Assessment of the Occurrence and Key Causes of Drinking-Water Quality Failures within Non-Metropolitan Water Supply Systems in South Africa, and Guidelines for the Practical Management Thereof

Grant Mackintosh
& Unathi Jack

TT 373/08

Water Research Commission

ASSESSMENT OF THE OCCURRENCE AND KEY CAUSES OF DRINKING-WATER QUALITY FAILURES WITHIN NON-METROPOLITAN WATER SUPPLY SYSTEMS IN SOUTH AFRICA AND GUIDELINES FOR THE PRACTICAL MANAGEMENT THEREOF

Report to the
Water Research Commission

by

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on behalf of

Emanti Management (Pty) Ltd

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WSAs involved

	Free State	Eastern Cape	Western Cape
1	Masiloyana LM	Chris Hani DM	Cape Agulhas LM
2	Matjhabeng LM	Amathole DM	George LM
3	Nala LM	Lukhanji LM	Stellenbosch LM
4	Tokologo LM	Emalahleni LM	Witzenberg LM
5	Tswelopele LM	Intsika Yethu LM	Cederberg LM
6	Mangaung LM	Mnquma LM	
7	Mantsopa LM	Amatola Water	
8	Naledi LM	Amahlathi LM	
9	Mafube LM	Ngqushwa LM	
10	Metsimaholo LM		
11	Moqhaka LM		
12	Ngwathe LM		
13	Dihlabeng LM		
14	Maluti-A-Phofung LM		
15	Nketoane LM		
16	Phumelela LM		
17	Sesoto LM		
18	Kopanong LM		
19	Letsemeng LM		
20	Mohokare LM		

Laboratories Involved

WSSA – Queenstown

CSIR – Bloemfontein

Buffalo City – East London

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ABBREVIATIONS

DM	District Municipality
DWAF	Department of Water Affairs and Forestry
DWQ	Drinking Water Quality
DWQM	Drinking Water Quality Management
DWSS	Drinking Water Supply System
EC	Eastern Cape
EIA	Environment Impact Assessment
EPA	Environmental Protection Agency
FS	Free State
LM	Local Municipality
MCL	Maximum Contaminants Level
SA	South Africa
SANS	South African National Standards
SSAT	Supply System Assessment Tool
SSF	Slow Sand Filters
THMs	Trihalomethanes
WC	Western Cape
WHO	World Health Organisation
WRC	Water Research Commission
WSA	Water Service Authority
WSP	Water Service Provider
WTW	Water Treatment Works

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EXECUTIVE SUMMARY

Of the many challenges inherited by the new South Africa, one of the more difficult and pressing challenges was that relating to the provision of adequate water services. Prior to the change of government in 1994, an estimated 30-40% of South Africa's population (14 to 18 million people) were without adequate water supply services and some 21 million people were without adequate sanitation (Van der Merwe, 2003).

The primary objective of the project has been to investigate Drinking-Water Quality Management in the provinces of Western Cape, Free State and Eastern Cape (these three provinces can be regarded as broadly representative of the conditions in South Africa) and identify the minimum requirements for effective and sustainable drinking-water service delivery within non-metropolitan water distribution networks in order to ensure an acceptable drinking-water quality is supplied to all consumers in South Africa. From the experiences gained, guidelines have to be developed.

Interviews with the management of the selected municipalities were conducted followed by site visits in order to:

- provide insight into current treatment plant and distribution network operation and maintenance procedures; and
- provide insight as to the key factors that result in drinking-water quality failures in non-metropolitan drinking-water distribution networks in South Africa.

Samples were collected both from the visited water treatment plants and a few points of the network. Results obtained were presented in deliverable 5: Critical analysis report.

A supply system assessment tool was developed in order to have a standard risk assessment tool for all the supply systems visited. This was initially an excel-based tool which was web-enabled at a later stage for easy access, easy use and output that is easily interpreted and understood by Water Service Authorities (WSAs). Practical guideline documents aimed at different levels and/or users of the water service team were also developed. The guidelines are aimed at:

- Management level
- Water treatment plant process controllers
- Distribution network personnel.

The guidelines developed are supported by two web-enabled tools available to WSAs via the electronic Water Quality Management System (eWQMS). Electronic Water Quality Management System is an electronic system that distributes a complete water quality management over the internet which has been rolled out nationally and was found to be very effective in assisting municipalities. Progress with eWQMS has received both national and international recognition. Emanti Management won the National Science and Technology Forum (NSTF) award for category E: Innovation developed through a small, medium and micro enterprise. This award was given for an outstanding contribution to science, engineering and technology. Furthermore, the International Water Associations' Project Innovation Award (for the Europe region) was awarded to DWAF, IMESA and Emanti.

In finalizing the project, an educational/awareness roadshow was carried out in all three aforementioned provinces where critical comments on the tool and guidelines from management of water services were given to the task team. This was carried out by conducting workshops that addressed the following:

- Introduction to the supply system assessment tool

- How to access the supply system assessment tool from eWQMS
- Benefits of the tool to the WSA
- Frequently asked questions from the visits
- Key issues identified from visits
- Challenges faced by municipalities.

In general, similar situations occur in Eastern Cape, Free State and Western Cape. There is a growing awareness within municipalities in terms of knowing responsibilities for water provision, understanding water quality related matters, knowing their issues and challenges, however, there are still significant challenges that need to be addressed in order for all WSAs to effectively supply drinking-water in a more sustainable manner. The challenges identified include:

- ***Operational Inefficiency & Equipment Shortcomings***
  Lack of adequate monitoring and associated instrumentation by WSAs.
  - Analyses cannot be carried out due to inadequate instrumentation or laboratory facilities.
  - Instruments are not being serviced at regular intervals.
  - Instruments are not regularly or properly calibrated.
  - No chemical standards available for instrument calibration.
  - Where instruments operate on batteries, none are available.
  - Process controllers are not familiar with operation, routine maintenance/calibration of equipment. In some instances the water treatment plant process controllers, with very little/no experience in analytical techniques, are required to carry out analyses.

  Poor routine and pro-active maintenance.
  - Major contributor to poor plant performances.
  - In some cases equipment has not been repaired or replaced for extended periods of time.

  A lack of proper dosing chemicals and/or dosing equipment.
  Use of inappropriate and insufficient disinfectants.

- ***Capacity Shortcomings***
  Process controllers do not have the necessary skills to effectively operate and maintain water treatment plants.
  Analytical staff does not have the necessary training to carry out water quality analyses and to apply internal quality control systems.
  Process controllers have no formal training in basic water treatment principles and techniques.
  In some cases process controllers do not have the ability to read and write.
  Process controllers often convey that they have low morale due to poor work conditions.
  Process controllers feel that superiors are not concerned with problems experienced.
  Lack of legislative awareness at management level.

- ***Environmental Factors***
  Increasing water demand (consideration must be given to introducing public awareness campaigns explaining the need to conserve water and/or introduction of water restrictions).
  Systems overload – resulting from increased production of domestic wastewater.
  Worsening resource quality.

- **Roadshows Feedback**

The guides and supply system assessment tools were well received by canvassed WSAs as a useful means of improving their water supply services in such a way that they:

  assist to identify key weaknesses and both
  - address these themselves where possible, and

- communicate high risk to other parties.

realise what is required to carry out a planned maintenance.

Proper management of water supply systems is becoming more complex and challenging as threats to resources and water supply systems increase. Managers and technical staff are expected to respond to disruptions of water resources and water supply system that threaten the quality of human life and environmental sustainability. In order to continuously provide safe drinking-water, procedures or tools are required that are able to guide a comprehensive and systematic approach to improving service delivery (to meet legislated and governance requirements). The guides provide details of how better to carry out three key areas of functionality in the water services as indicated below.

Management Guide

The management guide has been developed for people at the management level in order to fulfil the purposes mentioned below. The management guide has been developed with the purpose of providing assistance in terms of:

- Planning for effective delivery of drinking-water services.
- Understanding legislative requirements related to drinking-water services.
- Understanding of drinking-water quality issues.
- Understanding staff training issues.
- Importance of reporting.

Process Controller's Guide

The process controller's guide has been developed in such a way that it will assist the operations and maintenance personnel of drinking-water treatment plants to:

- provide practical guidelines for the persons responsible for operation and maintenance of the drinking-water treatment plants and indicate how to effectively operate the drinking water treatment plants.
- how to effectively maintain the system.
- identify if there are issues that need urgent attention and should be reported to the supervisor.

Supply system or plant supervisors could use the guide so that they have common understanding with the operations and maintenance actions and requirements including:

- providing the correct record sheet for the process controllers on-site to quickly identify issues of concern.
- providing necessary equipment for the process controllers.

Distribution System Personnel Guide

The distribution system personnel guide has been developed in such a way that it will assist the operations and maintenance personnel of drinking-water distribution system. This guide has been developed with the purpose of:

- providing practical guidelines for the persons responsible for operation and maintenance of the drinking-water distribution system.
- understanding typical failures experienced in drinking-water distribution system, and
- how to attend to and rectify such failures.

1. BACKGROUND

The primary objective of the project is to investigate drinking-water quality management in the three provinces of Western Cape, Free State and Eastern Cape (these provinces can be regarded as broadly representative of the conditions in South Africa) and identify the minimum requirements for effective and sustainable drinking-water service delivery within non-metropolitan water distribution networks such as to ensure an acceptable drinking-water quality is supplied to all consumers in South Africa.

Considering the above, the aim of this document is to:

- Provide insight into current treatment plant and distribution network operation and maintenance procedures, and review existing drinking-water quality monitoring initiatives and the availability of data.
- Provide insight as to the key factors that result in drinking-water quality failures in non-metropolitan drinking-water distribution networks in South Africa.

The findings presented are that obtained from interviews with (and preliminary site visits to) selected local and district municipalities in Western Cape, Free State and Eastern Cape. This document therefore provides feedback from the following authorities in these provinces.

Considering the above, the following is noted:

- In the Western Cape, feedback presented is that obtained from interactions with five Local Municipalities (LMs) in the province. These municipalities are the Water Service Authority (WSA) for their area of concern. Base information for the Western Cape was obtained from one on one interviews with municipal officials and subsequent site visits. One-on-one interactions were conducted with Cape Agulhas, Cederberg, George, Stellenbosch and Witzenberg LMs.
- In the Free State, feedback presented is that obtained from interactions with all 20 Local Municipalities in the province. These municipalities are the Water Service Authority for their area of concern. Information for the Free State was obtained through one-on-one interview with municipal officials and from other current provincial Department Local Government and Housing initiatives. These findings were verified through site visits by the project team and CSIR staff.
- In the Eastern Cape, feedback presented is that obtained from interactions with the targeted two District Municipalities (DMs) in the province (Chris Hani and Amathole DMs) Further interactions were with selected LMs within these two District Municipalities. The following important points are also noted:
  - Chris Hani DM and Amathole DM are designated Water Service Authorities for their District Municipality areas. The municipalities falling within their areas are Water Service Providers (WSPs).
  - Some municipalities operate and maintain their own systems while some municipalities utilise external service providers. These service providers operate and maintain the treatment works and distribution network and monitor the quality of water. Further details of these activities will be presented in subsequent sections.

Information for the Eastern Cape was obtained through one-on-one interviews with municipal officials and preliminary site visits by the project team.

2. PROJECT OVERVIEW

The main objective of the project is to develop suitable, practical guidelines for the management of drinking water distribution networks in non-metropolitan areas of South Africa. The aims of the project are to:

- Analyse the high percentage failure in the Western Cape and in particular contrast the water quality at the water treatment plant with that at point of use.

- Carry out a similar assessment of distribution networks of non-metropolitan areas of the Eastern Cape.

- Analyse the causes of failure in the Western Cape, Free State and Eastern Cape and identify key causative agents (e.g. disinfection, capacity, size of distribution network).

- The need for simple interventions (e.g. raise chlorine dosage) vs. detailed technical interventions (e.g. need for flow modeling within a reservoir) will be identified. The relative impacts of optimizing each intervention will be undertaken.

- Develop guidelines for the management of drinking-water quality in non-metropolitan distribution systems. The guidelines will include legislative compliance requirements, technical inputs (e.g. optimum Free Chlorine Residual levels), best practices (e.g. pro-active maintenance requirements), monitoring and management protocols and reporting protocols to consumers, provincial and national government.

- Carry out an educational/awareness Roadshow. Given the poor recognition of the value of effective drinking-water quality management, it is necessary that all officials responsible for the provision of a safe drinking-water supply are made aware of the need for effective monitoring and management.

It was envisioned that the above aims will be satisfied through completion of the following tasks:

a) Conduct a literature review to determine the current status quo of non-metropolitan drinking-water distribution networks in South Africa. The literature review will include consideration of legislative compliance requirements, monitoring and management procedures followed, current best practises, analysis of existing drinking-water quality data from the Western Cape.

b) Interact with local and district councils in the Free State, Western Cape and Eastern Cape to identify current water treatment plant and distribution network operation and maintenance procedures, and review existing water quality monitoring data (if any). Interactions in the Eastern Cape will be limited to the Amathole District Municipality and the Chris Hani District Municipality (DM).

c) Using findings from local and district council interactions, observations from site visits and water quality results analyse the main causes of failure in distribution networks and identify key causative agents (e.g. disinfection, capacity, size of distribution network). The findings will be used to identify necessary interventions if such problems arise, and how such problems can be prevented in the future.

d) Issues of concern identified through the site visits and sample collection should be immediately communicated to the applicable local and district councils via a fax report. Through this process this study will directly assist in prioritising issues of concern in these provinces, thus aiding decision-making and progressively ensuring an improvement in water service delivery to the various affected communities.

e) Investigate through site visits the status of non-metropolitan potable water distribution networks in the Free State, Western Cape and Eastern Cape and critically compare these findings with accounts by local and district councils. On-site observations from the various provinces will be critically compared, and be used to establish key issues of concern.

f) Investigate the difference (if any) between the physico-chemical and microbiological water quality at the water treatment works and at point of use in the Free State, Western Cape and Eastern Cape. In the Free State, existing water quality data will be analysed. In the Western Cape, it is envisioned that limited, cross-check sampling will occur with data analysis vs. existing data. In the Eastern Cape sampling will be undertaken at the Amathole District Municipality and Chris Hani District Municipality. Laboratories utilising standard analytical techniques and quality management systems will be used for water quality analyses (e.g. CSIR).

g) Populate an existing water quality database and web-based reporting system with the data obtained allowing easy retrieval of water quality related data for management review purposes.

h) Common issues of concern required remedial measures and best practises will be collated and used to develop guidelines to assist local and district councils in effectively drinking-water distribution networks.

i) In collaboration with regional offices of Department of Water Affairs and Forestry (DWAF), South African Local Government Association (SALGA) and local government carry out an educational/awareness roadshow where officials responsible for the provision of a safe drinking-water supply are made aware of issues faced and interventions required.

The process followed in achieving the terms of reference is reported below in a step-by-step wise manner.

3. METHODOLOGY

3.1 Literature Review Conducted

A literature review to determine the status quo of non-metropolitan drinking-water supply systems in South Africa was conducted based on the three Provinces (Western Cape, Free State and Eastern Cape). The literature review included consideration of legislative compliance requirements, monitoring and management procedures followed, current best practises, analysis of existing drinking-water quality data from the Western Cape and Free State.

A brief report on the literature review conducted is presented below:

3.1.1 Brief Overview of DWAF National survey

The DWAF Business Intelligence conducted a drinking-water quality survey for South Africa – 2004._Water Services: Directorate Planning & Information (DWAF, 2004). More specifically the survey set out to determine the likely status of drinking-water quality management by assessing *drinking-water quality monitoring*, *service quality* and *service reliability.* The methodology used was one of "self-assessment" via a survey questionnaire. This approach has the benefit of providing insight as to how those tasked with service delivery perceive themselves, and how well they understand their roles, responsibilities and accountability. A referenceable cross-check review based on drinking-water quality analyses was also conducted to assess the relative accuracy of information presented via comparison with current field circumstance. Data from the Free State Department of Local Government and Housing (DLG&H) monthly water quality audit and other drinking-water quality audits in the Western Cape and Eastern Cape were used to cross-reference the survey findings. This field experiences could then be used, in conjunction with the survey findings, to develop an appropriate strategy to improve drinking-water service delivery. 155 Municipalities were canvassed in the strategic survey on drinking-water quality.

In the survey, an analysis was carried out on the responses provided by each Municipality to assess the status of drinking-water quality monitoring (see Table 1 below). In order for a Municipality to be deemed acceptable in terms of water quality monitoring, the following conditions had to be met:

- Municipalities had to report that at least 70% of households received a water quality considered to be *ideal* and/or *good*.
- Municipalities had to monitor at various points within the *water supply system*.
- Municipalities had to at least monitor Group A water quality parameters/constituents (i.e. Electrical Conductivity/Total Dissolved solids, Faecal Coliforms/E.coli, pH, Turbidity and Free Chlorine).
- Municipalities had to use a laboratory for testing *water quality* (internal or external).

Municipalities lacking in any of the above listed areas were found to be "not acceptable" and therefore lacking in the delivery of water that is safe for drinking purposes.

Whilst the limitations of the Strategic Survey are clear, the findings of the Strategic Survey were found to have a good correlation with other initiatives, and to be in agreement on causative issues. Key observations included that Local Municipalities (LMs) are not familiar with drinking-water service requirements, and that inadequate monitoring of water quality results in services that regularly fail legislated requirements.

Table 1: *Water Quality Monitoring Results*

Province	Total LMs/Metros	LMs/Metros Responding To Survey	LMs/Metros Deemed Acceptable	Percentage Acceptable
Eastern Cape	39	25 (64%)	5	20%
Free State	20	7 (35%)	3	43%
Gauteng	12	9 (75%)	5	56%
KwaZulu Natal	51	34 (67%)	13	38%
Mpumalanga	19	15 (79%)	4	27%
Northern Cape	26	19 (73%)	7	37%
Limpopo	24	14 (58%)	7	50%
North West	21	11 (52%)	8	73%
Western Cape	25	21 (84%)	14	67%
National	**237**	**155 (65%)**	**66**	**43%**

3.1.2 Brief Overview of Western Cape Masibambane survey

A status quo assessment of drinking-water quality and service delivery was carried out in the Western Cape through the Masibambane Phase 1 project in 2004. The status quo assessment was carried out by the Masibambane Working Group through Stellenbosch Municipality between late 2003 and mid 2004. The project involved all 24 non-metropolitan WSAs and comprised interviews with Technical Directors (or delegated senior technical staff), and collection of drinking-water samples and testing of drinking-water quality at CSIR's South African National Accreditation System (SANAS) accredited laboratory in Stellenbosch.

The objective of the survey was to use the information gathered to (a) assess the current status of drinking-water quality and (b) the quality of drinking-water services in the Western Cape. The outcomes of the study would be used to guide future assistance to Water Service Authorities (capacity, infrastructure, operation and maintenance).

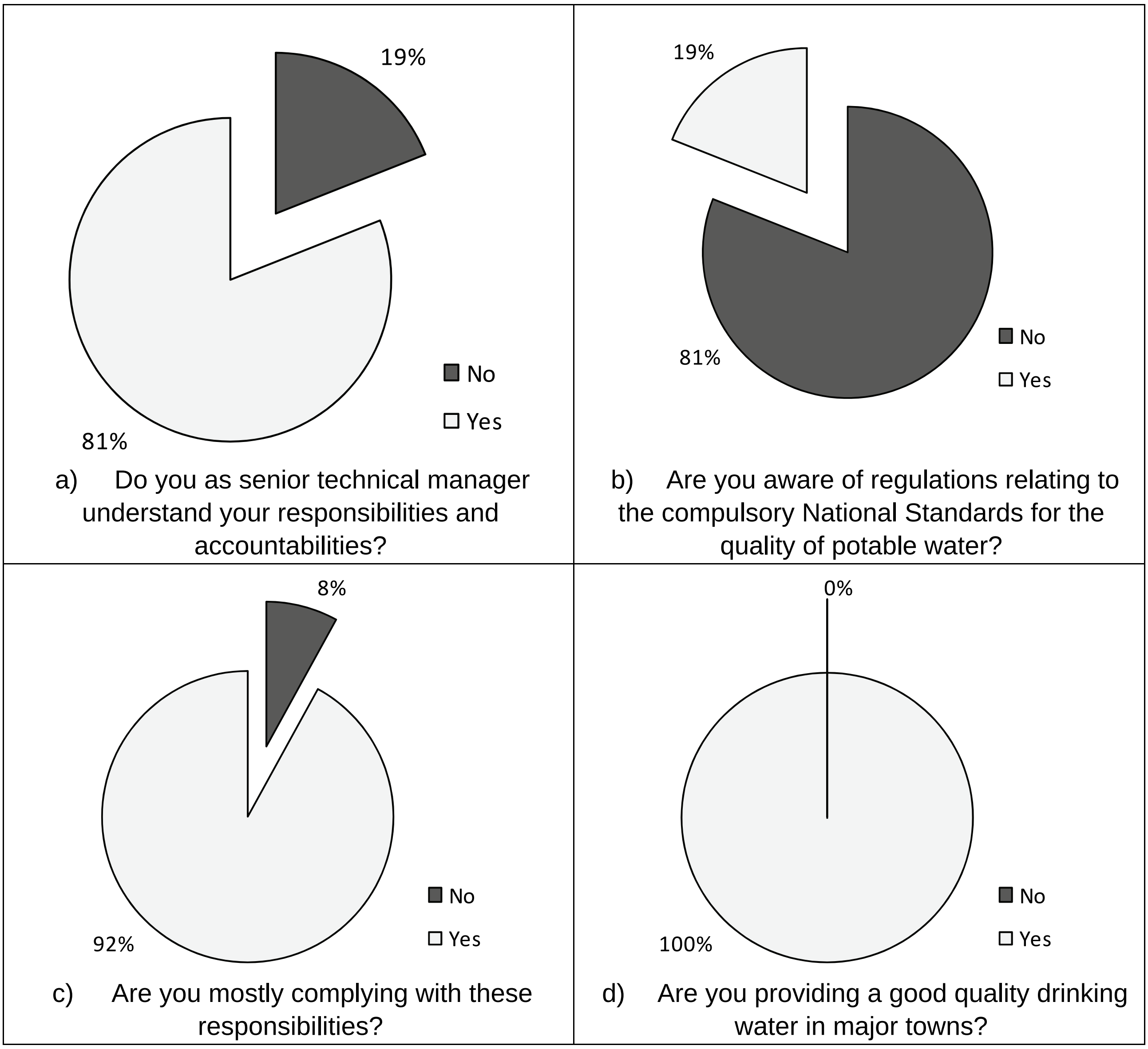
With regards to roles and responsibilities of WSAs, the key pie graphs in Figure 1 are noted.

- Although most Local Municipalities believed that they mostly understood their responsibilities and thought that they were complying, many municipalities noted that there were such a number of applicable laws and regulations that it was possible, or likely, that they were not completely compliant.
- Most interviewed officials were not fully aware of the regulations relating to the *Compulsory National Standards for the Quality of Potable Water*.
- Most interviewed officials stated that they would support an easy reference guide to legal accountability and responsibility, to be supported by a course explaining legal responsibilities in the water sector.

With regards to Drinking-Water Quality Management, Figure 1d is noted.

- All Local Municipalities believed that they were providing consumers with a good quality drinking-water. Many municipal officials stated with confidence that they were "providing the best water (quality) in South Africa". (Both of these observations being in strong contrast to the bacteriological results which showed an overall failure of 42% vs. total coliforms and 19% vs. faecal coliforms).
- Of concern is that a large proportion of municipal officials did not know what water quality was provided to consumers. This indicates a lack of understanding of *Compulsory National Standards for the Quality of Potable Water*.

- It must be noted that the percentage failure with regards to total and faecal coliforms was significantly higher at smaller towns/communities than that recorded at the major towns, again highlighting the fact that service delivery in these smaller towns/communities is different that of the larger towns in the same Local Municipality.



a) Do you as senior technical manager understand your responsibilities and accountabilities?

b) Are you aware of regulations relating to the compulsory National Standards for the quality of potable water?

c) Are you mostly complying with these responsibilities?

d) Are you providing a good quality drinking water in major towns?

Figure 1*: Review of key findings of the Western Cape Masibambane phase 1 drinking-water quality management project*

Summary of Water Quality Results from Once-Off Sampling

The drinking-water sampling programme was such that samples were collected at one major town, two smaller established towns, and two small communities within each district council of the Western Cape. In most instances, six treated drinking-water samples were collected in each town/community Samples were collected at the water treatment works (where applicable) and at household taps throughout the water distribution network of the town/community. Samples were analysed for the minimum determinants as outlined in SABS 241-2005 Drinking-Water Specification, namely: total coliform bacteria, faecal coliform bacteria, electrical conductivity, pH, turbidity, appropriate residual treatment chemicals (iron, aluminium) and disinfectants (free chlorine residual). A summary interpretation of bacteriological drinking-water results as compared to SABS 241-2005 Class I standards (the required quality standard for WSAs) is shown in Table 2. ***NOTE:*** Bacteriological results give an indication of the potential risk of contracting waterborne diseases and as such can be considered to have a direct and acute health impact.

Table 2: *Western Cape bacteriological drinking-water quality results (February to June 2004)*

Western Cape February to June 2004	Total Samples	Total Coliform % Samples Failing	Faecal Coliform % Samples Failing
All samples	162	42%	19%
Major town samples	30	7%	0%
Smaller established town samples	94	41%	20%
Village/community samples	38	71%	32%
SABS 241-2001 Class I Allowable Compliance*		4% of Samples, Max	

NOTE: Although the objective of disinfection should be to attain zero total coliform bacteria and faecal coliform bacteria, the SABS 241-2001 Class I allowable compliance is a maximum of 4% to have total coliform bacteria count greater than 10 per 100 mL and faecal coliform bacteria count greater than 1 per 100 mL.

The above table shows that:

- Significant failures with regards to both total coliforms (42% failure) and faecal coliforms (19% failure) were recorded at the towns/communities sampled (maximum 4% failure allowed).
- The percentage total and faecal coliform failure at villages/communities (71% and 32% failure respectively) was significantly higher than that recorded at the major towns (7% and 0% failure respectively).
- The percentage total and faecal coliform failure at smaller established towns (41% and 20% failure respectively) was also significantly higher than that recorded at the major towns (7% and 0% failure respectively).

Although not presented here, suffice to note that physico-chemical determinant analysis showed significant failures with regards to turbidity (33% failure) and iron (31% failure).

Summary of Key Findings

Some key findings of the study were:

- Most Local Municipalities do not understand what is required for effective drinking-water service delivery.
    - Lack of understanding of legislative requirements, water quality standards/guidelines, requirements for effective monitoring, etc.
    - Service delivery to smaller towns/communities is not as effective and efficient as that in the larger towns of the same local municipality.

- Inadequate monitoring (and associated pro-active management) of drinking-water services consistently results in drinking-water quality that fails legislated requirements.
    - Lack of drinking-water quality data
    - Lack of basic laboratory equipment
    - Drinking-water quality is not always ideal or good
    - Through monitoring water quality issues are identified
    - Accurate laboratory analysis is essential to enable informed decision-making.

- Inadequate infrastructure management results in premature failure of drinking-water services.
    - Maintenance budgets are not adequate to ensure sufficient asset maintenance
    - Appropriate and sustainable technologies are not always implemented.

- Present Water Service Authority institutional capacity (staffing, funding, expertise, education) is limiting adequate service provision.
    - Constant restructuring a staff stressed, demotivated, poor attitudes, no initiative
    - Staff numbers are not adequate; too many ghost posts
    - Skilled staff leave to higher paying jobs; away from small towns
    - Water Service Authorities have difficulty in attracting suitably qualified staff
    - Not sufficiently supported by LGWSETA in training and capacity building requirements.

3.1.3 Brief Overview of Eastern Cape survey

In addition to the above, a recent Water Research Commission (WRC) study in the Eastern Cape highlighted a number of issues resulting in drinking-water quality failures. Since 1997, Prof Momba of Tshwane University of Technology (TUT) has been working on water research projects at the University of Fort Hare. The projects aimed at monitoring the performance of small water distribution systems in the province. The study examined if the risks associated with microbiological hazards and exposure to microbiological agents add to the increase in water-related diseases in the Eastern Cape and to raise community awareness (Momba, 2005).

Summary of Prof Momba's key findings included:

- Water Service Authorities are not familiar with the minimum requirements for the quality of potable water.
- Inadequate monitoring of Water Quality and inadequate intervention when monitoring indicates poor water quality.
- Lack of technical and managerial capacity in many of the newly established municipalities.
- Focus of development in the water sector has been on improving access to water with insufficient attention on the quality of water produced.
- Lack of public awareness about water quality, health and hygiene issues in rural communities.

Following up on the findings presented in the literature, interactions with selected municipalities were conducted to identify the current water supply system operation and maintenance procedures and identify issues of concern.

3.2 Interactions with DMs and LMs Involved

The interactions presented are those obtained from interviews with the selected local and district municipalities in Western Cape, Free State and Eastern Cape. The municipalities involved are presented in Table 3.

- In the Western Cape, feedback presented is that obtained from interactions with 5 Local Municipalities in the province. These municipalities are the Water Service Authority for their area of concern. Base information for the Western Cape was obtained from one-on-one interviews with municipal officials (and subsequent site visits) conducted as a part of a DWAF Masibambane project. This base information was reviewed and updated by the project team for the purposes of this study. One-on-one interactions were conducted with the municipalities presented in the table below.

- In the Free State, feedback presented is that obtained from interactions with all 20 Local Municipalities in the province. These municipalities are the Water Service Authority for their area of concern. Information for the Free State was obtained through one-on-one interview with municipal officials and from other current provincial Department Local Government and Housing initiatives. These findings were verified through site visits by the project team and CSIR staff.

Table 3: *Dataset used to identify key issues resulting in drinking-water quality failures*

	Free State	Eastern Cape	Western Cape
1	Masiloyana LM	Chris Hani DM	Cape Agulhas LM
2	Matjhabeng LM	Amathole DM	George LM
3	Nala LM	Lukhanji LM	Stellenbosch LM
4	Tokologo LM	Emalahleni LM	Witzenberg LM
5	Tswelopele LM	Intsika Yethu LM	Cederberg LM
6	Mangaung LM	Mnquma LM	
7	Mantsopa LM	Amahlathi LM	
8	Naledi LM	Ngqushwa LM	
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15	Nketoane LM		
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18	Kopanong LM		
19	Letsemeng LM		
20	Mohokare LM		

- In the Eastern Cape, feedback presented is that obtained from interactions with the targeted two District Municipalities in the province (Chris Hani and Amathole). Further interactions were with the Local Municipalities within these two District Municipalities presented in the table above.

3.3 Identification of key causes of drinking water quality failures from interviews

In general, similar situations occur in Eastern Cape, Free State and Western Cape. The following section therefore briefly summarises the current status in all three provinces. Considering the findings from the interactions, the following key issues are noted:

- **Operational and Equipment Shortcomings**
  - Lack of existing monitoring data cross-checks with other departments or parties.
  - Transference of assets to the WSAs takes a very long time and the person responsible for maintenance around that becomes an issue.
  - Budgets constraints for maintenance and operation purposes of water services may result in water quality failures.
  - Process controllers are not familiar with operation, routine maintenance/calibration of equipment. In some instances, the water treatment process controllers with very little/no experience in analytical techniques, are required to carry out analyses.
  - Access roads and distance to the water treatment works in some areas is an issue.

- **Capacity Shortcomings**

  Water services department is understaffed; therefore the existing staff is overloaded.

  Process controllers do not have the necessary skills to effectively operate and maintain water treatment plants.

  Most process controllers have no formal training in basic water treatment principles and techniques.

  Lack of constant supervision results in lack of disciplined process controllers.

Identified key causes to drinking water quality failures are summarised in Table 4. Table 5 presents the summary of factors contributing to drinking water quality failures:

Table 4: *Key causes of drinking-water quality failures*

Failure	**Causes**
Source water	• There is an increasing water demand. • Groundwater sources are sometimes contaminated by wastewater or natural occurring chemicals from the soil. • Turbidity problems arise as the source water level drops.
Operation and maintenance of treatment works	• Budget does meet needs for adequate operation and maintenance. • Process controllers lack skills to do the job.
Storage	• Storage capacity is insufficient to meet demand for increasing population.
Distribution network	• Aging infrastructure leads to pipe bursts. • In areas where there is source water shortage, flushing is difficult to practice. • Design drawings, documentation, etc. of infra-structure not available.
Staff	• Not enough number of process controllers. • Process controllers are not trained/insufficient skills.
Monitoring	• LMs do not perform their required monitoring as WSAs/WSPs.

Table 5: *Current status of drinking-water quality*

Status	**Explanation**
Source	• Water availability is becoming an issue in most parts of South Africa. • Ground water sources are being abused due to the shortage in surface water sources.
Treatment	• Basic conventional treatment methods are used. • Basic chlorination of groundwater sources is not practised in many areas. • Advanced treatment methods are rarely used.
Storage and distribution	• Capacity of storage reservoirs needs to be upgraded. • Cleaning of reservoirs becomes a problem where there is not enough storage capacity.
Management	• Water service provision is not a priority in some areas. • Finance department normally does not understand the need and urgency of maintaining water infrastructure and performing water quality awareness.
Laboratory	• There is a new growing awareness of the need for monitoring. • There are very few accredited laboratories in South Africa. • Some areas lack monitoring equipment.
Communications	• There is no integrated planning between different municipal departments (e.g. housing and infra-structure).
Staff	• Lack of qualified staff in the water field. • Lack of supervision. • Lack of responsibility and dedication.
Data	• Water quality data is not properly stored and interpreted. • The understanding of water quality data leads to knowing the areas and issues of concern so as to take remedial measures.

3.4 Field Assessment: Supply System Assessment Tool development

The main objective of the project is to develop suitable, practical guidelines for the management of drinking-water supply system in non-metropolitan areas of South Africa. In order to achieve this, site visits to water treatment plants in the three regions were conducted in order to assess their status. The field observations were loaded onto the supply system scoring and risk profiling tools and the outcomes thereof are critically considered.

This section reports on the development both of an Excel based tool for performance scoring and risk profiling of water treatment plants together with their distribution networks. The initial tool developed had two sections or components, that is, the scoring section and the risk profiling section. This tool has undergone critical review by WRC together with DWAF and updated accordingly after the initial assessments. Therefore the tool presented below is the initial one used to assess the water supply system in the three regions. The updated tool is presented in section 6.

Development of water treatment plants and distribution network scoring tool

The spreadsheet based tool contained the following main categories for which points are allocated to provide an overall score for a water treatment plant and its distribution network.

- Section 1: Design
- Section 2: Operation and Performance
- Section 3: Maintenance
- Section 4: Supervision and Management
- Section 5: Waste Management
- Section 6: Safety
- Section 7: Emergency Preparedness and Response

Table 6: *Scoring for water treatment plants and distribution network*

	Applicable Scoring	**Actual Score**
SECTION 1: Design		
1.1 Is the design capacity of the plant known?	Yes – 1 No – 0	
1.2 Is the plant operating within its design capacity? (i.e. is there spare capacity available?)	Yes – 1 No – 0	
1.3 Is the plants raw water supply affected by treated wastewater/industrial effluent?	Yes – 0 No – 1	
1.4 Are the unit processes implemented at the plant appropriate for the raw water quality?	Yes (100%) – 3 Mostly (80%) – 2 Partly (50%) – 1 No – 0	
1.5 Are spare unit processes available at the plant for maintenance purposes? (e.g. multiple settling tanks, filters, etc.)	Yes – 2 No – 0	
1.6 Is there space available for future plant upgrades/expansion?	Yes – 1 No – 0	
1.7 Is there sufficient storage capacity in the distribution network (i.e. sufficient reservoirs with sufficient capacity)?	Yes – 1 No – 0	
1.8 Is there population growth in the area?	Rapid – 0 Slow – 1 None – 2	
END SECTION 1	**TOTAL**	

	Applicable Scoring	Actual Score
SECTION 2: Operation and Performance		
2.1 Is the quantity of raw and treated water metered at the plant?	Both – 2 One – 1 None – 0	
2.2 What is the frequency of these meter readings?	Daily – 2 Weekly or More – 1 None – 0	
2.3 Are all unit processes at the plant operating effectively?	Yes (100%) – 3 Mostly (80%) – 2 Some (50%) – 1 None – 0	
2.4 Are there sufficient numbers of plant operators?	Yes – 2 No – 0	
2.5 Are the responsible plant operators adequately trained?	Formal Qualification – 4 Some Coursework / On The Job training – 2 On the job training – 1 No – 0	
2.6 Is an operator's manual available on-site?	Yes – 1 No – 0	
2.7 Is the operator's manual in the appropriate language?	Yes – 1 No – 0	
2.8 Are charts/graphs available at the plant for process control/correcting typical issues of concern (e.g. dosages/chemical feed rates posted on walls, etc.)?	Yes – 1 No – 0	
2.9 Are standard plant operating procedures captured in writing (e.g. preparing batches of chemicals, changing gas cylinders, etc.)	Yes – 1 No – 0	
2.10 Is water quality monitored at the plant? • pH • Turbidity • Free chlorine residual • Residual chemicals (e.g. from addition of flocculant – alum, iron) • Other determinants	Max = 5	
2.11 What is the frequency of on-site drinking-water quality monitoring?	Hourly – 3 Daily – 2 Weekly or More – 1 None – 0	
2.12 Where is water quality monitored? • Raw water • Treated water • Along treatment chain	Max = 3	
2.13 Does drinking-water quality leaving the plant meet legislated requirements (i.e. SANS 241) for key parameters (pH, turbidity, bacteriological indicators, treatment chemical residuals, etc.)?	Class 0 – 3 Class I – 2 Class II – 1 Fail Class II / Don't know – 0	
2.14 Is jar test equipment/paddle stirrer equipment available for coagulation process review and control?	Yes or N/a – 1 No – 0	
2.15 Is all water quality monitoring equipment at the plant in good working order?	Yes – 1 No – 0	
2.16 Are chemicals/reagents required for analysis available on-site?	Yes – 1 No – 0	
2.17 Are on-site staff familiar with operation and maintenance of the monitoring equipment?	Yes – 1 No – 0	
2.18 What is the frequency of monitoring equipment calibration?	Monthly/more frequent – 2 > monthly to < 1 year – 1 > 1 year – 0	
2.19 Is power consumption/electricity usage monitored at the plant?	Yes – 1 No – 0	
2.20 Is a report highlighting issues of concern at the plant (quality, malfunctions, etc.) produced?	Weekly – 2 Monthly – 1 Longer period / None – 0	
2.21 Is a water treatment process specialist readily available (e.g. in-house or consultant) to assist with plant issues	Yes – 1 No – 0	

	Applicable Scoring	Actual Score
SECTION 2: Operation and Performance		
2.22 Is water quality monitored in the distribution network? • pH • Turbidity • Bacteriological indicators (faecal coliform, E.coli, total coliform) • Free chlorine residual • Residual chemicals (e.g. from addition of flocculant – alum, iron) • Other determinants	Max = 6	
2.23 What is the frequency of distribution network drinking-water quality monitoring?	Weekly/Fortnightly – 3 Monthly – 2 Quarterly or More – 1 None – 0	
2.24 Where is water quality monitored in the distribution network? • Reservoir • Hydrant • Household taps	Max = 3	
2.25 Are chlorine booster stations located in the distribution network to manage and maintain desirable chlorine residuals?	Yes or N/a – 1 No – 0	
2.26 How often are chlorine booster stations checked to ensure appropriate chlorine residual management in the distribution network?	Daily or N/a – 2 Weekly – 1 Longer or None – 0	
2.27 Does drinking-water quality in the distribution network meet legislated requirements (i.e. SANS 241) for key parameters (pH, turbidity, bacteriological indicators, treatment chemical residuals, etc.)?	Class 0 – 3 Class I – 2 Class II – 1 Fail Class II/Don't know – 0	
2.28 Where are distribution network drinking-water samples analysed?	In-house lab (SANAS) – 3 External lab (SANAS) – 3 In-house with cross-checks at External lab (SANAS) – 2 In-house lab – 1 External lab – 1	
2.29 Is a report highlighting issues of concern in the distribution network (quality, need for flushing, etc.) produced?	Monthly – 2 Quarterly – 1 Longer period or None – 0	
2.30 Is water quality data (both plant and distribution network) stored appropriately?	Database & hard copy – 3 Basic elec. & hard copy – 2 Hard copy alone – 1 None – 0	
END SECTION 2	**TOTAL**	

	Applicable Scoring	Actual Score
SECTION 3: Maintenance		
3.1 Does the drinking-water treatment plant appear to be well maintained (grass cut, site neat, etc.)?	Good – 2 Fair – 1 Poor – 0	
3.2 Are all unit processes at the plant functional?	Yes – 2 No – 0	
3.3 Do staff at the plant have access to necessary maintenance equipment? • Spade/wheelbarrow • Hose pipe • Net for collecting floating debris • Lawnmower	Max = 4	
3.4 Is ammonia available at the plant for detecting leaks on chlorine gas cylinders?	Yes or N/a – 1 No – 0	
3.5 Are any red or orange lights on the electrical board at the plant illuminated or are any amp meter readings higher than marked line on meter	Yes – 0 No – 1	
3.6 Do all pumps at the plant appear to be well maintained? (e.g. no excessive noise or leaking from glands/pipe connections)	Yes – 1 No – 0	
3.7 Is a plant maintenance schedule produced and adhered to? (i.e. pro-active maintenance and not reactive maintenance or crisis management)	Yes – 2 No – 0	
3.8 Is there sufficient technical back-up to perform required plant maintenance? • Mechanical • Electrical	Both – 2 One – 1 No – 0	
3.9 Are there sufficient distribution network maintenance personnel (e.g. plumbers)?	Yes – 2 No – 0	

	Applicable Scoring	Actual Score
SECTION 3: Maintenance		
3.10 Are the distribution network maintenance personnel adequately trained?	Formal Qualification – 4 Some Coursework/On The Job training – 2 On the job training – 1 No – 0	
3.11 Is a distribution network maintenance schedule produced and adhered to? (i.e. pro-active maintenance and not reactive maintenance or crisis management) • Reservoir cleaning, flushing • Network cleaning, flushing	Yes – 2 No – 0	
3.12 What is the age of the existing reservoir infrastructure?	Majority > 15 years – 0 Majority < 15 years – 1 Don't know	
3.13 What is the age of the existing pipe infrastructure?	Majority > 15 years – 0 Majority < 15 years – 1 Don't know	
3.14 Is there sufficient budget available to perform required maintenance? • Plant • Distribution network	Yes – 2 No – 0	
END SECTION 3	**TOTAL**	

	Applicable Scoring	Actual Score
SECTION 4: Supervision and Management		
4.1 Have responsibilities been assigned for both plant and distribution network operation and maintenance?	Yes – 2 No – 0	
4.2 Is a checklist/logbook regularly completed/updated at the plant? • Flow in/out • Determinants: e.g. turbidity, pH, free chlorine residual • Routine maintenance: e.g. filter backwashing, desludging • Signed by operator and checked and discussed with supervisor	Max = 4 None – 0	
4.3 Is a complaints register maintained? • Date of complaint, contact details, nature of complaint • Actions taken • Time frame to resolve issue • Signed by responsible officer and checked and discussed with supervisor	Max = 4 None – 0	
4.4 Are issues/findings from the plant operational report and complaints register discussed in appropriate LM water meetings on a regular basis (i.e. management review)?	Weekly – 2 Monthly – 1 Longer period or None – 0	
4.5 If issues of concern are noted, are required corrective actions implemented timeously? (give examples, where appropriate)	Yes – 2 No – 0	
END SECTION 4	**TOTAL**	

	Applicable Scoring	Actual Score
SECTION 5: Waste Management		
5.1 Is the quantity of waste (e.g. sludge, filter washwater, etc.) produced by the plant monitored?	Yes – 1 No – 0	
5.2 Are sludge/wastewater holding ponds/dams available at the plant?	Yes – 1 No – 0	
5.3 Are sludge/wastewater holding ponds/dams appropriately sized?	Yes – 1 No – 0	
5.4 Is filter washwater recycled at the plant?	Yes – 1 No – 0	
5.5 Is dry sludge produced from the plant landfilled/handled appropriately?	Yes – 1 No – 0	
END SECTION 5	**TOTAL**	

	Applicable Scoring	Actual Score
SECTION 6: Safety		
6.1 Is the plant site enclosed (fences, gates and locks)?	Secure access control – 2 Partly secure – 1 None – 0	
6.2 Are warning signs (e.g. near chemicals/gas cylinders) visible at all required points at the plant?	Yes – 1 No – 0	
6.3 Have staff received necessary safety training (e.g. handling chlorine gas/chemicals, etc.)?	Yes – 1 No – 0	
6.4 Do operators have required safety equipment/clothing? • Face and gas mask • Protective clothing • Showers/eye wash points	All – 2 Some – 1 None – 0	
6.5 Are chemicals stored appropriately at the plant?	Yes – 1 No – 0	
6.6 Is an inventory of chemicals at the plant maintained?	Yes – 1 No – 0	
6.7 Are MSDS for all chemicals used available at the plant?	Yes – 1 No – 0	
6.8 Is all operating equipment at the plant secured appropriately (e.g. level surface, screwed down, etc.)?	Yes – 1 No – 0	
6.9 Are safety rails/hand rails secure?	Yes – 1 No – 0	
6.10 Is there a bathroom with soap, warm water, etc. at the plant?	Yes – 1 No – 0	
6.11 Are safety inspections regularly conducted at the plant?	Yes – 1 No – 0	
END SECTION 6	**TOTAL**	

	Applicable Scoring	Actual Score
SECTION 7: Emergency Preparedness and Response		
7.1 Are emergency procedures available (e.g. unit failure, gas/chemical handling, change in raw water quality, etc.)?	Yes – 1 No – 0	
7.2 Are emergency procedures understood by responsible staff? (e.g. question staff how they would react to an incident)	Yes – 1 No – 0	
7.3 Are emergency drills conducted?	Yes – 1 No – 0	
7.4 Are emergency power generators available?	Yes – 1 No – 0	
7.5 Are standby units available for essential operating equipment at the plant (e.g. dosing pump, transfer pump, etc.)?	Yes – 1 No – 0	
END SECTION 7	**TOTAL**	

SUMMARY SCORES		
	MAX Score	**Actual Score**
SECTION 1: Design	12	9
SECTION 2: Operation and Performance	67	39
SECTION 3: Maintenance	27	11
SECTION 4: Supervision and Management	14	10
SECTION 5: Waste Management	5	0
SECTION 6: Safety	13	7
SECTION 7: Emergency Preparedness/ Response	5	1
TOTAL	**143**	**77**
PERCENTAGE	**100%**	**54**

The following section provides a risk assessment associated with the drinking-water system. The following risk categories are considered:

- Engineering risk – impact arises when the drinking-water system is poorly designed
- Maintenance risk – impact arises when the drinking-water system is not well maintained

- Management risk – impact arises when there is no assignment of responsibilities or checking of tasks completion
- Exposure risk – impact arises when safety aspects are not considered

In order to determine the risk, elements utilised in performing Environmental Impact Assessments (EIAs) and ISO 14001 Environmental Management Systems (EMS) evaluations were adapted and utilised. The following aspects are considered:

- **Extent –** This indicates whether the impact will be local and limited to one community served by the drinking-water treatment plant (i.e. one community of town) (Low); limited to one town served by the drinking-water treatment plant (Medium); or whether the impact may be realised regionally or even nationally (High).
- **Duration –** This reviews the lifetime of the impact, as being short term (0-1 year), medium term (2-5 years), long term (>5 years), or permanent.
- **Intensity –** This establishes whether the impact is destructive and should be described as low (e.g. no functions/processes affected, ideal/good water quality), medium (e.g. functions/processes continue to function but in a modified manner, water quality variable) or high (e.g. functions/processes are altered such that they are temporarily or permanently impaired, poor water quality).
- **Probability –** This considers the likelihood of the impact occurring and should be described as improbable (low likelihood), probable (distinct possibility), highly probable (most likely) or definite (impact will occur regardless of prevention measures).
- **Degree of confidence in predictions –** The degree of confidence in the predictions, based on the availability of information and specialist knowledge.

In order to quantify the relative significance, an ISO 14001 based scoring process can be used, with a maximum score of 40 possible. These risk scores can be interpreted as follows:

- 0-10 Low negative impact
- 11-20 Medium negative impact
- 21-40 High negative impact

B1: Engineering Risk
The following questions will assist with completion of the engineering risk assessment.

- ***Extent***
  Will the *extent* of poor design (and subsequent production of drinking-water of poor quality) be felt in one community of a town (i.e. water treatment plant only serves a small community), a town (i.e. water treatment plant serves entire town) or on a regional/national level (i.e. water treatment plant serves an entire area – e.g. from a water board).
- ***Duration***
  Will the *duration* of the impact due to poor design be short (e.g. plant in process of being upgraded) or will it be long (i.e. no funds available to improve process design, etc.).
- ***Intensity***
  Is the *intensity* low (i.e. drinking-water quality is still acceptable) or high (i.e. poor drinking-water quality is always produced).
- ***Probability***
  What is the probability of an impact occurring due to poor design?

Table 7: *Risk assessment of the water supply system*

RISK ASSESSMENT: Engineering Risk				
Extent	High	Medium	Low	
1. What could be the extent of the impact	3	2	1	
Duration	Permanent	Long Term	Medium Term	Short Term
2. What could be the duration of the impact	4	3	2	1
Intensity	High	Medium	Low	
3. What could be the intensity of the impact?	3	2	1	
SIGNIFICANCE OF IMPACT SCORE (1 + 2 + 3)				
Probability	Definite	Highly probable	Probable	Improbable
4. What is the probability of an impact occurring	4	3	2	1
TOTAL SCORE (Significance of Impact x Probability of occurrence)				
Impact Rating		LOW (0 – 10)	MEDIUM (11 – 20)	HIGH (21 – 40)
Degree of Confidence in prediction		LOW - 7	MEDIUM	HIGH

B2: Maintenance Risk

The following questions will assist with completion of the maintenance risk assessment.

- ***Extent***
  If maintenance fails (and a poor drinking-water quality is produced), will the *extent* be in one community of a town (i.e. water treatment plant only serves a small community), a town (i.e. water treatment plant serves entire town) or on a regional/national level (i.e. water treatment plant serves an entire area – e.g. from a water board).
- ***Duration***
  If maintenance fails (and a poor drinking-water quality is produced), will the *duration* be short (e.g. sufficient funds and staff available to sort out issue) or will it be long (i.e. no funds available, inappropriate staff, operators and management are not aware of issues, etc.).
- ***Intensity***
  If maintenance fails, will the *intensity* be low (i.e. drinking-water quality still acceptable, no equipment failures noted) or high (i.e. poor drinking-water quality is always produced, high equipment failures noted).
- ***Probability***
  What is the probability of an impact occurring due to maintenance failure?

RISK ASSESSMENT: Maintenance Risk				
Extent	High	Medium	Low	
1. What could be the extent of the impact	3	2	1	
Duration	Permanent	Long Term	Medium Term	Short Term
2. What could be the duration of the impact	4	3	2	1
Intensity	High	Medium	Low	
3. What could be the intensity of the impact?	3	2	1	
SIGNIFICANCE OF IMPACT SCORE (1 + 2 + 3)				
Probability	Definite	Highly probable	Probable	Improbable
4. What is the probability of an impact occurring	4	3	2	1
TOTAL SCORE (Significance of Impact x Probability of occurrence)				
Impact Rating		LOW (0 – 10)	MEDIUM (11 – 20)	HIGH (21 – 40)
Degree of Confidence in prediction		LOW	MEDIUM - 12	HIGH - 24

B3: Management Risk

The following questions will assist with completion of the management risk assessment.

- ***Extent***
  If management fails (and a poor drinking-water quality is produced), will the *extent* be in one community of a town (i.e. water treatment plant only serves a small community), a town (i.e. water treatment plant serves entire town) or on a regional/national level (i.e. water treatment plant serves an entire area – e.g. from a water board).
- ***Duration***
  If management fails (and a poor drinking-water quality is produced), will the *duration* be short (e.g. staffing will be improved shortly to sort out the issue) or will it be long (i.e. water issues not priority, inappropriate staff, etc.).
- ***Intensity***
  If management fails, will the *intensity* be low (i.e. drinking-water quality still acceptable) or high (i.e. poor drinking-water quality is always produced).
- ***Probability***
  What is the probability of an impact occurring due to inadequate management?

