GUIDELINES FOR PLANNING AND DESIGN OF SMALL WATER TREATMENT PLANTS FOR RURAL COMMUNITIES, WITH SPECIFIC EMPHASIS ON SUSTAINABILITY AND COMMUNITY INVOLVEMENT AND PARTICIPATION

Final Report

Prepared for the

WATER RESEARCH COMMISSION

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WRC Report No: 1185/1/04
ISBN No: 1-77005-103-1

December 2004

EXECUTIVE SUMMARY

A large number of small water treatment systems installed in South Africa are subject to failure during its life, some even right from the planning stages of the project. According to feedback at a recent conference held in East London (Appropriate Practice Conference, March 1999), of a number of more than 50 small treatment systems that were installed in Southern Africa, only a small percentage of these plants are performing to requirements and can be considered as successful water supply projects. This implies first and foremost that these communities for whom the plants are installed are still not involved and their support and participation not obtained during the initial phases of a water supply project. It is of utmost importance that the communities must accept the technologies and that the technology must work for the community.

A number of guideline documents have been drawn up about various aspects of rural water supply, and on the different technologies used in rural water treatment plants (WRC Reports No. 231/1/93, KV 58/94, TT 68/95, 449/1/95, 450/1/97, and 354/1/97; various Technical Guides by die CSIR Division of Water Technology). However, none of these guides specifically addresses the pitfalls that should be guarded against when designing small treatment systems, and which often lead to failures. It has been shown that these pitfalls in design can lead to numerous problems with the sustainability of the plants (Swartz, 1998).

Moreover, while the various manuals have proven to be valuable in allowing engineers, authorities and communities to plan and design small water treatment systems for rural communities, they do not specifically address the very important aspect of community involvement in the planning stages of a project as prerequisite to successful operation and sustainability of these plants. It is important that the water supply projects must be planned to standards that meet the requirements of approving authorities and financing agencies.

There was, therefore, a need for guidelines for planning and design of small rural water treatment plants, that specifically identify those aspects and pitfalls which should be avoided in the design of these plants, and that contain as main part of the document the very important guidelines on how to obtain community support and participation in the project.

Because many of the treatment systems designed by engineers for rural applications are over-designed or inappropriate (too sophisticated; the community does not accept the technology), there was a need to also provide information on “simpler” and indigenous technologies which can be used to ensure community participation and cost-reduction of the systems.

Aims of the project

The aims of the project were as follows:

a. To understand why small water treatment systems for rural communities often fail, and applying this information in the planning and design of new small water treatment plants, thereby preventing failures of future plants.

b. To provide design guidelines for rural water treatment technologies, in order that
- these systems will not be over-designed and hence unaffordable
- the systems will be sustainable, *i.e.* will have the support and involvement of the community and dedicated commitment from the persons responsible for operation and maintenance of the plants
- user-friendly maintenance programs can be drawn up

c. To create an understanding of the unit processes employed in small rural water treatment plants.

d. To provide practical and useful guidelines on how to obtain full involvement and participation from the communities when a new treatment system is planned or an existing treatment system is to be upgraded.

e. To provide information on indigenous water treatment technologies.

A major input towards the compilation of these guidelines for planning water treatment systems for rural communities was the presenting of a national workshop on small water systems during August 2002. The workshop attempted to bring together all the role players in the field of small water systems in Southern Africa to discuss the important issues regarding failure of small treatment systems that are installed across the country, and problems that are experienced with ensuring the sustainability of the systems. Recognized experts and role players in the field of small water systems (either on institutional or technological level or both) were invited to give presentations at the workshop, to present current viewpoints and their experiences, and to stimulate discussion. These papers were also intended to be used in compiling this guidelines document for planning and design of small water systems, with the main focus then on sustainability of treatment systems for rural communities.

The workshop was held at the Birchwood Executive Hotel near Johannesburg on the 22nd and 23rd of August 2002. The title of the workshop was "**Workshop on the Sustainability of Small Water Systems in Southern Africa**". The two-day event was attended by 96 persons from all spheres of the water treatment field, and included delegates from African and overseas countries.

The program of the workshop appears in Appendix A to the report. The first session served to set the scene and identify the issues relating to sustainability of small water treatment systems. In the second session, an overview was given by speakers on what is needed and what is available. The overseas perspectives were presented in the third session, with presenters from the USEPA (USA), Cameroon, Zimbabwe and Uganda providing their views. During the last session of the first day a facilitated discussion and planning session was held with the aim of forming an appropriate structure (association) for small water systems in Southern Africa. The session was facilitated by the Water Research Commission and led to the identifying of objectives for the new association to be formed, listing of organization type preferences and a list of proposed functions of such an association. These aspects are also given in Appendix A.

ACKNOWLEDGEMENTS

The research in this report emanated from a project funded by the Water Research Commission and entitled:
"Design Manual for Small Water Treatment Plants for Rural Communities with Specific Emphasis on Community Involvement"

The authors wish to record their sincere thanks to the following persons for their invaluable contributions towards compilation of the guidelines document and the organising and presentation of the workshop on sustainability of small water systems in Southern Africa:

Dr I M Msibi	Water Research Commission
Dr G Offringa	Water Research Commission
Mr C Crawford	Department of Water Affairs and Forestry
Ms L Stephenson	Rural Support Services
Mr V Weitz	Rural Support Services
Mr W M Malan	Consulting Engineer
Mr W Lőtz	Water Institute of Southern Africa (WISA)
Mr I Pearson	WATSUP Development
Mr M Marler	Development Bank of Southern Africa
Mr B Netshiswinzhe	Mvula Trust
Mr A Vermeulen	Department of Water Affairs and Forestry
Mr D Stephen	Umgeni Water
Mr J Rivett-Carnac	National Community Water and Sanitation Institute
Mr P Thompson	Umgeni Water
Dr L Pillay	Durban Institute of Technology
Prof E Jacobs	University of Stellenbosch
Mr G Mackintosh	CSIR Environmentek
Mr X Daniel	Rural Support Services
Dr J Schoeman	CSIR Environmentek
Mr G Mwiinga	Peninsula Technikon

The financing of the project by the Water Research Commission is acknowledged gratefully.

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CHAPTER 1

INTRODUCTION

1.1 NEED FOR GUIDELINES FOR PLANNING AND DESIGN OF SMALL WATER TREATMENT PLANTS FOR RURAL COMMUNITIES

A large number of small water treatment systems installed in South Africa are subject to failure during its life, some even right from the planning stages of the project. According to feedback at a recent conference held in East London (Appropriate Practice Conference, March 1999), of a number of more than 50 small treatment systems that were installed in Southern Africa, only a small percentage of these plants are performing to the requirements and can be considered as successful water supply projects. This implies first and foremost that these communities for whom the plants are installed are still not involved and their support and participation obtained during the initial phases of a water supply project. It is of utmost importance that the communities must accept the technologies and that the technology must work for the community.

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Moreover, while the various manuals have proven to be valuable in allowing engineers, authorities and communities to plan and design small water treatment systems for rural communities, they do not specifically address the very important aspect of community involvement in the planning stages of a project as prerequisite to successful operation and sustainability of these plants. It is important that the water supply projects must be planned to standards that meets the requirements of approving authorities and financing agencies.

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Because many of the treatment systems designed by engineers for rural applications are over-designed or inappropriate (too sophisticated; community does not accept the technology), there was a need to also provide information on “simpler” and indigenous technologies can be used to ensure community participation and cost-reduction of the systems.

1.2 AIMS OF THE PROJECT

The aims of the project were as follows:

a. To understand why small water treatment systems for rural communities often fail, and applying this information in the planning and design of new small water treatment plants, thereby preventing failures of future plants.

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c. To create an understanding of the unit processes employed in small rural water treatment plants.

d. To provide practical and useful guidelines on how to obtain full involvement and participation from the communities when a new treatment system is planned or an existing treatment system is to be upgraded.

e. To provide information on indigenous water treatment technologies.

1.3 INTENDED USE OF THE GUIDELINES DOCUMENT

It is the intention that the document will be used by the Department of Water Affairs and Forestry, local authorities, engineers and NGO's when planning and designing new small water treatment systems for rural communities, or upgrading existing treatment systems. It will also provide researchers and engineers with a compilation of conventional treatment technologies for rural applications when developing new processes for small water systems.

1.4 WORKSHOP ON SUSTAINABILITY OF SMALL WATER SYSTEMS IN SOUTHERN AFRICA

A major input towards the compilation of these guidelines for planning water treatment systems for rural communities was the presenting of a national workshop on small water systems during August 2002. The workshop attempted to bring together all the role players in the field of small water systems in Southern Africa to discuss the important issues regarding failure of small treatment systems that are installed across the country, and problems that are experienced with ensuring the sustainability of the systems. Recognized experts and role players in the field of small water systems (either on institutional or technological level or both) were invited to do presentations at the workshop to present current viewpoints and their experiences, and to stimulate discussion. These papers were also intended to be used in compiling this guidelines document for planning and design of small water systems, with the main focus then on sustainability of treatment systems for rural communities.

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As stated above, the presentations at the workshop forms a major part of this document, and are contained in full or as excerpts in Chapters 2 and 5. In Chapters 6 and 8 reference are made to other more technical papers that were presented at the workshop.

1.5 LAY-OUT OF THE DOCUMENT

Chapter 1 of the document provides an introduction to the need for guidelines for planning and design of small water treatment systems for rural communities, and gives the aims of the project that were carried out to compile the guidelines. The intended use of the document is stated, and an overview is given of the workshop that was held to obtain inputs towards drawing up these guidelines.

In Chapter 2 an overview is provided of the current problems and needs that are experienced with small water treatment systems in South Africa. It consists of presentations that were made at the workshop, mainly on issues relating to sustainability of small water systems, and important considerations to be addressed when planning for sustainable treatment systems.

Chapter 3 lists the community needs and expectations for small water treatment systems that were identified in the study by **Rural Support Services**. Following from this study, specific guidelines for obtaining community involvement and participation are presented in Chapter 4.

Chapter 5 presents an overview of the current status of institutional aspects relating to water supply in South Africa, with specific emphasis on small water treatment systems. The chapter consists of presentations made at the workshop by role players from Mvula Trust, the Department of Water Affairs and Forestry and Umgeni Water.

Chapter 6 presents the technological considerations for planning and design of small water treatment systems, which include legal considerations, water quality considerations, a summary of treatment technologies for small water systems, and process selection aspects.

in Chapter 7 information is given on indigenous materials that can be used in water treatment for rural communities, and in Chapter 8 design guidelines for the conventional water treatment processes that are used in small water systems are summarized and

Appendix A contains information on the workshop that was held in August 2002. Appendix B provides a checklist for the design of water treatment plants and Appendix C gives a list of South African guidelines documents and publications on drinking water treatment.

CHAPTER 2

OVERVIEW OF SMALL WATER SYSTEMS IN SOUTH AFRICA: PROBLEMS AND NEEDS

EXCERPTS FROM PAPERS PRESENTED AT THE WORKSHOP ON SUSTAINABILITY OF SMALL WATER SYSTEMS IN SOUTHERN AFRICA

2.1 WHY MODERN TECHNOLOGY CANNOT ENSURE THE SUSTAINABILITY OF SMALL WATER SYSTEMS BY ITSELF *(Marler, M., Development Bank of Southern Africa, August, 2002)*

2.1.1 Introduction

Since 1994, when the first democratic government was established in South Africa, progress with regard to restructuring and refocusing the water sector has been significant. The objectives of this process have been to ensure that backlogs, inequalities and inefficiencies in the water sector are addressed.

The South African Constitution, adopted in 1996, affirmed the right of all citizens to a healthy living environment, including the provision of affordable and adequate water and sanitation services. The responsibility for water services provision was given to local government with provincial and national support.

Institutional mechanisms for the provision of water services were set out in the Water Services Act of South Africa (Act 108 of 1997) which made the distinction between water services authorities and water service providers.

The water services policy, as defined in the 1994 White Paper and Water and Sanitation and the Water Services Act of 1997, is currently being revised in response to the new municipal legislation (Municipal Structures Act and the Municipal Systems Act).

Based on this the water sector vision for water services is:

- All people living in South Africa have access to adequate, safe and affordable water and sanitation services, practise safe sanitation and use water wisely.

- Water supply and sanitation services are sustainable and are provided by effective and efficient institutions that are accountable and responsive to those whom they serve.

- Water is used wisely, sustainably and efficiently in order to promote economic growth.

The focus of water services delivery has now shifted away from “communities”, as described in the 1994 White Paper, towards local government. Attention is given to the creation of sustainable water systems with local government involvement.

While the democratic government has been proud to announce that over 7 million additional people have been provided with access to water services in the past 7 years, there is still a backlog of another 7 million people who currently do not have access to even a basic level of service.

Water services in South Africa are provided by systems that include plants ranging from very large ones serving large metros and regions to small package type plants serving rural communities. Isolated households may also have point-of-use systems.

2.1.2 Definition of Small Water Systems

To ensure that there is a common understanding about the problem statement in this paper, it is necessary to define a “Small Water System”. In the water sector in South Africa this may be any water system that operates independently of other formal municipal services but may also include smaller rural towns where the size of the water system determines whether it is small or not. It may be a rural scheme or even an independent supply to an area where no water authority has been established. This aspect of water service provision is currently under review with the new Municipal Demarcations.

A number of other definitions exist that are linked either to the size of the town or to the number of people being served. WEDC has this definition, *“Small towns are settlements that are sufficiently large and dense to benefit from the economies of scale offered by piped systems, but too small and dispersed to be efficiently managed by a conventional urban water utility. They require formal management arrangements, a legal basis for ownership and management, and the ability to expand to meet the growing demand for water. Small towns usually have populations between 5,000 and 50,000 but can be larger or smaller.”*

In the U.S.A. small water systems are clearly defined as those serving fewer than 10,000 people.

For this discussion a broad definition of small water systems could be *"Non point-of-use systems that are not managed by a conventional utility management structure but may include small rural towns. Typically the number of people being served would be less than 10,000. System sizes would be less than 500,000 litres capacity per day while medium size systems would range from 0,5Ml to 2,5Ml per day."*

There also needs to be a common understanding of the use of the word SUSTAINABILITY. Fortunately the current international debate on this issue has given us clear directions. Development is considered to be sustainable if *"it meets the needs of the present without compromising the ability of future generations to meet their own needs."* While the word sustainability may mean different things to different people, it must, of necessity, include a consideration of the future. It is not sufficient for a system to be sustainable only for the present conditions. So, in the context of this discussion, water systems that are managed to satisfy the demands placed on them, both current and future, without the system failing, can be called sustainable.

2.1.3 Typical small water systems problems

Small water systems suffer from similar problems all over the world. In the U.S.A. a study was recently carried out to consider the status of small water systems (those systems that comply with the above definition). It is interesting to note, "More than 54,000 small water systems provide drinking water to approximately 20 percent of the U.S. population. Sixty percent of these systems serve communities with populations of 500 or fewer." Further in the report it states, "Many small communities lack a fee structure that is adequate to generate the necessary operating revenues, let alone funds for capital improvements." There is a strong correlation between this study and the situation in southern Africa. A superficial survey of people in South Africa served by small water systems shows that almost 20% of our population rely on these systems. The issue of affordability is also very much the same.

Recently a number of small water systems serving rural communities in South Africa were evaluated to establish how effectively they were meeting their design objectives. No basic technical failures were encountered. There were, however, systems where inappropriate technology had been installed because of incorrect design assumptions. Most problematic systems were not sustainable for non-technical reasons. Lack of financial management was on top of the list of reasons for systems failing. Lack of money resulted in the inability of the service provider to carry out repairs and preventative maintenance. Cost of fuel and other operating costs as well as operators' wages also caused problems.

Shortly after it started business in 1984, the Development Bank of southern Africa financed a water treatment plant in a small rural town. This was a simple slow sand filter system, which the author considered to be appropriate technology for the purpose. The consultant commissioned the plant to everybody's satisfaction and an employee of the municipality had been trained to operate it. Some years later the same municipality approached the DBSA for additional finance to increase the plant's treatment capacity. Coincidentally, the author was again approached for a technical opinion of the application. A simple review of the application revealed that the "increased" capacity of the plant was almost the same as the original design capacity. A site visit confirmed that the plant was not being operated properly. The town could not afford to pay the trained operator adequately so he had left to earn more money elsewhere and the Town Clerk was standing in as a part-time operator. The Clerk explained that every few months the sand filters blocked up and the municipality then had to spend a lot of money replacing this sand. When asked why the sand was not cleaned by backwashing the filters he declared that he did not know how to do that! While the DBSA lost out on another loan, it did retain a satisfied client and at least ensured the sustainability of the system.

2.2 THE SUSTAINABILITY OF COMMUNITY WATER SUPPLY AND SANITATION SYSTEMS: A RECIPE FOR SUCCESS? *(Rivett-Carnac, J., National Community Water and Sanitation Institute (NCWSTI) August 2002)*

The question as to what constitutes a successful i.e. sustainable community water supply, is something all of us who have been involved in implementing schemes, have pondered.

There are several factors that are cited as Sustainable Outcomes to be aimed at in the development of water systems. These include:

Ecologically Sustainable Supplies That is the supply or water source must not be exploited at a rate greater than its ability to be recharged from the environment and the environment mustn't be unacceptably affected by the introduction of the water supply scheme.

Socially Sustainable *i.e.* The system must be accepted and "owned " by the community . The process of development must be demand driven in order to satisfy this condition. Ownership brings with responsibility and acceptance by the community which is essential for cooperation in operating and maintaining the scheme ,particularly in rural areas and to avoid vandalism.

Technologically Sustainable This means that the technology employed must be appropriate to the needs and skills of the community to operate and maintain. Higher levels of technology require higher levels of skills and management to operate and maintain. To this rather narrow definition should be added the need for the technology to be energized at affordable and ultimately sustainable levels.

Energy Sustainability or at least best possible most efficient and economic energy technologies taking into account employment of renewable energies as the ultimate goal.

Institutionally Sustainable This is by far the most difficult condition to satisfy .It involves the building of capacity at a governance level and the training of staff at the operational maintenance monitoring and administration level.

Financial Sustainability The objective of which is sometimes defined as, at the minimum, full cost recovery for operational, maintenance and replacement costs *ie.* recurrent cost expenditure recovery.

Many are the causes for failure of small scale water supplies in South Africa and around the World. However the underlying cause in most cases can be traced to a lack of institutional capacity. This may be at all levels from National governments to local community or village level . At the same time there have been, and are many cases of successfully run community water supply schemes such as the Quanat or Falaj water schemes of Iran and Oman respectively, which have operated with a strict community organization for a thousand years or more. Utilizing the power of gravity these ingenious systems of underground tunnels bring ground water to irrigate oases in the desserts and also provide sustainable domestic supplies of water . They too are unfortunately now threatened with collapse due to the influence of the “global economy” and the devastating effects of consumerism, urban migration and the cash economy. (Waterlines Vol.2 No3. Jan 1984)

There are likewise many rural water schemes using appropriate technologies such as spring protection, rainwater harvesting and stream abstractions, where water quality is still relatively good and that are relatively reliable, cheap, easy to operate and inherently sustainable. However the risk of failure of a scheme is greatly increased when pumping mechanisms and treatment technologies are introduced .

2.3 INVESTIGATION OF SMALL WATER SYSTEMS TREATMENT PRACTICES AND TECHNOLOGIES IN SOUTH AFRICA *(Swartz, CD, Chris Swartz Water Utilization Engineers, August 2002)*

In order to establish what the problems and upgrading needs of small water treatment systems in South Africa are, a project to draw up upgrading guidelines was funded by the Water Research Commission and undertaken in collaboration with the CSIR (Swartz, 2000). The project aimed at identifying the problems and needs of small water treatment systems, so that measures could be investigated on how to solve these problems, avoid the shortcomings or potential problems when planning and designing new small systems, and identify aspects that require further research.

2.3.1 Aims of the project

The aim of the project was to draw up guidelines for upgrading existing small water treatment plants, thereby creating a better standard of living by optimally using existing facilities. This could be done by physical changes to the treatment plants or by better operation of the plant through training and education of operators.

The specific objectives of the project were to:

- determine the status quo of existing small water treatment systems
- identify problems experienced by the small water systems
- investigate measures with a view to appropriateness for upgrading
- develop a set of tools to measure the effectiveness (appropriate) of various small water treatment systems
- draw up the guidelines for upgrading of existing rural (small) water treatment systems.

2.3.2 Survey of small water treatment systems in South Africa

a. Determination of status quo of existing small water treatment systems

A database is was compiled with information (where available) on the quality of the raw water treated, treatment systems employed, operational aspects, if and how the plant is monitored, quality of the treated water, and an identification of needs identified for improvement, for small water treatment plants in South Africa. Data on the plants was obtained from a number of sources:

- **<u>CSIR reports on monitoring of water treatments plants</u>**
  These consist of rural water treatment plants in areas of the former self-governing states, *i.e.* mainly in Northern Province, Mpumalanga, Kwazulu Natal, Free State and Eastern Cape.

- **<u>Direct information gathering from local authorities and water boards</u>**
  Information request forms were drawn up to obtain all the necessary data on the treatment plants owned by the various water boards and local authorities in the country.

- **<u>Department of Water Affairs and Forestry (DWAF) database on registered water treatment plants</u>**

- **<u>CSIR Durban database of treatment plants in Kwazulu Natal</u>**
  Information was supplied in electronic format (dBase) by the CSIR in Durban on water treatment plants being monitored by them in Kwazulu Natal.

- **<u>Department of Water Affairs and Forestry Community Water Supply and Sanitation (CWSS) database on infrastructure upgrading equirements</u>**
  Database which are currently available at DWAF consist of the database of registered plants (see above), and a database which is currently being drawn up to determine what the condition of rural water supply and sanitation systems are. This is being done to prioritise the upgrading/improvement of these systems, and to make an estimate of costs that will be involved. Information of the plants that have been entered on the database to date were supplied by CWSS in electronic format.

b. Selection of treatment plants to investigate

A total of 25 small water treatment systems plants were selected country-wide to identify and investigate typical upgrading needs and methods. In selecting these 25 plants, the following aspects were taken into consideration as important selection criteria:

- the plants in total should be representative of all types of small water treatment plants in the country, *i.e.* include plants of various capacities; employing different unit treatment processes; treating raw waters of various qualities (*e.g.* waters with low, medium or high turbidities, eutrophic waters containing organic colour, fluoride, iron and manganese, and brackish waters); plants of varying ages, needing upgrading or in various conditions of the plant (whether the plant is under stress at present)

- preferably plants that are being monitored by either the CSIR or consultants, for obtaining plant records and information on plant condition, and to facilitate futher investigation of the plants
- be spread across the country (geographically)
- not at present be under jurisdiction of a water board

The following plants were selected in cooperation with the CSIR in Pretoria, Durban, King Williams Town (Bisho) and Bloemfontein:

Plant Name	Province	Capacity (Mℓ/d)	Raw water quality	Main treatment process
Moganyaka	Northern Province	0,8	High turbidity	Flocc / settling / slow sand filtration
Tompi Seleka	Northern Province	0,22	High turbidity	Flocc / settling / pressure filtration
Vandermerweskraal	Northern Province	0,10	Low turbidity	Chlorination
Hlogotlou	Northern Province	2,5	Low turbidity	Flocc / settling / rapid sand filtration
Vergelegen	Northern Province	2,4	High turbidity	Flocc / settling / rapid sand filtration
Piet Gouws	Northern Province	1,5	High turbidity	Flocc / settling / rapid sand filtration
Boschkloof	Northern Province	0,45	Low turbidity	Flocc / settling / slow sand filtration
Bethesda Hospital	Kwazulu Natal	0,5	High turbidity	Package plant
Jozini	Kwazulu Natal	1,6	High turbidity	Flocc / settling / pressure filtration
Mosvold Hospital	Kwazulu Natal	0,3	Low turbidity	Flocc / settling / slow sand filtration
Manguzi Hospital	Kwazulu Natal	0,55	Low turb / eutrophic	Flocc / direct filtration
Frischgewaagd	Kwazulu Natal	0,68	Medium turbidity	Flocc / settling / slow sand filtration
Upper Mnyameni	Eastern Cape	0,26	Low turbidity	Package plant
Pleasant View	Eastern Cape	0,65	Low turbidity	Flocc / settling / pressure filtration
St. Thomas	Eastern Cape	0,2	Medium turbidity	Flocc / settling / pressure filtration
Dordrecht	Eastern Cape	1,6	Low turbidity	Flocc / settling / rapid sand filtration
Joubertina	Eastern Cape	1,0	High colour	Flocc / settling / rapid sand filtration
Clocolan	Free State	2,0	Low turbidity	Flocc / settling / rapid sand filtration
Syferfontein	Free State	3,2	Medium turbidity	Flocc / settling / rapid sand filtration
Buisplaas	Western Cape	0,12	Iron	Aeration / settling / upflow contact filtration / pressure filtration
Calitzdorp	Western Cape	0,85	Colour and turbidity	Flocc / settling / slow sand filtration
Stellenzicht	Western Cape	0,15	Colour and turbidity	Package plant
Bitterfontein	Western Cape	0,22	Brackish	Reverse osmosis
Garies	Northern Cape	0,20	Brackish; fluoride	Chlorination
Colesberg	Northern Cape	0,43	High turbidity	Flocc / settling / rapid sand filtration

c. Visit to selected treatment plants

The plants were visited and questionnaires completed containing information on raw water quality, capacity of the plant, treatment processes employed, condition of the plant, any upgrading that was done/currently being done/planned, operational aspects, maintenance and quality assurance (monitoring).

