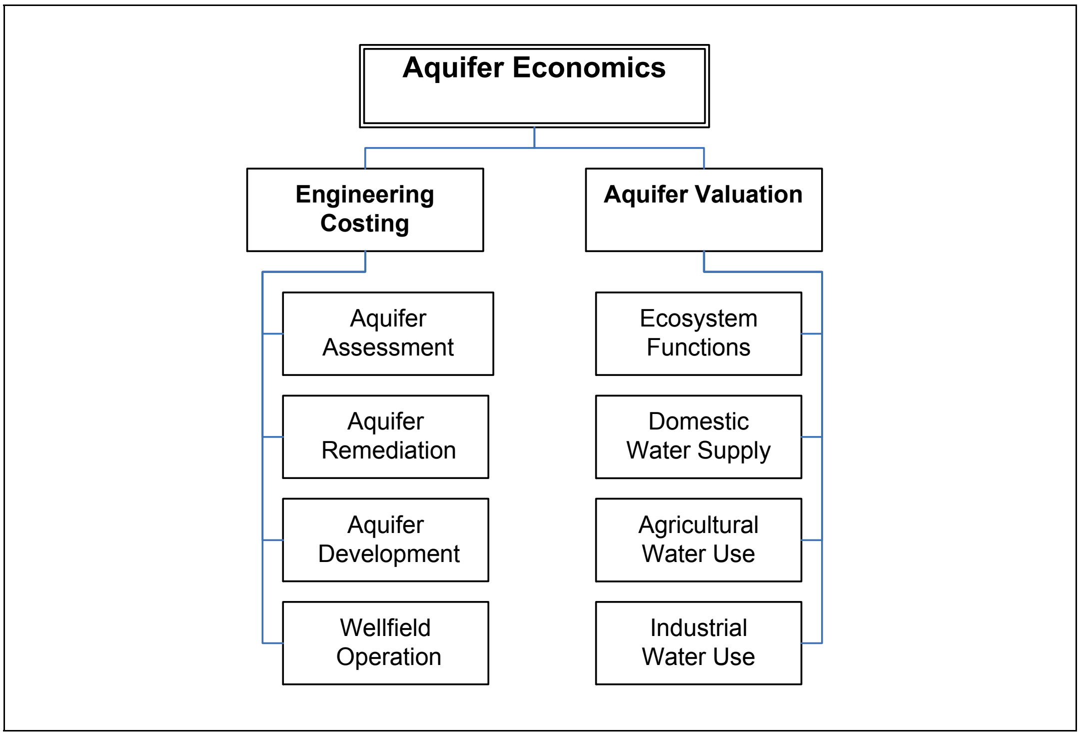


Figure 6-1 Aquifer Economics Category with Sub-categories 'Costs' and 'Valuation',

Economic value is not a fixed, inherent attribute of a good or service but rather depends on time, circumstances, and individual preferences. The economic value of a good or service can be inferred either from someone's willingness to pay (WTP) or willingness to accept compensation (WTA) for giving it up.

In order to put the economic value of groundwater into perspective, the United States Government commissioned a project in 1994 to determine the economic value of groundwater (NRC, 1997). According to that study the first and fundamental step in valuing of a groundwater resource is recognizing and quantifying that resource's total economic value (TEV). For the purposes of that study groundwater services have been divided into two basic categories: extractive services and in situ services. Each of these is considered to have an economic value. Hence, the **Total Economic Value (TEV)** is the sum of values for different uses, including non-use values and option values, as shown in **Figure 6-2**. This concept is superseded by the ecosystem approach, developed by the Millennium Ecosystem Assessment (2005), which is explained in Section 6.3.

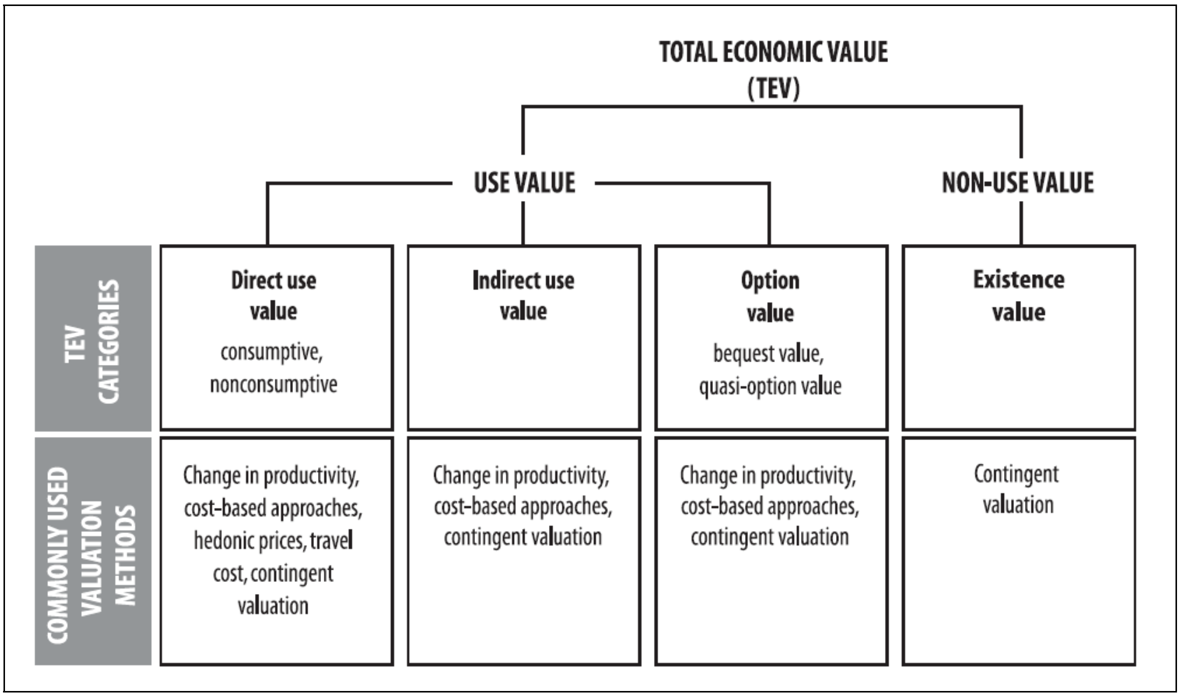


Figure 6-2 Economic Value Categories and associated Valuation Methods (MA, 2005)

Why and when to do valuation

It is important to note that one needs to be purposeful in applying economics. Often an engineering costing exercise is sufficient, and no economic analyses are required. There are at least two purposes to applying the "economics of aquifers":

(a) to use economic instruments, such as tariffs, taxes, subsidies, licenses (there may be others) as water policy instruments – i.e. to manage demand and/or to achieve some level of cost recovery;

(b) to understand the socio-economic consequences of particular management decisions relating to aquifers (developing a new aquifer, implementing a reserve, developing a mine, etc.).

6.2 Costs of Aquifer Utilisation

The determination of the costs of aquifer utilisation is normally a standard engineering costing exercise. However, this normally takes only capital costs and O&M costs into account, and does not include social opportunity costs and other external costs, which could arise from the aquifer utilisation (see **Figure 6-3**). These should be established using valuation techniques as discussed in Section 6.3. Furthermore, the real costs are often subsidized by the local authorities, so that only a portion of the actual costs is recovered.

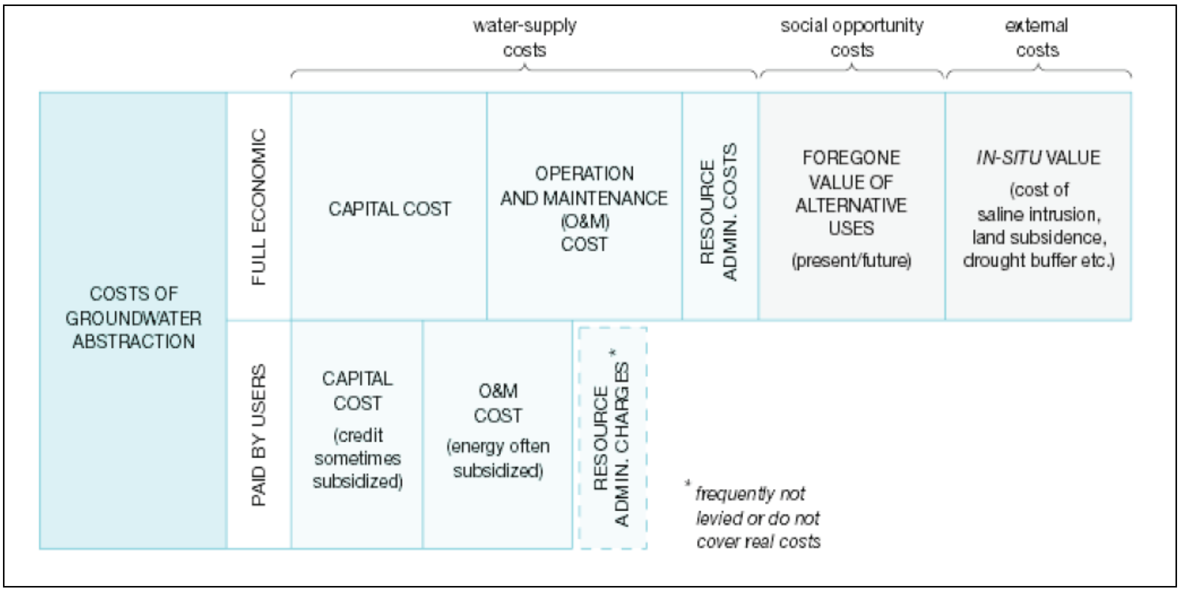


Figure 6-3 Elements of the costs of groundwater (C. Tovey, 2008)

The costing exercise is ideally part of any feasibility study and options analysis, and should be carried out for all sub-categories of both the Aquifer Protection and the Aquifer Utilisation.

An important aspect of the costing exercise for comparison of options is the discount rate. The selected discount rate reflects perceptions of risk, returns, and possibly intergenerational equity. A high discount rate implicitly places a low value on the water's value to future generations. A low rate implies the opposite (NRC, 1997). However, many citizens, policy-makers, and scientists believe that the discount rate does not adequately consider the value of goods or services for future generations.

6.3 Aquifer Valuation

The Aquifer Valuation Sub-category links into the structure of the Groundwater Management Framework (see **Figure 2-5**) and adopts the Millennium Ecosystem Assessment Framework (MA, 2005) for identifying and valuating the relevant ecosystem services linked to the aquifer. The methodology considers water as an **economic good**.

In Environmental Accounting practices (specified by the UN), water is a flow and the systems that produce them are assets. Valuation is undertaken for assets, not flows. So the notion of “the value of water” is somewhat erroneous and is replaced here with the “value of the groundwater resource or aquifer”.

The valuation framework is based on the following principles:

Water for basic needs is a human right, hence infinite. It is usually supplied to consumers free of charge or subsidised by municipalities.

Water supply sustains economic growth throughout all sectors.

Groundwater is a natural asset (like minerals) that lies in the “bank”, if not utilised.

The economic value derived from the water use is independent of supply costs, but depends on demand and output; hence, it varies for different user groups:

- Municipal supply
- Agriculture, irrigation
- Agriculture, stock
- Industry
- Mining
- Electricity.

Since the Groundwater Management Framework focuses on municipal supply, the following aquifer valuation methods are suggested:

Total economic benefit of domestic water being available at acceptable service levels (i.e. above RDP standard);

Economic value derived from current groundwater use;

Economic value of groundwater in “stock”;

Opportunity costs, if groundwater resource is only considered for future use;

Loss of income, if water is not available;

Resource rent, i.e. “royalty” for using a natural asset; these should cover any administrative and management costs as well as cater for unforeseen expenditure;

Cost for remediation, if groundwater source is polluted;

Cost for developing other water source, if groundwater source is polluted or not utilised efficiently;

Loss of ecosystem functions of receiving environment, if groundwater source is depleted or contaminated.

In addition, a methodology for determining the economic value of groundwater use for production (e.g. agriculture, industry) is proposed in Section 6.4. Both aspects of the aquifer valuation need to feed into the determination of the economic value as part of the Classification Process.

Each aquifer has a base value irrespective of its use, but related to the socio-economic and geographical / physical context. The base value can be determined through considering the following three components:

List of relevant ecosystem services

Total economic benefit

Resource rent.

Ecosystem Services

The first step is to determine the ecosystem services of the aquifer system (see **Table 6-1** for a list of ecosystem services as per MA Framework that are directly related to groundwater). The ecosystem services of the receiving environment, e.g. groundwater dependent wetlands, will need to be considered only, if impacts on these ecosystems are expected due to the changes in the groundwater system.

Table 6-1 Examples of Ecosystem Services directly linked to Groundwater (adapted from MA, 2005)

Category	Type of services	Description
Supporting	Water cycling	Processes of precipitation, evaporation, soil moisture storage and movement, aquifer recharge and discharge, and stream flow that combine as the hydrological cycle.
Regulating	Climate regulation	Ecosystems influence climate both locally and globally. Aquifers can play an important role in the greenhouse-gas cycle by artificially sequestering greenhouse gases.
	Water regulation	This relates to the form of the water level hydrograph, i.e. the timing and magnitude of recharge and discharge can be strongly influenced by changes in land cover.
	Water purification	Aquifers can be a source of impurities in freshwater but also can help to filter out organic and inorganic pollutants.
	Natural hazard regulation	In conjunction with catchment management, aquifers can be utilised to mitigate the impact of floods.
Provisioning	Fresh Water	Aquifers are the source of fresh water, and the state of the aquifer affects the assured delivery of such water, both in terms of yield and of quality.
Cultural	Knowledge systems	Ecosystems influence the types of knowledge systems developed by different cultures.
	Educational values	Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.

Total Economic Benefit

The economic benefits generated within a single project or single economic sector generate secondary benefits for other economic sectors. As output produced is further processed by other economic activities, which add further value downstream, the chain of value addition in all sectors linked forward with this activity is considered part of the total economic benefits indirectly emanating from a project.

Similarly, domestic water use at sufficient and appropriate levels of service allows for economic growth and supports the economy within the municipality, which supplies the water. Total economic benefits (TEB) are defined to represent the sum of direct and indirect benefits in various economic sectors that result from a project, firm or sector. Therefore:

TEB = direct effect + indirect effect + induced effect.

The calculation of the TEB for any aquifer must take current and potential future development into account and, hence, depends upon:

Aquifer Classification,

Proposed Management Class,

Storage volume (total, dynamic),

Potential yield,

Alternative sources,

Water requirements, and

Water Quality.

<u>Resource Rent</u>

Economists define rent as the surplus value, after subtraction of all economic returns to production factors. When analysing natural resources such as aquatic ecosystems or aquifers, the economic rent is commonly called resource rent.Resource rent is normally considered that part of the value of the water resource that is required for the water resource management and should be added to the costs of groundwater development and utilisation. It is similar to the Catchment Management Charge that DWA usually adds to its bulk water tariff. However, this charge does not consider the aspect of aquifer protection, which is now indirectly addressed with the Waste Discharge Charge System (WDCS).

It is important that an experienced and qualified economist carries out the aquifer valuation to ensure that all relevant aspects are covered and alternative options evaluated.

6.4 Conceptual Methodology to estimate the user dependent Value of Groundwater Use

A conceptual model structure is presented in **Figure 6-4**. The combined demand of all ground water users may not exceed the total volume of ground water allocated to these users from the ground water source.

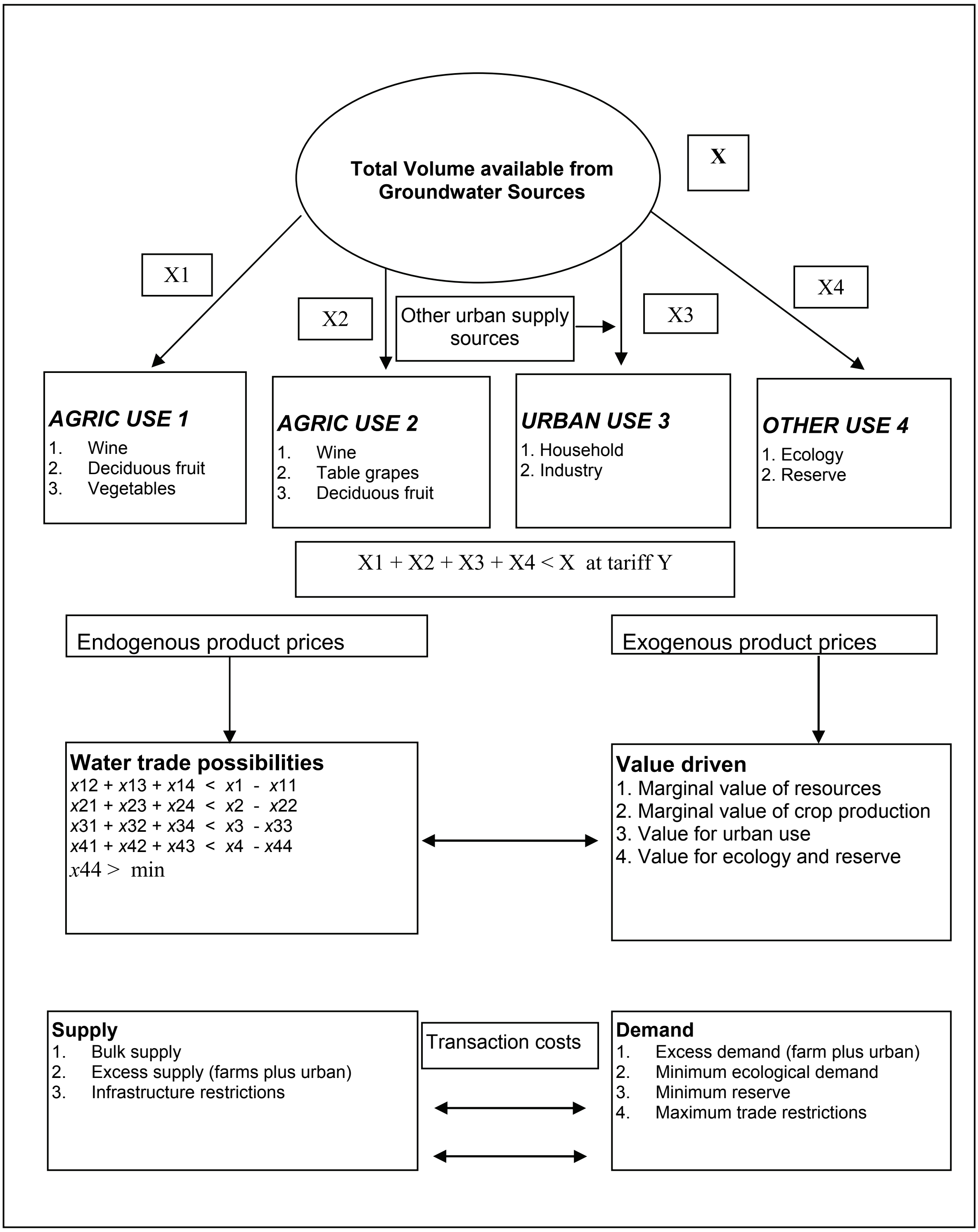


Figure 6-4 The Ground Water Valuation spatial equilibrium model conceptual framework

Although it is not foreseen that water trade will necessary be an option for the reallocation of water, the model will be constructed in such a way that water trade (flow) can theoretically take place between any of the users (e.g. x12 denotes trade between x1 and x2). However, trade is restricted by infrastructure constraints as well as transaction costs. The agricultural excess demand for water is determined by the availability of other resources and product prices. In a market regime water relocates from lower-value uses to higher-value uses and is therefore value driven.

The urban demand for water is determined by the unique value of water as a life-sustaining commodity (minimum demand to sustain life) but also by the urban sector's willingness to pay for other water uses.

South Africa is a relatively small role-player in international agricultural markets for the products produced. The area also produces a rather small proportion of most of these products for the South African market. The price of products produced by the agricultural sector is therefore exogenously determined.

It is proposed that the ground water modeling framework comprise at least four basic modules:

Agricultural water demand module

Urban water demand module

Reserve demand module (ecology and basic human needs)

Water supply module.

A defensible theoretical structure was developed to examine data intuitively and to permit comprehensive evaluation. This theoretical structured model can be used to **analyse the value of groundwater in alternative uses (mainly agricultural and urban use)**. A non-linear modelling approach is followed. The modelling framework consists of three basic elements:

An **objective function** (which will maximise both consumer and producer surplus and therefore total welfare)

Restrictions (basically water availability and water infrastructure capacities)

Activities (the demand for groundwater from alternative users).

The overall **objective** must be to maximise producer and consumer welfare simultaneously.

7 IMPLEMENTATION OF FRAMEWORK IN OVERSTRAND MUNICIPALITY

The groundwater management framework was tested and implemented as a case study in the Overstrand Municipality for the groundwater supply to Hermanus (targeting the Peninsula Aquifer of the Table Mountain Group) and the supply for Stanford (from the quaternary sands and limestones of the Bredasdorp Group).

7.1 Structure of the Overstrand Municipality

The Overstrand Municipality falls within the Breede Water Management Area (WMA) and is part of the Overberg District Municipality. The Overstrand Municipality is the Water Service Authority (WSA), responsible for the provision of water to all people within its area of jurisdiction.

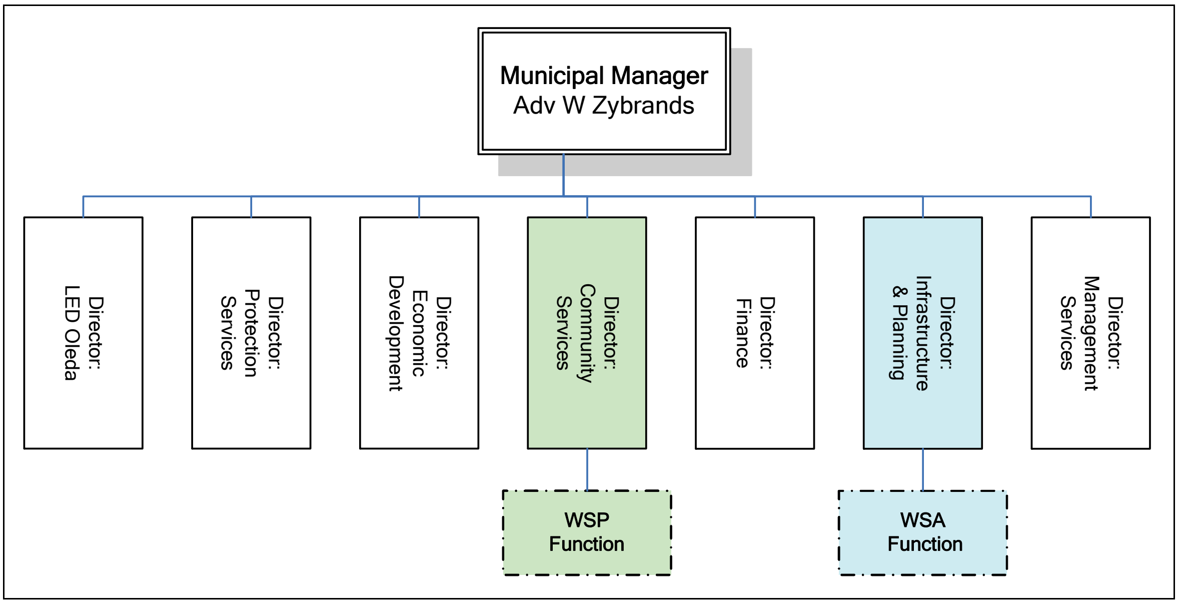


Figure 7-1 Organogram of the Overstrand Municipality

The Overstrand Municipality was chosen for this project, as it has separated the WSA and WSP functions within the municipal structures (see **Figure 7-1**), which is the preferred structure to comply with relevant legislation, i.e. the WSP should not supervise and police itself. This structure enables a clear tracking of roles and responsibilities, as well as required skills for the different functions.

The WSA functions are the responsibility of the water services manager within the Directorate: Infrastructure & Planning.

The WSP functions are the responsibility of the operations managers within the Directorate: Community Services.

7.2 Background to Hermanus and Stanford

Hermanus

Hermanus is approximately 115 km east of Cape Town along the shores of Walker Bay. The Greater Hermanus Area consists of the towns Hermanus, Voëlklip, Onrus River, Sandbaai, Vermont, Hawston and Fisherhaven. The total population in the area is about 60 000 people.

The Greater Hermanus Area currently obtains its bulk water supply from the De Bos Dam on the Onrus River, but the dam cannot support the current growth demands and projected future demands. The water allocation from the De Bos Dam to the municipality for domestic use is 2.8 million m^3 per annum which in not enough to supply the municipality, as the water demand for the area was about 4 million m^3 in 2010, and is expected to increase to well over 6 million m^3 per annum in 2015.