RISK ASSESSMENT: Management Risk				
Extent	High	Medium	Low	
1. What could be the extent of the impact	3	2	1	
Duration	Permanent	Long Term	Medium Term	Short Term
2. What could be the duration of the impact	4	3	2	1
Intensity	High	Medium	Low	
3. What could be the intensity of the impact?	3	2	1	
SIGNIFICANCE OF IMPACT SCORE (1 + 2 + 3)				
Probability	Definite	Highly probable	Probable	Improbable
4. What is the probability of an impact occurring	4	3	2	1
TOTAL SCORE (Significance of Impact x Probability of occurrence)				
Impact Rating		LOW (0 – 10)	MEDIUM (11 – 20)	HIGH (21 – 40)
Degree of Confidence in prediction		LOW	MEDIUM	HIGH - 24

B4: Exposure Risk

The following questions will assist with completion of the exposure risk assessment.

- ***Extent***
  If required safety procedures are not followed, will the *extent* be local (i.e. will affect water treatment plant staff), town-based (i.e. affects entire town) or on a regional/national level.
- ***Duration***
  If required safety procedures are not followed, will the *duration* be short (e.g. sufficient funds available to sort out issue) or will it be long (i.e. no funds available, management are not aware of issues, etc.).
- ***Intensity***
  If required safety procedures are not followed, will the *intensity* be low (i.e. working environment is a low risk to operator's health) or high (i.e. working environment is a high risk to operator's health – 1 person per shift, hazardous chemicals, etc.).
- ***Probability***
  What is the probability of an impact occurring due to poor safety?

RISK ASSESSMENT: Exposure Risk				
Extent	High	Medium	Low	
1. What could be the extent of the impact	3	2	1	
Duration	Permanent	Long Term	Medium Term	Short Term
2. What could be the duration of the impact	4	3	2	1
Intensity	High	Medium	Low	
3. What could be the intensity of the impact?	3	2	1	
SIGNIFICANCE OF IMPACT SCORE (1 + 2 + 3)				
Probability	Definite	Highly probable	Probable	Improbable
4. What is the probability of an impact occurring	4	3	2	1
TOTAL SCORE (Significance of Impact x Probability of occurrence)				
Impact Rating		LOW (0 – 10)	MEDIUM (11 – 20)	HIGH (21 – 40)
Degree of Confidence in prediction		LOW - 10	MEDIUM	HIGH

Figure 2: Photographs showing unsafe environment for operators

Looking at the figure above, the risks associated to process controller's exposure can be deduced by looking at such factors as:

- Do channels have safety rails?
- Is all equipment tight and secured?
- Is the working environment low or high risk to the workers?

Findings from this study revealed the following.

4. FINDINGS

4.1 Monitoring

Western Cape
In the Western Cape, structured monthly monitoring is carried out at the four out of five of the targeted LMs. These are Cape Agulhas, Cederberg, George and Stellenbosch. In Witzenberg, monitoring is conducted quarterly by the health practitioners. The data from all these LMs is loaded onto the existing electronic Water Quality Management System (eWQMS) database where issues of concerns are highlighted. Cross check samples that were collected by the task team during this study were taken to CSIR (accredited) laboratory in Stellenbosch.

Free State
Consultative audit of drinking-water and wastewater in the Free State province is conducted monthly. The data is loaded onto the provincial existing eWQMS database where issues of concern are highlighted. By the time of this study samples were taken to the CSIR laboratory in Bloemfontein.

Eastern Cape
In the Eastern Cape, there is no centralised database for the region, each DM or WSP has its own database. Some smaller LMs do not conduct any monitoring. The samples collected during this study were taken to Water and Sanitation Services Africa (WSSA in Queenstown) and Buffalo City laboratories in East London.

Analysis methods for all the laboratories involved are presented in **Appendix D**.

4.2 Findings from the Western Cape

- Western Cape is generally satisfactory in terms of design, the average percentage score is 69 percent.
- Operation and performance of selected Western Cape treatment plants together with their network is not doing bad either with a few exceptions.
- Supervision and management can be said to be average.
- Management of waste from the drinking-water treatment plants is bad.
  - Most plants discharge the filter wash water and desludge to the veld or nearby river.
  - The plants that are doing fine with their waste management discharge their waste into waste water treatment plants.
- Western Cape water treatment plants seem to provide safety environment to the process controllers with a very few exceptions.
  - The average percentage score for safety is 60 percent.
- Emergency preparedness and maintenance are the categories that are not doing good. This can be clearly seen from the table and graphs below.

Table 8: *Western Cape Assessment score results*

LM	WTW	Design		Op./Perf		Maint		Sup./Mngt		Waste Mngt		Safety		Emergency		Overall	MAX	Total %
		Max = 12	%	Max = 67	%	Max = 27	%	Max = 14	%	Max = 5	%	Max = 13	%	Max = 5	%	143	143	100%
Stellenbosch	Paradyskloof	9	75	41	61	16	59	8	57	2	40	8	62	2	40	86	143	60
	Idas Valley	10	83	43	64	17	63	10	71	0	0	10	77	2	40	92	143	64
	Franschhoek	5	42	15	22	12	44	6	43	0	0	7	54	0	0	45	143	31
Cape Agulhas	Bredasdorp	11	92	49	73	15	56	6	43	3.5	70	10	77	3	60	97.5	143	68
	Napier	10	83	33	49	13	48	7	50	2	40	8	62	0	0	73	143	51
George	George	11	92	54	81	12	44	13	93	3	60	12	92	3	60	108	143	76
	Wilderness	9	75	45	67	11	41	8	57	0	0	10	77	3	60	86	143	60
Cederberg	Graafwater	6	50	52	78	17	63	11	79	3	60	9	69	3	60	101	143	71
	Lamberts Bay	10	83	35	52	16	59	10	71	3	60	7	54	3	60	84	143	59
	Citrusdal	9	75	22	33	5	23									36	101	36
Witzenberg	Ceres	5	42	30	45	8	35	7	70	No waste produced		6	67	0	0	56	126	44
	Tulbagh	6	50	26	39	13	59	7	50	0	0	4	44	0	0	56	139	40
	Wolseley	7	58	24	36	15	68	7	50	0	0	4	44	0	0	57	139	41

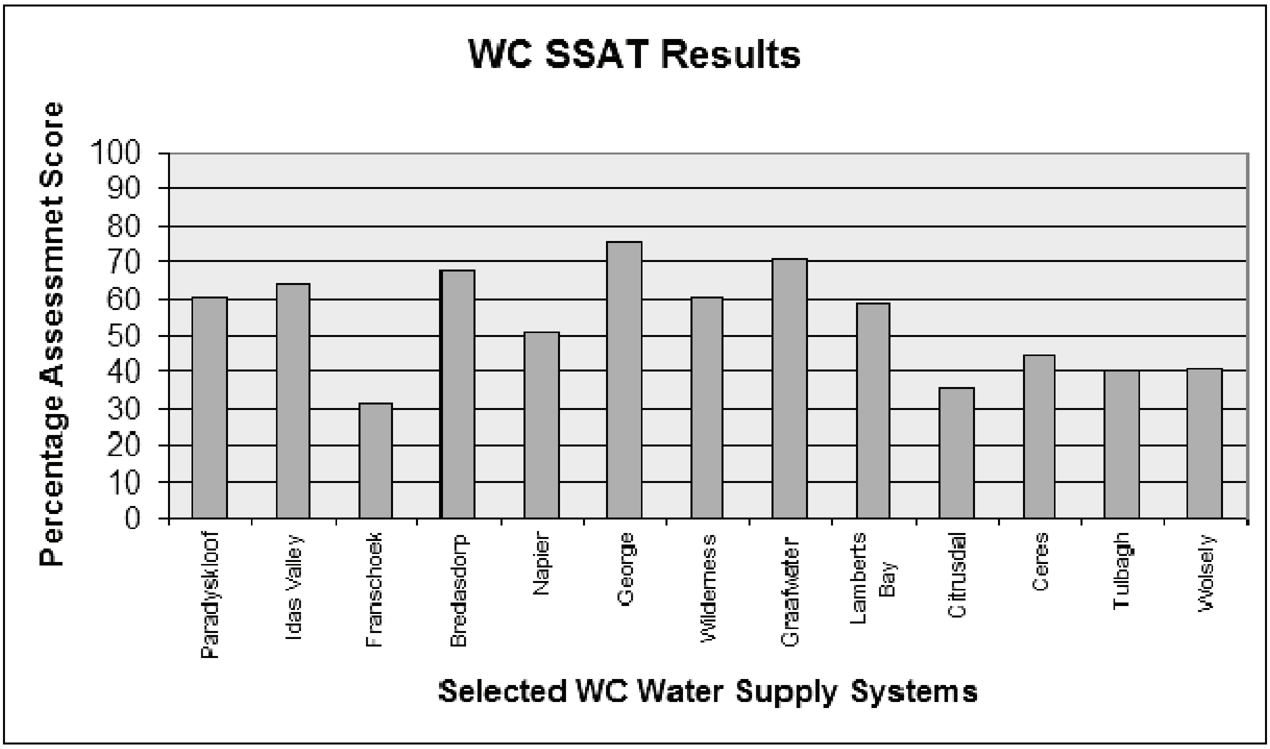


Figure 3: Representation of assessment score vs. selected WC water treatment systems

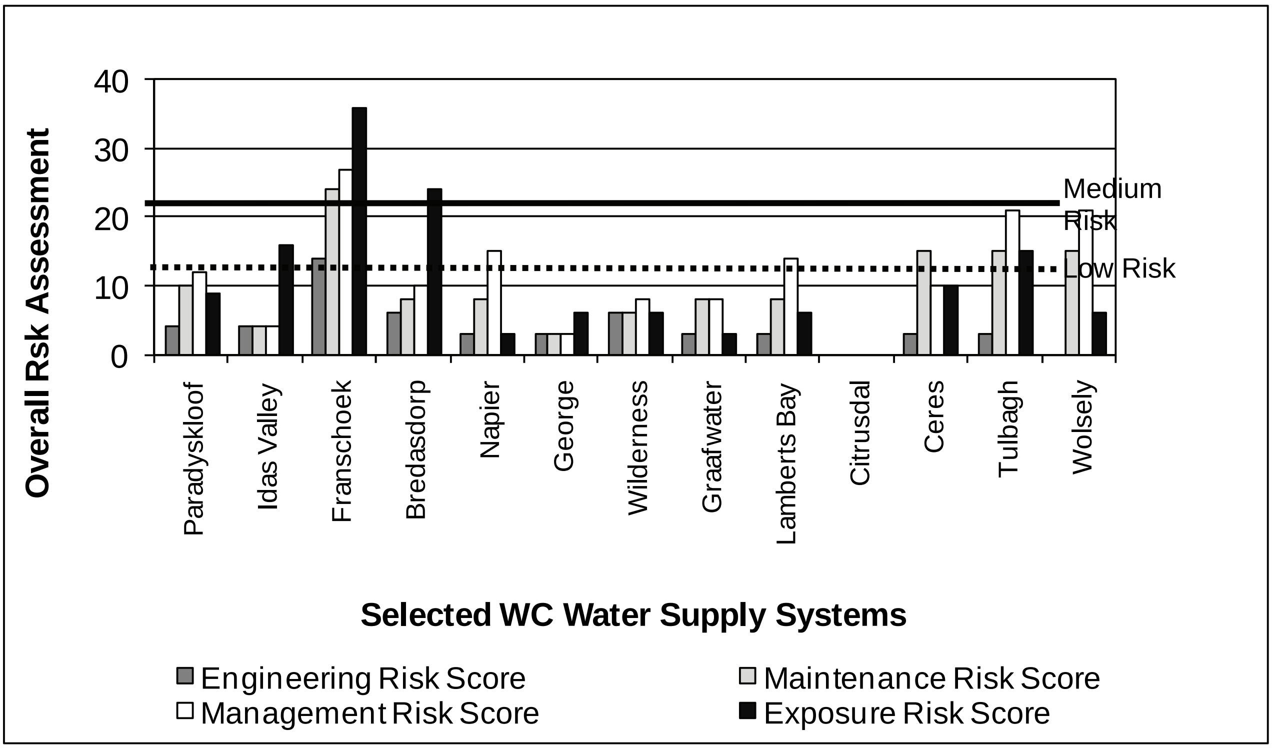


Figure 4: Representation of Risk profiling assessment for selected WC water supply systems

Key issues identified

Poor maintenance of water treatment plants together with their distribution network is as a result of:

- Aging water treatment plants, storage reservoirs together with their distribution networks.
- Most of process controller staff is not trained to deal with water quality issues.
- Inadequate staff, too many ghost posts in the water services field and skilled staff leave to higher paying jobs; away from small towns.
- There is lack of inter-departmental communication within DMs or LMs (e.g. housing, water, sanitation, etc.).
- Inadequate monitoring is conducted in smaller municipalities.

From the above it can be clearly seen that many of the key issues identified in 2004 are unchanged. Nevertheless, a new key finding is that Water Service Authorities are becoming aware of their legislated requirements regarding drinking-water quality treatment, monitoring and management. This can be attributed to a number of factors including:

- Development and profiling of National drinking-water quality management framework, and Regional Water Forums.
- Training programmes.
- Increased media coverage of areas where water quality issues and disease outbreaks occur (e.g. Delmas).
- DWAF-IMESA eWQMS initiative.

Summary of Strengths

The constant reinforcement of Drinking-Water Quality Management (DWQM) as a key component to support the growing awareness of water service delivery with significant primary health linkage appears to be receiving attention of municipal officials. A greater awareness of the role of WSA officials in ensuring provision of safe drinking water quality is developing. To support the growing awareness of water quality issues, it is essential that they are given tools to drive improved service delivery.

4.3 Findings from the Free State

- The Free State is generally satisfactory in terms of design with a few exceptions.
- Operation and performance of Free State treatment plants together with their network is not good.
- It is also evident from the table below that there is lack of supervision in the Free State.
- Management of waste from the drinking water treatment plants is bad.
  Most plants discharge the filter wash water and desludge to the veld or nearby river.
  In some instances, the discharge is done upstream and downstream water is drawn for drinking water treatment purposes.
- Safety of process controller staff is an issue.
- Emergency preparedness and maintenance are the categories that are doing really poor. This can be clearly seen from the table and graphs below.

The numbers in the graphs are a representative of the name of corresponding town or water supply system as indicated in the table below:

Table 9: *Free State Assessment score results*

	Town	Design		Op./Perf.		Maint.		Sup/Mngt		Waste Mngt		Safety		Emergency		Overall	MAX	%
	Max Score	**12**	**%**	**67**	**%**	**27**	**%**	**14**	**%**	**5**	**%**	**13**	**%**	**5**	**%**	**143**	**143**	**100%**
1	Theunissen	4	33	18	27	14	52	2	14	0	0	8	62	0	0	46	143	32
2	Winburg	11	92	23	34	16	59	7	50	3	60	8	62	1	20	69	143	48
3	Hobhouse	6	50	37	55	9	33	9	64	0	0	7	54	0	0	68	143	48
4	Ladybrand	10	83	31	46	14	52	1	7	0	0	8	62	4	80	68	143	48
5	Thaba Patchoa	10	83	18	27	12	44	2	14	0	0	6	46	0	0	48	143	34
6	Frankfort	9	75	30	45	8	30	5	36	0	0	9	69	0	0	61	143	43
7	Tweeling	8	67	31	46	12	44	4	29	0	0	8	62	1	20	64	143	45
8	Deneysville	8	67	31	46	19	70	8	57	0	0	11	85	1	20	78	143	55
9	Oranjeville	7	58	38	57	18	67	9	64	0	0	8	62	4	80	84	143	59
10	Kroonstad	9	75	43	64	10	37	9	64	1	20	12	92	2	40	86	143	60
11	Steynsrus	11	92	45	67	19	70	9	64	0	0	10	77	3	60	97	143	68
12	Viljoenskroon	9	75	11	16	7	26	2	14	0	0	6	46	1	20	36	143	25
13	Koppies	6	50	25	37	8	30	5	36	0	0	3	23	0	0	47	143	33
14	Parys	8	67	46	69	20	74	7	50	0	0	9	69	3	60	93	143	65
15	Bethlehem	9	75	56	84	23	85	9	64	2	40	12	92	3	60	114	143	80
16	Clarens	9	75	37	55	19	70	8	57	2	40	6	46	1	20	82	143	57
17	Fouriesburg	9	75	32	48	16	59	9	64	0	0	6	46	3	60	75	143	52
18	Harrismith (old)	7	58	28	42	8	30	5	36	0	0	3	23	0	0	51	143	36
19	Harrismith (new)	10	83	42	63	16	59	9	64	3	60	10	77	0	0	90	143	63
20	Arlington	10	83	29	43	17	63	10	71	0	0	8	62	1	20	75	143	52
21	Lindley	7	58	32	48	19	70	10	71	0	0	6	46	1	20	75	143	52
22	Petrus Steyn	8	67	38	57	16	59	8	57	0	0	6	46	1	20	77	143	54
23	Reitz	9	75	38	57	15	56	9	64	0	0	5	38	1	20	77	143	54
24	Vrede	11	92	27	40	18	67	11	79	0	0	9	69	0	0	76	143	53
25	Memel	8	67	24	36	14	52	9	64	0	0	7	54	0	0	62	143	43
26	Warden	7	58	11	16	14	52	6	43	0	0	8	62	0	0	46	143	32
27	Clocolan	10	83	17	25	21	78	2	14	0	0	7	54	0	0	57	143	40
28	Ficksburg	9	75	36	54	15	56	11	79	0	0	11	85	4	80	86	143	60

	Town	Design		Op./Perf.		Maint.		Sup/Mngt		Waste Mngt		Safety		Emergency		Overall	MAX	%
	Max Score	**12**	**%**	**67**	**%**	**27**	**%**	**14**	**%**	**5**	**%**	**13**	**%**	**5**	**%**	**143**	**143**	**100%**
29	Marquard	9	75	33	49	16	59	9	64	0	0	8	62	1	20	76	143	53
30	Senekal (Cyferfontein)	6	50	34	51	10	37	5	36	0	0	6	46	0	0	61	143	43
31	Senekal (Du Put)	6	50	34	51	9	33	4	29	0	0	6	46	1	20	60	143	42
32	Bethulie	10	83	47	70	17	63	10	71	4	80	9	69	1	20	98	143	69
33	Gariep Dam	8	67	49	73	14	52	9	64	0	0	12	92	1	20	93	143	65
34	Philippolis	8	67	46	69	16	59	10	71	0	0	10	77	1	20	0	143	64
35	Reddersburg	8	67	33	49	18	67	10	71	0	0	6	46	1	20	91	143	53
36	Jacobsdal	9	75	31	46	17	63	5	36	2	40	6	46	0	0	76	143	49
37	Koffiefontein	10	83	37	55	10	37	2	14	2	40	7	54	0	0	70	143	48
38	Luckhoff	8	67	22	33	14	52	2	14	0	0	6	46	0	0	68	143	36
39	Oppermansgronde	7	58	27	40	16	59	2	14	0	0	7	54	0	0	52	143	41
40	Smithfield	8	67	49	73	18	67	10	71	1	20	8	62	1	20	59	143	66
41	Rouxville	5	42	18	27	10	37	8	57	0	0	4	31	0	0	95	143	31
42	Zastron	8	67	18	27	11	41	6	43	0	0	8	62	2	40	45	143	37

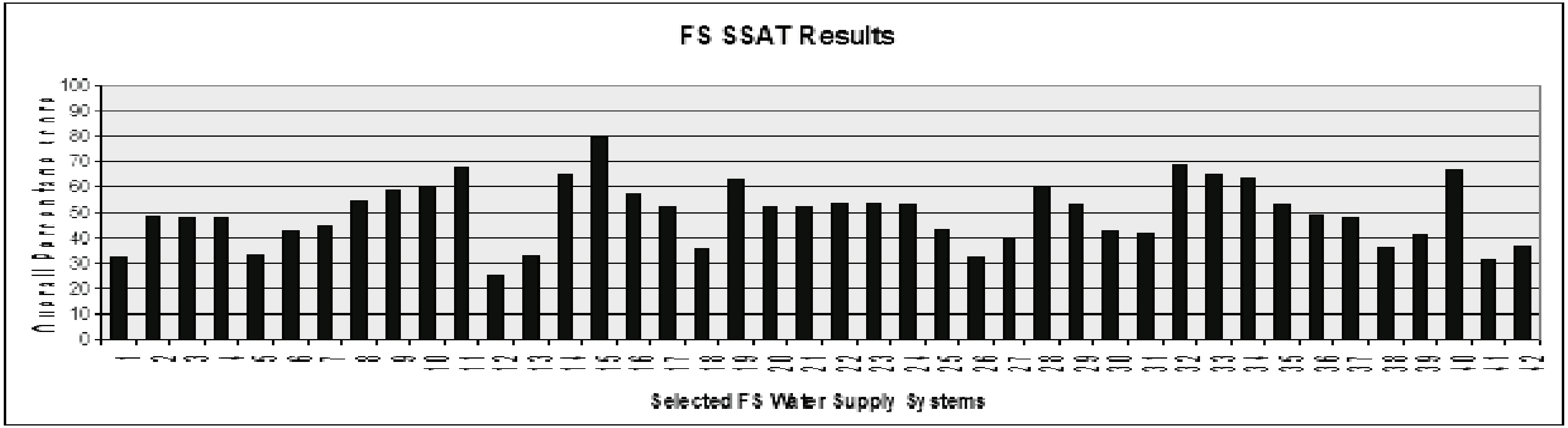


Figure 5: Representation of assessment score vs. FS Water Supply Systems

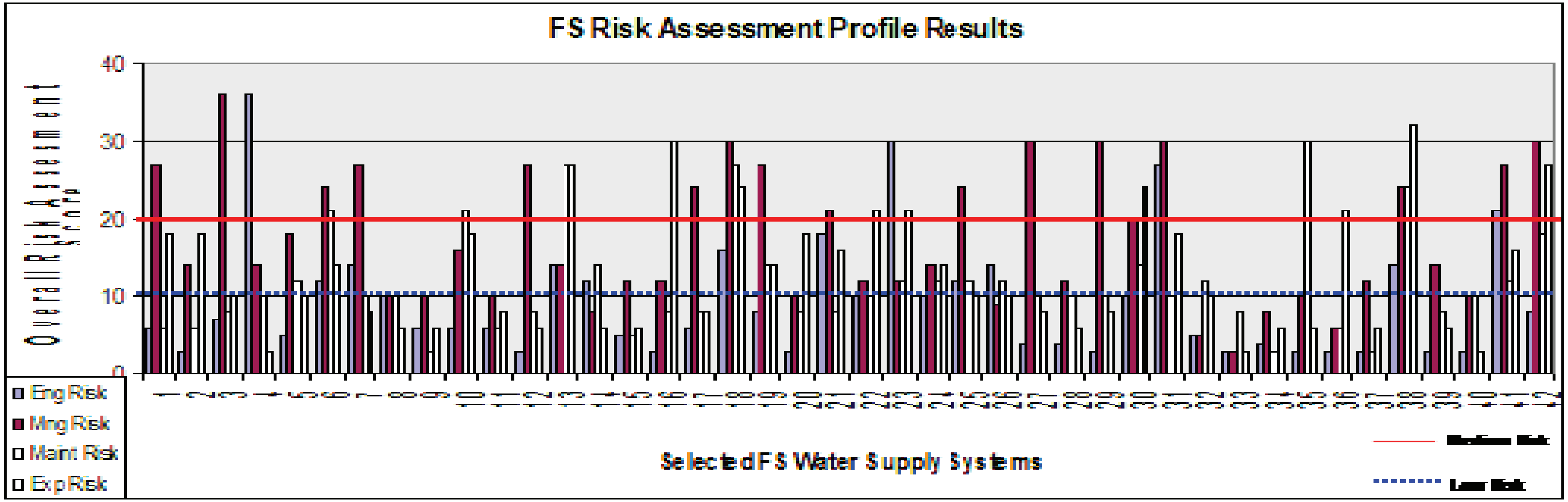


Figure 6: Representation of Risk profiling assessment for FS water supply systems

Key issues identified
Water quality failures in the region are as a result of the following:

- Most parts of the Free State are having a water demand problem.
- Aging water treatment plants, storage reservoirs together with their distribution networks.
- In cases where DWAF plants are handed over to either the DM or LM, there is always confusion as to who is responsible for supervision of the operator staff and maintenance of equipment.
- There is no succession of knowledge or transfer of skills between experienced, old process controllers and young inexperienced.
- Most process controller staff is not trained to handle water quality issues.
- Water Service Authorities do not conduct monitoring, they rely on the monthly audit conducted by CSIR.
- In most areas there are no cross-checks done with CSIR data.

Summary of Strengths

- There are sector forum meetings held quarterly in the region whereby water services issues are discussed.
- Consultative audit of drinking-water and wastewater in the province is conducted monthly.
- There is a provincial database that captures drinking and wastewater quality data and reports highlighting issues of concern are produced.

Water Service Authorities are now more aware of their legislated requirements regarding drinking-water quality treatment, monitoring and management. This can be attributed to a number of factors including the Free State Consultative Audit (communications of failures, summary reports, bi-annual meetings and feedback sessions, etc.), various national and provincial initiatives (National drinking-water quality management framework, water summits, water forums, etc.), training programmes and increased media coverage of areas where water quality issues and disease outbreaks occur.

4.4 Findings from the Eastern Cape

- Eastern Cape is generally doing well in terms of design, the average percentage score is 80 percent.
- Operation and performance of selected Eastern Cape treatment plants together with their network is not doing bad either with a few exceptions.
- Supervision and management can be said to be average.
- Management of waste from the drinking-water treatment plants is bad.
    Queenstown Water Treatment Works (WTW) discharges and desludges to the wastewater treatment plant.
    The other plants that are not doing bad, have got desludge ponds.
- Some water treatment plants in the Eastern Cape provide safe environment to the process controllers whereas the others are very poor in that.
- Emergency preparedness and maintenance are the categories that are not doing well. This can be clearly seen from the table and graphs below.

Table 10: *Eastern Cape Assessment score results*

		Score																
LM	**WTW**	**Section 1**		**Section 2**		**Section 3**		**Section 4**		**Section 5**		**Section 6**		**Section 7**				
		Design		**Op/Perf**		**Maint.**		**Sup/Mngt**		**Waste Mngt**		**Safety**		**Emergency**		**TOTAL**	**MAX**	**Total %**
		Max = 12	**%**	**Max = 67**	**%**	**Max = 27**	**%**	**Max = 14**	**%**	**Max = 5**	**%**	**Max = 13**	**%**	**Max = 5**	**%**	**143**	**143**	**100%**
Mnquma	Butterworth	9	75	39	58	11	41	10	71	0	0	7	54	1	20	77	143	54
Amahlathi	Cathcart	7	58	20	30	13	48	7	50	0	0	5	38	1	20	53	143	37
Emalahleni	Machubeni	9	75	41	61	10	37	6	43	0	0	8	62	2	40	76	143	53
Ngqushwa	Peddie	11	92	48	72	24	89	8	57	3	60	12	92	3	60	109	143	76
Lukhanji	Queenstown	10	83	49	73	20	74	13	93	3	60	8	62	3	60	106	143	74
ADM	SADA	10	83	29	43	14	52	3	21	3	60		0	3	60	62	143	43
Amahlathi	Stutterheim	11	92	57	85	22	81	11	79	4	80	12	92	3	60	120	143	84

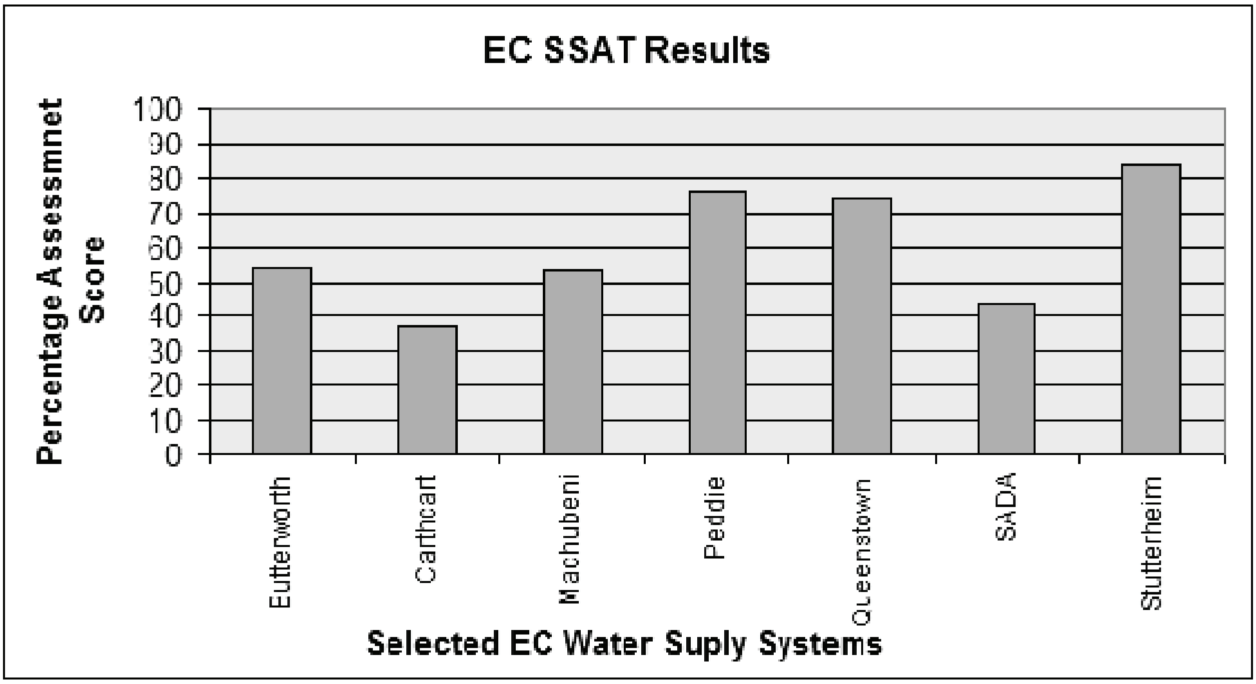


Figure 7: Representation of assessment score vs. EC Water Treatment Systems

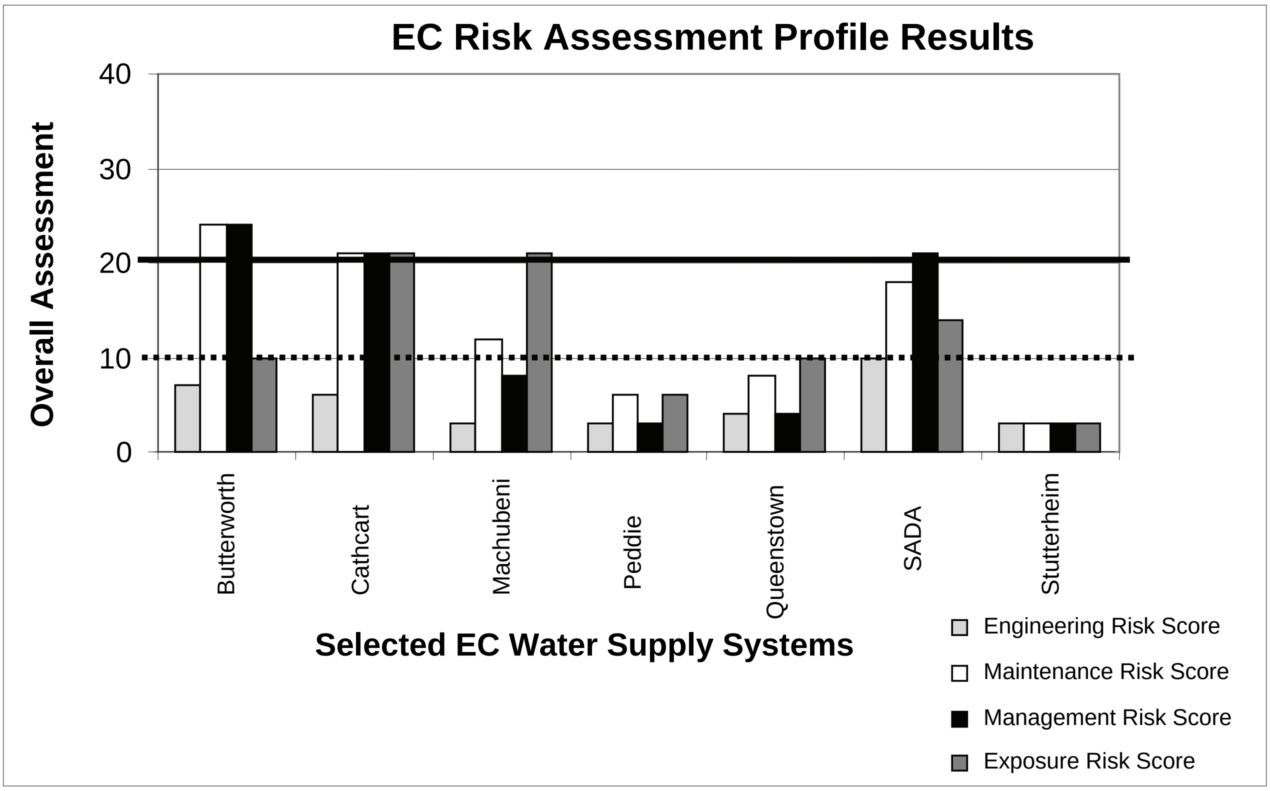


Figure 8: Representation of Risk profiling assessment for selected EC water supply systems

Key issues identified

Water quality failures in the region are as a result of the following:

- Aging water treatment plants, storage reservoirs together with their distribution networks.

- In cases where DWAF plants are handed over to either the DM or LM, there is always confusion as to who is responsible for the process controller staff and maintenance of equipment.
- Inadequate monitoring is conducted in smaller municipalities in the rural areas.
- Most of process controller staff is not trained to deal with water quality issues.
- Misuse of water services budget.

Summary of Strengths

- *Chris Hani DM*

In rural areas there are water schemes that form part of Rural Operation and Maintenance Programme (ROMP) that gets allocated a budget by Chris Hani DM for operations and maintenance purposes. Although at the moment there is no centralised database available for provincial drinking-water quality, each WSP and/or department has got its own database for its area of concern. In terms of dealing with emergency issues, there is a plan of having a centralised customer care centre in the district which will deal with consumer complaints. Water and Wastewater Solutions SA conduct monitoring in its area of concern.

- *Amathole DM*

The District Municipality provides assistance to its Local Municipalities in terms of finance. Amatola Water, Buffalo City and WSSA conduct monitoring in their areas of concern. There are plans of appointing a water service support agents which will be responsible for operations and maintenance of water services and budgeting related to water services in the Local Municipalities.

4.5 General Comments Based on the Study

Considering the above, the following key issues are noted:

- ***Operational Inefficiency & Equipment Shortcomings***

  Lack of adequate monitoring and associated instrumentation by WSAs.

  - Analyses cannot be carried out due to inadequate instrumentation or laboratory facilities.
  - Instruments are not being serviced at regular intervals.
  - Instruments are not regularly or properly calibrated.
  - No chemical standards available for instrument calibration.
  - Where instruments operate on batteries, none are available.
  - Analytical staff does not have the necessary training to carry out water quality analyses and to apply internal quality control systems.
  - Process controllers are not familiar with operation, routine maintenance/calibration of equipment. In some instances, the water treatment plant process controllers with very little/no experience in analytical techniques, are required to carry out analyses.

  Poor routine and pro-active maintenance.

  - Major contributor to poor plant performances.
  - In some cases equipment has not been repaired or replaced for extended periods of time.

  A lack of proper dosing chemicals and/or dosing equipment.

  Use of inappropriate and insufficient disinfectants.

- ***Capacity Shortcomings***

  Process controllers do not have the necessary skills to effectively operate and maintain water treatment plants.

Process controllers have no formal training in basic water treatment principles and techniques.
In some cases process controllers do not have the ability to read and write.
Process controllers often convey that they have low morale due to poor work conditions.
Process controllers feel that superiors are not concerned with problems experienced.
Lack of legislative awareness at management level.

- ***Environmental Factors***

  Increasing water demand (consideration must be given to introducing public awareness campaigns explaining the need to conserve water and/or introduction of water restrictions).
  Systems overload – resulting from increased production of domestic wastewater.
  Worsening resource quality.

5. RECOMMENDED REMEDIAL ACTIONS AND TOOLS

5.1 Introduction

The basic source of water is rainfall, which collects in rivers and lakes, under the ground, and in artificial reservoirs. Water from under the ground is called groundwater and is tapped by means of wells. Water that collects in rivers, lakes, or reservoirs is called surface water. Most large water supply systems draw surface water through special intake pipes or tunnels and transport it to the area of use through canals, tunnels, or pipelines. These feed a system of smaller conduits or pipes that take the water to its place of use.

A complete water supply system includes source, pumping stations, treatment stations, and storage facilities. Storage facilities are provided to reserve extra water for use when demand is high and, when necessary, to help maintain water pressure. Treatment stations are places in which water may be filtered to remove suspended impurities, aerated to remove dissolved gases, and disinfected with chlorine, ozone, ultraviolet light, or some other agent that kills harmful bacteria and micro-organisms.

Not all water supply systems are used to deliver drinking-water. Systems used for purposes such as irrigation and fire fighting operate in much the same way as systems for drinking-water, but the water need not meet such high standards of purity. In most municipal systems hydrants are connected to the drinking-water system except during periods of extreme water shortage. There are many ways in which water may be used by humans and animals and every user has different water quality requirements. Water must meet certain basic requirements to make it fit for domestic use. The most important requirement is that it must be safe to drink.

The following section explains drinking-water quality requirements, causes of contamination in drinking-water, typical contaminants and their effects.

5.2 Water Quality issues

There is no single measure that constitutes good water quality; as this depends on its final use. One should also keep in mind that some water quality problems (iron, manganese and turbidity) can be treated. Water quality is defined by analyzing it in terms of it's:
Physical Content: Turbidity, colour, odour, etc.
Biological Content: Faecal coliform, total coliform, viruses, etc.
Chemical Content: Hardness (calcium + magnesium), Metals (iron, etc.), nutrients (nitrogen and phosphorus), chloride, sodium, organic compounds, etc.

5.2.1 Physical characteristics of water

The physical characteristics of water are -

- Colour
- Turbidity (muddiness)
- Temperature
- Taste
- Odour
- Hardness
- Electrical conductivity
- Acidity

The colour in the water is generally created by the tannins that leach from trees and material such as bark and humus. Colour gives water its ‘tea-like appearance’. Turbidity on the other hand is the muddiness of the water, that is, the suspended particles of silt, clay, etc. floating around in the water. Both colour and turbidity have no direct impact on health per se but are direct indicators of risk to health that may lead to health issues if not managed. Consumers do not like drinking a discoloured glass of water as they form the opinion it is contaminated, even though it may not be. Therefore colour and turbidity are removed during the water treatment process.

5.2.2 Microbiological characteristics of water

Assessment of all parameters in water associated with potential infections is impractical for both technical and economic reasons. Bacteriological indicator organisms are therefore generally used for routine monitoring of the potential presence of pathogens in water. It is recommended that specific indicator organisms be analysed to optimize treatment processes for drinking water quality: The primary function of indicator organisms is to provide evidence of recent faecal contamination from warm blooded animals (Pontius, 1990). The general criteria for indicator organisms are:

- The indicator should always be present when the pathogenic organism of concern is present, and absent in clean, uncontaminated water.
- The indicator should be present in faecal material in large numbers.
- The indicator should respond to natural environmental conditions and to treatment processes in a manner similar to the pathogens of interest.
- The indicator should be easy to isolate, identify, and enumerate.
- The ratio of indicator/pathogen should be high.
- The indicator and pathogen should come from the same source.

Microbiological water quality monitoring is primarily based on tests for indicator organisms since there is no single indicator organism that can universally be used for all purposes of water quality monitoring (WHO, 2004a). Indicators most commonly used are of faecal or sewage origin and the following are some of the most important indicators:

Total Coliforms
Total coliforms are most often used to assess the general hygienic quality of water. When found they suggest poor treatment efficiency, post-treatment contamination and/or after growth (integrity of the distribution system questionable), or an excessive concentration of nutrients. The primary purpose of coliform tests is not to detect faecal pollution but to screen the general sanitary quality of treated drinking water supplies.

Faecal Coliforms and/or Escherichia coli
Faecal coliforms are bacteria more closely related to faecal pollution than total coliforms because most members of this group do not replicate as readily in aquatic environments. *Escherichia coli* is a member of the group of faecal coliform bacteria. The most important feature is that it is highly specific to the faeces of humans and warm-blooded animals. For all practical purposes these bacteria cannot multiply in any natural water environment and they are, therefore, used as specific indicators for faecal pollution (WHO seminar pack for drinking water quality, online).

5.2.3 Chemical characteristics of water

Chemicals in water can be both naturally occurring or introduced by human interference and can often have serious health effects. A large number of chemicals that exist naturally in the land, or which are added due to human activities, dissolve in the water, thereby contaminating it and leading to various diseases. Water gathers chemical constituents from the rocks and ground through which it permeates. Although water treatment can reduce levels of chemical contaminants, the variety of trace elements can be problematic, resulting in taste as well as potential health impacts. Typical constituents of concern are listed below:

- Nitrates/Nitrites
- Arsenic
- Chloride

5.2.4 What causes water contamination?

Good quality (potable) drinking-water is free from disease-causing organisms, harmful chemical substances and radioactive matter, tastes good, is aesthetically appealing and is free from objectionable colour or odour. It should be emphasized that there is a difference between "pure water" and "safe drinking-water". Pure water, often defined as water containing no minerals or chemicals, does not exist naturally in the environment. Safe drinking-water, on the other hand, may retain naturally occurring minerals and chemicals such as calcium, potassium, sodium or fluoride which are actually beneficial to human health. These will impart a taste to the water that may take some getting used to.

In some cases, however, groundwater can be contaminated with chemicals or bacteria. For example, it has been found that the health of people has been put at risk due to the presence of naturally occurring arsenic, fluoride and nitrates in drinking-water boreholes.

5.2.5 Water Contaminants

- Heavy Metals
  Heavy metals such as Lead, Copper, Iron, Zinc, etc. are a problem in certain areas of the country. The best way to identify their presence is by a laboratory test of the water or by speaking with the health department. Unless located down stream of mining trailing or a factory, the problem will probably affect the whole countryside or region. Heavy metals are unlikely to be present in sufficient levels to cause problems in the case of short-term use.
- Turbidity – refers to clarity, cloudiness, muddiness
  Turbidity refers to suspended solids, i.e. muddy water. Turbidity is undesirable for 3 reasons: 1) aesthetic considerations 2) solids may contain heavy metals, pathogens or other contaminants, 3) turbidity decreases the effectiveness of water treatment techniques by shielding pathogens from chemical or thermal damage, or, in the case of UV treatment, absorbing the UV light itself and thus preventing proper disinfection.
- Organic compounds
  Water can be contaminated by a number of organic compounds such as chloroform, gasoline, pesticides, and herbicides. These contaminants should be identified in a laboratory test. It is unlikely that ground water will suddenly become contaminated unless a quantity of chemicals is allowed to enter a ground water source or to penetrate the aquifer. Surface water may show great swings in chemical levels due to differences in rainfall, seasonal crop cultivation, and industrial effluent levels.
- Protozoa
  Some Protozoa such as cysts and oocysts are the largest pathogens in drinking-water. Not all Protozoa are pathogens though. Cysts and oocysts range in size from 2 to 15 microns (a micron is one millionth of a meter), but can squeeze through smaller openings. These can be removed by means of filtration. In order to insure their efficient filtration, filters with absolute pore size of 1 micron or less should be used. The two most common protozoa pathogens are *Giardia lamblia* (*Giardia*) and *Cryptosporidium* (*Crypto*).

- Bacteria
  Bacteria are smaller than protozoa and are responsible for diseases such as typhoid fever, cholera, diarrhoea, and dysentery. Pathogenic bacteria range in size from 0.2 to 0.6 microns, and a 0.2 micron filter is necessary to prevent transmission. Contamination of water supplies by bacteria is blamed for the cholera epidemics which devastate undeveloped countries from time to time. *E. coli* is frequently found to contaminate water supplies and recent studies have shown that *E. coli* can multiply in water. Dehydration from diarrhoea caused by *E. coli* has resulted in fatalities.
- Viruses
  Viruses are the second most problematic pathogen, after protozoa. As with protozoa, most waterborne viral diseases do not present a lethal hazard for a healthy adult. Waterborne pathogenic viruses range in size from 0.020-0.030 microns, and are too small to be filtered out by a mechanical filter. All waterborne enteric viruses affecting humans occur solely in humans, thus animal waste doesn't present a severe viral threat. At present, viruses do not present a major hazard to people drinking surface water, but this could change in a survival situation as the level of human sanitation is reduced. Viruses do tend to show up even in remote areas, so it is important to eliminate them as soon as possible.

As a result of the issues described above, water needs to be treated before being supplied to consumers. Proper management of water supply system is becoming more complex and challenging as threats to resources and water supply system increase. Managers are expected to respond to disruptions of water resources and water supply system that threaten the quality of human life and environmental sustainability.

In order to continuously provide safe drinking-water, procedures or tools are required that are able to guide a comprehensive and systematic approach to improving service delivery (to meet legislated and governance requirements). For this reason, legislative requirements and planning procedures are discussed in order to improve service delivery in the management guide below.

These are discussed in the following section.
The process controller’s and distribution network guides have been developed based on the experiences of the study with the purpose of providing practical guidelines for the water services team to understand their roles, and practical methods of looking after the water supply system.

5.3 MANAGEMENT GUIDE

Purpose of the guide

This guide has been developed with the purpose of providing assistance in terms of:

- Planning for effective delivery of drinking-water services
- Understanding legislative requirements related to drinking-water services
- Understanding of drinking-water quality issues
- Understanding staff training issues
- Importance of reporting.

This guide can be used in conjunction with the following WRC/DWAF guides:

- An illustrated guide to basic water purification operation is intended for process controllers at entry level and water care managers to guide the operations staff (WRC Report No. TT 247/05).
- Handbook for the operation of water treatment works (WRC Report No. TT 265/06). Intended for plant supervisors and process controllers to provide knowledge to properly operate, asses, optimise, understand implications and perform basic management tasks.

- Volume 5 Management Guide describing typical issues through water supply system and how they can be rectified (DWAF/WRC Report No. TT 162/01).
- All other references at the end of the document.

Who should use this guide?

- The guide has been developed for people at the management level in order to fulfil the purposes mentioned above.

5.3.1 Duties of Water Service Authority

All WSAs have the following primary responsibilities:

- **Realisation of the right of 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 (performance management, by-laws) and sustainability (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 (WSP):** 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).

In order to continuously provide safe drinking-water, procedures or tools are required that are able to guide a comprehensive and systematic approach to improving service delivery (to meet legislated and governance requirements). These are discussed in more details in the sections below which are in turn duties of WSAs.

5.3.2 Planning for water services

The most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer. The WHO Guidelines for drinking-water quality 3rd edition (2004) define such an approach as “water safety plans”.

The WHO states that a WSP has three key components which are guided by health-based targets and overseen through drinking-water supply surveillance and they are:

- System assessment to determine whether the drinking-water supply chain (up to the point of consumption) as a whole can deliver water of a quality that meets health-based targets. This also includes the assessment of design criteria of new systems;
- Identifying control measures in a drinking-water system that will collectively control identified risks and ensure that the health-based targets are met. For each control measure identified, an appropriate means of operational monitoring should be defined that will ensure that any deviation from required performance is rapidly detected in a timely manner; and

- Management plans describing actions to be taken during normal operation or incident conditions and documenting the system assessment (including upgrade and improvement), monitoring and communication plans and supporting programmes.

Matters for consideration in the preparation of water services development plans (WSDPs) in conjunction with an official plan policy (or, otherwise, policies) include:

- Investigating measures to resolve existing water problems within the municipality such as abatement of overflows or addressing limitations to pumping stations and water distribution systems;
- Investigate servicing efficiency measures, such as the adoption of water conservation toward reducing the demand on water supplies and treatment plant capacity;
- Address how the municipality intends to service anticipated growth and identify what the implications are for the water services and the need for new services;
- Account for the efficient use of available existing infrastructure by calculating and reporting on uncommitted reserve capacity for water treatment facilities and establish a monitoring program for future use of that capacity;
- Identify the physical and environmental constraints to development related to servicing;
- Generally describe the type and level of water supply services which would support municipal goals for environmental protection or enhancement, sustainability, urban intensification, and growth management in a manner which is efficient and cost effective;
- Draw conclusions regarding the principle of whether to permit development in areas outside existing full municipal services on the basis of:
    - an evaluation of servicing options which includes the potential for full municipal services and communal services;
    - a determination of appropriate areas to target for growth on the basis of the servicing option available within the context of criteria outlined under the Provincial Policy Statement;
- Investigate and classify areas outside fully municipal serviced areas which may be targeted for growth by generally evaluating the potential growth areas according to their suitability for servicing. These servicing/environmental investigations (along with other planning concerns) should be the basis for municipalities to direct appropriate forms of development to areas least likely to suffer adverse environmental impacts. To confirm that the principle of development is appropriate, the investigations should be an overview based on a evaluation using existing information on environmental constraints which include soils, groundwater and surface water conditions and use, agricultural uses, storm water drainage, existing land uses, and environmental and physiographic features.

5.3.3 Selection of water service providers

A WSA may either provide water services itself (internal mechanism), or contract a Water Services Provider (WSP) to provide water services (external mechanism). For an internal mechanism, the WSA must manage and account separately for the two functions. In practical terms this might mean that a municipal manager, acting on behalf of the municipality, contracts (as the WSA) 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 WSA must regulate the WSP according to the contract specifying clearly the allocation of roles and responsibilities between the regulator and the provider. Under all circumstances the WSA is the regulator of the service and is responsible to ensure that services are provided effectively, efficiently, sustainably and affordably.

Duties of water services providers
The main duty of WSPs is to provide water services in accordance with the Constitution, the Water Services Act and the by-laws of the WSA, and in terms of any specific conditions set by the WSA in a contract. A WSP must publish a consumer charter which is consistent with by-laws and other regulations, is approved by the WSA, and includes the duties and responsibilities of both the WSP and the consumer, including conditions of supply of water services and payment conditions.

Understanding of legislations relating to water services by the responsible persons/parties involved is very important.

5.3.4 Overview of legislation relating to water services

Key to effective water service delivery is the raised awareness of both legislative compliance requirements and the importance of water quality management in assuring provision of safe drinking-water and the protection of the environment. As the legal framework and institutional arrangements relating to water services provision is complicated and can be somewhat daunting even to the uninitiated, the following sections provide a brief overview of legislative aspects of drinking-water services.

Legal framework
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,** 1996, assigns responsibility of ensuring access to water services to local government. The role of the national and provincial spheres of government is to support, monitor and regulate local government.
- **The Water Services Act**, 1997, further defines the municipal functions of ensuring water services provision.
- **The National Water Act**, 1998, amended to 2006 defines a new way of managing South Africa's scarce water resources. This Act states that water is an indivisible national resource for which national government is the custodian.
- **The Local Government: Municipal Demarcation Act,** 1998, provides a legal framework for defining and implementing a post-transitional system of local government.
- **The Local Government: Municipal Structures Act,** 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 Local Government: Municipal Systems Act,** 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.
- **The Local Government: Municipal Structures Amendment Act,** 2000, places the function of ensuring access to water services (as well as Health and Electricity) at a district level, unless a local municipality is authorised to perform this function.

The municipal system
The second democratic local government elections held on 5th December 2002 heralded the introduction of the new local government municipal system. The new system reduced the number of local government structures from 843 to 284:
- 6 metropolitan municipalities (Metros – 'Unicities' with no sub-structures);
- 47 district municipalities covering the whole country; and
- 231 Local Municipalities located within the areas of the district municipalities.

A district municipality may typically contain three to six Local Municipalities. A local municipality usually includes two to three towns as well as surrounding rural areas.

The new local government structures are faced with many challenges, including amalgamation of old administrations, as well as the challenge posed by rural areas and parts of the former homelands. The division of powers and functions between district and local municipalities has been, and still remains, a major issue to resolve.

Overview of legislation relating to drinking-water quality
A useful and necessary means for tracking water services delivery is via the monitoring of the quality of drinking-water. Drinking-water quality monitoring allows the correct interpretation of simple and readily measurable analytical determinants gives insight into the operating state of water services provision, and draws attention to Operations and Maintenance requirements.

Most importantly, drinking-water quality monitoring is also necessary in that poor drinking-water quality has a direct impact on the health of the community. In South Africa, all Water Services Authorities are legally required to monitor drinking-water quality on a monthly basis. The Water Services Act introduced a compulsory national standard for drinking-water quality. The *Compulsory National Standards for the Quality of Potable Water*, as published in Government Gazette No 22355 of 8 June 2001, reads as follows:

Quality of potable water

(1) Within two years of the promulgation of these Regulations, a water services authority must include a suitable programme for sampling the quality of potable water provided to consumers in its water services development plan.