2.3.3 Problems of small water treatment systems

The following problems that are experienced at small water treatment systems were identified during the plant visits, in discussions with CSIR personnel and consultants, and from the completed questionnaires received for the database:

a. <u>Design</u>

Coagulation and flocculation
In general, coagulation and flocculation in small water treatment systems do not seem to give the same final water quality than one normally gets in large plants. While this essentially an operational problem relating to control of the chemical mixing and dosing process, there are also a number of design inadequancies that were found, namely:

- inadequate chemical mixing
- incorrect placing of chemical dosing points
- not sufficient flocculation retention time or G too high
- allowance not made for slower floc formation during winter months, resulting in potential poorer plant performance during the cold period

Settling

- neglect of inlet and outlet arrangements or of unit drainage during design results in poor performance of settling tanks

Filtration

- inadequate backwashing facilities for rapid sand filters
- a slug of poor quality water coming from filters directly after backwashing
- filtration plants using pumps for backwashing cease to function in the event of pump failure
- slow sand filters are sometimes used when a rapid sand filter or pressure filter are better choices (for instance, when chemicals are closed). This invariably results in lower flow rates or poorer water

quality when the slow sand filters are preceded by chemical dosing

- performance of slow sand filtration process not optimal when operating conditions are not nearly constant
- because of the size limitations of package plants, these systems often have to operate at high filtration rates, resulting in rapid accumulation of solids and hence short filter runs and more frequent backwashing, all of which leads too mechanical wear, wastage of clean water and high energy costs
- poor filtrate quality of short filter runs due to incorrect media in the filters (too coarse or too fine or depleted)

Disinfection

- insufficient chlorine contact time

General

- inappropriate process(es) used
- small systems based on coagulation, flocculation and filtration still have too many moving parts, resulting in maintenance problems, especially in remote areas
- equipment/plant not flexible enough ◘ cannot be adjusted
- abstraction of raw water from a dam or river is often done at a wrong location or with poor abstraction arrangements
- provision is not made during the design stage for stabilisation for corrosion control
- lime for stabilisation is dosed at a position where there is poor mixing (usually somewhere between the sand filters and clean water reservoir). The result is sedimentation of lime or the formation of calcium carbonate that also settles in the reservoir
- facilities for cleaning and drainage of tanks and equipment are not provided
- effect of weather (corrosion; flooding; etc.)
- too high technology (prone to failure) (difficult to operate/maintain/ repair)

b. Operation

Coagulation and flocculation

- Operators normally do not have a full understanding of coagulation chemistry, and can therefore not control (or be expected to control) the coagulation process properly
- Chemical dosing not proportional to flow at all times, resulting in either underdosing or overdosing during periods (which can be long) of operation

Settling

- Settling tanks are not always desludge when required, leading to compaction of sludge in the bottom of the setting tank, causing difficulties with withdrawal for disposal (do not control settling process by observing dept of sludge blanket or floc carry-over)

Filtration

- Slow sand filters not operated properly (frequency/method of scraping Schumtzdecke or washing/replenishing sand)
- do not follow prescribed procedures for backwashing of rapid sand filters

General

- operators not familiar with the basic principles of water treatment
- not familiar with working of equipment (not shown how it works or how to operate)
- operators not shown how it works or how to operate
- too easily convinced by chemical/equipment suppliers
- resistance against certain equipment
- do not know how to adjust processes
- not enough personnel for operation/process control/monitoring
- take short-cuts and compromise water quality
- inadequate monitoring/process control/lab. Equipment
- inaccuracy in chemical make-up/dosage control/lab. Analyses
- wrong perception of process control
- chemicals not readily available in local (or even regional) stores
- overloading of plants (settling tanks; filters)
- no attention to stabilisation of final water
- too easily into a routine of a certain procedure
- difficult to change perceptions

- not knowledge of what final water quality should look like, and why it is important
- power failures

c. **Maintenance**

- no back-up available (or take very long)
- spare parts not (readily) available
- do not have skills/tools to do maintenance themselves
- spare-parts not available
- over-sophistication of plants
- problems with servicing of remote plants (telemetry not feasible)
- poor communication between communities and support agencies
- access roads in poor condition
- no electricity
- do not realise importance of regular maintenance
- consultants and contractors located in distant urban centres
- no funds for maintenance

d. **Management**

- inter-personal problems/attitude/relationship
  - with subordinates
  - peers
  - superiors

- insufficient management supervision/interest (workers get frustrated)
- there is minimum cost-recovery, even of the operating costs, resulting in large portions of the government funding for new or improved systems being used merely to operate and maintain existing schemes
- problems with working conditions
  - pay
  - fringe benefits
  - working hours
  - distance from home to plant
  - access to training
  - career development
- lack of community involvement (especially over the longer term)

- do not feel □ownership□ (communities perceive the system as being government and therefore take no responsibility for it)
- shortcomings in the institutional arrangements can lead to project failures

Based on the information obtained during the visits and discussions, the main problems are broadly prioritised as a **lack** or **inadequacy** of the following:

- ***Funding/financing for***
  - ***timeous upgrading (plants have to operate under stress)***
  - ***maintaining equipment and infrastructure***

- ***Back-up service by equipment and chemical suppliers***

- ***Supervision and management support***

- ***Staffing and training of operators***

- ***Process control (especially chemical dosing)***

- ***Response to changing raw water quality***

- ***Corrosion control***

2.4 CRITICAL COMPONENTS FOR SUSTAINABLE SMALL WATER TREATMENT SYSTEMS

(Swartz, CD, Chris Swartz Water Utilization Engineers, August, 2002)

In striving towards the provision of sustainable small water systems that will overcome or avoid the problems as listed earlier, the following are essential elements of small water systems that must be borne in mind when planning, designing, managing or upgrading these systems(Swartz, 2000).

2.4.1 Low construction costs

Construction and operation costs should be compatible with the resources and preferences of the users, and limited or no use should be made of imported material.
Treatment processes should be integrated to provide efficient production of high quality water at minimal cost.

It is important to note that the community does not always choose the lowest-cost option, but rather an affordable option which they feel will provide them with a service they are satisfied with and are capable of maintaining.

2.4.2 Low operating costs

Processes that have high chemical or energy costs may be poorly suited for small systems. High operating costs leave meagre financial resources for other needs, such as operator pay or loan repayments, or result in high water tariffs.

In general, technologies offering higher services levels place correspondingly higher resource demands on the benefiting community. This refers to both the initial capital outlay as well as ongoing operation and maintenance costs. These latter costs include both technical skills and materials (fuel, chemicals, spares, etc.). This is an important consideration in the South African context where sponsorship or subsidies may be obtained for the initial capital investment, but not for the ongoing operating and maintenance requirements.

2.4.3 Simple operation

The treatment system should, if possible, be adaptable to allow part-time operation. Small systems frequently can afford only part-time operators.

Therefore, water treatment processes that require constant monitoring and operator attention are not well suited to small systems.

The treatment system must have a well-written and user-friendly operation and maintenance manual, that can be used by the plant manager and operators as first reference when problems are experienced or adjustments need to be made. It should contain sections on regular maintenance required and trouble-shooting, and must have complete and clear diagrams and drawings. The manuals should be written in the home language of the plant operators that will be using it.

It recommended that the plant manager also acquire copies of relevant quideline documents from the Water Research Commission that can assist in operation and management of the plants.

Operators should not look at suppliers (chemicals; equipment) to help them with their problems. They must use guideline documents or consultants.

Good operation of treatment systems depends mainly on good observation of the different parts of the process. This require patience and training as conditions change relatively slowly. Good observation will detect subtle changes early, so that corrective action can be taken before the situation develops into a more serious incident.

Backwashing of equipment can be done automatically, but this operation should be observed from time to time to verify that everything is in good working order.

2.4.4 Low maintenance

Service from manufacturers and chemical suppliers should be readily available.

Good access to the plant and to all process units should be provided.

2.4.5 Reliability of service

Provision should be made to prevent, or deal with, possible deterioration of the quality of raw water or breakdown of the treatment system.

Dosing pumps must be selected with due attention to expected reliability, lifetime and maintenance requirements.

To ensure that poor quality water does not leave the plant when dosing pumps are inoperative during power failures, a automatic valve should be provided on the outlet of the plant, which will closes automatically during the power cut.

2.4.6 Performance

The primary treatment requirement is always to ensure a microbiologically safe supply for drinking purposes. Hence disinfection of the water will usually be the primary treatment objective. Secondary objectives may include clarification of the water, and the removal of potentially harmful chemical components.

The choice of treatment depends to a large extent on the average raw water quality, the volume of water required, and the design considerations listed above.

There should be regular audits of small water systems from government side, or from contractors (consulting engineers) appointed by the authorities.

Appropriate systems should be included to monitor the performance of the treatment system. For instance, pH monitoring facilities with alarm indicators are important to ensure that the required process performance can be maintained under varying conditions.

The quality of water supplied should not under any circumstances deteriorate below certain acceptable limits during the period of time for which the system has been designed.

Transmittance of plant performance data from remote locations by telemetry is strongly advised, even if costly.

Often simply changing the point of disinfectant (chlorine) dosing can have a marked effect on the performance of the treatment system.

Better mixing of chemicals can be achieved by provision of injectors strategically placed before pipe bends and orifice plates.

Filtration systems should be designed so that the filters are drained and filled with clean water after backwashing before resuming normal filtration, so as to prevent the short period of final water quality deterioration.

Modification of the inlet and outlet arrangements of settling tanks can go a long way towards preventing floc carry-over and ensuring a higher quality settled water.

2.4.7 No serious residuals disposal problems

Disposal options for plant residuals should be readily available.

In coagulation-flocculation systems, the use of polymers in place of inorganic coagulants can result in production of smaller quantities of sludge. Because polymers have health significance, the dosage limit for a particular product must not be exceeded. Disposal of sludge will vary in difficulty, depending on several factors.

2.4.8 Provision for future upgrading

Provision for future upgrading requires the generation of finances to create a reserve fund within the system. This is important because outside loans or grants are unlikely to become available at the right time in the future to effect the needed or desired changes. Understanding of the importance of such a reserve fund is usually difficult for a community who often require cash just to secure the basic needs.

Specific measures that can be taken for upgrading existing rural plants, either to increase its capacity or to improve the quality of the treated water, or to make provision for changes in raw water quality, are being investigated and will be presented in the guidelines document emanating from the project.

A number of such measures are listed below as example:

- providing improved rapid mixing and/or flocculation systems
- retrofitting existing settling tanks with inclined plates or tubes
- changing filter media in rapid sand filters
- converting slow sand filters to rapid sand filters
- replacing drip-fed dosing systems with reliable mechanical/electrical dosing systems
- providing affordable on-line process control instrumentation
- improve backwashing facilities of filters

2.4.9 Well-trained operators

The plant should have a manager and operators that have a thorough understanding of all functions of a treatment system in order to maintain optimum water quality and to control cost.

Apart from more formal training courses on the principles and basics of water purification, it is even more important that operators should also be given on-the-job training at the plant where they will be employed, for a sufficient period to ensure that they are familiar and confident with all the aspects and responsibilities of operation of the plant. This should also include drills on procedures that needs to be taken during plant upsets or raw water quality changes.

After undergoing the basic in-service training, the operator should be given the opportunity to attend the course in water and wastewater treatment at a Technical Institution.

Training should not end after the initial training course and on-site training, but should be followed with regular refresher courses.

2.4.10 Community involvement

Operation, maintenance and construction (if feasible) should be within the competence of local technical staff or the users. Prior to construction or upgrading an assessment should be made of available skills in the community and the authority.

The choice of treatment system, as well as its implementation and management, must take into consideration the aspirations and preferences of the community itself.

Community participation has the following three dimensions:

- involvement of all those affected in decision making about what should be done and how
- mass contribution to the development effort, i.e. to the implementation of the decisions
- sharing in the benefits of the programmes.

Research has indicated that there is an on-going need for training in the following areas for communities:

- constituting and running of water committees
- bookkeeping, accounting and recording of minutes
- training of plumbers for constructing and maintaining unsophisticated water distribution systems
- training of borehole pump maintenance personnel
- training of water storage tank builders
- training of community health educators
- training of primary school teachers in the fundamentals of domestic water supply, management, public health awareness and personnel hygiene.

2.4.11 Institutional

Plants treating more than 150 m³/day of water must be registered by the Department of Water Affairs and Forestry.

In order to achieve successful institutional arrangements, more projects need to be implemented as pilot projects where all the institutional aspects receive attention. In particular, the full co-operation and involvement of the relevant government departments, local institutions, community members and other interested organisations should be assured.

The technology should be sustainable by the community with minimum external support.

2.5 PLANNING, DESIGN AND OPERATION OF SMALL WATER SYSTEMS
(Thompson, P, Umgeni Water, August 2002)

2.5.1 Introduction

Umgeni Water has been involved in the implementation of rural schemes since 1987. Many of the schemes implemented necessitated the need for a small water treatment works. The move from the typical large water treatment works, that Umgeni Water had grown accustomed to, to the small water systems required for rural schemes required a conscious change in our planning, design and operation philosophy. The experience gained over the last 15 years has afforded us the opportunity to compare the performance of various technologies and to review the reasons for success and failure of various institutional arrangements. The success or failure of small water treatment systems can be attributed to one of the following: Lack of Planning, Economy of Size, Technical/Operational Support or Choice of Treatment Technology.

This paper summarizes some of the lessons learnt in the planning, design and operation of small water treatment systems.

2.5.2 Planning Small Water Treatment Systems

a. Institutional Aspects

Each phase in the development of a small water treatment system requires considerable community participation. This involves assessing the community needs, level of affordability, availability of local resources, community empowerment and capacity building. These aspects are discussed in other papers presented at this workshop and this paper has concentrated on some of the technical aspects of planning, design and operation of small treatment systems.

b. Water Quality and Quantity Assessment

One of the primary pieces of data that is often missing when designing water treatment systems is historical water quality data. Besides DWAF and Water Boards monitoring of some of the larger rivers and dams, very little data is available for the smaller rivers and dams in our country. Process engineers are often called in at the beginning of the detailed design of the scheme and asked to design an appropriate treatment works. This is often too late as there is insufficient time to collect a representative set of water quality data that is needed for design purposes. Most schemes are planned 3-5 years ahead and it is at the planning stage that a proper water quality assessment should be undertaken.

As a minimum, data should be collected on a quarterly basis for a period of at least two to three years to ensure that seasonal fluctuations are taken into consideration. The choice of determinands depends on the source i.e. river, dam or aquifer. The water quality data should be measured in conjunction with the hydrological data such as velocity, discharge and water levels of dams and groundwater.

c. Water Quality Standards and Guidelines

In many of the larger works, emphasis is placed on the health effects of chronic diseases caused by substances such as trihalomethanes (THM's). These chemicals are associated with chronic health effects including cancer. However, it should be borne in mind that these effects require many years of exposure. In the typical rural areas where small treatment systems are required, the health effects of diseases such as cholera and dysentery are of much more relevance. Scientists and microbiologists thus need to balance these risks with the standards/guidelines that are applied to ensure the water is microbiologically safe. Setting very high standards or following first world standards could in some cases be inappropriate and these high standards should rather be set as goals. Exceptions do exist, especially for contaminants such as nitrates, arsenic and fluoride. These contaminants have to be removed if they exceed World Health Organisation (WHO) guidelines. Removal of these contaminants requires sophisticated technology and it is more appropriate to seek an alternative source.

2.5.3 Design of Small Water Treatment Systems

a. Design Criteria

In many of the small rural schemes, population statistics and growth rate data is often not available. Estimation of population density, growth rates and water consumption figures for design purposes in earlier years was poor. However, this has improved markedly over the last five years and this has resulted in changes to our design standards. A second parameter that has been improved is the design period for construction. The earlier design engineers used the traditional design periods of 20-30 years. These figures resulted in major water quality failures in the primary distribution system due to long retention times. These figures have been downgraded and designs are now undertaken for periods of 5-10 years and structures, such as reservoirs, are designed in a modular fashion to ensure ease of upgrade.

b. Source Selection

Source selection is a critical aspect of the design of a water treatment works. Groundwater would typically be the first choice as this requires minimal treatment and in many cases only needs to be disinfected. In Kwazulu-Natal a large proportion of the ground water sources tend to be contaminated with iron, manganese fluoride and nitrate. Removal of these contaminants requires sophisticated chemical processes that are difficult to operate in the rural environment. Often this contaminated underground water is the only source available and process engineers have no choice but to implement these sophisticated chemical treatment processes. Schoeman and Steyn (2002) have recently made considerable progress in the use of membranes for the removal nitrates in rural schemes. This has been made possible by ensuring that a well-trained technical team is readily available to assist the local community.

c. Unit Process Selection

In many rural schemes in Kwazulu-Natal, surface water has been the only source available and this has required the use of traditional treatment processes of chemical coagulation, flocculation sedimentation, filtration and disinfection. During the water quality assessment it is also necessary to ensure sufficient samples are taken for laboratory jar tests to determine optimum pH, coagulant type and dosage rates. If this information is not available, the design engineer should investigate whether other treatment plants abstract water from the same river or catchment as this would provide appropriate performance data for existing unit processes.

South African rivers tend to exhibit high turbidity and suspended solids necessitating the need for some form of pre-treatment. Historically roughing filters or horizontal flow sedimentation tanks have been used as a pre-treatment unit process followed by slow sand filtration. During the last decade chemical coagulation and sedimentation in upflow clarifiers combined with pressure filters have become the popular choice for many small treatment systems treating high turbidity water. There has been a tendency to move away from slow sand filters as they are regarded as “old” technology. Although pressure filters will produce acceptable water quality when operated correctly, it must be emphasized that slow sand filtration is still regarded as the most appropriate solution for small treatment systems where land is readily available and raw water quality meets the following minimum criteria:

Determinand	Maximum Concentration	Units
Turbidity	20	NTU
Colour	25	^{o}Hazen
Algae	200 000	cell/ℓ
Ammonia	3	mg/ℓ
Iron	1	mg/ℓ
Manganese	1	mg/ℓ
Dissolved Oxygen	>6	mg/ℓ

If the raw water exceeds the above the limits, an appropriate roughing filter or horizontal settling tank should be used. A recently published manual on roughing filter design, Wegelin (1996) provides an excellent reference for the design engineer interested in roughing filter design. Horizontal settling tanks have a well-proven history and are able to handle sudden changes in solids loading as can be experienced in river abstraction systems. Unfortunately in South Africa we have been dictated to by the "quick fix" package plants that have flooded the local market and in many cases have replaced the roughing filter/slow sand filter or horizontal settler/slow sand filter option. The trend towards package plants is primarily due to the lower capital cost but has also been caused by process failures, either in the design or the operation, of the slow sand filtration system. Slow sand filtration failure is often due to total blockage of the sand by the application of high turbidity raw water to the filters. Other causes of failure are due to the over-dosage in the pre-treatment systems and poor filtration rate control.

Design problems experienced with pressure filters tend to be the incorrect sizing of the filters due to budget constraints. In poorly planned systems, the cost of the treatment plant is often under-estimated and thus there is a limited budget when it comes to project implementation. This results in high filtration rates of 20-30 m/h, resulting in short filter runs and high energy costs due to the need for frequent backwashing. Many pressure filters have inefficient backwashing systems due to poor design. This inefficient backwashing system coupled with the fact that none of the typical pressure filters has a combined air/water backwashing system, leads to mudballing with subsequent deterioration of filtered water quality

Chemical dosing systems required for pressure filtration are frequently oversized resulting in overdosing. The modern trend is to replace conventional ferric and alum salts with polyelectrolytes. These polyelectrolytes are very sensitive to dose and minor deviations from the optimum dose will cause restabilsation of the particles and failure of the system. In small treatment systems, alum and ferric salts are still the preferred choice as they are less sensitive to over or under-dosage.

Other typical design problems include the lack of facilities for the measurement of raw water flow rate, filtration velocity and head loss development.

One of the major advantages of slow sand filtration is that there is often no need for chemical dosing. Slow sand filtration is more efficient than pressure filtration in the removal of pathogens and cysts such as G*iardia* and C*ryptosporidium*.

2.5.4 Operation of Small Water Treatment Systems

Schultz and Okun (1984) quote the following statement by George D Woods, former president of the World Bank (1965).

"Neither general programs nor even generous supplies of capital will accomplish much until the right technology, competent management, and manpower with the proper blend of skills are brought together and focused effectively on well conceived projects".

They rightly conclude that this statement "summarizes the dilemma that is faced in the provision of water in the developing world".

Many of the schemes implemented are sold as fully automated package plants and there is often the perception that there would either be no operators required or minimal operational input. We have found that irrespective of the degree of automation, a minimum operator input of two hours per day is required to ensure continual production of acceptable quality water. The operator needs to undertake the following measurements on a daily basis: chlorine, pH, turbidity, flow rates, reservoir levels and chemical dosages.

Intervention by the operator would depend on their level of training. However, it would be expected that they have been trained to make decisions such as optimising the chemical doses.

a. Technical and Management Support

All systems that have treatment plants will need some technical backup from management, artisans, technicians, laboratory personnel, scientists and process engineers. Small stand-alone treatment systems cannot afford this level of institutional backup and this is one of the primary reasons for failure of the entire system. Fortunately, in large institutions, such as Umgeni Water, these services are readily available as the overhead costs can be shared across a large number of small treatment systems.

b. Training and Development

On-going training and development is a prerequisite for the sustainability of small treatment systems. It has been our experience that local operators become highly marketable once they have been trained in the operation of treatment plants. This requires an on-going operator-training programme that provides technical and operational training skills.

There are limited numbers of locally based staff trained in operation of water treatment plants. It can take anything from 18 months to two years to get a local resident trained to the level required. It is thus best to identify suitable staff during the planning stage of the project and employ them during the construction stage. This ensures that they receive on-going training during the project life cycle whilst gaining an excellent understanding of the integration of the various unit processes.

c. Independent Water Quality and Process Audits

As part of the routine operation of the small treatment systems, an independent water quality audit needs to be undertaken to ensure that the water complies with the guidelines or standards that have been agreed to by the consumers and the water service authority. Independent process audits need to be undertaken to ensure that the treatment process is optimized and to assist with any major technical problems that have been identified. The frequency of these audits depends on the number of consumers being served and the volume of water supplied.

CHAPTER 3

COMMUNITY NEEDS AND EXPECTATIONS FOR SMALL WATER TREATMENT SYSTEMS

3.1 INTRODUCTION

A key challenge facing implementers of water provision in South Africa is the inadequate supply of this basic resource in rural areas. It is estimated that 65% of the 17 million people in rural areas do not have adequate water supply and 95% do not have access to adequate sanitation[1] . Being aware of this major challenge, the Department of Water Affairs and Forestry (DAWF) initiated the Community Water Supply and Sanitation (CWSS) programme to address these inadequate services and significiant financial resources have been committed to make a radical and meaningful impact.

It is well known that rural people are much poorer than their urban counterparts with 60% of households having income below R 800 on average[2] . Most of these rural folk have historically been located in former homelands with limited access to a range of financial resources and institutions. By year-end 1998, DWAF had served three million people, mainly in rural areas, with new water connections[3]. The sustainability of these water projects is however open to question. According to some reports, as many as 90% of the new taps are inoperative[4].