Overstrand Municipality has implemented water demand management strategies to reduce the rising supply/demand deficit. Demand management alone, however, will not provide a long-term solution. The Municipality therefore initiated a programme to evaluate the feasibility and viability of using groundwater to augment the area's water supply, and to manage the groundwater resource in conjunction with surface water.

The municipality is currently in the process of developing and establishing three wellfields in close proximity to Hermanus to augment the water supply (see **Figure 7-2**):

The Gateway Wellfield consists of three production boreholes, connected to an automated pre-treatment works, and a pipeline to the existing raw water treatment works. In 2005, the Overstrand Municipality applied to DWA for a license to abstract groundwater from the Gateway Wellfield. The wellfield is currently in 'Long Term Pumping Test' phase and some water is pumped to supply, but the volumes are not yet significant (~0.19 million m^3 over a 6 month period in 2008-2009).

The Camphill and Volmoed wellfields in the Hemel en Aarde Valley are currently explored and are expected to be available for augmentation of the water supply by 2012.

Currently treated water is used for irrigation purposes at the golf course and one school. Direct and indirect potable water re-use is currently not planned. However, selected water users could be supplied with up to 4 million m^3/a by 2030, assuming that 50% of the bulk water consumption is available for reuse.

Desalination of seawater is seen as a potential future supply source for Hermanus. A feasibility study was undertaken and the design for a pilot plant is available for implementation, if required. The following interventions are recommended for implementation (DWA, 2010):

Full implementation of the Water Conservation / Water Demand Management Strategy.

Full implementation of the Gateway wellfield.

Implementation of the Camphill and Volmoed wellfields.

Desalination.

Non-potable and indirect water re-use.

Stanford

Stanford is approximately 10 km east of the shore of Walker Bay, on the southern bank of the lower reaches of the Klein River, about 6 km upstream of the Klein River estuary. The town is situated on a coastal plain, at an elevation of between 15 m and 20 m above sea level. It is separated from the Walker Bay shoreline by a belt of ancient and modern sand dunes locally reaching elevations of over 100 m (amsl).

The Bredasdorp Aquifer, also known as the Stanford Aquifer is the main aquifer in the Stanford area. It is thought to comprise of the lower part of the Waenhuiskrans Formation (Qw – pulverized shells and calcrete lenses) and the underlying Qg zone (currently unnamed; sandy soil and fluvial and wind-blown sand) above the unconformity with the Bokkeveld Shale. There is a coarser conglomeratic facies in the Qg Formation, particularly where palaeochannels occur, which are likely to be structurally controlled by the underlying basement. The aquifer is recharged by rainfall and has a catchment area of approximately 104 km^2.

The boundaries of the Stanford Aquifer are defined as follows (see **Figure 7-3**):

North and Northwest – Klein River and Klein River Lagoon.

North and Northeast – Barrier created by surface exposure of the low permeability of the Bokkeveld Formation.

South and Southeast – Main watershed created by a bedrock high and regional faulting in the TMG. This fault is water bearing.

West and Southwest – Watershed created by the high-lying palaeodune structures of the Strandveld Formation.

The Stanford area has two springs associated with the Stanford Aquifer, which are the 'Eye' and the Springfontein site. The 'Eye' is located 1.3 km to the south of Stanford and is the main source of potable water to the town. The 'Eye' yields approximately 400 000 m^3/a and this does not meet the town's future water demand. The 'Eye' is also at risk of being polluted by a landfill site and settlements situated up hill of the spring.

Stanford is experiencing development growth which is increasing the water demand for the area. It is expected that the water demand for the town of Stanford will double within the next 30 years to 900 000 m^3/a.

Other sources of water in the Stanford include an existing, but unused wellfield at Middelberg Farm to the west with 7 production boreholes and 12 monitoring boreholes. It is estimated that the Middelberg wellfied can yield approximately 1.6 million m^3/a and at least 260 000 m^3/month (100 l/s) during peak demand.

The municipality commenced to develop a wellfield for domestic use in the Kouevlakte area south of the town. The area is divided into several farms, most of which are residential and game farms. The two boreholes recently drilled into the Kouevlakte paleochannel produce yields of about 10 to 15 l/s each (600 000 m^3/a to 900 000 m^3/a). This aquifer is considered the only water source for Stanford.

The Stanford aquifer is used by a variety of private and commercial users for water supply and hence, the risks to the aquifer of any wellfield development need to be fully understood, correctly managed and mitigated. Adaptive Management is a management approach that is recommended and monitoring is key to this approach. A Monitoring Protocol has been developed and implementation is on-going in the area.

7.3 Groundwater Management in Overstrand Municipality

Several aspects of groundwater management have been implemented by the Overstrand Municipality on an ongoing basis from 2002 onwards. Some of these are listed below.

Aquifer protection

SDF and Growth Management Strategy to take recharge areas and aquifer vulnerability into account:

- No development in aquifer recharge areas;
- Mapping of pit latrines and other possible waste water discharge points.

Waste site monitoring with respect to aquifer vulnerability:

- Groundwater quality monitoring at current and closed waste sites;
- Establish protection measures for waste site closure.

Municipal by-laws allow for registering and controling of boreholes and water use.

Groundwater assessment

Stanford, The Eye:

- Ongoing monitoring of abstraction, water level and remaining discharge from the spring into the leiwater system of the town.

Stanford, Kouevlakte:

- Reconnaissance investigation with identification of target areas in the Kouevlakte area;
- Options analysis between utilising existing wellfield at Middelburg Farm and new development at Kouevlakte;
- Exploration drilling and testing of two boreholes in the Kouevlakte area;
- Wellfield design for utilising these two boreholes to augment the supply.

Wellfield development

Gateway Wellfield:

- Reconnaissance investigation with identification of target areas in the Hermanus area;
- Investigation of groundwater resources with drilling and testing of several boreholes;
- Development of a Monitoring Protocol and regular upgrading of the monitoring network;
- Ongoing monitoring of water level, water quality, flow rates and ecological indicators;
- Monitoring of water level and quality at private Hemel en Aarde Estate in support of wellfield management;
- Wellfield design and implementation of three production boreholes;
- Licence application for abstraction of 1.6 million m^3/a.

Camphill and Volmoed wellfields:

- Investigation of groundwater resources with drilling and testing of several boreholes;
- Wellfield design and implementation of a total of seven production boreholes (four in Camphill, three in Volmoed);
- Licence application to be submitted imminently.

Wellfield operation and management

Gateway Wellfield (currently underway):

- Development and updating of an infrastructure asset register for the Gateway wellfield;
- Development of a Wellfield O&M Manual and Wellfield Managers Guide;
- Ongoing testing of pumps and monitoring equipment;
- Support in operational issues and maintenance, where required;
- Testing of borehole performance and cleaning of borehole to enhance the performance.

Stakeholder Participation

Regular meetings with municipal officials from both WSA and WSP functions;

Public participation during licensing and EIA processes;

Establishment and regular meetings of monitoring committees:

- Onrus Monitoring Committee (OMC) is a sub-committee of the Onrus Water Users Association that was established to oversee the monitoring of the groundwater project at the Gateway Wellfield. It was recently expanded to include the Camphill and Volmoed wellfields. The OMC comprises representatives of the municipality, WUA, Ratepayers Association, Cape Nature, Fernkloof Advisory Board, DWA, BOCMA, Onrus Lagoon Trust and other interested individuals.
- The Stanford Aquifer Monitoring Committee (SAMC) was established to inform other interested and affected parties in the Stanford area about the Stanford aquifer utilisation and to include them in the monitoring activities.

Based on these interventions and actions and the aquifer characteristics, a Groundwater Management Plan was derived for Hermanus comprising the following elements (see Appendix C):

Administrative structure and responsibilities within the municipality,

Aquifer details,

Technical specifications of wellfields,

Aquifer protection measures,

Alternative management options, and

Administrative / legal aspects.

7.4 Valuation of groundwater resources

The methodology as described in Section 6.4 was applied to the current situation in Hermanus, where groundwater is the next water source for urban supply.

Model Input Parameters

Agricultural demand and water supplies

Within the scope of this study it was not possible to conduct farms surveys to collect primary data to construct representative farms for the Overberg region. However, the basic model requires that typical farms are constructed to simulate the demand for agricultural water. Through telephonic discussions with the agricultural community in the regions it was established that wine grapes, stone fruit (including berries), vegetables (limited) and livestock is the major agricultural activities in the region.

Due to a lack of farm survey data, representative farms for the region were selected from the extensive data base of Optimal Agricultural Business Systems (OABS) for the Western Cape. The representative farms were selected to include a combination for the crop and livestock enterprises which are observed in the Hermanus region.

Due to the lack of agricultural data it was decided to include 20 representative farms with a wide range of agricultural activities to compensate for this shortcoming.

The main water sources for irrigation agriculture in the region are:

Surface water. According to Turkstraat (2010), it is estimated that the maximum surface water to be extracted for agricultural use is approximately 3.6 million m^3 per annum. If this is converted to area (ha), by assuming an average crop water requirement of 6000 m^3 per ha, a total of approximately 600 ha (max) can be irrigated. The surface water sources include farm dams, the Onrus River and other rivers.

According to Groenewald (2010), the current extraction form boreholes in the region is estimated at approximately 0.56 million m^3. If this volume is converted to area (ha), by assuming an average crop water requirement, this amounts to approximately 90 ha of irrigated land. Groenewald indicated that not all of the borehole water used by agriculture is from the same aquifer. However, for the purpose of demonstrating the model it was assumed that all the water extracted from boreholes is in competition used for the urban water use sectors. These include the three Gateway boreholes as well as potential future wellfields (Camphill and Volmoed).

For the purpose of this study, to be conservative and due to a lack of any other data, it was assumed for modeling purposes that a maximum of 600 ha are currently irrigated.

Urban demand and water supply

The urban water supplies for the Hermanus region consist of the existing water sources:

De Bos dam with a registered urban water use entitlement of 2.8 million m^3/a.

The Gateway wellfield. The sustainable volume that can be extracted from these boreholes is approximately 1.6 million m^3/a.

Two other wellfields are currently under investigation. The first is Camphill with an estimated sustainable yield of 900 000 m^3/a and Volmoed with 600 000 m^3/a.

Recycled water is mainly used for irrigating the golf course. The current capacity is 65 litres per seconds. This capacity converts to between 600-700 000 m^3/a.

Desalination of seawater was also included in the model at an estimated delivery cost of R8 per m^3. The costs of desalinating seawater vary substantially between the location of where the water is going to be used and the desalination technology.

For the purpose of this report it was assumed that approximately 90% of the current water supplies are used in the base analysis (the base to test scenarios). It was assumed that the monthly water use distribution will be similar to that of Cape Town.

The water tariff structure of the Overstrand area is based on a gliding scale (depends on the volume of water used). For the purpose of this report it was not possible to include the scale in the modelling structure. For the purpose of demonstrating the model an average water tariff per urban water use sector, based on the 2010/2011 tariffs was assumed.

Ecological and reserve requirements

The ecology and reserve requirements could not be established from the available data. It was therefore assumed that 15% of the estimated water availability of the Onrus River in summer must be released from the De Bos dam. For the purpose of the model it was assumed that this amounts to about 2.2 million m^3.

Scenarios and Modelling Results

Scenarios analysed

The scenarios which were analysed to demonstrate the model are shown in **Table 7-1**. In the base scenario current estimated land use, urban water use and water sources is simulated (marked in grey). The other scenarios are divided into two sets:

Set 1: Increase urban water demand by 2% per annum (Scen1 to Scen4)

Set 2: Reduce the availability of groundwater. Same as the base analysis but reduce all borehole water from 10% less (Scen5) to no borehole water (Scen14) and in Scen15 to no borehole water and no recycling.

It is noted that all the values shown in the model are the capitalised value over a 20-year planning horizon discounted at 6%. It is also important to note that the relative changes between scenarios are more important than the actual changes.

Table 7-1 Description of scenarios that were analysed

Scenario	Description
Base	Simulate the base situation given various assumptions (see report)
Scen1	Same as base but increased urban water demand by 2% per annum - 2015
Scen2	Same as base but increased urban water demand by 2% per annum - 2020
Scen3	Same as base but increased urban water demand by 2% per annum - 2025
Scen4	Same as base but increased urban water demand by 2% per annum - 2030
Scen5	Reduce all borehole water with 10%
Scen6	Reduce all borehole water with 20%
Scen7	Reduce all borehole water with 30%
Scen8	Reduce all borehole water with 40%
Scen9	Reduce all borehole water with 50%
Scen10	Reduce all borehole water with 60%
Scen11	Reduce all borehole water with 70%
Scen12	Reduce all borehole water with 80%
Scen13	Reduce all borehole water with 90%
Scen14	Reduce all borehole water with 100% - no borehole
Scen15	Reduce all borehole water with 100% - no borehole - no recycling

Model Results

The results of the Set1 scenarios are summarised in **Table** 7-2. The following can be concluded:

- The objective function value (total welfare) increases as the urban demand increase since water sales by the water supply utility to the urban sector increase. Simultaneously with the increase in water sales volumes, the tariff for urban water also increases as water from relatively cheap sources becomes scarcer and more expensive water supply sources are developed.

- Since agriculture is in direct competition with urban water (extraction from the same aquifers), there is a decrease in the area under optimal irrigation technologies towards deficit and supplemental irrigation (reduction in the application of irrigation water).

- There is also a decrease in the combination of short-term crops (in the case study mainly vegetables which have to be irrigated optimally).

- The net result is an overall decrease in crop area of about 16% in 2030 (40% increase in the base urban demand) when competition with agricultural water is severe.

- It is also clear from the results that agricultural irrigation water sources shifts away from borehole water towards farm dams which are mainly filled from winter water abstraction and through natural run-off.

- On the urban water supply side new water supply sources are developed as water becomes scarcer. As the "new" Camphill and Volmoed boreholes reach their maximum water abstraction capacities, recycling becomes more important.

Table 7-2 Set 1 scenario results – growth in urban water demand

		Urban demand growth scenarios - Overstrand			
	Base	Scen1: Urbdem 2015	Scen2: Urbdem 2020	Scen3: Urbdem 2025	Scen4: Urbdem 2030
Objective function(mill)	**1970.85**	**2049.86**	**2148.69**	**2195.91**	**2336.63**
Relative change in objective function (%)		**4.01%**	**9.02%**	**11.42%**	**18.56%**
Irrigated (ha)					
Long term-Optimum irrigation	273.53	273.48	270.98	263.59	239.14
Relative change in Optimum irrigation area (%)		**-0.02%**	**-0.93%**	**-3.63%**	**-12.57%**
Long term-Defecit irrigation	8.45	8.40	9.37	10.91	11.13
Relative change in Defecit irrigation area (%)		**-0.60%**	**10.82%**	**29.12%**	**31.74%**
Long term-Supplemental irrigation	38.07	38.07	40.15	47.70	78.05
Relative change in Supplemental irrigation area (%)		**0.00%**	**5.45%**	**25.28%**	**105.00%**
Total long-term	320.05	319.95	320.50	322.20	328.32
Relative change in long-term crop area (%)		**-0.03%**	**0.14%**	**0.67%**	**2.58%**
Short term-Optimum irrigation	329.14	330.09	271.27	223.41	213.69
Relative change in Short-term crop area (%)		**0.29%**	**-17.58%**	**-32.12%**	**-35.08%**
Total irrigated area (ha)	**649.19**	**650.04**	**591.77**	**545.61**	**542.01**
Relative change in total crop area (%)		**0.13%**	**-8.85%**	**-15.96%**	**-16.51%**
Water use(Agriculture)-Mill m^3					
Total extracted from Onrus	0.653	0.65	0.65	0.65	**0.70**
Relative change in water from Onrus (%)		**0.00%**	**0.00%**	**0.00%**	**7.42%**
Diversion to fill farm dam	0.044	0.08	0.06	0.13	**0.11**
Farm dam water extraction	**1.301**	**1.34**	**1.32**	**1.39**	**1.37**
Relative change in water from farm dams (%)		**3.12%**	**1.48%**	**6.51%**	**5.08%**
Borehole water					
Total used from Gateway	**0.386**	**0.47**	**0.06**	**0.06**	**0.01**
Relative change in water from Gateway (%)		**22.84%**	**-85.13%**	**-83.31%**	**-96.68%**
From other - Camphill	**0.344**	**0.26**	**0.14**	**0.15**	**0.02**
Relative change in water from Camphill (%)		**-23.84%**	**-58.82%**	**-55.61%**	**-95.45%**
From other - Volmoed	**0.000**	**0.00**	**0.26**	**0.03**	**0.11**
Relative change in water from Volmoed (%)		**NA**	**NA**	**NA**	**NA**
Total cubm used by Agriculture	**2.640**	**2.65**	**2.37**	**2.16**	**2.09**
Relative change in agricultural water use (%)		**0.24%**	**-10.19%**	**-18.13%**	**-20.70%**
Water use(Urban)-Mill m^3					
Total used from De Bos	**2.80**	**2.80**	**2.80**	**2.80**	**2.80**
Total used from Gateway	**1.77**	**1.69**	**2.10**	**2.10**	**2.15**
From other - Camphill	0.32	**0.49**	**0.76**	**0.75**	**0.88**
From other - Volmoed	0.00	0.00	0.34	**0.57**	**0.49**
From other - Desalination	0.00	0.00	0.00	0.00	0.00
From other - Recycling	0.00	0.00	0.00	0.00	0.47
Total cubm used-all sources	**4.89**	**4.98**	**6.00**	**6.21**	**6.80**
Relative change in urban water use (%)		**1.77%**	**22.70%**	**26.99%**	**39.03%**
Reserve requirement	**2.19**	**2.19**	**2.19**	**2.19**	**2.19**
Average marginal value of water					
Urban	**8.03**	**8.03**	**16.58**	**22.17**	**30.97**
Median agricultural value	**8.03**	**8.03**	**16.58**	**22.21**	**29.81**
Value of water sources Urban					
De Bos	**5.74**	**5.74**	**14.29**	**19.88**	**28.68**
Gateway	0.00	0.00	0.00	0.00	0.00
Camphill	0.00	0.00	0.00	0.00	0.00
Volmoed	-0.80	-0.80	0.00	0.00	0.00
Desal	-95.20	-95.20	-86.65	-81.06	0.00
Recycling	-22.94	-22.94	-14.39	-8.80	0.00
Value of water sources Agriculture					
De Bos	7.00	7.00	15.55	21.19	31.56
Gateway	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Camphill	**-0.80**	**-0.80**	**0.00**	**0.00**	**0.00**
Volmoed	**-7.80**	**-7.80**	**-15.50**	**-21.10**	**0.00**

- The capitalised marginal value of the water reflects the scarcity value of water. It is clear that in the base analysis, one additional unit of either recycling and or seawater will result in a decrease in the objective function value since there are still other water sources available at a substantial lower cost.

- However, as cheaper sources reach their capacities and the more expensive water resources needs to be developed (scen2,3, and 4), the value of the water for the more expensive source (Volmoed, recycling and desalination) becomes less negative and eventually zero when the system start to use it while there is still spare capacity of the new water source. In the Set2 analysis it will be demonstrated that the Zero values eventually becomes positive as the new sources also reach there capacities.

- In the case of the De Bos Dam water the marginal value becomes higher and higher as water becomes scarcer.

- Both the marginal value of urban and agricultural water increases as the scarcity value increases from a capitalised value of about R8.03 per m^3 in the base analysis to about R30 per m^3 in Scen4.

- The difference between the value of agricultural and urban water is insignificant since the model was constructed in such a way that most of the existing water can flow in any direction (similar to a free water market system). However, for the purpose of this report it was assumed that recycling and sea water desalination can only be used by the urban sector. In the Set2 scenarios it will be demonstrated how this impact on the difference in water values between the urban and the agricultural sector.

The results of the Set 2 scenarios are summarized in **Table 7-3**. The following can be concluded:

- The objective function value increases slightly as borehole water becomes scarcer and the urban water demand function responds with higher water tariffs but with a relative small decrease in the total urban water demand (about 6 to 10% decrease up to Scen11). However in Scen12 (80% reduction in the availability of groundwater) the model reach a turning point when both recycled and desalinized water enters the optimal solution. In Scenario 13 the total urban water demand is reduced by 21.46% and the objective function value start to decrease.

- The agricultural sector only start to respond in Scen8 (40% reduction in borehole water) since up to this point it is still possible to cope by shifting from optimal irrigation towards non-optimal irrigation (deficit and supplemental). In Scen8, the area under short-term crops (optimal irrigation) is also reduced, resulting in a net decrease of 4.25% in the total area under irrigation.

- With a reduction of more than 40% in the availability of groundwater, the main source of irrigation water gradually shifts from groundwater to surface water (farm dams). Total agricultural water usage is reduced with approximately 25%.

- On the urban demand side the urban sector responds by initially using more recycled water and eventually desalinate water in Scen12 (80% reduction in the availability of groundwater). The reason for the lag in response from the urban sector is that the urban sector uses some of the groundwater of agriculture which reduces the impact temporally.

- In Scen13 and 14 no desalinised water is used since there is a substantial reduction in the urban water demand (the urban demand function responding to higher tariffs). However, in Scen15, where for the purpose of this report recycling was blocked out, desalination remains the only alternative and about 0.64 million m^3 of seawater is desalinated.

- The capitalised marginal values of water indicate that both the urban and agricultural water values are the same until desalination and recycling (only available for the urban sector) becomes a necessity. In Scen11 when the recycling plant reaches capacity, there is a significant increase in the value of the urban water since the next available option is desalination. However, when the urban water demand is reduced due to an increase in water tariffs and desalination exits the solution, there is a slight reduction in the marginal value of urban water. As soon as desalination enters the solution again, the urban water value goes up again.

- Finally, the general trend of the marginal values of the water sources indicates that the surface water values (De Bos Dam) responds to the value of groundwater sources as they enter and exit the solution. It is clear that in Scen11 when recycling enters the solution there is a significant increase in the value of De Bos water from about R14 to R29 and when the recycling capacity reaches full capacity the value goes up from about R29 to R53 in the case of agriculture and to R82 in the case of the urban sector (since recycling is the next option). The marginal values also respond to the urban demand (determined by the urban demand function). When the urban demand is reduced, the relative scarcity of water decreases and is reflected in the marginal value for water (reduced marginal values). The reader will notice that some of the marginal values do not make sense (they are zero). This can be explained by the fact that there are many variables in a model of this magnitude that will impact on these values which cannot necessarily be explained. Also, it is not uncommon when the Positive Mathematical Programming technique is used to have more than one optimal solution. This results in scenario results where the marginal values are very difficult to explain.

Although there are many shortcomings in the data (especially on the agricultural side), the model illustrates the potential usefulness of modelling the value of groundwater resources. These kinds of models can be extremely useful in the following ways:

- The capitalised marginal values for water for different water uses (in this case agriculture and urban) gives an indication of the scarcity value of water and thus economic value of an additional unit of water for the sector.

- Similar, the capitalised marginal value of the water sources (in spite of difficulties to interpret) gives an indication of the economic value of the resource and is closely linked to the value of other water supply options and of the water demand and supply situation.