(2) The water quality sampling programme contemplated in sub regulation (1) must specify the points at which potable water provided to consumers will be sampled, the frequency of sampling and for which substances and determinants the water will be tested.

(3) A water services institution must compare the results obtained from the testing of samples with SANS 241: Specifications for Drinking Water; or the South African Water Quality Guidelines published by the Department of Water Affairs and Forestry.

(4) Should the comparison of the results as contemplated in sub regulation (3) indicate that the water supplied poses a health risk, the water services institution must inform the Director-General of the Department of Water Affairs and Forestry and the head of the Provincial Department of Health and it must take steps to inform its consumers-

(a) that the quality of the water that it supplies poses a health risk;

(b) of the reasons for the health risk;

(c) of any precautions to be taken by the consumers; and

(d) of the time frame, if any, within which it may be expected that water of a safe quality will be provided.

The guiding drinking-water quality document is SANS 241 specifies two classes of water in terms of physical, microbiological and chemical quality, which are:

- Class I: water that is known to be acceptable for whole lifetime consumption.
- Class II: water considered to be the maximum allowable for short-term consumption (usual and continuous daily consumption for periods not exceeding the specified number of years).

Class I is known to be acceptable for whole lifetime consumption, and is the targeted minimum drinking-water quality for WSAs and WSPs. **Class II** is an acknowledgement that, it is more prudent to allow consumption of the delivered drinking-water at a relaxed level for short-term consumption, where risk is quantifiable and understood and it is acknowledged that urgent actions are required to improve quality to Class I. Where water fails Class II, and in particular with regards to bacteriological quality, it should be regarded as unfit for human consumption and urgent attention and mitigative action is required.

Whilst the Water Services Act does not criminalise non-compliance with the national standards (and this is in keeping with the phased approach contemplated in the Water Services Act), the Water Services Act makes it an offence for any person to "fail or refuse to give information or to give false and misleading information when required to give information in terms of this Act". As such, as long as the WSAs comply with the absolute obligation under Sub-regulation 5(4) above and inform, the Minister and the Province, as well as its consumers, of its inability to meet its obligations under the law, it faces a vastly reduced risk of incurring penalties under the Act.

Clearly, a regulatory governance requirement therefore exists for Local Government to monitor drinking-water quality, and for both Provincial and National Government to ensure that such is taking place. Where Local Government lacks resources to carry out such monitoring, a co-operative government requirement would require Provincial and/or National Government to ensure that monitoring takes place.

The following are the important documents in the water services that explain the legislative requirements stated above.

- National Water Act, 1998
- Water Services Act, 1997
- Compulsory National Standards for Potable Water
- National DWQM Framework
- SANS 241 Drinking Water Specification

Additional information on drinking-water quality sampling, analysis, assessment, treatment and management can be found in the Department of Water Affairs and Forestry, Department of Health and Water Research Commission guides on the Quality of Domestic Water Supplies:

- Volume I: Assessment Guide
- Volume II: Sampling Guide
- Volume III: Analysis Guide
- Volume IV: Treatment Guide and
- Volume V: Management Guide

The above mentioned combine to create a clear governance requirement for every Water Service Authority to take proactive measures to ensure the provision of adequate drinking-water services. Importantly, the *Compulsory National Standards for the Quality of Potable Water* (as published in Government Gazette No 22355 of 8 June 2001) requires that Water Services Authorities (local or district municipalities) implement drinking-water quality monitoring programmes to monitor and improve drinking-water service delivery to consumers. An appropriate drinking-water quality management programme forms the basis for proactively:

- Ensuring legislative compliance and satisfaction of governance requirements,
- Progressively ensuring the provision of safe drinking-water quality,
- Progressively ensuring Infrastructural efficiencies, and
- Identifying and achieving the necessary training and capacity development.

More details on legislations relating to drinking-water provision are presented in **Appendix A.**

One of the challenges, which results in WSAs failing to comply with water quality standards, that was identified through studies conducted was that of unskilled or unqualified staff. The National Water Act, 1998 provides the qualifications the process controllers should be relative to the size and class of water treatment works. In order to achieve this with staff who are already in the workplace, training through learnerships may be practised. This is explained in details in the section below.

5.3.5 Staff training

Introduction

Learnership and skills development programmes are important innovations of the act and are envisaged to be the primary engines to power the new skills development and training revolution. Learnerships are a mixture of on-the-job training and education and training that is provided in a technical college, universities of technology, university or training centre. A person who completes a learnership successfully will have a qualification that is recognised throughout the country. Learnerships are new and different because they are about making sure that people can use the skills that they have learnt. It is important to note that generally speaking learnerships are different from apprenticeships. Apprenticeships were usually for young people starting their work lives. Learnerships are open to people of all ages.

Objectives of water related learnerships

The three objectives and outcomes of the water related Learnerships are:

- Improve skills in the workplace and redress past unfair discrimination in education, training and employment opportunities.
- Motivate the workers/employees and provide career paths of learners.
- Improve quality of water related services.

These outcomes are achieved through:

- Transforming workplaces into places of learning,
- Implementing learnerships using outcomes based education methods,
- Coupling learnership qualifications to career paths and organograms,
- Implementing a simple quality management system which includes standard operating procedures (SOP), operating reports against bench marks, and corrective action reports.

Staff training can be provided in more than one way. An external provider who gets appointed to undertake training in that particular DM, or the DM can provide the training itself or the DM goes in partnership with the accredited provider. The training also can be provided by:

- Universities of Technology
- Colleges
- Accredited Training Providers
- Municipalities

Control of labour

Assignment of duties to everyone and a reporting structure should be followed. Set staff requirements and the structure of such staff. Staff, e.g. process controllers, have to comply with statutory requirements as regards qualifications. With the staff already employed, conduct a staff skills audit to investigate which staff need training and the qualifications required. If there is a lack of financial resources, investigate funding methods available. Prepare procedures so that the work is done in a uniform and standardized way. Make sure that adequate records are kept. Log sheets should be designed to report all important items which may require looking at on a routine basis.

5.3.6 Documentation/ Reporting

Documentation of all aspects of drinking-water quality management is essential. Documents should describe activities that are undertaken and how procedures are performed. They should also include detailed information on:

- assessment of the drinking-water system (including flow diagrams and potential hazards and the outcome of validation);
- control measures and operational monitoring and verification plan;
- routine operation and management procedures;
- incident and emergency response plans; and supporting measures, including:
  - training programmes;
  - research and development;
- procedures for evaluating results and reporting;
- performance evaluations, audits and reviews;
- communication protocols;
- community consultation.

Records should be kept to allow proper management and control. Performance records are required for:

- trouble shooting
- to identify changes in operating conditions
- to identify reasons for process failure or water quality reduction
- for process optimization
- to record changes in effluent quality and process conditions.

Documentation and record systems should be kept as simple and focused as possible. The level of detail in the documentation of procedures should be sufficient to provide assurance of operational control when coupled with a suitably qualified and competent operator. Mechanisms should be established to periodically review and, where necessary, revise documents to reflect changing circumstances. Documents should be assembled in a manner that will enable any necessary modifications to be made easily.

Process flow charts, operating and maintenance manuals and the plant design details should be accommodated. These documents should be made available to the relevant personnel and specific requirements must be included in the operating details.

5.3.7 Community awareness

Effective communication to increase community awareness and knowledge of drinking-water quality issues and the various areas of responsibility helps consumers to understand and contribute to decisions about the service provided by a drinking-water supplier or land use constraints imposed in catchment areas. A thorough understanding of the diversity of views held by individuals or groups in the community is necessary to satisfy community expectations. The public should be kept informed of developments in the availability and quality of water. They can help in reducing wastage and identifying leaks in the distribution system.

DWAF National has decided that progress in achieving extension of service delivery with regards to Drinking-Water Quality can best be achieved by introducing a common Drinking-Water Quality Management System. Built on the experience of Western Cape, the preferred communication medium for the regional Drinking-Water Quality Management System is a web-based interface.

Furthermore, the process provides an environmental governance function, ensuring that acute and chronic issues are timeously identified and resolved. The components of this tool are presented in the section below.

The personnel responsible for water treatment (process controllers) need to understand the importance of water quality issues and how to maintain and manage the water treatment works so as to produce good quality water. The section below describes the roles and responsibilities of the process controllers and how to operate and maintain a water treatment works. Water treatment systems differ in operation and unit processes. This guide should therefore not be considered as an instruction manual but as a general guide.

5.4 PROCESS CONTROLLERS' GUIDE TO OPERATION AND MAINTENANCE OF WTW

Purpose of the guide
This guide has been developed with the purpose of:

- providing practical guidelines for the persons responsible for operation and maintenance of the drinking-water treatment plants
- understanding typical failures experienced in a drinking-water treatment plant , and
- how to attend to and rectify such failures.

Who should use the guide?
The guide has been developed in such a way that it will assist the operations and maintenance personnel of drinking-water treatment plants to understand:

- how to effectively operate the drinking water treatment plants
- how to effectively maintain the system
- if there are issues that need urgent attention and should be reported to the supervisor.

System or plant supervisors could use the guide so that they have common understanding with the operations and maintenance actions and requirements including:

- providing the correct record sheet for the process controllers on-site to quickly identify issues of concern
- providing necessary equipment for the process controllers.

5.4.1 Process operator's responsibilities

The specific duties of process controllers depend on the type and size of the plant. In smaller plants, one process controller may control all of the machinery, perform tests, keep records, handle complaints, and perform repairs and maintenance. In larger plants with many employees, process controllers may be more specialized and monitor only one process. The staff also may include chemists, engineers, laboratory technicians, mechanics, helpers, supervisors, and a superintendent. The guides referred to in the first page of the document summaries the duties of the process controller as follows:

- ***Set flow rates*** – this entails the adjustments of raw water flow into the works based on demand within area reticulated in town or reservoirs. When setting raw water flow rates to the works it should be borne in mind that better process stability is achieved if flow-rate changes to the works are minimized. With large water storage in the reservoirs it may be possible to run 24 hours per day at an essentially constant flow rate and allow reservoirs to rise and fall, accommodating the peaks and troughs in demand. An example of setting feed flow rates is shown in the picture below.

- ***Set dosages and chemical feed rates*** – depending on the raw water quality, a number of different chemicals may have to be added. These include coagulants, a floc aid, pH correction chemicals, pre-oxidants and disinfectants.
- ***Check plant and equipment*** – it is the duty of the process controller to check the plant equipment at routine intervals during his period of duty. The process controller should check whether the raw water and treated water pumps are operating normally and whether the back-wash system for filters is functioning satisfactory.

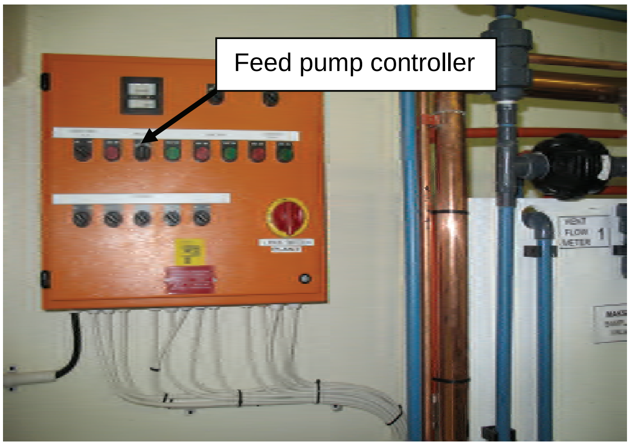


Figure 9: Illustration of feed pump controller

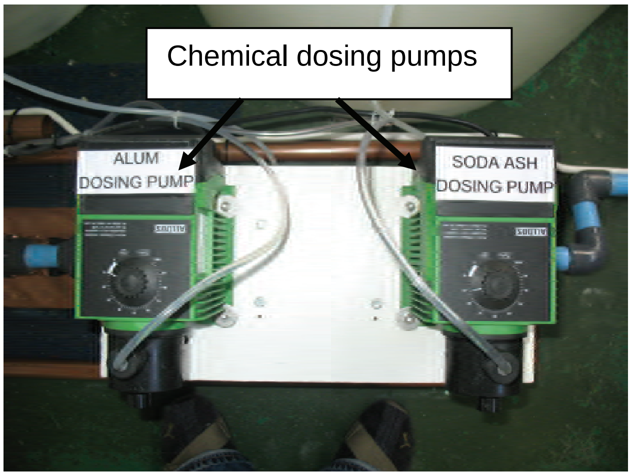


Figure 10: Illustration of chemical feed dosing controller

Figure 11: Illustration of sedimentation tanks cleaning

- ***Desludge clarifiers or sedimentation tanks as required*** – the accumulated solids in the tanks need to be desludged. The method of desludging depends on the type of tank installed. Floc in the clarifier that has collected as sludge at the bottom of the sedimentation tank should be periodically removed to prevent excessive build-up in the unit. Desludging of clarifiers and sedimentation tanks should be carried out routinely with the period and frequency of operation depending on conditions at the works. The frequency will be based on operating experience and recommendations of the designer of the plant installed.
- ***Backwash filters as required*** – slow sand filters operate for a period of several weeks before requiring attention. For a rapid gravity works, the filter run may vary quite widely depending on the nature of the raw water and sedimentation and flocculation. On a works without clarifiers, backwashing of filters is normally required two to three times per day. A filter may be backwashed either on a timed basis or on headloss. Backwashing procedures vary depending

on the type of filters installed. Most filters have air plus water backwash while some have water wash only. Rapid gravity filters in South Africa are normally provided with an air scour system. The purpose of air scour is to dislodge the dirt which has settled on or become attached to the sand particles in the filters. Air scouring loosens the dirt and enables the backwash water to remove it easily. Backwash water is then passed through the filter until backwash water is reasonably clean. This will also take several minutes but varies depending on the depth of the filter, the backwash rate and the amount of material to be removed. Pressure filters and some rapid gravity filters only have water backwash without air scour facilities. In this case all that is required is to close off the feed and the outlet, to start the backwash pumps and to backwash the filters for a certain period of time, and then to close the backwash valves and restart operation.

- ***Carry out treatment of sludge*** – sludge production takes place at a water works through the processes of coagulation and flocculation. Most of the sludge is settled out in sedimentation tanks or clarifiers and the remainder has to be removed in the filters. The sludge removed from the clarifiers and possibly from the filters has to be disposed of. The sludge is thickened to improve settling, and pumped to a press or drier system. After the drying process, the sludge is often called a cake because the consistency has changed with solids content. The least complicated would be a drying pond. For this exercise, assume two ponds are required. One pond is filled with sludge and allowed to bake in the sun. While one pond is drying, the other is filled. Before the second pond is filled, the first one is excavated using digging machines. Dried sludge or cake should be disposed using guidelines for sludge disposal.
- ***Test water quality and take corrective action –*** it is the responsibility of a process controller to ensure that the water he or she is producing is of acceptable quality according to SANS 241 standards. This is established by means of routine testing of samples. Though a complete analysis (in terms of SANS 241) is not normally carried out at a water works on a routine basis, there are a number of tests that should be carried out which provide an adequate check for routine purposes. These are listed as operational determinants in SANS 241.
- ***Carry out basic maintenance*** – most operating staff can be relied upon to carry basic routine activities such as cleaning of sedimentation tanks and routine lubrication.
- ***Record keeping*** – it is essential for the controlled operation of water works that the work carried out is recorded in suitable form. Records are kept of the following:

  unusual occurrences
  breakdowns(down time)
  pumping hours
  meter readings (raw water and final water volumes)
  dosage concentrations(chemicals used per day)
  water quality, etc.

  The water works manager (or treatment superintendent) should inspect the logs on a daily basis.
- ***Handle chemicals*** – operating staff should ascertain the precautions necessary for handling of all chemicals used. These are normally obtained from the suppliers of such chemicals who have manuals of practice and codes to handle chemicals. The municipality/organization has to comply with legislation regarding safety in terms of chemical storage and handling. These practices have to be formulated into an operating procedure, which has to be documented. Some storage requirements are written on the containers as shown in the figure below.
- ***Order chemicals, parts and tools/stock control*** – the manager or superintendent of the water works should establish a reporting system whereby he is timeously informed of the need to order chemicals. Spare parts should be available for critical equipment so that repairs can be carried out quickly. The operating authority should ensure that its procurement systems are adequate to cope with any emergency situations.

Figure 12: Typical issues on chemical storage

- ***Prepare and work to budgets*** – the operating staff assists in budget preparation by good record keeping. Budgets are required in any authority to plan expenditure over the coming financial year. Good estimates of proposed chemical consumption, planned maintenance, etc. are necessary as these are frequently large items in the overall budget.
- ***Works calculations*** – staff on any water works should be able to answer queries as to what the relevant dosages are at a particular time. This type of calculation is normally covered in the training of operators and these calculations should be used in ensuring that the operating staff has a full appreciation of dosages as well as consumption on the plant.
- ***Communicate with other process controllers and supervisors*** – any treatment plants operate in isolation and process controllers may therefore be unaware that the problems they are experiencing may be similar to those in adjacent towns or in other authorities elsewhere in the country. It is necessary when operating water works to periodically evaluate the process at the plant and to assess whether it is suitable for the water being received. That is why it is necessary to interact with other people who are doing the same job so as to share ideas and experiences. This can be done by means of establishing forums at that certain level.
- ***Safety inspections*** – safety is an important operational aspect. A water works should comply with safety procedures and all relevant legislation. The condition of safety equipment should be inspected and respiration apparatus, ladders, scaffolding, walkways, machine guards and similar items should be inspected on a regular basis. As it is primarily for process operator's sake, operators should be involved in the procedures.
- ***Start up and shut down*** – process operators running water works which operates continuously may not be familiar with the procedures for shutting down or starting up. In case of emergency (e.g. power failure) where the shutdown was not planned, the process operators should know the procedures of starting up.
- **Shift take over** - it is very important that the person taking over the shift be thoroughly informed of what happened during the previous shift in terms of water quality problems, dosages, people not reporting for work, reservoir levels, etc.

The primary objective of water treatment is to produce water that is fit for domestic use at a reasonable cost. This is done on the basis of water quality and quantity considerations, processes and operations. The health and hygienic aspect of water is of primary importance for domestic purposes. However, treated water should also be aesthetically pleasing, non-corrosive or scale forming and it should meet a number of other quality requirements. General operation of water treatment works is presented in the section below.

5.4.2 Operation of water treatment works

Introduction
Treatment works are places in which water may be filtered to remove suspended impurities, aerated to remove dissolved gases, and disinfected with chlorine, ozone, ultraviolet light, or some other agent that kills harmful bacteria and micro-organisms.

Raw water contains different inorganic and organic substances and micro-organisms that must be removed during water treatment to produce water that is fit for domestic use**.** To achieve this goal, a variety of purification and treatment processes are utilised which employ various physical and chemical phenomena to remove or reduce undesirable constituents from the water. These processes are explained in more detail below.

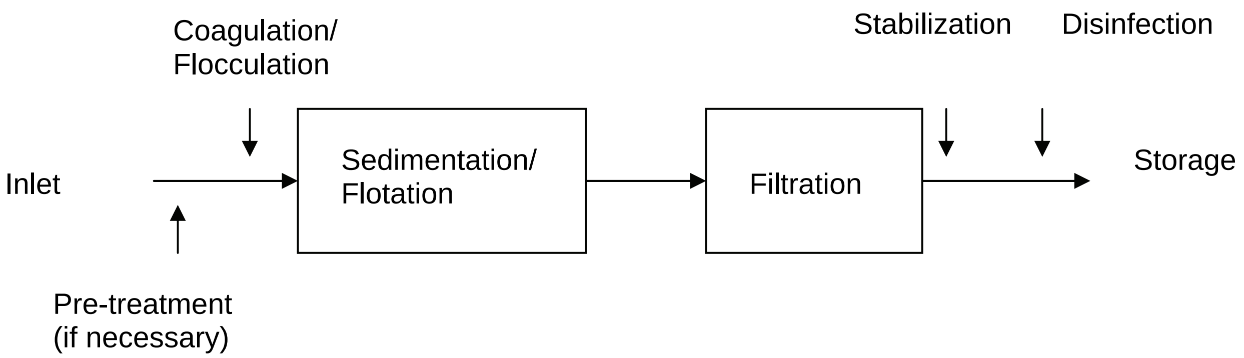


Figure 13*:* Schematic presentation of a drinking water treatment system

It is essential for each water treatment plant to have a representation of the layout of its water treatment system indicating the unit processes involved, indicating dosing points, sample collection points, etc. as illustrated in the figure below.

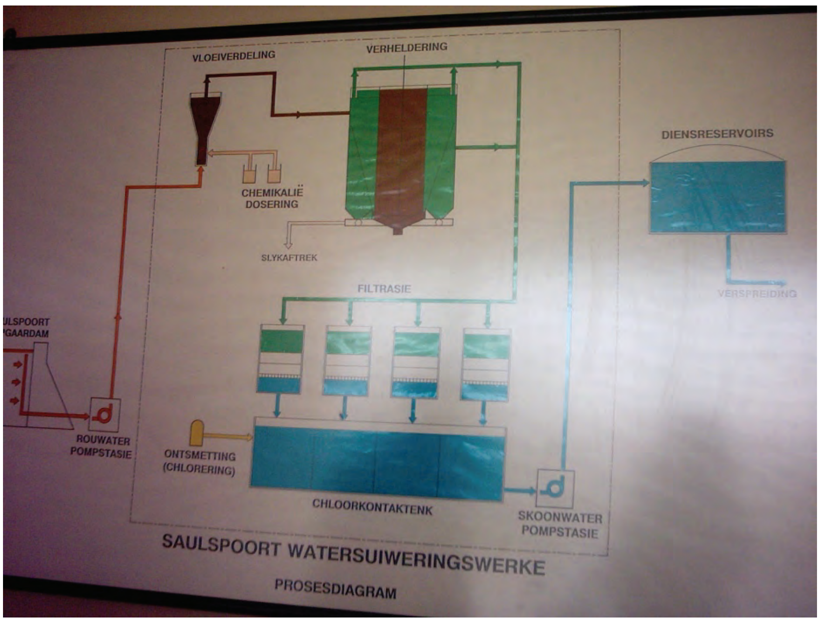


Figure 14: Layout of a drinking water treatment plant

Intake
Two general categories of water supply sources are surface water and groundwater. Surface water is the term used to describe water on the land surface and that could include streams, rivers, lakes

or reservoirs. Groundwater sources are waters contained within the geological formations accessed by springs, wells or boreholes. The water intake system normally requires pumping stations to remove water from a source to transport the water to the treatment facility. Some utilities may have the advantage of a water source that allows the use of gravity fed transport systems.

Initially water may be pumped directly from the source into distribution system, without any treatment apart from the intake screens or simple sedimentation without chemicals (Technical Notes for Emergencies: http://wedc.lboro.ac.uk/WHO_Technical_Notes_for_Emergencies/).

Modern water treatment works rely on inputs of chemicals, electricity and skilled process controllers as well as the constructed plant and machinery. Some simple treatment may take place at the intake, such as a coarse screen or aeration.

- check inlet meter readings and record them
- monitor raw water quality
- know the design and running capacities of the plant
- Check and control the flow into the water treatment system into the flocculation channel
- Seasonal fluctuations should also be evaluated

An example of a modern treatment plant with aeration and chemical dosing is shown below:

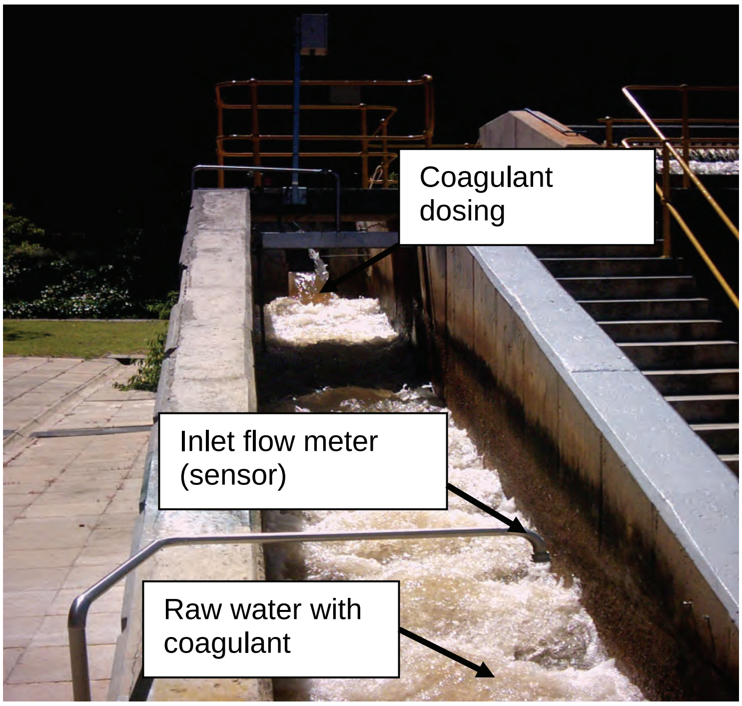


Figure 15: Illustration of a modern inlet of a drinking-water treatment plant

Pre-treatment: Pre-treat if necessary

Pre-treatment is normally achieved through a settling process in order to remove large suspended solids. Water is allowed to stand for a period of time to allow large particles to settle at the bottom of the tank or holding reservoir. Settling is mostly used as a pre-treatment step when the raw water contains relatively course suspended material.

Coagulation

Coagulation is the process by means of which electro-negatively charged colloidal particles aggregate. Aggregation results from the addition of positively charged ions (called coagulant) to the suspension resulting in destabilization of the particles and clumping of the particles to form larger flocs which are easier to separate from the water.

Different chemicals can be used as coagulants. The interaction between the coagulants and the particles would vary as result of the specific method of destabilization. It is common practice to use aluminium and iron salts as coagulants. Both salts hydrolyse when added to water. They form insoluble material (i.e. aluminium and ferric hydroxides) when reacting with calcium and magnesium carbonates and bicarbonates, which are almost always present in water and would consume alkalinity during precipitation. If those carbonates and bicarbonates are not present in sufficient concentration (soft water) hydrated lime $Ca(OH)_2$ or sodium carbonate Na_2CO_3 may have to be added as well. The formation of the insoluble hydroxides depends on the pH: it has been shown that aluminium sulphate coagulates best in a pH range between 4.4 and 6. At higher pH values, higher concentrations of soluble aluminate ions form. Sodium aluminate is generally used at medium pH values (6.5 to 8). Irons salts have the advantage of being effective over a wide range of pH values (except for values between 7 and 8.5). Turbidity is best removed within a pH range of 5.7 to 8.0; colour removal is generally obtained at acid pHs of about 4.4 to 6.0 pH units.

Alternatively, there is a range of chemicals known as polymeric compounds. Polymeric compounds are large organic molecules containing multiple charged groups. The charged groups attach themselves to the surface of particles thereby holding them together and causing them to coagulate. The charges may be positive (cationic) or negative (anionic).

Jar test

The jar test is a widely applied bench scale/laboratory method for the simulation of the treatment process to determine:

- The optimum pH for coagulation
- The coagulants to be used
- The need for dilution
- The optimum dosage of coagulants, coagulant aids and other chemicals to be used
- The sequence in which chemicals have to be added
- Points of addition
- The expected quality of the settled water before filtration.

The jar test could therefore be defined as a common laboratory procedure used to determine the optimum operating conditions for water or wastewater treatment. The method usually allows for a pH adjustment and variations in coagulant types on a small scale in order to predict the functioning of a large scale treatment operation. A jar test simulates the coagulation, flocculation and sedimentation processes for the removal of suspended colloids and organic matter which can lead to turbidity, odour and taste.

There are three stages in a jar test procedure, i.e. the initial rapid mixing phase, slow mixing phase and the sedimentation phase.

- The purpose of the initial rapid mixing phase in a jar test is to provide high turbulence or energy for the complete dispersion of the coagulant into the raw water in a fast and uniform manner, and to destabilise the particulate matter (charge neutralisation).
- The purpose of the slow mixing is to allow the particles to be attracted to each other and encourage the formation of large flocs, which will become heavier and promote effective settling.

- During the third stage the heavy flocs are removed by gravity and will settle at the bottom of the beakers. The removed flocs may either be naturally occurring material or the results of the coagulation process.

Recommended equipment

1. Jar test machine
2. 6 × 600 ml round beakers
3. Syringes (1 ml, 3 ml, 6 ml, 10 ml, 12 ml, 60 ml)
4. 500 ml measuring cylinder
5. Turbidity meter
6. pH meter
7. Stopwatch
8. 6 × 250 ml beakers

Procedure

1. Determine the turbidity and pH of your raw water and record it. Also measure for any other determinant for which the reduction has to be determined.
2. Using a 500 ml measuring cylinder carefully measure out 500 ml of raw water into each beaker.
3. Decide on the dosage of coagulant, e.g. ferric chloride to be used in the first six beakers. It is suggested to start with a low dosage of the tested coagulant, normally 5 mg/L, up to 30 mg/L increasing by 5 mg/L in each beaker. This means dosages of a coagulant will be 5, 10, 15, 20, 25 and 30 mg/L.
4. Use the equation provided below to determine the corresponding volumes to be used to work at the dosages provided in step 3. This is done as follows:

$$C_1V_1 = C_2V_2$$

where:

C_1 = Concentration of coagulant in stock solution
V_1 = Volume of coagulant to use (which is the one to be determined) = volume of concentration
C_2 = Concentration of coagulant in beaker
V_2 = Volume of raw water in beakers
$V_1 = (C_2V_2)/C_1$

Worked examples for water treatment calculations can be found from the book of Schutte 2006, pages 58 to 69.

1. Take the appropriate syringe to draw the above mentioned volumes.
2. Place the stirrers inside the beakers.
3. Start the machine and add the coagulant to the raw water using the syringes.
4. Continue monitoring the process as it goes through the flash mixing and flocculation stages. Watch the flocs grow during the flocculation stage of 8 minutes.
5. After the flocculation stage the machine will stop. Carefully remove the stirrers and allow the flocs to settle for 15 minutes.
6. After the 15 minutes of settling carefully draw off enough sample to determine the turbidity of the settled water and any other determinant of which the removal has to be optimized for.

Reduction in turbidity is mainly used as the parameter for determining the optimum dosage. Meaning, the lowest concentration of flocculant that results in the supernatant with the lowest turbidity is the correct concentration to be used.

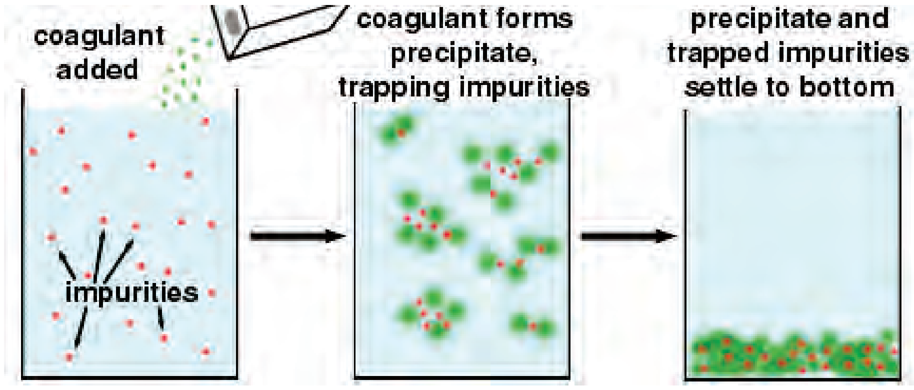


Figure 16: How solid particles agglomerate in addition of a coagulant (Momba, 2005)

Summary of coagulation
The following needs to be understood about coagulation or coagulants:

- Accurate make-up of coagulants
- Dosing quantities of chemical/s relative to change in water quality
- Properties of coagulant/s used relative to the type of water (e.g. if lime is used, the pH has to be lowered in order to stabilize the water chemically)
- Jar test equipment use
- Safety facts of the chemical/s used

Flocculation
Flocculation follows coagulation and is often regarded as part of one process: coagulation-flocculation. The objective of flocculation is to form more readily settleable flocs than the finely divided particles which comprise them.

After the rapid mixing that takes place during coagulation, a longer period of slow mixing is needed to promote particle collisions and enhance the growth of sticky gelatinous solids called "floc". This slow mixing is called flocculation and is accomplished using slow moving paddles or baffles. The formation of proper floc is necessary for particles to be removed during sedimentation and filtration. Below is a figure showing how flocculation is achieved.

Important aspects to understand on flocculation include:

- Correct choice of coagulant
- Accurate make-up of dosing chemical
- Correct dosing of flocculant into main water
- Cleaning flocculation channel when required
- Desludging when required
- Intensity of stirring

Table 11 below gives some details on the commonly used chemicals.

Figure 17: A Flocculation Process

Table 11*: Properties of commonly used chemicals as flocculants*

Chemical	Appearance	Use	Solubility (mass in g dissolving in 1 L water at 20°C)	Formula
Aluminium sulphate, Alum	White or brown kibbles, granules or powder	Acidic flocculant	870	$Al_2(SO_4)_3.xH_2O$ Al=0.09xAlum
Ferric sulphate	Brown solution	Acidic flocculant	Depends on pH	$Fe_2(SO_4)_3$
Ferric chloride	Yellow brown solution	Acidic flocculant	740	$FeCl_3$
Poly-ferrates	Liquid	Mildly acidic flocculant		
Sodium aluminate	White powder	Alkaline flocculant	Very soluble	NaAlOH
Poly aluminium chloride, PAC	Liquid	Near neutral flocculants		
Poly-electrolytes	White powder	Near neutral flocculants		
Quick lime, Burned lime	Usually lumps	Alkaline pH control	1.3	CaO
Slaked lime	Fine powder	Alkaline pH control	1.7	$Ca(OH)_2$
Sodium carbonate, Washing soda	Crystals or powder	Alkaline pH control	210	Na_2CO_3
Sodium hydroxide, Caustic soda	Crystals	Alkaline pH control	1090	NaOH

Sedimentation

Sedimentation is the effective first stage of phase separation after the colloidal particles have been aggregated. The flocs collect as sludge at the bottom of the sedimentation tank from where it must be removed on a regular basis. Clean water leaves the sedimentation tank through the collection troughs located at the top of the tank. Sedimentation tanks can be of different shapes, often rectangular or circular. All sedimentation tanks can be divided into four zones, each with a specific function. These are:

- *Inlet zone* - the purpose of inlet zone is to distribute the flow and suspended floc particles evenly across the cross section of the settling zone. It normally consists of a series of pipes or openings and baffles through which the flow is distributed into the settling zone.
- *Settling zone* - the settling zone is the largest part of the sedimentation tank and settling takes place as the water flows at reduced velocity through a large flow area.
- *Outlet zone* - the outlet zone provides a large area for the water to leave the sedimentation tank before flowing into a pipe or canal to transport the water to the sand filters.
- *Zone for sludge storage* – the configuration and depth of this zone depends on the tank design, quantity of sludge removed from the water and the method and frequency of cleaning.

Sedimentation tanks are sized in order to have an optimal sedimentation speed normally not more than 1-2 m/hr. If the sedimentation speed is too high, most particles will not have time to settle and will be carried over with the treated water. If too low, the tanks will be of an excessive size which could cause gas formation and poor settling. As turbulence is a damaging factor leading settled particles to go back into suspension, several devices are used to ensure a quiet flow, such as carefully designed water inlet with baffles.

Sedimentation may be made more efficient by the use of stacks of flat pieces that slope slightly upwards in the direction of flow (lamellar separators). They are parallel and separated by a small distance. These work in two ways:

1) They provide a very short distance for particles to settle.
2) Because flow is temporarily accelerated between the plates and then immediately slows down, this helps to aggregate very fine particles that can settle as the flow exits the plates.

The use of lamellar separators allows the sedimentation tank to be smaller and may enable finer particles to be separated. Typically such structures are used to treat waters containing colloidal materials that are more problematical to settle.

Water exiting the flocculation basin enters the sedimentation basin, also called a clarifier or settling basin. It is a large tank with slow flow, allowing floc to settle to the bottom. The sedimentation basin is best located close to the flocculation basin so the transit between them does not permit settlement or floc break up. Sedimentation basins can be in the shape of a rectangle, where water flows from end to end, or circular where flow is from the centre outward. The amount of floc that settles out of the water is dependent on the overflow rate and/or upflow velocity. The retention time of the water should therefore be balanced against the cost of a larger basin. The minimum clarifier retention time is normally 4 hours and average up-flow velocity less than 1 m^3/h. A deep basin will allow more floc to settle out than a shallow basin. This is because large particles settle faster than smaller ones, so large particles bump into and integrate smaller particles as they settle. In effect, large particles sweep vertically though the basin and clean out smaller particles on their way to the bottom.

Cleaning of sedimentation tanks

As particles settle to the bottom of the basin a layer of sludge is formed on the floor of the tank. This layer of sludge must be removed and treated. The amount of sludge that is generated is significant, often 3%-5% of the total volume of water that is treated. The cost of treating and disposing of the sludge can be a significant part of the operating cost of a water treatment plant. The tank may be equipped with mechanical cleaning devices that continually clean the bottom of the tank or the tank can be taken out of service when the bottom needs to be cleaned. Schematic presentation of sedimentation tanks is shown in the pictures below:

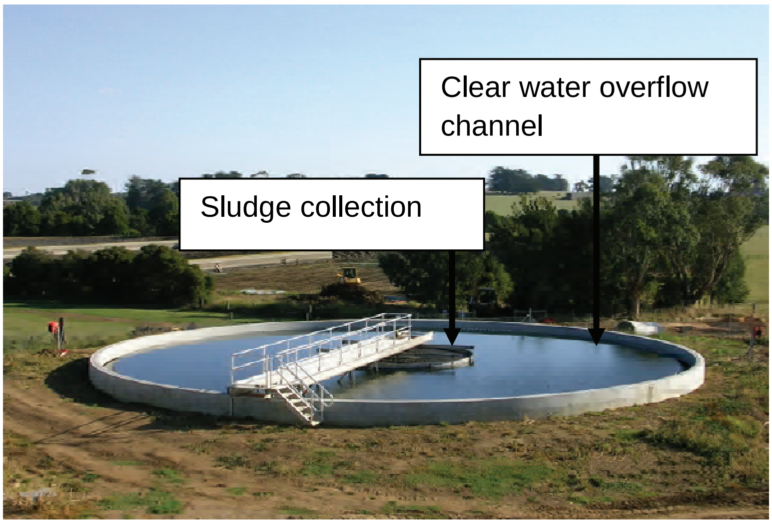


Figure 18*:* Representation of a Sedimentation tank

Dissolved air flotation

An increasingly popular method for the removal of flocs of a lighter nature is by dissolved air flotation. A proportion of clarified water, typical 6-10% of throughput, is recycled and air is dissolved in it under pressure. This is injected into the bottom part of the clarifier tanks where tiny air bubbles are formed which attach themselves to the floc particles and float them to the surface. A sludge blanket is formed which is periodically removed using mechanical scrapers. This method is very efficient for lighter floc (such as algae) removal and reduces loading on filters; however it is unsuitable for water sources with a high concentration of sediment.

Summary on sedimentation and flotation

The following needs to be understood about coagulation or coagulants:

- Purpose of sedimentation/flotation
- Tank capacities and configuration
- Flow rate into the tank relative to the tank surface area also known as surface loading.
- Residence time, which is the total volume divide by the flow-through rate
- Overflow or underflow rates relative to the design specifications
- How to deal with sludge build-up
- When and how to clean the sedimentation/flotation tanks.

Desludging

Desludging refers to the periodic removal of sludge that accumulates at the bottom of a settling tank or scraped off a floatation tank. Sludge is made up of solids in the water that have been separated out. Sludge must be removed to make room for more settling in the case of sedimentation tanks. In the case of flotation, the scrapers should be adjusted to ensure that sludge scraped off is not too dilute. Desludging must be timed so that the solids concentration of the underflow is within the design parameters of downstream equipment such as filters.

Filtration

Filtration normally follows sedimentation or flotation as the final polishing process. The filter process operates based on two principles, mechanical straining and physical adsorption. Sand filtration is mostly a physical process for separating suspended and colloidal impurities by passage through a bed of granular material. Water fills the pores of the filter medium, and the impurities are adsorbed on the surface of the grains or trapped in the openings. This is shown schematically in the figure below.

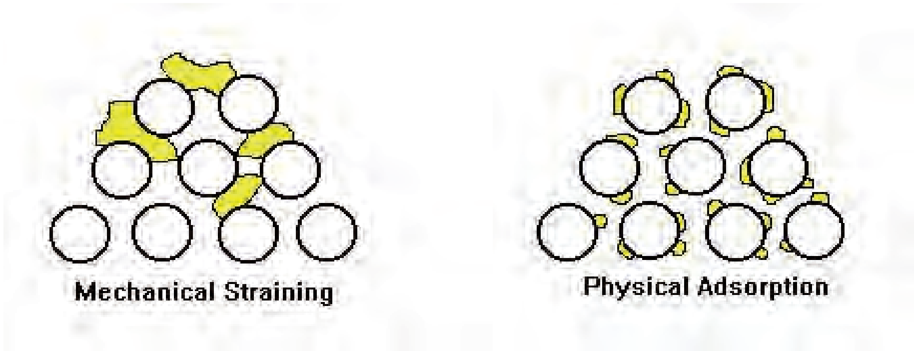


Figure 19*:* Schematic of basic filtration principles

Filters are classified based on:

- Media used
- Hydraulic arrangement
- The filtration rate, and
- Filtration, i.e. depth filtration or cake filtration.

The most commonly used filters in South Africa are slow sand, rapid sand and pressure filters.

These basic methods are described below:

Slow sand filtration

Design and construction

Typically the filter will consist of 60 cm of sand from the top, then a gravel layer in which the drain pipe is embedded. A typical loading rate for the filter is 0.1 – 0.2 meters/hour (the same as 0.2 m^3/m^2h of surface area). Slow sand filters (SSF) should only be used for continuous water treatment. If a continuous supply of raw water cannot be insured (say using a holding tank), then another treatment method should be chosen. Turbidity can be reduced by changing the method of collection (for example, building an infiltration gallery, rather than taking water directly from a creek), allowing time for the material to settle out (using a raw water tank), pre-filtering or flocculation (see previous section on flocculation).

The SSF itself is a large box, at least 1.5 meters high. In cases of a small system, the walls should be as rough as possible to reduce the tendency for water to run down the walls of the filter, bypassing the sand. The bottom layer of the filter is a gravel bed in which a slotted pipe is placed to drain off the filtered water. The slots or the gravel should be no closer than 20 cm to the walls, again to prevent the water from bypassing the sand.

The sand is added to a SSF to a minimum depth of 0.6 meters. Additional thickness will allow more cleanings before the sand must be replaced. 0.3 to 0.5 meters of extra sand will allow the filter to work for 3-4 years. The outlet of a SSF should be above the sand level, and below the water level. The water should be maintained at a constant level to insure an even flow rate throughout the filter. The flow rate can be increased by lowering the outlet pipe, or increasing the water level. One common idea for maintaining the water level is to use an elevated raw water tank or pump, and a ball valve from a toilet.

Operation

Slow sand filtration is accomplished by passing raw water slowly - driven by gravity; through a medium of fine sand. On the surface of the sand bed, a thin biological film develops after some time of ripening (different from the rapid filter). This film consists of active microorganisms and is called the "Schmutzdecke", or filter skin. It is responsible for the bacteriological purification effect. The slow sand filter is therefore also called "surface filter" or biological filter. The filter can be cleaned several times before the sand has to be replaced. Pathogens and turbidity are removed by natural die-off, biological action, and filtering. The packing and operation of the slow sand filter bed is shown in the figure below.

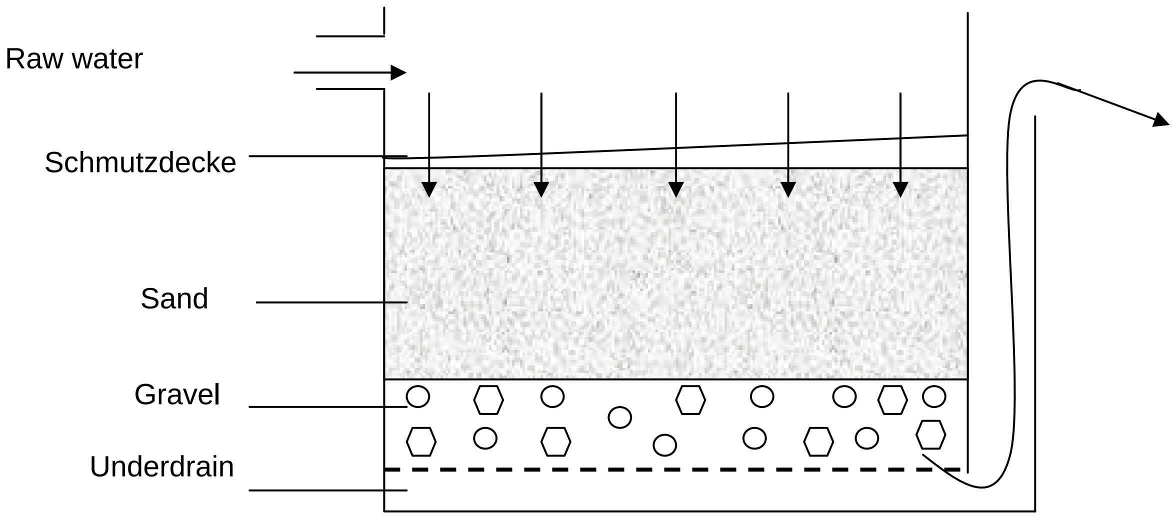


Figure 20*:* Schematic packing of a slow sand filter bed

Cleaning of SSF
Slow sand filters lose their performance as the Schmutzdecke grows and thereby reduces the rate of flow through the filter. Two methods of refurbishing the filter are these following:

- The top few centimetres of fine sand is carefully scraped off using mechanical plant and this exposes a new layer of clean sand. Water is then decanted back into the filter and re-circulated for a few hours to allow for a new Schmutzdecke to develop. The filter is then filled to full depth and brought back into service.
- The second method, sometimes called wet harrowing, involves lowering the water level to just above the Schmutzdecke, stirring the sand and thereby suspending any solids held in that layer, and then running the water to waste. The filter is then filled to full depth and brought back into service. Wet harrowing can allow the filter to be brought back into service more quickly.

Rapid sand filtration
Rapid sand filtration is contrasted to slow sand filtration by increased flow rate, method of cleaning and filter bed. Rapid sand filters are cleaned often by reversing the flow of water through the entire bed also known as backwashing.

Design and construction
The typical small-scale rapid sand filter is a round steel vessel approximately 1,5 m in height loaded with a 60 cm deep bed of sand supported on four layers of gravel graded to uniform size.

The stratified gravel bed performs two functions in the sand filter:

(1) It serves as a barrier which prevents the sand from washing through the underdrain into the tank during the filter cycle.
(2) It distributes the flow of water uniformly to the underside of the sand bed during the backwash cycle.

The size of sand particles in the filter bed is an important consideration. If the sand is too coarse, the voids between the particles are too large to trap fine solids. If the sand is too fine, the sand bed becomes too dense for dirt to accumulate between the sand grains.

Operation

Operation of a rapid sand filter during filtration is similar to operation of a slow sand filter but have a higher filtration rate from the use of coarser sand in the system. Instead of depending on the schmutzdecke for filtering action, the filters trap suspended matter through several centimeters or more of depth of filter sand. Rapid sand filters are designed for backwashing for cleaning. The packing and operation of the rapid sand filter bed is shown in the figure below.

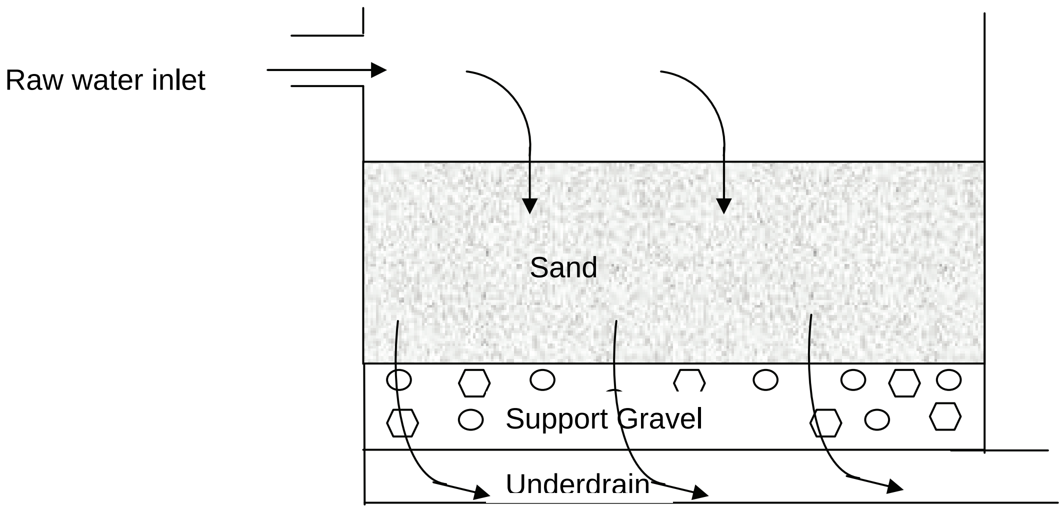


Figure 21*:* Schematic packing of a rapid sand filter bed

Cleaning of rapid sand filters also called "backwashing"

Backwashing is the process of reversing the flow of water through the filter media to remove the entrapped solids. The backwash flow rate is usually 8 – 10 times higher than the filtration rate in order to expand, or fluidize, the media in order to release the entrapped solids. This process may use two to four percent of the process water to clean the filters.

The degree of backwash attained by water alone is often not enough to properly backwash the media. It then becomes necessary to apply additional force to the media grains to release more of the specific deposit. A common way to achieve this is to bubble air through the bed; the so called air scour process. As the individual bubbles travel through the bed, the grains have to continuously move to and fro to let the air bubbles pass. In this way, the grains rub onto another. After a period of bubbling the air, backwash with water is still required to carry the fragments of the specific deposit out of the bed. Rapid sand filters equipment is shown in Figure 22.

- Smaller grains of filter sand will filter better as openings between the grains become smaller. In this way small particles need to be transported over a shorter distance to reach the media surfaces. Also, there are more contact points amongst the media grains. However smaller sand grains will allow quicker blockage of the filter.
- Larger particles will filter better due to a greater chance of getting stuck within the pores of the media.
- A larger filtration rate will lead to poorer particle retention due to the faster and more turbulent movement of the particles within the bed.

- Sudden changes in flow rates will tend to disrupt and dislodge the specific deposit, resulting in poor quality product water.
- Colder water is more viscous and will filter less effectively.

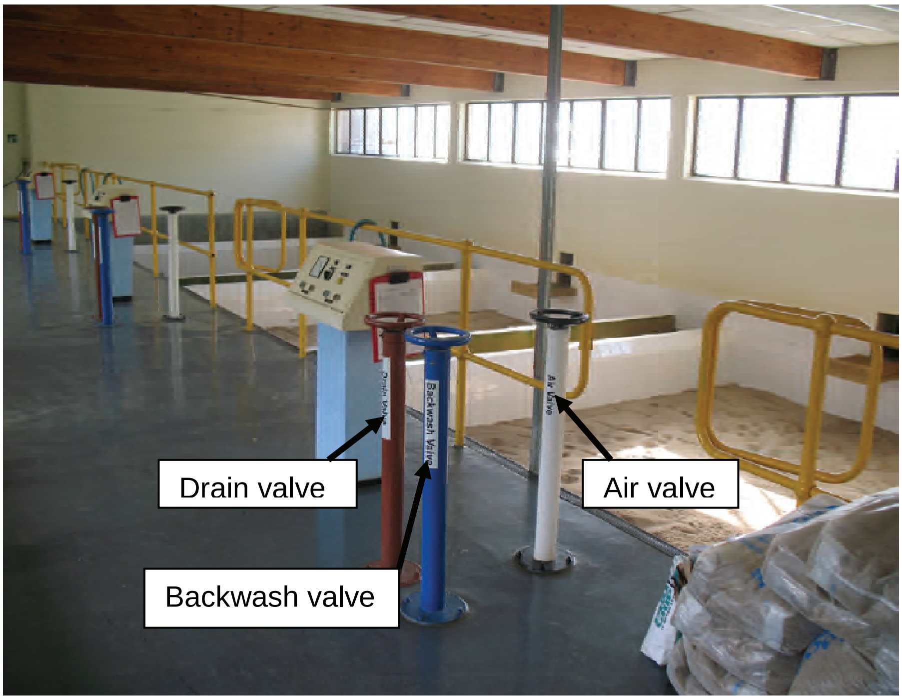


Figure 22: Equipment for rapid sand filters backwash

Filtration performance

Filtration is a dynamic process with each filter producing water of varying quality over time and consequently frequent monitoring and recording of the filtered water quality is required. In terms of SANS 241 specifications for Class 1 water, the final water turbidity has to be less than 1 NTU**.** To ensure that the production guidelines are met, the samples have to be drawn from the combined filtrate coming from all the filters. However, to get the detailed picture of how each filter is operating, it is necessary to monitor the individual outlets of all the filters. Filters could be sampled and tested for turbidity every two hours.