3.2 DELIVERY CRISIS

Minister Ronnie Kasrils recently said that there were more than eight million people in rural areas who did not have access to clean water and that the original date projected for the fulfillment of the department's water services target – the year 2007 – might be unrealistic. He admitted that if his Department continued at its present rate, it would take twenty rather than seven years to reach its goal[5].

Various recent studies of local water supply projects indicate a serious crisis in delivery and general failure to meet planned targets. There are generally said to be serious problems in the community water supply projects with a rate of failure

[1] Department of Water Affairs, sustainable management of rural water supply and sanitation services, framework for establishing water service providers in rural areas August 1998,p.1.
[2] I bid, p.2.
[3] Nelson Mandela, 1999.
[4] Bond, Dor and Ruiters, April, 1999.
[5] SAPA report June 2000, Minister Ronnie Kasrils Parliamentary report

as high as 90%. Apart from possible affordability constraints and an unwillingness to pay for communal standpipes, other important reasons for failure include poor quality of construction, areas within communities without service and intermittent supply.

Community water supply systems have led to numerous instances of inequity. Adjacent communities pay different amounts depending on the systems installed. Rural households pay for water from standpipes, whereas households in Durban getting water on site, get the first 6 kilolitres per month for free (according to the Durban Metro, 6 kilolitres is the break even point between the cost of collecting payment and the amount collected). Communities with new water systems must pay for the ongoing functioning of their water for free. These inequities have led to significiant levels of community tension within and between villages. And, despite the claim to provide "some to all," vast areas have not received water services to date[6].

A July 1998 evaluation of RDP 1 and completed RDP community water supply projects in the Eastern Cape indicated the extent of the problems[7]. The evaluation aimed to assess these projects, primarily with regard to sustainability and operation and maintenance. Four main areas were investigated:

- community participation and management
- training
- technical aspects
- post-project activities

The evaluation found that, with regard to community participation and management, communities felt they had not been properly consulted and were merely informed that they were to receive a water project. This led to problems including inappropriate services, conflict, and vandalism of pipes.

Despite guidelines stipulating consultation, community representatives were dissatisfied with the level of consultation by engineers. The result was that recipients were not informed of their responsibility for costs of operation and maintenance before work started. Community structures had little to do with organizing labour and there was dissatisfaction over rates and selection of who would get jobs. Men were also felt to be favoured above women in this process.

Training of community members was also inadequate. Key findings were:

- Most training was not project specific and did not equip committees to undertake operation and maintenance

[6] Bond, Dor and Ruiters 1999, and Bond and Ruiters 2000.
[7] DWAF 1997(b).

- Most training was received too late to be useful in implementation
- There was little assistance in setting up operation and maintenance systems
- Training would have been more appropriate in the project area.

The extent of the problem becomes clear when looking at technical issues.

- Of 29 schemes, only 48% were working and operational.
- If, however, management and collection systems are included, the number of operational projects was "dramatically less"
- Of 19 RDP schemes, only 26% were working
- Gravity systems were found to be more likely to be working than pumped systems, especially where there was inadequate capacity building and no development of an operation and maintenance system.

While there was virtually 100% willingness to pay (R5/household average) for *working* water services, many schemes were not operational. The key reason for this was that most projects had no operation and maintenance system due to:

- lack of training and support
- lack of consultation on responsibility
- lack of awareness of the need to pay for services,
- political conflict on the ground

There was no cost recovery on most projects and a general feeling of lack of consultation with the community[8].

Another study of rural water schemes discovers problems similar to those raised in the Eastern Cape study [9] above. This study was conducted in 1998 for the Water Research Commission[10].

Based on 22 Mvula Trust and 2 DWAF rural projects in Northern Province, the Eastern Cape and Kwazulu-Natal, the study looks at reasons for the failure of a high proportion of rural community water supply schemes. According to the author, this failure is manifested in communities withholding payments negotiated when the projects were initiated.

The results of the research point to problems with conceptualization of the national rural community supply initiative. The programme was designed to provide each household with 25 litres of clean water per person per day within 200 metres. Villagers were to pay operations and maintenance costs. Agreements were negotiated with elected community representatives (water

[8] SAPA 2000.
[9] DWAF 1997(b)
[10] Water Research Commission 1998.

committee) while community members were trained to manage the project as well as the ultimate water scheme.

The research found that

- Many communities already had their basic water needs met and wanted a higher level of services than the national water supply programme envisaged
- Projects that were successful were situated in villages with a dire need for water and which benefited appreciably from the project
- Communities which felt that their basic need for water was already satisfied (even if it was not clean water) and found that their expectation of a higher level of service (a tap in their own yard) was not met, withdrew their payments
- Collapse of water projects did not happen simply and directly – there were usually other problems during implementation. These were the real reasons for failure but the water committee could not find enough enthusiasm to resolve them, probably because they did not really need the water.

The study argues that a problem with the conceptualisation of the water programme is the assumption that community cohesiveness is a valid basis for election of a water committee with which outsiders can negotiate and conclude agreements. The research casts doubt on this assumption. In some cases the community preferred to abandon the project rather than risk internal conflict and loss of cohesion.

Within projects reasons for failure included:

- Weak community leadership
- Lack of communication between the water committee and the community
- Lack of project management expertise
- Impatient and ill-advised engineering consultants
- Unequal benefits from the water scheme to community members
- Projects proceeding without contributions from all community members
- No way of forcing community members to pay
- Multi-village schemes too difficult for a water committee to manage
- A low level of service
- Unwillingness to give money to fellow villagers
- The role played by organization such as South African National Civic Organisation and African National Congress Youth League.

The author claims that, affordability, although used as an excuse, does not seem to be the real reason for non-compliance.

The review recommends improved community management, including making consultation integral to the whole process; conflict resolution support; enforcement of equitable distribution of jobs between men and women; and consideration by DWAF of project steering committee representation at project management meetings.

It is also suggested that training and capacity building should begin early and be viewed as integral to the whole process. Such training must be project specific, not generic, and should ensure accountability and transparency of committees *vis-à-vis* the community. Operating and maintaining is essential for community management. Community members should also be offered mentorship and support while the capacity of local government should be strengthened.

Other general points include the need to address training shortcomings at completed projects and assist committees to develop management, tariff collection and technical management systems. Initial feasibility studies should include institutional and social assessment and mechanisms must be put in place to address the communication gap between DWAF and communities on completed projects.

Additional issues for consideration include: consideration of flexible basic service options, the need for an ongoing monitoring and evaluation mechanism and resolution of outstanding technical issues.

These are all clearly issues, which demand a greater involvement of the appropriate local government structures. Given that many of these structures currently lack the capacity and resources to play an appropriate support role, some sort of interim arrangements are necessary.

CHAPTER 4

GUIDELINES FOR COMMUNITY INVOLVEMENT AND PARTICPATION

4.1 EXPERIENCE AND CURRENT POLICY TRENDS INTERNATIONALLY

Problems such as those noted in the above two reports are common to many projects both locally and internationally. One international response to a generalized crisis in rural water delivery is the World Bank's proposal for a transition from *supply-oriented* to *demand-responsive* services.

The demand-responsive approach was the key theme of the World Bank's Community Water and Sanitation Conference held in Washington DC in May 1998[11]. The approach has subsequently been promoted internationally by the Bank as the alternative to the traditional supply-oriented or basic service approach.

There are four overarching principles, which form the basis of the demand responsive approach (DRA):

- Water should increasingly be managed as an economic as well as a social good
- Management should be focused at the lowest appropriate level
- A holistic approach to the use of water sources should be employed
- Women should play a key role in the management of water[12].

The Bank argues that the demand responsive approach is "one in which supply is tailored to meet the economic demands of users". The approach is summed up as one in which technology and services options are "based on the willingness to pay – based on the principle that more expensive systems cost more"[13]. Leaving aside the Bank's talk of a "holistic approach" and a key role for women in water management, it is clear that a demand-responsive approach means that the level of service will ultimately depend on what rural consumers of are able to pay.

Explaining this approach further, a paper by the Bank's Mike Garn[14] describes the approach as a change in thinking about the nature of water from social good to economic good. The test of this approach is whether the users are willing to pay at least as much as the economic cost of water services.

[11] The World Bank, 1998
[12] J. Sara, M. Garn, T. Katz; The World Bank 1998.
[13] J. Sara, M. Garn, T. Katz; The World Bank 1998.
[14] M. Garn, The World Bank 1998.

According to Garn, the supply-dominated approach (such as is proposed in the Reconstruction and Development Plan) has led to the adoption of appropriate low-cost technologies and a minimum level of service, whether or not users see them as an improvement over existing water systems. Most projects do not offer users choices of different levels of service, as this would increase the cost to government. Dissatisfaction with service quality leads to non-payment, cutbacks and the need to ration reduced funds.

For Garn, one response is to offer a choice between different levels of service at a clearly stated price to the user – let the user decide. The issue of competition for funds can according to this model, be resolved by letting communities self-select for projects under widely understood rules about cost-sharing requirements for various service options. Incentives for demand-based local selection of service level can be provided through negotiated agreements (between the supplier organisation and the community) about payment for costs under established cost-sharing rules.

The demand-responsive approach to service delivery is also put forward as providing increased scope for private sector and/or NGO involvement in implementation of rural water and sanitation projects.

It is argued that demand (willingness to pay) is often enough to support service levels above the minimum often prescribed. Demand is not well correlated with needs-based estimates of affordability and can't be predicted on basis of income alone. This means that projects targeting only the poor do not require extensive government subsidies as many had assumed. While the assumption was that people would be willing to pay 3 to 5% of their income for water services, in reality some will want to pay less and some may be willing to pay more.

According to a 1993 World Bank study[15] : "household income, though often important, is not the overriding determinant of demand for improved services".

Garn argues that a number of factors in fact influence demand for improved water services and willingness to pay for improvement. These include:

- household income, gender, education, occupation and assets
- the relative merits of the current supply system (cost, quantity, quality, reliability)
- household attitudes toward government policy in the sector and towards other organizational representatives with whom local citizens deal as well as the degree to which there is a sense of entitlement to services.

[15] The World Bank 1993

For successful demand-responsive water projects, says Garn, participation cannot be token. The community must play a role in designing programmes and selecting the type of facility, the level of service and conditions under which they are offered. There will be a willingness to pay more if people perceive that improved service will provide more, better and more reliable services than current sources do. They will also be willing to pay more for higher levels of service.

A project can be considered to be demand-responsive if users make a substantial number of decisions about the type and level of service they want and there are negotiated arrangements for cost sharing based on transparent rules.

While subsidies are allowed in demand-oriented programmes, the approach emphasizes that users should be responsible for operation and maintenance costs (paid in cash or labour). The subsidies should also be given as a per capita or household amount with users responsible for all additional costs. Government's fiscal responsibility can thus be fixed and users get a relatively clear picture of price to them of various level-of-service options.

In his recommendations Garn argues that supply-driven and centrally directed approaches to rural sector services have little chance of sustainable improvement. The rural sector is, as a result, in transition to a more locally controlled and demand-oriented approach. The main elements of the approach are:

- rules that give users incentive to reveal their demand and supply agencies incentive to act on that information
- implementation procedures that encourage adherence to rules and transparency in their application

The Water Research Commission[16] study mentioned above, purposes solutions which are largely in line with the World Bank's approach. The report recommends an essentially demand-responsive approach:

- The national water initiative should be adjusted to provide for a higher level of service where communities feel their basic need for water has already been met. This would entail taps in each yard where the water source can support this.
- Users should pay towards the higher level of service as well as the operation and maintenance costs, preferably by pre-payments.
- Projects should be undertaken with community consultation.

[16] Water Research Commission 1998

- Projects should include some kind of provision for the indigent.

Based on the above agreement in favour of a demand responsive approach by DWAF, it has been proposed that the notion of sustainability and community participation should underpin the objectives of this approach. These objectives are articulated as follows:

- User satisfaction.
- Community empowerment and self reliance.
- Community ownership.
- Strengthening community organisational skills which can be transferred to other development initiatives.
- Resource mobilization from many sectors.

A starting point of DRA is that the community initiates a demand for water services. In cases where there is insufficient demand from the community, the demand needs to be stimulated, but in a manner where the community themselves decide what is best to meet their needs[17].

Thus in the earliest stages of the project it is important to ensure that:

- Communities are aware of and understand the value of water and that they are being offered a service
- Communities see the value of water as being greater than merely having access to water for domestic use, i.e. there are health benefits and economic benefits.
- Communities recognize that the process of being involved in the planning, design and implementation of water project brings additional benefits to the community such as skills development, problem solving abilities, etc. which can be used in other development initiatives and in their own local economic enterprises.
- Communities select their own level of service which they are able afford and for which they are willing to pay.
- Communities are involved in management decisions.

- The approach requires that communities are given the responsibility for making choices and decisions around the following:

- How they want to participate in the different phases of the project.

[17] DWAF, I.S.D. package for water supply projects, March 1999.

- How and with whom they want to plan, develop, implement and operate and maintain the water services.
- What type of scheme they require.
- The level of service they want.
- Where the services should be located.
- How the services will be paid for.
- Allocating funds for maintenance of the service.
- How the institutional arrangements ensure ongoing community decision-making and participation.

4.2 COMMUNITY PARTICIPATION

4.2.1 Definition and General Discussion

The term community participation simply means the involvement of people in projects that are aimed at improving their own situation. Due to the diversity of project objectives and activities, this term has been understood and interpreted differently by different people. However, a working definition seems to emerge among some international development organizations. According to this definition[18], participation has three dimensions as follows:

- The involvement of all these affected in decision making about what should be done and how
- The mass distribution, to the development effort, which is the implementation of decisions
- Sharing in the benefits of the project

These three dimensions define community as an active involvement of the local population in defining their problems and making decisions concerning the project, their implementation and evaluation thereof. Community participation is further defined as an organized involvement of a community in a development effort with all major groups being represented as opposed to a person-to-person relationship[19].

The involvement of a community in physical work alone cannot be considered participation unless there is at least some degree of sharing of decisions between community and consultants. Therefore, if an outside agency remains in total control of the process and merely calls upon beneficiaries to give their labour directly, one cannot speak of community participation though there is an element

[18] White, 1981, p.2.
[19] IRC, 1988, p.1.

of self-help labour. This practice is still prevalent as has happened in the apartheid South Africa, where the government and consultants merely employ labour from the community to dig trenches and then claim popular participation when in actual fact the community has had no input in the decision-making process.

What development practitioners should understand is that in any development process there are three participants, identified by Berger,[20] there are policy makers, the theorists (engineers, social scientists, ect) and the ordinary masses. The first two participants have their own different objectives and policies, and their tendency is to empower as well as to ignore the needs of the masses. In planning water supply projects, project implementing agents or consultants need to take cognizance of the fact that the ordinary masses know best the situation and complexities of their everyday life situation.

Therefore, a dialogue should be encouraged between the project planners and user community in order to negotiate a strategy to implement a water supply project. This is where the sociologist or social scientists role becomes crucial. The sociologist should be able to encourage the parties to open up to the views of others, rather than ignoring or eliminating them. The organic and indigenous leadership existing in the community should not be ignored.

Community facilitators may be selected from teachers, nurses, and agricultural officers, and will help to provide information about community attitudes, perceptions, preferences and doubts.

Most importantly, the facilitator must also be able to understand and communicate the technical and economic aspects of available alternative technologies to allow communities to make appropriate choices.

4.2.2 Who Should Participate

Ideally, all the people in the community should participate, irrespective of their political affiliation or social status. It is therefore essential that an outreach strategy should be developed in order to motivate and encourage even the poorest of the poor to participate. There is always the tendency to think that the views of elite are the views of the disadvantaged, and the sociologist and facilitator should exercise maximum vigilance in this regard.

[20] Coetzee, 1986, p.122

Participation in most projects tends to come from the economically well-off and educated elite rather than the poor. It is also true that despite the fact that women fetch the water normally at a distance, men make decisions regarding the choice and sitting of water schemes. It is therefore imperative that facilitators should guard against these tendencies. Efforts should also be made that groups in the community be involved; and this could be done through consultations with opinion leaders, women's groups, youth and religious groups.

4.2.3 Procedure for Community Participation

There is no one perfect model for community participation that is applicable to all situations. Even in the same country, participation may take different forms because of different socio-economic situations of people. It is therefore necessary to point out that aspects highlighted here could be modified to suit particular circumstances. Most of the information presented here is derived from local research studies as well as our own (RSS) experience gained in implementing and evaluating water and sanitation projects.

Phase I: Problem Identification And Selection Of Communities To be First Served

In this phase, planners need to identify communities with problems related to water supply and sanitation in their area of operation. In view of the fact that not all communities can be served simultaneously, there is a need for prioritization. Criteria that might be applied in prioritizing communities include:

- Communities who take some initiative to upgrade their own services;
- Communities where water sources are polluted and unprotected such as springs, ponds and rivers where animals drink and wade;
- Communities where facilities have broken down, or are functioning poorly;
- Poor/disadvantaged communities who live below the poverty level (worse socio-economic problems);
- Communities where water is scare with an availability of less than 20 litres per person per day;
- Communities with a history of repeated and/or frequent incidence of water and excreta related diseases;
- Communities where sanitary facilities are limited[21].

A village profile needs to be compiled and include more information on indicators of community organization, previous experience in participation of projects, local

[21] Chandler, 1986, p.2.

leadership and factions within the community. In addition[22] the following critical questions be considered in this pre-planning stage:

- Is there a legal framework, which permits community participation?
- What has been the background of community participation in the country and particularly in the region of the project?
- What is the likely level of 'social readiness' for changes envisaged and for the desired level of community support?
- What governmental and non-governmental organizations are concerned with water supply and sanitation, community involvement and the involvement of women?
- Who can assist in preliminary designs of community participation?
- What is the variation in the country or region in terms of cultural traditions, languages, felt need for improved water supply and sanitation?
- Will technological solutions influence levels of acceptance and community participation?
- What is the political climate which supports or constraints community participation?
- How can existing social or developmental structures be best used in new projects?

This information would be used to assess the level of readiness of a community to participate in water supply and sanitation project. In this way, planners will be in a position to rank communities into high and low-priority groups, with the former selected for initial action.

Phase II: Participatory Planning

Having drawn up a priority list of communities to be served, the next step which must be treated with circumspect is the establishment of contract with the community. A more humane approach is imperative in order to foster long-term rapport with the community. This phase involves consideration of a number of key issues, each discussed individually as follows:

- **Negotiation with local authority and focus groups/opinion leaders.**

At the outset, local authority and other community leaders must be contacted to assess the need and priority given to water supply and sanitation in relation to other priority needs. The planners should explain the rationale for choosing that particular community; objectives of the project as well as the possible spin offs

[22] IRC, 1988, p.18.

the project will bring about. A dialogue should be encouraged at all stages of negotiation. If the local authority is in favour of the project, it becomes imperative that planners conduct further discussions with focus groups in the community to ensure that all parties are fully aware of the project. Focus groups of not more than six people may include:

- Transitional local councils
- Burial societies / savings groups
- Women's leagues
- Professional and business elite
- Youth groups
- Political groups
- Development forums

Throughout the discussions, planners must ensure that open dialogue is encouraged, thus, encourage the introverts or reticent members of the group to feel no constraints against expressing their views. Unless more specific information is needed, the discussions must be kept as informal as possible. Informal discussions are valuable in eliciting a variety of information as well as creating a relaxed atmosphere conducive enough for group members to supply information. A checklist of information that needs to be gathered is essential.

However, questions could be memorized in order to maintain the smooth flow of discussion. Group interviews are advantageous because:

- Community members who for whatever reason are unable to express their views publicly are able to do so in small group discussions. For example, in most African cultures, it is still a taboo for women to speak in front of men, therefore, group interviews gives them a chance to voice their options. Moreover, women are more knowledgeable about water use in the family unit.
- Group interviews usually facilitate as self-correcting mechanisms. For instance, if one person over or underestimate the number of perennial springs in the village, his group members will give a more realistic view of the situation.

If the project is acceptable to all community members (or at least the majority) the next step is to arrange a formal meeting.

- **Community meeting**

A formal meeting is vital to ensure that all members of the community know about the project. The implementing agent or consultant should once again explain the rationale behind the undertaking of the project. Possible spin offs should also be explained. Planners must also try by all means to determine the indigenous knowledge available in the community. All possible water supply and treatment alternatives should be explored.

Constructive dialogue should be encouraged, and both planners and community members must formulate alternatives based upon suggestions made. The diverse ideas of the community must be taken into account at all times.

At this stage the consultant must negotiate to conduct a socio – technical feasibility study to ensure local details within the community. The results for the study should be reported at another meeting.

- **Feasibility study**

It is crucial to undertake a survey in order to assess aspects that may influence the potential success of the project. Although the data could be gathered from group discussions, there is some personal data, which could only be gathered at

household level. Such data include water use and practice, income level, and demographic factors to support available statistics.

However, a combination of group discussions and individual interviews to gather this data could be used.

A representative sample of a few households could be interviewed to ensure that the following details are established[23] :

- Mortality, especially among infants.
- Practices in relation to water, sanitation and health.
- Household as an economic unit.
- Migration patterns (especially of men).
- Source and level of income.
- Attitudes to paying for water.
- Possibility of paying in ways other than cash.
- Attitudes and willingness to work together as a group.

[23] Whyte, 1986, p.18-19.

- Levels of education for different sex and age groups.

Technical considerations may include:
- Available / potential water resources
- Distance
- Per capita usage
- Assess technically feasibility of various alternatives
- Workout cost/ benefits of alternative sources
- Local technical knowledge, skills and capabilities

The local people need to be involved in the survey, particularly on social aspects because they are more knowledgeable about habits and resources available in the village. This involvement can come about through the selection of facilitators. In most cases, these facilitators are experienced in working with the community, share its culture and know who the leaders are. It is necessary however, that basic training on social science techniques of gathering information, listening and interviewing are given. Another advantage of involving local facilitators is to eliminate suspicion especially if outsiders conduct surveys on their own.

- **Second community meeting**

This is the stage at which the results of the feasibility study as well as the analysis of technical alternatives suggested by the community are reported back for discussion. The planners should be in a position to clearly explain the implications of the various options with respect to capital costs, operation and maintenance (physical and cost) and replacement. At this stage it is vitally important that a dialogue be encouraged because the future sustainability of the project hinges largely on this crucial step. The community should be guided into choosing an acceptable and affordable technology (ies). In addition, the technology should be simple, fulfil the users' needs and expectations and be easily maintained by the beneficiaries.

Having chosen an appropriate technology for the villages, a project steering committee (PSC) should be elected (it sometimes happen that a committee is already in place, but may need training or re-training). This committee must be as representative as possible, and their roles and responsibilities should be clearly defined in order to limit misunderstandings.

A checklist of aspects to be considered at this stage include the following: [24]

- Timing for construction
- Choice of level of service and sitting of schemes
- Allocation of tasks
- Provision of paid or free labour
- Supervision of labour
- Provision of local materials
- Provision of refreshments for workers
- Applying penalties/allocating rewards
- Management of community funds
- Keeping records of labour as well as financial contributions
- Provide storage for tools
- Eligible people to be trained in operation and maintenance of schemes

In fact, the above tasks will be the duty of the steering committee who, after planning would report back to the community.

Phase III: Implementation

The role of all parties should be clearly defined prior to implementation. It is important that the community have a major input into scheduling implementation of the project according to seasonal activities such as cultivating the land, planting and harvesting. The community should be encouraged to decide on the most appropriate time to start with the construction.

The planner's role is to design and supervise construction. The on-the-job training of personnel for operation and maintenance should begin as soon as possible[25]. In most cases, some committee members assist in the construction process itself.

Throughout the project cycle, health education should be emphasized. Householders should be encouraged to build pit latrines in order to prevent contamination of the water sources. At completion of this phase, a ceremony may be organized to officially inaugurate and hand over the facility to the community. It needs to be noted that there is a need for establishment of links with a programme support network to ensure back-up assistance, where necessary. The programme support network may also include a unit to evaluate projects.

[24] Whyte, 1986, p.43.
[25] Chander, 1986, p.5.

4.3 THE IMPORTANCE OF INSTITUTIONAL ARRANGEMENTS

4.3.1 Previous Institutional Failures

The different institutions and organizations involved in making sure that clean water reaches rural people are set out in the Water Services Act (Act 108 of 1997).