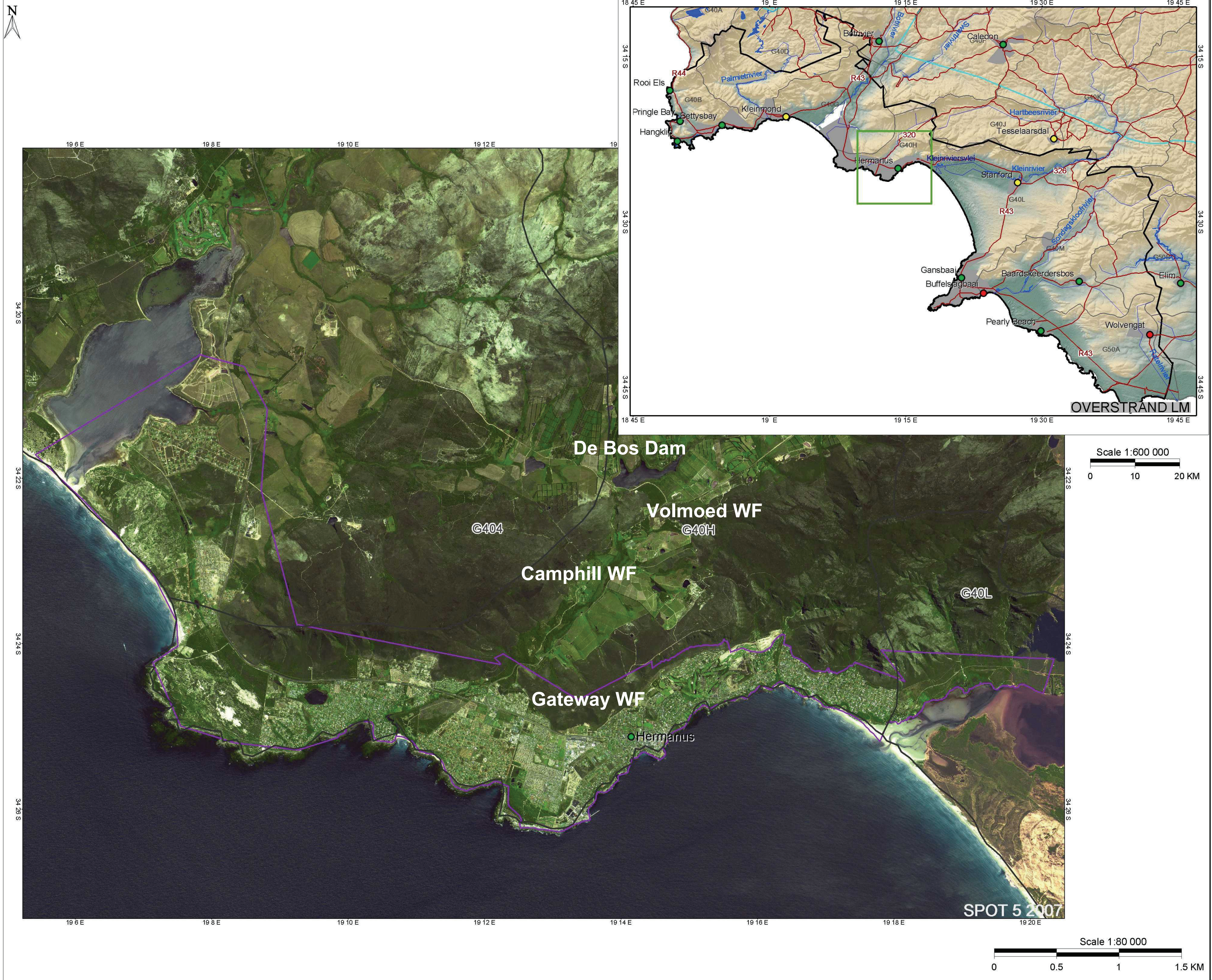
- These models are also extremely useful to determine under which conditions the following water supply option will kick in.

Table 7-3 Set 2 scenario results – reduction in groundwater availability

		Groundwater availability scenarios - All groundwater Scen15 no recy					
	Base	Scen5: 10% reduction	Scen6: 20% reduction	Scen7: 30% reduction	Scen8: 40% reduction	Scen9: 50% reduction	Scen10: 60% reduction
Objective function(mill)	**1970.85**	**1954.66**	**1987.16**	**1981.73**	**1972.56**	**1992.77**	**2015.39**
Relative change in objective function (%)		**-0.82%**	**0.83%**	**0.55%**	**0.09%**	**1.11%**	**2.26%**
Irrigated (ha)							
Long term-Optimum irrigation	273.53	273.55	273.52	273.53	271.04	239.21	239.21
Relative change in Optimum irrigation area (%)		**0.01%**	**-0.01%**	**0.00%**	**-0.91%**	**-12.55%**	**-12.55%**
Long term-Defecit irrigation	8.45	8.48	8.46	8.47	9.38	11.18	11.18
Relative change in Defecit irrigation area (%)		**0.28%**	**0.12%**	**0.24%**	**11.03%**	**32.27%**	**32.27%**
Long term-Supplemental irrigation	38.07	38.07	38.07	38.07	40.18	78.00	78.00
Relative change in Supplemental irrigation area (%)		**-0.01%**	**-0.01%**	**-0.01%**	**5.52%**	**104.87%**	**104.87%**
Total long-term	320.05	320.10	320.05	320.07	320.60	328.38	328.38
Relative change in long-term crop area (%)		**0.01%**	**0.00%**	**0.01%**	**0.17%**	**2.60%**	**2.60%**
Short term-Optimum irrigation	329.14	329.77	329.33	329.79	300.97	213.63	213.63
Relative change in Short-term crop area (%)		**0.19%**	**0.06%**	**0.20%**	**-8.56%**	**-35.09%**	**-35.09%**
Total irrigated area (ha)	**649.19**	**649.86**	**649.37**	**649.86**	**621.57**	**542.01**	**542.01**
Relative change in total crop area (%)		**0.10%**	**0.03%**	**0.10%**	**-4.25%**	**-16.51%**	**-16.51%**
Water use(Agriculture)-Mill m^3							
Total extracted from Onrus	**0.653**	**0.653**	**0.653**	**0.653**	**0.653**	**0.701**	**0.701**
Relative change in water from Onrus (%)		**0.00%**	**0.00%**	**0.00%**	**0.00%**	**7.42%**	**7.42%**
Diversion to fill farm dam	0.044	0.122	0.113	0.083	0.107	0.162	0.133
Farm dam water extraction	**1.301**	**1.379**	**1.370**	**1.340**	**1.364**	**1.419**	**1.389**
Relative change in water from farm dams (%)		**5.97%**	**5.29%**	**3.00%**	**4.86%**	**9.06%**	**6.79%**
Borehole water							
Total used from Gateway	**0.386**	**0.036**	**0.027**	**0.117**	**0.015**	**0.000**	**0.030**
Relative change in water from Gateway (%)		**-90.59%**	**-92.92%**	**-69.72%**	**-96.17%**	**-99.94%**	**-92.30%**
From other - Camphill	**0.344**	**0.698**	**0.700**	**0.441**	**0.540**	**0.093**	**0.045**
Relative change in water from Camphill (%)		**103.04%**	**103.71%**	**28.20%**	**57.07%**	**-72.87%**	**-87.00%**
From other - Volmoed	**0.000**	**0.000**	**0.003**	**0.176**	**0.031**	**0.044**	**0.063**
Relative change in water from Volmoed (%)		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Total cubm used by Agriculture	**2.640**	**2.644**	**2.641**	**2.643**	**2.495**	**2.095**	**2.095**
Relative change in agricultural water use (%)		**0.17%**	**0.05%**	**0.13%**	**-5.48%**	**-20.62%**	**-20.62%**
Water use(Urban)-Mill m^3							
Total used from De Bos	**2.80**	**2.80**	**2.80**	**2.80**	**2.80**	**2.80**	**2.80**
Total used from Gateway	**1.77**	**1.91**	**1.70**	**1.40**	**1.28**	**1.08**	**0.83**
From other - Camphill	0.32	0.00	0.02	0.19	0.00	0.36	0.32
From other - Volmoed	0.00	0.00	0.06	0.14	0.33	0.26	0.18
From other - Desalination	0.00	0.00	0.00	0.00	0.00	0.00	0.00
From other - Recycling	0.00	0.00	0.00	0.00	0.00	0.08	0.29
Total cubm used-all sources	**4.89**	**4.71**	**4.58**	**4.53**	**4.41**	**4.57**	**4.42**
Relative change in urban water use (%)		**-3.70%**	**-6.34%**	**-7.42%**	**-9.79%**	**-6.50%**	**-9.61%**
Reserve requirement	**2.19**	**2.19**	**2.19**	**2.19**	**2.19**	**2.19**	**2.19**
Average water marginal values (Rand/m^3)							
Urban	**8.03**	**8.03**	**8.83**	**8.83**	**15.76**	**30.97**	**30.97**
Median agricultural value	**8.03**	**8.03**	**8.83**	**8.83**	**15.76**	**30.97**	**30.97**
Value of water sources Urban							
De Bos	**5.74**	**5.74**	**6.54**	**6.54**	**13.47**	**28.68**	**28.68**
Gateway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Camphill	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
Volmoed	-0.80	-0.81	0.00	0.00	0.00	0.00	0.00
Desal	-95.20	-95.21	0.00	-94.40	0.00	-72.26	-72.26
Recycling	-22.94	-22.95	0.00	-22.14	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Value of water sources Agriculture							
De Bos	7.00	7.00	7.80	7.80	14.73	29.94	29.94
Gateway	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-1.15**	**-1.15**
Camphill	**-0.80**	**-0.80**	**0.00**	**0.00**	**0.00**	**-1.15**	**-1.15**
Volmoed	**-7.80**	**-7.80**	**0.00**	**-7.80**	**0.00**	**-29.90**	**-29.90**

Table 7-3 (cont.)

Grourycle	Base	Scen11: 70% reduction	Scen12: 80% reduction	Scen13: 90% reduction	Scen14: 100% reduction	Scen15: 100% no recycle
Objective function(mill)	**1970.85**	**2084.48**	**2093.25**	**1897.60**	**1874.30**	**1825.73**
Relative change in objective function (%)		**5.77%**	**6.21%**	**-3.72%**	**-4.90%**	**-7.36%**
Irrigated (ha)						
Long term-Optimum irrigation	273.53	216.33	219.48	216.34	216.33	216.32
Relative change in Optimum irrigation area (%)		**-20.91%**	**-19.76%**	**-20.91%**	**-20.91%**	**-20.91%**
Long term-Defecit irrigation	8.45	11.18	11.83	11.19	11.18	11.18
Relative change in Defecit irrigation area (%)		**32.34%**	**40.03%**	**32.40%**	**32.34%**	**32.27%**
Long term-Supplemental irrigation	38.07	100.73	98.18	100.73	100.73	100.73
Relative change in Supplemental irrigation area (%)		**164.59%**	**157.88%**	**164.59%**	**164.59%**	**164.59%**
Total long-term	320.05	328.25	329.50	328.26	328.25	328.23
Relative change in long-term crop area (%)		**2.56%**	**2.95%**	**2.56%**	**2.56%**	**2.56%**
Short term-Optimum irrigation	329.14	175.94	201.40	175.93	175.95	175.95
Relative change in Short-term crop area (%)		**-46.54%**	**-38.81%**	**-46.55%**	**-46.54%**	**-46.54%**
Total irrigated area (ha)	**649.19**	**504.19**	**530.90**	**504.19**	**504.20**	**504.18**
Relative change in total crop area (%)		**-22.34%**	**-18.22%**	**-22.34%**	**-22.33%**	**-22.34%**
Water use(Agriculture)-Mill m^3						
Total extracted from Onrus	**0.653**	**0.701**	**0.701**	**0.701**	**0.701**	**0.701**
Relative change in water from Onrus (%)		**7.42%**	**7.42%**	**7.42%**	**7.42%**	**7.42%**
Diversion to fill farm dam	0.044	0.170	0.143	0.116	0.140	0.147
Farm dam water extraction	**1.301**	**1.426**	**1.400**	**1.372**	**1.396**	**1.404**
Relative change in water from farm dams (%)		**9.65%**	**7.60%**	**5.48%**	**7.33%**	**7.92%**
Borehole water						
Total used from Gateway	**0.386**	**0.000**	**0.012**	**0.000**	**0.000**	**0.000**
Relative change in water from Gateway (%)		**-100.00%**	**-96.97%**	**-100.00%**	**-100.00%**	**-100.00%**
From other - Camphill	**0.344**	**0.000**	**0.048**	**0.000**	**0.000**	**0.000**
Relative change in water from Camphill (%)		**-100.00%**	**-86.18%**	**-100.00%**	**-100.00%**	**-100.00%**
From other - Volmoed	**0.000**	**0.000**	**0.004**	**0.000**	**0.000**	**0.000**
Relative change in water from Volmoed (%)		**NA**	**NA**	**NA**	**NA**	**NA**
Total cubm used by Agriculture	**2.640**	**1.958**	**2.021**	**1.958**	**1.958**	**1.958**
Relative change in agricultural water use (%)		**-25.82%**	**-23.42%**	**-25.82%**	**-25.82%**	**-25.82%**
Water use(Urban)-Mill m^3						
Total used from De Bos	**2.80**	**2.80**	**2.80**	**2.80**	**2.80**	**2.80**
Total used from Gateway	**1.77**	**0.65**	**0.42**	**0.22**	**0.00**	**0.00**
From other - Camphill	0.32	0.27	0.13	0.09	0.00	0.00
From other - Volmoed	0.00	0.18	0.12	0.06	0.00	0.00
From other - Desalination	0.00	0.00	0.18	0.00	0.00	0.64
From other - Recycling	0.00	0.67	0.67	0.67	0.67	0.00
Total cubm used-all sources	**4.89**	**4.57**	**4.33**	**3.84**	**3.47**	**3.44**
Relative change in urban water use (%)		**-6.49%**	**-11.49%**	**-21.46%**	**-28.95%**	**-29.56%**
Reserve requirement	**2.19**	**2.19**	**2.19**	**2.19**	**2.19**	**2.19**
Average water marginal values (Rand/m^3)						
Urban	**8.03**	**81.88**	**103.23**	**63.50**	**94.69**	**103.23**
Median agricultural value	**8.03**	**27.33**	**26.25**	**26.25**	**27.33**	**27.33**
Value of water sources Urban						
De Bos	**5.74**	**79.59**	**100.94**	**61.21**	**92.40**	**100.94**
Gateway	0.00	32.36	0.00	58.91	0.00	0.00
Camphill	0.00	29.18	0.00	55.47	0.00	0.00
Volmoed	-0.80	29.18	0.00	54.67	0.00	0.00
Desal	-95.20	0.00	0.00	0.00	-8.54	0.00
Recycling	-22.94	50.91	72.26	32.53	63.72	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
Value of water sources Agriculture						
De Bos	7.00	53.87	102.20	53.87	53.87	53.87
Gateway	**0.00**	**0.00**	**-76.30**	**0.00**	**-27.95**	**-27.40**
Camphill	**-0.80**	**0.00**	**-76.30**	**0.00**	**-27.95**	**-27.95**
Volmoed	**-7.80**	**0.00**	**-102.20**	**0.00**	**-53.90**	**-53.90**



LEGEND

Town Priorisation

- High
- Medium
- Low
- Roads
- Rivers
- Quaternary Catchmants
- Schemes
- Hermanus
- Dams

CONSULTANT

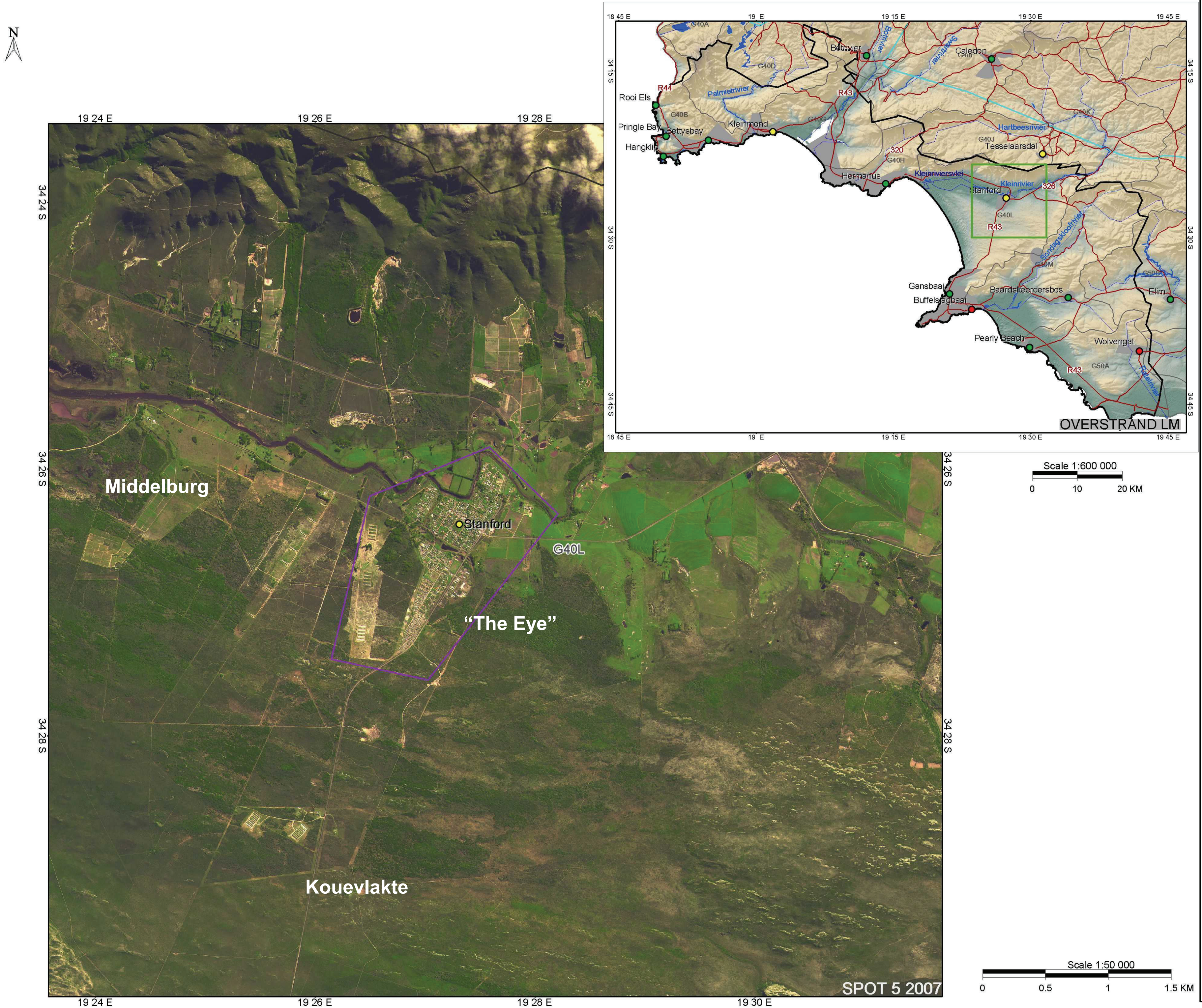
UMVOTO

TITLE

HERMANUS

LOCALITY MAP

Figure 7-2



LEGEND

Town Priorisation

- High
- Medium
- Low
- Roads
- Rivers
- Quaternary Catchmants
- Schemes
- Stanford
- Dams

CONSULTANT

UMVOTO

TITLE

STANFORD

LOCALITY MAP

Figure 7-3

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The Groundwater Management Framework proposed in this document is an overarching guideline that brings the different guidelines for groundwater management together and fills the gaps of these guidelines.

The case studies emphasise the main factors of success:

Appropriate technology for groundwater monitoring and management;

Scientific support from external consultants on request;

Efficient management structure;

Committed staff; and

Adequate funding mechanism.

The main elements of the framework are:

Definition and grouping of all aspects of groundwater management, including aquifer protection, wellfield development, O&M and monitoring;

Linking the aspects of groundwater management to the legal framework of the National Water Act and the Water Services Act;

Definition of management functions with respect to groundwater management;

Roles and responsibilities of local government officials for the different aspects of groundwater management;

Detailing of the complete monitoring cycle and feedback cycle for sustainable groundwater management;

Development of a framework and methodology to establish the value of the groundwater resource;

Outline and example of a Groundwater Management Plan.

The trial implementation of the framework in the Overstrand Municipality for the case studies of Hermanus and Stanford showed that the split between WSA and WSP function within the municipality supports the responsibilities for groundwater management, especially if both functions are involved in the wellfield planning.

The test of the valuation methodology in the case study of Hermanus indicates the usefulness and applicability of the methodology and highlights the high value that need to be put on the groundwater resource for protection and management of the resource.

8.2 Recommendations

The framework has proven to be of high significance for local government to understand their responsibilities and required actions in groundwater management. Hence, it is of utmost importance to introduce municipalities to this framework and train the relevant officials in using the guidelines to achieve sustainable groundwater management.

Furthermore, it is strongly suggested that the Department of Water Affairs adopt this framework as an overarching guideline and incorporates the suite of existing guidelines into this framework.

The following future work is recommended to support the above suggestions and to achieve a successful implementation of the framework:

Roll-out of framework to local government;

Training of municipal officials in elements of the framework and guidelines;

Update DWA Guideline for Assessment and Management to incorporate details of the levels of assessment and planning;

Develop guideline for monitoring data handling, including processing, quality control, storage and sharing of data;

Develop guideline for adaptive management (Monitor – Model – Manage);

Refine valuation methodology to include ecosystems and aquifer characteristics;

9 REFERENCES

ACSAD-BGR, 2003. Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region. Volume 4 – Guideline for Groundwater Vulnerability Mapping and Risk Assessment for the Susceptibility of Groundwater Resources to Contamination. Prepared by the Arab Centre for the Study of Arid Zones and Dry Lands (ACSAD) Damascus and the Federal Institute for Geosciences and Natural Resources (BGR) Hannover as part of the Technical Cooperation Project No,1996.2189.7

ACSAD-BGR, 2003. Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region. Volume 5 – Guideline for the Delineation of Groundwater Protection Zones. Prepared by the Arab Centre for the Study of Arid Zones and Dry Lands (ACSAD) Damascus and the Federal Institute for Geosciences and Natural Resources (BGR) Hannover as part of the Technical Cooperation Project No,1996.2189.7

ACSAD-BGR, 2003. Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region. Volume 6 – Guideline for Sustainable Groundwater Resources Management. Prepared by the Arab Centre for the Study of Arid Zones and Dry Lands (ACSAD) Damascus and the Federal Institute for Geosciences and Natural Resources (BGR) Hannover as part of the Technical Cooperation Project No,1996.2189.7

ACSAD-BGR, 2004. Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region. Volume 7 – Guideline for Groundwater Monitoring. Prepared by the Arab Centre for the Study of Arid Zones and Dry Lands (ACSAD) Damascus and the Federal Institute for Geosciences and Natural Resources (BGR) Hannover as part of the Technical Cooperation Project No,1996.2189.7

Alley WM, Reilly TE & Lehn Franke O, 1999. Sustainability of Groundwater Resources – U.S. Geological Survey Circular 1186.

Bidwell V, 2003. Groundwater Management Tools: Analytical Procedures and Case Studies. MAF Technical Paper No. 2003/06. Retrieved from: http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/water-efficiency/groundwater-management-tools/tech-paper-0306-groundwater-management-tools.pdf

Braune E, Hollingworth B, Xu Y, Nel M, Mahed G & Solomon H 2008. Protocol for the Assessment of the Status of Sustainable Utilization and Management of Groundwater Resources with Special Reference to Southern Africa. WRC Report No TT 318/08

Chevalking S, Knoop L, Van Steenbergen F, 2008. Ideas for Groundwater Management. Retrieved from: http://www.metameta.nl/downloads/ideas_for_groundwater_management.pdf

City of Cape Town, 2006. Ecological and Hydro(geo)logical Monitoring Protocol. Prepared by the TMG Aquifer Alliance as part of the Exploration Phase of the Table Mountain Group Aquifer Feasibility Study and Pilot Project. Final Report

Colvin C, Cave L and Saayman I, 2004. A functional approach to setting resource quality objectives for groundwater. Water Research Commission Report no. 1235/1/04, WRC, Pretoria.

Department of Water Affairs and Forestry, 1997. Minimum Standards and Guidelines for Groundwater Resource Development for the Community Water Supply and Sanitation Programme. Edition 1. Pretoria

Department of Water Affairs and Forestry, 2000. Policy and Strategy for Groundwater Quality Management in South Africa. Waste Management Subseries, Number W.1.0; Edition 1. Pretoria

Department of Water Affairs and Forestry, 2002. Environmental Management Framework. First Draft, Pretoria

Department of Water Affairs and Forestry, 2003. A Protocol to manage the Potential of Groundwater Contamination from on site Sanitation. Edition 2. Pretoria

Department of Water Affairs and Forestry, 2004. National Water Resource Strategy. Edition 1. Pretoria.

Department of Water Affairs and Forestry, 2004. A Framework for Groundwater Management of Community Water Supply. Produced under: The NORAD-Assisted Programme for the Sustainable Development of Groundwater Sources under the Community Water and Sanitation Programme in South Africa. Pretoria

Department of Water Affairs and Forestry, 2004. Implementing a Rural Groundwater Management System: a step-by-step guide. Produced under: The NORAD-Assisted Programme for the Sustainable Development of Groundwater Sources under the Community Water and Sanitation Programme in South Africa. Pretoria

Department of Water Affairs and Forestry, 2004. Guidelines for Groundwater Resources Management in Water Management Areas, South Africa: Integrated Water Resource Management Strategies, Guidelines and Pilot Implementation in Three Water Management Areas, South Africa

Department of Water Affairs and Forestry, 2006. Proposed Integrated Water Resource Management Plan Guidelines for Local Authorities. WRC Discussion Report. PTA.

Department of Water Affairs and Forestry, 2007. GRDM – Groundwater Resource Directed Measures, Version 3. Software Package developed by the Institute for Groundwater Studies (IGS).

Department of Water Affairs and Forestry, 2007. A Framework for a National Groundwater Strategy (NGS). Edition 1. Pretoria.