Summary of filtration

- Understand type of filtration and filter media used
- Understand the filtration method
- Understand the effect of media depth
- Understand the effect of media size
- Understand media cleaning methods
- Understand cleaning procedures
- Know where the filter wash water goes (whether recycled or discharged)
- Know when to replace the filtration media
- Understand sludge disposal/storage

Stabilisation

Stabilisation of water refers to the chemical stability of water. Chemical stability affects the tendency of water to be corrosive or to form chemical scale in pipes and fixtures. Some water supplies can become acidic by dissolving or reacting with the material they are in contact with. This can cause piping systems and hot water services to corrode and cause dissolved metals to be present in the water. For example, a common sign of copper corrosion is a bluish stain where a tap drips onto a surface. Other waters may again have dissolved scale forming compounds of calcium and magnesium (typically). Stabilization of water involves the addition of chemicals to the water to adjust its chemical properties in order to prevent corrosion or scale formation. To prevent corrosion, many waters are chemically stabilised to a particular pH before distribution by adding lime and sometimes carbon dioxide.

Important notes on stabilisation
- Understand the purpose of stabilisation
- Know/understand the type of water
- Know chemicals to be used.

Disinfection
Water is disinfected to kill any pathogens that may be present in the water supply and to prevent them from re-growing in the distribution systems. Without disinfection, the risk from waterborne disease is increased. Complex chlorine dosing systems use chlorine gas, but liquid or solid chlorine compounds are also available and can be used manually. The treated water needs to be stored for a while to allow the chemical to work. The effectiveness of chlorination is reduced for water that is dirty or will be re-contaminated, so priority should be given to cleaning the water to the required turbidity and ensuring it stays clean before disinfecting it. The efficiency of chlorination is adversely affected by turbidity. Turbidity will also contribute to the occurrence of bacterial re-growth in the distribution network.

Key factors to be considered in selecting a disinfection system:
- Effectiveness in killing a range of micro-organisms.
- Potential to form possibly harmful disinfection by-products.
- Ability of the disinfecting agent to remain effective in the water throughout the distribution system.
- Safety and ease of handling chemicals and equipment.
- Cost effectiveness.

Possible disinfection methods/ how is disinfection practiced
Micro-organisms can be destroyed or inactivated by various physical and chemical methods. A summary of each of the main disinfection processes is given in Table 12.

Physical Methods
Physical methods of disinfection include Ultra-violet (UV) radiation, ultrasonics, heating, freezing and ionization. Ultrasonic methods of disinfection are still experimental. Boiling of water is practical only in small-scale applications. UV radiation is a good biocide but provides no persistent residual for distribution protection. Even though UV disinfection is easy for small plants, it does not have any residual disinfection effects and re-contamination may result if not used as a point of use disinfection method.

Chemical methods
Chemical methods depend mostly on selected chemicals with biocidal properties. Their practical applications range from removing undesirable constituents to disinfecting water supplies, wastewater treatment effluent, or industrial waters. The most commonly used chemicals include chlorine and some of its compounds (e.g. calcium hypochloride, sodium hypochloride and chloramines. Chlorine dioxide is used internationally to safeguard quality in the distribution system and ozone may be used to ensure *Giardia* and *Cryptosporadium* kill.

Table 12*: Advantages and disadvantages of most commonly used disinfection methods*

BOILING	
Advantages	**Disadvantages**
❖ Readily available ❖ Well suited for emergency and temporary disinfection ❖ Will drive volatile organic chemicals out of water ❖ Extremely effective disinfectant that will kill even *Giardia* cysts	❖ Requires a great deal of heat ❖ Time to bring to boil and cool before use ❖ Typically limited capacity ❖ Not an in-line treatment system ❖ Requires separate storage of treated water
ULTRAVIOLET LIGHT	
❖ Does not change taste or odor of water ❖ Kills bacteria almost immediately ❖ Compact and easy to use	❖ High electrical demand ❖ No disinfection residual if used at point of use only ❖ Requires pre-treatment of cloudy or colored water ❖ Requires cleaning and new lamp annually
CHLORINATION	
❖ Provides residual disinfectant ❖ Residual easy to measure ❖ Chlorine readily available at reasonable cost ❖ Low electrical requirement ❖ Can be used for multiple water problems (bacteria, iron, etc.) ❖ Can treat large volumes of water	❖ Requires contact time of 30 minutes for simple chlorination ❖ Turbidity (cloudy water) can reduce the effectiveness of chlorine ❖ Gives water a chlorine taste ❖ May combine with precursors to form THMs ❖ Does not kill giardia cysts at low levels ❖ Careful storage and handling of chlorine is required ❖ Need residual especially in rural areas
IODINE	
❖ Does not require electricity ❖ Requires little maintenance ❖ Provides residual treatment ❖ Residual easy to measure	❖ Health effects of iodine underdetermined ❖ Concentration affected by water temperature ❖ Gives water a slight straw colour at high levels ❖ Gives water an iodine taste ❖ Not effective as an algicide

Chlorine and its compounds have been historically the most popular chemical disinfection agents. Chlorine combines with water to form hypochlorite ion. Under typical drinking water conditions, negligible chlorine gas remains in solution. Chlorine reacts in water with residual organic material to produce THMs Although, free chlorine disinfection produces trace quantities of harmful by-products, free chlorine is an excellent biocide and provides a persistent residual to maintain the microbiological safety of the finished water as it passes through the distribution system (Pontius, 1990).

Ozone is the most powerful disinfectant and oxidant of those used in water treatment and is typically used at a concentration of a few milligrams per liter. It is moderately soluble in water. It normally enhances the coagulation process despite its inherent weakness in leaving practically no residual in the distribution system. Ozone is highly unstable in water and lacks persistent residual (Pontius, 1990). As a result, application of additional secondary disinfectants such as chlorine or chloramines is generally necessary to protect water in the distribution system. However, there is some evidence that it forms smaller amounts of hazardous trihalomethanes (THMs) when employed to treat polluted waters (Schutte 2006). However, it is not used as disinfectant in South Africa

Hydrogen peroxide has been well known for its high oxidative and germicide activity but its application as a water disinfectant has not gained wide acceptance. The advantages and disadvantages of most commonly used disinfection methods are given in table 2 overleaf as laid out by the Ohio State University in the Bulletin 795- Disinfection methods.

Iodine can occur in water as iodine (I_2), hypoiodous acid, (HOI), iodate (IO_2) or iodide (I^-). Iodine at has been used to disinfect both drinking water and swimming pools. An iodide residual of about 1,0 mg/L is required for effective disinfection. Iodine is an essential trace element, required for synthesis of the thyroid hormone. The estimated adult requirement is 80 to 150 µg/day, where deficiency results in goitre. Most intake of iodine is from food, especially seafood. Iodine is only used in emergency water supply.

Factors affecting disinfection using chlorine

Chlorination is still the most dominant disinfection method throughout the world, with the use of chloramination, ozonation and UV irradiation being on the increase (Pontius, 1990) Hence, chlorination method will be discussed in detail in this section. Whilst other forms of disinfection are recognised, Chlorine provides a residual effect. Some of the most important influencing factors to be considered in chlorination practices are the following:

- Chorine demand
- Contact time
- Ct values (which is dosage concentration x contact time)
- Turbidity
- Water temperature
- Sunlight
- pH
- Chorine dosage

Many of these factors are working at the same time, and may be working against each other. However, they will be discussed as separate effects.

Contact time

Contact time is the length of time the chlorine is in contact with water before used. Chlorine needs time to spread throughout the water**.** The contact time could be in a tank or in the water distribution main. The chlorine contact tank should therefore be designed in such a way as to provide the optimum distribution of residence time for contact between the disinfectant and the pathogens. The distribution of residence time may differ appreciably in tanks of different geometrical configuration. Free available (residual) chlorine is the free chlorine concentration remaining after 30 minutes after break point chlorination of the water (DWAF, 1998). The free chlorine residual is an indication of the efficacy of the disinfection process and thus a rapid and important indicator of the probable microbiological safety or otherwise of the treated water.

Ct values

Ct is the product of C (the residual concentration of disinfectant, measured in mg/L) and t (the disinfectant contact time, measured in minutes). The minimum Ct values required to kill different types of micro-organisms are determined by exposing specific organisms to various compound that can be used as a disinfectant. This value is not the same for all micro-organisms due to resistance of individual micro-organisms against different disinfectants. Therefore micro-organisms with little resistance against a disinfectant would require a shorter period or contact time at a specific disinfectant concentration. Ct values at different conditions are presented in pages 131-132, Schutte (2006) and pages 38 – 40, Momba (2005).

Turbidity
Turbidity in water is caused by suspended solids. It makes the water looks cloudy. SANS 241 suggested that whenever any disinfection (such as chlorine) is used as a main disinfectant, turbidity should be less than 1 NTU, by means of the treatment processes described earlier.

When turbidity levels are high, chlorine becomes less effective, either because the chlorine starts to react with the material in the water or because of a shielding effect. The shielding effect happens when the suspended particles shield the bacteria from chlorine. When this happens, chlorine does not come into direct contact with the bacteria or virus thereby causing chlorine to be less effective. That is why the process controllers of water distribution systems should prevent suspended material from entering the system or settling in the lines. Flushing mains at least once a year is a good practice.

Water temperature
Temperature has a strong effect on how well chlorine works. The chlorine reacts much faster in warm water than in colder water. Twelve °C is a critical temperature for chlorination (Department of Environment, online http://ewr.cee.vt.edu/environmental/teach/wtprimer/rapid). Below that temperature, the effect of chlorine is much slower because of the lower metabolic activity of the bacteria.

Sunlight
Sunlight breaks down free chlorine. If free chlorine is used as the main disinfection, contact time must take place in a covered tank or a water main.

pH
pH is a measure of how acidic a water is. The addition of chlorine in water reduces both the alkalinity and the pH. Chlorination works best below a pH of 7.0. When chlorine is added to water the following reaction takes place to yield hypochlorous (HOCl) acid and hydrochloric acid (HCl).

$Cl_2 + H_2O = HOCl + HCl$
The HOCl dissociates further according to the following reaction to form hydrogen and hypochlorite ions. This reaction is temperature and pH dependant and has significant effect disinfection efficiency.

$HOCl = H^+ + OCl^-$
Molecular concentrations of Cl_2, HOCl and OCl^- present in water are expressed as free available chlorine. Due to its properties, HOCl is the most effective and strongest bactericidal species of the available chlorine compounds. At higher pH levels the HOCl portion is drastically reduced. This is shown in Figure 23 below.

Chlorine dosage
Dosage is the amount of chlorine that is added per unit volume of water. The actual dosage will be different for each water system. It depends on factors such as the amount and kind of impurities, pH and so on.

Prevention of chlorine by-products
There is some evidence that chlorine forms smaller amounts of unwanted/potentially unhealthy trihalomethanes (THMs) when employed to treat polluted waters or wastewater effluent. Approaches to minimize or preventing the formation of these THMs are:

- Removal of the THM formation by improving organic removal. In some cases it may be justified to lower the pH for better coagulation of organics. Biological removal of organic substances on filter or granular activated carbon (GAC) is increasingly used.
- Use of alternative disinfectants such as chloramines or chlorine dioxide which do not form or form little THMs.

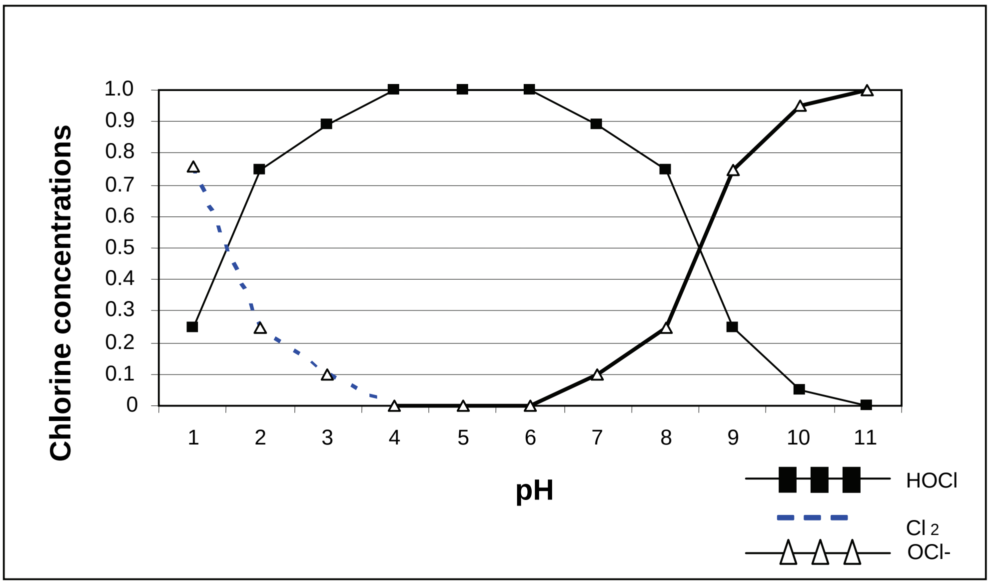


Figure 23*:* The effect of pH on the dissociation of hypochlorous acid

Consequences / What happens if water is not disinfected

Microbiological polluted water has long been associated with the transmission of infectious diseases such as gastroenteritis, cholera, typhoid fever, hepatitis A, etc. (Craun, 1986 cited by Pontius, 1990). Infectious diseases occur as the result of interactions between pathogenic micro-organisms and the host.

Water-related diseases can be classified as follows:

- Waterborne diseases – are those transmitted through the ingestion of contaminated water. The water acts as the passive carrier of the infectious or chemical agent. Classic waterborne diseases are cholera and typhoid fever.
- Water-washed diseases – are related to poor hygienic habitats and sanitation. Unavailability of water for washing and bathing contributes to diseases that affect the eye and skin.
- Water-based diseases are those in which the pathogens spend an essential part of its life in water. Schistosomiasis and Dracontiasis are examples of water-base diseases.
- Water-vectored diseases – such as yellow fever and malaria are transmitted by insects that breed in water or that bite near water.

Safe chlorine residual levels

The approach to a general standards for disinfection is the WHO Guidelines which recommends that the treated water should have a free chlorine residual of at least 0,2 to 0,5 mg/L after a contact time of 30 minutes to ensure disinfection in the distribution system (DWAF, 1998). If these recommended levels are not maintained, it cannot be assured that the water in the system is protected against waterborne diseases. This will also be depended on the residence time of the water in the network.

Increasing free chlorine residual levels can increase corrosion of water distribution system piping (Department of Environment, online; DWAF, 1998). Excess chlorine residuals can be controlled by a de-chlorination procedure. Department of Environment (online) stated that the most commonly used chemical for partial and complete removal of the residual chlorine is sulphur dioxide gas. Chlorinated cooling waters and wastewaters need to be de-chlorinated before discharging into water bodies in view of their toxicity to aquatic life.

Taste and odour problems associated with chlorination

The levels at which chlorine tastes or odours become noticeable, or unpleasant, differ from person to person. The average level at which free chlorine residual starts to become noticeable ranges from 0,075 mg/L to 0,450 mg/L at pH 5**.** Algae are small water plants that grow rapidly during the daylight and decay during the night. However, the Department of Environment, (http://ewr.cee.vt.edu/environmental/teach/wtprimer/rapid) advises never to reduce chlorine levels below those WHO recommended (0.2 – 0.5 mg/L) because of complaints about taste.

Chlorine storage and supply

Safety considerations of chlorine storage and supply are described below:

- Chlorine storage and chlorinator equipment should be housed in a separate building. If not, it should be a separate room, if separate building is not available, with an outside door that can be locked.
- Adequate ventilation at floor level should be provided because chlorine gas is heavier than air. Fan control and gas masks should be located at room entrance.
- The temperature in the chlorine supply area should not be allowed to drop below 10 °C.
- Storage should be provided for at least a 30 day supply.

Chlorine dosing equipment

Chlorine is supplied as liquefied gas under high pressure in containers varying in size from 68 kg to 909 kg. Chlorine can be abstracted directly from the gas phase of the pressurized container with a chlorinator. The most widely chlorinators are those using vacuum-feed devices. In each of these systems, the chlorine injector is the basic component. The injector is used to create the vacuum that is used to draw the chlorine gas from the storage supply through the chlorine regulator, which serves as metering device, and into the injector. At the injector, the chlorine dissolves in the injector water to form hypochlorous acid. From the injector, the hypochlorous acid solution flows to the point where it is to be injected into the clarified water. At liquid chlorine temperatures of 10°C, about 10 kg chlorine/h can be evaporated per 909 kg container. A chlorine concentration of 2.5 g chlorine/L (or higher) at the injector can be obtained in this way.

Treated water storage

The supply and demand for water varies throughout the day; to cater for this variation, a tank (reservoir) is used. This also provides water for use in emergencies - such as for fire fighting or for short breakdowns in the WTW. Once the WTW is producing water, this can then be distributed to the population. Tankers may be used if the piped system is out of use. The transmission mains may have in-system storage reservoirs and even disinfection systems if it is necessary to protect the transport lines from bacterial growth. The following types of storage tanks are generally used:

- *Plastic tanks*

  Both fibreglass and polypropylene tanks are commonly available. Both types will suffer slightly from UV degradation in sunlight. Simply painting the outside of the tank will stop the UV degradation and will probably make the tank more aesthetically pleasing (Water Systems, http://wedc.lboro.ac.uk/WHO_Technical_Notes_for_Emergencies/). An example of a plastic tank is presented below.

Figure 24: Plastic tank/reservoir **Figure 25:** Concrete tank/reservoir

- *Concrete tanks*
  Concrete tanks is one of the best storage solutions, but initially expensive. Any concrete tank will need to be coated internally with a special sealer to be water tight. An example of a concrete tank or reservoir is shown below.
- *Pressure tanks*
  These are used in pumped systems to store pressurized water so that the pump does not have to start for every glass of water. No photos of this type of tanks were found.

5.4.3 Process controller safety

Consideration must be given to the safety of water plant personnel and visitors. The following are the basic requirements to ensure the safety of the personnel on-site:

Drinking-water treatment plant and system operators work both indoors and outdoors and may be exposed to noise from machinery and to unpleasant odors. Process controller's work is physically demanding and often is performed in unclean locations. Process controllers must pay close attention to safety procedures because of the presence of hazardous conditions, such as slippery walkways, dangerous gases, and malfunctioning equipment. Drinking water treatment includes use of chemicals for coagulation, flocculation, disinfection, etc. Therefore workers may be exposed to corrosive chemical reagents (e.g. HCl, lime, sodium hydroxide, carbonate salts, sulphide salts, etc.) used in the process. The reagents may be in powder or liquid form, and may pose an exposure hazard through either inhalation, dermal and/or ingestion routes. These reagents may corrode piping system components.

Respiratory protection equipment

Respiratory protection equipment, meeting the requirements of the National Institute for Occupational Safety and Health (NIOSH) shall be available where chlorine gas is handled, and shall be stored at a convenient heated location, but not inside the room where chlorine is used or stored.

Chlorine leak detection
A bottle of concentrated ammonium hydroxide (56 per cent ammonia solution) shall be available for chlorine leak detection; where one ton containers are used, a leak repair kit approved by the Chlorine Institute shall be provided. Continuous chlorine leak detection equipment is recommended. Where a leak detector is provided it shall be equipped with both an audible alarm and a warning light.

Ventilation
Special provisions shall be made for ventilation of chlorine feed and storage rooms.

Protective equipment
The following protective equipment need to be provided:

- At least one pair of rubber gloves,
- A dust respirator of a type certified by NIOSH for toxic dusts,
- An apron or other protective clothing
- Goggles or face mask shall be provided for each process controller as required by the reviewing authority.
- A shower and eye washing device should be installed where strong acids and alkalis are used or stored.

Any other protective equipment should be provided as necessary.

5.4.4 Hazards of chemicals used
Minimization of worker exposure may include the delivery of chemical reagents (e.g. lime, sodium hydroxide solutions, etc.) through a closed system, and/or the use of personal protective equipment (e.g. an air-purifying respirator using cartridges appropriate to the reagents). Material Safety Data Sheets (MSDS) should be consulted prior to handling reagents to determine the specific chemical hazards associated with the chemicals. Design considerations should also include the appropriate materials for piping and system components.

Flow controls may be needed to help prevent addition of excessive amounts of chemical reagents (e.g. hydrochloric acid, sodium hydroxide, lime, etc.). The oxidation/reduction reagents should be stored in separate areas under cool, dry conditions. Pressure-relief systems and over-pressurization alarms must be part of the process design. Chemical piping should be located low to the ground, if possible, in case of rupture. Lime sludge from the treatment process may have a high pH, which may cause skin burns for workers handling the material. Controls for this hazard may include neutralization of the sludge prior to handling, or the use of personal protective equipment such as rain gear, rubber gloves (e.g. butyl rubber for hydrochloric acid or sodium hydroxide), and splash shields.

Workers may be exposed to acids or bases used for pH adjustment. The secondary containment storage areas for acids and bases should be constructed of materials compatible with storage of these materials and clearly marked. Acids and bases should be stored in separate areas. Handling of pH agents should be automated to the extent practical. An emergency plan should be prepared and facility personnel should be trained to safely handle acids and bases. Manual handling of acids and bases should be done by personnel familiar with their properties and equipped with personal protective equipment (PPE), such as leather or rubber acid-resistant boots, chemical-resistant coveralls, goggles and face shields, air-purifying respirators (as indicated by the reagent), and rubber or other acid and base resistant gloves (e.g. nitrile) or gauntlets.

Following the treatment plant, the protection of the distribution system is essential for providing safe drinking water because of the nature of the distribution system, which may include many kilometers of pipe, storage tanks, inter-connections with industrial users and potential for tampering and vandalism, opportunities for microbial and chemical contamination exist. Contamination can occur within the distribution system.

The wide variety of treatment systems capable of producing safe drinking water are without exception subject to potential breakdown and human failure in operation, supervision and quality surveillance. Successful operation and supervision of treatment systems, improvement of technical capabilities, and training programmes aimed at meeting water quality requirements are very important.

As much as this tool gives a guide as to what the important aspects are to consider in supplying safe drinking water, the responsibilities of the network personnel are stated in the Water Distribution System Asset Management (2005). The management of a water distribution system is becoming more sophisticated as management is demanding that the operating departments not only keep the system in good repair, but, do so in an optimal manner. Some aspects of effectively managing and maintaining the distribution system are discussed below.

5.5 DISTRIBUTION SYSTEM PERSONNEL GUIDE

Purpose of the guide

This guide has been developed with the purpose of:

- providing practical guidelines for the persons responsible for operation and maintenance of the drinking-water distribution system.
- understanding typical failures experienced in drinking-water distribution system , and
- how to attend to and rectify such failures.

Who should use the guide?

The guide has been developed in such a way that it will assist the operations and maintenance personnel of drinking-water distribution system:

- how to effectively maintain the distribution system
- how to determine if there is a problem with the distribution system
- if there are issues that need urgent attention and should be reported to the supervisor.

5.5.1 Introduction

Drinking-water entering the distribution system passes through a series of pipes from the treatment facility to the water pipes connected to customers. As a result of lengthy distribution pipe structures in the delivery system, the quality of the water coming from the treatment works can deteriorate (Guttma, 2004). This is due to the fact that piped systems can be prone to leaks, intermittent operation and contamination (ISO, 2005). It is necessary to maintain and renew the distribution network infrastructure (including mains and storage facilities) so that it does not deteriorate to the point of loss. Un-maintained water mains can result to the deterioration of the drinking water quality in the mains and chlorine decay.

The distribution system is the last barrier before water reaches the consumer. There are many chances for water to become re-contaminated once it leaves the water treatment works, so investments in water quality improvements need to be assessed by looking at the whole system and seeing the impact at the point of use. System-related outbreaks occur as a result of a number of factors including improper installation practices, inadequate flushing, infiltration, faulty storage and construction and repairs in the distribution system.

The distribution system is designed to

- reliably distribute bulk water supplies to the users;
- provide water at the correct elevation and/or pressure; and
- buffer the diurnal peaks in demand from the consumers.

To achieve these objectives, particular combinations of reservoir storage, pipe network and pumping are used, depending upon the system topography and size.

5.5.2 Components of a distribution system

The drinking-water distribution system is designed to deliver water from source (usually a treatment plant) in the required quantity, quality and at satisfactory pressure to individual consumers. In order to continuously and reliably transport water between source and a consumer, the system includes the following general components:

- Storage tanks/ reservoirs
- Pipe network
- Valves
- Pumps/ pump stations
- Hydrants
- Flow meters

A detailed understanding of how water is used is critical to understanding water distribution system design and operation. Almost universally, the manner in which industrial and residential customers use water drives the overall design and operation of a water distribution system.

Storage reservoirs

Reservoirs are used to provide storage capacity to meet fluctuations in demand, to provide reserves for fire fighting use and other emergency situations and to equalize pressure in the distribution system. The most frequently used type of storage facility is the elevated tank, but other types of reservoirs include in-ground tanks and open or closed reservoirs. Materials of construction include plastic, concrete and steel.

Design Effects

A drinking-water reservoir is a structure that allows for different inflow and outflow at any given time. Important entry points to a reservoir for contaminants include wildlife access and human access. Reservoirs should be designed to keep the water fresh and avoid carryover of sediment. Features designed to maintain water cleanliness include the following:

- Reservoirs must have a secure lid.
- Access control is necessary against non-authorised people gaining access. These may consist of security fences, locked manhole covers, etc.
- The outlet should be designed to avoid picking up any sediment that may settle in the reservoir.
- If the outlet for draining the reservoir discharges to a sewer or storm-water system, an air-gap or other suitable backflow prevention must be provided.
- Reservoir operation should encourage turnover of water at least every few days. If a reservoir is filled and remains so, it is likely that fresh water is going directly to the users while the water in the reservoir sits for considerable time. This situation is common where the inlet and outlet

mains are the same pipe, often supplied by the pump. The reservoir should draw down to ensure mixing and renewal is occurring.

A typical example of such a design is shown in Figure 26.

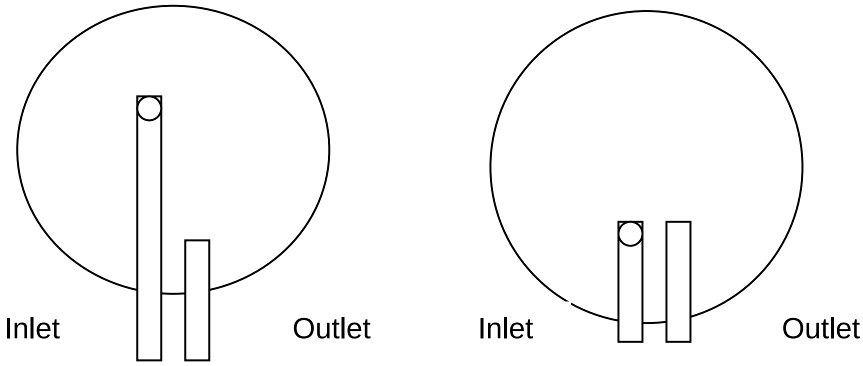


Figure 26: Reservoir short circuiting illustration

Reservoir maintenance cleaning

Drinking-water reservoirs can act as sedimentation tanks. Over time it is common for sediments to accumulate on the floor of the reservoir. It is also possible that slime, algae, or chemical deposits will accumulate on the interior walls. Eventually the accumulated material can adversely affect the quality of the water. Planned maintenance frequency requires the accumulation of experience of the particular reservoir, there is no rule for how often any particular should be cleaned. A regular inspection programme, coupled with water quality testing, is the best way to assess this frequency. Cleaning of reservoirs can be achieved in the following way as suggested by WHO, 1994:

- Drain/empty the reservoir. Open the outlet valve and drain out any remaining liquid. Collect the liquids so that they can be safely disposed.
- Clean/ scrub all internal surfaces. Use a mixture of detergent and water to clean all internal surfaces of the reservoir. This can be done with stiff brush or a high pressure jet. Take special care to clean corners and joints so that no small amount of the original liquid remains.
- Wash all internal surfaces. To remove all traces of detergent. This is most easily done with a high pressure hose or water jet but if they are not available the tank can be filled with water and left to stand for a few hours. Drain all the water from the reservoir and collect for safe disposal. Continue flushing the reservoir until there are no longer traces of detergent in the water.

However, initiation of a reservoir cleaning procedure may be due to any one of the following:

- Customer complaint about taste, odour or appearance,
- Water quality testing showing quality degradation,
- Random checking showing a cleaning programme is due.

If the procedure has been initiated by customer complaints, the problem is urgent and should be attended to directly.

Pipe Network

The system of pipes that carries water from the source (e.g. water treatment plant) to the consumers is often categorised as transmission, distribution and service mains.

- Transmission mains usually convey large amounts of water over a long distance, such as from the water treatment plant to a storage reservoir within the distribution system. They are likely to have control valves and can often be taken out of service for several hours without interrupting general supply. Transmission mains rarely have customer connections and often do not have fire hydrants.

- Distribution mains are typically smaller than the transmission mains and generally follow city streets. They are used to supply consumers directly and thus have service connections made to them. They are usually fitted with fire hydrants.
- Service mains are pipes that carry water from the distribution main to the building or property being served. Service mains can be of any size, depending on how much water is required to serve a particular customer, and are sized so that the utility's design pressure is maintained at the customer's property for the desired flows. The most commonly used pipes for water mains are poly vinyl chloride (PVC), otherwise in the past iron, pre-pressed concrete, reinforced plastic were also used. Commonly used PVC network pipes are shown in the figure below.

Figure 27: Illustration of PVC pipes

Design Effects

The mains should be placed in areas along the public right of way, which provides for ease of access, installation, repair, and maintenance. In the past, it has been standard practice to design the carrying capacity of the pipe in the distribution system as higher than required, in order to provide the design flow easily and keep pumping costs as low as possible. However, there has been recent concern that excess capacity can lead to long residence times and thus contribute to deterioration in water quality (EPA/600/R-06/028).

- Water distribution system materials are required to have corrosion resistance to the water inside them, not only so they do not collapse but so that problematic materials don't pass into the water.
- Materials must also be resistant to adverse ground water chemistry, the aggressiveness of the supply and to breakages.
- A poor choice of materials can lead to deterioration in water quality as well as increased maintenance and early replacement.

Network pipes cleaning

Water mains gradually accumulate sediments and corrosion products, particularly where flow velocity is low. In some cases biofilms will form that must be cleaned off. Flushing – by running the main at high velocity to waste, will generally control the rate of accumulation. Flushing must continue until satisfactory clarity of water is obtained. This is a routine task that may need to occur every few months or only once every two or three years. Dead end mains may require weekly flushing. The procedure and programme for this practise should be documented. The flushing water is typically disposed of to the storm-water drain. Water with significant chlorine levels has the potential to kill fish, and/or the organisms on which they feed. It may be necessary to neutralise the chlorine. When this is done with chemicals such as sodium thiosulphate or caustic soda, they should not be overdosed, as they will damage the receiving environment.

The method of cleaning network pipes is discussed below as suggested by WHO Technical notes, http://wedc.lboro.ac.uk/WHO_Technical_Notes_for_Emergencies/

- The section to be flushed should be isolated from the rest of the system.
- It should be confirmed that there is adequate water and sufficient pressure to flush the repaired pipeline.
- If there is insufficient water additional pumps and storage tanks will be needed. The section can be flushed by opening the stop valve on the supply side slowly, and open the washout valve on the remote end.
- Water should be injected through the pipe section continuously for a period of long enough (about 15 minutes) to stir up deposits inside the water main and wash out all silt.
- Flushing water should be directed away from the traffic, pedestrians and private plots. Pipe flushing is practised in the manner presented in the section below:
  - Prepare a chlorine solution of 25 mg/litre of free chlorine and mix it with clean water in the tanker.
  - Keeping the pipeline isolated, set up the feed tanker at the injection site.
  - Fill up the pipeline section with the chlorine solution. Keep the water in the pipeline for a minimum of 24 hours, during which time all valves and hydrants along the main should be operated to ensure their proper disinfection. Check the chlorine residual in the pipeline. If it has dropped significantly, repeat the disinfection procedure.
  - Flush the pipeline section with clean water until a chlorine residual of 0.2-0.5 mg/litre is achieved.
- The water quality should be tested and if it is not yet satisfactory, the procedure should be repeated.
- When the water quality has been restored to normal, the washout valve should be slowly closed.

If water in the distribution system cannot be guaranteed to stay clean, it may be better to supply some users (such as hospitals) with water in a tanker, that can be disinfected and the quality maintained. Simple treatment can be provided at a more local level, such as cleaning and chlorinating local water storage tanks in the following manner:

Cleaning Storage Tanks/Reservoirs

Often the quickest way of providing a water supply is to transport water in tankers from a nearby source and store the water in tanks and/or reservoirs. However it is rare for water tankers and reservoirs to be readily available in such situations. The most common solution is to hire vehicles and tanks that have been used for other purposes but they must be cleaned and disinfected before they can be used. The tank must be cleaned to ensure that water stored in the tank does not become contaminated by dirt or traces of the substance the tank previously held. This can be achieved by following the steps below as described in WHO Technical Notes for Emergencies No.3: Cleaning and disinfecting water storage tanks.

1. Drain/empty the tank: Open the outlet valve/tap and drain out any remaining liquid. Collect the liquids so that they can be safely disposed of. Most tankers have their outlet valve at the back, so park it on a slope so that all the liquids can be discharged.

Permanent storage tanks are usually fitted with a washout valve that draws water from the base. Use this for emptying rather than the normal outlet valve. The process of emptying the remaining liquids from portable tanks will depend on the shape and design of the tank. Some can be tipped on their side and others dismantled.

2. Clean/scrub all internal surfaces: Use a mixture of detergent and water (household laundry soap powder will do) to clean all internal surfaces of the tank. This can be done with a stiff brush or a high pressure jet. If the tank has contained volatile substances such as oil or organic liquids such as milk, try not to enter the tank as the gases given off by the liquids could be dangerous. Attaching the brush to a long pole may make it possible to clean the tank without entering it. Special care should be taken to clean corners and joints so that no small amounts of the original liquid remain. Even minute amounts of some liquids can give the water a bad taste and people will refuse to drink it. Leave the outlet valve open whilst cleaning and collect the waste liquid for safe disposal.

3. Wash all internal surfaces to remove all traces of detergent. This is most easily done with a high pressure hose pipe or water jet but if they are not available the tank can be filled with water and left to stand for a few hours. Drain all the water from the tank and collect for safe disposal as before. Continue flushing the tank until there are no longer traces of detergent in the water.

Disinfecting the tank

- To effectively disinfect the tank, fill it with clean water up to quarter level only. It is important to not fill the tank too much as this will reduce the concentration of the chlorine solution and limit the effectiveness of cleaning. To estimate quarter of the tank, use a stick with graded markers to indicate the water level. The markers should be marked on to the stick at 10 cm intervals beginning at 0 cm at the base of the tank and then upwards to 10, 20 cm, etc.
- Prepare a concentrated chlorine solution to disinfect the tank. The best source of chlorine to use is High Test Hypochlorite (HTH) granules or powder as this normally contains 50 to 70% chlorine. A method used for calculating the appropriate chlorine dose to disinfect a tank using HTH granules are outlined in the section below.
- Pour the solution slowly into the tank, mixing as you pour and then fill the tank up to full capacity with clean water. Let the chlorine stand in the tank for 24 hours to ensure that the tank is fully disinfected. If the tank has a cover (which is recommended) it should be closed. If the tank is required for use urgently double the quantity of chlorine added to the tank. This will reduce the standing time from 24 to 8 hours.
- Completely empty the tank and carefully dispose of the disinfecting water as it will contain a high concentration of chlorine.
- Remember to also clean and disinfect any pipes or hoses connected to the tank. Use the same procedure as described above.

Preparing chlorine disinfection solution

- Calculate the total volume of the tank.

$V = \pi d^2 h$	Where:
π = is a constant 3.14	
d = diameter of the tank (m)	
h = tank height (m)	

- Fill a 20 litre bucket with clean water.
- Add 50 g of HTH to the water and stir until dissolved.
- Add 10 litres (half a bucket) of the chlorine solution to the water in the tank for every cubic meter (m^3) of tank volume.
- Remember 1 m^3 = 1000 L

Example: Say we have a tank or reservoir with the following dimensions;
Diameter = 2,5 m
Height = 2 m

To calculate the volume of tank/reservoir
$V = \pi d^2 h$
$= (3{,}14)\ (2{,}5\ m)^2\ (2\ m)$
$= 39{,}3\ m^3$

If 10L has to be added for every tank m^3
Therefore for a 39,3 m^3 tank = 10x39.3 L
= 393 L of chlorine solution has to be added

Storage tank chlorine testing

- Refill the tank with clean water and allow to stand for 30 minutes. Test the residual chlorine left in the tank using a comparator.
- If the free residual chlorine concentration is 0.5 mg/l or less the tank is safe to use for water storage. If the concentration is greater than 0.5 mg/l, empty the tank again and refill with clean water. Re-test to check that the chlorine concentration is 0.5 mg/l or less.

Valves

There are two general types of valves in a distribution system viz. isolation valves and control valves:

- Isolation valves are used in the distribution system to isolate sections for maintenance and repair. These valves are located in a system so that the areas isolated will cause a minimum of inconvenience to other service areas. Maintenance of the valves is one of the major activities carried out by a utility. Many utilities have a regular valve-turning program in which a percentage of the valves are opened and closed on a regular basis. It is desirable to turn each valve in the system at least once per year (EPA/600/R-06/028). In large systems this may or may not be practical, but periodic exercise and checking of valve operations should occur. This practice minimises the likelihood that valves will become inoperable due to corrosion. The implementation of such a programme ensures that, especially during an emergency, water can be shut off or diverted and that valves have not been inadvertently closed.
- Control Valves are used to regulate the flow or pressure in a distribution system. Typical types of control valves include pressure reducing valves, pressure sustaining valves, flow-rate control valves and check valves. A picture showing control valves is presented below.

Pumps/ Pump Stations

Pumps are used to impart energy to the water in order to boost it to higher elevations or to increase pressure. Routine maintenance, proper design and operation, and testing required ensuring that they will meet their specific objectives. Pumps tests are typically run every five to 10 years to check the head-discharge relationship for the pump. Many systems comprise of two pumps: one set duty and the other on standby. To avoid accumulation of very old water in the standby system, the allocation of the duty and standby pumps should be alternated from time to time. The lubricant used for in water supply pumps should be suited to the application. Where there is any risk of contamination of water supply, oil designed for potable applications should be considered. An illustration of a pump station is shown in Figure 29.

Hydrants

Hydrants are preliminarily a part of the fire fighting infrastructure of a water system. Proper design, spacing and maintenance are needed to insure an adequate flow to satisfy fire-fighting requirements. Fire hydrants are typically exercised and tested periodically by water utility or fire department personnel. An illustration of a hydrant is shown in Figure 30.

Figure 28: Illustration of control valves

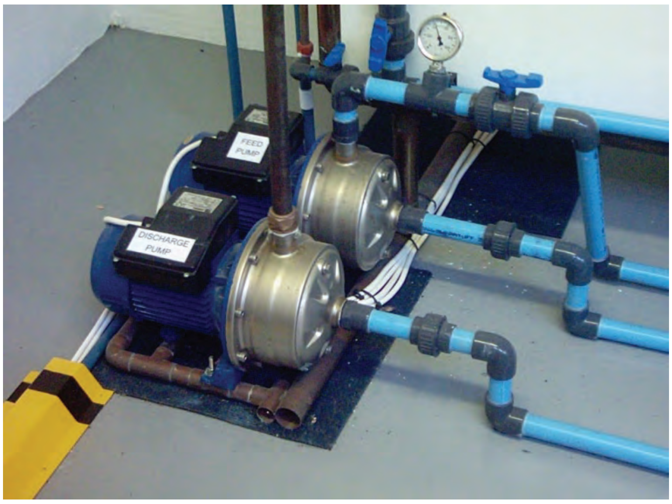


Figure 29: Illustration of a pump station

Figure 30: Illustration of a hydrant

5.5.3 Impact of system design and operation on water quality

Based on the design and configuration of a particular system, there are many opportunities for water quality to change as water moves between the treatment plant and the consumer. Water contamination is an obvious and direct risk to public health. It can occur directly by intrusion of contaminants into the system or by chemical reactions within the system. These unwanted changes may occur due to various reasons including the following:

- Failures at the treatment barrier
- Transformations in the bulk phase
- Corrosion and leaching of pipe material
- Biofilm formation and
- Mixing between different sources of water.

EPA/600/R-06/028 report states that bacteriological growth can cause taste and odour problems, discoloration, slime build-up and economic problems, including corrosion of pipes and biodeterioration of materials. Bacterial numbers tend to increase during distribution and are influenced by several factors, including bacterial quality of the finished water entering the system, temperature, residence time, presence or absence of a disinfectant residual, construction material and availability of nutrients for growth.

The most direct sources of contamination of reticulated water supplies arise from:

- open fire hydrants during mains repairs
- direct entry into broken mains or services
- backflows from individual properties.

Backflows are defined as the flow of (possibly contaminated) water from the consumer's premises into the public supply. It is necessary for the water supplier to ensure that there is sufficient positive flow through the pipes to prevent any backflow or inflow that could contaminate the supply. The network must be monitored to ensure that this is so.

Network Pipes

The most direct sources of contamination of reticulated water supplies arise from:

- open fire hydrants during mains repairs
- direct entry into broken mains or services
- backflows from individual properties

Backflows are defined as the flow of (possibly contaminated) water from the consumer's premises into the public supply. It is necessary for the water supplier to ensure that there is sufficient positive flow through the pipes to prevent any backflow or inflow that could contaminate the supply. The network must be monitored to ensure that this is so.

5.5.4 Network Maintenance

There are basically two types of maintenance methods that can be carried out those are preventative or routine maintenance and reactive maintenance. Preventive maintenance, including leak detection, should be carried out continuously according to pre-established schedules. These schedules are established according to rational considerations such as the manufacturer's recommendations for servicing the equipment. Once agreed upon, these schedules need to be kept to and the results recorded. Special programs such as intensive leak detection, surveys to detect illegal connections, or distribution network analysis, may be scheduled on an annual or one-time basis. An important aspect of routine maintenance is the systematic inspection and replacement of consumption meters. This usually requires a meter repair shop for cleaning, repair, and testing. Information on the condition of meters is vital for future protective and procurement purposes. In general, domestic meters should be taken out of service every five to seven years and completely overhauled.

Reactive maintenance is needed where past routine maintenance has been insufficient, as well as after accidents and where plant is aging. All interventions need to be analyzed and the causes of malfunction or breakage recorded, so as to guide future procurement decisions and help in deciding whether part or all of a network should be upgraded or replaced.

Repair breakages

Broken or leaking water mains should be repaired as soon as possible to minimize property damage and loss of water. From the assessment of the damage carried out, determine and acquire the resources (manpower, equipment and materials) required for the repair work. Start at, or near, a source of supply and work outwards into the distribution system. Repair the pipeline in a stepped manner, one section after another. Select a pipeline section that can easily be isolated by existing stop valves, of say 500 m apart. The maximum length that can be repaired, flushed and pressure-tested effectively is 1000 m. Before starting any repair work, locate other underground utilities in the work area, and liaise with their Maintenance Department, if necessary.

As a safety precaution, find out what type of industries are nearby or which have ever used the site. If the soil is thought to contain hazardous wastes, the local responsible authority should be contacted for advice on further precautionary measures.

Isolate the section by shutting valves and close off all service connections. Arrange to install washout valves and fire hydrants if none can be traced in the selected section. Traffic should be routed away from the work area.

It is often necessary to quickly provide a basic water supply during and shortly after an emergency. This may be because the normal supply has been damaged or destroyed, or because people collect in a place where no water supply exists.

Checking for leaks

Reducing leakage can improve both the quantity and quality of water available to the public, but the distribution system is difficult to assess because it will be buried and spread out over the whole urban area. Obvious leaks should be the first to repair as they are likely to be the largest. Ask the public to report problems and sightings of leaks and puddles. Offer a small reward for information – this will be cost effective as it will quickly identify problem areas in the distribution network. Meters and pressure tests may also identify leaks and broken pipes.

As pointed out earlier, maintaining good water quality in the distribution system depends on the design and operation of the system and on maintenance and survey procedures to prevent contamination and to prevent and remove accumulation of internal deposits. Figure 31 shows the procedure for carrying out the assessment.

As the management of some aspects of the drinking-water system often falls outside the responsibility of a single department, it is essential that the roles, accountabilities and responsibilities of the various departments involved be defined in order to coordinate their planning and management. Appropriate mechanisms and documentation should therefore be established for ensuring stakeholder involvement and commitment. The following section discusses those issues.

Security Risks

It is a basic human right for every individual to be provided with a supply of potable water. The South African government introduced the free basic water policy in 1994 in order to supply poor communities with potable water. While the main focus of this report concerns the impacts on water quality and its effects on public health, it must be emphasized that water quantity is highly compromised. Wastage of water through un-metered or illegal household connections, and leakages in pipes and other valves can lead to massive volumes of water loss. The impact that illegal connections have on reducing water quality has been inadequately addressed due to the limited information available however it should be known that illegal connections could lead to failing water quality in the distribution network.

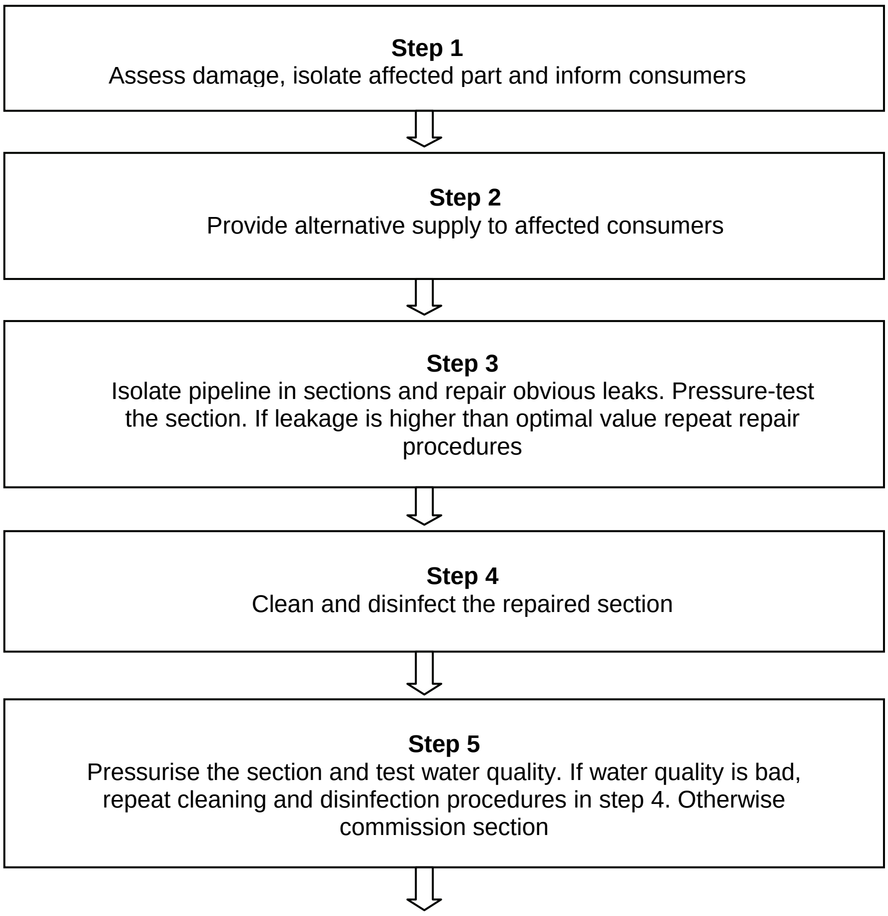


Figure 31*:* Stepwise approach to maintenance of the network system

5.5.5 Summary on network maintenance

- Re-chlorination: Some parts of a distribution system may experience long travel times from the treatment plant resulting in loss of chlorine residual. Installation of booster chlorination facilities at these locations can sometimes be an effective means of insuring an adequate residual in these areas.
- Conventional Flushing: This procedure involves opening hydrants in an area until water visibly runs clear. The object of this action would be to quickly remove contaminated water, however, it would not likely be effective in removal of contaminants that become attached to the pipe surfaces. Flushing only provides a short-term remedy.
- Unidirectional Flushing: This procedure involves the closure of valves and opening of hydrants to concentrate the flow in a limited number of pipes. Flow velocities are maximised so that shear velocity near the pipe wall is maximised.

The importance of differentiating between the general status of a water treatment system, and the risk associated with that system was noted in terms of the different types of decisions that would arise. The following section provides a risk assessment associated with the drinking-water supply system.

5.5.6 Water quality management

Water quality monitoring

There is no single measure that constitutes good water quality, it depends on its use. Water quality is defined by analyzing it in terms of its:

1) Chemical content: Hardness (calcium + magnesium), metals (iron, etc.), nutrients (nitrogen and phosphorus), chloride, sodium, organic compounds, etc.
2) Physical content: Turbidity, colour, odour, etc.
3) Biological content: Faecal coliforms, total coliforms, viruses, etc.

Good quality drinking water is free from disease-causing organisms, harmful chemical substances and radioactive matter, tastes good, is aesthetically appealing and is free from objectionable colour or odour. It should be emphasized that there is a difference between "pure water" and "safe drinking water". Pure water, often defined as water containing no minerals or chemicals, does not exist naturally in the environment. Safe drinking water, on the other hand, may retain naturally occurring minerals and chemicals such as calcium, potassium, sodium or fluoride which are actually beneficial to human health. These will impart a taste to the water if in significant concentrations, that may take some getting used to.

To ensure a safe and acceptable quality water supply, effective water quality monitoring and management is required. There are many possible situations, some which may arise very quickly, that could cause potentially hazardous situations to develop (e.g. microbiological contamination). Case studies have shown that poor water quality, which is often associated with smaller towns and rural areas can primarily be attributed to a lack of regular assessment/management of water quality, including source water protection, water and wastewater treatment optimization, supply reliability, and maintenance of water quality within the distribution network.

Recommended sampling program
The implementation of monitoring procedures enables assessment of water quality against accepted standards/guidelines (e.g. SANS 241 specification). Compliance with water quality standards/guidelines provides assurance that the water supplied to households and effluents discharged to the environment are safe. Further to monitoring, both professional evaluation of collected results, and implementation of corrective action (when required) are vital aspects to the successful operation of a water quality management programme. The recommended sampling programme of drinking water quality is presented below:

- *Sample sites* - Typical sampling sites included in water quality monitoring programmes include raw water sources, water and wastewater treatment works, reservoirs, extremities of the distribution network, sites where previous sampling revealed problems and random sites, such as multi-occupancy buildings (e.g. hospitals, schools, etc.) NOTE: The number of samples collected varies with the size of the community. The figure below shows water supply system units to be taken into considerations in order to effectively manage and/or monitor drinking water quality.
- *Water quality determinants* - Based on knowledge of raw water characteristics and water treatment operations, microbiological, physical and chemical water quality parameters are determined.
- *Sampling, analysis and data review* - Trained staff should carry out sample collection, handling, transport, storage and processing in accordance with standard sampling techniques. All analyses should be conducted using standard laboratory techniques (preferably in South African National Accreditation System (SANAS) accredited analytical laboratories). The analytical results are then compared to the appropriate water quality standards/guidelines.
- *Iterative management of water quality* - An iterative management procedure is followed depending on results from the information review. Where no failures occur, information is used to optimise treatment procedures. Where failures occur, a process of investigation and

trouble-shooting takes place with subsequent implementation of temporary and medium-term solutions.

- *Summary report* - A summary report displaying water quality, discussion thereof and recommended actions is produced. This report serves as an important tool for on-going management of the water supply network. The report is structured in such a way to bring attention to problematic areas, such that the responsible parties are immediately aware of potential problems.