One of the failures of sustaining water plants is the lack of building a community capacity and social institutional arrangements. Provisioning in the past was based on a top down approach with particular reference to implementing policies in former homelands. It is important to note that these "governments" received sufficient funding from the fiscus of the former South Africa government but little attention was paid to the principles of a demand driven approach, hence the high failure rate of such schemes[26] . At present there is agreement that the facilitation of effective social institutions and capacity of these bodies are pivotal to the success of water delivery programmes in rural areas.

DWAF has developed a framework of how institutional development could be established and capacitated. Institutional and Social Development (ISD) in a water project refers to a "set of principles towards ensuring that a development approach is taken when planning, designing and implementing a water project[27]. Development is defined as "a process of social, economic and human empowerment through which ordinary people gain greater control over the factors which control their lives. It is a process where people are at the center of their own emancipation with the support of others"[28].

ISD requires that:

- Communities participate in decision making and are actively involved in all the phases of the project cycle as well as the ongoing operations and maintenance of the water service
- Local capacity is build towards managing water services and partnerships are developed between communities, local government and water service institutions.

The key complimentary goals of ISD is to ensure sustainability and effective use of water services. The concept of effectiveness refers to the optional way of how household use their water services, meaning that:

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[26] DWAF, August 1998.
[27] DWAF, ISD package, March 1999, p.1.
[28] Ibid, p.1-2.

- Households are using water services rather than their traditional water source;
- Water services is used in a hygiene way and that;
- Water services provides developmental spin-offs[29].

4.3.2 Key Institutional Arrangements

a. Project Steering Committee (PSC) and labour desk

A PSC needs to be established towards ensuring that all role players participate in the planning and decision making of the project. Part of the ISD work is to facilitate the establishment of this committee and to ensure that it is able to perform its decision making and governance role during the implementation of the project.

A labour desk also needs to be established to ensure that local workers are included in the construction of the projects and that they develop appropriate technical skills.

Powers and functions of the PSC

As the main decision-making body regarding the management of the project, the powers and functions of the PSC will involve:

- Ensuring that the proposed scheme is carried out in accordance with the RDP principles and policies.
- Recommendation for the appointment of consultants (note the PSC merely recommends who should be appointed, since approval and appointment is the responsibility of the implementation agent acting on behalf of the Department).
- Recommendation for the appointment of a training agency.
- Recruitment of labour by means of sub-commitees / work groups, i.e. labour subcommittee or technical task team.
- Advising on and assisting in the management of labour intensive aspects of the work
- Advising on and assisting the implementation agent in the appointment or dismissal of employees subject to policies, rules and procedures as stipulated in the RDP guidelines.

[29] Ibid, p.3-4

- Approving the disbursement of funds.
- Participating in the drafting and approval of the Business Plan
- Establishing and monitoring sub-committees / task groups to undertake specific functions e.g finance task team.
- Planning, reviewing and implementing all operational activities
- Constant liaison between the community and the PSC through its members
- Participate in the monitoring and evaluation of the project

b. Water Services Authority

This institution regulates how water supply and sanitation services are provided and who provides them within its area. The Water Service Authority must understand the water supply and sanitation needs of customers, and also ensure that progressive action is taken to meet these needs. As Selection 11 (1) of the Act says: Every water services authority has a duty to all consumers in its area of jurisdiction to progressively ensure efficient, affordable, economical and sustainable access to water services"[30]. (Chapter 3 of the Act deals with the Water Services Authority).

i. Tasks and duties

The Act says the Water Services Authority must:

- Prepare a water services development plan outlining how water services will be provided.
- Involve communities in drawing up the plan, and report on how it is being implemented.
- Carry out the functions of the Water Services Provider itself, or enter into a contract or joint venture with one or more Water Services Providers.
- Create and pass by-laws which regulate conditions for water services provision, and set tariff structures for payment.

ii. Other important functions of the Water Services Authority are to:

- Channel funds to Water Services providers, Implementing Agents, and other relevant institutions
- Monitor and facilitate services provision
- Settle disputes

[30] DWAF

The Water Services Authority is the local government structure – usually the District of Regional Council, or sometimes the TLC / TRC. Water services can only be obtained through a Water Services Authority and its contracted Water Services Providers, according to the Act.

c. Water Service Provider

This institution does the work of providing water services to customers – according to its contract with the water services authority. It operates the water services supply system, interacts with customers and sees that payments are made, amongst other things. The water services authority can contract a community-based organization e.g., a Water Board, a private company an NGO or an adjoining local authority, to be the Water Services Provider. No Water Services provider even ordinary water vendors – may operate without permission from the Water Services Authority.

i. Tasks and duties

These will depend on its contract with the Water Services Authority, but the Water Services provider must at least:

- Operate the water services provision system
- Handle customer relations
- Collect revenue payments for water services
- Enter into a contract with a bulk water services provider (if the scheme requires a bulk water supply)
- Contract in support services, if necessary

ii. Below are other important tasks and duties of a Water Services Provider. (if it does not have enough capacity to do them itself, these can be contacted out):

- Prepare business and operations plans, and manage human and technical resources
- Install and maintain water services and provision and infrastructure so that customers stay satisfied with the service.
- Prepare budgets and manage funds
- Do major repairs and maintenance

- Gather information about water and sanitation provision and make this available.

In some places (typically urban areas), the Water Services provider will be the same body as the Water Services Authority. Here a contract must also be made – between the Council and the actual department or unit working to provide the service.

d. Support Services Agent

Support Services Agents help community-based and other small Water Services providers carry out their work efficiently and to the satisfaction of customers. A contract is drawn up with the Support Services Agent who can be any person or organization offering a broad range of support activities.

Tasks and functions

The main functions of the Support Services Agent is:

- Providing regular mentoring and advice, both in the technical and institutional and social development (ISD) fields.
- Assisting with major maintenance which is beyond the capacity of the Western Services provider to undertake.
- Assisting with purchasing equipment and materials, and making best use of bulk buying opportunities.
- Assisting with sanitation pit cleaning.

With all functions, a contract is drawn up to cover the conditions of work.

4.3.3 Water Provision Options

In the discussion in the previous sector of the document it was emphasized that water provision options are of critical importance to communities in implementing a water project. What follows is description of these options.

OPTION 1

Local Government is Water Services Provider

Local government takes on the full water services provision role, including bulk water supply (if appropriate), as well as providing retail water services to customers.

Features:

- Sanitation promotion or project implementary may be contracted out
- Water Services Authority and Water Services Provider functions are managed and carried out separately.

Advantages:

Good for building up local government capacity and staffing
Simple arrangement of organizations and functions

Disadvantages:

- Difficult to build capacity soon enough to effectively serve many widely spread settlements.
- Hard to keep close contact with customers.
- Can easily lead to top-down development.

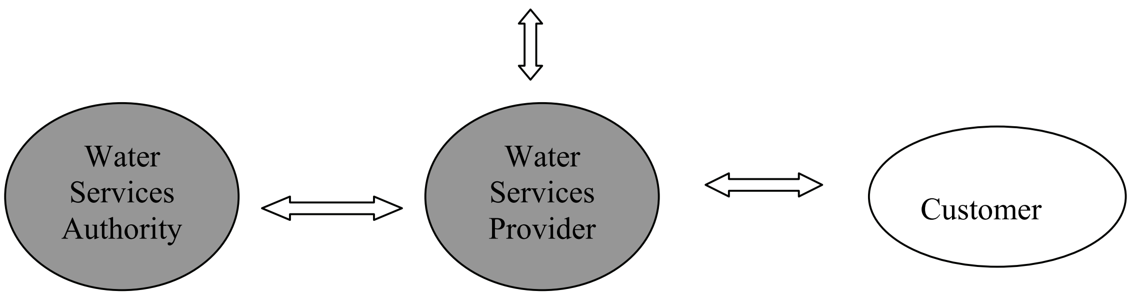
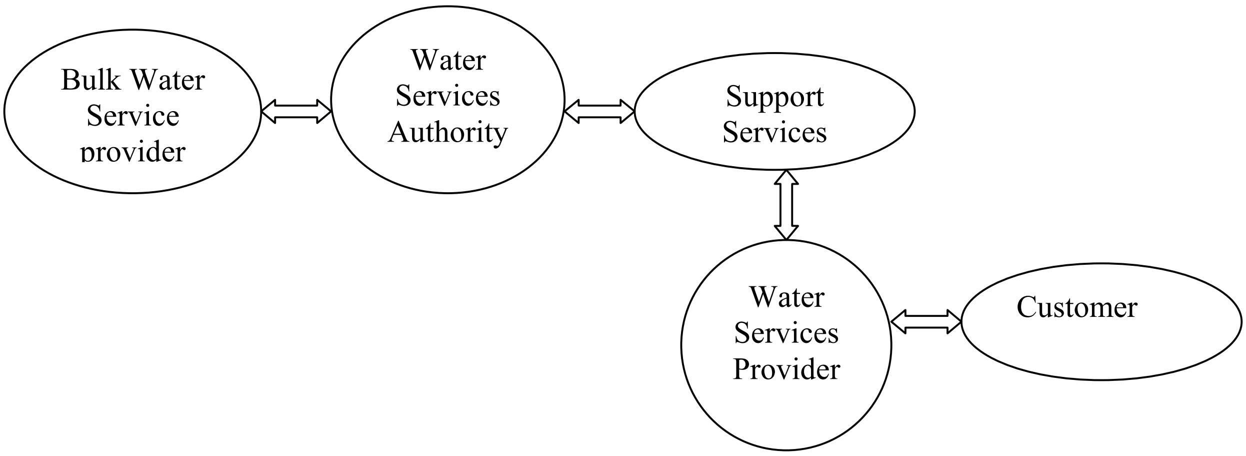


DIAGRAM SHOWS WATER PROVIDING

OPTION 2

Community based organization is the Water Services provider (with Water Services Authority Support)



Local government contracts a community-based organization (usually water committees) to take on the Water Service provider tasks and responsibilities, and it supplies bulk water and other support services itself.

Features:

- Water Service Authority (local government) has contract with community-based Water Services Provider
- Local government (as the Authority) must monitor the community provider.
- Sanitation promotion or implementing activities may be contracted out.

Advantages:

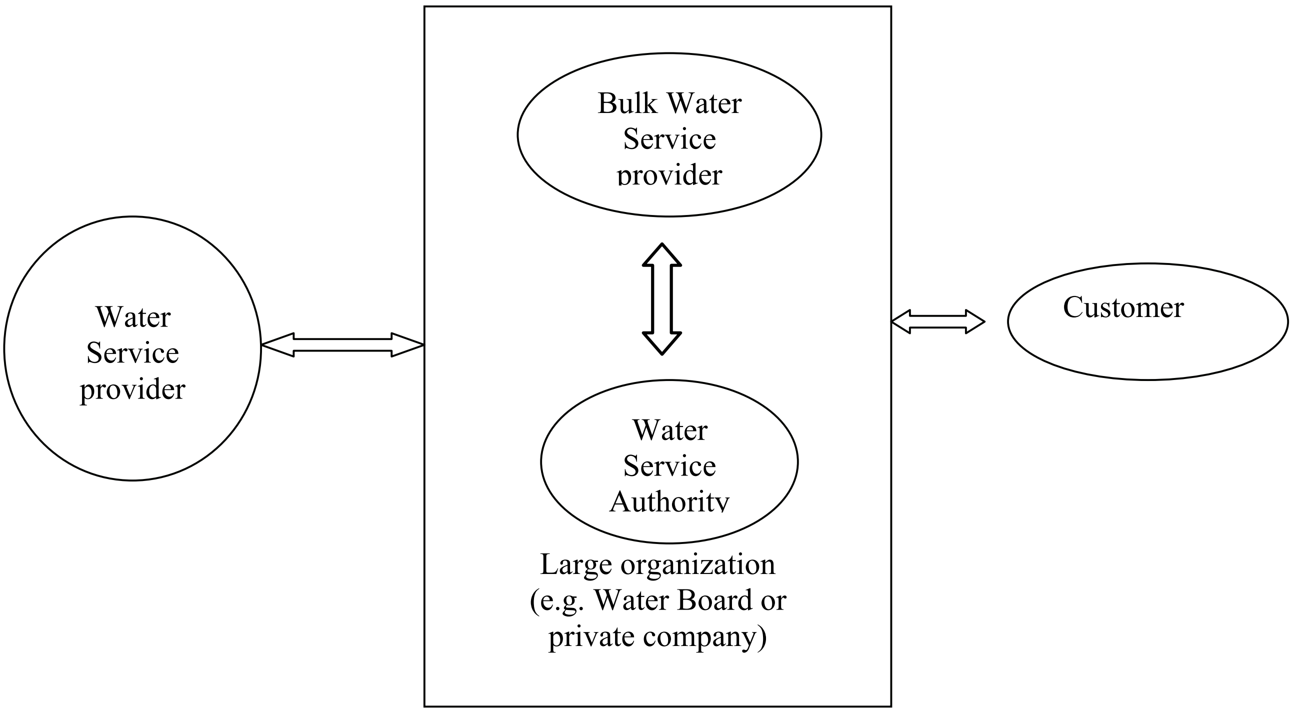
- Benefits of demand responsive approach can be realized
- Responsibilities delegated to communities, so a better “bottom-up approach
- Cost effective
- Good track record in South Africa

Disadvantages:

- Large number of Water Services Providers to monitor
- Water Services Authority has no direct link with customers
- Large capacity needed within local authority to be both Water Services Authority and to provide bulk supply and support services

OPTION 3

Large organisation is Water Services Provider



Local government contracts out all water services provision functions to another large organization e.g. Water Board or private company.

Features:

- Single contract – only with the large organization.
- As Water Services Authority, the local government monitors water services provision.
- Local government may do some functions itself (e.g. support services or sanitation promotion).

Advantages:

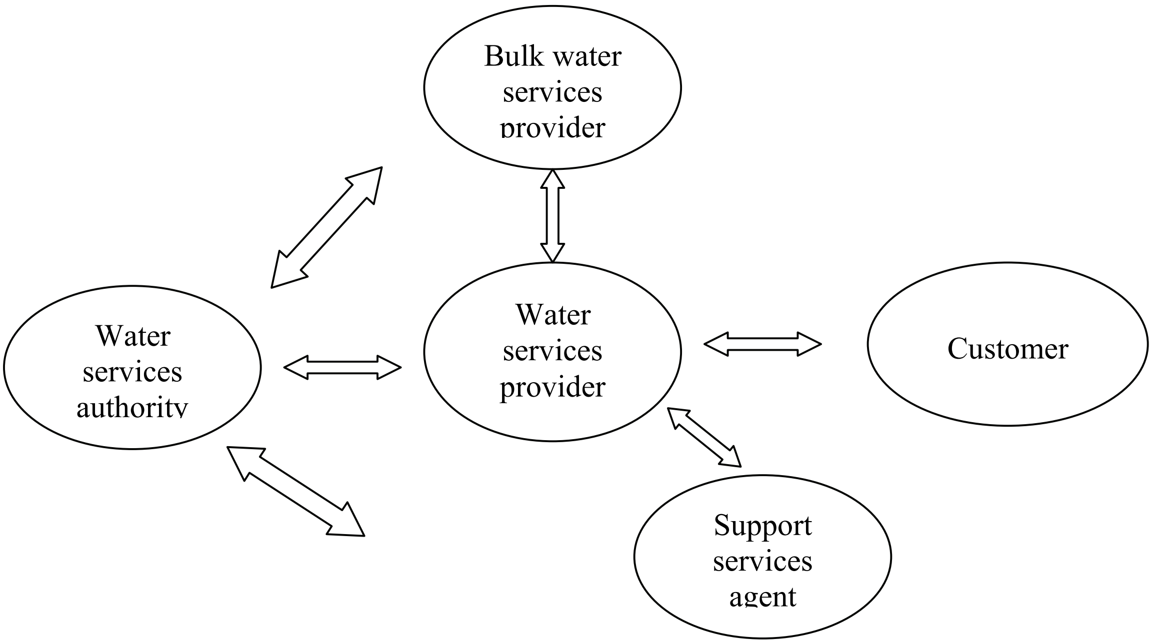
- Brings in strong capacity for water provision, provided delivery is effective and pricing is reasonable.
- Simple arrangement of organizations and functions

Disadvantages:

- Depends on competence of a single Water Service Provider
- Possibly a high cost option for customers
- Water Services Authority has no direct link to customers
- Likely to be top-down' approach
- Water Services provider links to customers depends on closeness to community

OPTION 4

Community based organization is Water Services Provider (with Support Services Agent)



Local government contracts a community based organization to be the Water Services provider Agent, who in turn contracts in a Support Services Agent (or agents) to provide support services as required. Local Government also contracts a large organization e.g Water Board or Private Company to provide bulk water, it required.

Features:

- Local government contracts out all services functions, but, as the Water Services Authority, retains a monitoring and regulatory role.
- Is required, a Bulk Water Services Provider contracts a Support Services Agent (or agents) to assist with, for example, sanitation promotion, ISD and technical mentoring, bulk purchasing, and project implementation.

Advantages:

- Makes best use of community-based providers and highly skilled organizations.
- Local government does not have to build large capacity.
- Low cost option.
- Benefits of demand responsive approach can be realized.
- Responsibilities delegated to communities, so better ‘bottom-up’ approach.

Disadvantages:

- Depends on availability and capacity of Support Services Agent’s.
- Possibility of many Water Services Providers to monitor.
- Water Services Authority has no direct link with customers.

4.4 THE IMPORTANCE OF OPERATION AND MAINTENANCE

It is necessary to establish the main activities and functions that should be fulfilled for an effective project and one that will be sustainable in the long term.

This refers to the everyday workings of the water supply. For example, the starting and stopping of the engine and pump, the purchase and storage of diesel, the opening and closing of valves or the regular dosing of chemicals for purification. Operation activities will vary depending on the scheme that has been installed.

Maintenance: This refers to the activities that must be undertaken to ensure that the schemes remain in working condition. For example, fixing of taps and broken pipes, cleaning of reservoirs or replacing of the V-belt on the pump. Preventative maintenance of equipment and infrastructure is very important.

Two types of maintenance should be done, running repairs and preventative maintenance:

Equipment needs to be repaired when it is broken to ensure that the services is not disrupted. Running repairs would include the fixing of taps, broken pipes, broken pump etc. Preventative maintenance would include the servicing of the pump, the cleaning of reservoirs i.e. activities that are done routinely to prevent damage to the system. Preventative maintenance is the best way to: minimize unplanned emergency breakdowns; minimize crisis maintenance; usually saves money in the long term. Continual crisis maintenance leads to; frequent breakdowns; an unreliable water supply; poor service levels'; a lack of user confidence; the complete failure of the system.

4.4.1 Developing a Monitoring System

The most effective way to ensure effective operation and maintenance is to institute a monitoring system. This will allow committee members and the community first hand knowledge as to whether or not their water scheme is operating effectively and will be sustainable in the long term.

Some guidelines to successful operation and maintenance monitoring:

- Keep it simple;
- Monitoring should be supportive and useful to the those doing the monitoring;
- Do not collect more information which is easily verifiable;
- Ensure the data collected is not too complex to process;
- Involve users and water committees in the process;
- Be flexible
- Develop indicators (see below) which are understood by all who are part of the operation and maintenance system. The main problem with most monitoring systems is that they are often imposed on the committee by an outside agency. A suggested approach is to include the committee and other role players in setting the indicators to measure the sustainability of the project. The monitoring system must be appropriate to the needs of the users.

The following steps are suggested for the development of a community based monitoring system in conjunction with the water committee:

1). Identify the basic operation and maintenance tasks – "Baseline" (include key tasks such as the purchasing of equipment, fuel and spare parts)
2). Identify basic operation and maintenance performance indicators
3). Test the indicators for a limited period to allow the users to give feedback and the modify the indicators accordingly.

There are two main direct benefits to the consumers if operation and maintenance is conducted effectively, *viz*:

Improved health through the use of sufficient clean water.

If the system is maintained, the beneficiary will receive the designed amount of water. If not, the beneficiary will have to resort to using unsafe sources of water collection. This will lead to an increased risk of illness and result in health care expenses.

Close access to water can save the collectors considerable time and energy, which could be used for other activities. If the water supply is disrupted, the beneficiaries will be forced to seek water from sources that are located some distance from their homes. Collection from these sources may involve long hours of traveling. This time could have been more productively spent.

4.4.2 Broadly stated, a water supply scheme is sustainable if:

1. The water source is not over used and the consumption rate is lower than the supply rate i.e. the amount of water required by the consumers does not exceed the available supply from the river, spring or borehole.

2. The facilities are operated and maintained in a condition that ensures a reliable and sufficient supply of potable water i.e. the supply is continuous.

3. Even though it is important to assign operation and maintenance tasks to specific individuals, the role of the community as a whole remains crucial. Community based operation and maintenance involves communities taking an active part in identifying and acting on problems as they occur.

4. The community should collaborate with support agencies to provide assistance when the committee is confronted with as problem that they are unable to solve. Support Agencies would include consultants, District Councils, NGOs or any one who has knowledge about community based water systems and can provide some assistance.

5. There are a number of key elements to ensure effective operation and maintenance. These should be monitored to avoid possible future problems in operation and maintenance.

4.4.3 An Outline for Key Areas that Needs to be Addressed to Ensure the Sustainability of the Scheme:

- **<u>Demand for the service and health awareness:</u>**
  The existence of a genuine need for the supply of accessible safe clean water to ensure that users support the operation and maintenance activities, for example, if people stop valuing the benefits of clean water as a means to good health, they will start using other unsafe sources and therefore undermine the value of the water system.

- **<u>Strong institutions:</u>**
  Community structures must have recognized legal status, clear roles and responsibilities, adequate financial controls, good committee organization and the representation of all the stakeholders of the community on the structures. A poorly managed scheme will fail to satisfy the expectations and needs of the community.

- **<u>Expertise and skills:</u>**
  The operation and maintenance skills needs to identified and the capacity of the office bearers and staff to fulfill their obligations must be ensured through training. A pump attendant must have the necessary skills to service the pump, just the same as the bookkeeper must be able to keep accurate books.

- **<u>Supportive attitudes:</u>**
  The office bearers and the staff are committed to share responsibilities and display a sense of ownership. A positive commitment from the community to strive for a reliable water source is crucial. If individuals or political elements aim to disrupt or take over the scheme, the system is sure to fail.

- **<u>Appropriate level of service:</u>**
  The service needs to be affordable and manageable. It must be upgradeable in future when required. If a scheme is too expensive to operate or does not deliver the expected level of service, the project will not be supported by the community.

- **<u>Materials and equipment:</u>**
  Spare parts must be available locally to avoid unnecessary stoppages.

- **<u>Support services:</u>**
  Operation and Maintenance systems must be effective. Support agencies should be locally based. The committee should know who to contact if they are confronted with problems that they are unable to solve themselves eg. engine repairs.

- **<u>Financial matters:</u>**
  The financial sustainability of the system is likely to be influenced by the ability and willingness of the beneficiaries to pay. Paying for operation and maintenance is an important part of the sustainability of a scheme. Insufficient funds will result in a break in the delivery of water. A poor service leads to poor tariff payment, which in turn leads to lack of resources for operation and maintenance.

4.4.4 The Basic Operation And Maintenance Tasks

There are four main areas that need attention:

- ***Institutional Arrangements***

A WSP committee must be in place. A clear structure and lines of accountability between the VWC and the WSP must be documented and understood by committee members.

A constitution for the community based WSP should be in place and be accepted by the WSA.

Contracts between the WSP and the WSA, WSP and any support agents, WSP and Bulk WSP should be signed by the relevant parties.

Office bearers must have received training in their various portfolios.

Employed staff must be trained in their various tasks and their conditions of employment and job descriptions clearly agreed upon.

An up to date data base of all residents must be kept including the number of households and the number of people per household.

A register must be in place for all taps including new or disconnected yard taps. A map showing the location of all the tap stands would be very useful.