Department of Water Affairs and Forestry, 2007. Guidelines for Catchment Management Strategies Towards Equity, Sustainability and Efficiency. Edition 1. Pretoria

Department of Water Affairs and Forestry, 2008. KwaZulu-Natal Groundwater Plan. Edition 2. Pretoria

Department of Water Affairs and Forestry, 2008. A Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa, Edition 1. Pretoria

Department of Water Affairs and Forestry, 2008. Draft Operational Guideline in M-Series to assist in the compilation of an Integrated Water and Waste Management Plan. Version 0.4, Pretoria

Department of Water Affairs and Forestry, 2008. Proposed institutional framework for community-level groundwater management. DANIDA

Department of Water Affairs and Forestry, 2008. Strategic Framework on Water for Sustainable Growth and Development – Summary Discussion Document

Department of Water Affairs, 2009. National Groundwater Strategy – Review of groundwater management examples in South Africa. Prepared by J. Cobbing and K. Pietersen as part of the National Groundwater Strategy project. First Draft. July 2009

Department of Water Affairs, 2010. Reconciliation Strategy for Hermanus. Prepared by Umvoto Africa as part of the All Towns Reconciliation Strategy Study.

European Union, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Retrieved from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:HTML

Food and Agricultural Organisation (FAO) (2003). A basis for groundwater access and allocation. Water Reports 25, ISBN 92-5-104908-4

Foster S, Hirata R, Gomes D, D'Elia M and Paris M, 2002. Groundwater Quality Protection – a guide for water utilities, municipal authorities, and environment agencies.

Foster S & Kemper K (Editors), 2002-2006. Sustainable Groundwater Management: Concepts & Tools; Worldbank GW MATE Briefing Note Series.

Garduno H, Nanni M, Foster S, Tuinhof A, Kemper K, Dumars C, 2006: Stakeholder Participation in Groundwater Management. Worldbank GW MATE Briefing Note 6

Government of South Africa, 1997. South African Water Services Act. Act No. 108 of 1997. Volume 390.

Government of South Africa, 1998. South African Municipal Structures Act. Act No. 117 of 1998. Volume 402.

Government of South Africa, 1998. South African National Water Act, Act No. 36 of 1998. Volume 398.

Government of South Africa, 1998. The National Environmental Management Act, Act 107 of 1998.

Government of South Africa, 1998. Municipal Demarcation Act, Act 27 of 1998.

Government of South Africa, 2000. South African Municipal Systems Act. Act No. 32 of 2000. Volume 425.

Government of South Africa, 2000. Municipal Structures Amendment Act, Act 33 of 2000.

Groenwald, L. (2010). SRK consulting. Personal interview.

Hay, R., J.A. van der Linde & K Riemann, 2006. Experience has a price. In proceedings: Knowledge for Action – 70th IMESA Conference, 2006, Soweto

Lange and Hassan, 2006. The Economics of Water Management in Southern Africa: an environmental accounting approach

Louw, D.B. & H.D. van Schalkwyk (2001). The development of a methodology to determine the true value of water and the impact of a potential water market on the efficient utilisation of water in the Berg River Basin. University of the Free State, Bloemfontein

Lowry T, Bright J, Robb C, 2001. Groundwater Resource Management: Information Gaps Analysis. Report No. 4482/1 Retrieved from: http://www.mfe.govt.nz/publications/water/groundwater-gaps-report-sep01.pdf

Meyer R, 2002. Guidelines for the monitoring and management of ground water resources in rural water supply schemes. WRC Report 861/1/02a.

Millennium Ecosystem Assessment (MA), 2003. Ecosystems and Human Well-being: A Framework for Assessment. Island Press, Washington, DC.

Millennium Ecosystem Assessment (MA), 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Millennium Ecosystem Assessment (MA), 2005. Ecosystems and Human Well-being: Wetland and Water Synthesis. Island Press, Washington, DC.

Millington P, 2006. Integrated River Basin Management – From Concepts to Good Practice: Briefing Note 15: The Finishing Touches to the Creation of a River Basin Organization.

National Research Council (NRC) (1997). Valuing Ground Water: Economic Concepts and Approaches. Committee on Valuing Ground Water. National Academy of Sciences, ISBN: 0-309-52362-1

Parsons R & Wentzel J, 2007. Groundwater Resource Directed Measures Manual. Setting Resource Directed Measures (RDM) for Groundwater: A Pilot Study, WRC Report No TT 299/07Pretoria, 109pp

Ruttenberg, F.Z. (2007). Estimating true groundwater value takes time and research. San Antonio Business Journal, Vol 21, No. 46.

Seward P, Xu Y, Brendonck L, 2006. Sustainable Groundwater Use, The Capture Principle and Adaptive Management. Water SA; Retrieved from http://www.wrc.org.za

Stephens A, Newton L, Mischker CA, Bredenkamp DB & Reid KO, 2005. Situational Analysis for the Preparation of Institutional Arrangements for Groundwater Management in the NWDWA. WRC Report, :Pretoria

Titus R, Pietersen K, Williams M, Adams S, Xu Y, Saayman I & Colvin C, 2002. Groundwater Assessment and Strategies for Sustainable Resource Supply in arid Zones -The Namaqualand Case Study. WRC Report 721/1/02

Tovey, C., 2008. Social and Economic Aspects of Groundwater Management. Presentation at "Mobilizing Groundwater Management Protection in South and East Asia, 4-9 February 2008

Turkstraat, B. (2010). Chair of the groundwater committee of the Onrusrivier WUA. Personal interview.

United Nations, 2003. Groundwater Management: The Search for Practical Approaches. Retrieved from: ftp://ftp.fao.org/agl/aglw/docs/wr25e.pdf

UNESCO, 2001. African workshop report of the United Nations Educational Scientific and Cultural Organization's 'Man and the Biosphere' program (UNESCO-MAB) [http://www.unesco.org/mab/brim/workshopdoc/Yaounde.pdf]

UNSD, 2006. United Nations Statistics Division

Vegter, J.R., 2001. Groundwater development in South Africa and an introduction to the hydrogeology of groundwater regions. Water Research Commission (WRC) Report No. TT134/00, 106 pp.

Water Information Network SA, 2009. Cooperation with Catchment Management Agencies – A guide for municipalities

Water Information Network SA, 2009. Cooperation with Municipalities – A Guide for Catchment Management Agencies

Xu Y, Colvin C, van Tonder GJ, Hughes S, Le Maitre D, Zhang J, Mafanya T & Braune E, 2003. Towards the resource directed measures: Groundwater component. WRC Report No. 1090-2/1/03, WRC, Pretoria.

Appendix A – Literature Review

Legal Framework – Relevant Acts
Institutional Arrangements for Water Services
Legal Framework – National Strategies

DWA Guidelines – Integrated Water Resource Management
DWA Guidelines – Groundwater Management
DWA Guidelines – Groundwater Quality Management

WRC Reports
WIN-SA Guidelines

International Guidelines
International Articles

Water Resource Valuation

Legal Framework – Relevant Acts

Since 1994 various pieces of legislation concerning the water and local government sectors have been finalised. The most important are:

The Constitution of South Africa, Act 108 of 1996.

The National Water Act, Act 36 of 1998.

The Water Services Act, Act 108 of 1997.

The National Environmental Management Act, Act 107 of 1998.

The Local Government: Municipal Demarcation Act, Act 27 of 1998.

The Local Government: Municipal Structures Act, Act 117 of 1998.

The Local Government: Municipal Systems Act, Act 32 of 2000.

The Local Government: Municipal Structures Amendment Act, Act 33 of 2000.

National Water Act, No. 36 of 1998

The National Water Act (NWA), Act 36 of 1998, defines the procedures of managing South Africa's scarce water resources. 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.

The Preamble of the NWA highlights the focus on integrated water resource management and decentralisation of management functions.

Preamble

Recognizing that water is a scarce and unevenly distributed national resource which occurs in many different forms which are all part of a unitary, inter-dependent cycle;

Recognizing that while water is a natural resource that belongs to all people, the discriminatory laws and practices of the past have prevented equal access to water, and use of water resources;

Acknowledging the National Government's overall responsibility for and authority over the nation's water resources and their use, including the equitable allocation of water for beneficial use, the redistribution of water, and international water matters;

Recognizing that the ultimate aim of water resource management is to **achieve the sustainable use of water** for the benefit of all users;

Recognizing that the protection of the quality of water resources is necessary to ensure sustainability of the nation's water resources in the interests of all water users; and

Recognizing the need for the **integrated management of all aspects of water resources** and, where appropriate, the **delegation of management functions to a regional or catchment level** so as to enable everyone to participate;

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 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.

Chapter 1 sets out the fundamental principles of the Act. Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act.

The NWA defines two levels of strategic planning for water resources management in Chapter 2, i.e.: the National Water Resource Strategy (NWRS) and the Catchment Management Strategies (CMS), both of which will be described in more detail in Section 2.3 and 3.1 below.

The National Water Act, Section 80, prescribes the initial functions of the Catchment Management Agency (CMA) as being to manage regional water resources and ensure stakeholder participation in WMAs (see **Table 9-1**). It is the role of the CMA to promote community participation in water resource management and to facilitate the participatory process so that understanding and consensus drives management. The functions of the CMA include:

Plan and implement Integrated Water Resource Management

Develop and implement a Catchment Management Strategy

Investigate, advise on and regulate the use, protection, conservation, management and control of water resources

Promote coordination between the Catchment Management Strategy and municipal Water Services Development Plans (WSDPs)

Facilitate stakeholder participation and coordination

As CMAs develop they may take on the implementation and coordination of water management programmes, e.g.:

- Working for Water
- Water demand management
- Emergency response
- Operation and maintenance of water resource systems
- Development of water resource infrastructure

The Catchment Management Strategy (CMS) is an instrument that provides the CMA with an opportunity to harmonise various roles and at the same time to minimise conflict and overlap.

Catchment management strategies must be in harmony with the National Water Resource

Strategy (see **Table 9-1**, Section 9). In the process of developing this strategy, a catchment management agency must seek co-operation and agreement on water-related matters from the various stakeholders and interested persons.

Table 9-1 Extract from National Water Act with respect to catchment management

Section 9 – Guidelines for catchment management strategies A catchment management strategy must— a. Not be in conflict with the NWRS; **b. Set out the strategies, objectives, plans, guidelines and procedures of the CMA for the protection, use, development, conservation, management and control of water resources within its WMA;** c. Take into account the geology, demography, land use, climate, vegetation and waterworks within its WMA; d. Contain water allocation plans which are subject to S 23, and which must set out principles for allocating water, taking into account the factors mentioned in S 27(1); e. Take account of any relevant national or regional plans prepared in terms of any other law, including any development plan adopted in terms of the Water Services Act, 1997 (Act No. 108 of 1997); **f. Enable the public to participate in managing the water resources within its water management area;** g. Take into account the needs and expectations of existing and potential water users; and set out the institutions to be established. h. Take into account the class of water resources and resource quality objectives contemplated in Chapter 3, the requirements of the Reserve and, where applicable, international obligations; i. Set out the institutions to be established.
Section 80 – Functions of a catchment management agency 1. To investigate and advise interested persons on the protection, use, development, conservation, management and control of the water resources in its water management area; **2. To develop a catchment management strategy;** **3. To co ordinate the related activities of water users and of the water management institutions within its water management area;** 4. To promote the co ordination of its implementation with the implementation of any applicable development plan established in terms of the Water Services Act, 1997 (Act No. 108 of 1997); and **5. To promote community participation in the protection, use, development, conservation, management and control of the water resources in its water management area.**

Chapter 3 of the NWA stipulates the measures for the protection of water resources that is fundamentally related to their use, development, conservation, management and control. These measures, which are together intended to ensure the comprehensive protection of all water resources, include the classification of water resources, resource quality objectives, the Reserve and pollution prevention.

Water use is defined broadly in the NWA Section 21, and includes taking and storing water, activities which reduce stream flow, waste discharges and disposals, controlled activities (activities which impact detrimentally on a water resource), altering a watercourse, removing water found underground for certain purposes, and recreation (see **Table 9-2**). In general a water use must be licensed unless it is listed in Schedule I, is an existing lawful use, is permissible under a general authorisation, or if a responsible authority waives the need for a licence.

The Act further allows for the establishment of different mechanisms to support efficient and sustainable water resource management, i.e. licensing of water use, quantification of the Reserve, classification of water resources, establishment of catchment management agencies and water user associations to decentralise the management of water resources, *inter alia*.

Table 9-2 Extract from National Water Act with respect to water use

Section 21 – Water Use

For the purposes of this Act water use includes—

(a) taking water from a water resource:
(b) storing water:
(c) impeding or diverting the flow of water in a watercourse:
(d) engaging in a stream flow reduction activity contemplated in section 36;
(e) engaging in a controlled activity identified as such in section 37(1) or declared under section 38(1):
(f) discharging waste or water containing waste into a water resource through a pipe, canal. sewer. sea outfall or other conduit:
(g) disposing of waste in a manner which may detrimentally impact on a water resource;
(h) disposing in any manner of water which contains waste from. or which has been heated in. any industrial or power generation process;
(i) altering the bed, banks, course or characteristics of a watercourse:
(j) removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people
(k) using water for recreational purposes,

The National Water Act specifies that national monitoring systems on water resources must be established with the purpose of, among other matters, assessing the quantity of water in various water resources and compliance with resource quality objectives. This implies that groundwater levels and water quality need to be monitored, but the Act is not specific on monitoring requirements. The Act allows for such requirements (and reporting to the CMA) to be specified in the license conditions.

Water Services Act, No. 108 of 1997

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 (see **Table 9-3**). 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 (see Section 2.2).

Table 9-3 Extract from Water Services Act

Paragraph 4

(1) Water services must be provided in terms of conditions set by the water services provider.
(2) These conditions must—
- (a) be accessible to the public;
- (b) accord with conditions for the provision of water services contained in bylaws made by the water services authority having jurisdiction in the area in question; and
- (c) provide for—
  - (i) **the technical conditions of existing or proposed extensions of supply**:
  - (ii) the determination and structure of tariffs:
  - (iii) the conditions for payment;
  - (iv) the circumstances under which water services may be limited or discontinued;
  - (v) procedures for limiting or discontinuing water services: and
  - (vi) measures to promote water conservation and demand management.

Paragraph 11

(1) Every water services authority has a duty to all consumers or potential consumers in its area of jurisdiction to progressively **ensure efficient, affordable, economical and sustainable access to water services**.
(2) This duty is subject to -
- *(a)* the availability of resources;
- *(b)* the need for an equitable allocation of resources to all consumers and potential consumers within the authority's area of jurisdiction;
- *(c)* the need to regulate access to water services in an equitable way;
- *(d)* the duty of consumers to pay reasonable charges, which must be in accordance with any prescribed norms and standards for tariffs for water services;
- *(e)* the duty to conserve water resources;
- *(f)* the nature, topography, zoning and situation of the land in question; and
- *(g)* the right of the relevant water services authority to limit or discontinue the provision of water services if there is a failure to comply with reasonable conditions set for the provision of such services.

Municipal Structure Act, No. 117 of 1998

Municipal Structures Act, Act 117 of 1998, defines types and structures of municipalities. Three categories of municipalities exist in South Africa after demarcation: Category A (Metropolitan), Category B (Local), Category C (District).

The Municipal Structures Act (MSA) does not deal directly with any water or groundwater matters. However, the MSA is relevant with respect to groundwater management in terms of how to implement management structures and procedures, such as sub-councils, processes to create by-laws, etc. This includes assigning responsibilities to the appropriate sections of local government.

The primary responsibility for water services provision rests with local government. In terms of Section 84 of the Municipal Structures Act, the responsibility for providing water services rests with district and metropolitan municipalities. However, the Act allows the Minister of Provincial and Local Government Affairs to authorise a local municipality to perform these functions or exercise these powers. The district (or authorised local) municipality is the Water Services Authority as defined in the Water Services Act. There can only be one Water Services Authority in any specific area (that is, Water Services Authority areas cannot overlap).

Municipal Systems Act, No. 32 of 2000

Municipal Systems Act, Act 32 of 2000, defines how local government should operate and allows for various types of partnership arrangements a municipality may enter into to ensure delivery of services, for example water.

Institutional Arrangements for Water Services

An important part of the legal framework is how it sets out the powers and functions of both Water Service Authorities and Water Service Providers.

> ***Water Services Authority*** *means a municipality responsible for ensuring access to water services.*
>
> ***Water Services Provider*** *means an organisation that provides water services to consumers or to another water services institution.*
>
> ***Water Services Institution*** *means a water services authority, a water services provider, a water board or a water services committee.*

Figure 9-1 Definitions for different Water Services Institutions

Duties of Water Services Authorities

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 Water Services Authority is essentially the regulator of the service and is responsible to ensure that services are provided effectively, efficiently, sustainably and affordably. The operational function is undertaken by the Water Services Provider, the institution that actually provides the service. There must always be a contract between the Water Services Authority and the Water Services Provider.

A Water Services Authority may either provide water services itself (internal mechanism), or contract a Water Services Provider to provide water services (external mechanism). For an internal mechanism, the Water Services Authority must manage and account for the two functions separately. In practical terms this might mean that a municipal manager, acting on behalf of the municipality, contracts (as the Water Services Authority) with the manager of the water services department to provide water services in terms of a performance contract with the municipality. In the second case, the Water Services Authority must regulate the Water Services Provider according to the contract specifying clearly the allocation of roles and responsibilities between the regulator and the provider.

Duties of Water Services Providers

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. A water services provider must publish a consumer charter which

is consistent with by-laws and other regulations,

is approved by the water services authority, and

includes the duties and responsibilities of both the WSP and the consumer, including conditions of supply of water services and payment conditions.

Types of Water Services Providers

The most common "types" of Water Services Providers are described below for the purposes of illustration. This listing is both brief and incomplete. This is because the definition of WSP is broad and a variety of possible organizational forms for Water Services Providers exist. Both the content of the contract between a Water Services Authority and Water Services Provider and its enforceability (that is, the ability to perform the service effectively) are more important than the type of Water Services Provider.

Municipalities – A Water Services Authority can also be a Water Services Provider, both within its own area as well as by contract with another Water Services Authority or Water Services Provider.

Municipal entities – These are municipal-owned and controlled public providers which can be set up in terms of either a by-law or the Companies Act.

Water boards – These are Water Services Providers whose primary function is the provision of water services to other water services institutions.

Community-based Organisations – A community-based organisation, acting as a WSP, is a not-for-profit organisation within a specific community providing a municipal service to that community with the mandate of that community, where the organisation is acting in the overall interests of the community.

Private operators – These can vary from SMME's to more established larger private operators. They could be locally or foreign owned and can include multinational corporations.

Other types of Water Services Providers – In some cases Water User Associations (WUA), industries and mines provide water services to or on behalf of municipalities. In these cases, the organisation is a Water Services Provider even though the provision of water services is not the main business of the organisation and the provision of water services is undertaken for the purposes of assisting municipalities who have limited alternatives. The relationship between the Water Services Provider and the Water Services Authority must be defined in terms of an appropriate contract.

Legal Framework – National Strategies

National Water Resource Strategy, 2004

Author	DWAF
Title	National Water Resource Strategy, First Edition, September 2004
Year	2004

Two levels of strategic planning for water resources exist: the **National Water Resource Strategy (NWRS)** and the **Catchment Management Strategies (CMS)**. The NWRS provides the framework for the protection, use, development, conservation, management and control of water resources for the country as a whole. It also provides the framework within which water will be managed at a regional or catchment level in defined water management areas.

The NWRS recognizes that groundwater plays a pivotal role in especially rural water supplies, but states that "A systematic approach to groundwater was neglected in the past as a result of its "private water" status under the previous legislation, and relatively little was invested in comprehensive resource assessment. Through research and development investment in the past five to ten years it has become clear that groundwater is utilisable, […] even in the aquifer systems that are classified as "poor". With a focus on the development of local resources groundwater's role in reconciling future demand and supply could rise significantly, and meeting relatively small water requirements from groundwater would be especially attractive."

However, optimal management and utilization of groundwater resources will require improved capacity to assess groundwater potential and monitor trends, and a better understanding of aquifer functioning, the interactions between surface and groundwater and the impacts of groundwater use on ecological functioning. Proposals to expand and refine the groundwater monitoring and assessment system are outlined in Chapter 3 of the NWRS.

The NWRS highlights two measures to ensure sustainable water resource management:

Resource-directed measures to ensure that water use is sustainable.

Source-directed controls for the protection of water quality focusing on land-based activities that impact on water bodies in the vicinity; both surface water and groundwater.

At the time of developing the NWRS, groundwater levels and water quality were recorded on a continuous basis at 150 points and at regular intervals at about another 1 000 points. The NWRS states the intention to refine and develop the present system to create an integrated monitoring network at three levels, namely

National monitoring by the Department in relatively unimpacted areas to provide background and baseline information on water levels and water quality.

Monitoring of major aquifers by catchment management agencies to determine trends in water levels and water quality resulting from human activity.

Local impact monitoring by users in terms of the conditions attached to general authorisations and licences.

National Groundwater Strategy Framework, 2007

Author	DWAF
Title	A Framework For A National Groundwater Strategy, First Edition,
Year	2007

The Framework for a National Groundwater Strategy intends to set out the principles and focus area for the National Groundwater Strategy (NGS) that is currently being developed by the DWA. Hence, the description in the framework is generic and needs to be specified further in the NGS. The NGS must guide not only the policy-maker and regulator, but also the many users and service sectors, including the research and information sectors.

The Framework states that the aims of the National Groundwater Strategy should be that:

Groundwater as a resource is given its rightful status alongside surface water, helping to meet the growing water demand as a recognised strategic resource within an integrated water resource management approach

The knowledge and use of groundwater is increased along with the capacity to ensure sustainable management

Pro-active groundwater management programmes are developed and implemented at required water resource management levels, focusing on both quantity and quality aspects.

The Framework states that "the NGS should bring a focus to the management of existing supplies. […] A National Groundwater Strategy should create a strong ethos regarding the management aspects of the resource."

The National Groundwater Strategy Framework is based on the Integrated Water Resource Management approach as set out in the National Water Act. Proposed management strategies include

sustainable management of groundwater,

resource protection,

importance of information sharing among stakeholders,

analysis of specific groundwater management functions at a national and local level.

Interviews with stakeholders have highlighted the following aspects relating to the use and management of groundwater, which need to be given attention in the NGS,

Full integration of the groundwater resource into water resource management has yet to occur.

Poor understanding of the groundwater resource and its relation to surface water.

There are strong negative perceptions about groundwater.

Human resource capacity losses are severe.

Abstraction and use are often not monitored.

Investment in groundwater has been very low.

Knowledge of groundwater is neither as accurate nor adequate as for surface water.

The research needs for groundwater are not loudly expressed.

Managing the decant of polluted mine water.

Groundwater is also susceptible to pollution.

Over-abstraction can result in irreversible damage to aquifers.

Inefficiencies can arise from under-utilisation.

Poor development can result in unreliable supply.

Unbalanced publicity between successes and failures.

Guidelines will have to be developed to support the groundwater management and related functions of both water resource management and water services institutions at regional and local levels. Guidelines are needed for, inter alia:

The licensing of groundwater abstraction and use

Integrated groundwater management at Water Management Area (WMA) level

The shared management of local groundwater resources from a water user perspective

Groundwater monitoring and information management at WMA level and between WMAs

The setting up of Groundwater WUAs

The management of trans-boundary aquifers.

The National Groundwater Strategy is currently under development, based on the principles outlined in the Framework.

Water for Sustainable Growth and Development, 2008

Author	DWAF
Title	Strategic Framework on Water for Sustainable Growth and Development – Summary Discussion Document
Year	2008

The Minister of Water and Environmental Affairs had called for a strategy on Water for Sustainable Growth and Development to answer the question: how best can the water sector respond to issues of access to water for economic growth? This strategic framework attempts to find solutions and to propose strategies to address the increasing demand on water resources.

The framework states that "A number of changing factors mean that the water sector cannot continue with business as usual in terms of providing water for economic growth. The sector must examine its performance critically and find new and better ways of managing water and making it available for economic growth. These factors include global climate change, demographic change, economic growth, international factors such as the global financial crisis and rising food prices, the need for redress in access to water, the risks posed by aging and poorly maintained infrastructure and decreasing water quality.

There is a need to develop greater capacity in the sector to respond adaptively to this increasing uncertainty and risk. Aligned to this is a need to be more innovative and bold in terms of technology and management strategies.

This requires greater investment in people. It requires rebuilding the traditional skills base, but also requires the building of new skills sets to manage the new challenges, including resource economics, water financing, water conservation and groundwater management. Equally important is the need to rebuild the relationship between people and state representatives and to rebuild an understanding of citizens' rights and responsibilities.

The framework lists the following opportunities for using water to enable growth and development:

Adaptation and innovation

Investing in people

Leveraging infrastructure

Finance and pricing

Institutional reform

Integrated planning

The framework promotes the use and further development of groundwater, while recognising the mismanagement resulting in negative perception. One of the focal points of the framework to overcome these problems is investment in people through skills development.