Figure 32: Effective DWQ Management (Ref: DWAF Strategic Framework, 2003)

Test Parameters

In order to establish microbial quality guidelines for drinking water, it is useful to under-stand the guidelines and regulations for EPA drinking water and SANS 241. The regulated contaminants are listed below:

1. Coliform bacteria - are a reliable indicator of the possible presence of faecal contamination and is, consequently, associated with the presence of pathogens. The EPA and SANS 241 limit is less than one coliform per 100 ml.

2. *pH* - the guide specifically mentions pH as something that may necessitate periodic monitoring. The reason for setting a limit is that low pH water is corrosive and can dissolve plumbing components. This is especially a concern when water contacts brass and copper piping systems where copper, zinc, and lead can dissolve into the drinking water. High pH can promote hardness scale precipitation and that chlorine disinfection is not as effective at high pH. Recommended ranges for acceptable pH:

• 6.5–8.5 for water that contacts brass and copper plumbing components
• 2.5–8.5 for water in stainless steel and/or plastic piping systems

Note: For most effective chlorine disinfection, pH should be below 7.0.

3. Total Dissolved Solids (TDS) or Electrical Conductivity (EC) - Total dissolved solids and conductivity both indicate the total inorganic mineral content of drinking water**.** Maximum limits should be set based on the supply water quality and the specified performance of the purification process. Maximum allowable limits of 150 – 370 mS/m for Electrical conductivity are stated in SANS 241.

*4. Disinfectant - a*n automated drinking water system may contain residual disinfectants from the public drinking water supply or additional disinfectants may be injected into drinking water to control bacterial growth. The EPA has proposed maximum contaminants levels (MCL) for these common disinfectants:
Chloramine proposed MCL = 4 mg/L.
Chlorine proposed MCL = 4 mg/L.
WHO recommended values of 0.2 - 0.5 mg/l for free chlorine residuals were given.

5. Other - Test drinking water for any other contaminants that might interfere with research protocols at your facility.

Test Methods
To ensure a safe and acceptable quality water supply, effective water quality monitoring and management is required. There are many possible situations, some which may arise very quickly, that could cause potentially hazardous situations to develop (e.g. microbiological contamination). The implementation of monitoring procedures enables assessment of water quality against accepted standards/guidelines (e.g. SANS 241 specification for water for domestic supplies and others). Compliance with water quality standards/guidelines provides assurance that the water supplied to households is safe. Further to monitoring, both professional evaluation of collected results, and implementation of corrective action (when required) are vital aspects to the successful operation of a water quality management programme.

There are specified tests for all primary drinking water contaminants, meaning those chemicals or water quality parameters for which EPA has identified a health risk from excessive exposure and for which EPA has set a MCL. There are also specified tests for some secondary contaminants, those contaminants which may present aesthetic problems but which are not generally regarded as a health risk. These water quality parameters include pH and TDS. Not all secondary contaminants have a specified test.

Bacterial analyses must be carefully performed to prevent the sample from being contaminated and also in the laboratory; conditions should be such that no contamination can take place. In the case of bacteriological analyses special care should be taken when sampling too. Another important factor is the methodology of sampling; the tests are for instance very much temp depended. The tap should be briefly burnt to ensure that any detected bacteria are from the water itself and not the pump surfaces. Then the water should flow for 2-3 minutes before a sample is obtained. The sterile plastic sample bag or bottle can be then filled; taking care that the inner surface of the bag is not touched by anything (including hands).

Analysis
Analysis can be carried out either in the field (normally done by sampler using appropriate field test equipment and kits) or at a laboratory. The various types of laboratories that are commonly used in South Africa to analyse water quality include:

Internal Laboratories – these laboratories are normally operated and maintained by the Water Service Authority. Large Water service Authorities (e.g. Metropolitan Municipalities) may have both laboratories at their Water/Wastewater Treatment Works and a central laboratory. Smaller Water Service Authorities usually only have basic laboratories at their Water/Wastewater Treatment Works (if any).

External Laboratories – these laboratories are those that are operated by external parties/Professional Service Providers. These include those laboratories operated and maintained by Water Boards (e.g. Rand Water), scientific bodies (e.g. CSIR) and other government departments (e.g. National Health Laboratory Service).

The SANAS gives formal recognition that Laboratories are competent to carry out specific laboratory tasks. External laboratories that are SANAS accredited have therefore satisfied specified criteria.

6. UPGRADING OF SUPPLY SYSTEM ASSESSMENT TOOL (SSAT)

6.1 Introduction

The most effective means of consistently ensuring the safety of a drinking water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer. In order to continuously provide safe drinking-water, procedures or tools are required that are able to guide a comprehensive and systematic approach to improving service delivery (to meet legislated and governance requirements). The importance of differentiating between the general status of a Drinking Water Supply System (DWSS), and the risk associated with that system was noted in terms of the different types of decisions that would arise. Hence this tool was developed in order to provide a method of risk assessment associated with the drinking-water system.

In order to determine the risk, elements utilised in performing Environmental Impact Assessments (EIAs) and ISO 14001 Environmental Management Systems (EMS) evaluations were adapted and utilised. The following aspects are considered:

- **Extent –** This indicates whether the impact will be local and limited to one community served by the drinking-water treatment plant (i.e. one community of a town) (Low); limited to one town served by the drinking-water treatment plant (Medium); or whether the impact may be realised regionally or even nationally (High).
- **Duration –** This reviews the lifetime of the impact, as being short term (0 – 1 year), medium term (2 – 5 years), long term (>5 years), or permanent.
- **Intensity –** This establishes whether the impact is destructive and should be described as low (e.g. no functions/processes affected, ideal/good water quality), medium (e.g. functions/processes continue to function but in a modified manner, water quality variable) or high (e.g. functions/processes are altered such that they are temporarily or permanently impaired, poor water quality).
- **Probability –** This considers the likelihood of the impact occurring and should be described as improbable (low likelihood), probable (distinct possibility), highly probable (most likely) or definite (impact will occur regardless of prevention measures).
- **Degree of confidence in predictions –** The degree of confidence in the predictions, based on the availability of information and specialist knowledge. With respect to the assessment of the significance, the degree of confidence is stated as a description as to whether the impact will be positive (a benefit), negative (a cost), or neutral.

  Impacts are described both before and after the proposed mitigation and management measures have been implemented.

  All impacts are evaluated for the full-lifecycle of the proposed development, including construction operation and decommissioning.

  The impact evaluation takes into consideration the cumulative effects associated with this and other facilities that are either developed or in the process of being developed in the region.

  Attempts are made to quantify the magnitude of potential impacts (direct and cumulative effects) and outline the rationale used. Where appropriate, national standards are used as a measure of the level of impact.

6.2 Purpose of the tool

This tool has been developed with the purpose of providing WSAs with a method of self assessing their water supply system. This would enable WSAs to:

- Identify areas of risks that need urgent attention then
- respond and/or plan in time for those issues
- identify and track emergency issues
- understand the maintenance methods of the DWSS.

It can also be used as DWAF auditing tool in order to:

- identify WSAs challenges related to water supply services that will in turn result in DWAF
- identifying assistance required by the WSA.

6.3 Tool aimed at

This tool should be filled in by a head of water. Assistance may be required from the supervisors and superintendents but the responsibility should be taken by the head of water since:

- he carries the responsibility of drawing future plans
- he is responsible for handling water services budget

6.4 Upgrading of supply system assessment tool

Completion of the table below based on data gathered from site visits and interactions with Local Municipalities are inputted into the performance based scoring/weighting system and used to produce a score for a particular site. Using this score, the various water treatment systems are ranked. The weights were allocated in such a way that:-

If the issue may/will lead to:

Medium/long term sustainability	5
Aesthetic conditions	10
Equipment failure and poor maintenance	20
Unavailability (is there adequate water resource) /poor quality of water	40
Direct health threat	100

The questionnaire shown in Table 13 is available to be printed and taken on-site for assessment purposes both in **Appendix B** and the eWQMS website. Two case studies showing the use of this questionnaire (that is used for medium to larger conventional system) together with the one used for smaller systems (where no formal water treatment process are included) are also presented. A guide as to how to access, fill in the questionnaire and get outputs is presented in section 7 below.

Table 13: *Supply System Assessment Tool*

Actual Score = Likelihood*Consequence

	Likelihood	Conse-quence	Actual Score	Max. Score
SECTION 1: Design				
1.1 Is the design capacity of the plant known?	Yes – 1 No – 0	5		5
1.2 Is the plant operating within its design capacity? (i.e. is there spare capacity available?)	Mostly – 1 Partly – 0	20		20
1.3 Is the plants raw water supply affected by treated wastewater/industrial effluent/run-off from informal communities/ animal waste?	Yes – 0 No – 1	40		40
1.4 Is there sufficient and dependable raw water supply?	Mostly – 2 Partly – 1	40		80
1.5 Are the unit processes implemented at the plant appropriate for the raw water quality?	Yes (100%) – 3 Mostly (80%) – 2 Partly (50%) – 1 No – 0	20		60
1.6 Are spare unit processes available at the plant for maintenance purposes? (e.g. multiple settling tanks, filters, etc.)	Yes – 1 No – 0	10		10
1.7 Is there space available for future plant upgrades/expansion?	Yes – 1 No – 0	5		5
1.8 Is there sufficient storage capacity in the distribution network (i.e. sufficient reservoirs with sufficient capacity)?	Yes – 1 No – 0	5		5
END SECTION 1 (225)	**TOTAL**			

	Likelihood	Conse-quence	Actual score	Max. Score
SECTION 2: Operation				
2.1 Is the quantity of raw and treated water metered at the plant?	Both – 2 One – 1 None – 0	10		20
2.2 Are all unit processes at the plant operating effectively?	Yes (100%) – 3 Mostly (80%) – 2 Some (50%) – 1 None – 0	20		60
2.3 Are there sufficient numbers of plant operators?	Yes – 1 No – 0	10		10
2.4 Are the responsible plant operators adequately trained?	Formal Qual. – 3 Short Courses – 2 On the job – 1 No – 0	20		60
2.5 Is an operator's manual available on-site?	Yes – 1 No – 0	5		5
2.6 Are charts/graphs available at the plant for process control/correcting typical issues of concern (e.g. dosages/chemical feed rates posted on walls, etc.)?	Yes – 1 No – 0	5		5
2.7 Are standard plant operating procedures captured in writing (e.g. preparing batches of chemicals, changing gas cylinders, etc.)	Yes – 1 No – 0	5		5
2.8 What is the frequency of on-site drinking-water quality monitoring?	Hourly – 3 Daily – 2 Weekly or More – 1 None – 0	10		30
2.9 Where is water quality monitored at the plant? • Raw water • Final Treated water • Along treatment chain	All – 2 Some – 1 None – 0	10		20
2.10 Are chemicals/reagents required for analysis available on-site?	Yes – 1 No – 0	10		10
2.11 Are on-site staff familiar with operation and maintenance of the monitoring equipment?	Yes – 1 No – 0	10		10

	Likelihood	Conse-quence	Actual score	Max. Score
SECTION 2: Operation				
2.12 Is a water treatment process specialist readily available (e.g. in-house or consultant) to assist with plant issues	Yes – 1 No – 0	10		10
2.13 Is a report highlighting issues of concern at the plant (quality, malfunctions, etc.) produced?	Weekly – 2 Monthly – 1 Longer period or None – 0	20		40
2.14 What is the frequency of distribution network drinking-water quality monitoring?	Weekly/Fortnightly – 3 Monthly – 2 Quarterly – 1 None – 0	10		30
2.15 Where is water quality monitored in the distribution network? • Reservoir • Hydrant • Household taps	All – 2 Only res/taps. – 1 None – 0	10		20
2.16 Are chlorine booster stations located in the reservoirs/ distribution network to manage and maintain desirable chlorine residuals?	Yes or N/a – 1 No – 0	10		10
2.17 How often are chlorine booster stations checked to ensure appropriate chlorine residual management in the distribution network?	Daily or N/a – 2 Weekly – 1 Longer or None – 0	10		20
END SECTION 2 (365)	**TOTAL**			

	Likelihood	Conse-quence	Actual Score	Max. Score
SECTION 3: Water Quality and Performance				
3.1 Is operational monitoring conducted for the bacteriological parameters?	Yes – 1 No – 0	100		100
3.2 Is operational monitoring conducted for physical parameters?	Yes – 1 No – 0	20		20
3.3 Is operational monitoring conducted for residual chemicals?	Yes – 1 No – 0	40		40
3.4 Does drinking-water quality leaving the plant meet legislated requirements (i.e. SANS 241-2005) for bacteriological indicators	Always – 2 Mostly – 1 Never – 0	100		200
3.5 Does drinking-water quality leaving the plant meet legislated requirements (i.e. SANS 241-2005) for physical parameters?	Class I – 2 Class II – 1 Fail Class II/Don't know – 0	100		200
3.6 Does drinking-water quality leaving the plant meet legislated requirements (i.e. SANS-2005) for residual chemicals and health related chemicals?	Always – 2 Mostly – 1 Never – 0	40		80
3.7 Is all water quality monitoring equipment at the plant in good working order?	Yes – 1 No – 0	20		20
3.8 Do you perform compliance monitoring for bacteriological analysis (faecal coliform, E.coli)?	Yes – 1 No – 0	100		100
3.9 Do you perform compliance monitoring for physical parameters?	Yes – 1 No – 0	20		20
3.10 Do you perform compliance monitoring for residual chemicals and health related chemicals?	Yes – 1 No – 0	40		40
3.11 How frequently is water quality monitored in the distribution network	Weekly/More – 3 Monthly – 2 Quarterly – 1	40		120
3.12 Does drinking-water quality in the distribution network meet legislated requirements (i.e. SABS 241-2005) for key parameters (pH, turbidity, bacteriological indicators, treatment chemical residuals, etc.)?	Class I – 2 Class II – 1 Fail Class II/Don't know – 0	100		200
3.13 Where are distribution network drinking-water samples analysed?	SANAS Accredited lab – 3 Accredited methods – 2 In-house/field test kit – 1	40		120
3.14 Is a report highlighting issues of concern in the distribution network (quality, need for flushing, etc.) produced?	Monthly – 2 Quarterly – 1 Longer period or None – 0	20		40
3.15 Is water quality data (both plant and distribution network) stored appropriately?	Database & hard copy – 3 Basic elec. & hard copy – 2 Hard copy alone – 1 None – 0	10		30
END SECTION 3 (1210)	**TOTAL**			

	Likelihood	Conse-quence	Actual Score	Max. Score
SECTION 4: Maintenance				
4.1 Does the drinking-water treatment plant appear to be well maintained (grass cut, site neat, etc.)?	Good – 2 Fair – 1 Poor – 0	5		10
4.2 Is ammonia available at the plant for detecting leaks on chlorine gas cylinders?	Yes or N/A – 1 No – 0	10		10
4.3 Do all pumps at the plant appear to be well maintained? (e.g. no excessive noise or leaking from glands/pipe connections)	Yes – 1 No – 0	10		10
4.4 Is a plant maintenance schedule produced and adhered to? (i.e. pro-active maintenance and not reactive maintenance or crisis management)	Yes – 1 No – 0	10		10
4.5 Is there sufficient technical back-up to perform required plant maintenance? • Mechanical • Electrical	Both – 2 One – 1 No – 0	10		10
4.6 Are there sufficient distribution network maintenance personnel (e.g. plumbers)?	Yes – 1 No – 0	10		10
4.7 Are the distribution network maintenance personnel adequately trained?	Qualified – 3 Short Courses – 2 On the job – 1 No – 0	20		60
4.8 Is a distribution network maintenance schedule produced and adhered to? (i.e. pro-active maintenance and not reactive maintenance or crisis management) • Reservoir cleaning, flushing • Network cleaning, flushing	Yes – 1 No – 0	10		10
4.9 Is there sufficient budget available to perform required maintenance? • Plant • Distribution network	Yes – 1 No – 0	40		40
4.10 Is a pump stations maintenance schedule and adhered to?	Yes – 1 No – 0	10		10
4.11 Are water meters in the distribution network regularly checked Are there water meters in the distribution network to understand water consumption	Yes – 1 No – 0	5		5
4.12 Is asset register produced and adhered to	Yes – 1 No – 0	40		40
END SECTION 4 (225)	**TOTAL**			

	Likelihood	Conse-quence	Actual Score	Max. Score
SECTION 5: Supervision and Management				
5.1 Have responsibilities been assigned for both plant and distribution network operation and maintenance?	Yes – 1 No – 0	10		10
5.2 Is a complaints register maintained? • Date of complaint, contact details, nature of complaint • Actions taken • Time frame to resolve issue • Signed by responsible officer and checked and discussed with supervisor	All – 2 Some – 1 None – 0	20		20
5.3 Are issues/findings from the plant operational report and complaints register discussed in appropriate LM water meetings on a regular basis (i.e. management review)?	Weekly – 2 Monthly – 1 Longer / None – 0	10		10
5.4 If issues of concern are noted, are required corrective actions implemented timeously? (give examples, where appropriate)	Yes – 1 No – 0	40		40
5.5 Are there any telemetric system connected to alarms used	Yes/ N/a – 1 No – 0			
5.6 Do you have any mechanism in place to indicate reservoir levels	Yes – 1 No – 0			
5.7 Do you have a Master Plan in place (e.g. 20 yr plan)	Yes – 1 No – 0	40		40
5.8 Do you have a WSDP (e.g. 5 yr plan)	Yes – 1 No – 0	40		40
5.9 Is there any skills development programme in place for training staff?	Yes – 1 No – 0			
END SECTION 5 (160)	**TOTAL**			

	Likelihood	Conse-quence	Actual Score	Max. Score
SECTION 6: Water Treatment Sludge Management				
6.1 Are sludge/wastewater holding ponds/dams available at the plant?	Yes – 1 No – 0	20		20
6.2 Are sludge/wastewater holding ponds/dams appropriately sized?	Yes – 1 No – 0	10		10
6.3 Is dry sludge produced from the plant landfilled/handled appropriately?	Yes – 1 No – 0	10		10
END SECTION 6 (40)	**TOTAL**			

	Likelihood	Conse-quence	Actual Score	Max. Score
SECTION 7: Safety				
7.1 Are warning signs (e.g. near chemicals/gas cylinders) visible at all required points at the plant?	Yes – 1 No – 0	5		5
7.2 Have staff received necessary safety training (e.g. handling chlorine gas/chemicals, etc.)?	Yes – 1 No – 0	10		10
7.3 Do operators have required safety equipment/clothing? • Face and gas mask • Protective clothing • Showers/eye wash points	All – 2 Some – 1 None – 0	20		40
7.4 Is all operating equipment at the plant secured appropriately (e.g. level surface, screwed down, etc.)?	Yes – 1 No – 0	10		10
7.5 Are safety rails/hand rails secure?	Yes – 1 No – 0	10		10
7.6 Is there a bathroom with soap, water, etc. at the plant?	Yes – 1 No – 0	10		10
7.7 Are safety inspections regularly conducted at the plant by an appointed safety representative?	Yes – 1 No – 0	5		5
7.8 Are emergency procedures available for distribution network (e.g. handling Cl)	Yes – 1 No – 0	20		20
7.9 In terms of Occ. Health & Safety Act, does your WSS meet requirements correctly?	100% compl. – 3 50% compl. – 2 None – 0	20		60
7.10 Have all Chlorine stations been correctly certified as a major hazardous installation?	Yes – 1 No – 0	20		20
END SECTION 7 (190)	**TOTAL**			

	Likelihood	Conse-quence	Actual Score	Max. Score
SECTION 8: Emergency Preparedness and Response				
8.1 Are emergency procedures available (e.g. unit failure, gas/chemical handling, change in raw water quality, etc.)?	Yes – 1 No – 0	10		10
8.2 Are emergency procedures understood by responsible staff? (e.g. question staff how they would react to an incident)	Yes – 1 No – 0	10		10
8.3 Are emergency power generators available?	Yes – 1 No – 0	20		20
8.4 Are standby units available for essential operating equipment at the plant (e.g. dosing pump, transfer pump, etc.)?	Yes – 1 No – 0	20		20
END SECTION 8 (60)	**TOTAL**			

SUMMARY SCORES			
	MAX Score	**Actual Score**	**Percentage**
SECTION 1: Design	225		
SECTION 2: Operation	365		
SECTION 3: Water Quality and Performance	1210		
SECTION 4: Maintenance	225		
SECTION 5: Supervision and Management	160		
SECTION 6: Waste Management	40		
SECTION 7: Safety	190		
SECTION 8: Emergency Preparedness/ Response	60		
TOTAL	**2475**		
PERCENTAGE			

ALLOCATION OF WEIGHTS/ SCORES

Weight	Consequences
100	WILL lead to: • Direct health threat
40	WILL lead to: • Poor DWQ → bacteriological and chemical (e.g. no maintenance, overloaded) • Unavailability of water (i.e. is there adequate water resource) • Incorrect/ unreliable information can lead to health issue • Plant and monitoring equipment HAS failed due to poor maintenance/lack of staff
20	Legislative requirements WILL lead to: • DW which has poor aesthetics (physical) • Environmental/ Safety/ Health issues
10	MAY Lead to: • Environmental/ Safety/ Health issues • Equipment MAY fail due to poor maintenance/ staff availability • Insufficient capacity (infrastructure, analysis chemicals, personnel)→ can't perform maintenance
5	Medium/long term sustainability • Site aesthetic • Good practise

Results can also be presented in a form of a "colour coded spider diagram". The percentage score obtained per category can then be plotted using this spider-diagram to indicate the current status of the particular category and highlight where WSA efforts should be focused. An example of the "spider-diagram" plot is shown in Figure 33 below.

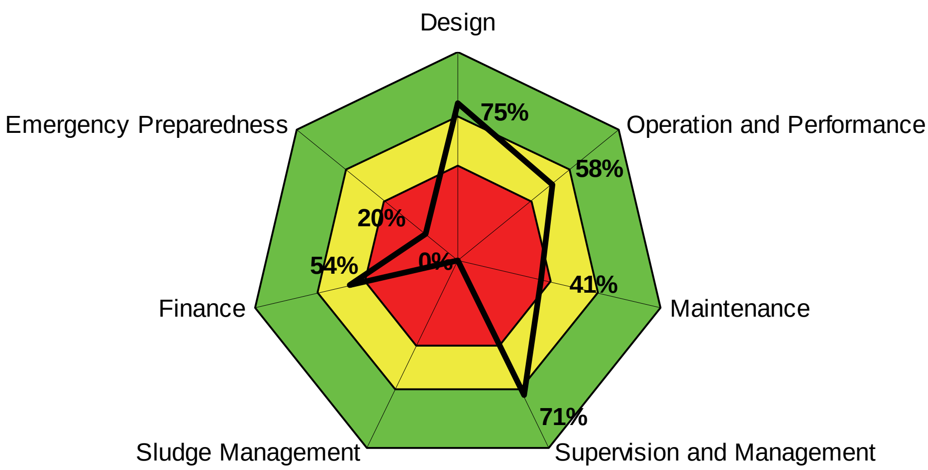


Figure 33: SSAT Results presentation

Considering the methodology presented above, the following performance characterisation can be considered for determining the status of each of the various categories.

Table 14: *Performance Characterisation*

Category Score	Characterisation	Comment
70%-100%	Acceptable	Usually require minor interventions to ensure sustainability
45%-69%	Marginal	Sustainability is in question if interventions are not implemented
<45%	Poor	WSA is likely to collapse if urgent interventions are not implemented

7. MANUAL FOR USING ELECTRONIC WATER QUALITY MANAGEMENT SYSTEM (EWQMS) AND SUPPLY SYSTEM ASSESSMENT TOOL

Purpose of this Manual
The purpose of this manual is to:

Introduce the eWQMS to the reader
Highlight some of the key features/functions of the eWQMS
Provide step-by-step guidance as to how to use the Supply System Assessment Tool on the eWQMS.

7.1 Background

Water Services Authorities (WSAs) have responsibilities including protection and management of water resources, operation and maintenance of infrastructure, monitoring and management of water quality, reporting to DWAF with regards to the aforementioned, etc. In order to ensure an effective and sustainable water service, the above mentioned aspects must be addressed by WSAs. However, a number of recent surveys have indicated that many WSAs in the South Africa are not effectively monitoring and managing water quality. Accordingly, DWAF and other water sector partners (e.g. IMESA, SALGA, WRC) have undertaken various initiatives to assist WSAs with operation and management of water services. In particular, DWAF, together with IMESA have rolled out the eWQMS to all 169 WSAs in South Africa. The eWQMS allows WSAs to interpret water quality data and highlights issues of concern requiring intervention. Data loaded by WSAs onto the eWQMS are transferred to the National Information System (NIS). Recent developments to the eWQMS have further enhanced functionality including the ability of WSAs to conduct self assessments of DWQM, infrastructure, etc. The Drinking Water Supply System Assessment Tool falls into this category allowing a WSA to conduct a self-assessment of their drinking water supply systems and identify key risks/issues which need to be addressed.

7.2 IMESA Lead Iterative Enhancement Process

IMESA's specific roll is as an impartial honest broker ensuring that the eWQMS solution is appropriate and supportive of Municipal Engineering requirements. This is achieved by IMESA participating in both initial municipal interaction forums, and subsequently by IMESA led iterative feedback sessions with municipal users. At these sessions, recent new developments are presented to WSAs, ideas are brainstormed with WSAs, and WSAs are given the opportunity to provide feedback regarding:

- Useful features/functions of the eWQMS
- Features/functions that could be improved/amended
- Future desirable features/functions.

Water Services Authorities are also asked to rank new and/or desirable features/functions from High to Low.

The above process helps to determine the actual on-the-ground needs at WSAs. Feedback obtained from these sessions is collated and desirable features/functions categorised and ranked. Subsequently, incremental improvements and enhancements are introduced to the tool.

7.3 Brief Overview of the eWQMS System

The eWQMS tool is a well proven comprehensive Water Quality Management tool, which has an established track record of being successfully used by WSAs, Regional and National DWAF offices, and the public. The eWQMS has been set up to assist WSAs to meet the National Drinking Water Quality Management Framework requirements, and is a full management system. In addition, roll-out of the wastewater component of the eWQMS is currently being fast-tracked. In particular, the eWQMS able to guide:

- Regulatory compliance by WSAs
- The timeous supportive intervention in water quality failures (chronic and acute)
- Infrastructure improvement
- Capacity development of municipal staff.

The eWQMS is an internet accessible database system (accessible at www.wqms.co.za) utilising open source components (mySQL, XML, etc.), and has been found following detailed assessment by DWAF's IT support team to be fully compatible with and compliant to DWAF Water Services National Information System and DWAF Regulatory System requirements.

Importantly, the eWQMS has been developed in a "bottom up" approach with WSAs, IMESA, DWAF and the Water Research Commission. Data can be loaded by WSAs onto eWQMS via the internet, spreadsheet or specific import scripts. Furthermore, the eWQMS can provide useful automated regulatory compliance reporting to all WSAs and sector partners. The eWQMS also provides easy access to useful water quality tools and information. Presently, the eWQMS consists of the following main components:

- Login/Logout
- Water Quality
- Infrastructure
- Risk Toolbox
- Administration
- Information.

Considering the above, the following main features are described (***NOTE:*** A full demonstration will be gladly provided on request):

System Access

The system is usually accessible via the internet for full use (including via DBSA's LGNET), providing considerable costs and operational efficiency benefits over local application based systems. Nevertheless, the system can run as an independent local application if required. Information and reference material can be accessed without the need to login (This is especially useful to members of the public (e.g. teachers, students, etc.) and saves municipal officials time).

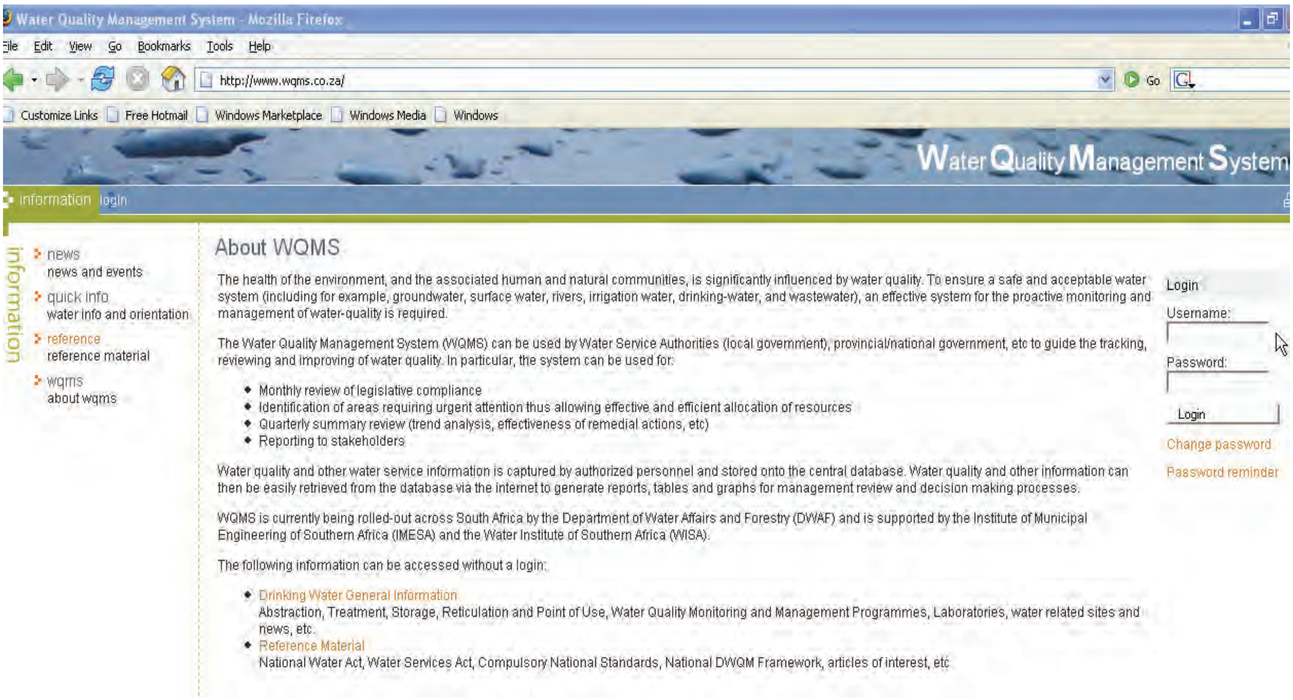


Figure 34: eWQMS access via the internet

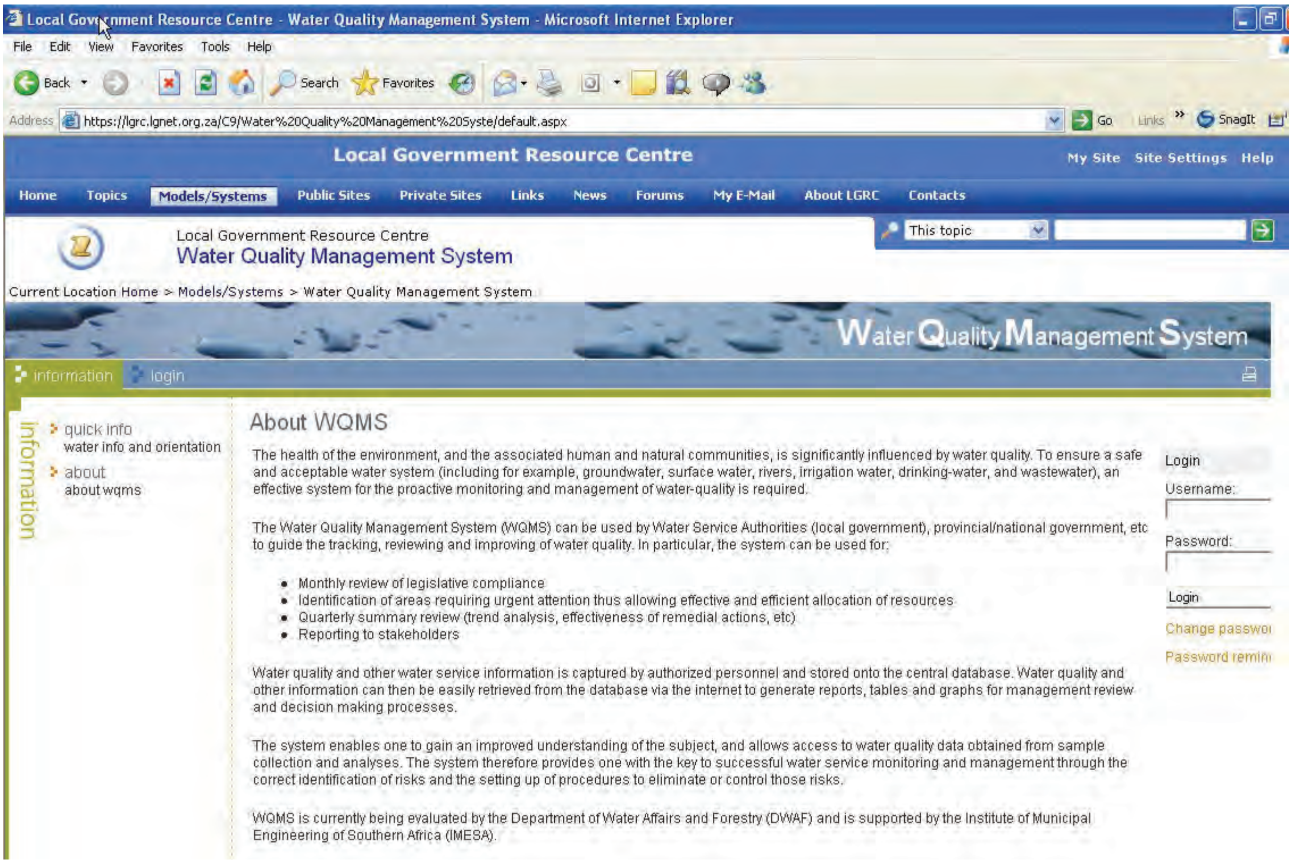


Figure 35: eWQMS access via DBSA's LGNET

System Compatibility

The system can be set up to run off existing water quality management systems, such as LIMS systems. A number of “import scripts/patches” already exist, and where necessary additional will be written for data import; *e.g. of import scripts/patches includes Johannesburg Water and eThekwini.*

Login/logout

A user is provided with username and password. A particular user will be provided with a WSA, District, Provincial or National view. Furthermore, limited detail “public” views of DWQ can be set up if required; *e.g. of Provincial view includes Free State; public view includes Stellenbosch.*

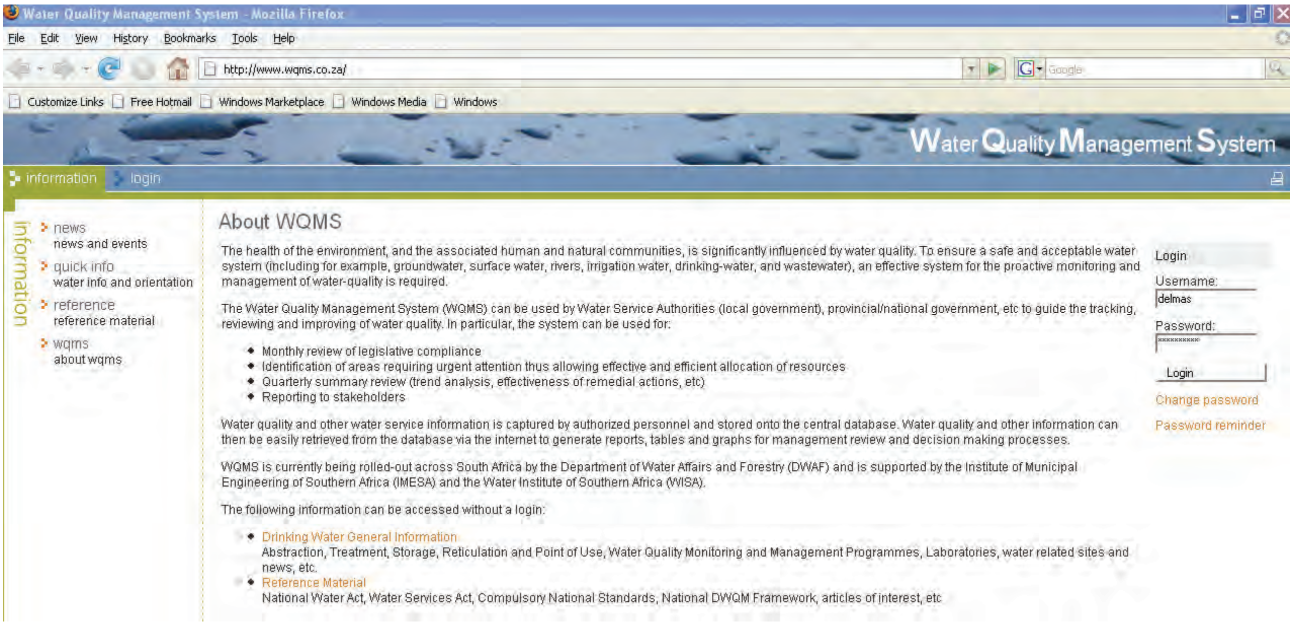


Figure 36: eWQMS login (Delmas Municipality, Mpumalanga)

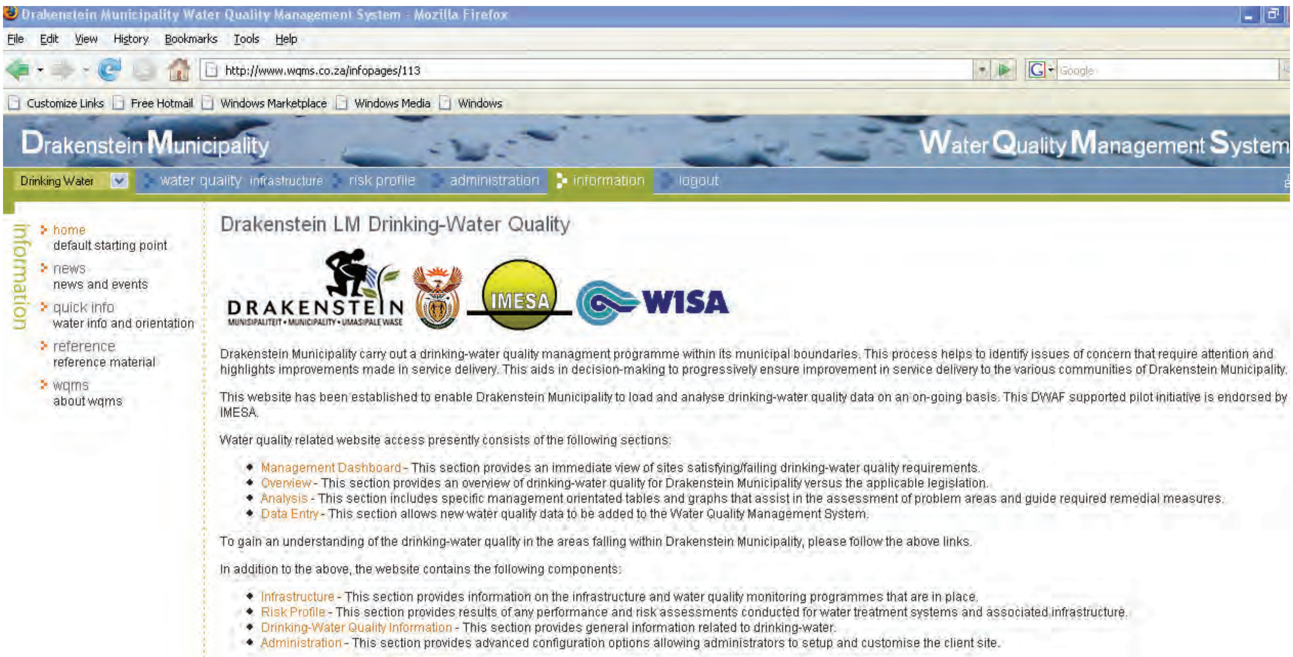


Figure 37: WSA homepage (Drakenstein Municipality, Western Cape)

Water Quality Management

A key functional requirement is easy water quality data loading and interpretation. The system can interpret data against a range of standards, but defaults to SANS 241. The system is capable of interpreting wastewater and river water quality data. Current functionality includes:

Management Dashboard [summarised monthly view of legislative compliance & identification of areas requiring urgent attention; easy colour coding to show compliance (green), failure of SANS 241 class 1 (yellow), and failure of SANS 241 Class 2 (red)].

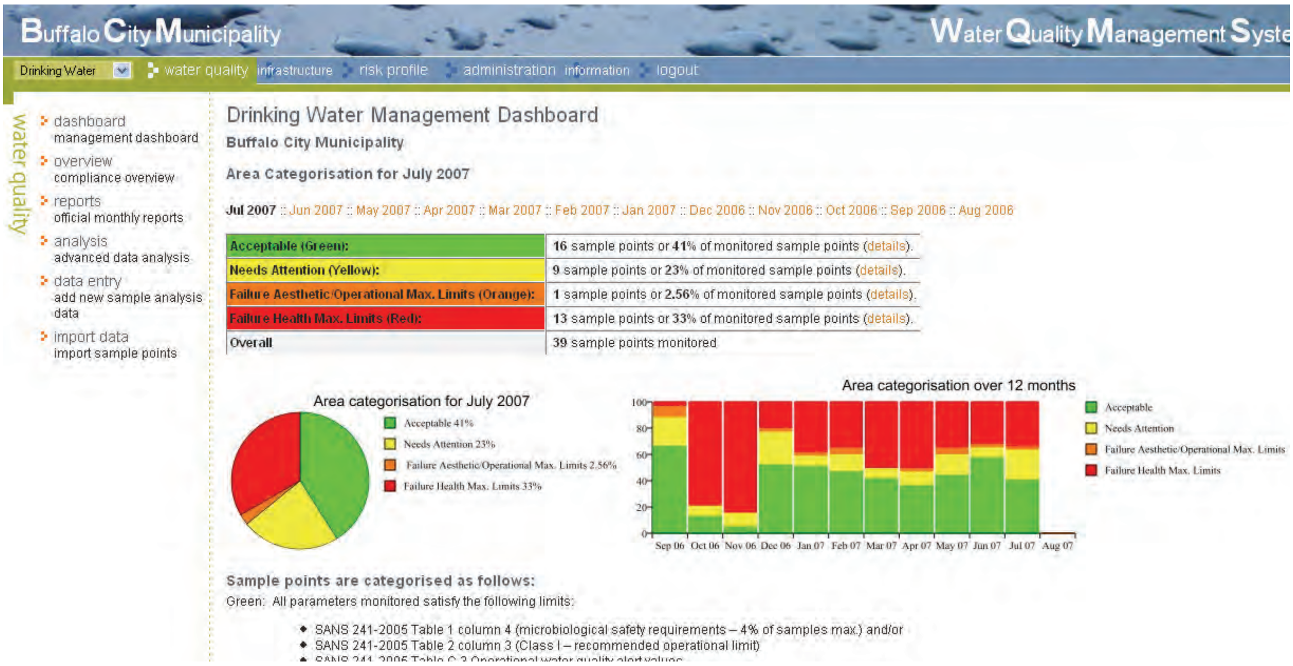


Figure 38: eWQMS Management Dashboard (Buffalo City, Eastern Cape)

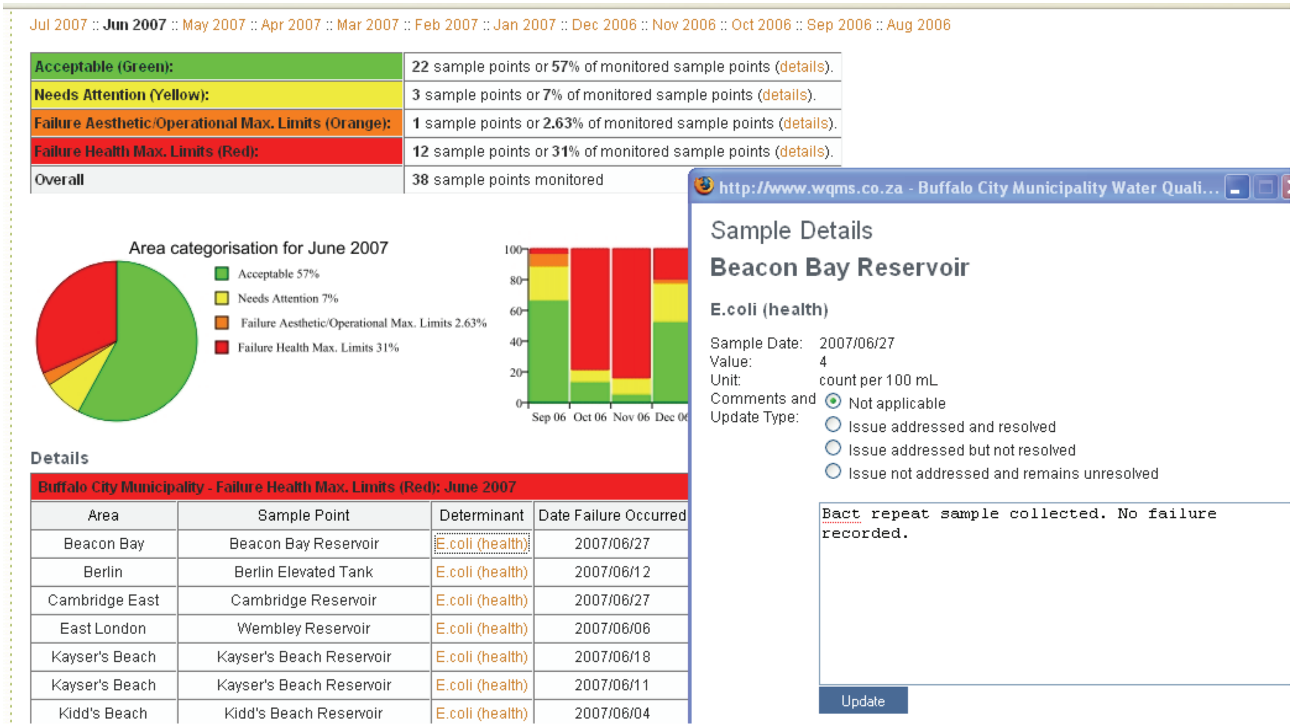


Figure 39: Detail of "Red" failure and actions taken to address issue of concern (Buffalo City, Eastern Cape)

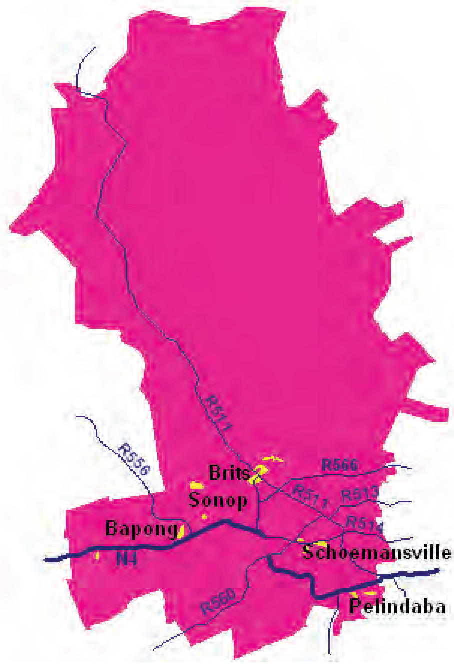
Overview (map-based interface with "period based" compliance summary of bacteriological, physical and chemical DWQ).

Drinking Water Overview

Madibeng Municipality

Water Quality Summary
Links to Useful Tables and Graphs

- Brits
- Cosmos East
- Damonsville
- Elandsrand
- Hartbeespoort
- Jericho
- Letlhabile
- Madidi
- Meerhof
- Mmakau
- Mothotlung
- Sonop



Drinking Water Quality Summary

Microbiological Safety :: Microbiological Operational :: Physical :: Chemical

Configure Parameters	Faecal Coliforms (health)		E.coli (health)	
Area	SampleCount	Compliance %	SampleCount	Compliance %
South Africa	*11920*	*98 (view)*	*24070*	*96 (view)*
North West	*1295*	*99 (view)*	*1139*	*99 (view)*
Bojanala Platinum District Municipality	*114*	*100 (view)*	*642*	*99 (view)*
Madibeng Municipality			*161*	*100 (view)*
Brits			15	100 (*view*)
Cosmos East			15	100 (*view*)
Damonsville			19	100 (*view*)
Elandsrand			15	100 (*view*)
Hartbeespoort			17	100 (*view*)
Jericho			17	100 (*view*)
Letlhabile			12	100 (*view*)
Madidi			11	100 (*view*)
Meerhof			13	100 (*view*)
Mmakau			14	100 (*view*)
Sonop			13	100 (*view*)
Data Period	2006/09/01 to 2007/08/30			

Quality of Water System	Microbiological requirement	Chemical requirement	
	Column 5 of Table 1	Class I	Class II
Excellent	>= 99%	>= 95%	>= 97%
Good	>= 98%	>= 90%	>= 95%
Fair	>= 97%	>= 85%	>= 90%
Poor	< 97%	< 85%	< 90%

Figure 40: eWQMS Overview (microbiological safety) (Local Municipality of Madibeng, North West)

Configure Parameters	Aluminium (health)			Iron (aesthetic/operational)		
Area	SampleCount	Compliance %	Median(mg/L as Al)	SampleCount	Compliance %	Median(mg/L as Fe)
South Africa	***1917***	***87 (view)***	***0.07***	***5351***	***85 (view)***	***0.04***
Western Cape	***482***	***76 (view)***	***0.12***	***1142***	***68 (view)***	***0.11***
Knysna Municipality	***67***	***34 (view)***	***0.41***	***67***	***47 (view)***	***0.20***
Buffalo Bay	15	0 (view)	1.14	15	93 (view)	0.06
Karatara	13	100 (view)	0.05	13	69 (view)	0.11
Knysna (Town)	12	50 (view)	0.29	12	41 (view)	0.30
Rheenendal	12	8 (view)	1.30	12	0 (view)	0.40
Sedgefield	15	20 (view)	0.36	15	26 (view)	0.25
Data Period	2006/05/02 to 2007/04/30					

Notes:

- The median value displayed is the median of all samples collected in the particular area. The median value is compared to *SANS 241* an
- The percentage compliance displayed is the percentage of all samples collected in the area falling within *SANS: Physical, Organoleptic, (*
- Based on samples taken during the last 12 months.

Applicable Standards

SANS: Physical, Organoleptic, Chemical: Class I	
SANS: Physical, Organoleptic, Chemical: Class II	
Failure Phys-Organo-Chem: Class II (Aesth/Operat)	
SANS: Failure Phys-Organo-Chem: Class II (Health)	

SANS 241-2005 Table C.2: Compliance frequency targets in respect of microbiological and chemical requirements that have health implicati

Quality of Water System	Microbiological requirement	Chemical requirement	
	Column 5 of Table 1	Class I	Class II
Excellent	>= 99%	>= 95%	>= 97%
Good	>= 98%	>= 90%	>= 95%
Fair	>= 97%	>= 85%	>= 90%
Poor	< 97%	< 85%	< 90%

Figure 41: eWQMS Overview (chemical) (Knysna Municipality, Western Cape)

Quick Analysis (quick links to regularly used operational efficiency and legislative compliance tables/graphs and trend analysis)

Free Hotmail | Windows Marketplace | Windows Media | Windows

Sandton / Alex	732	0
Soweto	606	0
Data Period	2006/09/01 to 2007/08/30	

Notes:

- The median value displayed is the median of all samples collected in the particular area. The median value is compared to *SANS 241* and colou
- The percentage compliance displayed is the percentage of all samples collected in the area falling within *SANS: Microbiological Safety: Column*
- Based on samples taken during the last 12 months.

Applicable Standards

SANS: Microbiological Safety: Column 3	
SANS: Microbiological Safety: Column 4	
SANS: Microbiological Safety: Column 5	
SANS: Failure Microbiological Safety: Column 5	

SANS 241-2005 Table C.2: Compliance frequency targets in respect of microbiological and chemical requirements that have health implications

Quality of Water System	Microbiological requirement	Chemical requirement	
	Column 5 of Table 1	Class I	Class II
Excellent	>= 99%	>= 95%	>= 97%
Good	>= 98%	>= 90%	>= 95%
Fair	>= 97%	>= 85%	>= 90%
Poor	< 97%	< 85%	< 90%

Configure Parameters for Summary

Useful Tables and Graphs

- E.coli - Percentage Failure
- Free Chlorine Residual - Median per Area
- pH - Median per Area
- Total Coliform - Percentage Failure
- Turbidity - Median per Area

Figure 42: Example of quick analysis links at the bottom of the Overview

Detailed Analysis (dynamic Tables and Graphs with full flexibility)

Drinking Water Analysis

Report Selection

Point Analysis Table

single determinant | determinant set

The point analysis table provides a detailed water quality analysis for a selected sampling point vs. the applicable water quality standards.