- ***Financial issues***

  - A Treasurer must be elected
  - The Treasurer must have received the necessary training
  - A bank account must be opened and must have a positive balance.
  - A projected budget must be prepared to assist the WSP to plan its spending and be realistic about what it can afford.
  - A register of the contributions from each household (showing all payments eg. monthly or quarterly payments) must be compiled.
  - A tariff collection system must be put in place.
  - A cash book must be in place to record transactions.
  - The wages for the employed staff must be set.
  - The monthly household tariff for communal stand posts must be established. This tariff must cover the cost of all operation and maintenance activities including wages, diesel or electricity, purification materials and repairs.
  - The rate for yard connections must be set.
  - The cost of a legal yard connection must be calculated to include the pipe fittings, valve box, flow meter, standpipe, apron and any labour.

- ***Technical Operation and Maintenance***

Village level Technical Operators must be “employed’ by the community based WSP.

Technical Operators must be trained to do operation and maintenance of the various components of the system, including preventative maintenance.

The process for ordering and purchasing spare parts must be understood by die Committee and the Technical Operator.

The Committee and the Technical Operator must have a copy of the As-Built drawings which show the actual completed infrastructure.

A register/log book of meter readings, both bulk and yard meters must be kept by the Technical Operator.

Training on water balance analysis must be done .i.e. how much water is being used compared to how much has been supplied, to establish if there are any water losses due to leaks or illegal connections.

An Operation and Maintenance Manual for the entire scheme must exist, this should have been developed together with the Training Consultant

A schedule of maintenance must be planned.

The operator must have a site diary to record operation and maintenance activities.

- ***Communication Strategy***

It is important that the Committee and community have a clear understanding of what the communication structures for the water scheme are.

A programme for regular committee meetings must be scheduled.

A regular date must be identified for the Annual General Meeting (AGM).

The role of the WSA must be clearly defined and documented.

The role of the TRC Rep must be clearly defined and documented.

The process for communication to the community of decisions, new rates etc by the Committee must be established and documented.

A public liaison officer must be identified to deal with community inquiries, requests and conflict that may arise.

4.5 VILLAGE CASE STUDIES

4.5.1 Context

Qoqodala is a multi-village project consisting of 12 villages. This study covers four of the villages, Mannelspoort, Xusha, Lalini and Nzolo. These villages were selected for study on a random basis. The Qoqodala villages lie in a wide, dry, valley surrounded by mountains some 30 kilometres from Queenstown. The valley has no electricity network. Solar-powered telephones have recently been installed there.

The water supply project for these villages was initiated in 1994 and completed in 1996. The project however dates back to 1989 when the local Development Forum approached the then Transkei Military Council for assistance. Various NGOs were subsequently contacted, including Rural Support Service which referred the Forum to the

Mvula Trust for funding. During project implementation Rural Support Service facilitated technical training and institutional and social development for local structures.

Each of the 12 Qoqodala villages has its own water committee. There is no tribal system in the villages and the local transitional rural council (TRC) is the accepted authority. Since the inception of the water scheme, each village has had its own reservoir and pump. Operations and maintenance are carried out by village technical teams, which were trained to maintain the water systems. Each household originally contributed R20 to kickstart the operation and maintenance (O & M) process and households now contribute between R2 and R5 per month depending on circumstances in the village. The residents of each village determine the size of the contribution. Since these are small village level borehole schemes, there are no treatment plants. However, environmental impact studies have been conducted, and samples of the water have been tested for suitability. The reservoirs are cleaned periodically, and domestic bleach is used to sterilize the water.

A brief description follows of the water supply situation in each of the four selected Qoqodala villages.

4.5.2 Mannelspoort

Local conditions:

This village consists of 146 households and lies at the end of a gravel road about 3 kilometres from Qoqodala. Poverty is a significant problem in the village with only 15 % of households surveyed having a formally employed member. 45 % of households surveyed were wholly or partly dependent on a pension for their survival, while 30 % of households were wholly or partly dependant on remittances from an absent family member.

The project:

The project became operational in 1996. The water committee which was originally elected and trained to manage, maintain and operate the water scheme has since been replaced by a new committee. The project uses a diesel pump to pump water from a borehole. This supplies 18 tap stands serving the 146 households and a population of 2430. Water from the taps is supplemented with water from a protected spring located at a higher level. A piped connection to the spring was built by the community using its own resources and training gained through the project. This connection allows the community to save on diesel expenditure as it operates on the basis of a gravity feed. The project and the gravity feed from the spring have resulted in significant savings in time for the community, as they no longer need to walk long distances to fetch water.

Water from the reservoir is also used to irrigate a communal vegetable garden. 85 % of respondents say that they now get most of their water from tap stands as opposed to the river, which was previously their main source 70 % state that they get all their water from the scheme. All respondents interviewed felt that women's water workload was reduced as a consequence of the scheme. Households pay a monthly tariff of R5 to the water committee and 60 % are prepared to pay more for a yard tap on their own property.

Apart from occasional payment problems, no significant difficulties have been experienced since the inception of this scheme. This is partly due to a thorough training and empowerment process undertaken with the community. This started early on in the project and addressed financial and administrative, technical, maintenance, construction and health aspects.

Synopsis:

This is a small, closely-knit community and it is easy for most residents to take part in decision-making around the water scheme. In addition, the community was thoroughly trained and involvement in project work was ensured. As a consequence of the training process and thorough community involvement in the project, payment levels for water are good despite prevailing levels of poverty in the village. The project provides a good standard of service.

4.5.3 Xusha

Local conditions:

The village is situated at the eastern end of Qoqodala. It has a population of 2 500, living in 114 households. Only 25 % of households include a formally employed person while 65 % are wholly or partly dependent on a pensioner. Half of all households are wholly or partly dependent on remittances from a absent member.

The project:

The project became operational in 1996. The scheme uses a diesel pump to secure water from a borehole to a 50 000 litre reservoir. This in turn supplies 16 communal taps. Villagers currently use less than minimum standard designed for (25 litres per person per day). Exact consumption figures are not available but 95 % of respondents say they now get their water from a communal tap and 90 % say that 25 litres is always available. Respondents state that the average family (5.8 persons) uses three 25 litre containers of water daily. Respondents express a desire for a higher level of service 65 % state their preparedness to pay more for a yard tap on their own property.

The project is managed by a water committee which mainly consists of women (the chairperson, secretary and treasurer are all women). Technical assistance is obtained from a company in Queenstown, which supplies a mechanic if required. Households pay a monthly tariff of R8.50 of which half goes towards payments of the operator. While there are a number of people behind with their monthly payments, according to respondents, the project operates well overall. Committee members did however complain of poor attendance at meetings called to address problems with the scheme.

Synopsis:

The scheme operates satisfactorily although a number of households are behind with their payments. 65 % however say they would be prepared to pay more for a tap in their own yard. The project seems to have a committee which is dedicated to running the system. There is a strong indication that the community took part in the project at various stages, including planning, choice of technology, implementation and operation and maintenance.

4.5.4 Lalini

Local conditions:

The village lies alongside a mountain at the very edge of Qoqodala. It consists of 120 households and 2 110 people. This village is one of the poorest in Qoqodala with a higher than average proportion of household members of school-going age or younger (over 65% versus an average for all villages surveyed of about 52%) in households surveyed. None of the 20 households surveyed has a member in formal employment, while 55% are wholly or partly dependent on a pensioner. 70% of households surveyed are wholly or partly dependent on a absent contributor.

The project:

The project began operating in 1996 after initial problems with payments for labour and inconsistent work output. The system serves 13 tap-stands laid out in accordance with RDP standards.

According to participants in a focus group, 40% of the community have not contributed the monthly charge of R5 for several months. Those paying have decide that no water will be pumped by the scheme until everyone pays. In the event of special needs such as a funeral or other function, the affected family usually buys its own diesel to permit water to be made available. The water committee has tried a number of approaches to achieve a satisfactory payment level, including calling in the Qoqodala Coordinating Committee. The committee has resorted to reporting defaulters to the police; and since then a large majority has resumed payments, and the water is flowing again.

There is, however a significant resistance by a substantial minority to paying the monthly tariff. Some maintain that some of those able to pay are unwilling to do so. Others say

that they are unable to afford the monthly tariff due to other responsibilities such as payments for food and school fees. Unemployment and dependence on pensions do seem to be genuine problems for many in Lalini.

Most people have reverted to using a nearby mountain spring as well as the river. Although they originally agreed on a diesel-powered system, the focus group now concedes that it may have been better to opt for a gravity-fed system drawing water from the spring. This would be a cheaper and more sustainable option. Whether or not the implementing agent was told about this option is a matter of dispute. The agents' records indicate that the community did not raise this option.

Synopsis:

There is a delivery problem in this village as a result of a conflict between those prepared to pay for water and a substantial minority of defaulters. Extreme poverty seems to be at the root of the problem. A better consultation process may however have resulted in the choice of a more appropriate technical option and avoided the current divisions in the community which lead to dependency on potentially unhealthy water sources. A decline in attendance of community meetings means that crucial issues are not debated.

4.5.5 Nzolo

Local conditions:

This village has population of 2 360 in 110 households, according to a census conducted by the water committee for purpose of tariff collection. Unemployment is high (only 20% of households have someone in formal employment) and half of households surveyed are partially or wholly dependent on a pensioner. The village also has a higher than average proportion of children at school or younger (over 56% versus 52% on average).

The project:

The project started operating in 1996 and has run smoothly ever since. The scheme uses a diesel pump to pump water from a borehole to a 50 000 litre reservoir. This in turn supplies 19 communal taps. The monthly tariff is R5 per household.

There are substantial problems with local organization . There is substantial non-payment of water charges but little community interest in attending meetings to deal with the issue as long as water continues to flow. The original water committee continues to run the scheme but is without a chairperson as he was forced to resign due to a combination of community pressure and old age.

The community was involved in the initial stages of the project through to implementation. There seems to be a perception that now that the project is running, it is the duty of the committee to run the project. The larger community does not seem to see a role for themselves other than passive consumers of water.

Synopsis:

This scheme is a success in terms of delivery, operation and maintenance. Serious weakness in the committee might however lead to longer term problems and community participation is poor. There is clearly a need to strengthen community involvement in water delivery and build the capacity of the water committee.

4.6 A MATRIX OF EVALUATION AND MONITORING VILLAGE WATER SCHEMES

	Strength areas	**Weakness areas**	**Recommendations**
1. Qoqodala villages			
1.1 Maqwathini	• Committee is active • Committee makes attempts to collect tariffs from the households.	• Community members refusing to pay the agreed upon tariffs. • As a result supply of water has been stopped by project leaders. • One of the reasons for this lack of co-operation from the community side is lack of understanding on the terms of project implementation (e.g	• RSS to give information on the difference between the scheme in this village and other neighbouring villages (e.g difference with regard to funders and the implication that has on the terms of the project). • RSS to give

		neighbouring villages with different funders had different project terms)	information on the implication of non-payment of tariff on sustainability.
1.2 Maqwatini			

1.3 Lalini	• Local Government (DC) is involved (services the engine). • One PSC member is still active and functioning.	• Inconsistent flow of water because 40% of the community does not pay monthly tariffs. • Reason for non payment , they cannot afford the amount that is suppose to be paid. • Closure of the scheme has been proposed up until everyone pays. • Possibility of water abuse when water is supplied on request of the household that has got a function (e.g. a funeral. • Meetings are not attended by community members and minutes are not properly filed. • Only one member of the committee is available. Community is using an alternative original source of water.	• Re-susitate PSC and activate local government involvement • Re-negotiate payments of tariffs with community • Community awareness on health and sanitation issues.
1.4 Mannelsport	• Quality of water acceptable & delivery reliable • Community also uses an alternative original water source, thereby saving money to be for the operation of the new system.	• Reluctance in the transferring of skills from the old to the new committee members.	• RSS to encourage and give information on the transfer of skills between the old and new committee members

	• Committee takes the initiative in protecting both the original and new water source. • Community members give each other a chance to be in the committee. • Operator is a community members and is paid in kind and receives special favours. • Community involved in a fight against vandalism. • Local Government (SDC)actively involved		
1.5 Mayaluleni	• Water supply is reliable • Committee is actively involved. • Law enforcement agents (police) are used successfully enforce the law. • Local Government(SDC) is actively involved maintenance. • Tariff paid per person, per household, per month is affordable (60 cents) • Operators volunteering	• Some community members refuse to contribute tariffs even thou it is affordable. • Amount of tariff too low-may pose a threat to the sustainability of the scheme in future.	• Re-open debate on tariffs
1.6 Mmangweni	• Water flowing • Clear division of responsibility between the committees. • They are working well with the neighbouring village who they share the system with. • There may be a problem with the household payment of funds to maintain the water scheme 9 e.g. taps.	• Main committee is fatigue. • There is a possibility that they may withdraw with no one taking over from them.	• Re-susitate WSP and build new leadership

	• Tariff affordable ?		

1.7 Mazongozini	• Taps are maintained. • Tariffs affordable and collected accordingly. • Few committee members active.	• Committee fatigued with community members refusing to be elected is posing a threat to the institutional structure that is suppose to manage the scheme • Activeness of only one committee member is dangerous to the sustainability of the scheme. • Both issues pose threat to the sustainability of the scheme	• Refresher training to prospective new committee members
1.8 Blangwe	• Committee is active. • The scheme is still operating even though taps have been locked by the committee members.	• Community members do not attend report back meetings • Taps have been closed by the committee	• New tariff structure to be negotiated taking in consideration those households that are unable to pay.
1.9 Xusha	• Most community members pay the o & M fund. • The scheme is in full operation.	• Committee has been in operation for too long, it is therefore fatigued. • Community members do not want to replace the old committee because they fear the responsibility. • Few community members are not paying the o & m funds.	• Committee could continue for at least another year
1.10	• Community is	• Vandalism and	• Education on

Luxeni	actively involves in the maintenance of • Committee is also active in O & M. • Committee keeps track of their financial. • Community uses both the original and the new water resources	neglect are caused of deterioration of the taps. • There's possibility of cost-recovery problems because community members are of the opinion that they are getting water for free.	importance of tariffs • Assessment on costing caused by vandalism and deterioration of taps.
1.11 Langedraai and Gallawater B	• Committee members are still active and they organize outside organisation to assist. • The community seriously wants clean, accessible water.	• Scheme is no longer in operation. • Community has not paid their balance from ESKOM. • Even though the scheme is mot in operation, the community is being charged for renting ESKOM equipment. • Committee and technicians are no longer active because the scheme is not working.	• Re-establish committee and negotiate with ESKOM on operating scheme
1.12. Gallawater A	• Scheme is still in operation. • Committee is still active. • Community is involved in the maintenance of the scheme and making sure that it is not vandalised.	• Local Government is not involved. • Some taps are not working. • Problems in distribution of water in different areas of the village.	• Assess costing on deterioration of taps. • Active local government to play an active role to solve issue.
1.13 Gubevu	• Committee is involved in approaching outside organisation for assistance. • Community willing to pay for whatever charges that they are suppose to pay in	• Scheme no longer in operation • Committee members are not trained on the handling of the scheme. • Operators no longer leave in this village. • Vandalism of the	• Total assessment on costing to be done and further investigation necessary

	a scheme that can be installed.	scheme is common.	

1.14. Mbaxa	• Committee achieve. • Scheme is in operation. • Operators are both fully active and are paid. • Community members do not have to pay for the scheme used.	• There are illegal yard connection • Vandalism of the scheme is common. • Local Government is not involved. • Lack of co-operation between the community and committee members.	• Project has completely deteriorated and further assessment needed to assess whether programme could be retrofitted.

4.7 SALIENT POINTS

- It is clear that where sufficient intervention has taken place in terms of social infrastructural and institutional arrangements, minimum problems and contentious issues arise and the schemes become sustainable.

- The case studies indicate that democratic procedures regarding training and institution building is realisable in remote rural areas. In essence this situation is relatively unique as many water supply projects have been effected negatively because of political contention between traditional leadership and democratic structures.

- Mentoring should be practised on an ongoing basis. A range of problems emerge throughout the maintenance of the project, e.g committee members leave the village for job opportunities or do not transfer skills to new emerging leaders compared to the maintenance of technical guaranties on the durability of material being used in the project it is difficult to 'guarantee' the maintenance of social institutions over a period of ten to fifteen years. In the main it seems that problems emerging have their roots within relationships between members of the community or institutions that are not firmly established.

- Women benefit from these schemes as they do not need to walk far distances to fetch water. Water service providers have increasingly put women in decision making structures of these schemes and consequently changed power relationships in villages.

- A real problem is the level of poverty in these communities. In one village, Lalini, it was found that none of the twenty households surveyed has any form of formal employment. Indications are that communities have agreed to pay tariffs, but given the poverty indicators it is clear that they are unable to afford these payments. It needs to be noted that the tariff issue poses a threat to the sustainability of schemes.

- A real issue pertaining to tariffs is the inconsistency of payment policies that exist in various schemes, e.g in many previous homeland water supply projects communities were never encouraged to pay for services and in some cases the Department of Water Affairs and Forestry still pay for operation and maintenance.

- Other problems experienced in schemes range from inadequate report back from committee members to communities, vandalism, technical operators leave villages for more favourable employment opportunities, non-involvement of local government, inconsistent flow of water and illegal yard connections.

CHAPTER 5

INSTITUTIONAL ASPECTS

EXCERPTS FROM PAPERS PRESENTED AT THE WORKSHOP ON SUSTAINABILITY OF SMALL WATER SYSTEMS IN SOUTHERN AFRICA

5.1 INSTITUTIONAL ARRANGEMENTS FOR SUSTAINABLE RURAL WATER SCHEMES

(Netshiswinzhe, B., The Mvula Trust, August 2002)

5.1.1 Introduction

Since 1994, the water supply sector in South Africa (SA) has provided over seven million rural people with access to clean water. Parallel to this, a number of policy and legislative changes were effected to amongst other things, support local government as the primary organ of state responsible for water services provision, and overall development at local level. The new policies and legislation include: Water Services Act of 1997, Municipal Structures Act of 2002, Municipal Systems Act of 2000, Division of Revenue Act of 2002, White Paper on Local Government 2000, White paper on Household Sanitation 2001, and Free Basic Water Policy 2000.

While there have been considerable achievements over the past seven years, the pressure to fast track delivery, the changing institutional environment and shifting government polices have raised new concerns around sustainability of completed projects.

Emerging evidence from the field points to the fact that the sector is still grappling with basic issues relating to sustainability of rural water projects. Initially the concerns relating to sustainability of projects centred on cost recovery. While cost recovery is an important element of sustainability, it is by no means the only one, and it is this single-issue oriented approach that seems to be crippling the sector. Evaluations conducted over the past few years have begun to raise other issues pertinent to the sustainability of rural water schemes. The issues raised include, amongst others the following: institutional arrangements, appropriate technology, participatory planning, training and capacity building, effective communication, customer relations, conflict resolution, participation of women, role of traditional leaders, water as an entry point to economic development, appropriate level of service, community-based management, and effective monitoring and evaluation systems.

This paper presents an argument for the appropriateness of community-based organisations (CBOs) as a preferred option for sustainable institutional arrangements for rural water services provision. The paper is based on lessons learnt from community-based managed rural water projects implemented by The Mvula Trust over the past seven years. Since 1993 The Mvula Trust has completed over 300 rural water projects. Close to 100% of these projects are still being managed by Village Water Committees, and are supplying safe water to over 600,000 people with little or no support from government. This is so even within the context of the recently announced government policy on free basic water. When the free basic water policy was announced in 2000, there was great panic that most rural schemes would collapse, as people would completely stop paying for water services. However, it seems communities decided to adopt a pragmatic wait and see approach, i.e. they will believe basic water is free as and when it becomes a reality. They are fully aware that any attempt to stop payment for water services, on the assumption that free basic water will be applied immediately (as of July 2001 as announced), will be detrimental to their projects. These achievements demonstrate the success of a demand-responsive approach, which puts emphasis on management at the lowest possible level. Evidently the same cannot be said about projects implemented through top-down approaches which gave communities little or no role to play, apart from being the recipients or users of services provided.

5.1.2 Revisiting Institutional Arrangements for Rural Water Services

In South Africa, responsibility for providing water services rests with local government as the water services authority (WSA). The WSA is mainly the regulator of services, and is responsible for ensuring that services are provided efficiently, effectively, sustainably and affordably (Draft White Paper on Water Services, August 2002). To achieve this requires the establishment of appropriate institutional arrangements. For example, operational functions relating to day to day provision of water at local level have to be performed by a water services provider (WSP). A WSP can be defined as any organization or person who has a contract wht a WSA to provide water to consumers within a specific geographic area.

Currently, Village Water Committees (VWCs) have been functioning as de-facto WSPs in the absence of a formally appointed person or organization. As a result of this, a considerable amount of experience to manage water services has been developed at local level, and municipalities can therefore take advantage of existing capacity. However, emerging evidence suggests that the potential of CBOs as viable options as WSP, especially in rural areas, is being undermined as municipalities are reluctant to afford them the necessary trust and support. There is a growing misperception that CBOs do not have legal status and, therefore, there are huge risks in appointing them as WSPs. However, a recently completed study by The Mvula Trust demonstrates that CBOs as voluntary associations with constitutions are legal entities. What is required is a clear risk management plan, such as would apply to any WSP municipality would like to contract for the provision of services.

In KwaZulu Natal, for example, there is an emerging trend towards keeping WSP functions within municipalities through the establishment of multi-jurisdictional municipal service districts (MJMSD). In the Free State, Maluti a Phofung Municipality, has appointed Water Boards as WSPs. There are many such examples across the country where municipalities are sidelining CBOs in favour of centralising the WSP function, or appointing a commercial entity. Many CBOs, that have previously managed water supply at local level risk being disbanded. This is despite huge investments made in building the capacity of these CBOs. Furthermore, municipalities seem to be ignoring the benefits that come with using CBOs as WSPs. Experience has shown that in small remote rural areas, CBOs are the only viable WSP option to achieve water services that are affordable, cost efficient, reliable and sustainable.

While there are few municipalities that are thinking positively around the use of CBOs as WSPs, we have still to witness a signed contract. Alfred Nzo and OR Tambo District Municipalities in the Eastern Cape are considering the appointment of CBOs as WSPs.

Within this emerging trend of sidelining CBOs, municipalities should realise that there are legislative and policy imperatives requiring them to engage civil society and CBOs. This trend will therefore constitutes a violation of the principles that underpin developmental local government.

5.1.3 Defining CBOs

Definitions of CBOs abound, and some are perhaps misleading. This lack of clarity adds to the reluctance to engage CBOs in municipal service partnerships. There is a perception that CBOs are informal, unstructured voluntary entities with no “governance systems and professional skills” applicable for efficient and effective service delivery.

The Department of Water Affairs and Forestry (DWAF) defines CBOs as "*a not for profit organisation within a specific community providing a municipal service to that community with the mandate of that community, where the organisation is acting in the overall interests of the community"* (DWAF, CBOs as WSP Guidelines, 2001). As an organisation, a CBO therefore should have a ***set of rules*** that govern its activities, roles and responsibilities. These rules are drawn up in the form of a constitution or any other legal documents which, when adopted, makes it a legal entity.

Other elements embodied in the definition given above are that: a CBO is ***not for profit, is based within*** *a defined community, has the* ***mandate*** *of the community, acts in the* ***overall interests*** *of the community and therefore is* ***accountable*** *to the community.*

5.1.4 Why CBOs as WSPs?

CBOs are an organ of civil society. The contribution made by civil society in the development and transformation of South Africa, speaks for itself. It is civil society organisations who stand up, often with very little resources, to ensure that communities were organised around ensuring access to basic services. In rural areas community level structures have in one way or another been managers of water services. The challenge for municipalities should be to find creative ways to harmonise local expertise and resources for efficient and effective water services delivery. The advantages of using CBOs as WSPs include the following:

- **Cost efficiency**
  It is a fact that many rural municipalities are financially very poor, with no economic base, and characterised by dispersed settlement patterns that make accessibility and service delivery expensive. Using local community-based service providers to deliver and manage services helps to bring the costs down. This is even more important now within the context of free basic services where consideration for costs in service provision is critical. Bringing in outsiders, or keeping the WSP function within municipalities will push up costs of service provision. CBOs are not for profit organisations and, therefore, do not come with huge markups and overhead costs. The costs of running a CBO are generally very low because there are no huge overheads, and any surplus generated is likely to be invested back into the project or the broader community for the benefit of everyone.

The challenge for municipalities is not only to provide services that are sustainable, but also affordable, and this means providing services efficiently and effectively.