Environmental Management Framework

Author	DWAF
Title	Environmental Management Framework
Year	2002

This Environmental Management Framework document was intended to inform and guide the then Department of Water Affairs and Forestry (DWAF) Water Resources Management Branch at a strategic decision-making level. The objectives of the EMF include:

Aligning and optimising the environmental management processes required by the relevant legislation;

Ensuring that environmental considerations are efficiently and adequately taken into account during all stages of development and implementation processes within DWA, which will assist to effectively perform Departmental environmental functions;

Ensuring that activities and projects are compatible with the environmental legislation and meet the environmental requirements, thus ensuring compliance;

Ensuring that in-house and funded DWA Water Resource Management projects apply, and thus conform, to minimum environmental standards through the use of environmental procedures;

Ensuring the integration, development and implementation of environmental management tools and processes within DWA, thus promoting the National Environmental Management principles as set out in NEMA; and

Encouraging integrated resource management, sustainable environmental development and utilisation and sound environmental management practices within DWA.

The relevant departmental functions include *Water Resource Infrastructure Planning, Development and Operation, Policy and Strategy Development, Water Resource Protection, Regulating Water Use, Water Services Project Development and Implementation, Operation and Maintenance of Schemes, Water Services Planning,* as well as *Monitoring and Auditing.* These functions are detailed further and mapped onto the departmental structure of directorates and sub-directorates.

Although possible, the document does not attempt to assign the above line functions to the four basic management functions. This aspect is further discussed in Section 6.2.

The function of policy and strategy development entails developing coherent policies, strategies and regulatory frameworks for other functions to implement, and includes:

Long-term strategic planning and visioning for the Water Resource Management function;

Developing legislation and regulations, ensuring coherence and integration;

Developing the National Water Resource Strategy, e.g. undertaking water situation assessments, developing and applying a National Water Balance Model, and developing national scenarios for reconciling water requirements with available resources;

Developing Catchment Management Strategies, which include water use allocation plans, at a regional or water management area level;

Developing methodologies and guidelines for Water Resource Management;

Financial planning and business planning for the Water Resource Management function;

Formulating the organisational roles and responsibilities of water institutions; and

Formulation of the national pricing strategy for water use.

The water resource protection function is fundamental to the new approach to water resource management and compliance with sustainability principles. This function includes the following components, as highlighted in the NWRS:

Implementing Resource Directed Measures (RDMs).

Implementing Source Based Controls (SBCs).

Resource Directed Measures target protecting the health of a water resource. These address the quantity and quality of water in a water resource, the animals that live in that resource, and vegetation around the resource. E.g., RDMs are used to manage and restrict abstraction of water to avoid over-use with detrimental impacts.

Source Based Controls target the control of impacts that result (or could result) from the use of a water resource or adjacent areas. They typically aim to control and manage pollution (disposal of effluents) of water resources.

The Department is responsible for developing and maintaining systems that will provide information to the WSA, the WSP and other water services institutions.

Catchment Management Strategy Guideline, 2007

Author	DWAF
Title	Guidelines for Catchment Management Strategies Towards Equity, Sustainability and Efficiency
Year	2007

A vital component of Integrated Water Resources Management (IWRM) in South Africa is the progressive devolution of responsibility and authority over water resources to Catchment Management Agencies (CMAs). This document sets out the principles and guidelines for the CMAs to develop Catchment Management Strategies (CMS).

It is important to note that the development of a Catchment Management Strategies by a CMA is a legislative requirement as set out in the NWA (see Section 2.1).

The CMS must set out the strategies, objectives, plans, guidelines and procedures of the CMA for the protection, use, development, conservation, management and control of water resources within its WMA or sub-catchment level to ensure

Sustainability,

Equity, and

Efficiency

The issue of sustainability is addressed through resource protection and water-use regulation. This is most clearly captured in Resource Directed Measures, together with Source Directed Controls, which are measures to regulate water use so that the water resources are used sustainably.

Different scales of planning may be needed for different circumstances. In the case where catchments within a WMA vary markedly, it will be essential to draft Catchment Management Plans that will address issues relevant to a specific catchment or sub-catchment. The Catchment Management Plans are then consolidated into a CMS for the WMA.

The Guideline proposes an adaptive management approach with the development of an objectives hierarchy – in other words one adapts as one learns – a management system where feedback, iterative planning and evaluation are essential for successful implementation.

However, the Catchment Management Agency (CMA) alone cannot do the management of water resources. An important responsibility of the CMA is that of establishing and maintaining contact with role-players and stakeholders so as to draft and implement the CMS.

Proposed Integrated Water Resource Management Plan Guidelines

Author	DWAF / WRC
Title	Proposed Integrated Water Resource Management Plan Guidelines for Local Authorities
Year	2006

The primary objective of the guideline is to assist a local authority to develop an Integrated Water Resource Management Plan (IWRMP) to facilitate the water use authorisation application process and local implementation of IWRM. The guideline states that an IWRMP seeks to reach an appropriate balance between the need to protect and sustain water resources on the one hand, and the need to develop and use them on the other i.e. IWRM enables a local authority to provide services to all sectors within its area of jurisdiction but without comprising either environmental integrity or human health.

The second objective of the guideline is to provide clarity on the main constraint to implementing IWRM in local authorities, namely the limited integration between water resource development and land use planning. This constraint was identified during the stakeholder participation process, and is largely due to:

The different levels of understanding that prevail regarding the concept of IWRM;

Lack of clarity regarding the role of Local Authorities in IWRM;

No standardised approach to incorporating IWRM principles into the planning and implementation of projects;

The lack of or limited integration between the various departments responsible for the different components of IWRM, such as stormwater management, water services, billing, etc.

According to the guideline, the legally required sectoral plans, namely Integrated Waste Management Plans (IWMP) and Water Service 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.

The key responsibilities of the local authorities, 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.

In practice, however, integration will ultimately rely on good governance, no matter how good the developmental framework and legislation is. Good governance is built upon an effective interface between councillors and officials, strong links between financial and technical divisions, and an appropriate organisational structure.

IWRM is intended to enable the local authorities to meet the needs of their people for water, jobs and economic growth in a manner that also allows protecting and, where necessary, rehabilitating the aquatic ecosystems. IWRM aims to:

Strengthen the linkages between the catchment management strategy (CMS) and environmental and social policies;

Improve information acquisition, management and dissemination;

Consider the direct and indirect effects that actions in one part of the catchment may have on another, as each component of the hydrological cycle must be managed with regard to its inter-relationships with the others;

Ensure actions taken are not in conflict or in isolation of the actions taken by another agency, including local authorities;

Ensure actions take other stakeholders into account;

Encourage environmental awareness, participation, empowerment and local decision making, through education and training.

Part of the IWRMP includes undertaking a groundwater situation assessment. In this assessment the following should be undertaken or examined:

An overview of the geology of the area in question

Database of abstraction and monitoring boreholes

Aquifer parameters and aquifer test data

Groundwater users

Overview of groundwater quantity and quality

Groundwater quality – description, coordinates and location of all groundwater monitoring points

Groundwater quality – identification of boreholes of concern (quantity and quality) and potential pollution sources

All existing IWRM related policies, plans and strategies should be assessed in relation to the identified impacts and risks and all identified gaps must be addressed as part of the continuous feedback loop required for IWRM.

The following are required for successful implementation of the IWRMP:

Availability of adequate resources – financial and human resources;

Appointment of a coordinator or champion to facilitate the necessary integration, communication and collation and dissemination of information;

Support of the coordinator at the managerial and political level, including enabling access to resources to perform the functions of the coordinator adequately;

Involvement of the local authority in a DWA – Local Authority Forum dealing specifically with IWRM to facilitate implementation of local authority IWRMPs in conjunction with implementation of the WSDPs and IWMPs;

Inclusion of IWRM issues in existing intergovernmental forums established in terms of cooperative governance;

Provision of assistance to local authorities from provincial and national government departments;

Operational Guideline to assist in the Compilation of an Integrated Water and Waste Management Plan

Author	DWAF
Title	Operational Guideline to assist in the Compilation of an Integrated Water and Waste Management Plan
Year	2008

This guideline contains a framework for an Integrated Water and Waste Management Plan (IWWMP), aiming at local authority as implementor and DWA / CMA as regulator. The main purpose of the IWWMP is to consolidate all the various site specific programmes (e.g. water and salt balances, storm water management plans, water reuse and reclamation plans, water conservation and demand management plans, waste minimization and recycling) of a specific water user into a simple implementable management plan, clearly reflecting the implementation of all strategic objectives and IWRM principles

The Catchment Management Authority (CMA) or other regulatory authority should be responsible for evaluating the proposed actions of the IWWMP against the requirements of the CMS/IWRMP, and accepting them or proposing any alterations prior to approval for implementation. The agreed actions may be formalised into a Programme of Actions, and should be implemented by the water user within the time-frame specified in the IWWMP.

The outcome of the water resource management planning and the roles and the responsibilities of stakeholders, communities and their representatives should be communicated with the broader public. Emphasis needs to be laid on suitable communication channels and formats which will make it easier to communicate complex technical issues.

The strategies outlined in the IWWMP need to be translated into implementable actions. The final set of actions associated with all the water management strategies will form a Programme of Actions for implementation. The procedures, time frame and responsibilities for this programme need to be outlined in the IWWMP to facilitate the effective and transparent implementation and administration thereof by means of a regulatory tool such as the issuance of a licence. The water management program entails the following components:

Waste minimization and recycling program

Water use efficiency and reclamation

Water demand and conservation management

Storm water management

Groundwater management

Remediation and Rehabilitation

Water Monitoring

Minimum Standards and Guidelines for GW Development, 1997

Author	DWAF
Title	Minimum Standards and Guidelines for Groundwater Resource Development for the Community Water Supply and Sanitation Programme
Year	1997

The aim of this document is to provide the basic framework within which groundwater development programmes for community water supply purposes should be undertaken.

It was intended that the Local Government level through the offices of a Transitional Local Council (TLC) or a District Council representing a third tier agency fulfils the function of implementation, operation and maintenance of services.

Second tier agencies/institutions will include Water Boards and Provincial Governments, whilst Central Government, represented by its Department of Water Affairs and Forestry (DWAF), will form the first tier institution.

The development of groundwater resources for community water supply purposes must be viewed holistically. This includes aspects such as:

(1) the current source(s), type and reliability of water supply,

(2) the extent of water reticulation,

(3) the nature, type and level of sanitation facilities,

(4) demographic information in respect of the community,

(5) the existence of institutional Implementing Authorities and

(6) operation, maintenance and payment-for-services considerations.

Project data and information must not only be documented in a technical report. As much relevant data/information as is possible must be entered into an approved electronic database that is compatible to NGDB.

This document is superseded as a guideline by the NORAD toolkit (DWAF, 2004) and the Guideline for the Assessment, Planning and Management of Groundwater Resources (DWAF, 2008).

NORAD Toolkit, 2004

Author	DWAF, NORAD
Title	A Framework for Groundwater Management of Community Water Supply
Year	2004

Purpose of this document is to provide a framework for managing groundwater in rural water supply schemes. The target audience comprises Water Services Authorities (WSA), Water Services Providers (WSP) and Catchment Management Agencies (CMA).

The toolkit groups groundwater management into five groups:

1. Fulfilling of legal obligations.
2. Monitoring and analysis of data
3. Optimising groundwater usage
4. Protection of groundwater from contamination
5. Creating awareness and educating people about sustainable groundwater use.

The framework describes how data is to be collected in rural areas and presented to those who have authority to make water resource management (WRM) decisions. It then describes the duties of each institute in the WRM chain.

It acknowledges the need for one groundwater management system, though it gives different models to accommodate differences in institutional capabilities and preferences regarding water management roles and responsibilities.

The functions of groundwater management are described as:

Groundwater resource management (data provision to ensure aquifers are not being over pumped).

Provision of data to ensure optimum operation of the scheme.

The guiding principles for groundwater management are defined as:

Integration of monitoring activities with O&M activities (Operation and maintenance) of the WSA or WSP.

Groundwater monitoring should be part of a monitoring scheme that includes all aspects of a schemes operation

Processing data only necessary for groundwater management – keeping of logbooks at boreholes. Detailed analysis necessary for selected boreholes

Integrate with other WRM institutions.

Groundwater management for rural water schemes involves the management of data collection, transfer and analysis and implementation requirements (see **Figure 4-2**). Key to success of this is provision of training to pump attendants, administrators in local government and water service institutions to collect reliable and accurate data.

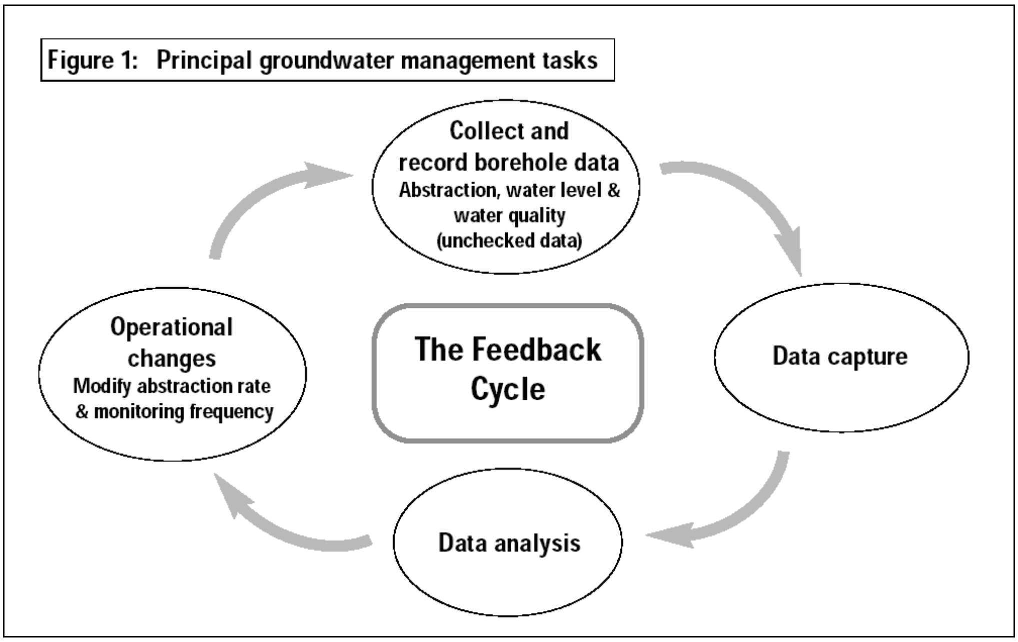


Figure 9-2 The Feedback Cycle of Groundwater Management (DWAF, 2004)

Groundwater management for community water supply purposes requires maintaining a groundwater management system and integrating it into O&M activities. Different institutions need to contribute to the operation of the system. Their responsibilities will include one or more of the following:

Responsibility for data collection.

Responsibility for ensuring that the data is analysed by an experienced groundwater professional (which includes payment for this service if consultants are used).

Responsibility for ensuring that the data is passed on to relevant authorities, such as DWA and CMAs.

Responsibility for ensuring that the management recommendations are heeded.

The proposed institutional model for groundwater management that is based on existing legal requirements and the guiding principles (see above) is presented in **Figure 9-3** and outlined below:

The CMA is responsible for setting up the groundwater management system. It may do this with in-house personnel, or with support from the DWA Regional Office or consultants.

The WSA will effectively be the groundwater manager for rural water supply. This is because groundwater management and O&M (ultimately, a WSA responsibility) are closely linked. The CMA will assist the WSA in setting up the groundwater management system and training staff in specific tasks.

The WSA may delegate some or all of the groundwater management responsibilities to WSPs. If so, this would be incorporated into the water services provision contract (WSPC). The nature of the responsibilities that can be delegated would depend on the capacity of the particular WSP.

The WSP will collect relevant groundwater data and pass it on to the WSA. This should be included in the WSP contract, together with scheduling O&M activities and monitoring scheme performance. The additional tasks involved with groundwater monitoring are small in comparison to the necessary tasks required for on-going O&M and scheme performance assessment. By including groundwater monitoring scheduling in the WSP contract a comprehensive O&M monitoring plan can be developed.

The WSA will analyse the data (possibly with assistance from the CMA, DWAs Regional Office or consultants).

The WSA will inform the WSP of operational improvements that should be made such as modifying pumping schedules.

The WSA will provide the CMA with a summary report on groundwater use and quality.

The WSA will provide the Council with a report on the effectiveness of rural groundwater supply schemes.

Where the WSA also fulfils the role of the WSP, all the roles and functions of groundwater monitoring would be retained by the WSA. The WSA can enter into service contracts with external organizations to assist them with specific task and this could include some of the functions of groundwater monitoring and reporting.

With an external services delivery mechanism, the level of monitoring that would be delegated to the WSP would depend on the capacity of the individual WSP. In the case of community based WSP's, the following would typically be delegated to the WSP and these delegated functions would be detailed in the contract between the WSA and the WSP:

Measuring and recording water levels.

Measuring and recording abstraction.

Providing monitoring data to the WSA on a regular basis (a minimum of every two months is recommended).

Facilitating access to the infrastructure for water quality monitoring.

Functions that would remain with the WSA would include:

Sampling and testing water quality.

Collating and processing the monitoring data.

Interpreting the monitoring data.

Providing feedback and recommendations regarding the operation of the infrastructure.

Reporting to the CMA.

The WSA may choose to enter a service contract (not a WSP contract) with a service provider to provide some or all of these functions.

In cases where the external WSP's have sufficient capacity, most of the monitoring functions could be delegated to the WSP and would be contained in the WSP contract. Typically, such a contract would specify the reporting required by the WSA to adequately monitor the functioning and compliance of the WSP.

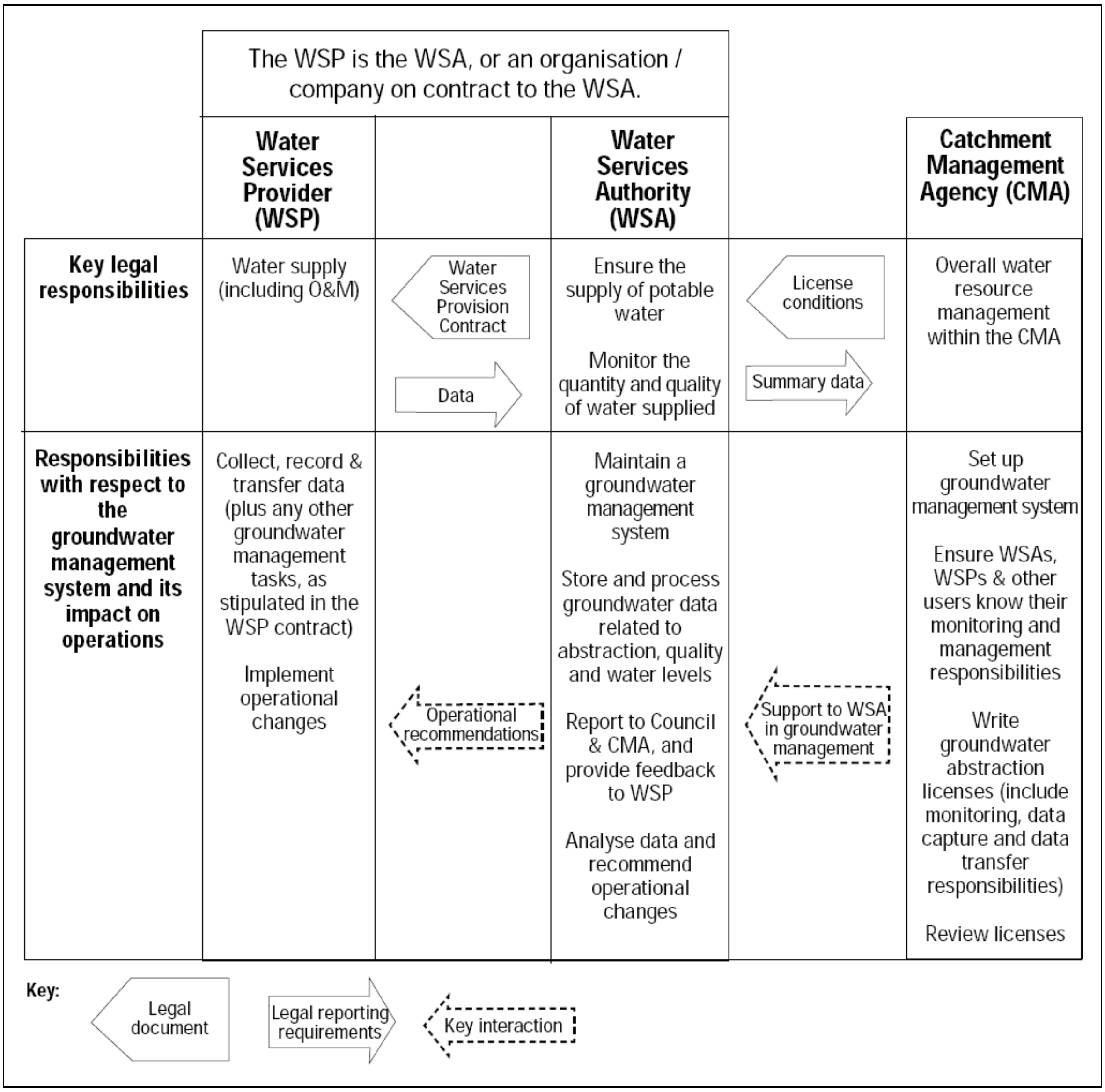


Figure 9-3 Proposed institutional framework for community-level groundwater management (DWAF, 2004)

DANIDA – Guidelines for Groundwater Resources Management, 2004

Author	DWAF
Title	Guidelines for Groundwater Resources Management in Water Management Areas, South Africa: Integrated Water Resource Management Strategies, Guidelines and Pilot Implementation in Three Water Management Areas, South Africa
Year	2004

The guideline outlines the principles of groundwater management in the context of IWRM. The main authorities involved in groundwater management include

Department of Water Affairs – DWA is responsible for national legislation and planning; the development of national groundwater resource policy, regulation and monitoring, and provision of support to other water resource institutions

Catchment Management Agencies – CMAs are responsible for water resource management within their water management area

Water User Associations – WUAs are responsible for function at a local level, representing individual water users and providing vehicles for public participation.

The guideline proposes that each CMA will employ a groundwater coordinator who will ensure the integration of groundwater into water resource management, and interaction with all water management authorities and stakeholders. Their responsibilities are broken down as follows:

Contribution to the regular review of the National Water Resource Strategy

Implementation of catchment management strategies

Ensuring groundwater conservation and protection

Integration of groundwater development into water resource management

Assessment of the groundwater resource

Registration of groundwater use and allocation of groundwater to users

Monitoring of borehole use, groundwater quality and water table drawdown

Management of an effective groundwater information system.

Groundwater Resource Directed Measures Manual, 2007

Author	DWAF
Title	Groundwater Resource Directed Measures Manual
Year	2007

The main responsibility of DWA is to ensure that sufficient water of an acceptable quality is available to meet basic human needs and to support economic and social development. South Africa is not a water-rich country and, as a result, water has to be managed and used wisely.

The Manual describes the approach to undertaking the assessment and development of Groundwater Resource Directed Measures (GRDM). The assessment comprises six sequential phases of investigation, including classification, reserve determination and setting resource quality objectives. It forms part of the water management process in South Africa required by the National Water Act. GRDM focuses on the principles of sustainability, while equity and efficiency are addressed elsewhere in the water management process. Because of groundwater's unique characteristics, methods of assessment are different from other components of the hydrological system (rivers, wetlands, estuaries), but it is crucial that Resource Directed Measures assessments be undertaken in an integrated manner.

A three-tier system of delineation is used for GRDM assessments. Primary delineation is based on the default use of quaternary catchment boundaries and is usually only used for desktop and rapid assessments. More complicated and data-intensive delineation is undertaken for intermediate and comprehensive GRDM assessments. In some cases, it may be difficult to manage an aquifer on the basis of physical delineation considerations and it may be more practical and meaningful to use management criteria for delineation.

The outcome of a GRDM assessment is the Resource Quality Objectives (RQO), which defines the aquifer management goals and relevant indicators. These should be applied by the relevant authority and the water user to manage the groundwater abstraction.

Assessment, Planning and Management Guideline, 2008

Author	DWAF
Title	A Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa
Year	2008

This document intends to assist in the sustainable development, protection and management of the groundwater resources, and in achieving the overall goal of integrated water resources management (IWRM) within the Department.

Management of groundwater resources relates to the sustainable use and development of these resources. It focuses on the sustainable development of the groundwater resources without compromising resource integrity (quantity and quality). Management thus involves monitoring quantity and quality over a long term period and the use of information to determine compliance against set goals and to assess whether the strategic goals of the department are being met.