Point Analysis Graph

single determinant

The point analysis graph provides a graphical water quality analysis for a selected sampling point vs. the applicable water quality standards.

Median Value Graph

single determinant

The median value graph shows the median value of a particular determinant in an area vs. the applicable water quality standards.

Compliance Table

single determinant | multiple determinants

The compliance table analyses the percentage compliance in an area vs. the applicable water quality standards.

Failure Table

single determinant

The failure table highlights failures in an area vs. the applicable water quality standards.

Failure Graph

single determinant

The failure graph shows the percentage failure of a particular determinant in an area vs. the applicable water quality standards.

Combined Compliance/Failure Graph

single determinant

The combined Comliance/Failure graphs show the percentages of particular determinant in an area vs. the applicable water quality standards.

Raw Analysis Data

analysis values as csv

Download analysis values in CSV format.

Raw Sample Point Data

Figure 43: eWQMS Analysis (tables and graphs)

Dynamic Drinking Water Reports

Water Quality Compliance Table

E.coli (health) (count per 100 mL) for Central

	June 2006		July 2006		August 2006	
Area	Samples Complied	% Compliance	Samples Complied	% Compliance	Samples Complied	% Compliance
Central	***22 / 22***	***100%***	***22 / 22***	***100%***	***23 / 23***	***100%***
Berea North	2 / 2	100%	2 / 2	100%	2 / 2	100%
Berea South	2 / 2	100%	2 / 2	100%	2 / 2	100%
Bluff	2 / 2	100%	2 / 2	100%	2 / 2	100%
Chatsworth	2 / 2	100%	2 / 2	100%	2 / 2	100%
Durban Centre	2 / 2	100%	2 / 2	100%	2 / 2	100%
Durban North	2 / 2	100%	1 / 1	100%	2 / 2	100%
Merebank	2 / 2	100%	1 / 1	100%	2 / 2	100%
New Germany	2 / 2	100%	2 / 2	100%	2 / 2	100%
Phoenix	1 / 1	100%	2 / 2	100%	2 / 2	100%
Pinetown	2 / 2	100%	2 / 2	100%	2 / 2	100%
Umbilo	2 / 2	100%	3 / 3	100%	2 / 2	100%
Umhlanga	1 / 1	100%	1 / 1	100%	1 / 1	100%

water & forestry
Department: Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA
IMESA
WISA

Figure 44: Compliance table example (Ethekwini Municipality, KwaZulu-Natal)

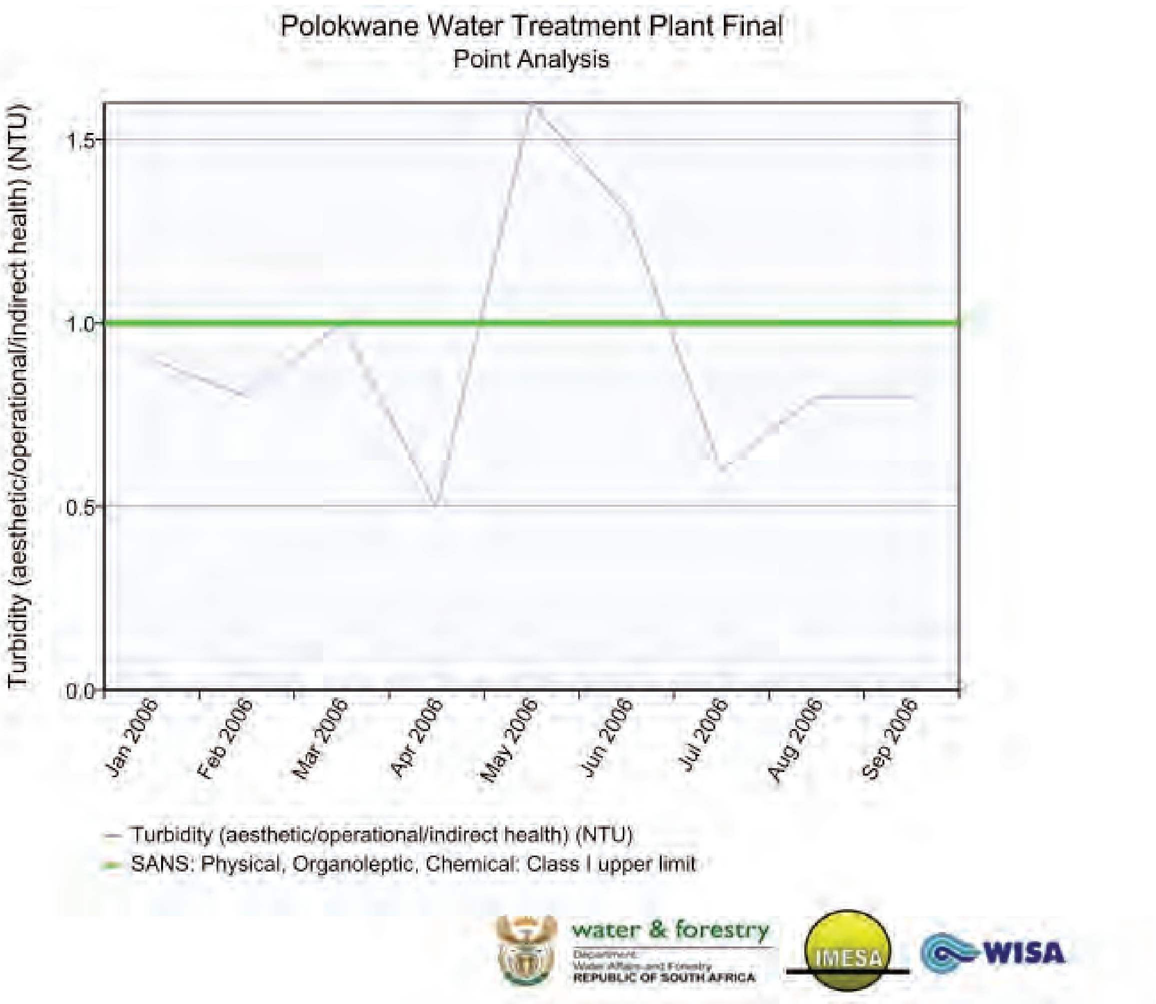


Figure 45: Point analysis graph example (Polokwane Municipality, Limpopo)

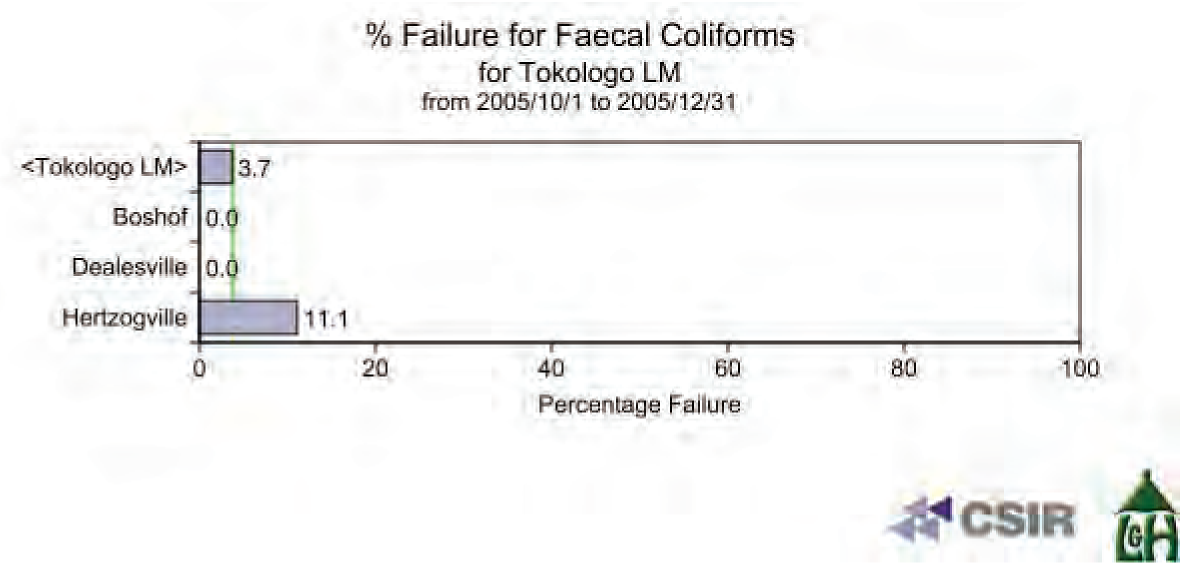


Figure 46: Percentage failure graph example (Tokologo Municipality, Free State)

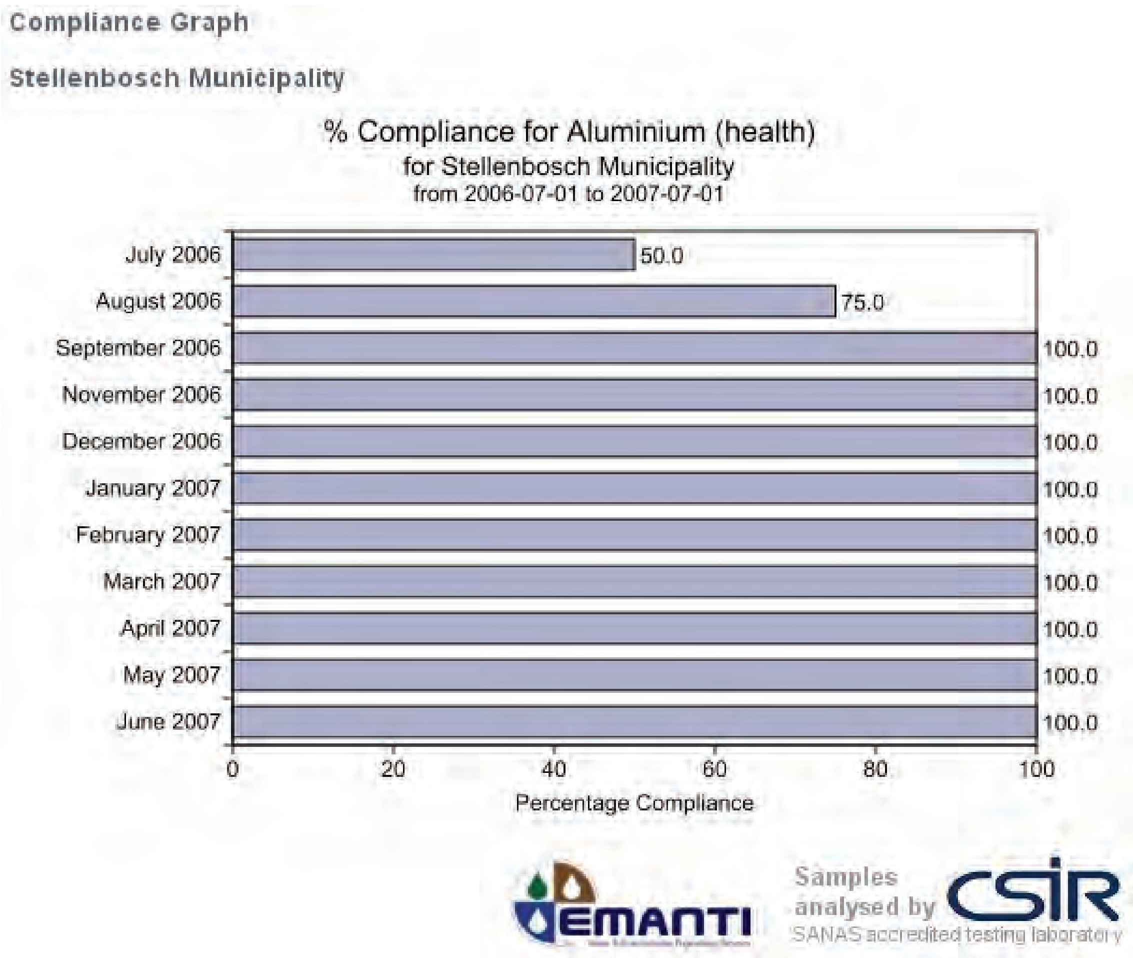


Figure 47: Area monthly compliance graph (Stellenbosch Municipality, Western Cape)

Reports (archive of water quality management reports in Adobe Acrobat format).

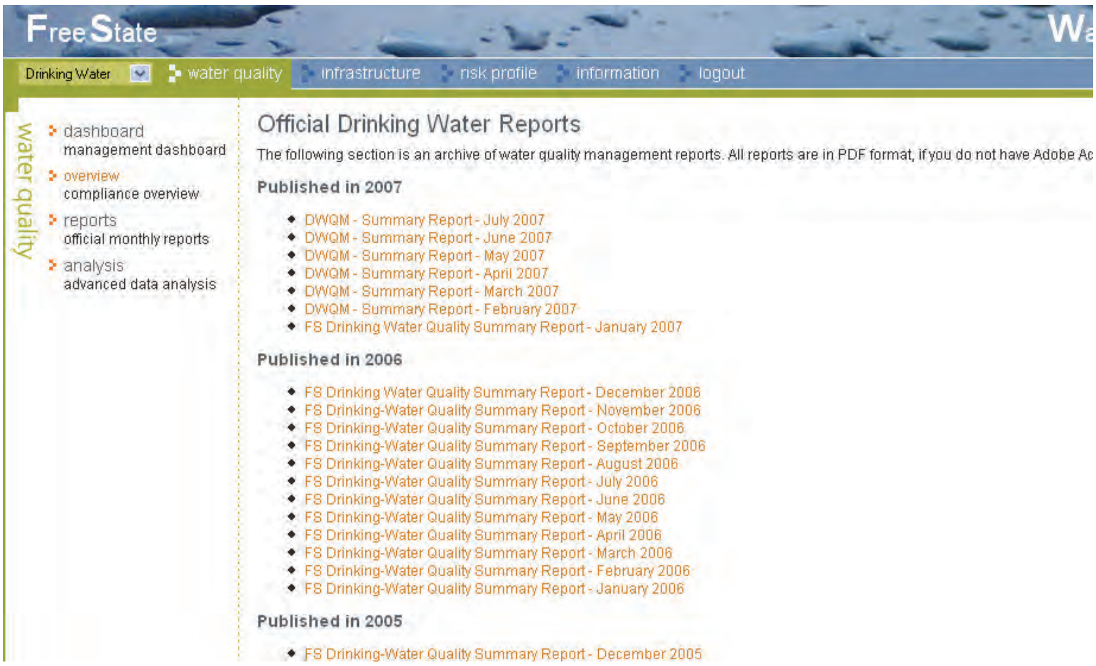


Figure 48: eWQMS reports (Free State)

Data Entry - mostly via internet and/or Excel, but patches exist and can be developed for to link to existing systems such as LIMS / UNIX / etc. for specific clients)

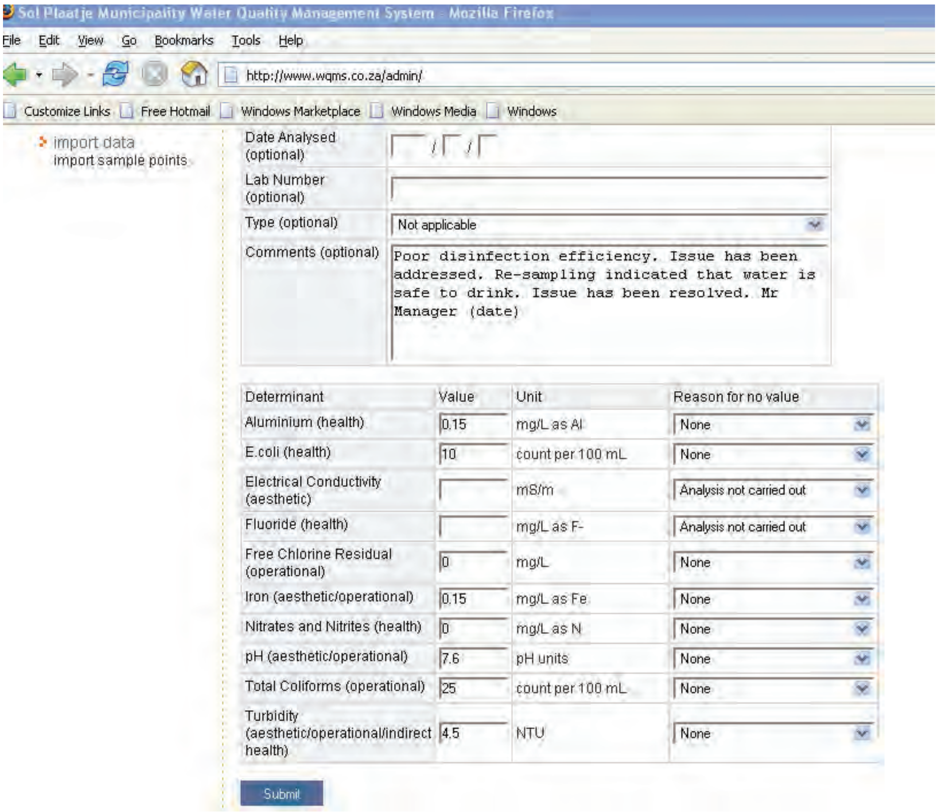


Figure 49: eWQMS data entry via the internet (Sol Plaatje, Northern Cape)

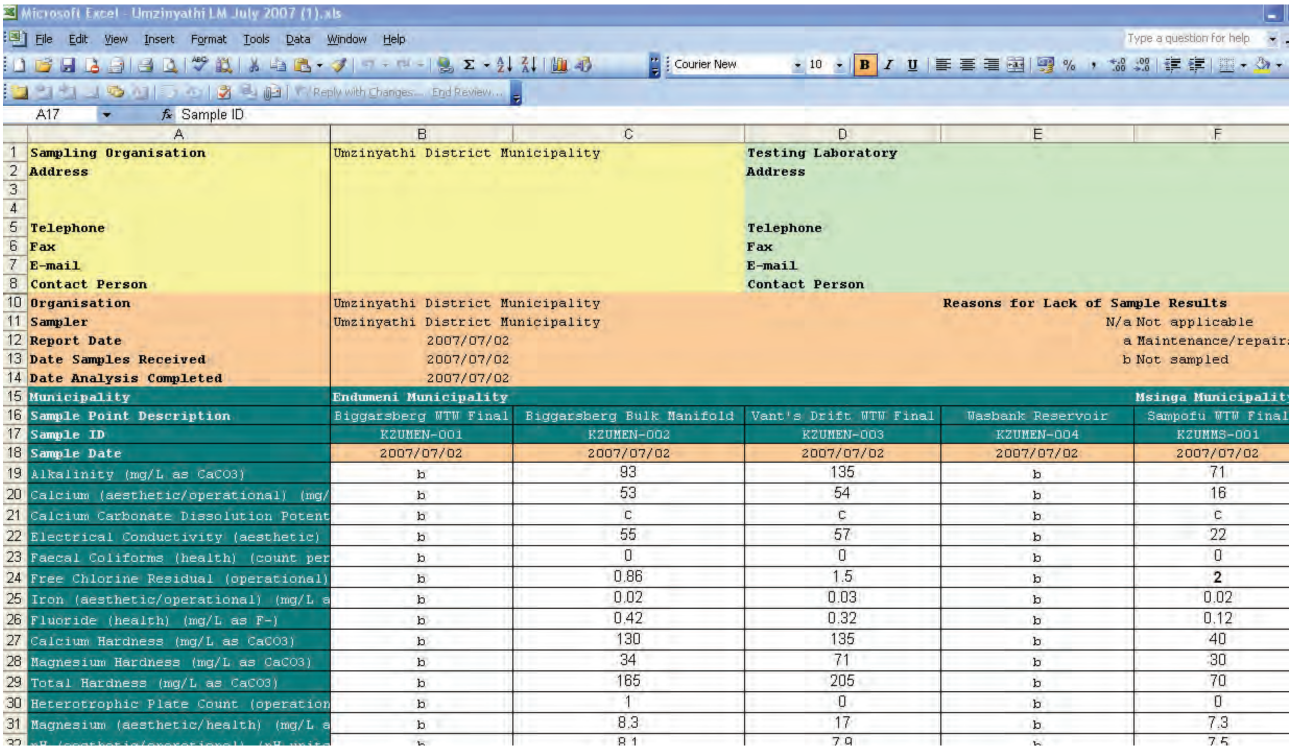


Figure 50: eWQMS data entry via spreadsheet (submitted via e-mail) (Umzinyathi Municipality, KwaZulu-Natal)

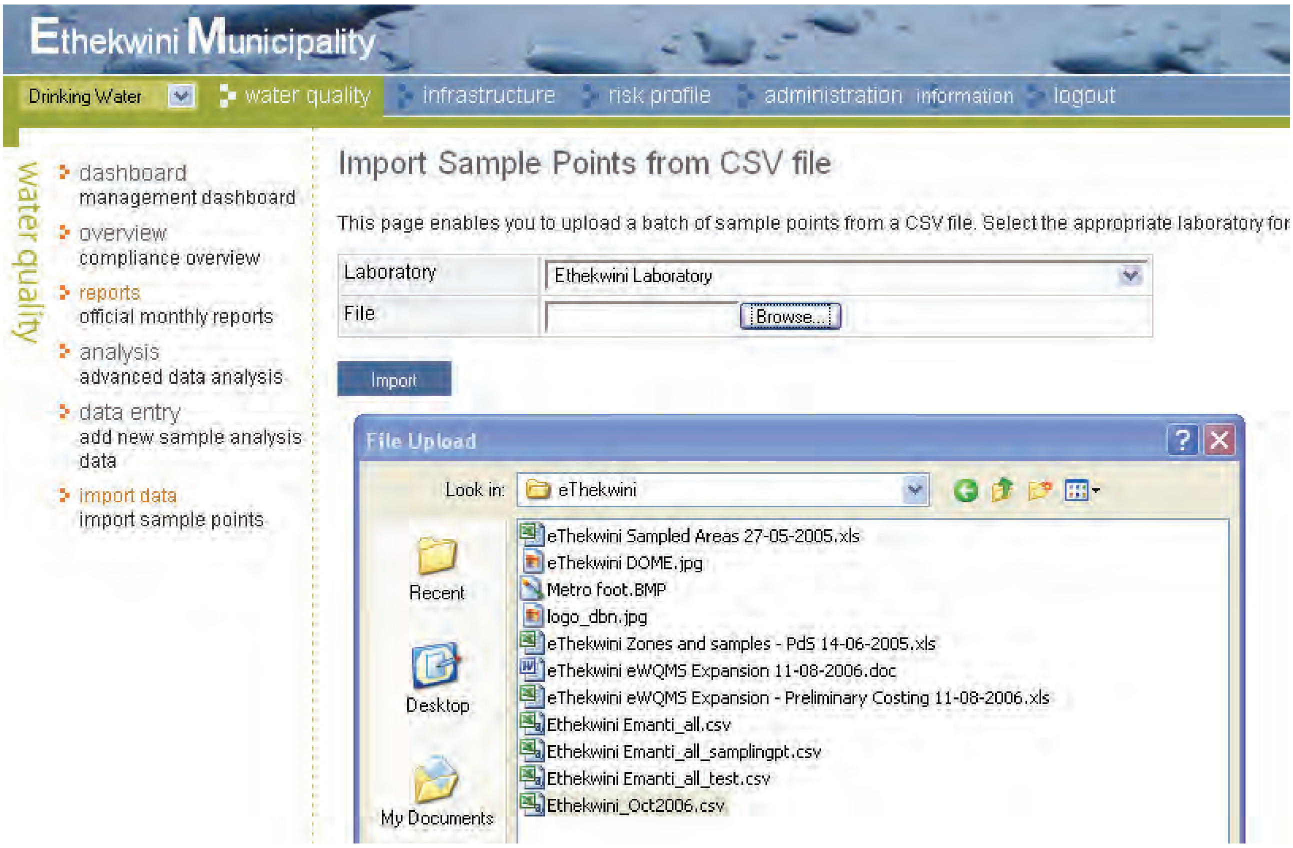


Figure 51: eWQMS data loading via import script/patch (Ethekwini Municipality, KwaZulu-Natal)

Automation (auto-notification by e-mail of failures, generation of auto-reports and summary reports for feedback to the full range of participating parties)

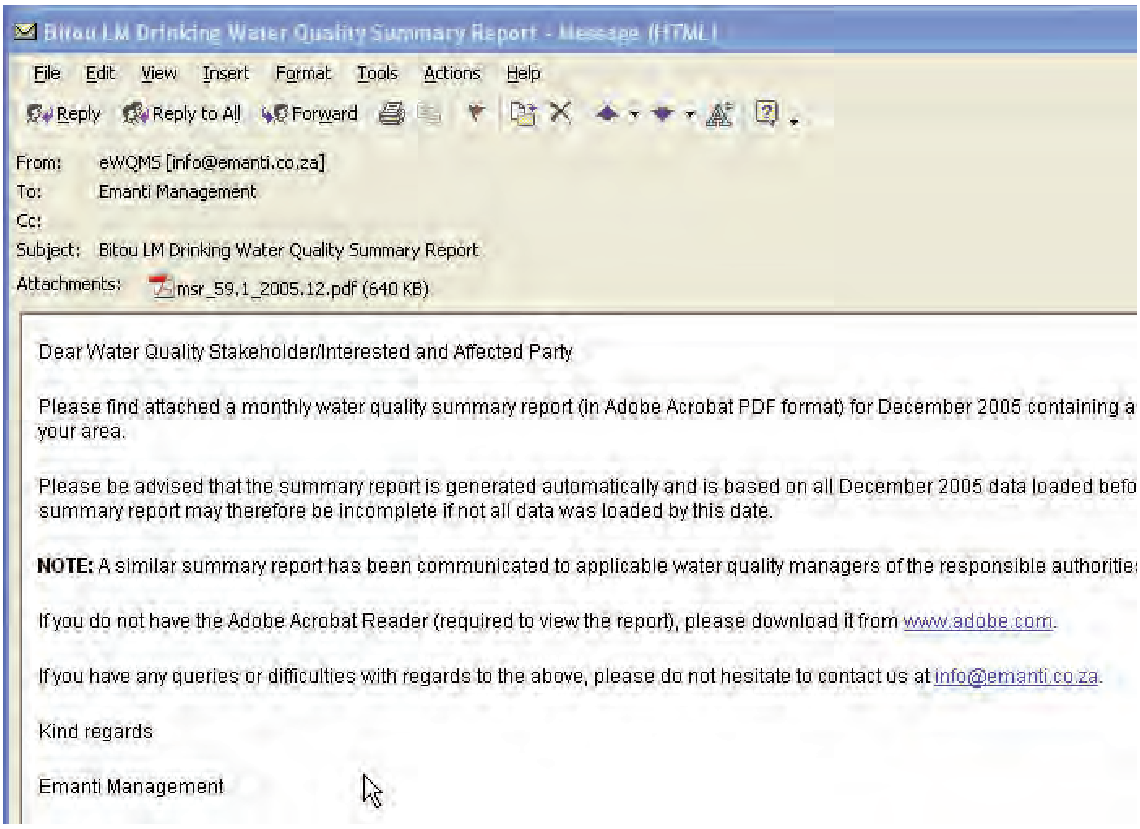
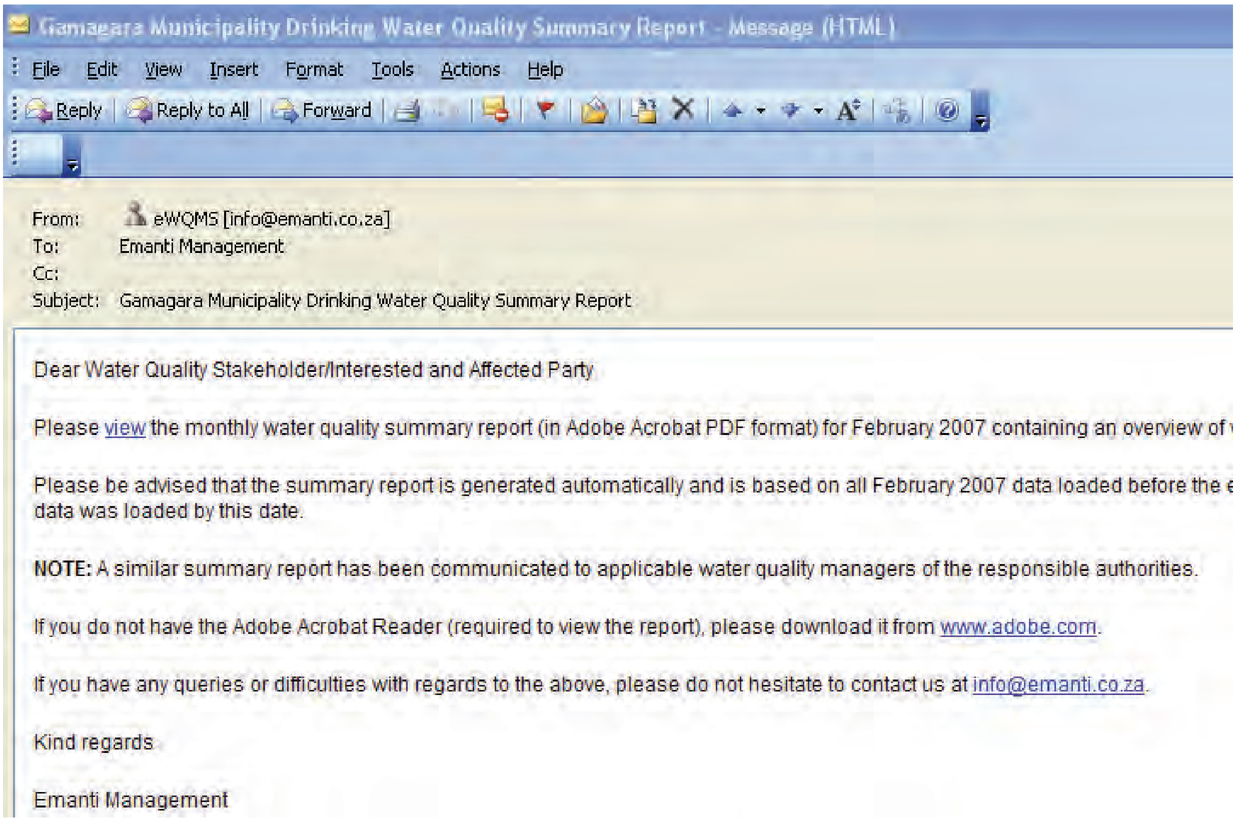


Figure 52: eWQMS e-mail with report as attachment ((Bitou Municipality, Western Cape)



Gamagara Municipality Drinking Water Quality Summary Report - Message (HTML)

File Edit View Insert Format Tools Actions Help

Reply | Reply to All | Forward

From: eWQMS [info@emanti.co.za]
To: Emanti Management
Cc:
Subject: Gamagara Municipality Drinking Water Quality Summary Report

Dear Water Quality Stakeholder/Interested and Affected Party

Please view the monthly water quality summary report (in Adobe Acrobat PDF format) for February 2007 containing an overview of

Please be advised that the summary report is generated automatically and is based on all February 2007 data loaded before the
data was loaded by this date.

NOTE: A similar summary report has been communicated to applicable water quality managers of the responsible authorities.

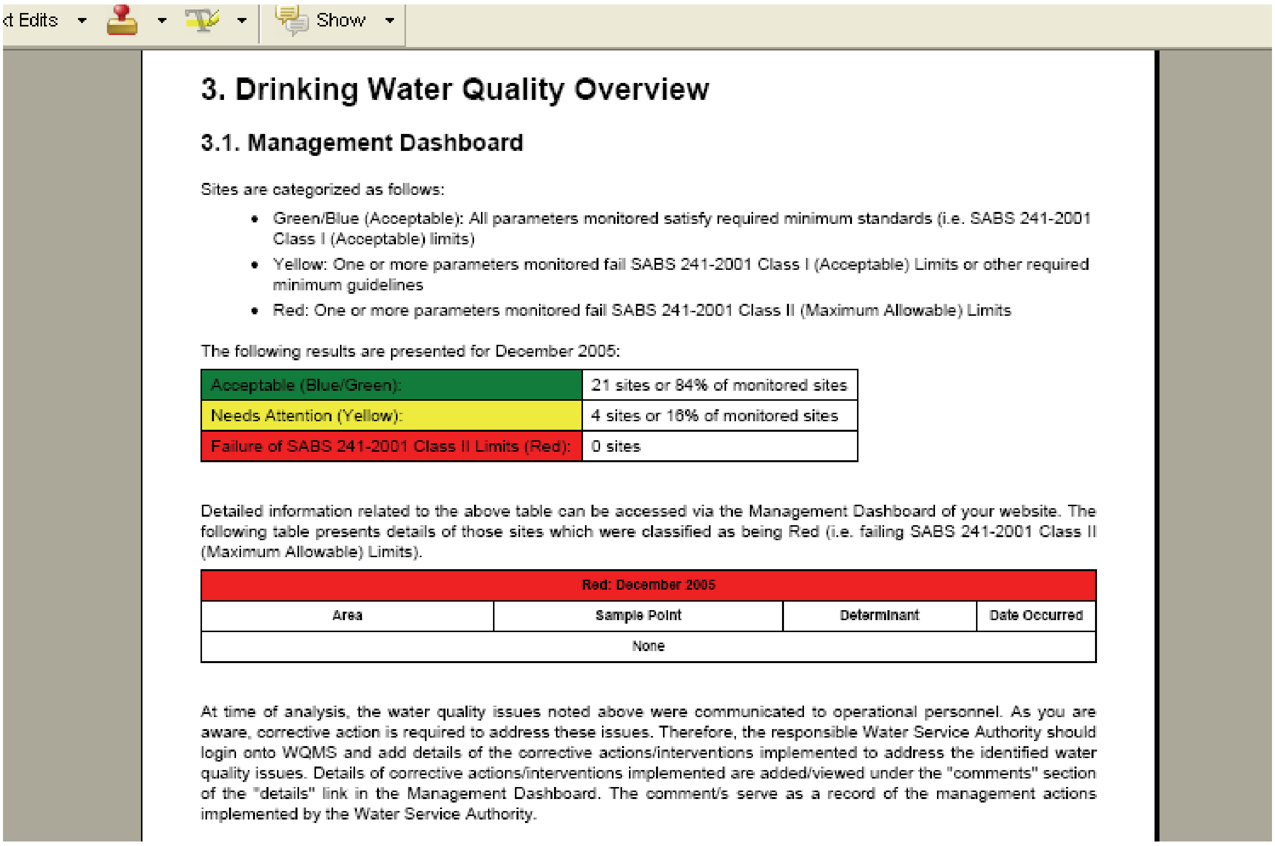
If you do not have the Adobe Acrobat Reader (required to view the report), please download it from www.adobe.com.

If you have any queries or difficulties with regards to the above, please do not hesitate to contact us at info@emanti.co.za.

Kind regards

Emanti Management

Figure 53: eWQMS e-mail with report accessible via internet link (Gamagara Municipality, Northern Cape)



t Edits | Show

3. Drinking Water Quality Overview

3.1. Management Dashboard

Sites are categorized as follows:

- Green/Blue (Acceptable): All parameters monitored satisfy required minimum standards (i.e. SABS 241-2001 Class I (Acceptable) limits)
- Yellow: One or more parameters monitored fail SABS 241-2001 Class I (Acceptable) Limits or other required minimum guidelines
- Red: One or more parameters monitored fail SABS 241-2001 Class II (Maximum Allowable) Limits

The following results are presented for December 2005:

Acceptable (Blue/Green):	21 sites or 84% of monitored sites
Needs Attention (Yellow):	4 sites or 16% of monitored sites
Failure of SABS 241-2001 Class II Limits (Red):	0 sites

Detailed information related to the above table can be accessed via the Management Dashboard of your website. The following table presents details of those sites which were classified as being Red (i.e. failing SABS 241-2001 Class II (Maximum Allowable) Limits).

Red: December 2005			
Area	Sample Point	Determinant	Date Occurred
None			

At time of analysis, the water quality issues noted above were communicated to operational personnel. As you are aware, corrective action is required to address these issues. Therefore, the responsible Water Service Authority should login onto WQMS and add details of the corrective actions/interventions implemented to address the identified water quality issues. Details of corrective actions/interventions implemented are added/viewed under the "comments" section of the "details" link in the Management Dashboard. The comment/s serve as a record of the management actions implemented by the Water Service Authority.

Figure 54: Extract from an automatic monthly summary report

Infrastructure Captures WSA infrastructure details related to abstraction points, treatment systems, storage facilities (e.g. reservoirs), reticulation/point of use (e.g. sampling points), DWQM Programmes (frequency of monitoring, parameters, etc.) and laboratories utilised.

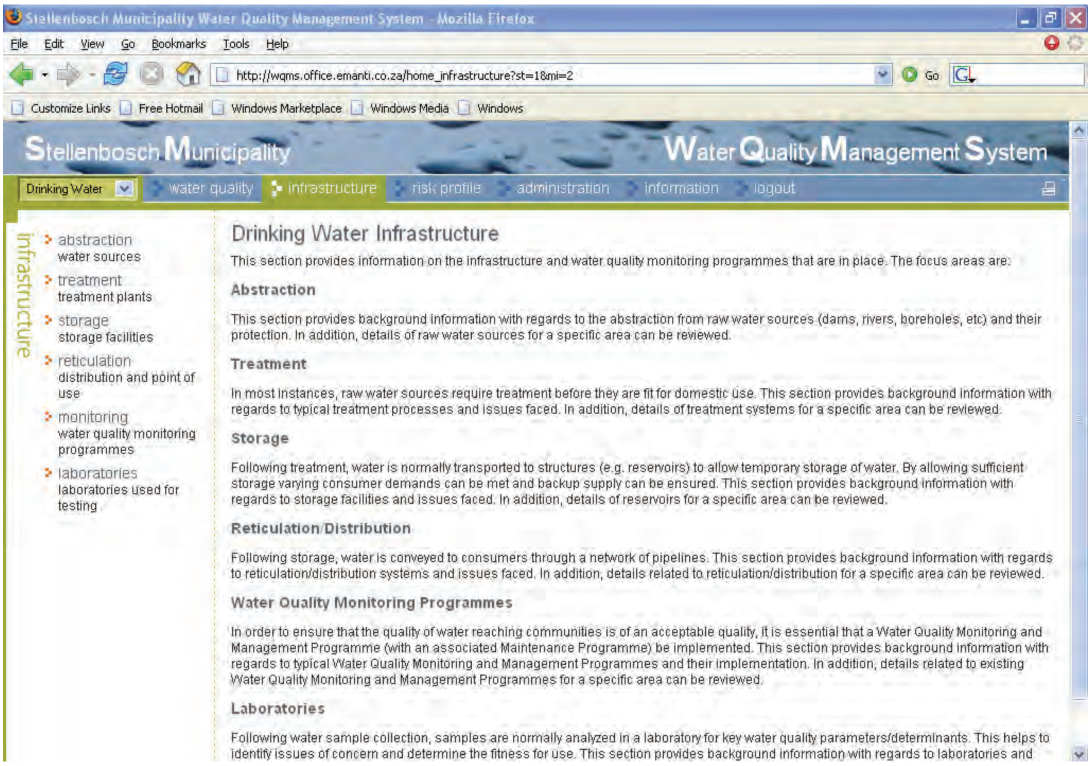


Figure 55: eWQMS Infrastructure component

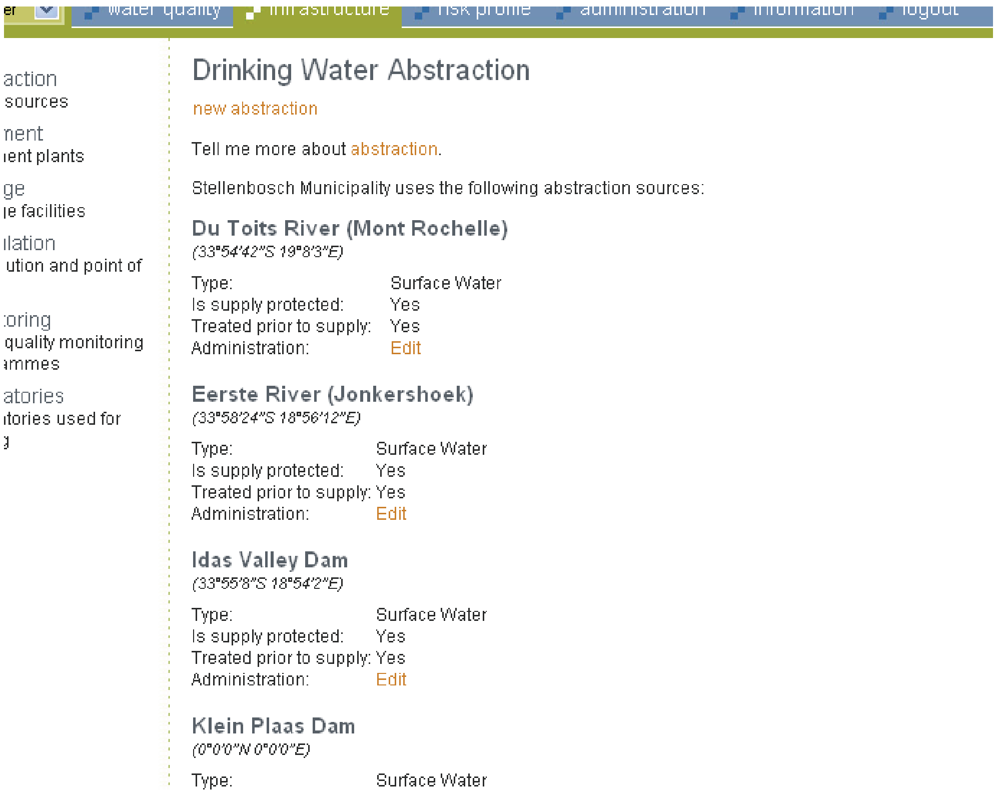
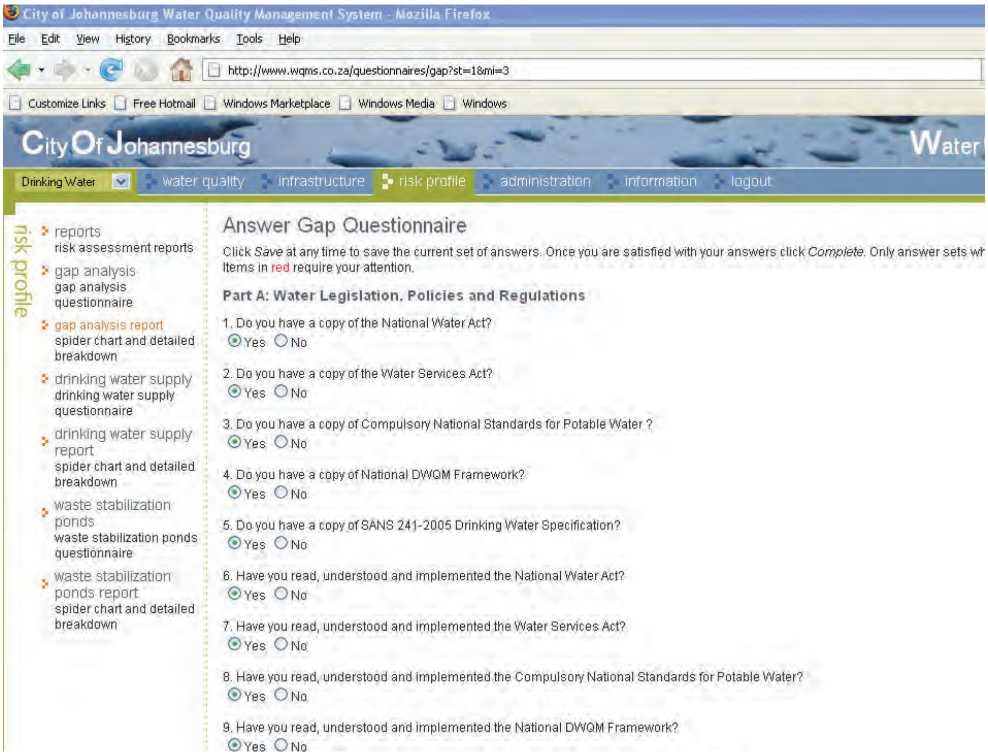


Figure 56: Example of raw water abstraction details on the eWQMS (Stellenbosch Municipality, Western Cape)

DWQM Risk Profiles Assessment tools have been introduced which allow WSAs to perform a self-assessment of the status of their WSA. Examples include a strategic level WQM Sustainability Analysis (Gap Analysis) and a Water Research Commission "Drinking-Water Treatment Plant and Distribution Network Assessment and Risk Profile" system.



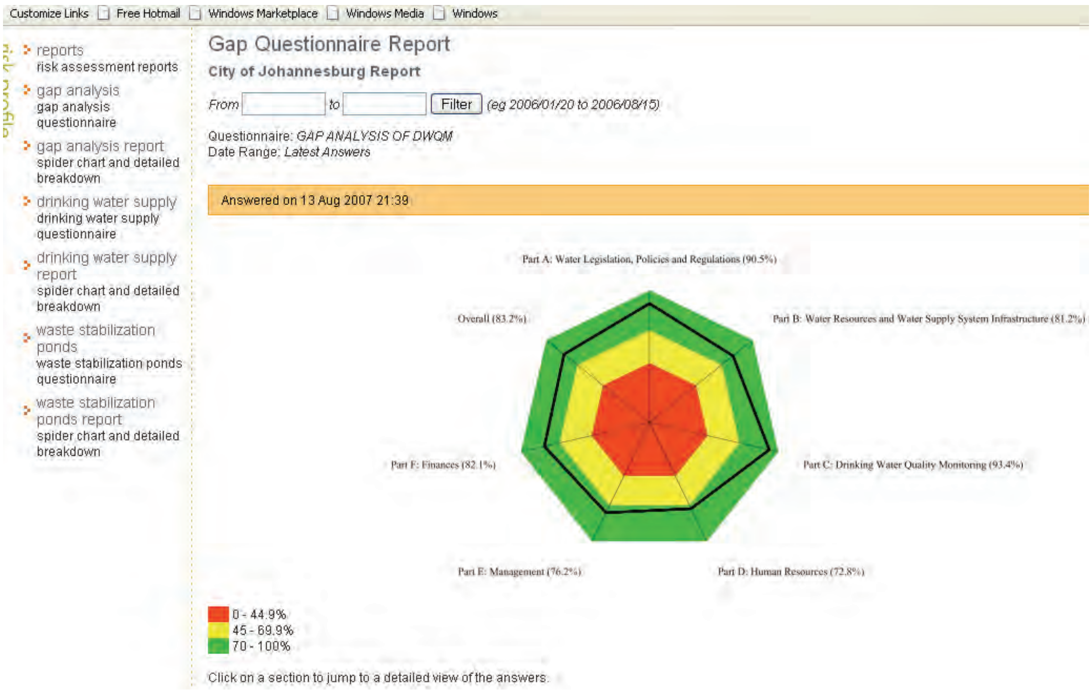
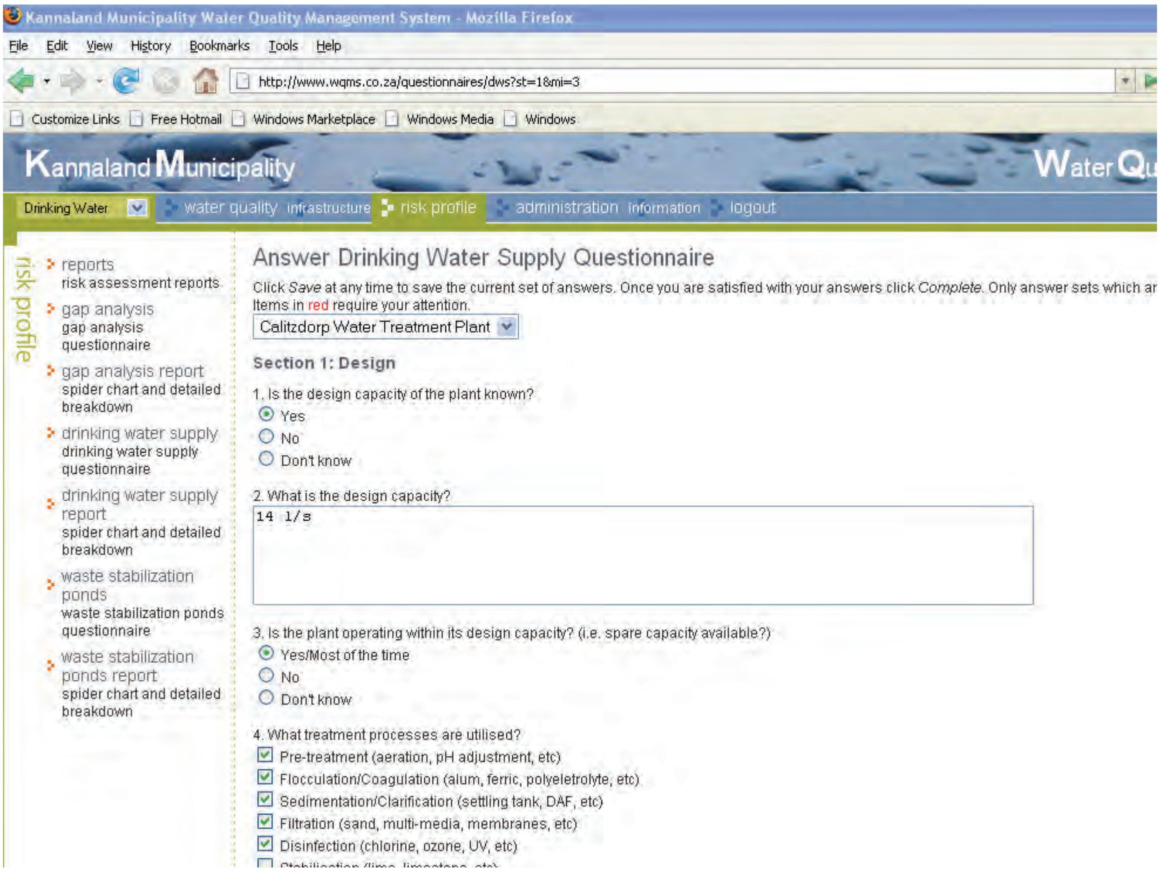


Figure 57: Gap analysis questionnaire and spider diagram output (City of Johannesburg, Gauteng)



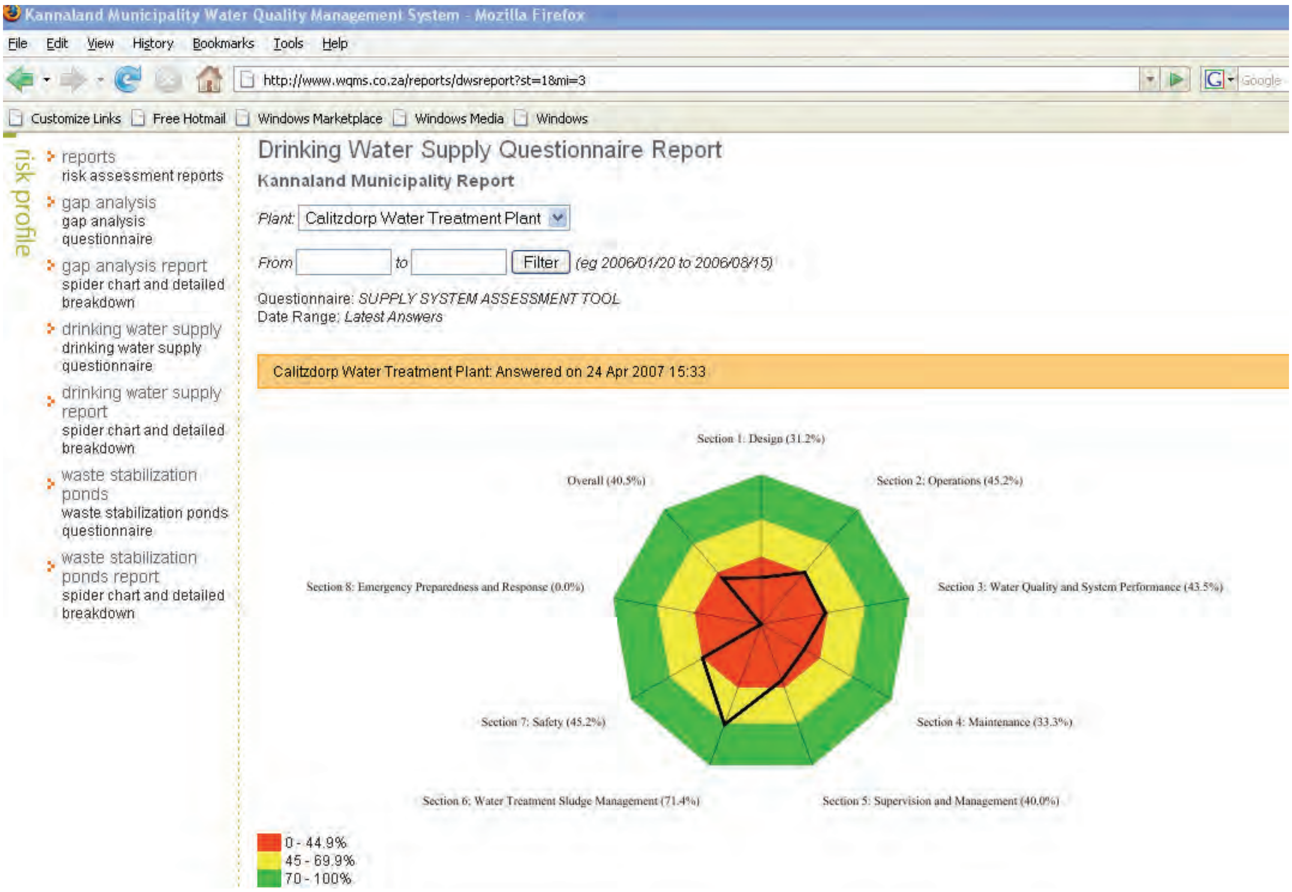


Figure 58: Water supply system questionnaire and spider diagram output (Kannaland Municipality, Western Cape)

Administration Current WSA functionality includes the ability to manage sample points (add new/edit existing), manage recipients/distribution lists for automated communications, manage required automatic notifications (e-mail, summary report), data entry (water quality, infrastructure, etc.) and ability to add comments related to drinking-water failures and actions taken to address issues of concern (i.e. comments serve as an action record taken to address issues of concern).