- **Local economic development**
  The challenge facing South Africa is not only to develop rural areas that are socially cohesive, but of great importance is also to ensure economic viability of these areas. Local economic development will happen when municipalities make it their business to develop and invest in their own people and resources. By using CBOs to manage projects municipalities are not only fulfilling their development agendas, but also maximising funds from projects that are spent and retained at local level, and furthermore are contributing to skills development and job creation. Using external service providers does not promote local economic development as the money spent and earned from projects is invested outside the areas. This only serves to perpetuate the imbalance between the cities and rural areas.

- **Developmental local government**
  The legislative and policy framework in South Africa requires that local government functions in a developmental way. This means that municipalities have to actively involve local communities, not only for consultation purposes, but most importantly in the implementation and management of services provided. By partnering with CBOs municipalities begin to embrace and apply the principles of developmental local government.

- **Community ownership**
  When project implementation and management are driven by local people, through community-based structures, there is a greater sense of ownership and responsibility for services provided. It takes away the stigma of calling projects by the names of the funders or implementing agents. How often have we heard people saying that that these are “government projects”? This only serves to undermine community ownership so that for example, when things breakdown people will wait for government to come and fix the problem.

  Community ownership is an essential element to ensuring sustainability of projects. A sense of ownership develops when people identify with projects, are involved from planning and implementation to management thereof. In projects where there is a strong sense of community ownership there tends to be increased cost recovery, more effective operations and maintenance, and decreased vandalism. CBOs are therefore appropriate vehicles for cultivating a sense of community ownership of projects.

- **Local solutions for local problems**
CBOs are made up of local people. Local residents have existential knowledge of their environments. Their approach to dealing with problems relates to local conditions and culture. This helps to ensure buy-in and support for intervention measures taken to deal with problems. For example, the sustainability evaluations conducted by The Mvula Trust showed that decentralised operation and maintenance systems, whereby tariff collection is managed and co-ordinated at tap level, has been developed and implemented successfully by many rural communities. The system was developed by local people without being told what to do and how to do it.

On the otherhand, where technical experts introduced prepaid systems as a way of maximising cost recovery, vandalism has been rife. Even where systems were not vandalised, there have been other negative effects, for example, the cost of water drastically went up, and consumption dropped significantly, thereby minimising desired health benefits.

5.1.5 Rethinking CBOs as WSPs

CBOs on their own are not a magic wand to solve the problems of institutional arrangements for rural water supply. Thinking that CBOs alone are a perfect answer will be naïve. For CBOs to be successful, necessary support mechanisms will need to be put place. Considerable amount of support is required to develop and build the capacity of CBOs to efficiently and effectively manage rural water services. It is encouraging that in South Africa there is already debate on establishing what is called Support Services Agents (SSAs). The thinking is that a municipality or appointed agency can perform the SSAs function. The role of SSA would be to provide continued specialist support relating to major breakdowns, policy and systems development, as well as an initial mentoring role. .

Support for CBOs to fulfill their roles and responsibilities is particularly required given that, in the past, they were not established formally established as WSPs. As a result they have functioned without the necessary resources and infrastructure support. For example, many CBOs do not even have offices and proper administrative systems. CBOs will have to be formally appointed as WSPs, with clear contracts stipulating roles and responsibilities of all parties involved.

The Mvula Trust's experience with CBOs is limited to small rural settlements of about 500 households. The application of the CBO WSP model will therefore require on-going scrutiny to adopt it to specific local conditions. Different CBO WSP models can be developed and applied to meet different needs at project level. A lot of work in this regard has been initiated, and there are lessons to draw from.

This paper is in no way arguing that there is no role for other stakeholders, for example, the private sector. The argument being made here is that, in small rural areas, it makes economic sense to contract CBOs. The private sector at local level can be involved through small medium-micro enterprises (SMMEs). In this way, the community-based management approach to rural water services contributes to the local economic development agenda of municipalities.

5.1.6 Conclusion

Setting up effective institutional arrangements for sustainable rural water services remains a challenge In South Africa. It seems that a realistic approach would be to establish supportive partnerships between municipalities and all other key role-players. The experience of The Mvula Trust remains that in rural areas, CBOs-WSPs are the best possible option. What is required is a concerted effort to both strengthen the capacity of CBOs to deliver, and to ensure that municipalities recognise the legality of the constitution of the CBO. In this way municipalities may be encouraged to contract CBO WSPs, so necessary for ensuring that rural citizens of our country have access to sustainable basic services. Investments and efforts put into this will be earned back easily through cost efficiency, effectiveness and contribution to local economic development.

5.2 INSTITUTIONAL FRAMEWORK FOR WATER SERVICES PROVISION IN RURAL AREAS

(Vermeulen, A., Department of Water Affairs and Forestry, August 2002)

5.2.1 Background

In 1994, South Africa had its first democratic election after which a new system of Government was established. In 1996, the Constitution of South Africa was finalised and roles and functions were assigned to the three spheres of government, national, provincial and local.

5.2.2 Legal Framework

Various pieces of legislation concerning the water and local government sectors have been finalised over the past few years. 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 exists 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.
- **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

5.2.3 A New Municipal System

On 05 December 2000, the second democratic local government elections were held to implement the new local government system. The new system reduced the number of local government structures from 843 to 284 as follows:

- six 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 (up to nine) as well as the challenge posed by rural areas and parts of the former homelands. The division of powers & functions between district and local municipalities have been a major issue to resolve, but the line departments have reached an agreement with Provincial and local government about a position – this will be announced soon.

5.2.4 Background of water services

In 1994, all former homeland water services schemes became the responsibility of the national Department of Water Affairs & Forestry (DWAF) for the interim. These schemes now have to be transferred to WSA's (local government). The Government also embarked on the Reconstruction and Development Program (RDP) and since 1994, DWAF has overseen the implementation of approximately 200 new water schemes, which also have to be transferred to WSA's.

Further to that, it is estimated that another 7 million people do not have access to basic water supply and 18 million do not have access to an appropriate sanitation service. It is clear that the challenge facing the sector is huge.

5.2.5 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 as defined in the Water Services Act. There can only be one water services authority in any specific area (that is, water services authority areas cannot overlap). Water services authorities have the following primary responsibilities:

- **Realisation of the right to access to basic water services:** ensuring progressive realisation of the right to basic water services subject to available resources (that is, extension of services), the provision of effective and efficient ongoing services (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).

There must be a clear separation of authority and operation functions. Within this framework, the water services authority is essentially the regulator of the service and is responsible to ensure that services are provided effectively, efficiently, sustainably and affordably. The operational function is undertaken by the water services provider, the institution that actually provides the service. There must always be a contract between the water services authority and the water services provider.

A water services authority may either provide water services itself (internal mechanism), or contract a water services provider to provide water services (external mechanism). For and internal mecahnism, the water services authority 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 water services authority) with the manager of the water services department to provide water services in terms of a performance contract with the municipality. In the second case, the WSA must regulate the WSP according to the contract specifying clearly the allocation of roles and responsibilities between the regulator and the provider.

5.2.6 Water Services Providers

a. Duties of water services providers

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

A water services provider must publish a consumer charter which is consistent with by-laws and other regulations, is approved by the water services authority, and includes the duties and responsibilities of both the water services provider and the consumer, including conditions of supply of water services and payment conditions.

b. Types of water services providers

The most common "types" of water services providers are described below for the purposes of illustration. This listing is both brief and incomplete. This is because the definition of water services provider is broad and a variety of possible organisational forms for water services providers exist. Both the content of the contract between a water services authority and water services provider and its enforceability (that is, the ability to perform the service effectively) are more important than the type of water services provider.

- **Municipalities**. As already mentioned, a water services authority can also be a water services provider, both within its own area as well as by contract with another water services authority or water services provider.
- **Municipal entities**. These are municipal-owned and controlled public providers which can be set up in terms of either a by-law or the Companies Act.
- **Water boards**. These are water services providers whose primary function is the provision of water services to other water services institutions.
- **Community-based organisations**. A community-based organisation, acting as a water services provider, is a not-for-profit organisation within a specific community providing a municipal service to that community with the mandate of that community, where the organisation is acting in the overall interests of the community. A more specific detailed definition of a CBO, together with a discussion of CBOs acting as water services providers, is given below.

- **<u>Private operators</u>**. These can vary from small, medium and micro enterprises (SMMEs) to more established larger private operators. They could be locally or foreign owned and can include multinational corporations.
- **<u>Other types of water services providers</u>**. In some cases water user associations, industries and mines provide water services to or on behalf of municipalities (but not as an intermediary – see section below). In these cases, the organisation is a water services provider even though the provision of water services is not the main business of the organisation and the provision of water services is undertaken for the purposes of assisting municipalities who have limited alternatives. The relationship between the water services provider and the water services authority must be defined in terms of an appropriate contract.

Internal and external water services providers – some examples
The Municipal Systems Act defines "internal" and "external" service delivery mechanisms. The Municipal Systems Act sets out a process to be followed when selecting an external service delivery mechanism (see section 0). For the sake of clarity, examples of internal and external water services providers are given in the table below.

Internal water services providers	External water services providers
• The municipality itself • A department within the municipality • A ring-fenced business unit within a municipality	• A municipal entity • A community-based organisation • Another municipality • A water board • A private company (including SMME's) • Any other arrangement

c. Service provision across water services authority boundaries

Where regional water supply systems cross water services authority boundaries, water services authorities must co-operate with one another to establish arrangements to manage the cross border infrastructure. There are three broad options available to these water services authorities:

- **Service agreements**. The authority reliant on a service from a neighbouring municipality may enter into a service delivery agreement (contract) with its neighbour who would then be a water services provider in relation to this authority.
- **Water board or municipal entity**. The water services authorities may contract with an existing external water services provider (for example, a water board) or establish an external water services provider (for example, a municipal entity) to serve the region. Each water services authority will then contract separately with this external water services provider.
- **MJMSD**. The water services authorities concerned may establish a multi-jurisdictional municipal service district (MJMSD) which implies the delegation of the water services authority function to this MJMSD. The MJMSD could then be the water services provider for the combined municipal area itself or it could contract other services providers.

Regional co-operation based on a services delivery agreement

Municipality A is a water services authority but is reliant on a bulk water supply system located in neighbouring Municipality B. Municipality A contracts with Municipality B in terms of a service delivery agreement to provide Municipality A with bulk water at the point there the pipeline crosses the municipal boundary. In this context Municipality B is a bulk water services provider to Municipality A.

Regional co-operation based on the establishment of a municipal entity

Two municipalities agree that there are practical and economy-of-scale advantages to operating their water services at regional scale. After considering various options, as required under the Municipal Systems Act, they decide to set up a municipal entity in the form of a company with each municipality a shareholder. They decide that this entity will be the water services provider for their whole area, taking responsibility for bulk and retail services. (This arrangement could apply to bulk water services only.)

Regional co-operation through a water board

A water board provides water services to (or on behalf of) a grouping of municipalities in terms of service delivery agreements, but ownership and control of the water board rests with national government.

d. Choosing water services providers

Preference for public sector provision. The "Framework for the Restructuring of Municipal Service Provision" (concluded between SALGA and COSATU on 11 December 1998) includes a set of guiding principles which state that public sector provision of municipal services is the preferred option. This preference arises from two primary concerns:

- the concern that the profit motive, an important motivating factor within the private sector (in addition to good service), will result in unaffordable services and lack of focus on servicing people without access to basic services; and
- the concern that private sector participation in the operation of water services could result in the loss of jobs, specifically public sector jobs.

As a result of this agreement, the Section 78 process in the Municipal Systems Act prescribes a procedure for the selection of the mechanism of municipal service provision in which *municipal provision of services is to be considered first*. The Water Services Act also incorporates a *preference for public sector provision* by requiring that public sector provision options are considered prior to the consideration of provision of water services by the private sector.

Protecting the public interest. It is important to bear in mind that protection of the public interest should be the primary consideration when selecting a water services provider and that there needs to be a balancing of interests between public sector workers on the one hand and consumers on the other. In a context of resource and capacity constraints, it may be the case that the appropriate involvement of the private sector in the provision of water services could result in the more effective and efficient provision of water services in some instances and that this would promote the public interest more effectively than a service provided wholly by the public sector which is inefficient and/or ineffective. The ultimate test is the protection and promotion of the public interest. For this reason, there is scope for private sector participation in the provision of water services notwithstanding the government's stated preference for public sector provision.

Choosing external water services providers. Water services authorities may choose to contract with external (including private) sector operators as water services providers provided that (1) they follow a defendable process and have applied their minds to the respective merits of available choices, (2) they are able to show the merits of choosing an external water services provider over and above an internal water services provider, (3) they employ best practice with respect to entering into contracts with external water services providers, and (4) they use competitive procurement when entering into contracts with private water services providers.

In practical terms, this means the following:

- A water services authority must have applied its mind to the merits of providing water services itself prior to making a decision to consider other service delivery options. It should take into account (1) the implications of providing the service itself (that is, the "costs and benefits" which are defined broadly to include financial, environmental, social and economic factors), (2) the municipality's current and future capacity to effectively provide the service, and (3) general trends in the sustainable provision of municipal services.
- A water services authority must have compared the respective merits of public versus private provision of the service, taking into account the factors listed above. It should be able to make a rational and sound case for the operation of the service by a private water services provider, including a motivation for the strategic and operational benefits for the water services authority.
- Furthermore, the water services authority must report on the respective forms of private sector involvement considered and account for the selection of the proposed form.
- When choosing a private water services provider, the water services authority must employ a competitive tendering process and be able to show that the contract will provide value for money, be affordable to the institution and transfer appropriate technical, operational and financial risk to the private party.
- The *extent of consideration* referred to above in the case of the choice of a private water services provider will depend on the extent and nature of the contract. It is obvious that the extent of consideration should be related to the level and complexity of the function being contracted.

Form and content of contracts. Whenever a water services authority chooses a water services provider to operate water services on its behalf, it must enter into a written contract with the water services provider. This contract should follow best practice contracting guidelines. In general, and where practical, it *is preferable for a water services authority to enter into a single contract with one water services provider who assumes full responsibility for the provision of the full service in a specific geographic area*, or alternatively into separate contracts for bulk and retail services. It is also preferable that these contracts include sanitation so as to promote integrated water and sanitation planning. The regulation of contracts is discussed further in section **Error! Reference source not found.**.

e. Community-based organisations as water services providers

Definition. A community-based organisation means a not-for-profit organisation situated within a defined community that is mandated by that community to provide a specific municipal service to that community on behalf of the municipality, provided that (1) all members of the governing body of the organisation are nominated members of the community and are permanently resident within the community; (2) all employees of the organisation are members of the community and are permanently resident within the community; and (3) the area constituting the community is defined by the municipality.

Legal form. A community-based organisation must be a legal entity. There are various ways of forming a legal entity, but a voluntary association is the most appropriate legal form for CBOs providing water services at a relatively small scale in rural communities.

Establishment and support of CBOs. Ideally, CBOs should be established as a result of a broadly participative community process. It is likely that this establishment process will require support. This support (which may need to be ongoing) could be undertaken directly by the water services authority or by an agency on behalf of the water services authority.

Criteria for choosing a CBO as WSP. There are two key criteria that a water services authority must take into account when considering entering into a service agreement with a community-based organisation to provide water services:

- the appropriate legal status and
- the ability to provide water services as (or more) cost-effectively compared to other alternatives.

Process for selecting CBO's. The Municipal Systems Act classifies CBO's acting as water services providers as an external mechanism. This means that the selection of CBO's as water services providers requires a competitive tendering process. This is not appropriate and a recommendation to change the Municipal Systems Act will be made.

A water services authority may undertake a “generic process” (in terms of Section 78 of the Municipal Systems Act) which identifies the general conditions where the selection of CBO’s as water services providers is appropriate. This means that a water services authority does not need to undertake a Section 78 process for every decision to appoint a CBO as a water services provider.

Selection of CBO’s and the Water Services Act. The feasibility of CBO’s acting as water services providers should be considered prior to engaging with private operators in terms of the Water Services Act.

f. Water services intermediaries and the provision of services on private land

A water services intermediary is any person who is obliged to provide water services to another in terms of a contract where the obligation to provide water services is incidental to the contract (as per the Water Services Act). This means that the intermediary must have a contract with the consumer for a purpose other than the provision of the water services (for example an employment or property lease contract) in order for it to be recognised as an intermediary rather than a service provider.

Where a person providing water services does not have a primary contract with the consumer for a purpose other than providing water services, but continues to provide water services, the person providing services is not an intermediary but a water services provider. This is the case irrespective of whether the provision of such services are incidental to the main purpose of that institution. Water services authorities must ensure that appropriate contracts are in place between itself and these water services providers.

The central objective of water services policy is to promote access to basis services by the poor. Intermediaries have a key role to play in this regard, considering that approximately 8% of South Africans live on commercial farms and probably another 2% or so live in “private towns” run by mines, Eskom and other big companies. Under this policy water services intermediaries are required to provide services to these people and the water services authority must ensure that this is done. The water services authority may regulate water services provided by intermediaries in terms of municipal by-laws.

Examples of intermediaries:

- **Farmers**: Where farm workers (and their families) receive water services (usually associated with accommodation) as part of their employment contract with the farmer, the farmer is an intermediary to his workers. This also applies to retired workers and their families. Where there are other people living on the farm who are not linked through a current or former employee relationship, and where the farmer agrees to provide services to these people, the farmer becomes a water services provider.
- **Mines and other industries**: Where employees receive water services (usually associated with accommodation) as part of their employment contract with the mine or industry, the mine or industry is a water services intermediary to these employees and not a water services provider.
  However, if there are people living in the town who are not employed (or no longer employed) by the mine/industry and the mine/industry decides to provide these people with water services, then the mine is acting as a water services provider.
  Where a mine/industry provides bulk and/or retail water services to a neighbouring town on behalf of a water services authority, the mine/industry is a water services provider.
- **Sectional title or lease of property**: Where co-owners or tenants receive water services as part of their contract for management of the total property or lease of a property, the owner/landlord/body corporate is an intermediary to the co-owners or tenants.
- **Water user associations**: Where employees receive water services (usually associated with accommodation) as part of their employment contract with the water user association (WUA), the WUA is an intermediary to its employees.

5.3 SUPPORT SERVICES AGENTS: THEIR ROLE IN ACHIEVING SUSTAINABILITY OF RURAL WATER SCHEMES *(Stephen, D.A., Umgeni Water, August 2002)*

5.3.1 INTRODUCTION

The aims of the workshop on the "Sustainability of Small Water Systems in Southern Africa", which has been arranged under the auspices of the Water Research Commission (WRC), the Water Institute of Southern Africa (WISA), the Department of Water Affairs and Forestry (DWAF) and the Department of Health (DoH), are to:

(i) identify and understand the main problems and challenges facing small water systems, and

(ii) to adopt an approach and develop a methodology for addressing the problems relating to sustainability of small water systems through the formation of appropriate structures at a national and/or provincial level to provide assistance and support.

All authorities (at national, provincial, district and local government levels), water services institutions (including water services authorities, water services providers, water boards and water services intermediaries), NGO's, consulting engineers, funding organizations, community-based organizations, water treatment technology suppliers, and any other service provider involved with small water systems, have been invited to attend and participate in the workshop.

It is recognized that within South Africa, a large number of role-players have been involved with the delivery of water infrastructure, as well as the on-going provision of water services. Technical issues, such as the selection of appropriate technologies, functional and "life-cycle cost effective" designs, and operational efficiencies are of vital importance. However, it should be noted that technical solutions are not sufficient to ensure the sustainability of small water systems (typically found in the rural context).

Support arrangements must be considered within the context of changing legislation, policies, funding mechanisms, modes of infrastructure delivery and options for water services provision, and must be flexible enough to adapt to such changing circumstances (which are not always progressive, nor predictable!).

This paper describes a **modular approach to the provision of support services for rural water schemes** which have been, or are about to be, transferred to local government in its capacity as Water Service Authority (see Figure 1, which shows the key components of the project-life cycle for DWAF-funded rural water schemes). The WSA may choose from a menu of modules, depending on what is required to support the particular scheme or group of schemes (see Figure 2). The "Support Services Agent" (SSA) concept recognizes the legal authority of local government as the WSA, and a fundamental component in this approach is the institutional support and development which the SSA provides in enabling the WSA to assume its full legal responsibility (in terms of its governance and provision functions), and in the area of skills transfer (e.g. project management, finance, administration, etc.).

This paper offers one approach as a contribution to the debate around how best to support small water systems within Southern Africa.

5.3.2 BACKGROUND

Many water schemes are in the process of being formally transferred from the Department of Water Affairs and Forestry (DWAF) to the relevant Water Services Authorities (WSA's) within South Africa. This is being done to comply with legislation related to local government, the Water Services Act and the Division of Revenue Act.

It is important to both the funder and to the receiving authority that the transferred schemes continue to be operated, managed and funded in as sustainable a manner as possible. There are a number of water services provider (WSP) options that are available to WSA's, and appropriate choices need to be made depending on the particular characteristics and requirements of each scheme. There may be different WSA/WSP arrangements within a WSA's area of jurisdiction, and possibly within a scheme itself.

In terms of s11(1) of the Water Services Act (No. 108 of 1997) (DWAF, 1997), WSA's are required to "progressively ensure efficient, affordable, economical and sustainable access to water services". This responsibility includes both the delivery of infrastructure and the on-going provision of water services. In terms of the Act, WSA's may carry out the WSP function themselves, enter into a written contract with a WSP, or form a joint venture with another water services institution in order to provide water services. The WSA could consider a contract or partnership arrangement with a local municipality (Category B), water board, NGO, private sector company, or community-based organization.

A number of WSA's are in the process of increasing their own capacity, or developing contract agreements in order to fulfill their legal obligations in water services provision. However, for many of them this is proving to be a difficult task, and interim measures are required to be put in place, in the short- to medium-term at least.

Opportunities now exist for water boards, NGO's and private sector companies to enter into contractual agreements with WSA's to provide the necessary expertise. Each WSA differs in respect of its current capacity and outlook in respect of WSA/WSP options. Flexibility is therefore required in providing appropriate solutions.

At a scheme operational level, it is proposed that support services provided by a Support Services Agent be covered by a contract agreement which could include up to seven modules, viz.:

1. Management functions
2. Technical support
3. Administration support
4. Financial systems and controls
5. Water Quality Monitoring programme
6. Water Loss Management programme
7. Operation & Maintenance Reporting

5.3.3 DESCRIPTION OF MODULES

The seven modules are described in more detail as follows:

Module 1: Management Functions

Management is regarded as a separate function, as it serves to hold the other modules together, irrespective of who carries out those functions. It includes, *inter alia*:

- Co-ordination and communication with all stakeholders
- Customer service centre management
- Project management
- Contract administration
- Community liaison and facilitation
- Monitoring and evaluation

- Interventions

Module 2: Technical Support

Technical support includes:

- Inspections, planned maintenance and repair work
- Emergency repairs
- Meter readings
- Disconnections
- Technical inspections
- Special investigations (with recommendations to resolve problems)

Depending on the requirements of the WSA, the SSA could either provide direct technical assistance, or assist local staff who are employed by the WSA itself.

Module 3: Administration Support

Administration support includes:

- Development of administrative policies and procedures
- Training and development of local staff
- Record keeping and filing
- Audit procedures
- Development of appropriate procurement policies and procedures.

All policies, procedures and training requirements need to be developed in close consultation with the WSA, and will depend on the choice of WSA/WSP arrangement, and extent of delegated authority.

Module 4: Financial Systems and Controls

Financial systems and controls support includes:

- Development of appropriate financial policies and systems which are easily understood at local level, and able to be implemented
- Adequate control mechanisms to reduce the risk of financial loss and fraud
- Financial procedures
- Training and development of local staff

- Record keeping and filing
- Financial audits, with recommendations to resolve and/or improve financial management and control

All policies, systems, procedures and training requirements need to be developed in close consultation with the WSA, and will depend on the choice of WSA/WSP arrangement, and the legal status of the body responsible for scheme-specific financial matters.