Management is generally an iterative process that has two components:

Setting management objectives, including strategic objectives set at a national level, the catchment management strategy (CMS) and management plans set at catchment and site-specific levels, and

Monitoring and reporting against these objectives, as well as updating the strategies and management plan on an ongoing basis.

The guideline describes the management principles at the national, the CMA and the site specific level. Management of water resources is enabled through water allocation and water use authorization. Management at site-specific level entails, among others, maintenance and control, monitoring and measurement, data management and reporting, auditing and management of impacts. Review of compliance with water use authorization conditions is undertaken at the catchment level, as well as managing the cumulative impacts of the various water user groups on the system. The auditing of compliance with strategic goals and strategic reviews is undertaken at the national level.

Catchment level management includes, among other functions, the following components:

Monitoring cumulative impacts on aquifer systems and data management

Refining the control mechanisms for the management of water use, including operational rules for aquifer utilisation and procedures for combating overexploitation of the aquifer resources, and

Assessment of the aquifer behaviour as result of impacts imposed against the RQOs

Auditing the compliance of water use against licensing conditions

Reporting to both the national and site-specific levels, and

Feedback to the water users.

The Water Manager will be responsible for the catchment level management function. The inputs to the process include the details from the site-specific management function.

Site-specific management includes the following tasks:

Collection, collation, storage and assessment of monitoring data within, and surrounding the water use(s)

Implementation of water development options identified as part of the planning process

Supervision, or implementation, of the remedial measures identified as part of the monitoring and management function

Operation and maintenance

Control of specific water uses, and

Reporting

The water user (e.g. Local/District Municipality, WUA, mine, industry or delegated personnel) will be responsible for site-specific management.

The steps involved in site-specific management are

Set up WSDP, IDP, EMP

Implement water use scheme or remedial actions

Install/update and maintain monitoring network

Operation and maintenance of the system

Data management: Gather, store and assess the monitoring data

Control of water use

Summarise monitoring data in a site specific report

The guideline focuses on the monitoring and data management as essential components of the overall management programme for the groundwater resources on all three levels. It also highlights the need for public participation in the whole cycle of assessment, planning and management.

Figure 2-3 indicates the proposed institutional framework for the assessment, planning and management of water resources in South Africa. This framework is underpinned by the formation of an Aquifer Management Committee (AMC) in areas where the aquifer(s) span(s) more than one WMA and Catchment Committees for addressing site-specific issues.

The AMC will be an advisory body (not legislated) to provide strategic input to the assessment, planning and management of the groundwater resources in the affected areas. The Catchment Committee will be a legal entity, set up by the Catchment Management Agency (CMA) in accordance with Section 82(5) of the National Water Act.

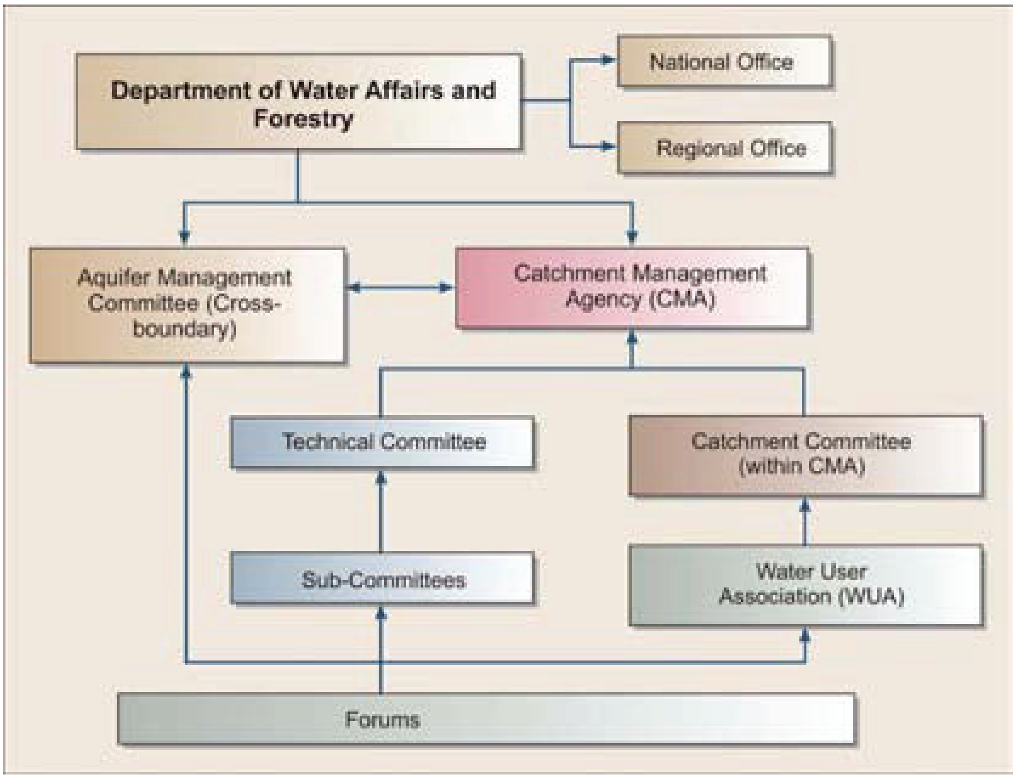


Figure 9-4 Proposed Institutional Framework (DWAF, 2008)

DWA Guidelines – Groundwater Quality Management

Policy and strategy for GW Quality Protection and Management, 2000

Author	DWAF
Title	Policy and Strategy for Groundwater Quality Protection and Management in South Africa
Year	2000

The groundwater quality management strategy forms part of the department's National Water Resources Strategy.

This document, as a starting point for implementation of groundwater quality management within the Department, specifies strategic objectives and broad functional strategies. It should be viewed as being dynamic and must be expected to evolve as other areas of strategy enabled by the National Water Act are developed.

According to the document DWA assumes all responsibilities relating to the groundwater quality management at a national level. DWA adopts integrated catchment management for the operational implementation of water resource management. The basic management unit is considered a quaternary surface water catchment.

Protocol to manage Groundwater Contamination, 2003

Author	DWAF
Title	A Protocol to Manage the Potential of Groundwater Contamination from On Site Sanitation
Year	2003

This protocol gives two options when assessing groundwater contamination: a single-stage assessment and a two-stage assessment.

Under a two-stage assessment, stage one includes an area-based assessment preferably undertaken by a hydrogeologist. This is followed by a community-based assessment undertaken by a technician or an engineer.

In a single-stage assessment only a community-based assessment is undertaken. However, it is more intensive than it would have been if it were to have been accompanied by an area-based assessment.

WRC Reports

Meyer – Guidelines for the Monitoring and Management of Groundwater Resources in Rural Water Supply Schemes

Author	R Meyer
Title	Guidelines for the Monitoring and Management of Groundwater Resources in Rural Water Supply Schemes
Year	2002

The main goal of this report is to develop guidelines for monitoring and management of groundwater resources in local communities, who are largely dependent on the long-term sustainability of the groundwater resource. The developed guideline is similar to the NORAD toolkit, which in effect supersedes this report. However, the report contains relevant aspects that are not addressed in the NORAD toolkit.

Although groundwater is a renewable resource, the availability of it is also influenced by climatic patterns. As with other renewable resources, demand can exceed supply, and therefore some form of control or management of the use of the resource should be in place, to ensure long-term access by users. Management does not imply that users are guaranteed to have access to unlimited quantities of the resources at all times, but rather that under normal circumstances, users will be ensured of a specified minimum quantity at all times. It must however, also be realized that South Africa, being located in a region with vastly different rainfall conditions, periods of extreme climatic conditions do occur, and that even with the best intentions, there may be times when even these minimum standards of supply cannot be met.

Four primary reasons why groundwater should be monitored and managed are identified in the report. These are:

To prevent the groundwater resource from being over-utilised.

To prevent that groundwater of a lower quality is drawn into the area of influence of the production/abstraction borehole.

To prevent groundwater contamination from surface sources such as pit latrines, waste disposal areas, kraals and dipping tanks, or other underground sources.

To optimise individual borehole pumping rates.

Several issues and requirements relating to the proper management of rural groundwater resources are included. Along with these issues, the entities or persons responsible for addressing these issues are set out. These issues include

Community related aspects. Amongst other things, there are the size, current and future water requirements, borehole infrastructure and water consumption patterns of the community to be considered. Responsibility is assigned to the provincial department responsible for community and infrastructure development, as well as community development officers.

Monitoring of geohydrological variables. These include water levels, borehole yields, water quality, water consumption and recording of data. Responsibility for these issues lies with locally trained pump operators and geohydrologists.

Monitoring equipment. This refers to the design and installation of the equipment, as well as the safety and reliability of measurement. The responsibility lies with geohydrologists.

Transfer of information. This refers to how and why certain information is transferred, as well as in what form. Geohydrologists in consultation with service providers and DWA are responsible for obtaining this information.

Management. Responsibilities within management and the level of decision taking are issues that need to be examined. The Water Committee in consultation with geohydrologist is responsible for this.

The responsibilities of various institutions and agencies are set out as follows:

Village Water Committees and Water Service Providers – Must ensure that pump attendants collect groundwater data and send data to relevant authority

Rural Councils – Do not need to have any management or water supply responsibilities

District/Regional Councils and Water Service Authorities – Delegate responsibility for collecting and transferring groundwater data to relevant authorities. They should also act as conduits for groundwater data and management recommendations and fund the data analysis

Water Boards – Water Boards should only take on groundwater management responsibilities if District/Regional Councils lack capacity and if Catchment Management Agencies have not yet been established

Water User Associations – A Water User Association should not need to perform any groundwater management tasks, unless DWA feels that this is necessary

Catchment Management Agencies – Catchment Management Agencies will become the institution responsible for the overall management of groundwater in their areas. This will probably include setting up a groundwater management system.

DWA Regional Offices – Identify areas where groundwater management is most needed.

According to the report DWA recognizes that naturally occurring water can be effectively managed only within a catchment area. This has resulted in the adoption of the philosophy of Integrated Catchment Management which aims to combine environmental, economic and social issues which affect a catchment basin, into an overall management philosophy. Based on this the development of groundwater must therefore be carried out in the context of an adequate catchment management plan, based on an understanding of the sustainable yield of the local groundwater resources.

The following points highlight how groundwater management forms an integral part of Integrated Catchment Management:

Groundwater forms an integral part of the hydrological cycle and therefore an important part of Integrated Catchment Management.

Groundwater contributes to wetlands, springs and the base-flow of rivers.

Groundwater contributes to the sustainability of aquatic and associated ecosystems.

Groundwater quality has an impact on the type of agricultural and forestry activity practiced in the area.

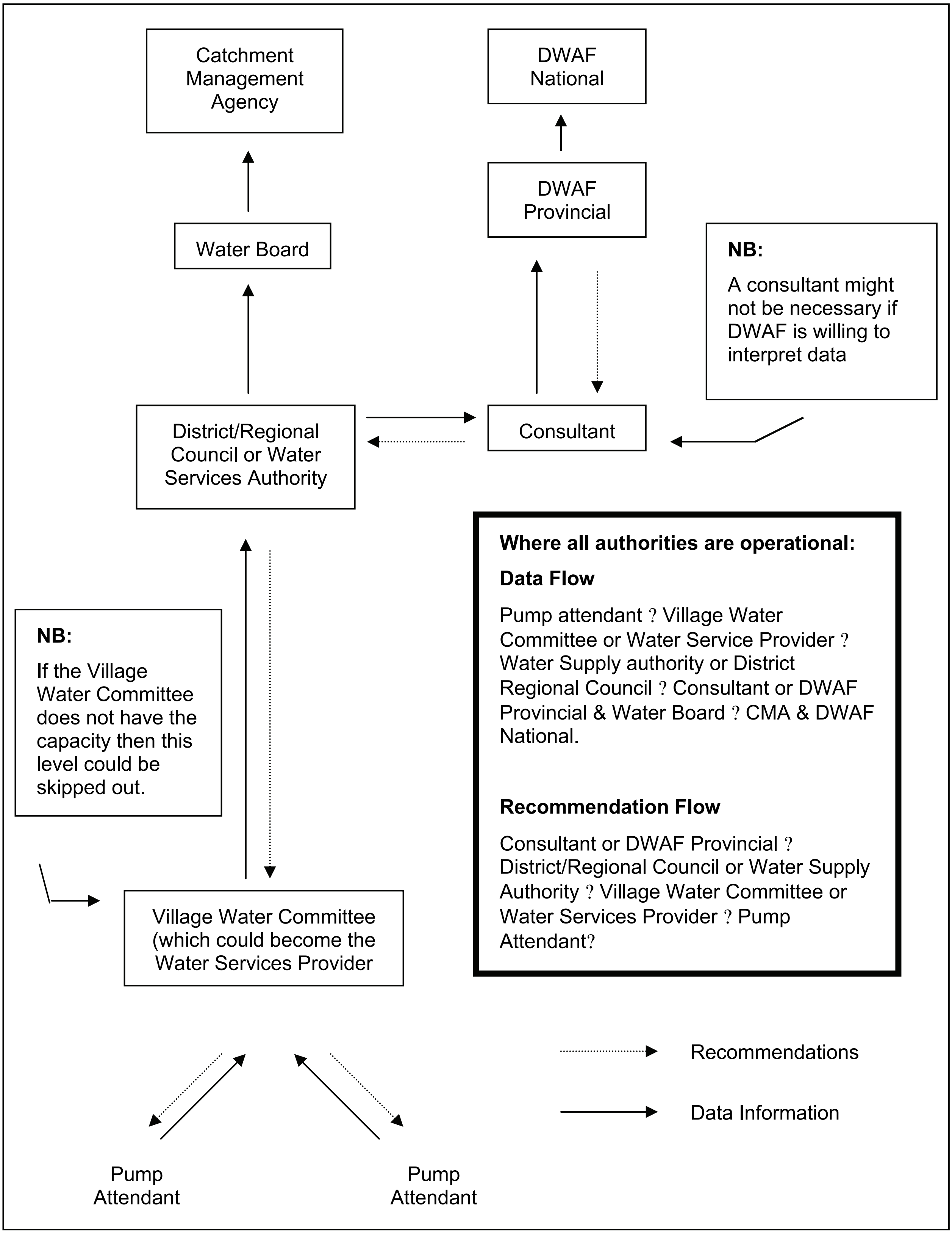


Figure 9-5 Proposed Flow Paths for the Transfer of Groundwater Information and Data Management Recommendations (after Meyer, 2002)

Stephens et al. – Situational Analysis for the Preparation of Institutional Arrangements for Groundwater Management

Author	A Stephens, L Newton, CA Mischker, DB Bredenkamp & KO Reid
Title	Situational Analysis for the Preparation of Institutional Arrangements for Groundwater Management in the NWDWA
Year	2005

The main aim of this report is to develop institutional arrangements for the management of a water resource shared by three Water Management Areas (WMAs) in the North West dolomitic area.

The process of delineating groundwater management units for WUAs does not conform to social or political boundaries. It is a process that is informed by geohydrology and water demand. In terms of the geohydrology, a piezometric drainage map of the natural groundwater drainage over the entire dolomitic aquifer has been compiled based on the limited data available. This process has confirmed that the groundwater flow corresponds to the topography.

Four different scenarios are sketched in the report, shifting from worst to ideal scenario. When focusing on organizations or civil society, this includes WUAs and CMAs, in the worst case scenario there is a weak civil society, with no organizations or individual involvement in water management. Rural and peri-urban communities are unempowered with no opportunities for productive use. This is compared to the ideal scenario where WUAs and CMAs are functioning efficiently and there is trust in DWA, meaning there is mainly lawful water use. When examining the scenarios for institutions, under a worst case scenario there is a centralization of power and knowledge at the national office of DWA, the DWA regions are week and the national office has better understanding of groundwater than the actual regions. Under an ideal case scenario, DWA is decentralized, with the head office maintaining and updating numerical models and merely making strategic decisions. There is excellent regional and local capacity with CMAs functioning efficiently. The WUAs are being supported and their capacity needs are being addressed.

According to the report the basis for effective management of a resource requires the following:

A conceptual model of the aquifer system

Reliable assessments of the aquifer characteristics

Different methods of addressing the groundwater balance and assessing impacts on the system

The monitoring of hydrological parameters that is essential to the evaluation of the status and performance of the aquifer

In the report, it is stated that the establishment of effective structures that would be representative of all stakeholders seems to be problematic, mainly because of inadequate knowledge of stakeholders about the geological and hydrological controls governing the occurrence of groundwater and its effective management.

Braune et al. – Protocol for the Assessment of the Status of Sustainable Utilization and Management of Groundwater Resources

Author	E Braune, B Hollingworth, Y Xu, M Nel, G Mahed & H Solomon
Title	Protocol for the Assessment of the Status of Sustainable Utilization and Management of Groundwater Resources with Special Reference to Southern Africa
Year	2008

The purpose of the report is to position the SADC region for a possible piloting of the resolutions of the African Ministerial Conference on Water (AMCOW) regarding groundwater resources management in Africa.

The specific objectives of the study are to:

Assess the state of sustainable utilization and management of groundwater resources in the sub-region;

Develop a plan of action that will lead towards a broad-based, multi-sectoral initiative aimed at building the sub-region capacity for sustainable, integrated management of groundwater resources, which can also serve as prototype for the wider region.

Currently, there are only a limited number of agreed indicators of what constitutes good groundwater management. What has been published addresses mainly resource quantity and quality, resource use and resource vulnerability. Other, more readily available indicators of good management could be expressions of the available information on groundwater, e.g. how current records are, how regularly published and how well expressed in predictive models. However, with the increasing devolution of water resources management to lower levels, in particular river basin organizations, clear guidance will also become increasingly important for the full spectrum of management actions.

Two broad management types, according to the report, emerge when dealing with groundwater and the sustainable development thereof, namely:

(a) 'Thin and wide' approaches may encompass blunt tools such as power pricing, subsidies for efficient technologies, economic policies that discourage water intensive crops, etc. They can be applied over whole countries or regions.

(b) 'Thick and deep' approaches deal with specific aquifers based on command and control management whereby aquifer management targets are set and enforced through a resource regulator.

The report describes groundwater management within the Southern African Development Community area within the IWRM framework

<u>Cooperation of Catchment Management Agencies and Municipalities</u>

Author	WIN-SA
Title	Cooperation with Catchment Management Agencies – A guide for municipalities
	Cooperation with Municipalities – A Guide for Catchment Management Agencies
Year	2009

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), as shown in **Figure 2-2**:

Providing municipal water services

Rural water provision

Infrastructure provision and management

Pollution control and water-quality management

Wastewater treatment and disposal

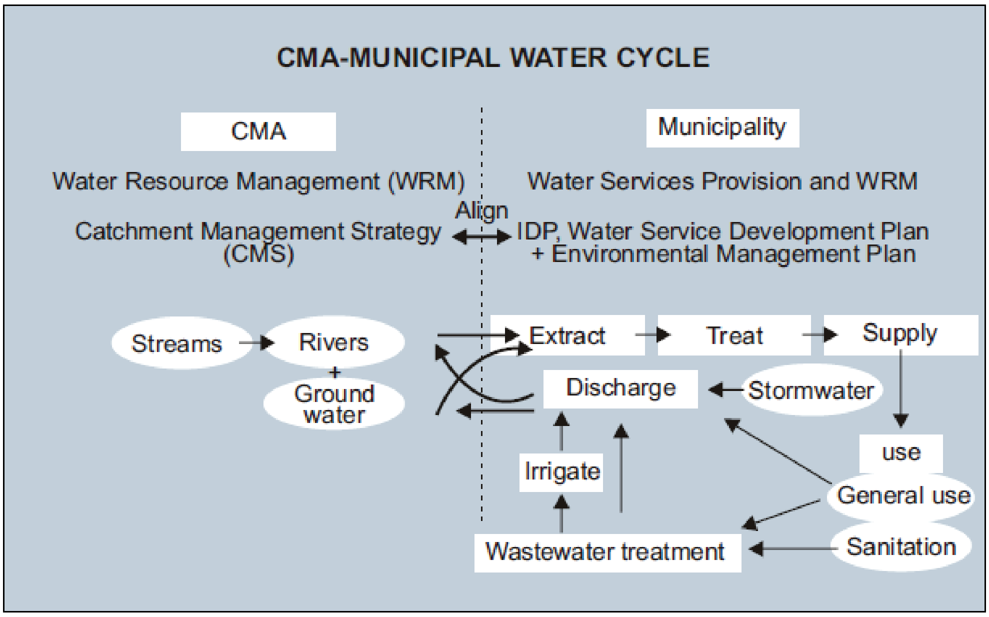


Figure 9-6 Water Resource Management functions between CMA and Municipality (WIN-SA, 2009)

These guidelines describe the functions of both the Catchment Management Agency and the municipality, and propose ways of interaction and cooperation between the two institutions.

Cooperation between CMAs and municipalities is critical, and municipalities need to prioritise interaction with CMAs. CMAs do not provide water services, but play an essential role in ensuring the availability of sufficient water resources (and their quality) for municipalities and other direct users.

Cooperation between municipalities and CMAs involves sharing information and knowledge, and coordination and cooperation with regard to WRM. Municipalities depend on CMAs for their water, and are also involved in activities that protect and conserve water, such as water demand management and environmental conservation. Other municipal activities such as wastewater treatment and disposal, and solid waste management can pollute water resources, if not properly managed.

Municipalities are the third and local tier of government in SA, and are responsible for delivering most basic services. Elected municipal councils have authority to govern their areas and make by-laws, within the framework of the Constitution, and national and provincial government policies.

Municipalities are responsible for most local basic public services, including:

water and sanitation

solid waste management

roads and stormwater

electricity

If the municipality acts as Water Services Provider, it is responsible for providing water to communities and other users, which entails providing and maintaining water infrastructure, procuring and treating water, and selling it to users.

Municipalities have important roles as WSAs in WRM which require cooperation with CMAs. For example, IDPs include various sector plans that impact on water resources and WRM:

Spatial plans for new settlements and recreational areas

Water Services Development Plans

Environmental Plans to:

- protect water resources, the environment and community health
- promote environmental health
- develop environmental awareness
- require Environmental Impact Assessments (EIAs) of high-impact developments
- identify and address environmental hazards

Key WRM-related areas in which CMAs and municipalities need to cooperate are:

water services and sanitation

water quality monitoring

protection of water resources

conservation / water demand management

stormwater management

Municipalities have a complex relationship to CMAs, due to the range of roles that municipalities play. This role complexity must be understood by both parties, and which roles apply in specific situations. Some roles place municipalities and CMAs on the same side of the table, with joint WRM responsibilities (provider/protector) requiring coordination and cooperation; whilst others place them on opposite sides of the table (customer – supplier, regulator – regulated), and require negotiated agreements.

There are also potential role conflicts, e.g. municipalities as project implementers and regulators, where CMAs may need to mediate or intervene, if water resources are affected.

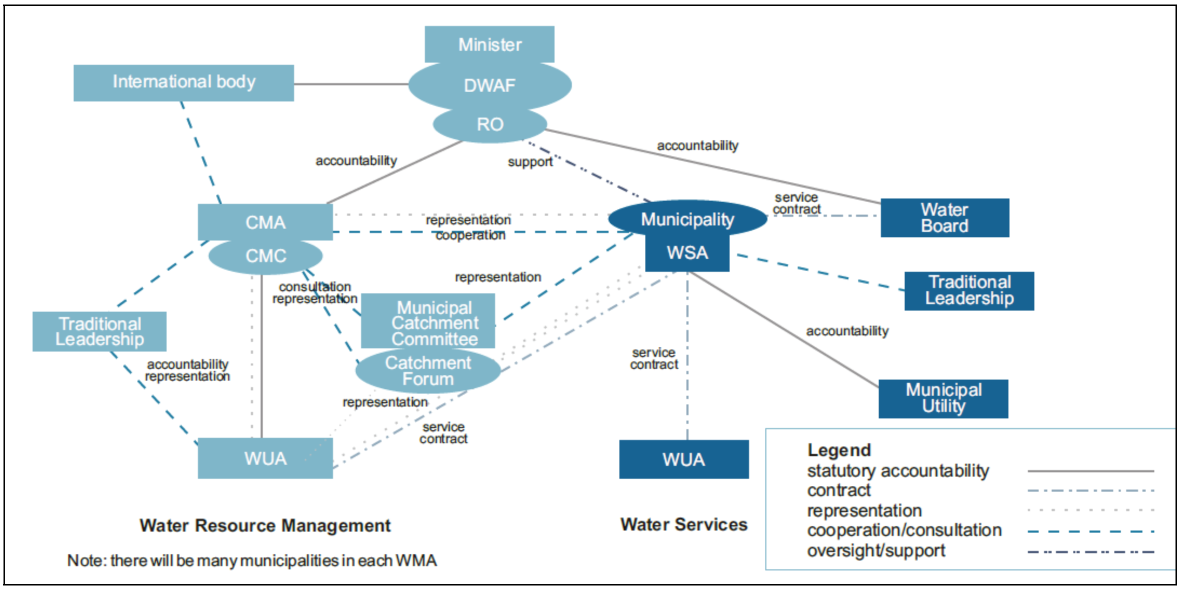


Figure 9-7 Water institutions and their relationships in Water Management Areas (WIN-SA, 2009)

International Guidelines

UN Publication – Groundwater Management: The search for practical approaches

Author	United Nations
Title	Groundwater Management: The Search for Practical Approaches
Year	2003

This publication deals with groundwater management and the problems facing it from a sociological prospective. It describes limitations in the management of groundwater and lists certain gaps in groundwater management, such as:

The inability to cope with the acceleration of degradation of groundwater systems by overabstraction, and effective resource depletion through quality changes (pollution, salinity)

In general, a lack of professional and public awareness about the sustainable use of groundwater resources. In particular, a lack of coherent planning frameworks to guide all scales of groundwater development and the consequent lack of appropriate policy responses and institutional development to prevent and attenuate degradation to groundwater systems.