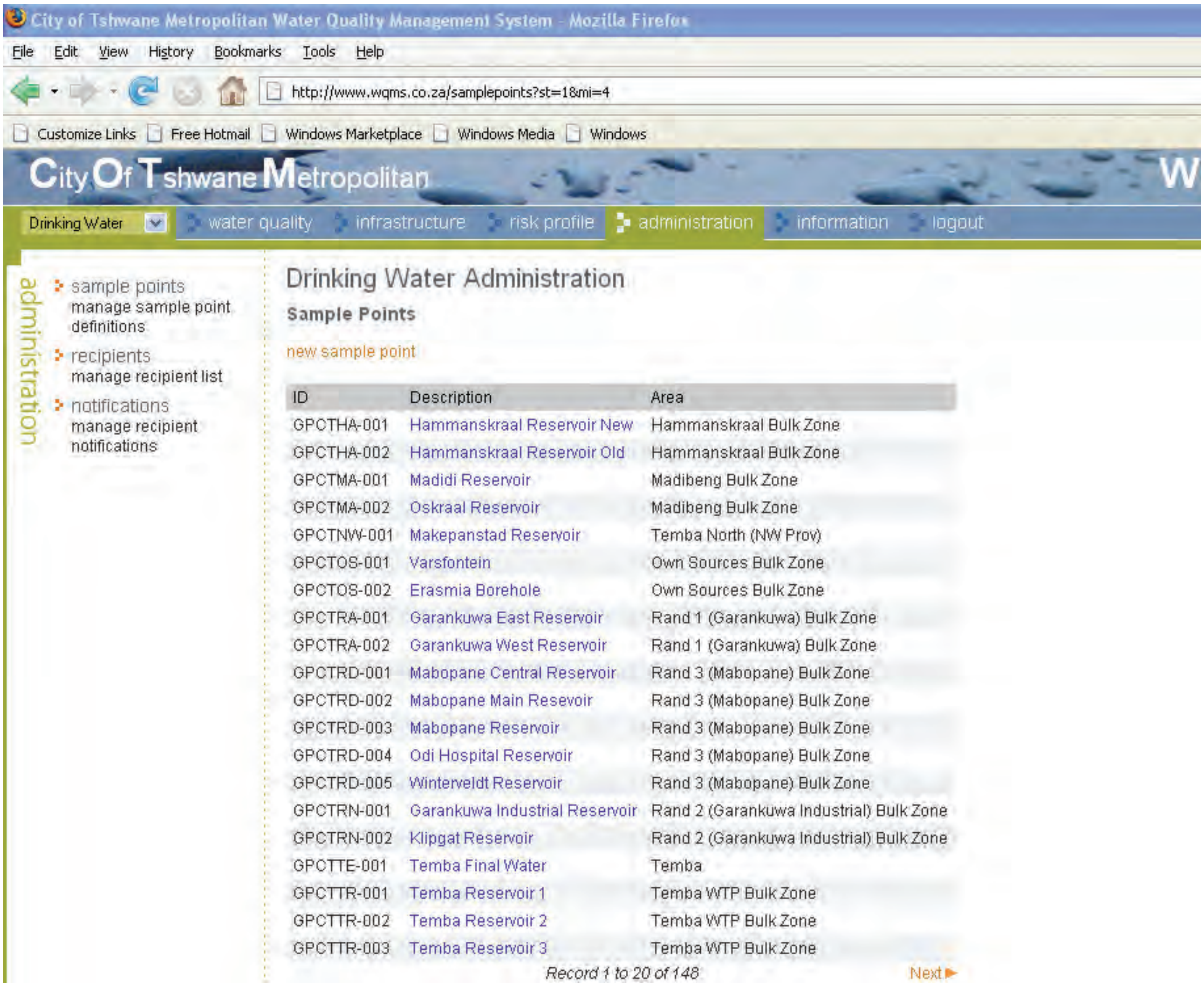
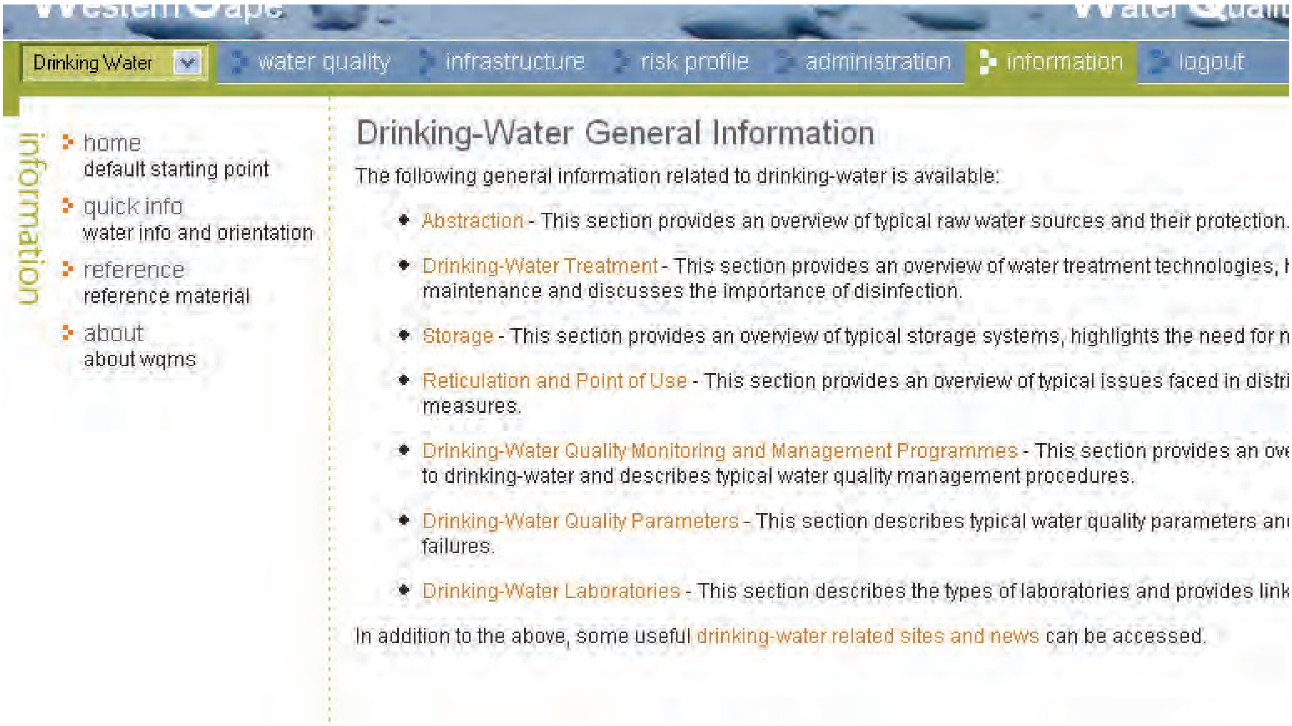


Figure 59: Sample point administration (City of Tshwane, Gauteng)

Guiding Information Current functionality includes a convenient repository of drinking-water related information including: abstraction, treatment, storage, reticulation and point of use, Water Quality Monitoring and Management Programmes, water quality parameters, their effects and how to rectify issues, laboratories, water related sites and news and References including National Water Act, Water Services Act, Compulsory National Standards for DWQ, National DWQM Framework, etc.



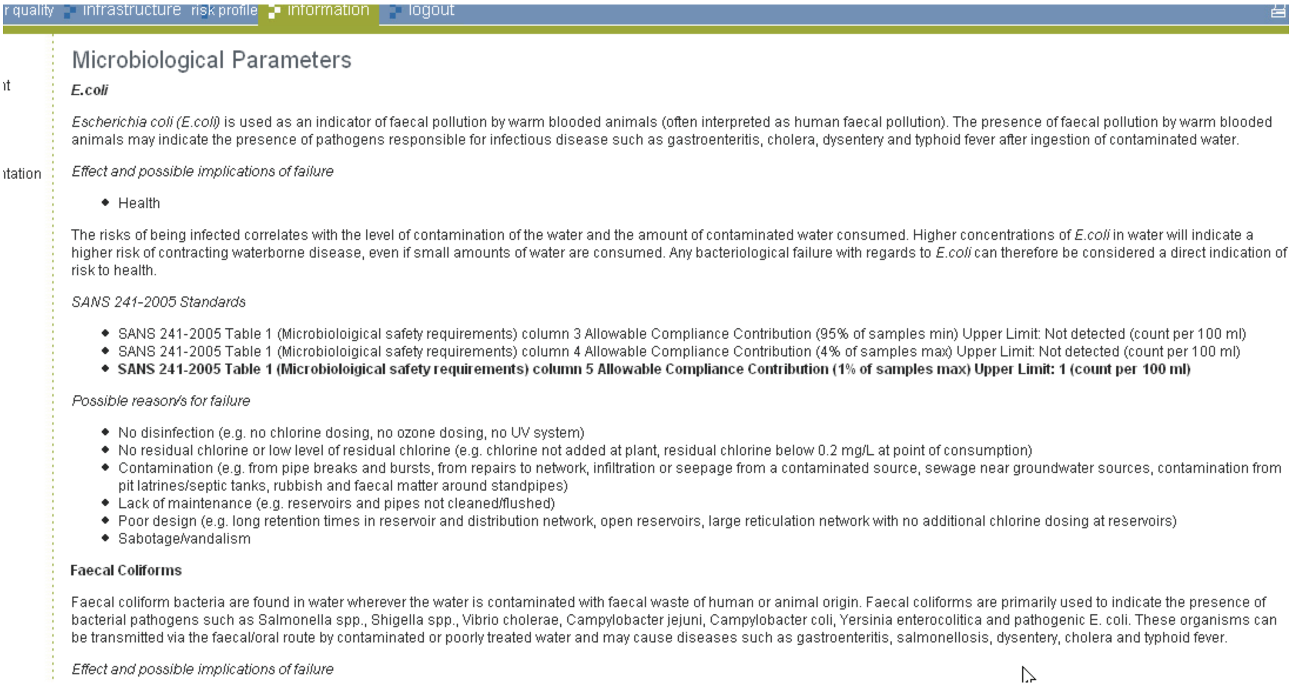
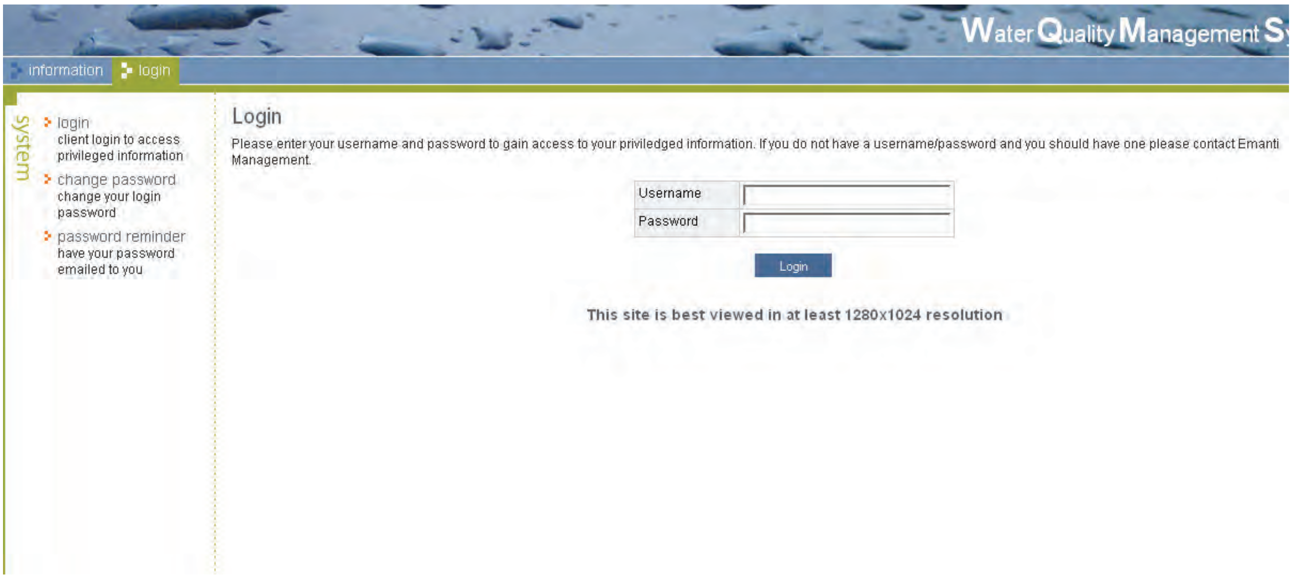


Figure 60: Information examples

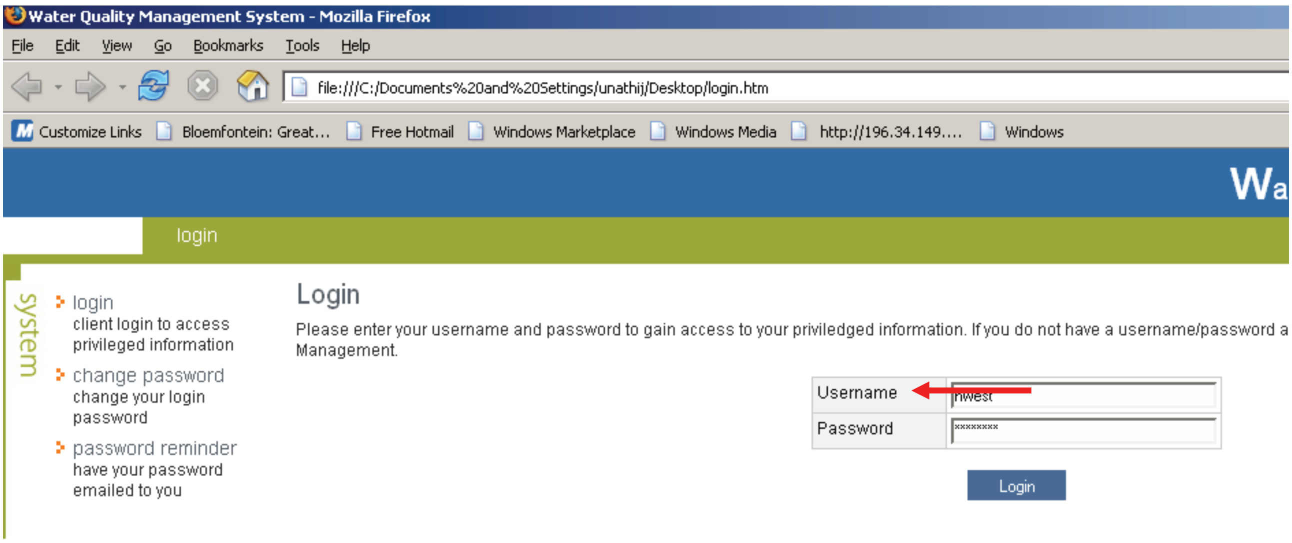
7.4 Step-by-Step Guide of How to Use the Drinking-Water Supply System Assessment Tool

Step 1: Accessing the eWQMS

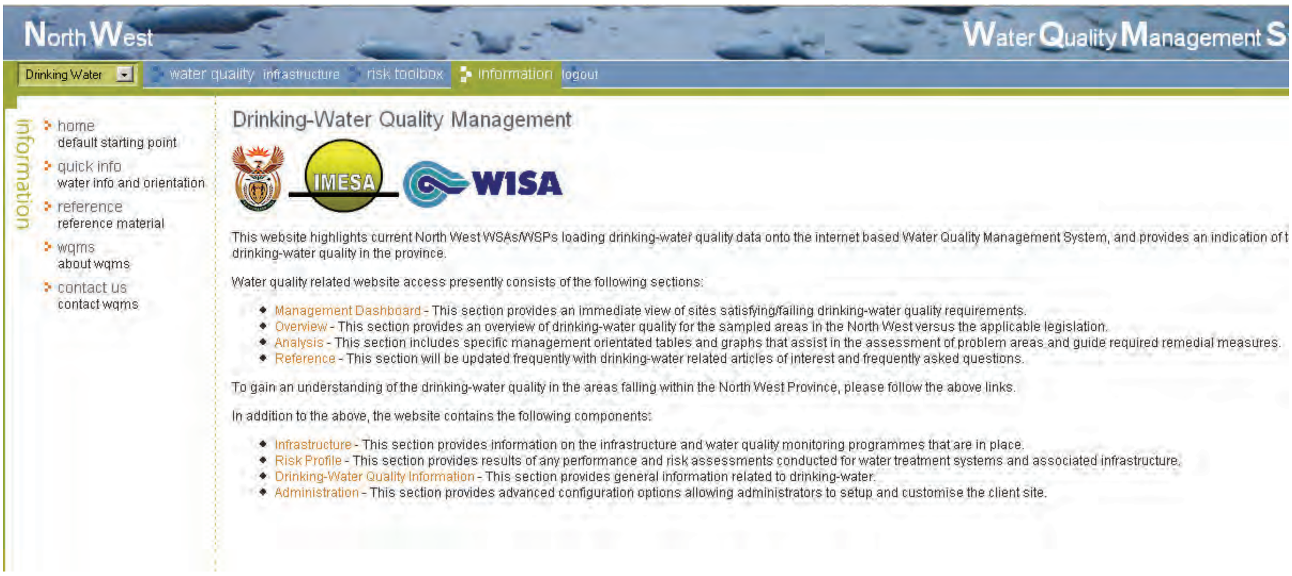
Make sure you are connected to the internet. Go to www.wqms.co.za. The following screen prompting a username and password should appear.



Fill in your username and password as required. If you don't know the username and password please contact your Municipal Technical Director or Manager for those details. Alternatively contact info@emanti.co.za and request login details.

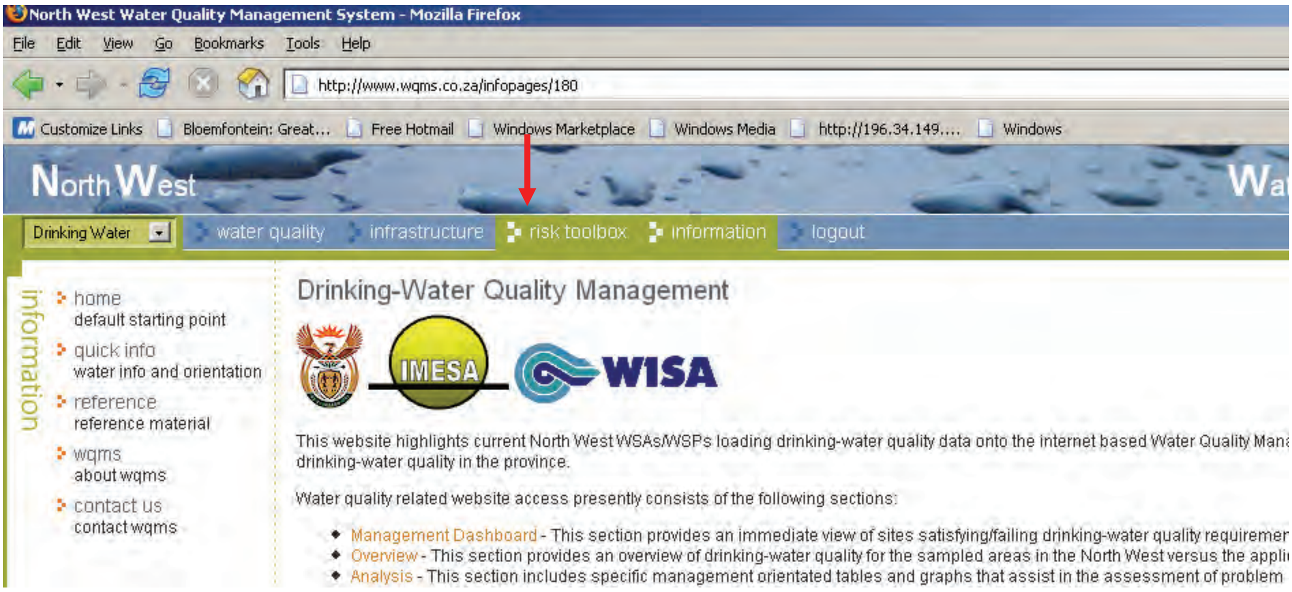


Once logged in; the name of your municipality or logged client appears on top with all the features of the eWQMS.

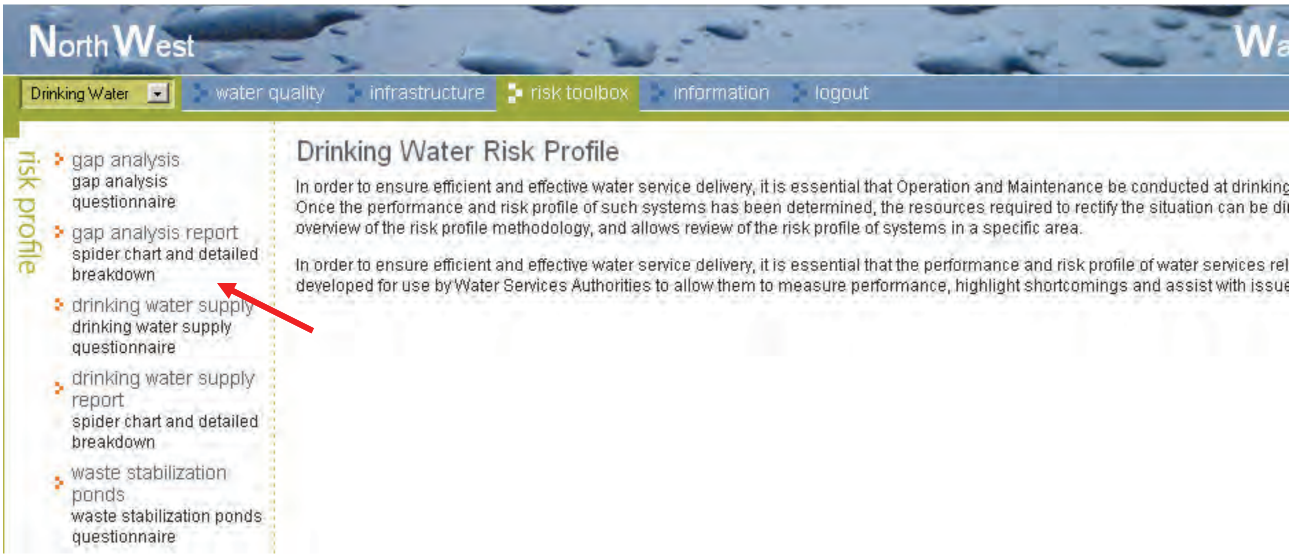


Step 2: Accessing the Supply System Assessment Questionnaire

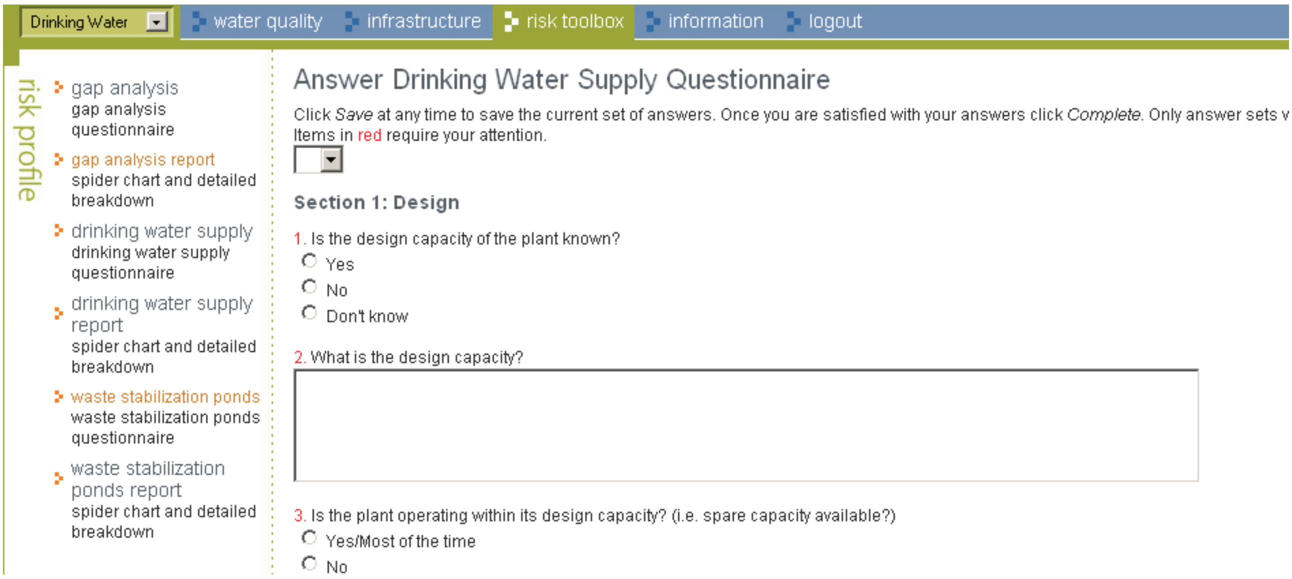
On the top menu, click risk toolbox as indicated below.



The screen shown below should appear. On the left hand side of the screen click drinking-water supply questionnaire.



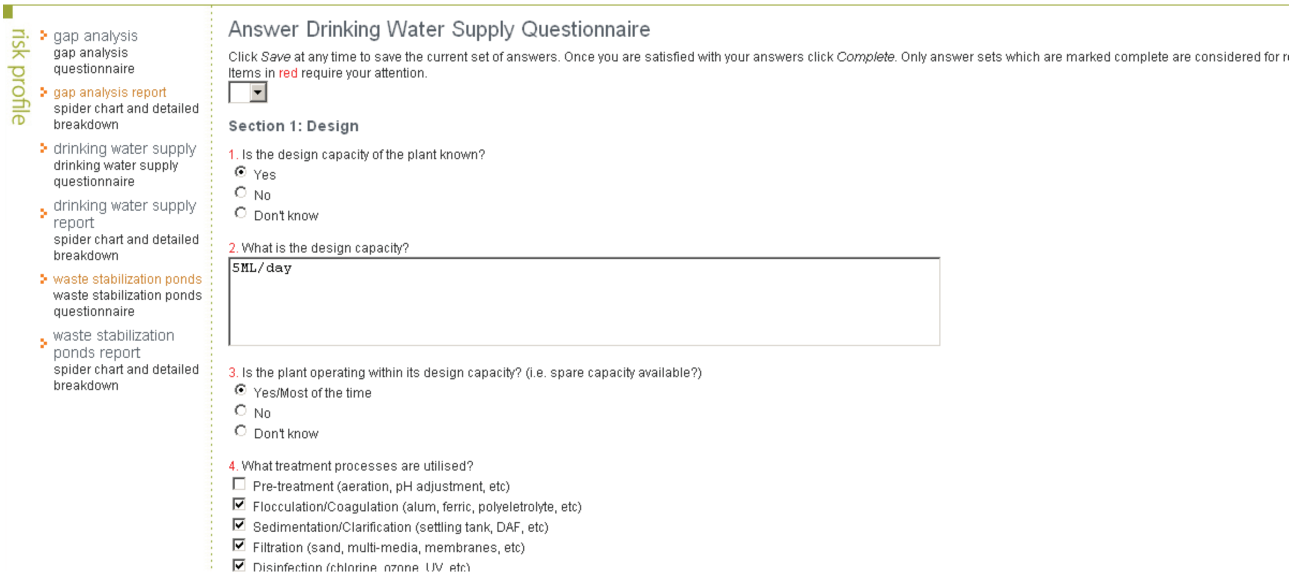
A screen showing the questions should appear as shown below.



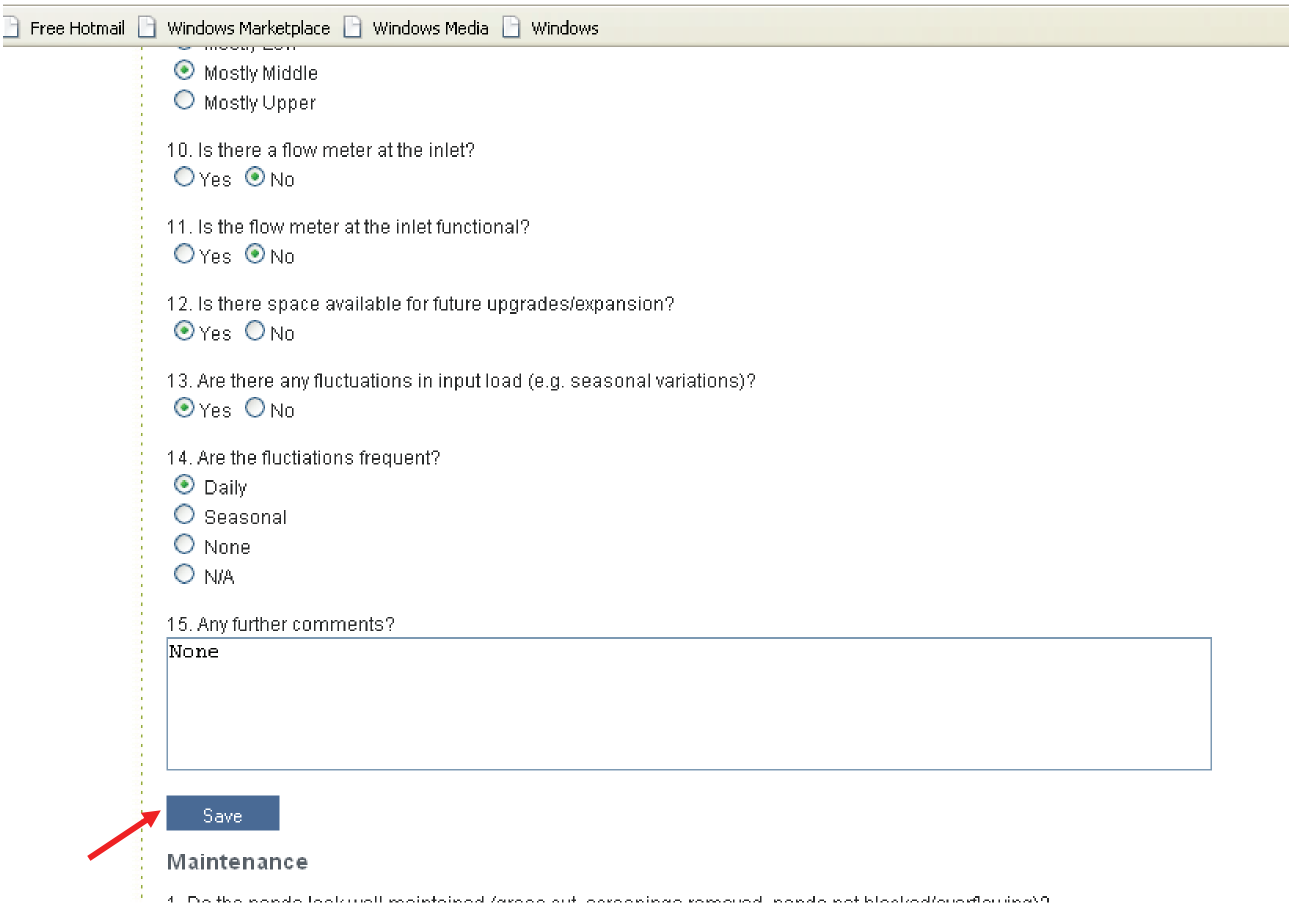
Step 3: Loading information for the Supply System Assessment Tool

NOTE: Before the questionnaire can be completed, a site visit of the drinking water supply system facility is required. It is advisable that a copy of the questionnaire be printed out prior to the site visit. This can then be pre-completed during the site visit for population once back at the office.

Once you have all the information, fill in the questionnaire by clicking on the possible provided answers as shown in the example below. Answer all questions. (***NOTE:*** If an answer is not known, please indicate "don't know". To receive an output, all questions MUST be filled in)

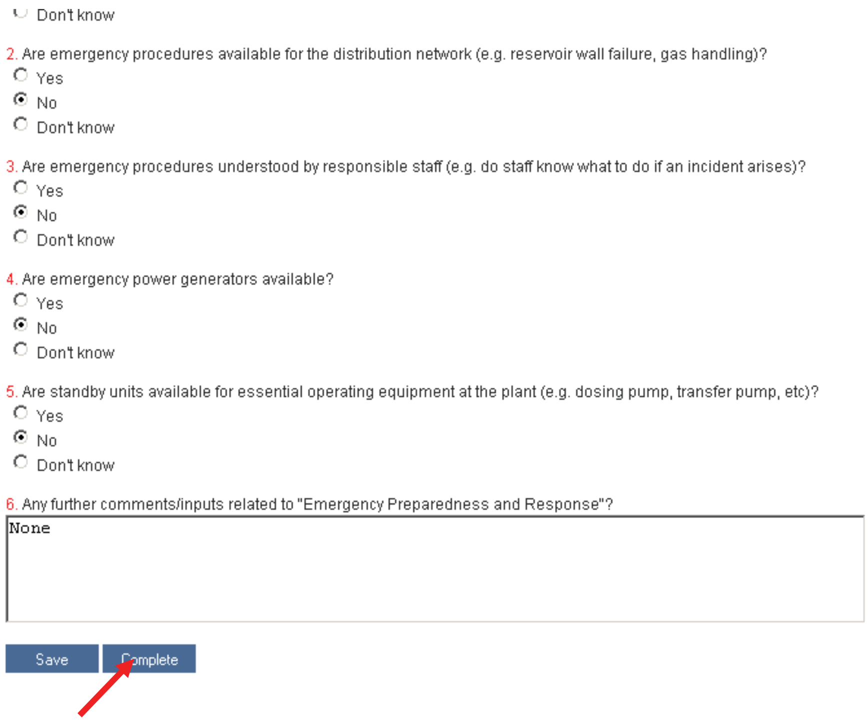


Complete each section and then click the "save" button at the end of each section. ***NOTE:*** The "save" button can be clicked at any stage, for example, after completing only 2 or 3 questions. It is where recommended that the save button is clicked at least every 10 minutes, and more frequently if you are in an area with variable internet connection speed/poor connectivity.

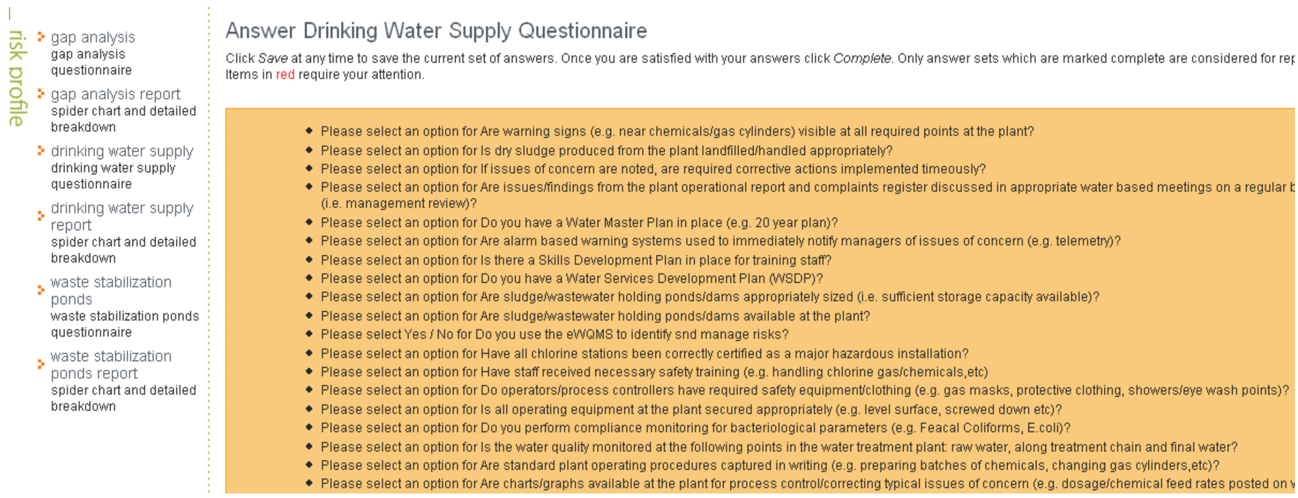


Step 4: Completing the Supply System Assessment Questionnaire

Once you have completed all sections click the complete button at the end of the questionnaire.



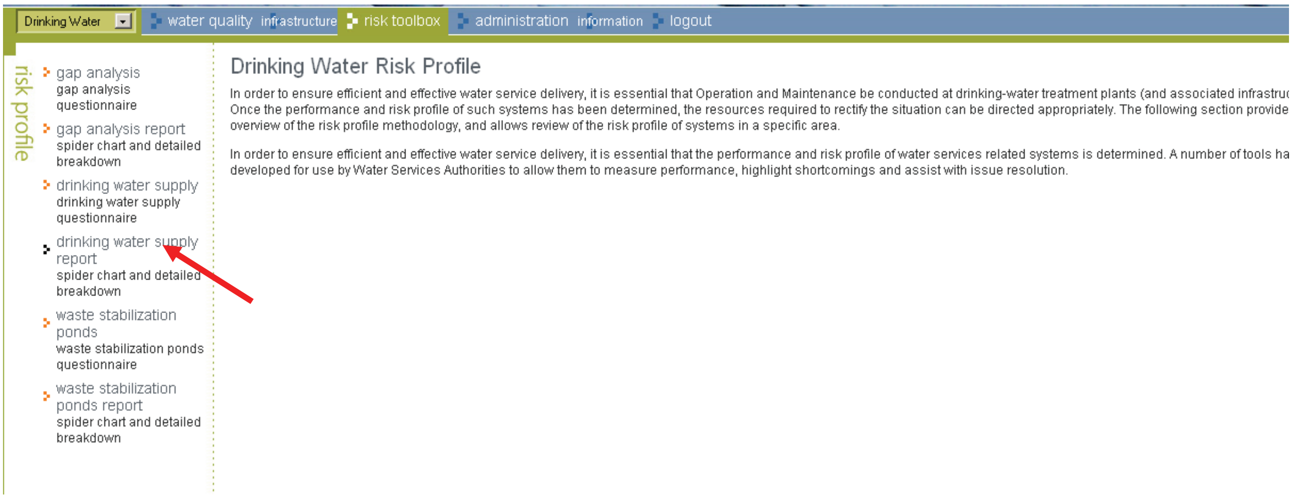
If there are questions that are not filled in or incorrectly filled in, an error message will appear.



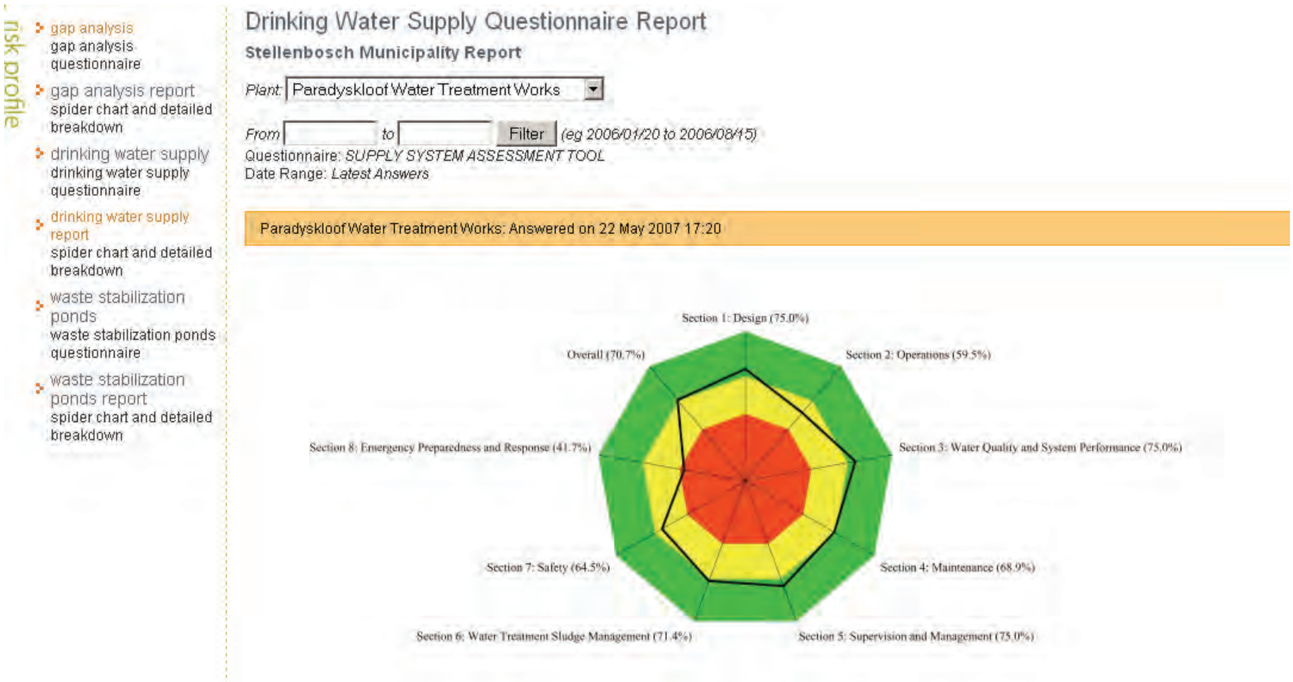
If you have successfully completed the questionnaire, then you are able to view the Supply System Assessment Tool report.

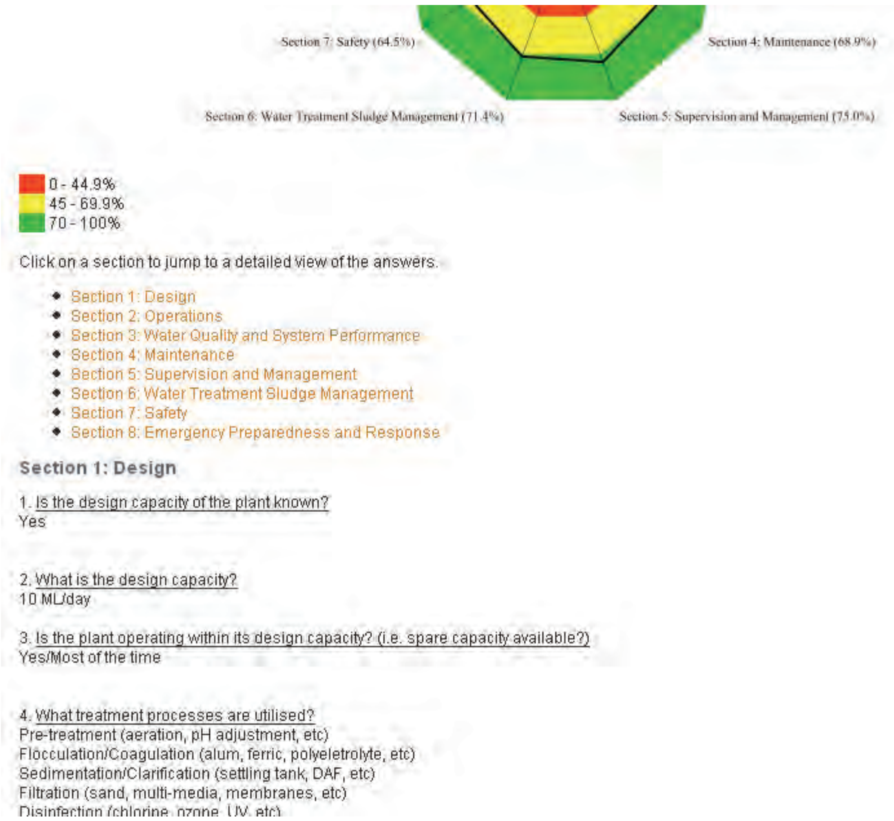
Step 5: Accessing the Supply System Assessment Tool report

Once you have successfully completed the questionnaire, access the report by clicking on the available link.

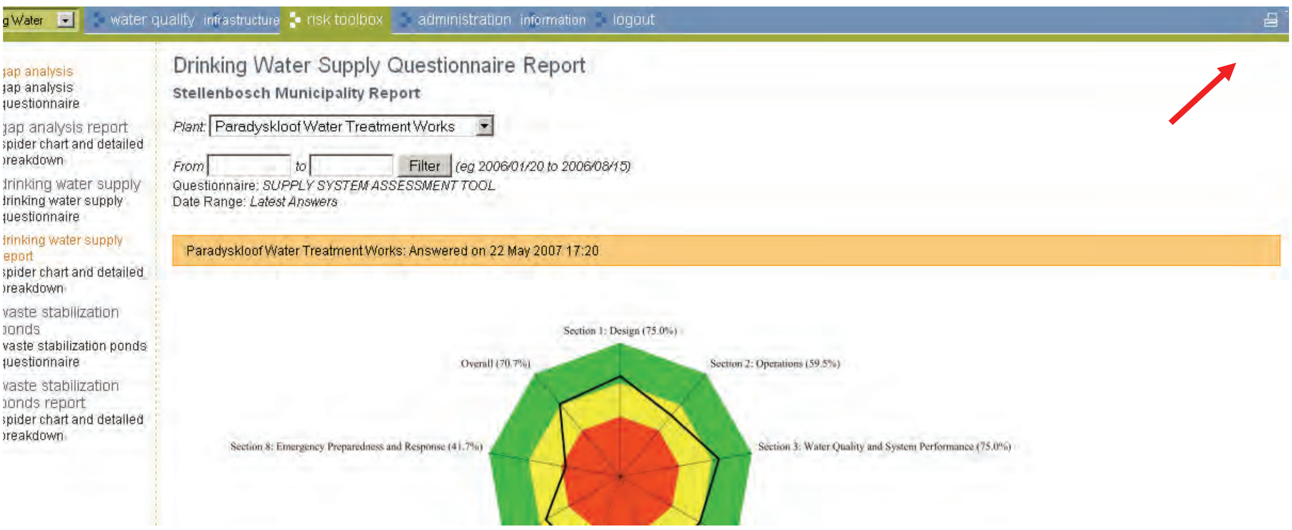


The report should automatically generate with a “spider-diagram” and associated supporting text (questionnaire answers).





To generate a print friendly version of the report, click on the printer icon in the top right hand corner.



8. ROADSHOWS

8.1 Objectives

One of the objectives of the study is to carry out an educational/awareness roadshow. Given the poor recognition of the value of effective drinking-water quality management, it is necessary that all officials responsible for the provision of a safe drinking-water supply are made aware of the need for effective monitoring and management of water services and issues faced and interventions required.

This was carried out by conducting workshops that address the following:

- Introduction to the supply system assessment tool
- How to access the system from eWQMS
- Benefits of the tool to the WSA
- Frequently asked questions from the visits
- Key issues identified from visits
- Challenges faced by municipalities.

8.2 Who was invited and or participated?

In terms of invitations, the following people were targeted and invited

- All Water Services staff of the three provinces of Eastern Cape, Free State, Western Cape
- Drinking water quality champions at Provincial Government, including LGH, DOH, etc.
- DWAF Water Services Staff
- WISA and IMESA members of the Free State chapters
- People from scientific services
- Environmental health practitioners of the three provinces
- Municipal councillors.

Western Cape comprises of 20 WSAs where 17 were presented at the workshop. The participants ranged from mayors, technical managers, superintendents, foremen, process controllers, plumbers, consultants and environmental health practitioners. More than 90 percent of the audience was technical people who deal directly with water services issues.

Eastern Cape comprises of 17 WSAs where 7 were presented at the water services forum meeting. More than 90 percent of the delegates were environmental health practitioners and people from the laboratory services.

Free State comprises of 20 WSAs where 5 district and 5 WSAs as local municipalities were presented. More than 90 percent of the delegates were from the department of health and environmental health practitioners.

Generally people from the following fields attended the workshops:

- DWAF Water Services Staff
- Water Boards
- Scientific or laboratory services
- SALGA
- Consulting Engineers
- Department of Health and environmental health

8.3 Key issues from interactions

The discussions were highly technical though most participants are not in the decision making positions which could result in some issues not properly addressed. The following were general issues of concern

- Councilors should have been part of such discussions. There is a strong feeling that councilors need to be workshopped in water services issues so as to prioritize.
- Lack of capacity issue was highlighted as one factor that could result in water quality failures.
- Training of staff was identified to be becoming difficult as training colleges are no longer offering training on water services.
- A need to ring fence water services was identified.
- Motivation of staff in the process controller's position was identified to be lacking.
- Irregular and/or insufficient communication between the process controllers and management.
- Lack of skill and knowledge at the management level could result in people on the ground suffering therefore resulting in water services failures.
- Insufficient process controllers seem to be a general problem. Process controllers were identified to be working unreasonable overtime with no leave. In case where process controllers have to attend a course or sick someone from other department is used as a replacement.
- Lack of career path in the water services field was identified.
- Emergency funds were identified not be easily made available by the municipality.

Experiences from other provinces have shown that there are issues that need to be addressed and well understood by responsible people in the water services. Therefore 6 questions relating to those issues were posed to the attendees where there should be an indication as "agree, unlikely and disagree". The questions were:

1. Tap water is of high quality and almost always safe for consumption
2. Provision of safe drinking water quality is a high priority and well funded
3. Municipality has adequate skills and capacity to ensure provision of safe drinking water
4. My municipality oversees a holistic drinking water quality management programme
5. My municipality allows for the easy dissemination of drinking water quality information by consumers
6. My municipality communicates any health threats that may arise from time to time

The results obtained from these questions are shown below in Table 15.

Table 15: *Free State results from 6 specific questions*

	Question	Agree	Disagree	Unlikely
Q1	Tap water is of high quality & almost always safe for consumption	82	11	7
Q2	Provision of safe DWQ is a high priority & well funded	6	76	18
Q3	Municipality has adequate skills & capacity to ensure provision of safe drinking-water	5	9	86
Q4	My Municipality oversees an holistic DWQ Management programme	0	64	36
Q5	My Municipality allows for the easy dissemination of DWQ info by consumers	0	7	93
Q6	My Municipality communicates any health threats that may arise from time to time	11	6	83

8.4 Common Challenges

The common challenges that could result in municipalities failing to deliver were identified as follows:

- Interpretation of legislations is difficult. Legislations normally require things that are very difficult to comply with.
- Operations and maintenance such as aging infrastructure, concentration on new infrastructure and ignoring or unawareness of the existing infrastructure.
- Use of potable water to irrigate and other things whilst water demand is becoming a problem.
- Lack of dedication and skill from personnel at the supervisory positions. There's lack of interest from people on-site in training if there won't be change in salaries.
- Running capacity of most plants is exceeding the design capacity.
- Raw water quality vs. design.
- Lack of capacity in terms of skills, training needed by personnel in the water services field due to financial constraints.
- Political complications result in water services team functioning under stress.

8.5 What needs to be done

The challenges faced within the water services team were discussed. With those in consideration, suggestions were given in order to close the gap.

- DWAF and WSAs should enforce policies.
- Water demand management should be taken into consideration.
- Groundwater protocol should be followed.
- Avoid spillages that end up contaminating water resources.
- Asset management needs to be followed.
- The constitutional right to inform the public about water issues should not be overlooked.
- Training of people needs priority. A suggestion to make training mandatory was mentioned. Need for improvement every time.
- Alignment of responsibilities with positions should be considered.
- WSAs need to have a plan for emergencies.
- Workplace skills plan should include training programmes.

- There is a need to do more to motivate process controllers on site. When giving incentives, they should be linked to level of training.
- WSAs need motivation from other partners such as DWAF and LGH.