Module 5: Water Quality Monitoring Programme

A Water Quality Monitoring (WQM) Programme includes:

- Sampling of water at source(s) and consumer supply points
- Analysis of water samples
- Reporting of results
- Recommendations for improvement of water quality, including treatment processes
- Specific interventions as required
- Community health and hygiene awareness programme

Module 6: Water Loss Management Programme

A Water Loss Management (WLM) Programme includes:

- Water balance analyses
- Verification of water meter accuracy and calibration
- Water system audits
- Water loss control through physical leak detection
- Pressure management
- System optimization
- Hydraulic and statistical modeling
- Benchmarking studies
- Revenue analyses
- Training and development of local staff
- Record keeping and filing

Module 7: Operation & Maintenance Reporting

In terms of s23 of the Water Services Act, the WSP is required to give information to a wide range of interested parties, including the WSA, Provincial Authorities, the Minister of Water Affairs and Forestry and consumers (both existing and potential). An Operation and Maintenance Report has already been developed and is being used to monitor and evaluate a number of rural water schemes in KwaZulu-Natal (Stephen, 2001).

The O&M Report serves as a valuable **management tool** for WSP's by providing a record, on a regular monthly basis, of both the technical and financial aspects of water schemes, and by providing a means for sound business planning.

It also serves as a **management information system** for WSA's by providing the information necessary for appropriate and timeous interventions to assist in the long-term functional and financial sustainability of schemes.

The SSA could assist in the report's preparation, its interpretation (to both WSA and WSP), or use it as a teaching tool. Improvements in the managerial, technical, financial or administrative aspects of schemes are some of the desired outcomes arising from the use of the report. The O&M Report provides information relating to schemes at both local operational level and at overall scheme level (i.e. including support and mentoring costs), in both tabular and graphical forms.

It includes information on:

- Scheme design parameters and utilization figures
- Capital costs
- Tariffs
- Finances (targets, historical, monthly, cumulative and average figures)
- Water volumes
- Water losses
- Population served
- Consumption per capita
- Reliability of supply
- Water quality performance
- Incidents of vandalism
- Employment figures

Linked to the O&M Report would be graphed Key Performance Indicators (KPI's), with targets set for each scheme (Stephen & Still, 2000).

The O&M Report should be seen as a critical component of the SSA's function, and must be accurately and diligently completed on a monthly basis. The information obtained should be critically assessed, and appropriate interventions applied in order to improve the performance of the scheme.

5.3.4 CRITICAL SUCCESS FACTORS

Some of the critical success factors which need to be taken into account when developing the Support Services Agent contract agreement include the following:

- A clear understanding of the institutional, legal and financial policy framework within which the SSA agreement is to be structured, and the roles and responsibilities of the various parties already involved.

- A knowledge of the existing policies and procedures which are in place (if any) within the WSA, relating to the provision of water services to rural communities in general (and the scheme in particular), and the terms and conditions of the current WSA/WSP contract agreement (if available).

- Mutual understanding and acceptance that the SSA becomes a supporting partner to the WSA, WSP and the Community, and has not been appointed to remove any obligations that are the responsibility of any other party. The shared objective is to achieve a sustainable water scheme, and improve the quality of life of the benefiting consumers.

- An appreciation of and respect for the inherent capabilities and resources which are available within the community being served by the water scheme, and a commitment to making use of such resources.

- The availability of documentation relating to: (i) the technical aspects of the scheme (including design reports, commissioning or closure reports, record drawings, operation and maintenance instruction manuals, O&M reports (if available)), (ii) administrative procedures and records, and (iii) financial system procedures and records (including audited statements (where available)).

It is important to note that the content and pricing structure of the SSA agreement will depend not only on the resources which may be within the WSA, WSP and community, but on extent to which those resources are prepared (in the case of human resources) to be committed to the scheme itself. Experience has shown that resources may exist within organizations, but are not able to be effectively

used in the achievement of the stated goals and objectives.

A major factor in determining the price of the SSA contract agreement is the apportionment of risk between the various parties.

5.3.5 CONCLUSION

The SSA concept is a new one for many WSA's within South Africa, but one which is being considered by a number of role-players within the water sector who have been, and continue to be, involved with the delivery of infrastructure and water services provision to rural communities.

A number of delivery mechanisms are available to WSA's for the planning and implementation of schemes which are both efficient and cost-effective. However, within the context of new legislation and changing policies at national, provincial and local government levels, there are still many challenges facing the operation and maintenance stage of rural water schemes.

The contribution which a Support Services Agent can make is to provide expertise, where needed, in order to enhance the functional and financial sustainability of schemes, and to ensure that water of an acceptable quality is supplied reliably to consumers, to improve the quality of life of rural communities.

The modular approach described in this paper is intended to allow flexibility for WSA's to select appropriate levels of support for schemes of varying complexity. The full scope of services would be applicable to larger piped rural water schemes. Smaller, stand-alone schemes which rely on protected springs or boreholes fitted with hand-pumps, would only require limited support.

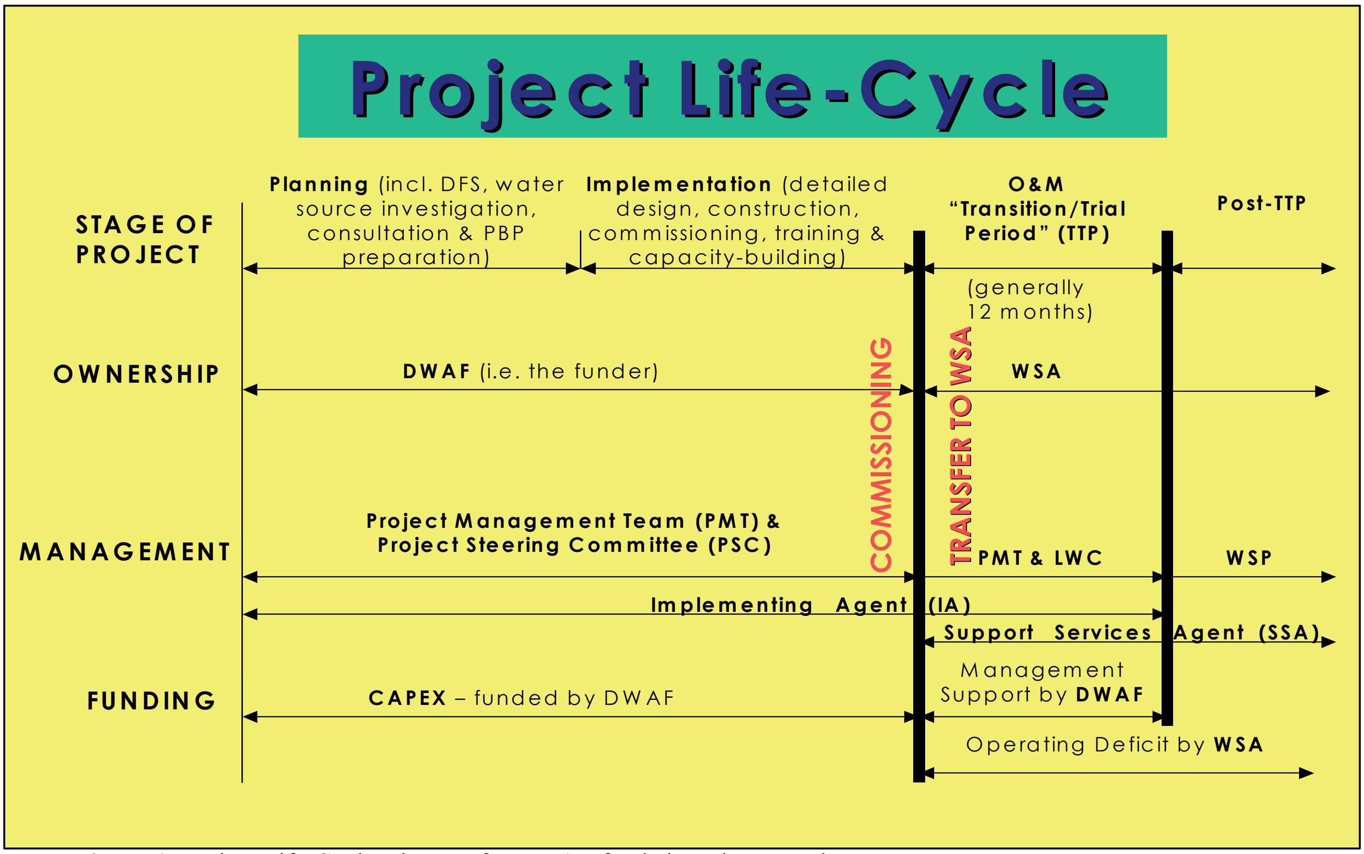


Figure 1: Project Life-Cycle Diagram for DWAF-funded rural water schemes

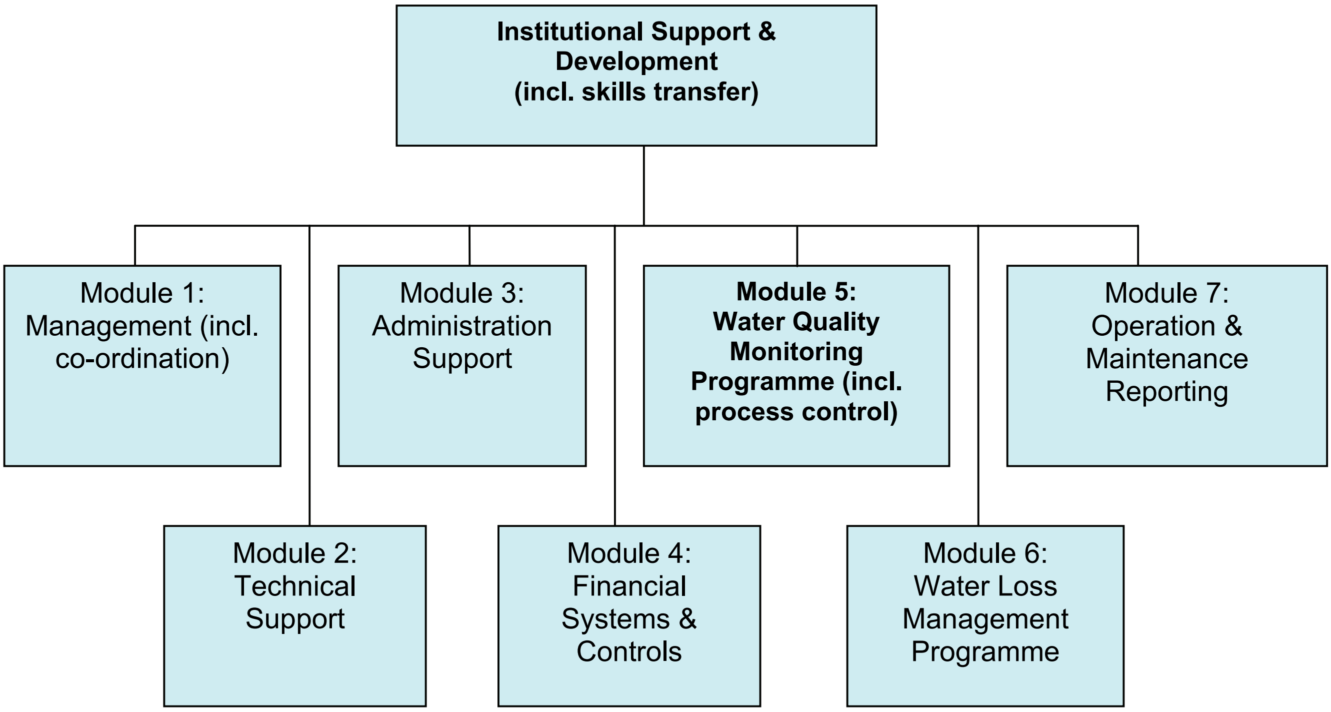


Figure 2: Components which could be included in a Support Services Agent (SSA) contract agreement

ACKNOWLEDGEMENTS

The writer wishes to acknowledge the support given by Umgeni Water, and the positive contribution of a number of people involved with the on-going provision of support services for rural water schemes in KwaZulu-Natal.

CHAPTER 6

TECHNOLOGICAL CONSIDERATIONS FOR PLANNING AND DESIGN OF SMALL WATER TREATMENT SYSTEMS

6.1 INTRODUCTION

The availability of an adequate supply of potable water can be considered as one of the primary needs of human beings. South Africa, being a semi-arid country, has large areas where this commodity is sadly lacking, or in scarce supply. Even where ample water sources are available, development of the land has brought in its wake the ravages of pollution, which have rendered otherwise safe sources unsuitable for use without some degree of treatment.

Water is used for domestic, industrial, agricultural and recreational purposes. To ensure that it is acceptable for human consumption, the quality should conform to certain hygienic and aesthetic standards. The economic aspect is also important, because the price will determine its acceptability for domestic as well as industrial purposes. Various industries may impose standards which require water from a particular source to be treated in special ways to remove undesirable substances, or to impart properties that are specifically desired.

The three main aims when treating water for potable use are therefore:

- **Safe for human consumption**
  The first and most important requirement is that the water must be safe for human consumption, i.e. it will not have a negative effect on health, even if it is consumed over a long period of time.

- **Aesthetically acceptable**
  A second requirement is that the water must be acceptable to the user from an aesthetical point of view, *i.e.* it must appear attractive and should not contain any tastes, odours, colour or turbidity.

- **Stability**
  Purified water is conveyed to the user in a pipe system, which is normally laid undergroud to minimize damage to and breakage of the pipes. To prevent

deterioration of this expensive asset, the water that it conveys should be neither corrosive or scale-forming (*i.e*. forming calcium carbonate precipitates or deposits).

6.2 LEGAL CONSIDERATIONS

Although water supply authorities traditionally aimed at supplying users with safe water for consumption, there were up to 1997 no legal requirements to do so. With the promulgation of the Water Services Act (Act No 108 of 1997), authorities are now obliged to supply drinking water of which the quality must comply with certain laid-down requirements.

In the assessment of the suitability of a water for potable purposes, a variety of assessment criteria can be used. It is also important to bear in mind that there are no such thing as absolute standards. As the concentrations of certain substances in the water increase, the risk to the consumer increases accordingly.

Accordingly to the South African Bureau of Standards (SABS) Specifications for Drinking Water (SABS 241 of 1999 [revised in 2001]), waters are classified into three major classes based on the maximum values that are allowed, *viz*

- Class 0 - Ideal water
- Class I - Acceptable water
- Class II - Maximum allowable

The three classes are defined in terms of physical, organoleptic and chemical constituents, that are suitable for delivery as drinking water; it describes an ideal (class 0) standard that is closely comparable to current international standards for water quality, and also a standard (class I) which is known to be acceptable for whole lifetime consumption. The third classification (class II) specifies requirements that are considered to be the maximum allowable for short term consumption.

The classifications class 0, class I and class II are closely comparable to the classifications Blue, Green and Yellow used in differentiating between water qualities available for drinking purposes and described in **"Quality of Domestic Water Supplies: Volume 1: Assessment Guide"** (see References).

6.3 WATER QUALITY

6.3.1 Introduction

The quality of water is determined by analysis of a sample taken from the source. Since the designer must have a clear understanding of the meaning of the various parameters being measured, a general discussion on water quality and analysis will first be presented.

Water derives its quality in the first instance from substances with which it comes into contact during its passage through air (as small droplets); as well as the ground over which it flows or through which it seeps. It thus dissolves gases from the atmosphere, salts from surrounding rock strata, organic substances from decaying vegetation, and carries along clay particles which imparts turbidity. Water containing the above substances is a suitable environment to sustain ever present micro-organisms (mostly bacteria and alge); which in turn may impart further undesirable characteristics to the water; e.g. taste, odour and colour; and may also cause disease.

When water is sampled for analysis, a grab sample is usually taken. It is advisable to sample and analyse frequently and also to evaluate the conditions affecting the source, especially the likelyhood of quality deterioration on account of bacterial pollution or stormwater influx which may increase turbidity markedly. A golden rule is never to evaluate water on the basis of a single grab sample; without knowledge of the source, as well as of conditions at the time of sampling.

The following are general positive environmental indicators in terms of a suitable water source:

- A borehole or well, sealed at the surface to prevent influx of surface water; and no source of ground water pollution like refuse tips, sewage disposal systems or intensive animal farming (feed lots) within 1 km.

- A spring with the same constraints as for a borehole, fenced in or covered over to prevent access by humans or animals.

- A stream or dam with an uninhabited catchment; with no intensive farming activities or sewage effluent discharges within the catchment.

The following are general negative environmental indicators in terms of a suitable water source:

- An unsealed borehole or well
- A water source accessible to humans and animals
- A stream into which sewage effluent (even well purified) is discharged
- A water source enriched with nutrients (nitrogen and phosphorus) as indicated by algal blooms
- Waters with high mineral salt content (brackish taste)

6.3.2 Micro-organisms

a. <u>Introduction</u>

Since the safety of water, i.e. the absence of pathogenic (disease causing) micro-organisms, is of primary importance in water supply, consideration of this aspect of water quality is of prime importance.

Large numbers of micro-organisms (bacteria, viruses, algae, fungi and protozoa) are always present in the environment. These organisms are often supplemented by organisms excreted by animals and humans, especially where proper sanitation does not exist. Some of the organisms from human and animal origin may be pathogenic. Water is an excellent habitat for all micro-organisms; especially when the water is enriched with organic material. Micro-organisms originating from the intestinal tract of humans and warm blooded animals normally find the natural environment too hostile to sustain themselves, and die off within a few weeks from beign excreted. However, if water from a freshly source polluted source is consumed, an outbreak of disease may occur.

b. <u>Tests for micro-organisms</u>

Since it is impractical to test for all possible pathogens in water, routine tests are directed only at establishing the presence of the so called “indicator organisms”, which indicate whether the water has been in contact with faecal material, and therefore may contain pathogens.

Plate count

The standard plate count for the number of heterotrophic bacteria present in water is sometimes reported. This is regarded as an indication of the water's

ability to sustain bacteriological life; and therefore of its level of biodegradable organic material. The test is carried out at 37 °C for 48 hours which will favour heterothrophic bacteria originating from warm blooded animals.

Coliforms

The test for coliforms (or total coliforms) is the most common test, and often the only one being performed. Although organisms originating from the human intestinal tract is reflected by the numbers determined by this test, bacteria originating from other warm blooded animals; as well as bacteria that live freely in nature on vegetable matter may also be included. It is therefore not a conclusive test, but a positive result immediately casts doubt on the safety of the water.

Faecal coliforms

Faecal coliforms are secreted by all warm blooded animals. This test is therefore more specific than total coliforms; and since many organisms that may cause disease are common to humans and animals, the presence of faecal coliforms are sufficient reason to regard water as unsafe.

Protozoan pathogens

The protozoan parasites Giardia and Cryptosporidium are environmentally resistant intestinal parasites sometimes found in surface waters, and can cause gastroenteritis in humans when ingested. As a practical guideline, there should be no cysts of oocysts respectively of these organisms present in drinking water.

c. Significance

The presence of indicator organisms is usually regarded as unacceptable in drinking water. Elimination of these organisms, as well as pathogens (except the protozoa) is however, relatively easily achieved by chlorination. For the removal of protozoan parasites, flocculation followed by filtration, or slow sand filtration is required.

6.3.3 Physical characteristics

a. Introduction

Physical characteristics are those which may be observed by the senses of sight, taste and smell. Consumers are usually sensitive to physical characteristics and erroneously perceive water as being unsafe if it exhibits undesirable physical characteristics.

The most important physical parameters are suspended matter, turbidity, colour, taste and odour.

Suspended matter

Suspended matter in natural waters usually consist of leaves, small twigs and small animals like tadpoles, insect larvae, water fleas, etc. It is understandable that consumers get upset if these objects are visible in water from the distribution system.

Turbidity

Turbidity is very common in inland rivers, and gives water a murky appearance. It is caused by clay particles which are negatively charged and consequently remain in colloidal suspension. Algal blooms will also give water a green turbid appearance.

Colour

Coloured waters are found in the coastal areas where decaying organic material imparts a brownish colour to the water. These waters are usually soft with a low pH, which causes them to be corrosive.

Odour

Odour may have various origins. Water from deep boreholes are often devoid of oxygen and have a stuffy smell. In some parts of the country (particularly the Karoo and north western regions), ground water some times contains hydrogen sulphide with its associated bad egg smell. Waters from large shallow impoundments or eutrified (enriched) sources, may exhibit earthy, fishy, or grassy odours, which are accentuated by the addition of chlorine.

For potable use, odour should not be objectionable.

b. Test for physical characteristics

Turbidity and colour are usually the only two physical characteristics which are determined routinely on a scientific basis, and the results are reported as turbidity units and colour units. See Appendix A for limits.

c. Significance

Physical characteristics are generally of little importance of health risks, but are the first to cause complaints from consumers because concentrations in excess of recommended limits are easily detectable. It is therefore pshycologically desirable to ensure that water is physically attractive.

6.3.3 Chemical Constituents

a. Introduction

Since water is an excellent solute, it will dissolve a large variety of chemical compounds. When the chemical compounds exceed certain concentrations in the water, various undesirable characteristics may develop.

The chemical compounds also generally establishes the pH value of the water.

b. Tests for chemical constituents

There are routine analytical procedures available, whereby the elements and compounds comprising the macro and micro chemical constituents may be measured.

With respect to the salinity of water, it has become customary to measure conductivity (in mS/m), which reflects the water's ability to conduct electrical current, and hence gives an indication of the concentration of mineral salts in solution.

c. Trace organics

With the ever increasing use of pesticides and herbicides, as well as the discharge of sophisticated organic compounds in waste waters, the level of trace organics in the environment is ever increasing. These organic compounds, when subjected to chlorine, are oxidised to form what is generally known as trihalomethanes (THM's), which are suspected of being carcinogenic in high concentrations.

Tracing of THM's requires sophisticated equipment which is available only in a few large centres in South Africa. It is therefore not a routine test and will only be done if there are strong indicators that these substances may be present, *e.g.* if the water source contains large amounts of chlorinated sewage effluent.

d. Significance

Excesses of chemical constituents may manifest in various ways. Water may taste salty or brackish if the salt concentration (especially chlorides) is high, and stomach upsets may result. High concentration of calcium and magnesium cause hardness. Iron and manganese will cause brown or black stains on white surfaces. Excessive fluoride will cause staining of teeth, and heavy metals like cadmium and chromium may cause chronic poisening. Low pH values will cause corrosion of metals and concrete. Water oversaturated with calcium carbonate will cause pipelines to be clogged by calcium carbonate deposits.

Some of the chemical characteristics of water may be changed fairly easily, e.g. pH by the addition of acid or base. Others, e.g. a high salt content, will require desalination which is an expensive process.

In the selection of unit processes, the designer should have a clear understanding of the abilities and limits of such processes to change the chemical characteristics of the water.

6.4 CHOICE OF A TREATMENT SYSTEM

The extent to which water for domestic use is treated will be limited by economic and technical considerations. In rural areas complicated treatment schemes may not be suitable. In cases where it is required, a better solution may in many instances be to exploit an alternative unpolluted source which requires little or no treatment, even when this source is at a greater distance.

In selecting an appropriate treatment system(s) for the plant under consideration, table 6. may be used as a rough guide in terms of disinfection and turbidity removal within the constraints of costs and available operating skills. However, it is strongly recommended that each case be thoroughly investigated before making the final choice. In particular, it is recommended that all surface waters should be filtered and disinfected.

TABLE 6.1 Guidelines for the selection of a water treatment system for surface water in rural areas (from WRC Report No. 231/1/93)

Average raw water quality	Water demand (m^3/d)	Treatment Suggested	Skills Need	Capital + Operating costs
Turbidity < 5 NTU Faec coliform 0/100 ml Bilharzia not endemic	up to 2000	No treatment (filtration and disinfection recommended for surface water treatment)	nil (low - med)	nil (med + med)
Turbidity < 10 NTU Faec coliform 0/100 ml Bilharzia endemic	up to 5000	1. Rapid filtration or 2. Slow sand filtration	med low	med + low med +v.low
Turbidity < 10 NTU Faec coliform 1 - 500 per 100 ml	up to 5000	1. Rapid sand filtration + disinfection (Cl_2) 2. Slow sand filtration + disinf. if poss.	med low	med + med med + low
Turbidity: 20-50 NTU Faec coliform 1 - 500 per 100 ml	up to 5000	1. Sedimentation + rapid sand filtrat. + disinfection (Cl_2) 2. Sedimentation + slow sand filtrat. + disinf. if poss.	med med	high + med high + low
Turbidity: 50-150 NTU Faec coliform > 500 per 100 ml	up to 5000	Pretreatment (coag, floc & sedimentat.) + filtration (slow or rapid sand) + disinfection	high	v. high + high
Turbidity > 150 NTU	Detailed investigation and possible pilot study work may be required			

6.5 SUMMARY OF TREATMENT TECHNOLOGIES FOR SMALL WATER TREATMENT SYSTEMS

In order to perform proper planning and design of small water treatment systems for rural communities, it is necessary to know what the different treatment technologies/systems are that can be used for treating small water supplies. These technologies are not described in detail and the reader of the guidelines document is referred to the references and to existing CSIR and WRC reports with more detailed information on these treatment systems (see Appendix C). Rather, the different treatment options are listed and briefly described, with comments on how well they have been found to perform locally.