The failure to resolve competition for groundwater and aquifer services between sectoral uses and environmental externalities.

The publication recommends certain approaches to address the limitations of groundwater management and attempts to overcome the information gaps. Recommendations on the following areas include:

1. Collaborative initiatives in groundwater management
2. Rethinking the approach to groundwater management
3. Basic research
4. Groundwater monitoring and data collection
5. Data dissemination and access
6. Integrated management in strategic locations
7. Laying the foundations for management in complex locations
8. Disseminating global lessons
9. Support for the World Water Assessment Programme

World Bank – Sustainable Groundwater Management: Concepts & Tools

Author	Stephen Foster and Karin Kemper (Editors)
Title	Sustainable Groundwater Management: Concepts & Tools; Briefing Note Series
Year	2002-2006

The series comprises 15 briefing notes on the different aspects of groundwater management, ranging from introductory concepts to protection and conservation of groundwater to resource governance and management practice. The most relevant notes in the context of groundwater management functions are:

Note 1: Groundwater Resource Management

Note 3: Groundwater Management Strategies

Note 4: Groundwater Legislation & Regulatory Provision

Note 6: Stakeholder Participation

Note 7: Economic Instruments

Note 8: Groundwater Quality Protection

Note 9: Groundwater Monitoring Requirements

Note 13: Groundwater Resource Development in Minor Aquifers

This publication emphasises the importance of involving stakeholders in groundwater management. Regulatory framework, definition of water rights, stakeholder participation and use of economic instruments are the main elements in integrated groundwater resource management – leading to a virtuous circle (see **Figure 9-8**).

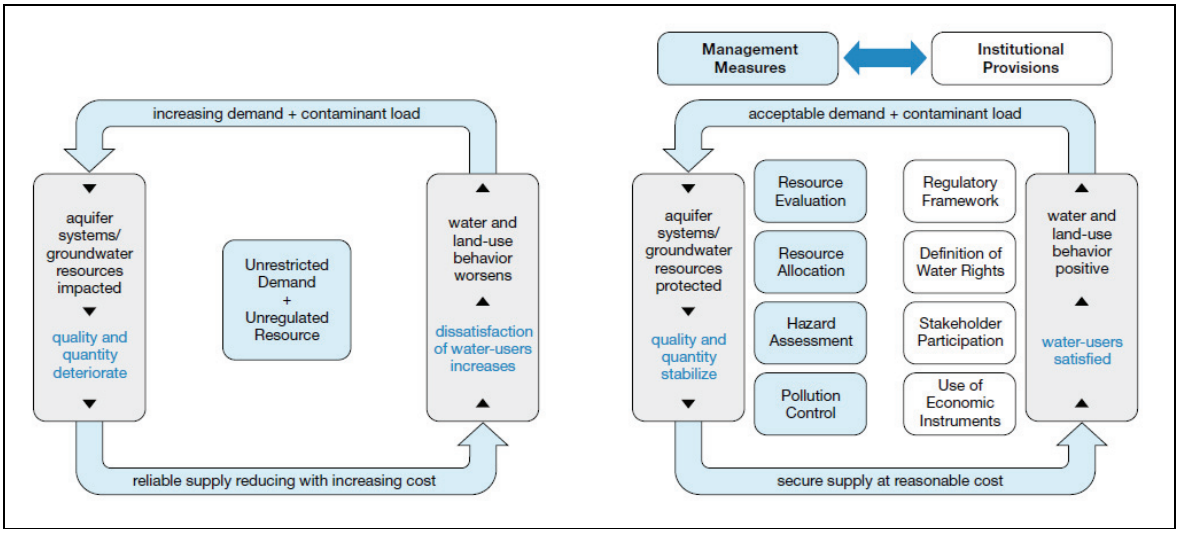


Figure 9-8 a) supply-driven groundwater development – leading to a vicious circle; b) integrated groundwater resource management – leading to a virtuous circle

Groundwater stakeholders are those who have an important interest in the resources of a specified aquifer. This may be because they use groundwater, or because they practice activities that could cause groundwater pollution, or because they are concerned with groundwater resource and environmental management.

Stakeholder participation in groundwater management is essential for the following reasons:

Management decisions taken unilaterally by the regulatory agency without social consensus are often impossible to implement

It enables essential management activities to be carried out more effectively and economically through cooperative efforts and shared burden

It facilitates the integration and facilitation of decisions relating to groundwater resources, water use and waste management.

The document sets out the institutional mechanisms for effective stakeholder participation in groundwater management, as well as the groundwater management functions that can be performed through stakeholder participation.

World Bank – Groundwater Quality Protection

Author	Stephen Foster, Ricardo Hirata, Daniel Gomes, Monica D'Elia and Marta Paris
Title	Groundwater Quality Protection – a guide for water utilities, municipal authorities, and environment agencies
Year	2002

The guide outlines the methodological approach to groundwater protection, of which the main elements are:

Mapping aquifer pollution vulnerability

Delineation of groundwater supply protection areas

Inventory of subsurface contamination load

Assessment and control of groundwater pollution hazards

The procedures presented in this guideline for groundwater pollution hazard assessment and monitoring are the logical precursor to a groundwater quality protection program. As such they provide the basis for requests to the local water resource and/ or environment regulator for action on groundwater protection measures where needed.

The guideline further states that "These actions have to be promoted within the social and economic framework of the area concerned, thus full stakeholder participation in the pollution hazard assessment and in the formulation of control measures will be essential for success."

World Bank – Integrated River Basin Management

Author	Peter Millington
Title	Integrated River Basin Management – From Concepts to Good Practice: Briefing Note 15: The Finishing Touches to the Creation of a River Basin Organization
Year	2006

The note is one in a series explaining the attributes and practical application of integrated river basin management. This note discusses:

The importance of a clear management style and accountability framework,

The impacts of poor organisational management practices, and

The need to value and respect management and staff.

This Briefing Note series considers five main attributes or features as crucial for good integrated river basin management:

Clear and strong institutional arrangements, supported by clear regulations, decrees, or agreements and with well-defined implementing procedures

Good water-related data, information, systems, and models readily available to the river basin partners and those agencies and bureaus operating within the basin

A complete and clear suite or package of basin-wide policies, procedures, and strategies to guide water and natural resource planning, management, and administration

An appropriate form of communication and participation for all basin stakeholders and partners

Basin sustainability performance indicators and an agreed approach to monitor and report on how the basin is being managed and the resources consumed and protected.

However, the assumption, that the basin's resources will be successfully and sustainably managed, if these attributes are in place, is not always true. There is one other factor that should be taken into account: the overall performance of the river basin organization itself – staff performance, internal management systems and approaches, financial and intellectual resource management.

If staff are not adequately skilled and the organization lacks strong, effective leadership, work performance will suffer – regardless of whether all the necessary systems and technology are in place. This note outlines the various ways of motivating and managing staff for optimum performance.

Although not written explicitly for groundwater resource management, the principles outlined in this note are relevant and can be applied to groundwater management. This is the only document so far, that specifically addresses the importance of the management function of "Directing".

US Geological Survey Circular 1186

Author	William M. Alley, Thomas E. Reilly & O. Lehn Franke
Title	Sustainability of Groundwater Resources – U.S. Geological Survey Circular 1186
Year	1999

This circular focuses on the sustainability of groundwater resources. With this in mind it lists the major priorities in groundwater management as follows:

Sustainable long-term yields from aquifers

Effective use of the large volume of water stored in aquifers

Preservation of groundwater quality

Preservation of the aquatic environment by prudent abstraction of groundwater

Integration of surface water and groundwater into a comprehensive water and environmental system.

The circular discusses “water budgets” as a means of measuring groundwater with the goal of achieving sustainability. The circular then gives a case study from the field as to the effect that “pumping” has on the sustainability of groundwater. The effect that groundwater development has on other water bodies such as streams, lakes, wetlands and coastal environments are also discussed.

The circular proposes the following as alternative management strategies that promote the sustainability of groundwater resources.

Use of water resources other than local groundwater

Change rates or spatial patterns of groundwater pumpage

Increase recharge to the groundwater system

Decrease discharge from the groundwater system

Change the volume of groundwater in storage at different time levels.

International Articles

Bidwell – Groundwater Management Tools

Author	Vince Bidwell
Title	Groundwater Management Tools: Analytical Procedure and Case Studies
Year	2003

This document focuses specifically on the issue of “how to manage groundwater allocation under conditions of increasing abstraction and imperfect, but developing, knowledge of the resource. The overall objective is to maintain sustainability of the groundwater resource in terms of acceptable environmental effects”.

The report sets out the management objective of groundwater resources as follows:

“The amount of groundwater stored in an aquifer at any instant of time depends on the dynamic relationship between recharge inputs, through the overlying land surface and from rivers, and outflow to surface waters and pumped abstraction. Aquifer storage provides a buffer between highly variable, climatically-driven recharge processes and the less variable outflow that supports surface water ecology. Abstraction of groundwater for human use, and some kinds of land use changes, alters the dynamic balance between “natural” recharge and the state of surface waters. The resource management objective is to determine the regime of abstraction that results in acceptable environmental effects.”

The report also focuses of monitoring groundwater levels, as well as, methods to quantify inputs and outputs to groundwater sources, in order to manage the sustainability of these sources.

The report proposes using an adaptive method towards groundwater management i.e. “learning while doing”. It states

“The companion report to the present one (Lowry, 2002) provides a comprehensive description of the nature of adaptive management in the context of managing groundwater resources in New Zealand. Material is quoted from that report, in this section, as a means of describing the role of analytical methods that support management.

... adaptive management develops management polices as experiments that test the responses of ecosystems to changes in people’s behaviour.

... shall be thought of as managing the people who interact with the ecosystem, not management of the ecosystem itself.

Adaptive management is a process of ‘learning while doing’.

The emphasis is on cooperative management by stakeholders who need to understand the reasoning behind the possible range of outcomes. The role of models is seen as expressing the collective understanding of the participants about how the groundwater system operates, assessing the uncertainties, and predicting the effects of various management actions.”

The analytical tools that support adaptive management require at least the following characteristics:

Conceptual plausibility to the stakeholders, which means that the physical basis and assumptions can be clearly presented

Ability for implementation in a “real-time” mode consistent with the time scale of adaptive decision-making

Suitable for use with the available data.

The report continues to show various mathematical models for determining inputs and outputs of groundwater resources including the “Eigenmodel”. Included within these mathematical models are case studies from New Zealand showing the effects of using these mathematical models. Within the case studies, the tools of adaptive management are also represented.

Chevalking S et al. – Ideas for Groundwater Management

Author	Simon Chevalking, Lenneke Knoop and Frank van Steenbergen
Title	Ideas for Groundwater Management
Year	2008

The report emphasizes the importance of groundwater as water resource. It starts off by giving an overview of groundwater use and the importance of monitoring groundwater, both for quantity and quality reasons

Information sharing is expressed as a helpful tool in groundwater management. In order to improve this technique of information-sharing, classification of aquifers and flow systems, use of hydrological maps and a pollution locater and hotline are suggested.

Regulating the use of groundwater through such techniques is suggested. These examples include minimum distance rules, zoning, banning of certain types of crops and wells. This report goes on to describe other practices, tools and methods to regulate the use of groundwater.

Promoting the recharge of groundwater through techniques, such as re-activating flood plains and using porous pavements, is emphasized as an important tool in groundwater management.

Techniques for improving and maintaining groundwater quality are given

This report also describes several different types of groundwater management organizations and how to go about establishing them. In so doing groundwater awareness towards the public is increased and this aspect of groundwater management is discussed further in the report.

Lowry et al. – Groundwater Resource Management – Information Gaps Analysis.

Author	Thomas Lowry, John Bright, Christina Robb
Title	Groundwater Resource Management: Information Gaps Analysis
Year	2001

This report focuses on 2 main areas, namely the methodology and procedures in performing a gap analysis on groundwater issues and analyzing the gaps in light of groundwater management issues.

It proposes the following methodology, when undertaking a gap analysis:

Determine what information is required to manage groundwater resources

What information exists and where is it held

Identify the gaps

Determine ways to manage in presence of gaps and ways to fill the gaps.

The report identifies gaps specifically in New Zealand; followed by suggestions as to how to manage groundwater with these gaps in information, as well suggestions for filling these gaps follow. Some of these suggestions include:

Calculation of groundwater allocation on quantity considerations

Calculation of land-use limits on groundwater quality considerations

Managing groundwater systems as information becomes available

Economic benefits of monitoring and investigations

Relating the adaptive management approach to the identified gaps

Water Resource Valuation

Abstracts from the FAO (2003):

Estimates of the value of groundwater have assumed great importance in the context of the massive investments required to avoid pollution, remediate polluted aquifers and control overdraft. Some objective basis, related to the total economic value of the resource (including wider social and environmental values), is required to determine how much to invest in specific situations. However, the available valuation methods are partial at best. Techniques for quantifying the economic value of groundwater resources include:

Contingent valuation, which essentially involves asking people how much they would pay to maintain the resource or services dependent on it under carefully specified conditions.

Hedonic pricing, e.g. obtaining a measure of the value of groundwater through differences in the value of lands with and without access to it.

Derived demand and production cost analysis, essentially estimating the contribution of water to profits within a given set of economic activities.

Loss analysis, estimating the value of groundwater as equivalent to the total social costs incurred when drought or depletion constrain economic activity.

Averting behaviour in which the value of groundwater is estimated by the investments made to avoid water shortage.

Substitution, the value of groundwater as equivalent to the least cost alternative source of supply for meeting the same set of services.

The above quantitative techniques do not capture adequately many of the qualitative values associated with groundwater, the full range of services and benefits that it provides. They also assume perfect knowledge of the groundwater systems in space and time and the precise impact of uses (including disposal). Non-use and *in situ* values, such as the prevention of saline intrusion and the protection of the environment against low-frequency events, are particularly difficult to establish values for.

A similar ethical divide surrounds questions of ability versus willingness to pay. Quantitative measures of willingness to pay established by any of the primary methods ignore questions of ability to pay. For example, the socio-economic status of respondents can colour their responses in contingent valuation surveys. Access to groundwater is often a critical factor in the quality of life for socio-economically marginal populations in developing countries. However, their ability to pay for maintaining groundwater resources is often minimal. How this contradiction can be resolved depends on whether groundwater is treated as a common heritage (to which all have equal and fundamental rights) or as an economic good.

In sum, the degree to which people understand groundwater and its contributions to economic, environmental and other services may well influence the value they place on the resource.

Reallocation of groundwater rarely occurs through the consensual transfer of use rights and in these instances it could be argued that the application of valuation methods would achieve little. Irrespective of the technical ability to capture groundwater, irrigated agriculture cannot compete with higher value municipal uses on economic grounds alone.

<u>Abstract from "Valuing Ground Water" (National Research Council, 1997):</u>

(Economic Concepts and Approaches Committee on Valuing Ground Water, National Research Council, USA)

One of the major challenges in valuing ground water is how to integrate the hydrologic and physical components of ground water resources into a valuation scheme. An appropriate conceptual basis for valuation identifies service flows as the central link between economic valuation and ground water quality and quantity.

Defining the best long-term management of the resource requires balancing the needs of the present with those of the future. In theory, the balancing is done everyday by markets as reflected in the discount rate. However, many citizens, policy-makers, and scientists believe that the discount rate does not adequately consider the value of goods or services for future generations. The discount rate a water utility employs when valuing ground water reflects perceptions of risk, returns, and possibly intergenerational equity. A high discount rate implicitly places a low value on the water's value to future generations. A low rate implies the opposite.

In order to put the economic value of groundwater into perspective the United States Government commissioned a project in 1994 to determine the economic value of groundwater. According to that study the first and fundamental step in valuing of a groundwater resource is **recognizing and quantifying that resource's total economic value (TEV)**. For the purposes of that study groundwater services have been divided into two basic categories: **extractive services** and **in situ services**. Each of these is considered to have an economic value which can be summed up as follows:

TEV = extractive value + in situ value.

The most familiar of these two are the extractive values, which are derived from municipal, industrial and agricultural demands met by groundwater. (In the majority of these cases the economic value of groundwater is only translated in related costs, e.g. cost of exploration and production drilling, pumping equipment and operational costs (such as electricity, lubricants and repairs), but not as a value per unit of groundwater abstracted.) The in-situ services (i.e. services or values that occur or exist as a consequence of water remaining in place in an aquifer) include e.g., the capacity of groundwater to, a) buffer against periodic shortages of surface water supplies, b) prevention or minimizing of subsidence due to groundwater abstraction (sinkholes), c) protect water quality by maintaining the capacity to dilute and assimilate groundwater contaminants.

The valuation of extractive and in-situ services of groundwater requires an understanding of geology, geohydrology and ecology of a certain groundwater resource. Hydrological and geohydrological information includes numerous factors such as rainfall, runoff, depth to groundwater, whether the water-bearing zone if confined or unconfined, the groundwater flow rates and direction, type of vadoze and water bearing zone materials and water quality associated with different strata.

Most groundwater applications in especially the agricultural sectors have focused on the valuation of limited production related services provided by groundwater. This has lead to misallocation of resources in the past. Enormous amounts have been spend in attempting to augment water supplies in agriculture, trying to clean up polluted groundwater resources and fighting court battles resolving water allocation issues. A valuation framework must take into account how time, institutions, water quality and quantity, hydrologic factors, and services interact to affect the resource's value.

Abstract from D.B. Louw & H.D. van Schalkwyk (2001).

(The development of a methodology to determine the true value of water and the impact of a potential water market on the efficient utilisation of water in the Berg River Basin. University of the Free State, Bloemfontein)

Conclusions, which emerge in similar studies (Shah, 1993; World Bank, 1995; Gibbons, 1986; Gazmuri and Rosegrant, 1996; Briscoe, 1996; World Bank Water Demand Research Team, 1993) that draw together large amounts of available data, include:

Value in irrigated agriculture in industrialised countries: It is, firstly, important to note that irrigated agriculture accounts for a large proportion of water use, especially in many water-scarce areas. The value of water for many low-value crops (such as food grains and fodder) is universally very low. Where reliable supplies are used on high-value crops, the value of water can be high, sometimes of an order of magnitude similar to the value of water in municipal and industrial end uses.

Value of irrigation water in developing countries: The picture in developing countries is similar. In Western India groundwater is exploited by private farmers and is provided in a timely and responsive fashion to users (the farmers themselves and others to whom they sell the water). The water is used on high-value crops (including fruits, vegetables and flowers). The value of water, as reflected in active and sophisticated water markets, is high. In public (mostly surface) irrigation systems in the same country, the quality of the irrigation supply is poor, foodgrains are the major crop produced, and the value of water is typically only about 0.5 cents per cubic meter, orders of magnitude lower than in the private groundwater schemes. Similar very large and persistent differences are found in publicly run irrigation schemes throughout the developing world (Gibbons, 1986).

The value of water for household purposes is usually much higher than the value for most irrigated crops. Not surprisingly, the value for "basic human needs" and for household uses is much higher than the value for discretionary uses (such as garden watering). An important finding (similar to that emerging from the irrigation data) is that people, even poor people in developing countries, value a reliable supply much more than they value the intermittent, unpredictable supplies which are the norm in most developing countries.

The value of water for industrial purposes is typically of a similar order of magnitude to that of supplies for household purposes.

The value for environmental purposes (such as maintenance of wetlands, wildlife refuges and river flows) also varies widely, but typically falls between the agricultural and municipal values. In developing countries most similar work has been done on the value of mangrove swamps (in El Salvador, Malaysia, Indonesia and Fiji), which are critically dependent on inflows of fresh water. These data, too, show quite high values (primarily due to the off-site impacts on fisheries).

Millennium Ecosystem Assessment Framework (MA, 2005)

The Millennium Ecosystem Assessment was established with the involvement of governments, the private sector, nongovernmental organizations, and scientists to provide an integrated assessment of the consequences of ecosystem change for human well-being and to analyze options available to enhance the conservation of ecosystems and their contributions to meeting human needs.

The assessment framework developed for the MA offers decision-makers a mechanism to:

Identify options that can better achieve core human development and sustainability goals.

Better understand the trade-offs involved—across sectors and stakeholders—in decisions concerning the environment.

Align response options with the level of governance where they can be most effective.

Extract from Chapter 2 – Ecosystems and their Services

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans are an integral part of ecosystems.

A well-defined ecosystem has strong interactions among its components and weak interactions across its boundaries. A useful ecosystem boundary is the place where a number of discontinuities coincide, for instance in the distribution of organisms, soil types, drainage basins, or depth in a water body. At a larger scale, regional and even globally distributed ecosystems can be evaluated based on a commonality of basic structural units.

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth.

An assessment of the condition of ecosystems, the provision of services, and their relation to human well-being requires an integrated approach. This enables a decision process to determine which service or set of services is valued most highly and how to develop approaches to maintain services by managing the system sustainably.

Extract from Chapter 6 – Concepts of Ecosystem Value and Valuation Approaches:

Decision-making concerning ecosystems and their services can be particularly challenging because different disciplines, philosophical views, and schools of thought conceive of the value of ecosystems differently.

In the utilitarian (anthropocentric) concept of value, ecosystems and the services they provide have value to human societies because people derive utility from their use, either directly or indirectly (use values). People also value ecosystem services that they are not currently using (non-use values).

Under the utilitarian approach, numerous methodologies have been developed to try to quantify the benefits of different ecosystem services. These are particularly well developed for provisioning services, but recent work has also improved the ability to value regulating, supporting, and cultural services. The choice of valuation technique is dictated by the characteristics of each case and by data availability.

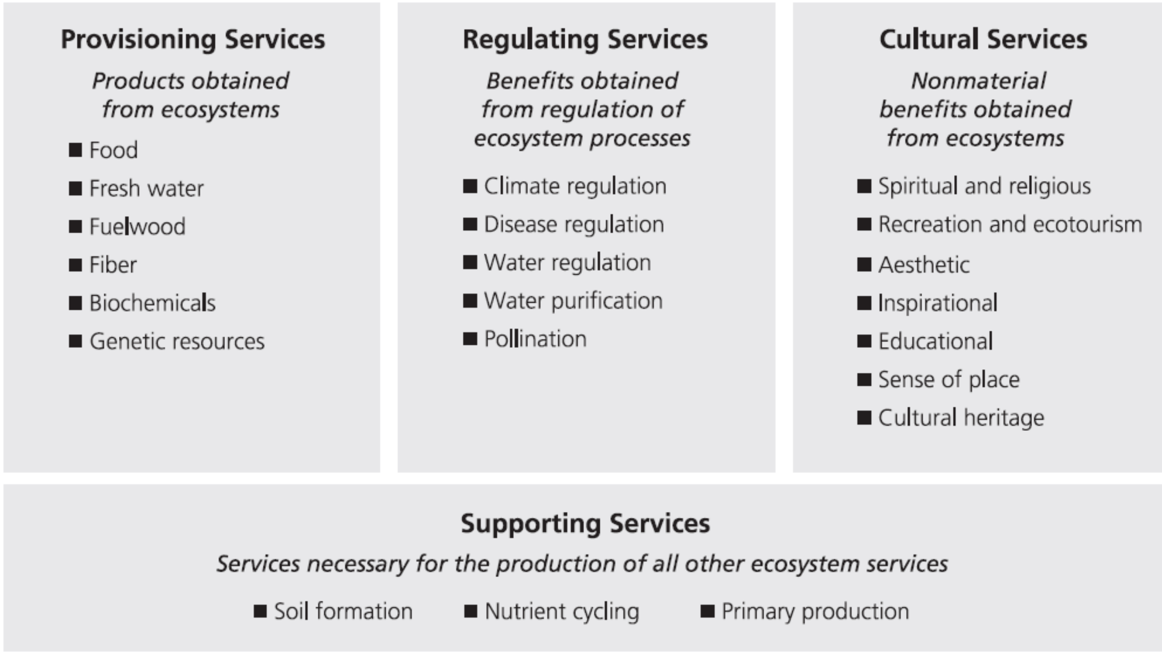


Figure 9-9 Structure of Ecosystem Services (MA, 2005)

Non-utilitarian value proceeds from a variety of ethical, cultural, religious, and philosophical bases. These differ in the specific entities that are deemed to have value and in the interpretation of what having non-utilitarian value means. Notable among these are ecological, sociocultural, and intrinsic values. These may complement or counter-balance considerations of utilitarian value. The legal and social consequences for violating laws or regulations based on an entity's intrinsic value may be regarded as a measure of the degree of that value ascribed to them.