8.6 Good practices

The following were suggestions and/or information sharing about what is practised in some municipalities:

- Grievances by the process controllers are discussed between supervisors and process controllers then they are taken to the management.
- For smaller towns, communication related to water services (e.g. boil water alerts, interruptions) is distributed by means of pamphlets and by the word of mouth (i.e. is a car going around announcing on the loudspeaker). For lager cities, broad based communication such as radios and newspapers are used.
- eWISA system is used for asset management.
- To ensure presence of process controllers onsite, a push button on telemetric system that reports at certain times is used.
- As means of motivation, some municipalities nominate the best town of the year based on WQ and response to failures in water quality performance is selected and given an award.
- Long weekend off for good quality water monthly is given as a motivation to process controllers.

9. CONCLUSIONS

There is a growing awareness within municipalities in terms of knowing responsibilities for water provision, understanding water quality related matters, knowing their issues and challenges; however, there are still significant challenges that need to be addressed in order for all municipalities to effectively supply drinking-water in a more sustainable manner. The growing awareness could be as a result of the eWQMS initiative that has been introduced to all municipalities in South Africa and has been recognised as a best practice. In general, similar situations occur in Eastern Cape, Free State and Western Cape. Findings from this study have indicated the following:

Summary of Key Issues

- **Operational and Equipment Shortcomings**

  Lack of existing monitoring data cross-checks with other departments or parties.

  Transference of assets to the WSAs takes a very long time and the person responsible for maintenance around that becomes an issue.

  Budgets constraints for maintenance and operation purposes of water services may result in water quality failures.

  Process controllers are not familiar with operation, routine maintenance/calibration of equipment. In some instances the water treatment process controllers holds very little/no experience in analytical techniques, however they are required to carry out analyses.

  Access roads and distance to the water treatment works in some areas is an issue.

- **Capacity Shortcomings**

  Water services department is understaffed; therefore the existing staff is overloaded.

  Process controllers do not have the necessary skills to effectively operate and maintain water treatment plants.

  Most process controllers have no formal training in basic water treatment principles and techniques.

  Lack of constant supervision result in lack of disciplined operators.

It was recognised that the conclusions above are well in line with the municipal official's views about the municipal responsibilities in terms of water services as reflected by Free State findings in section 8 above. Identified key causes to drinking water quality failures are summarised in Tables 16 and 17 below.

10. RECOMMENDATIONS AND WAY FORWARD

Considering the issues of concern highlighted above, the following recommendations were made:

- The workshops were only conducted at the three provinces where the feedback and participation was great. There is a need to conduct such workshops in other provinces where the councillors and high level people who are decision maker should be included. This was highlighted as an important issue at the other workshops.
- It is recommended that the guides be published as separate documents for easy distribution and be specific for targeted users and be made available both electronically on eWQMS and WRC hard copy reports.

Table 16: *Key Causes of Drinking Water Quality Failures*

Failure	Causes
Source water	• There is an increasing water demand. • Groundwater sources are sometimes contaminated by wastewater or natural occurring chemicals from the soil. • Turbidity problems arise as the source water level drops.
Operation and maintenance of treatment works	• Budget does not meet needs for adequate O&M • Operators lack skills to do the job
Storage	• Storage capacity is insufficient to meet demand for increasing population
Distribution network	• Aging infrastructure leads to pipe bursts • In areas where there is source water shortage, flushing is difficult to practice • Design drawings, documentation, etc. of infra-structure not available
Staff	• Not enough number of operators • Operators are not trained/insufficient skills
Monitoring	• LMs do not perform their required monitoring as WSAs/WSPs

Table 17: *Current status of Drinking Water Quality*

Status	Explanation
Source	• Water availability is becoming an issue in most parts of South Africa. • Ground water sources are being abused due to the shortage in surface water sources.
Treatment	• Basic conventional treatment methods are used • Basic chlorination of groundwater sources is not practised in many areas • Advanced treatment methods are rarely used
Storage and distribution	• Capacity of storage reservoirs needs to be upgraded • Cleaning of reservoirs becomes a problem where there is not enough storage capacity
Management	• Water service provision is not a priority in some areas • Finance department normally does not understand the need and urgency of maintaining water infrastructure and performing water quality awareness.
Laboratory	• There is a new growing awareness of the need for monitoring • There are very few accredited laboratories in South Africa • Some areas lack monitoring equipment
Communications	• There is no integrated planning between different departments (e.g. housing and infrastructure)
Staff	• Lack of qualified staff in the water field • Lack of supervision • Lack of responsibility and dedication
Data	• Water quality data is not properly stored and interpreted • The understanding of water quality data leads to knowing the areas and issues of concern so as to take remedial measures.

REFERENCES

BOURNE D E and COETZEE N (1996) An Atlas of Potentially Water-Related Diseases in South Africa. *WRC Report No 584/1/96*, Pretoria

BTW CONSULTING (Pty) Ltd (2006), An Illustrated Guide to Basic Water Purification Operations, *WRC Report No. TT 247/05,* Pretoria

COMMON WEALTH OF AUSTRALIA (1996) National Water Quality Management Strategy. *Australian Drinking Water Guidelines.*

DWAF (12th May 2004) Chief Directorate Water Services. Survey Report on the Quality of Water *Services in Local and Metropolitan Municipalities*.

DWAF (2002 a) A National Water Resource Strategy for South Africa. Using water wisely. *Department of Water Affairs and Forestry*.

DWAF (2002 b) Guidelines for Compulsory National Standards – Regulations under Section 9 of the Water Services Act (Act 108 of 1997).

DWAF (2004 b) Rapid Review to identify key Provincial drivers. National Drinking Water Quality Management Initiatives. *Department of Water Affairs and Forestry*

DWAF (2005 a) Drinking Water Quality Management Guide. Manage your drinking water quality effectively for the health of your people. *Department of Water Affairs and Forestry*.

DWAF (2005 c) A Drinking Water Quality Management Framework for South Africa. *Department of Water Affairs and Forestry.*

DWAF (September 2003) Strategic Framework for Water Services. *Department of Water Affairs and Forestry.*

DWAF and WRC (2004) The philosophy and practice of integrated catchment management: Implications for water resource management in South Africa. Integrated Catchment Management. Draft-06. *Department of Water Affairs and Forestry and Water Research Commission,* Pretoria

DWAF, DoH and WRC (1998) Assessment Guide. Quality of Domestic Water Supplies, 2nd Ed. Volume 1. *Department of Water Affairs and Forestry; Department of Health and Water Research Commission.*

EMANTI MANAGEMENT (Pty) Ltd. (July 2004) Drinking-Water Quality Management System for the Western Cape. Submitted to Stellenbosch Municipality for Masibambane Western Cape.

EPA (2005) Human Health, Private Drinking Water Wells. U.S *Environmental Protection Agency*, US

FORD T, RUPP G, BUTTERFIELD P and CAMPER A (2004) Report of an international colloquium. Protecting Public Health in small water systems. *Montana Water Centre*, Bozeman, Montana

GRENVILLE and LANARK DISTRICT HEALTH UNIT: (accessed on 25/08/2005) Choosing a Water Treatment System, *Water Safety*, Leeds Available online: *http://www.healthunit.org/water/infosheet/system.htm*

GUTTMAN H (2004) The case for Drinking Water and Sanitation as Keys to Healthy Cities. R V *Anderson Associates Limited.* Available online: *http://www.rvanderson.com/resource/2004_papers*

Health impacts of water pollution. (accessed on 25/08/2005) Available online: *http://edugreen.teri.res.in/explore/water/health/htm*

ISO (2005) *ISO/CD 24512*

MACKINTOSH G S, DE SOUZA P F, WENSLEY A and DELPORT E (2004) South Africa's Compulsory National Standards for Potable Water: Practical Considerations For Water Service Authorities. *Paper presented at IMIESA 2004 Conference,* Mossel Bay

MACKINTOSH G S, MANXODIDI T, WENSLEY A and UYS F M (2004) Safe Drinking Water through Regulatory Governance. Climbing South Africa's Water Services Ladder, *Emanti Management*, Stellenbosch

MOMBA M N B and BROUCKAERT B M (2005) Guidelines for ensuring sustainable effective disinfection in small water supply systems. *Department of Biochemistry and Microbiology*, University of Fort Hare

MUNICIPAL FINANCE MANAGEMENT ACT NO 56 (2003) *Local government*. Republic of South Africa

National Water Act (Act No 36 of 1998) Republic of South Africa

RANDWATER – Health and Fitness: (accessed on 10/08/2005) Available online: *http://www.randwater.co.za/Water_Quality/Details.asp*

RI WATER BOARD – Water Allocation Project: (accessed on 23/12/2004) Available online: http//www.wrb.state.ri.us/programs/wa/wapac/pdf/impactanrec.pdf

ROBERTSON (2001) Microbiological Contamination of Distribution System- What Lies Beneath. Effective Approaches to Managing Microbiological Water Quality, *Health Stream Article* – Issue 22 June 2001, Health Canada

SCHUTTE FRIK (2006) Handbook for the operation of water treatment works, *WRC Report No TT 265/06*

SMITH L (2000) Municipal Services Project. *The Urban Political Ecology of Water in Cape Town*, South Africa

SOUTH AFRICAN NATIONAL STANDARDS (SANS) 241:2006 Edition 6.1 ISBN 0-626-18876-8

The Department of Environment (accessed on 16/08/2006) Available online: http://ewr.cee.vt.edu/environmental/teach/wtprimer/rapid

THE WATER PAGE - Water for Basic needs: (accessed on 10/08/2005) Available online: *http://www.thewaterpage.com/basic_needs.htm*

THOMPSON H. (2005) Policies, Legislation and Organizations Related to Water in South Africa, with Special Reference to the Olifants River Basin. *South Africa Working Paper No. 7*

UNESCO/WHO/UNEP (1992) Water Quality Assessment – A guide to use Biota, sediments and Water in Environmental Monitoring, 2nd Edition Chapter 2. Available online: *http://www.who.int/docstore/water_sanitation_health/wqassess/ch07htm*

VAN DUUREN (1997) Water Purification Works Design, *Water Research Commission Report No TT 92/97*

Water Services (Act No 108 of 1997) Republic of South Africa

Water Services Act (Act No 108 of 1997) Government Gazette. Republic of South Africa

Water Supply System (accessed on 16/08/2006) Available online: *www.chemistry.wustl.edu/~edudev/LabTutorials/Water/PublicWaterSupply/PublicWaterSupply.html*

WHO (2001) World Water Day 2001*: Naturally Occurring Hazard* (accessed on 11/08/2005) Available online: http:www.worldwaterday.org/wwsay/2001/thematic/natural.htm

WHO (2004 a) Microbiological Aspects. WHO Seminar pack for Drinking Water Quality. *World Health Organization,* Geneva

WHO (2004 b) Managing microbial Water Quality in Pipe Distribution System. Safe Piped Water. *IWA Publishing*, London

WHO (2004) Guidelines for drinking-water quality, 3rd ed., *World Health Organization*, Geneva

WHO (2005) Water Safety Plans, Drinking Water Quality Guidelines. *World Health Organization*, Geneva

WHO (accessed on 12/08/2005), WHO Technical Notes for Emergencies, Available online: *http://wedc.lboro.ac.uk/WHO_Technical_Notes_for_Emergencies/...*

WRC (2004) Amanzi newsletter online (accessed on 11/08/2005) Available: wrc.org.za

APPENDIX A

LEGISLATION RELATING TO DRINKING WATER SERVICES

A1 INTRODUCTION TO DRINKING WATER SERVICE PROVISION IN SOUTH AFRICA

Considering co-operate governance requirements, suffice to note that numerous organizations are involved in ensuring that effective water service provision occurs. The overarching principles of water management are set by DWAF, who is the overall regulator in the water sector. The following three key principles form the basis of water management in South Africa (National Water Act, Act 36 of 1998):

- **Sustainability** – means that water must be used to promote social and economic development. At the same time the environment must be protected because that is where water comes from.
- **Equity** – means that every citizen of the country must have access to water and the benefit of using water.
- **Efficiency** – means that water must not be wasted, instead must be used to the best possible social and economic advantage.

There are a number of serious health risks that can arise from contaminated water. Therefore a focus on the entire system, from source to tap is a better way of protecting public health. Considering the above, and as South Africa is not rich in water (water resources are facing growing demands and threats related to water wastage and pollution), a number of water management goals have been set in order to achieve acceptable drinking water quality in South Africa. These include (DWAF, 2002 b):

- Making sure that there is enough water for basic human needs
- Making sure that the natural environment is protected
- Making sure that everyone has equal access to water
- Making sure that water is not wasted and that it is used efficiently
- Making sure that there is enough water for future, for a healthy economy and a prosperous society.
- Making sure that everyone pays their fair share for the cost of water that they use, in other words that there is equity in payment for water.
- Honouring South Africa's obligations to its neighbours, Lesotho, Swaziland, Mozambique, Zimbabwe, Botswana and Namibia.

Considering the above, it is clear that an understanding of the roles and responsibilities of various organisations in the water sector is required in order to ensure that the above general water management principles and goals are achieved.

The organizations involved in drinking water management can, for the purpose of interactions and relationships between them, be grouped into the following groups:

- Regulators
- Water-service authorities
- Water-service providers
- Facilitators
- Water users
- Conflict resolvers, and
- Other interested groups

The relationships between an organization and water users can be regulating, intervening, service providing, conflict resolving, consulting and information providing, based on the principle of co-operative government or on the concept of good public governance. According to Thompson (2005) and DWAF (2005) these relationships mean the following:

- A regulating relationship consists of the monitoring and regulating of water users activities by a regulator by relying primarily on the application of instruments such as standards, practices, licenses and controls (e.g. DWAF).
- An intervening relationship develops when an organization, usually a water-services provider or a regulator cannot or does not fulfil its water management obligations effectively, and a regulator intervenes by taking appropriate steps to ensure fulfilment of those obligations (e.g. DWAF).
- A service-providing relationship consists of the provision of water services usually to water users by a water-services provider or a water services authority (e.g. Water Boards).
- A conflict-resolving relationship consists of the resolving of conflicts between two or more organizations by another organization.
- A consulting relationship exists when an organization consults with one or more other organizations before the first-mentioned organization exercises a power or performs a function (e.g. Consultants).
- An information-providing relationship occurs when information is made available by one organization or a group of water users to another organization or another group of water users (e.g. WSAs).

The concept of good public governance requires that a proper balance be achieved between freedom to manage, accountability and the interests of the different stakeholders. Hence it is important that there is a good relationship between these organizations.

Considering the above, and in order to provide a clear understanding of the various roles and responsibilities of the various organisations, a brief summary of the various role players with regards to Drinking-Water Quality Management in South Africa is presented:

Department of Water Affairs and Forestry (DWAF) – supports the Drinking Water Quality Management function by:

- Developing and maintaining a national Drinking Water Quality Management Framework;
- Managing information, including a sector database and information sharing system covering key aspects such as tracking WSA monitoring systems and drinking water quality data;
- Undertaking periodic regulatory audits of the data and management systems of WSAs;
- Developing appropriate, practical and sustainable technical support documents and tools;
- Assisting WSAs by reviewing of Water Services Development Plans, to ensure that drinking water quality monitoring is included.

Department of Health (DoH) – supports the Drinking Water Quality Management function by:

- Collection of information on the incidence of waterborne diseases (for example, diarrhoea) and the use of this information to facilitate interventions;
- Being the lead 'early warning' authority and execution agents for medical intervention under emergency drinking water quality conditions.

At District Municipality and Metropolitan level, the Environmental Health Officers support the Drinking Water Quality Management function by assuming the primary responsibility for health and hygiene education related to water and sanitation services, and undertaking drinking water quality monitoring as a routine audit function at point-of-use. DoH drinking water quality monitoring will focus on health-risk related constituents, particularly indicators of faecal contamination.

The Department of Provincial and Local Government (DPLG) – The Department of Provincial and Local Government (DPLG) supports the Drinking Water Quality Management function by the *allocation of Municipal Infrastructure Grant, Capacity Building Grant and Equitable Share to address areas of need impacting on effective Drinking Water Quality Management.*

Civil Society – Government is committed to promoting the active involvement of civil society in the provision of sustainable and affordable water services, including Drinking Water Quality Management. The Strategic Framework for Water Services (2003) notes that 'the most important and effective monitoring strategy for the sector is strengthening the voice of consumer'.

WSAs – A WSA may either provide water services itself (internal mechanism), or contract a Water Services Provider (WSP) to provide water services (external mechanism). The primary responsibility for the provision of safe drinking water rests with WSAs. WSAs have a legal responsibility to:

- Monitor the quality of drinking water provided to consumers;
- Compare the results to national drinking water standards; and
- Communicate any health risks to consumers and appropriate authorities.

as described in the regulations to the Water Services Act (No. 108 of 1997)

A 2 OVERVIEW OF LEGISLATION RELATING TO DRINKING-WATER SERVICES

Legal South African Framework

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,** 1996, assigns responsibility of ensuring access to water services to local government. The role of the national and provincial spheres of government is to support, monitor and regulate local government.
- **The Water Services Act**, 1997, further defines the municipal functions of ensuring water services provision
- **The National Water Act**, 1998, defines a new way of managing South Africa's scarce water resources. This Act states that water is an indivisible national resource for which national government is the custodian.
- **The Local Government: Municipal Demarcation Act,** 1998, provides a legal framework for defining and implementing a post-transitional system of local government.
- **The Local Government: Municipal Structures Act,** 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 Local Government: Municipal Systems Act,** 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.
- **The Local Government: Municipal Structures Amendment Act,** 2000, places the function of ensuring access to water services (as well as Health and Electricity) at a district level, unless a local municipality is authorised to perform this function

The New Municipal System

The second democratic local government elections held on 5th December 2002 heralded the introduction of the new local government municipal system. The new system reduced the number of local government structures from 843 to 284:

- 6 metropolitan municipalities (Metros - 'Unicities' with no sub structures)
- 47 district municipalities covering the whole country; and
- 231 Local Municipalities located within the areas of the district municipalities.

A district municipality may typically contain three to six local municipalities. A local municipality usually includes two to three towns as well as surrounding rural areas.

The new local government structures are faced with many challenges, including amalgamation of old administrations, as well as the challenge posed by rural areas and parts of the former homelands. The division of powers and functions between district and local municipalities has been, and still remains, a major issue to resolve.

Institutional Arrangements for Water Services

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 (WSA) as defined in the Water Services Act. There can only be one WSA in any specific area (that is, water services authority areas cannot overlap).

Duties of Water Service Authorities

All WSA's 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 (performance management, by-laws) and sustainability (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).

A WSA may either provide water services itself (internal mechanism), or contract a Water Services Provider (WSP) to provide water services (external mechanism). For an internal mechanism, the WSA must manage and account separately for the two functions. In practical terms this might mean that a municipal manager, acting on behalf of the municipality, contracts (as the WSA) 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 WSA must regulate the WSP according to the contract specifying clearly the allocation of roles and responsibilities between the regulator and the provider. Under all circumstances the WSA is the regulator of the service and is responsible to ensure that services are provided effectively, efficiently, sustainably and affordably.

Duties of Water Services Providers

The main duty of WSP's is to provide water services in accordance with the Constitution, the Water Services Act and the by-laws of the WSA, and in terms of any specific conditions set by the WSA in a contract. A WSP must publish a consumer charter which is consistent with by-laws and other regulations, is approved by the WSA, and includes the duties and responsibilities of both the WSP and the consumer, including conditions of supply of water services and payment conditions.

Overview of Legislation Relating To Drinking-Water Quality

A useful and necessary means for tracking water services delivery is via the monitoring of the quality of drinking-water. Drinking-water quality monitoring allows the correct interpretation of simple and readily measurable analytical determinants gives insight into the operating state of water services provision, and draws attention to Operations and Maintenance requirements. Most importantly, drinking-water quality monitoring is also necessary in that poor drinking-water quality has a direct impact on the health of the community. In South Africa, all Water Services Authorities are legally required to monitor drinking-water quality on a monthly basis. The Water Services Act introduced a compulsory national standard for drinking-water quality. The *Compulsory National Standards for the Quality of Potable Water*, as published in Government Gazette No 22355 of 8 June 2001, reads as follows:

Quality of potable water

5. (1) Within two years of the promulgation of these Regulations, a water services authority must include a suitable programme for sampling the quality of potable water provided to consumers in its water services development plan.

(5) The water quality sampling programme contemplated in sub regulation (1) must specify the points at which potable water provided to consumers will be sampled, the frequency of sampling and for which substances and determinants the water will be tested.

(6) A water services institution must compare the results obtained from the testing of samples with SANS 241: Specifications for Drinking Water; or the South African Water Quality Guidelines published by the Department of Water Affairs and Forestry.

(7) Should the comparison of the results as contemplated in sub regulation (3) indicate that the water supplied poses a health risk, the water services institution must inform the Director-General of the Department of Water Affairs and Forestry and the head of the Provincial Department of Health and it must take steps to inform its consumers-

(a) that the quality of the water that it supplies poses a health risk;
(b) of the reasons for the health risk;
(c) of any precautions to be taken by the consumers; and
(d) of the time frame, if any, within which it may be expected that water of a safe quality will be provided.

The guiding drinking-water quality document is SANS 241, which specifies three classes of water in terms of physical, microbiological and chemical quality, as follows:

- Class I: water that is known to be acceptable for whole lifetime consumption.
- Class II: water considered to be maximum allowable for short-term consumption (usual and continuous daily consumption for periods not exceeding one year).

Class I is known to be acceptable for whole lifetime consumption, and is the targeted minimum drinking-water quality for WSAs and WSPs. **Class II** is an acknowledgement that, at present and for the foreseeable future, in many cases South Africa' s piped drinking-water will not satisfy the previous existing Maximum Allowable Limit (Class I) (SANS 241); and yet there is a risk to condemning as "unfit for human consumption" piped municipal drinking water that only marginally fails Class I and thereby driving consumers to a potentially worse quality and possibly "illegal" source.

It is acknowledged that it is more prudent to allow consumption of the delivered drinking-water at a relaxed level for short-term consumption (Class II), where risk is quantifiable and understood and it is acknowledged that urgent actions are required to improve quality to Class I. Where water fails Class II, and in particular with regards to bacteriological quality, it should be regarded as unfit for human consumption and urgent attention and mitigative action is required.

Whilst the Water Services Act does not criminalise non-compliance with the national standards (and this is in keeping with the phased approach contemplated in the Water Services Act), the Water Services Act makes it an offence for any person to "fail or refuse to give information or to give false and misleading information when required to give information in terms of this Act". As such, as long as the WSAs comply with the peremptory obligation under Sub-regulation 5(4) above and inform, the Minister and the Province, as well as its consumers, of its inability to meet its obligations under the law, it faces a vastly reduced risk of incurring penalties under the Act.

Clearly, a regulatory governance requirement therefore exists for Local Government to monitor drinking-water quality, and for both Provincial and National Government to ensure that such is taking place. Where Local Government lacks resources to carry out such monitoring, a co-operative government requirement would require Provincial and/or National Government to ensure that monitoring takes place.

APPENDIX B

B 1 ASSESSMENT QUESTIONNAIRE

Actual Score = Likelihood*Consequence

SECTION 1: Design	**Likelihood**	**Conse-quence**	**Actual Score**	**Maximum Score**
1.1 Is the design capacity of the plant known?	Yes – 1 No – 0	5		5
1.2 Is the plant operating within its design capacity? (I.e. is there spare capacity available?)	Mostly – 1 Partly – 0	20		20
1.3 Is the plants raw water supply affected by treated wastewater/industrial effluent / run-off from informal communities/ animal waste?	Yes – 0 No – 1	40		40
1.4 Is there sufficient and dependable raw water supply?	Mostly – 2 Partly – 1	40		80
1.5 Are the unit processes implemented at the plant appropriate for the raw water quality?	Yes (100%) – 3 Mostly (80%) – 2 Partly (50%) – 1 No – 0	20		60
1.6 Are spare unit processes available at the plant for maintenance purposes? (e.g. multiple settling tanks, filters, etc)	Yes – 1 No – 0	10		10
1.7 Is there space available for future plant upgrades/expansion?	Yes – 1 No – 0	5		5
1.8 Is there sufficient storage capacity in the distribution network (i.e. sufficient reservoirs with sufficient capacity)?	Yes – 1 No – 0	5		5
END SECTION 1 (225)	**TOTAL**			

SECTION 2: Operation	**Likelihood**	**Conse-quence**	**Actual Score**	**Max. Score**
2.1 Is the quantity of raw and treated water metered at the plant?	Both – 2 One – 1 None – 0	10		20
2.2 Are all unit processes at the plant operating effectively?	Yes (100%) – 3 Mostly (80%) – 2 Some (50%) – 1 None – 0	20		60
2.3 Are there sufficient numbers of plant operators?	Yes – 1 No – 0	10		10
2.4 Are the responsible plant operators adequately trained?	Formal Qual. – 3 Short Courses – 2 On the job – 1 No – 0	20		60
2.5 Is an operator's manual available on-site?	Yes – 1 No – 0	5		5
2.6 Are charts/graphs available at the plant for process control/correcting typical issues of concern (e.g. dosages/chemical feed rates posted on walls, etc)?	Yes – 1 No – 0	5		5
2.7 Are standard plant operating procedures captured in writing (e.g. preparing batches of chemicals, changing gas cylinders, etc)	Yes – 1 No – 0	5		5
2.8 What is the frequency of on-site drinking-water quality monitoring?	Hourly – 3 Daily – 2 Weekly or More – 1 None – 0	10		30
2.9 Where is water quality monitored at the plant? • Raw water • Final Treated water • Along treatment chain	All – 2 Some – 1 None – 0	10		20
2.10 Are chemicals/reagents required for analysis available on-site?	Yes – 1 No – 0	10		10
2.11 Are on-site staff familiar with operation and maintenance of the monitoring equipment?	Yes – 1 No – 0	10		10
2.12 Is a water treatment process specialist readily available (e.g. in-house or consultant) to assist with plant issues	Yes – 1 No – 0	10		10

SECTION 2: Operation	Likelihood	Conse-quence	Actual Score	Max. Score
2.13 Is a report highlighting issues of concern at the plant (quality, malfunctions, etc) produced?	Weekly – 2 Monthly – 1 Longer period or None – 0	20		40
2.14 What is the frequency of distribution network drinking-water quality monitoring?	Weekly/Fortnightly – 3 Monthly – 2 Quarterly – 1 None – 0	10		30
2.15 Where is water quality monitored in the distribution network? • Reservoir • Hydrant • Household taps	All – 2 Only res/taps. – 1 None – 0	10		20
2.16 Are chlorine booster stations located in the reservoirs/ distribution network to manage and maintain desirable chlorine residuals?	Yes or N/a – 1 No – 0	10		10
2.17 How often are chlorine booster stations checked to ensure appropriate chlorine residual management in the distribution network?	Daily or N/a – 2 Weekly – 1 Longer or None – 0	10		20
END SECTION 2 (365)	**TOTAL**			

SECTION 3: Water Quality and Performance	**Likelihood**	**Conse-quence**	**Actual Score**	**Max. Score**
3.1 Is operational monitoring conducted for the bacteriological parameters?	Yes – 1 No – 0	100		100
3.2 Is operational monitoring conducted for physical parameters?	Yes – 1 No – 0	20		20
3.3 Is operational monitoring conducted for residual chemicals?	Yes – 1 No – 0	40		40
3.4 Does drinking-water quality leaving the plant meet legislated requirements (i.e. SANS 241-2005) for bacteriological indicators	Always – 2 Mostly – 1 Never – 0	100		200
3.5 Does drinking-water quality leaving the plant meet legislated requirements (i.e. SANS 241-2005) for physical parameters?	Class I – 2 Class II – 1 Fail Class II/Don't know – 0	100		200
3.6 Does drinking-water quality leaving the plant meet legislated requirements (i.e. SANS-2005) for residual chemicals and health related chemicals?	Always – 2 Mostly – 1 Never – 0	40		80
3.7 Is all water quality monitoring equipment at the plant in good working order?	Yes – 1 No – 0	20		20
3.8 Do you perform compliance monitoring for bacteriological analysis (faecal coliform, *E. coli*)?	Yes – 1 No – 0	100		100
3.9 Do you perform compliance monitoring for physical parameters?	Yes – 1 No – 0	20		20
3.10 Do you perform compliance monitoring for residual chemicals and health related chemicals?	Yes – 1 No – 0	40		40
3.11 How frequently is water quality monitored in the distribution network	Weekly/More – 3 Monthly – 2 Quarterly – 1	40		120
3.12 Does drinking-water quality in the distribution network meet legislated requirements (i.e. SABS 241-2005) for key parameters (pH, turbidity, bacteriological indicators, treatment chemical residuals, etc)?	Class I – 2 Class II – 1 Fail Class II/Don't know – 0	100		200
3.13 Where are distribution network drinking-water samples analysed?	SANAS Accredited lab – 3 Accredited methods – 2 In-house/field test kit – 1	40		120

SECTION 3: Water Quality and Performance	**Likelihood**	**Conse-quence**	**Actual Score**	**Max. Score**
3.14 Is a report highlighting issues of concern in the distribution network (quality, need for flushing, etc) produced?	Monthly – 2 Quarterly – 1 Longer period or None – 0	20		40
3.15 Is water quality data (both plant and distribution network) stored appropriately?	Database & hard copy – 3 Basic elec. & hard copy – 2 Hard copy alone – 1 None – 0	10		30
END SECTION 3 (1210)	**TOTAL**			

SECTION 4: Maintenance	Likelihood	Conse-quence	Actual Score	Maximum Score
4.1 Does the drinking-water treatment plant appear to be well maintained (grass cut, site neat, etc)?	Good – 2 Fair – 1 Poor – 0	5		10
4.2 Is ammonia available at the plant for detecting leaks on chlorine gas cylinders?	Yes or N/a – 1 No – 0	10		10
4.3 Do all pumps at the plant appear to be well maintained? (e.g. no excessive noise or leaking from glands/pipe connections)	Yes – 1 No – 0	10		10
4.4 Is a plant maintenance schedule produced and adhered to? (i.e. pro-active maintenance and not reactive maintenance or crisis management)	Yes – 1 No – 0	10		10
4.5 Is there sufficient technical back-up to perform required plant maintenance? • Mechanical • Electrical	Both – 2 One – 1 No – 0	10		10
4.6 Are there sufficient distribution network maintenance personnel (e.g. plumbers)?	Yes – 1 No – 0	10		10
4.7 Are the distribution network maintenance personnel adequately trained?	Qualified – 3 Short Courses – 2 On the job – 1 No – 0	20		60
4.8 Is a distribution network maintenance schedule produced and adhered to? (i.e. pro-active maintenance and not reactive maintenance or crisis management) • Reservoir cleaning, flushing • Network cleaning, flushing	Yes – 1 No – 0	10		10
4.9 Is there sufficient budget available to perform required maintenance? • Plant • Distribution network	Yes – 1 No – 0	40		40
4.10 Is a pump stations maintenance schedule and adhered to?	Yes – 1 No – 0	10		10
4.11 Are water meters in the distribution network regularly checked Are there water meters in the distribution network to understand water consumption	Yes – 1 No – 0	5		5
4.12 Is asset register produced and adhered to	Yes – 1 No – 0	40		40
END SECTION 4 (225)	**TOTAL**			

SECTION 5: Supervision and Management	**Likelihood**	**Conse-quence**	**Actual Score**	**Maximum Score**
5.1 Have responsibilities been assigned for both plant and distribution network operation and maintenance?	Yes – 1 No – 0	10		10
5.2 Is a complaints register maintained? • Date of complaint, contact details, nature of complaint • Actions taken • Time frame to resolve issue • Signed by responsible officer and checked and discussed with supervisor	All – 2 Some – 1 None – 0	20		20
5.3 Are issues/findings from the plant operational report and complaints register discussed in appropriate LM water meetings on a regular basis (i.e. management review)?	Weekly – 2 Monthly – 1 Longer period or None – 0	10		10
5.4 If issues of concern are noted, are required corrective actions implemented timeously? (give examples, where appropriate)	Yes – 1 No – 0	40		40
5.5 Are there any telemetric system connected to alarms used	Yes/ N/a – 1 No – 0			
5.6 Do you have any mechanism in place to indicate reservoir levels	Yes – 1 No – 0			
5.7 Do you have a Master Plan in place (e.g. 20 yr plan)	Yes – 1 No – 0	40		40
5.8 Do you have a WSDP (e.g. 5 yr plan)	Yes – 1 No – 0	40		40
5.9 Is there any skills development programme in place for training staff?	Yes – 1 No – 0			
END SECTION 5 (160)	**TOTAL**			

SECTION 6: Water Treatment Sludge Management	**Likelihood**	**Conse-quence**	**Actual Score**	**Maximum Score**
6.1 Are sludge/wastewater holding ponds/dams available at the plant?	Yes – 1 No – 0	20		20
6.2 Are sludge/wastewater holding ponds/dams appropriately sized?	Yes – 1 No – 0	10		10
6.3 Is dry sludge produced from the plant landfilled/handled appropriately?	Yes – 1 No – 0	10		10
END SECTION 6 (40)	**TOTAL**			

SECTION 7: Safety	**Likelihood**	**Conse-quence**	**Actual Score**	**Maximum Score**
7.1 Are warning signs (e.g. near chemicals/gas cylinders) visible at all required points at the plant?	Yes – 1 No – 0	5		5
7.2 Have staff received necessary safety training (e.g. handling chlorine gas/chemicals, etc)?	Yes – 1 No – 0	10		10
7.3 Do operators have required safety equipment/clothing? • Face and gas mask • Protective clothing • Showers/eye wash points	All – 2 Some – 1 None – 0	20		40
7.4 Is all operating equipment at the plant secured appropriately (e.g. level surface, screwed down, etc)?	Yes – 1 No – 0	10		10
7.5 Are safety rails/hand rails secure?	Yes – 1 No – 0	10		10
7.6 Is there a bathroom with soap, water, etc at the plant?	Yes – 1 No – 0	10		10
7.7 Are safety inspections regularly conducted at the plant by an appointed safety representative?	Yes – 1 No – 0	5		5
7.8 Are emergency procedures available for distribution network (e.g. handling Cl)	Yes – 1 No – 0	20		20
7.9 In terms of Occ. Health & Safety Act, does your WSS meet requirements correctly?	100% compl. – 3 50% compl. – 2 None – 0	20		60
7.10 Have all Chlorine stations been correctly certified as a major hazardous installation?	Yes – 1 No – 0	20		20
END SECTION 7 (190)	**TOTAL**			

SECTION 8: Emergency Preparedness and Response	**Likelihood**	**Conse-quence**	**Actual Score**	**Maximum Score**
8.1 Are emergency procedures available (e.g. unit failure, gas/chemical handling, change in raw water quality, etc)?	Yes – 1 No – 0	10		10
8.2 Are emergency procedures understood by responsible staff? (e.g. question staff how they would react to an incident)	Yes – 1 No – 0	10		10
8.3 Are emergency power generators available?	Yes – 1 No – 0	20		20
8.4 Are standby units available for essential operating equipment at the plant (e.g. dosing pump, transfer pump, etc)?	Yes – 1 No – 0	20		20
END SECTION 8 (60)	**TOTAL**			

APPENDIX C

CASE STUDIES SHOWING RELATIVE APPLICATION OF TWO ASSESSMENT TOOLS DEVELOPED

It is necessary to understand what the limitations and challenges are within the drinking-water supply system, from source to consumer. Proven methods exist and the project adopted the methodology based on the World Health Organisation's Water Safety Plan approach. An Excel based tool was developed (see C1) for smaller systems and an electronic based tool (see C2) for medium to large systems and the output is conveniently presented in a Risk Profile "Spider Diagram" as shown.

C1: A small system tool example: Kamiesberg LM case study

This tool is particularly useful and appropriate for small communities where no formal water treatment processes are included. The tool was used at Kamiesberg in the Northern Cape. The tool assesses the following main categories:

- Part A: Source
- Part B: Treatment
- Part C: Storage
- Part D: Distribution
- Part E: Households/standpipes
- Part F: Laboratory
- Part G: Drinking-water quality

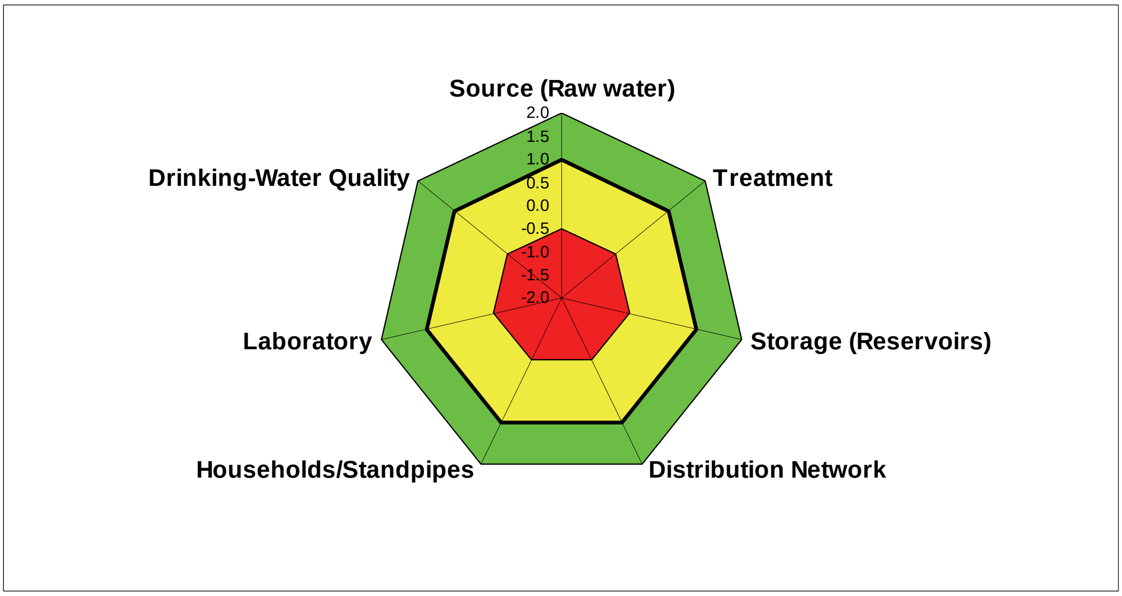


Figure C1: Small Community Drinking Water Risk Assessment Tool Output Example

Table C1: Risk/ Health Check Score Example

Risk/health check score	3.40	Medium Risk	Total Health Check Risk Levels
Individual Risks (Scores from -2 to +2)			
Source (Raw water)	1.00		8 to 14 Low Risk
Treatment	1.00		1 to 7 Medium Risk
Storage (Reservoirs)	1.00		-6 to 0 High Risk
Distribution Network	-1.20	*WARNING*	-14 to -7 Impossible
Households/Standpipes	1.00		
Laboratory	-0.40	*WARNING*	
Drinking-Water Quality	1.00		

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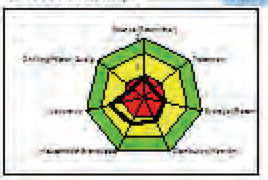
Small Drinking-Water System Risk Assessment Tool

EMANTI

Assessed by: Shawn Moorgas, Emanti/ WISA

Assessment date: KEIS



See "Figure" tab for enlarged view of this diagram

Risk/health check score	-3.20	High Risk	Total Health Check Risk Levels
Individual Risks (Scores from -2 to +2)			
Source (Raw water)	-0.60	WARNING	8 to 14 Low Risk
Treatment	-1.20	WARNING	1 to 7 Medium Risk
Storage (Reservoirs)	-0.60	WARNING	-6 to 0 High Risk
Distribution Network	-0.20	WARNING	-14 to -7 Impossible
Households/Standpipes	0.00		
Laboratory	0.40		
Drinking-Water Quality	-1.00	WARNING	

This Small Drinking-Water System Risk Assessment Tool is based on the World Health Organisation's Water Safety Plan approach and methodology

Scoring Rules	
Strongly disagree or don't know	-4
Disagree	-2
Neutral (or not applicable)	0
Agree	2
Strongly agree	4

Source (Raw water)	
The water source is safe from contamination by communities (recreational use, surface run-off of faecal matter, leaking septic tanks, etc)	-2
The water source is safe from contamination by industry, agriculture and livestock	-2
Is the raw water storage reservoir (if applicable) protected	0
The quantity of water available from the resource is sufficient for community needs	-4
The raw water quality has not deteriorated or otherwise changed in the last 5 years	2

Treatment	
The unit operations are appropriate to the raw water quality	-2
The unit operations are all in good working order and operating within capacity	-4
The works has sufficient chemicals/ materials required for operations including standby spare equipment	-4
The works has sufficient operators with appropriate skills including on job training	2
An appropriate works operating procedure, safety plan and maintenance schedule is available and implemented	-4

Reservoirs	
Reservoir sites are fenced and secure	2
All vents, inspection covers, etc are in place and in good condition	-2
No leaks, corrosion or damage is evident on the reservoirs, inlets, outlets, etc	0
No stagnant or dirty water collects on or near the reservoirs	-2
Reservoirs are cleaned and maintained on a regular basis (e.g. annually)	-4

Distribution Network	
There is no evidence of leaking on pipes, at booster / pump stations, etc in the distribution network	0
There is no evidence of visibly cracked, damaged or leaking pipes in the distribution network	2
There is no evidence of potential faecal contamination at booster/ pump stations, valve boxes/chambers, etc within the distribution network	2
All system valves, booster stations and pump stations are in good working order	-2
An appropriate network maintenance schedule is available and implemented	-4

Households/Standpipes	
There is no evidence of leaking standpipes or household connections within communities	2
There is no evidence of the supply pipes to the standpipes/household connections being exposed	-4
There is no evidence of faecal material/ solid waste dumps laying exposed 10 m from standpipes or household connections	-2
There is no evidence of surface water collecting around standpipes	2
There is no evidence that household supply pipes pass through stagnant water, sewage, pit latrines, septic tanks or foul water bodies	2

Laboratory	
The laboratory utilised has appropriate equipment in good working condition	2
The laboratory utilises standard methods of analysis	2
The laboratory equipment is appropriately calibrated on a frequent basis	2
Cross-checks are performed with other laboratories	2
The laboratory is within reasonable travelling distance (less than 2 hrs travel)	-4

Drinking-Water Quality	
Operational monitoring (at works/reservoir) is done on a frequent basis (e.g. daily/weekly)	-4
The works operator has appropriate monitoring equipment to conduct operational monitoring (pH meter, turbidimeter, free chlorine comparator, etc)	-4
Compliance monitoring is done on at least a monthly basis	2
The treated water leaving the works meets SANS 241 requirements	-2
The drinking-water at point of use meets SANS 241 requirements	-2

Below is an example of one assessed site in Kamiesberg LM

C2: Water Research Commission Supply System Assessment Tool

This tool is a more comprehensive and sophisticated version of the aforementioned tool. The tool is aimed at developed systems which include comprehensive water treatment plants, and it provides WSAs with a method of self assessing their water supply system. The tool has been developed with inputs from WSAs and DWAF, and is available as an on-line tool to all WSAs via eWQMS.

The tool assesses the following main categories:

- Section 1: Design
- Section 2: Operation
- Section 3: Water Quality and Performance
- Section 4: Maintenance
- Section 5: Supervision and Management
- Section 6: Waste Management
- Section 7: Safety
- Section 8: Emergency Preparedness and Response

Data gathered from site visits and interactions with WSAs are entered into the tool and used to produce a score for a particular site. The score is calculated by considering both likelihood of an event and consequence related to that event. Results are then presented in a "colour coded spider diagram". The percentage score obtained per category is plotted using this spider-diagram to indicate the current status of the particular category and highlight where WSA efforts should be focused. An example of the "spider-diagram" plot is shown below.

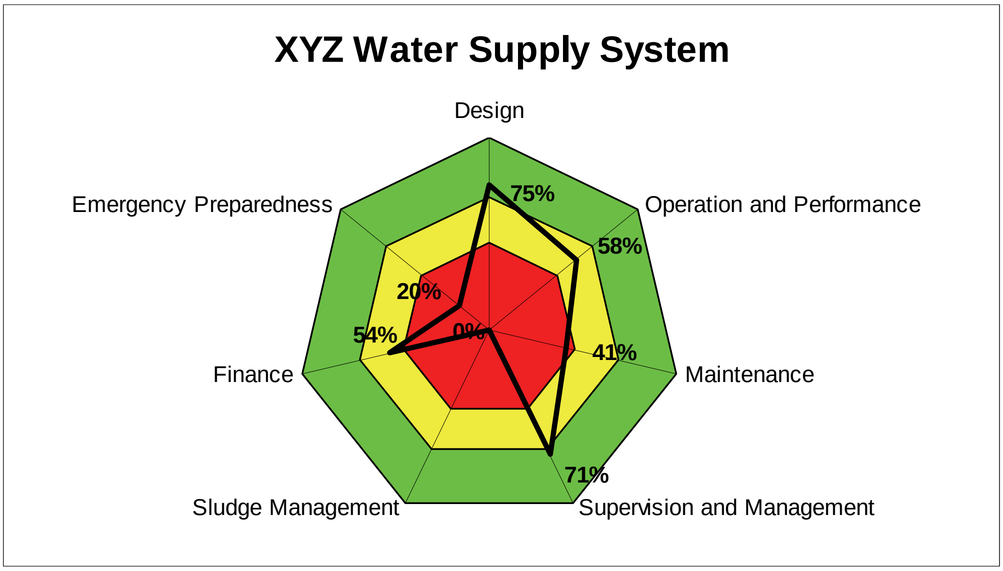


Figure C2: Water Supply System Assessment Tool output example highlighting very poor sludge management

APPENDIX D

ANALYSIS METHODS USED BY THE LABORATORIES INVOLVED

Determinant	CSIR (Bloemfontein)	WSSA (Queenstown)	Buffalo City (East London)
pH	Potentiometry WTW pH meter	Hanna pH 212 meter with a pH electrode	Beckman 32 pH meter
Turbidity	Nephelometry Hach 2400 Bench model	Hach 2100P meter	HACH Ratio Turbidimeter
Conductivity	Potentiometry WTW Conductivity meter	Hanna EC 215 meter with a conductivity electrode	Inolab Cond level 2
Iron			Varian Spectr AA - 10 Atomic Absorption Spectrometer
Calcium		Titration using EDTA (0.01M) and calcium hardness buffer (NaOH), with Devarda's alloy indicator.	
Total Coliforms	Filtration/Colilert	M-Endo agar	MPN - MacConkeys
Feacal Coliforms	Petri film Filtration	M-FC Agar	
E. coli	MPN/Colilert		MPN - Tryptone Water
Heterotrophic Plate Count	MPN/ petri film	Petrifilm method	Nutrient agar

APPENDIX E

SUGGESTED DW MONITORING PROGRAMME AND NORTHERN CAPE EXAMPLE

SUMMARY OF DRINKING WATER ANALYSES PROGRAMME

This is a suggested monitoring programme for drinking-water supply system

DETERMINANDS			
pH			
Temperature	Daily	Weekly	Monthly
Turbidity			Monthly
Electrical conductivity 25°C	Daily	Weekly	Monthly
Free chlorine	Daily	Daily	Daily
Colour	Weekly		Monthly
Chloride		Monthly	Yearly
Sulphate	Monthly		
Calcium	Monthly		Yearly
Magnesium		Weekly	Yearly
Total alkalinity	Monthly		Yearly
Nitrates and Nitrites	Weekly		Monthly
Heterotrophic plate count	Daily		Monthly
Total coliforms			Monthly
Faecal coliforms/ *E. coli*	Weekly	Weekly	Monthly
Fluoride			Yearly
Potassium			Yearly
Sodium	Monthly	Yearly	Yearly
Cadmium			Yearly
Chromium (total)	Monthly	Yearly	Yearly
Cobalt			
Copper	Monthly	Yearly	Yearly
Lead			Yearly
Nickel	Monthly	Yearly	Yearly
Arsenic (inorganic)	Monthly		Yearly
Selenium (inorganic)	Monthly	Yearly	Yearly
Aluminium	Monthly	Yearly	Yearly
Iron			Yearly
Manganese	Monthly	Yearly	Yearly
Trihalomethanes	Monthly	Yearly	Yearly

Take into consideration that for determinants that have proven to be a problem, analysis should be carried out more frequently.

Below is a table providing an idea of how to determine annual analysis costs based on the population served which determines the number of samples to be collected. Understanding which determinants to be analysed at each sample point then the budget could be drawn. The costs indicated in the table below are applicable for the years 2006/2007. Below is an example of how this was done in the Northern Cape.

DWAF Northern Cape example

DWQM Costs

SANS 241 Min Required Determinants	
Determinant	**Cost**
Total Coliforms	R80
Faecal Coliforms / *E. coli*	R80
pH	R15
Electrical Conductivity	R15
Turbidity	R15
Free Chlorine Residual	R15
Residual Chemicals / Source water specific	R30
Total Cost per sample	**R250**

District		Municipality	Sum of Pop 2006	No. of Samples	Bacteriological Costs		Phys-Chem Costs		Total Analytical Costs	
					Monthly	Annually	Monthly	Annually	Monthly	Annually
Frances Baard	1	Dikgatlong	47 671	17	R2 720	R32 640	R2 550	R30 600	R5 270	R63 240
	2	Magareng	26 500	5	R800	R9 600	R750	R9 000	R1 550	R18 600
	3	Phokwane	68 611	9	R1 440	R17 280	R1 350	R16 200	R2 790	R33 480
	4	Sol Plaatje	213 940	24	R3 840	R46 080	R3 600	R43 200	R7 440	R89 280
	5	Frances Baard DM	361 797	54	R8640	R34 560	R0	R0	R8 640	R34 560
Pixley Ka Seme	6	Emthanjeni	35 207	14	R2 240	R26 880	R2 100	R25 200	R4 340	R52 080
	7	Kareeberg	8 740	4	R640	R7 680	R600	R7 200	R1 240	R14 880
	8	Renosterberg	9 648	5	R800	R9 600	R750	R9 000	R1 550	R18 600
	9	Siyancuma	42 113	8	R1 280	R15 360	R1 200	R14 400	R2 480	R29 760
	10	Siyathemba	18 096	5	R800	R9 600	R750	R9 000	R1 550	R18 600
	11	Thembelihle	15 491	5	R800	R9 600	R750	R9 000	R1 550	R18 600
	12	Ubuntu	17 133	6	R960	R11 520	R900	R10 800	R1 860	R22 320
	13	Umsobomvu	24 409	6	R960	R11 520	R900	R10 800	R1 860	R22 320
	14	Pixley Ka Seme DM	173 865	38	R6 080	R24 320	R0	R0	R6 080	R24 320
Kgala-gadi	15	Gamagara	25 284	8	R1 280	R15 360	R1 200	R14 400	R2 480	R29 760
	16	Ga-Segonyana	85 667	10	R1 600	R19 200	R1 500	R18 000	R3 100	R37 200
	17	Moshaweng	88 447	10	R1 600	R19 200	R1 500	R18 000	R3 100	R37 200
	18	Kgalagadi DM	206 620	32	R5 120	R20 480	R0	R0	R5 120	R20 480
Nama-kwa	19	Hantam	20 805	7	R1 120	R13 440	R1 050	R12 600	R2 170	R26 040
	20	Kamiesberg	12 144	15	R2 400	R28 800	R2 250	R27 000	R4 650	R55 800
	21	Karoo Hoogland	10 717	4	R640	R7 680	R600	R7 200	R1 240	R14 880
	22	Khâi-Ma	12 638	5	R800	R9 600	R750	R9 000	R1 550	R18 600
	23	Nama Khoi	49 350	21	R3 360	R40 320	R3 150	R37 800	R6 510	R78 120
	24	Richtersveld	10 764	8	R1 280	R15 360	R1 200	R14 400	R2 480	R29 760
	25	Namakwa DM	117 344	26	R4 160	R16 640	R0	R0	R4,160	R16 640
Siyanda	26	!Kheis	12 449	5	R800	R9 600	R750	R9 000	R1 550	R18 600
	27	//Khara Hais	81 791	19	R3 040	R36 480	R2 850	R34 200	R5 890	R70 680
	28	Kai !Garib	64 332	22	R3 520	R42 240	R3 300	R39 600	R6 820	R81 840
	29	Kgatelopele	12 654	5	R800	R9 600	R750	R9 000	R1 550	R18 600
	30	Mier	7 690	3	R480	R5 760	R450	R5 400	R 930	R11 160
	31	Tsantsabane	26 600	8	R1 280	R15 360	R1 200	R14 400	R2 480	R29 760
	32	Siyanda DM	217 203	41	R6 560	R78 720	R0	R0	R6 560	R78 720
		Total WSA samples/month		**258**	(this is how much data should come in as a minimum)					