The Millennium Ecosystem Assessment plans to use valuation as a tool that enhances the ability of decision-makers to evaluate trade-offs between alternative ecosystem management regimes and courses of social actions that alter the use of ecosystems and the services they provide. This usually requires assessing the change in the mix of services provided by an ecosystem resulting from a given change in its management.

Most of the work involved in estimating the change in the value of ecosystem benefits concerns estimating the change in the physical flow of benefits (quantifying biophysical relations) and tracing through and quantifying a chain of causality between changes in ecosystem condition and human well-being. A common problem in valuation is that information is only available on some of the links in the chain, and often in incompatible units.

Ecosystem values in terms of services provided are only one of the bases on which decisions on ecosystem management are and should be made. Many other factors, including notions of intrinsic value and other objectives that society might have, such as equity among different groups or generations, will also feed into the decision framework.

The Economics of Water Management in Southern Africa: an environmental accounting approach (Lange and Hassan, 2006)

Extract from Chapter 7 – Methodologies for Valuation of Water Services

Like other ecosystem services, the value of water derives from its importance and contribution to the well-being of humans and other life on earth. Fresh water is essential to the survival (physiological need) of all living resources including human population (provisioning services). Water also provides indirect use benefits as an intermediate input in economic production (irrigation and industry) and in maintenance of critical ecological processes and functions (ecological production, for example, regulating and supporting services). People also use water for recreational, aesthetic, social and religious purposes (cultural services). The above economic, ecological and sociocultural values of water are conceived and measured in different ways, depending on disciplines of study and philosophical conceptions of enquirers.

The **economic value of water** is the price that an economic agent or consumer would pay for a unit of water for a particular purpose (household use, irrigation, etc.) rather than do without the water. However, the price charged for water does usually not reflect the scarcity of the resource.

There are two basic reasons why a competitive water market cannot develop:

Water is a necessity for human survival: The Willingness-to-pay (WTP) or value for basic survival is infinite.

The natural characteristics of water inhibit the emergence of competitive markets.

Extract from Chapter 9 – The value of water for off-stream uses in South Africa

Use of water for domestic purposes in South Africa ranked second followed by services and manufacturing activities. Managing the demand for domestic and industrial use is important for policy, especially in economies where the supply of water is scarce.

In urban areas water is usually supplied by municipal authorities to domestic and industrial users through a water reticulation network. In such systems water consumption is metered and users pay tariffs on their water use. […] Unlike urban dwellers, rural populations are typically not supplied with metered water and usually do not pay for the water they fetch directly from rivers, lakes and underground sources. […] Demand for water by rural households is non-responsive to the tariffs charged for water supplied from communal standpipes.

Results documented in this chapter indicate that off-stream users in South Africa generate higher economic benefits from water than what they typically pay for it. The policy implication of this result is that there is an economic surplus margin to exploit, at least for recovering water supply costs from off-stream activities.

Appendix B – Case Studies

Baviaans Municipality – Willowmore

Emthanjeni Municipality – De Aar

Cederberg Municipality – Elands Bay

Examples from National Groundwater Strategy

Baviaans Municipality – Willowmore

Locality

Willowmore is located approximately 170 km north east of George along the N9. The Willowmore area is characterised by central plains and lowlands bordered by low parallel hills and mountains to the north and south.

The area has a semi-arid climate, typical of the Karoo Region. The annual rainfall varies over the years, with an average of 272 mm, measured over the past 32 years at Willowmore.

Water Supply Source and Infrastructure

The town of Willowmore obtains all of its bulk water supply for municipal consumption from wellfields developed in the Wanhoop and Grootkloof areas, ~25 km south of the town. The six boreholes are spread over an area of approximately 2 km.

The water pumped from the boreholes and that sourced from the spring are mixed at the head of the water treatment works and the ph is corrected before flowing into the raw water storage dam. From the raw water storage dam the water is pumped through spray nozzles located in four $10m^3$ polyethylene tanks, thereby aerating the inflow, where after the water gravitates to two settling tanks and on to four rapid gravity sand filters. The filtered water is then chlorinated and gravitates to a storage reservoir. The clear water is pumped into Willowmore via a 29 km long rising main to three reservoirs.

Willowmore is presently fully reticulated with all residential consumers having house connections. All non-residential erven are also serviced with individual water connections. The bulk of the reticulation is reasonably old and reasonably high reticulation losses could be expected. No water loss management programme is presently in place.

The wellfields are used to their maximum capacity. Due to low-cost housing development and other infrastructure development at Willowmore, the water requirements have increased and further groundwater resources are required to augment the bulk water supply.

The current supply is estimated at 20l/s whilst the requirement demand is approximated to 37 l/s. The quaternary catchments, where the current boreholes are located, have a water balance of 491 l/s which can still be harvested in a sustainable fashion.

Problems and issues

Groundwater monitoring was limited to monthly or quarterly measurements. The boreholes are run on a timer switch. The WSA/WSP did not comply with the minimum requirements for O&M as the groundwater monitoring and O&M resources like staff, vehicles and equipment were not adequate. In order to rectify this situation the WSA has identified that a comprehensive Operational & Maintenance Plan needs to be developed that will cover all the required activities. Based on these, the financial resources required to comply with these plans can be calculated and the WSA can then determine what this effect would have on the tariff structure to ensure compliance in providing the required O&M.

The WSA has a service level agreement with the Environmental Health section of the Health Department of the Cacadu District Municipality in order to conduct the monitoring of the water quality.

The municipality has identified the following strategies to address the current problems and issues:

Augmenting the bulk-water supply either by increasing number of boreholes.

Instillation of a telemetry system for effective groundwater resource management.

Installations of zone meters and establish accurate detail of the reticulation pipelines and layout plans.

Training staff and purchasing more vehicles.

Develop pollution control plan.

Develop environmental awareness and education.

The municipality has also developed and implemented a Water Conservation and Demand Management Strategy to reduce losses and increase water use efficiency,

In addition, the following recommendations for groundwater management were given by the geohydrological consultant and implemented by the municipality:

The recommended borehole pumping rates and pump installation depth should not be exceeded.

Monitoring of borehole abstraction rates, water levels and water quality should be carried out as part of the water management plan for the Willowmore bulk water supply scheme.

Regular assessment and reporting of the monitoring data should be carried out by a qualified hydrogeologist for incorporation in the management plan.

Institutional Situation

Baviaans has become a Water Services Authority (WSAs) in terms of the Water Services Act through the finalisation of the division of powers and functions. The Baviaans Municipality are in the final stages of reviewing the Section 78(1) reports regarding the assessment of Internal Service Delivery Mechanisms as required by the Municipal Systems Act, Act 32 of 2000.

The preliminary findings of the above report recommend *" to explore the possibility of providing the service through an external mechanism mentioned in section 76(b) by proceeding with further investigations n terms of section 78(3) of the Act*". The findings of this report will have an impact on what capacity development is required by the WSA.

The Baviaans Municipality does not have separated the staff for water, sanitation, finance and corporate services. Currently the staff members perform other functions out side of the water and sanitation services.

Baviaans' ability to finance its water services capital programme from its tariff revenue is weak. Income generated from water in 2003/04 was R 731 588, whereas capital expenditure for that year amounted to R1,800,000 for the development of water resources and R 1,800,000 for sanitation services in Steytlerville.

Of particular concern is the low provision for repairs and maintenance; at 2.5% for

2003/04 this is well below the acceptable norm of around 9%. The expenditure trend on this item has been declining over the last financial years from 8.5% in 2000/2001, 7% in 2001/02 to 4.5% in 2002/03. Declining expenditure in maintenance is a strong indicator of stress within the operating budget. Given systemic underinvestment from infrastructure maintenance since 1985 provision for maintenance should perhaps be exceeding 10% for some time in order to avoid asset stripping.

Standard indicators of operating financial health profile of Baviaans municipality in general reflect a picture of a constrained budget resulting in declining expenditure in maintenance. Given the planned increases in infrastructure extension it is predictable that the stress in the operating account will increase, resulting in increasing pace of asset stripping. As a consequence the financial sustainability of Baviaans Municipality to provide, expand and maintain its water services portfolio can be questioned.

There is no generally accepted norm for water services staffing efficiency. From the data available it does not seem as if Baviaans has a particularly inefficient staffing profile. What is less obvious is the sufficiency of human resources at all levels to sustain the existing services footprint. Most municipalities have faced a significant increase in operational responsibility since amalgamation in 2000 that has not been mirrored in the increase of operational capacity. However, this problem, although significant, is hardly unique to Baviaans Municipality. Due to National Treasury growth limitations imposed on municipal budgets it can be assumed that the pressure on municipal staffing levels will not change within an internal service delivery arrangement; the existing municipal capacity cannot realistically be expected to grow.

Success parameters

Despite these bleak outlooks the municipality succeeded in establishing sustainable groundwater management. The main success parameters are:

Telemetry System to assist groundwater management;

Scientific support from external consultants on request;

Wellfields far away from possible pollution sources;

Using undersized pumps to avoid over-abstraction;

Committed staff taking proud in delivering good quality water.

Emthanjeni Municipality – De Aar

Locality

Emthanjeni Municipality was formed when the three towns of De Aar, Britstown and Hanover were combined in accordance with the Municipal Demarcation Act (Act 27 of 1998). Emthanjeni Municipality is both the Water Services Authority and the Water Services Provider for De Aar. The town of De Aar is located in the Northern Cape Province along the N10 road between Hanover (60 km away) and Britstown (50 km away). It lies approximately 270 km southwest of Bloemfontein and 400 km inland from Port Elizabeth. De Aar falls in the 'Lower Orange' Catchment Management Area (WMA 14) and is located on the drainage divided between the D62C and D62D Quaternary Catchments. De Aar falls under the jurisdiction of Emthanjeni Local Municipality (LM) in Pixley ka Seme District.

Water Supply Source and Infrastructure

The main geology underlying the area comprises of Karoo Sediments with the Adelaide Subgroup (mudstone with sub-ordinate sandstone) being present in the southeast and the Ecca Group (shale) in the northwest. A large number of dolerite intrusives (dykes and sills) are present, of which the contact zones with the Karoo Sediments constitute prominent aquifers. Sand and clay rich alluvial deposits occur along major rivers, where in some places thicknesses of up to 16 m are attained, and a basal (coarse grained) sand and gravel aquifer (2 to 4m thick) is commonly present.

Natural water level fluctuations (dynamic storage) and corresponding aquifer storativity were estimated from the monitoring data for all 10 groundwater units. The aquifers are shallow and seldom extend to depths > 20 mbgl. Water levels during high rainfall periods are less than 3.5 m deep with critical operational water levels ranging between 7.5 up to 20 mbgl. The dynamic storage estimates for all groundwater units varied between 1.3 to 3.5 m. This yielded a combined dynamic storage capacity of 7.254 million m^3 per annum, sufficient to meet the current water requirements from storage for 3 years.

De Aar relies solely on groundwater abstracted from ten groundwater units / wellfieds comprising of 51 production boreholes located up to 35 km from the town. De Aar is currently pumping 2.3 million m^3 of groundwater per annum. The boreholes are equipped with electrical and diesel powered pumps and monitored and controlled via a telemetry system.

These groundwater units are spread over two quaternary surface catchments, namely D62C and D62D which have been historically subdivided into five broad geographic areas or schemes, namely:

South-Western Scheme

Northern Scheme

Caroluspoort Scheme

South-Eastern Scheme

Burgerville / Zewefontein Scheme

In the past the De Aar has suffered from numerous water shortages which resulted in the Department of Water Affair and Forestry (DWAF) conducting two extensive geohydrological investigations in the mid 1970's and late 1980's with the aim of securing sufficient groundwater resources to meet the towns water requirements until 2020. The town's current water requirements are estimated at ~2.3 Mm^3/a, although only 1.6,Mm^3 was abstracted in 2006. The monthly groundwater abstraction is read from water-meters attached to each production borehole and the information is archived at the Municipal offices. This information is supposed to be captured into the AquiMon Database by the Municipal official, but lack of adequate computer skills, inadequate training and accidental loss of the database, which had not been backed-up, have held back efforts of trying to monitor and manage groundwater accurately. However, this is now solved through the installation of the latest version of the AquiMon groundwater monitoring and management software and adequate training of responsible staff.

Management options

A number of recommendations have been made for the Emthanjeni Municipality:

Lime softening has been recommended for the treatment of the water in Emthanjeni. This process removes the hardness, reduce scaling and improve the ability of cleaning products to foam. Lime softening would also make the water more palatable by removing the bitterness.

An accurate monitoring programme to be established to monitor especially those variables that are of concern to the health of the individuals using the water.

A better borehole management system is also recommended in terms of a blending procedure and should be implemented to achieve the dissolved solid concentrations required (1200-1300 mg/l) and this is linked to the water quality programme.

Water quality between the periods 2000-2003 has been of fairly good quality when comparing the sodium, sulphate and chlorine concentrations with the ones recorded during the 1980's and 1990's. It is recommended that the trend towards an improved water quality should be monitored.

A preliminary analysis of the De Aar water supply system estimates that about 12.1% of the current bulk input volume is being lost, and part of this can be saved over a period of 5 years if WC/WDM measures are put in place.

Success parameters

In the town of De Aar analytic data is limited but is available for the period 1980-2003 and during this period the number of production boreholes has increased and no boreholes have been closed. Water for the supply of De Aar is sourced from 7 extensive borehole fields consisting of 55 boreholes. The configuration of some 50 boreholes is capable of delivering 260 L/s and has an updated (2007) maximum capacity to yield 2.798 million m^3 per annum (7.666 Mℓ/d). Recommended borehole yields range from 3 to 15 ℓ/s for daily duty cycles of 4 to 16 hours. The sustainable use of the groundwater resources is achieved through:

Telemetry System to assist groundwater management;

Data management and data evaluation;

Scientific support from external consultants on request;

Adequate funding and budgeting; and

Committed staff.

Cederberg Municipality – Elands Bay

Locality

The Water Services Authority (WSA) is the Cederberg Municipality (CM). CM falls within the Olifants / Doorn Water Management Area (WMA). The Olifants / Doorn WMA is located on the west coast of South Africa, extending from about 100 km to 450 km north of Cape Town. The major river in the WMA is the Olifants River and the main tributaries are the Doring River (draining the Koue Bokkeveld and Doring areas) and the Sout River (draining the Knersvlakte).

Clanwilliam, Citrusdal, Lamberts Bay, Elands Bay, Graafwater, Leipoldtville, Wupperthal, Paleisheuwel and Elandskloof all fall under the Cederberg Municipality. Elands Bay is a small fishing and farming town on the West Coast about 250 km north of Cape Town.

Water Supply Source and Infrastructure

The town water supply is obtained entirely from groundwater making the aquifer from which this water is abstracted critical and very important. In addition, the role groundwater plays in the environment is also significant.

The aquifer thickness is between 9 and 30 m with a transmissivity of 600 m^2 for the deepest part of the aquifer. Aquifer tests proved that, with correct screen emplacement and proper drilling and development, yields of up to 10 l/sec are possible in the most transmissive zones. A number of boreholes show increasing electrical conductivity (EC) with depth. The deep brackish groundwater may be associated with the underlying Piekenierskloof basement rocks.

This town had seven production boreholes that supplied water. Boreholes R1 and R2 provide relatively good quality water, but their water levels are dropping. Borehole R3 is stable in terms of water levels and quality. R4, R6 and R7 in terms of standards set by SABS should essentially be decommissioned as their water quality exceeds the maximum permissible quality. R5 has already been decommissioned due to poor water quality; meaning approximately 23% of the current water supply to Elands Bay should be discontinued.

The groundwater abstraction for 2006 was 186 932 m^3, which is estimated to increase to 190 643 m^3 by 2011.

It is important that additional water be secured for the town of Elands Bay. Under a recently completed groundwater exploration project in the dune field area to the north of Elands Bay, three borehole sites were identified (see below). Elands Bay needs immediate management intervention and the current water supply situation of the town is in a state of crisis.

Management options

The Cederberg Municipality has committed itself to monitoring the quality of water from its own sources on a quarterly basis in order to ensure that it is healthy enough for human consumption. The quality of the water abstracted from boreholes is also monitored on a regular basis.

Elands Bay is dependent on groundwater and with the recent construction of two reservoirs; the town is well catered for in terms of water reticulation. The monitoring of groundwater is essential for Elands Bay because of the high importance of groundwater. The town's management options include:

Groundwater data should be collected weekly, and recorded in logbooks.

Groundwater data should be collected for the seven production boreholes and the listed monitoring boreholes.

A water sample should be collected every 3 months and analysed for major constituents, including nitrate by an accredited laboratory.

All collected data should be maintained on a database at the Eland's Bay and Clanwilliam municipal offices.

The Groundwater Coordinator, DWA or a consulting hydrogeologist must review the results initially on a six monthly basis.

A proper monitoring protocol must be established and implemented.

The Cederberg Municipality, DWA and GEOSS (Pty) Ltd are collecting the groundwater data at different intervals. Both groundwater level data and less frequently groundwater quality data is collected for Elands Bay and three other areas within the CM which also use groundwater (Graafwater, Lamberts Bay and Leipoldtville). The CM is doing good work with regard to groundwater monitoring and monitors key boreholes on a monthly basis. Monitoring programs of the status of the aquifer indicate that the source shows signs of over-utilisation.

A groundwater exploration programme was undertaken to explore the groundwater potential of the most favourable area. This area is on the farm Waaihoek, 10 km of Elands Bay on the Elands Bay – Redelinghuys road. Four boreholes were drilled and three of the four showed good groundwater potential both in terms of yield and quality. The three boreholes (OD00525, OD00526 and OD00528) were pump tested and water samples collected.

It is recommended that once the three new boreholes are incorporated into the Elands Bay supply scheme, the boreholes R4-R7 be no longer used. The abstraction rates or associated volumes must not be increased from boreholes R1, R2 and R3.

Success parameters

Although the groundwater situation for Elands Bay is difficult, and the water quality is deteriorating, the municipality manages the aquifer to the best of its capability due to the following factors:

Data management and data evaluation;

Scientific support from external consultants on request;

Support from DWA and the West Coast District Municipality;

Committed staff.

Examples from National Groundwater Strategy

The report "National Groundwater Strategy: review of groundwater management examples in South Africa" by the Department of Water Affairs (DWA, 2009) lists six examples, of which four are relevant to this project and can be utilized as additional case studies:

City of Cape Town – Atlantis

Beaufort West

Prince Albert

Pretoria

The main factors determining the success of groundwater management in all or some of these areas are given in the report as:

Competent and dedicated local management

Ongoing monitoring and data evaluation

Adequate funding

Support of WRC and DWA

Ongoing scientific support by external specialists

The example of Dendron in Limpopo highlights the problems and issues that can easily lead to failure of the borehole supply:

Involvement of DWA as regulator has been weak;

Different users are not unified – no leadership;

No incentives for sustainable management.

The report further highlights the importance of Operation & Maintenance (O&M) for sustainable groundwater management, an area that is often neglected in guidelines and practice. "*Ensuring that O&M tasks are always carried out requires strong overall management, training of operators, and adequate funds. […] Critical to successful O&M are more generic municipal and institutional functions and procedures such as budgeting, training and retention of staff, accountability frameworks, and other features …*"

Appendix C – Example Groundwater Management Plan

(not comprehensive)

Groundwater Management Plan – Hermanus Municipality			
Administrative and Organisational Structure			
Administrative Structure	**Name**	**Responsibility**	**Authority**
Mayor		Political	Approve groundwater management expenditure
Municipal manager		Ultimate	Budget for costs of groundwater management
WSA manager	Mr H Blignaut	Technical	Prepare costs for groundwater development and management
Operational manager	Mr P Burger	Technical	Operate wellfield according to licence conditions
Wellfield operator		Operate boreholes, undertake routine maintenance, react to emergency calls	Switch off boreholes in emergencies
Data collector (groundwater bailiff)		Collecting the required data as per monitoring protocol; Report any problems to OM and WSA Manager	

Aquifer Detail			
Name	**Type**	**Well fields occurring in this aquifer**	**Capacity of this aquifer (m^3/a)**
Peninsula Aquifer, Resource Unit 2	Secondary (TMG sandstone)	Gateway	1 600 000
Peninsula Aquifer, Resource Unit 3	Secondary (TMG sandstone)	Camphill	Under development
		Volmoed	Under development
Skurweberg Aquifer, Resource Unit 2	Secondary (TMG sandstone)	Hemel en Aarde Estate	Private (landscaping)
Bredasdorp (Stanford) Aquifer	Primary, Karst	Springs	400 000
		Kouevlakte	Under development
		Middelburg	Private (irrigation)

Aquifer Detail			
Name	**Type**	**Well fields occurring in this aquifer**	**Capacity of this aquifer (m^3/a)**
Alluvium Aquifer, Resource Unit 2	Primary Aquifer	Private users	Private (gardening)

Technical specifications of municipal wellfield and boreholes					
Wellfield Name	**Borehole Number/name**	**Borehole Depth**	**Borehole Yield**	**Pump capacity**	**Duty Cycle**
Gateway	GWP01	104m	12 l/s	9 l/s	24 hours
	GWP02	210m	25 l/s	20 l/s	24 hours
	GWE06	164m	16 l/s	16 l/s	24 hours
Camphill	HAV1	156m	N/a	N/a	N/a
	HAV2	110m	N/a	N/a	N/a
	HAV3	204m	N/a	N/a	N/a
	HAV4	113m	N/a	N/a	N/a
Volmoed	T4/1	220m	N/a	N/a	N/a
	T4/2	250m	N/a	N/a	N/a
	T4/3	205m	N/a	N/a	N/a
	T4/3	210m	N/a	N/a	N/a
Stanford springs	Eye	N/a	33 000 m^3/month		On demand
	Springfontein	N/a	Unknown	N/a	Not used
Kouevlakte	KVE01	114m	N/a	N/a	N/a
	KVE02	117m	N/a	N/a	N/a

Aquifer Protection			
Name	**Protection Zone**	**Value of Aquifer**	**Comment**
Peninsula Aquifer, Resource Unit 1	Recharge area	Main source of water for Hermanus	Nature Reserve
Peninsula Aquifer, Resource Unit 2	Confined area around Gateway Wellfield	Main source of water for Hermanus	Confined by Cedarberg Shale, overlain by Skurweberg Aquifer
Peninsula Aquifer, Resource Unit 3	Recharge area	Secondary source of water for Hermanus	Mountainous area
Bredasdorp/Stanford	Recharge area	Sole source of water for Stanford	Monitoring of possible pollution from informal settlement and waste site

Alternative management options			
Action	**Costs/m^3**	**Details**	**Comments**
Demand management		10-step WDM programme	Applied
Conservation management		Clearing of alien vegetation	Applied
Desalination			Design is ready
Reclamation		Effluent water is used for irrigating Golf Course	Applied
Bulk purchase			N/a
Water trading			N/a
Surface water sources		Feasibility study undertaken for Hartbees Dam	Not feasible
Additional groundwater sources		Camphill and Volmoed	Under development

Administrative/legal aspects		
Document Name	**Progress**	**Comment**
Water Services Development Plan	Is this Groundwater Management Plan duly reflected in the WSDP	
Integrated Development Plan	Is this Groundwater Protection Zoning duly reflected in the IDP	
Integrated Water Resource Management Plan	Is the Groundwater Management Plan duly reflected in the IWRMP	
Green Drop	Is the impact of effluent water on shallow aquifer considered	
Blue Drop	Is groundwater quality considered in treatment process	

Signatures

Place, Date		Place, Date	
Approved		Approved	
Name		Name	
Designation	WSA Manager	Designation	Operational Manager
Institution	Overstrand Municipality	Institution	Overstrand Municipality
Place, Date		Place, Date	
Approved		Approved	
Name		Name	
Designation	Municipal Manager	Designation	Mayor
Institution	Overstrand Municipality	Institution	Overstrand Municipality