The primary treatment requirement is always to ensure a microbiologically safe supply of water for drinking purposes. Hence, disinfection of the water will usually be the primary treatment objective. Secondary objectives may include clarification of the water, and the removal of potentially harmful chemical components.

6.5.1 Disinfection

As mentioned above, the single most important requirement of drinking water is that it should be free from any microorganisms that could transmit disease or illness to the consumer. In cases where no other methods of treatment are available or required, disinfection may be the only treatment process utilised before the water is supplied to consumers.

a. Chlorination

The ability of chlorine and chlorine compounds to destroy pathogens in water quickly, and their wide availability, make them well suited for use as disinfectants. Their cost is moderate and they are therefore widely used as disinfectants throughout the world.

Effective chlorination of water supplies has in many cases achieved a substantial reduction in those enteric diseases that are primarily water-related.

The following three products that are used for chlorination are readily available and are approved by the South African Department of Health and Population Development for use with drinking water.

- Chlorine gas
- Sodium hypochlorite (Jik, Javel, or other non-perfumed bleaches)

- Calcium hypochlorite

(Calcium hypochlorite is commonly supplied in South Africa as HTH dry granular chlorine).

Other chlorination systems

Chlorine from salt

Chlorine can be generated from salt on-site using a small chlorine generator. Simple generators employing carbon electrodes may be obtained from swimming pool chemical suppliers. More robust units employing specially coated electrodes and/or an ion selective membrane are commercially available. Units which operate with solar power for use in more remote areas are also available. The chlorine produced is in the form of sodium hypochlorite at concentrations from 0,1 to 5 %. Chlorine produced on-site may often be found to be cheaper than other forms of chlorine if the unit operates efficiently.

In-line tablet chlorinator

In-line chlorinators use calcium hypochlorite tablets. The tablets are available in a cartridge which is fitted to the chlorinator. The chlorine dosage is adjustable and may be set to meet the demand of any specific source. The chlorinator is easy to install and also easy to operate. However, it requires a pressurised pipeline into which it can be connected, and the tablets are more costly than equivalent chlorine in other forms. Furthermore, very little control over the chlorine concentration in the water is possible. These systems find more application in industrial applications and are not recommended for rural applications.

b. UV systems

Water passed in close contact to ultra-violet (UV) lamps can also be disinfected by this means. The low pressure mercury lamps produce light rays of around 254 nanometers wavelength. The lamps are protected from the water by special quartz or plastic shields. Commercially available systems are simple to install and operate. However, the major draw-back with UV systems is that no disinfectant residual is available (reference, Bettina).

c. Other disinfection technologies

A number of alternative disinfection technologies have been evaluated by the CSIR with the aim of providing more appropriate systems specifically for the developing communities where funding and operational skills are limited. More information on these technologies, which include UV radiation, mixed oxidant gases generated on-site for disinfection (MOGGOD), microfiltration and the use of metallic ions can be found in the WRC Report No. 449/1/95 by the CSIR Division of Water Technology, entitled "Non-Conventional Disinfection Technologies for Small Water Systems". Chloramination is suitable for long lines, but has too many pitfalls to be suitable for small water systems. The reader is also referred to the paper presented by I Pearson at the Workshop on Sustainability of Small Water Systems in Southern Africa, entitled "**An Assessment of Disinfection Options for Small Water Supply Systems**" (August, 2002).

6.5.2 Filtration

Filtration is a process for the removal of suspended matter (turbidity) from a water supply by means of a physical barrier. It is achieved by the passage of water through a porous medium in which the particles are trapped, either superficially when the rate of flow is slow (slow sand filters) or by deep penetration into the bed (rapid sand filters). Two types of filtration mechanisms are therefore used, *viz.*

depth filtration - where the suspended matter is removed as the water passes through a deep layer of large particles, usually sand; and
surface filtration - where the suspended matter is retained on the surface of a physical screen.

Depth filtration will generally have a greater capacity for the removal of suspended matter than surface filtration before cleaning of the filter is required. A number of different filters are used in water treatment, some more suitable for use in rural areas than others.

a. Slow sand filtration

Slow sand filtration can be an effective, simple, and low running cost water treatment processes and may be suitable for rural areas in developing countries, providing it is employed in the correct application. The process differs from rapid sand filtration because of its biological nature, and is in particular suitable for village level operation and maintenance.

A layer of sand having an effective particle size of 0,25 to 0,35 mm is supported on an underdrainage system consisting of graded stone material

above a perforated collection pipe, and contained in a suitable reactor constructed from brickwork or concrete.

b. **Rapid sand filtration**

In rapid sand filtration, sand is also used as the filter medium, but the process is quite different from slow sand filtration. This is so because much coarser sand is used with an effective grain size in the range 0,4 to 1,2 mm, and the filtration rate is much higher, generally between 5 and 15 $m^3/m^2/h$ (120 to 360 $m^3/m^2/day$). Due to the coarse sand used, the pores of the filter bed will be relatively large and the impurities contained in the raw water will penetrate deep into the filter bed. Thus the capacity of the filter bed to store suspended impurities is much more effectively utilized and even very turbid river water can be treated with rapid filtration.

For cleaning a rapid sand filter bed, it is not sufficient to scrape off the top layer. Cleaning of rapid sand filters is effected by back-washing. This means directing a high-rate flow of water back through the filter bed whereby it expands and the sand is scoured. The backwash water carries the trapped suspended solids out of the filter. To affect efficient cleaning, the backwashing-step can be preceded by air scouring, or, as is more often used lately, by simultaneous backwashing with water and air. The cleaning of a rapid sand filter can be carried out quickly; it need not take more than about one half an hour. It can be done as frequently as required, if necessary, two or three times per day. This means that a rapid sand filter can treat water in which the suspended solids levels may vary from low levels to very high levels without adversely affecting the production of clean water. Rapid sand filters are often supplied as proprietary units by commercial firms, which includes the pumps, valves, filter nozzles, air blower, control systems and pipework.

Multi-media filters are gravity-type downflow filters with the filter bed composed of several different materials that are placed coarse-to-fine in the direction of flow. The sand can be overlain by a layer of larger diameter particles of lower density than sand (usually anthracite), and/or underlain by a layer of smaller diameter particles of a denser material (garnet). According to theory these filters can be operated at higher filtration rates, and smaller filters are therefore required. The relative diameters of the different filter media and the backwash velocities are interrelated if the layers are to remain separate during backwashing. At rural treatment plants operational skills and controls are generally lacking, with the result that the media gets mixed during backwashing or the anthracite is washed out, and the advantage is lost.

c. <u>Pressure filtration</u>

Pressure filters are of the same construction as gravity-type filters but the filter bed together with the filter bottom is enclosed in a watertight pressure vessel. The driving force for the filtration process is the water pressure applied to the incoming feed water which can be so high that almost any desired length of filter run is obtainable.

Pressure filters are commercially available as complete units. They can be used in modular configurations so that upgrading at a later stage is very simple. The pressure drop across the filters is generally higher than that across a gravity filter, requiring appropriate pumps unless sufficient static head is available.

d. <u>Upflow filters</u>

Upflow filters provide for a coarse-to-fine filtration process. The coarse bottom layer of the filter bed filters out the major part of the suspended impurities, even from a turbid raw water, without an excessive increase of the filter-bed resistance due to the large pores. The overlaying fine layers have smaller pores but here also the filter resistance will increase slowly as only fine impurities make their way through to the upper layers. Upflow filters are therefore reputed to have a much larger dirt-holding capacity than downflow filters. This type of filter is not used widely any longer as a result of difficulties with backwashing the filters.

e. <u>Direct series filtration</u>

Series filtration is a two-stage filtration process consisting of either an upflow or downflow filter as contact clarifier in the first stage, followed by a rapid gravity downflow filter as the second stage.

The application of the direct series filtration process for the treatment of South-African surface waters presents an economical option for the removal of turbidity from surface waters, as a result of the low-cost and ease of constructing these filters. For low turbidity waters only coagulation and direct series filtration need to be used, while for high turbidity waters the filtration step can be preceded by flocculation and settling.

Apart from lower capital costs, direct series filtration also has the following benefits:

- easy and economical upgrading of existing treatment systems
- flexibility because of the use of modular sections
- high filtration rates can be achieved
- low coagulant dosages.

Direct series filtration plants have been built at a number of locations in South Africa. Practical experience gained through operation of these full-scale plants indicates that (Swartz, Van der Walt and Van der Merwe, 1997) :

- the system consistently provides water of acceptable quality and quantity for small, developing communities

- by exploiting modular design and the use of prefabricated concrete pipe sections, capital cost savings of 20% to 50% are attained compared to conventional treatment

- indirect evidence suggests that coagulant savings of 20% could be realised for series filtration

- with appropriate safety factors and degree of automation, the system can be successfully operated with limited operator skill, provided that competent technical back-up and guidance are provided at least monthly

f. Automatic self-backwashing gravity filter (also called valveless filter)

An innovative design of a gravity sand filter is the automatic self-backwashing gravity filter which is being used in both rural areas, and in some industrial water treatment processes. The advantage of the valveless filter is that it can be left to operate on its own without concern of the filter blocking. Once the head loss across the filter increases to a fixed value, the filter automatically goes into a backwash cycle and cleans the filter bed. No electricity is required for the filter to operate valves, etc., and because of the simple, robust design, very few problems due to breakdowns are likely to be experienced. Figure 6.5 illustrates the filter.

Shortcomings of the filter are that the cost is relatively high and that backwashing is not very efficient (because no air-scour is applied) resulting in gradual build-up of impurities in the media and short filter

runs. There is also concern over the long-term robustness of the filter, especially corrosion of the construction materials.

In an attempt to improve the performance and robustness of this type of filter, and at the same time reduce the capital cost, Umgeni Water has recently completed on a WRC project to investigate the filter and develop design criteria.

g. **Roughing filtration**

Sometimes a more limited treatment than conventional rapid filtration can be used for treating the raw water. This can be accomplished by using gravel or plant fibres as filter material in a filter system. In the upflow mode, three layers would be used having grain sizes of 10 - 15 mm, 7 - 10 mm and 4 - 7 mm from the bottom upward, and with a simple underdrain system. This coarse ("roughing") filter will have large pores that are not liable to clog rapidly. A high rate of filtration, up to 20 m/h, may be used. The large pores also allow cleaning at relatively low backwash rates since no expansion of the filter bed is needed. The backwashing of roughing filters takes a relatively long time, about 20 to 30 minutes.

Horizontal flow-roughing filtration is a treatment process that is based mainly on sedimentation, although with time, biological activity may also play a role. The suspended solids removed from the raw water will slowly build up in the filter. After some time, this will reduce the efficiency of the filter and ultimately lead to complete clogging. Efficiency can be restored by fully opening the underdrain system, and flushing out the deposits by fast drainage and a water spray on the surface. Nevertheless, some solids may remain and make subsequent fast drainage less effective and

it may therefore become necessary to clean the filter material after several years. Cleaning can be carried out by removing and washing the filter material, and then replacing it.

h. Cross-flow sand filter

Dynamic cross-flow sand filtration is a special type of slow sand filtration. The major difference between these two types of filters is the way in which the raw water is fed into the unit. Instead of the standard 1 m static head of supernatant water on top of the filter bed in a typical slow sand

filter, the dynamic filter has a running flow with a head of a few millimeters. Th effect of this cross flow is to push the heavier suspended solids over a weir at the end of the filter which then drains back into the river. Part of the flow percolates through the sand bed into the underdrain system, and is conveyed to a clear water well or reservoir.

The greatest benefit of the cross-flow sand filter is its cleaning simplicity, which comprises raking the sand surface for only a few minutes on a recommended daily basis. The main disadvantage is that large volumes of feed water is required which reduces the applicability of these filters to mountainous or hilly area where rivers have positive gradients and there is no need for pumping. The excess water overflows back to the river from where it was diverted.

More information on the evaluation of dynamic cross-flow sand filters by the CSIR, and design guidelines, can be found in the WRC Report No. 539/1/97 by Environmentek, CSIR (Kariuki and Solsona, 1997).

6.5.3 Coagulation and flocculation

Coagulation and flocculation is widely used for the removal of turbidity and colour. Both turbidity and colour are mostly present as colloidal particles (or true colour in solution). Colloids are kept in suspension by electrostatic repulsion and hydration.

Certain chemicals (coagulants) have the capacity to compress the double layer of ions around the colloidal particles which reject neighbouring particles. This reduces the electrostatic repulsion, and thus enable the particles to come together and join (*i.e.* to flocculate). The flocs so formed can grow by joining with more and more particles in the same way. When the flocs are of a sufficient size and weight they can be removed by settling or filtration.

a. Rapid mixing systems

Rapid mixing ensures the immediate dispersal of the entire dose of chemicals throughout the mass of the raw water. To achieve this, it is necessary to agitate the water violently and to inject the chemical in the most turbulent zone, in order to ensure its uniform and rapid dispersal.

Many devices are used to provide rapid mixing for the dispersal of chemicals in water. Basically, there are two groups, hydraulic rapid mixing and mechanical rapid mixing.

Hydraulic rapid mixing units that are used are:

- hydraulic jumps
- free falling water over a weir (0,5-1,0m)
- in-line mixer in a pipe (orifice plate)
- suction side of pumps

Mechanical rapid mixing units that can be used include electrical motors with impellers, propellers or turbines. Generally, mechanical rapid mixers are less suitable for rural treatment plants than hydraulic units since they require a reliable and continuous supply of power, as well as regular maintenance.

b. Flocculation systems

Flocculation is the process of gentle continuous stirring of coagulated water for the purpose of forming larger flocs through the aggregation of the minute particles present in the water. It is thus the conditioning of water to form flocs that can be readily removed by settling or filtration. The efficiency of the flocculation process is largely determined by the number of collisions which can be induced between the minute coagulated particles per unit of time. As for rapid mixing, there are both mechanical and hydraulic flocculators.

In mechanical flocculators, the stirring of the water is achieved with devices such as paddles, paddle wheels or rakes.

In hydraulic flocculators, , the flow of the water is agitated by hydraulic structures which cause a stirring action, such as channels with baffles, flocculator chambers placed in series, gravel bed flocculators, and hydraulic jet mixer type flocculators.

Baffled channels are the most common and can be either the over-and-under type or round-the-end type.

As with the rapid mixing units, hydraulic systems are preferred over mechanical ones for rural treatment plants, for the same reasons of power and maintenance requirements.

6.5.4 Sedimentation

Sedimentation is the settling and removal of suspended particles which takes place in static or slow flowing basins. Turbulence is negligible and particles having a specific weight greater than that of water will settle to the bottom of the settling basin.

Two basic types of sedimentation processes are generally used: the horizontal flow type and the upflow clarification type. Upflow type clarifiers work well under conditions of relatively constant hydraulic loadings and raw water quality. Horizontal flow type sedimentation tanks are more tolerant to shock hydraulic and water quality loads, mainly due to a longer detention time.

a. Horizontal flow sedimentation tanks

Horizontal flow settling tanks are rectangular types where the average horizontal flow rate remains constant along its full length.

b. Vertical flow clarifiers

Two basic types of vertical flow tanks have been developed during recent years. The first type consists of a circular tank with the inlet in the centre and an annular section for clarified water on the outside.

The second design makes use of a fluidized floc bed known as a sludge blanket. The design of this type of tank is based on the fact that flocculated water is discharged near the bottom of the tank, which is shaped like an inverted pyramid. The turbulence or agitation caused in the bottom of the tank by the dissipation of kinetic energy enhances floc formation. The water then rises inside the inverted pyramid with decreasing velocity as a result of the widening horizontal diameter of the tank. The vertical velocity of the water is calculated to keep the floc particles in suspension in the lower part of the tank, with a sharp dividing zone between the suspension and the clear water above. The height of the floc bed is regulated by intermittent or continuous withdrawal of settled sludge.

Unlike the floc in a horizontal flow tank, the quality of floc in a vertical flow tank depends on the flow rate, which is therefore of critical importance. If the settling velocity of the finest particles is greater than the upflow velocity of the water inside the tank, they will settle out of suspension and clear water will be produced. If the velocity of settlement is, however, lower than the upward velocity of the water, all the finer floc particles will be carried over the top, with the result that the settled water will be very turbid.

If very turbid water is flocculated, the sludge will constitute a considerable percentage of the total volume until it has had an opportunity to settle out completely and consolidate.

c. Floc-blanket type sedimentation tanks

A number of patented designs are available on the market, therefore only the basic principles will be mentioned. Their special feature is flocculation in the presence of previously formed floc; i.e. the “floc blanket” principle is applied. Freshly dosed raw water is introduced at the bottom of a tank, causing the small floc particles to move upwards through a layer of settling floc particles which move downward. The small particles adhere to the larger particles.

The objective is to obtain a floc that will settle at a rate twice that of the upflow rate of the water. In some units a portion of the flocculated water is recirculated through the zone of agitation.

Tanks of this type are sometimes used in lime-soda softening units.

d. Inclined plate settlers

An improvement in settling efficiency can be obtained by the installation of extra bottoms (trays) in a settling tank. The space between such trays being small, it is not possible to remove the sludge deposits manually with scrapers. Hydraulic cleaning by jet washing would be feasible but a better solution is the use of self-cleaning plates. This is achieved by setting the plates at a steep angle of 40° to 60° to the horizontal. The most suitable angle depends on the characteristics of the sludge which will vary for different types of raw water. The slope must be steep enough to allow the sludge to accumulate and then slide down the sloping plate. Such installations are called inclined or tilted plate settling tanks.

Instead of tilted plates, closely packed tubes may be used. These can easily be made of PVC pipes, usually of 3 to 5 cm internal diameter and sloping about 60° to the horizontal. For large installations commercially available tube models can have merit. A low cost alternative is the use of sheet plastic which has been welded at regular intervals to form a matrix of linked tubes. When expanded a lightweight, flexible sloping tube matrix results.

The possibility of increasing the efficiency of a tank through the installation of tilted plates or tubes may be used with great advantage for raising the capacity of existing settling tanks. Where the available tank depth is small (less than 2 m), the installation of the tilted plates or tubes is likely to meet with problems. In deeper tanks, they can be very advantageous.

In considering the expansion of existing facilities by the addition of tilted plates or tubes, it is important to remember that more sludge will be generated and so additional removal facilities may be required. Inlet and outlet pipe sizes and weir capacity should also be checked to see if they can carry the increased loading.

6.5.5 Oxidation

Oxidation is utilized for various purposes in water treatment. In particular oxidants are used to remove or destroy undesirable tastes and odours, to aid in the removal of iron and manganese, for disinfection, and to help improve clarification and colour removal. Oxygen, chlorine, potassium permanganate and ozone are the most frequently used oxidizing agents, and the use of each is discussed below.

For small water treatment systems, it is recommended that chlorine be considered before other oxidants since chlorine will normally be used for disinfection too. If the use of chlorine for oxidation is not practical, then the use of air, potassium permanganate or ozone could be evaluated on an economic basis. Aeration and ozone requires only a capital investment and perhaps ongoing pumping and electricity costs, as opposed to ongoing chemical costs for chlorination and the use of potassium permanganate.

6.5.6 Membrane filtration

Membrane technology is a very effective process for drinking water production. Ultrafiltration (UF) and microfiltration (MF) are membrane processes that are ideal for producing drinking water from non-saline raw surface waters, without requiring any chemicals to be added to the water.

Contaminants that are removed by UF include colloids and suspended solids (100% removal), bacteria and parasites (100%), some viruses, high molecular mass dissolved organics, oxidized iron (98%), oxidized aluminium (90%) and oxidized manganese (60%). The water produced by UF is of a very high quality and usually exceeds the quality of water produced by conventional water treatment methods (*i.e.* coagulation and flocculation, clarification and sand filtration). (Pillay and Jacobs, 2002)

Internationally, there is a strong swing towards using UF and MF in drinking water production. The advantages include very good water quality without any chemical addition; the quality of the product is fixed by the membrane, does not vary as the raw water quality varies; membrane systems are modular, and capacity can be increased easily; systems can be fully automated, avoiding problems due to operator error; and the membrane acts as a positive barrier to pathogens.

Five years ago a project was initiated to develop a local UF system for potable water production in rural and peri-urban areas of South Africa (Univ. Stellenbosch, M L Sultan Technikon, Water Research Commission). A major aim of the project was to develop a technology that would be sustainable in developing economy conditions. More information on the use of membrane technologies (MF and UF) in rural areas can be obtained in the paper presented at the Workshop on the Sustainability of Small Water Systems in Souther Africa, by Pillay and Jacobs, entitled "**The Application of Membrane Technology for Potable Water Production in Developing Communities**", August 2002.

6.5.7 Special treatments

a. Nitrate removal

In South Africa the recommended limit for nitrate in drinking water is 6 mg/l as N. When waters have a high nitrate content, various methods are available to reduce this to within the recommended limits. Physical-chemical methods include ion exchange, reverse osmosis and distillation, while biological methods include algal ponds and denitrification.

i. Physical-chemical methods

- **Ion exchange:** Investigations carried out at Aroab in South West Africa (Namibia) demonstrated that ion exchange is feasible for the removal of nitrate in the production of drinking water for small communities. Small household ion exchange units (similar to household water softeners currently on the market) are now commercially available. Table salt (NaCl), used for regeneration (once or twice a month), is relatively inexpensive.

- **Reverse osmosis:** Reverse osmosis systems are very expensive, especially on a small scale, and although they can be justified if desalination of the product water is also required, they cannot seriously be considered for nitrate removal. Schoeman (2002) showed that very good results can be obtained with reverse osmosis plant in a rural area (Limpopo province) for nitrate removal (Paper presented at the Workshop on the Sustainability of Small Water Treatment Systems, entitled "**Demonstration of Reverse Osmosis Technology for Nitrate Removal from Borehole Waters in a Rural Area in South Africa**", August 2002).

- **Distillation:** Desalination by distillation has been applied in many technical process variations and refinements, but the cost of thermal energy makes large-scale distillation uneconomical.

  Owning to rising fuel costs, solar energy is becoming increasingly attractive. Solar distillation is used extensively in the USA and Australia, and should also be applicable in the hot South Africa climate. Since the yield per exposed surface unit area is rather low (about 1 to 6 litres per m² per day) the capital outlay for solar stills is rather high and, at this stage, justifies only small-scale use (such as for households or small communities).

  The National Institute for Water Research (1973), now known as the Division of Water Technology, CSIR, developed a design for a greenhouse type solar still that is very easy to build and maintain (Van Steenderen, 1977). Extensive test in South West Africa have shown it to be reliable.

ii. Biological methods

- **Algal ponds**: Nitrate can be assimilated by algae and thereby removed from solution in the water. Cultivation of algae is a slow process, very much dependent on temperature and light intensity. Algal ponds must be shallow and exposed to light. The problem of separating the algae from the water before the water can be utilised presents an additional problem. It appears, at this stage, that algal ponds are not very suitable for the production of denitrified potable water.

- **Denitrification:** Bacteria also utilise nitrates in the water in their metabolic process. In particular, certain groups of bacteria, among them Thiobacillus denitrificans, utilised nitrate as a source of oxygen under anoxic conditions converting the nitrate to nitrogen gas or nitrous oxide. The main disadvantage of biological deniltrification for the production of potable water is that the presence of biological sludge residues, colour and micro-organisms, make further treatment necessary to render the water suitable for human consumption. The water can, however, be used for stock watering.

b. Fluoride removal

When water supplies contain excessive fluorides, the growth of the bones and teeth of consumers can be adversely affected. This is often evidenced by the teeth of people using the water being mottled with a permanent black or grey discolouration of the enamel.

Three methods are normally used for fluoride removal. The first two methods employ ion exchange media, *i.e.* activated alumina or bone char, which remove the fluorides as the water percolates through them. The media are periodically regenerated by chemical treatment when they become saturated. In the third method, the fluorides are removed by alum flocculation and settling. The activated alumina ion exchange method is the most efficient, but also costly. The use of crushed bone or bone char has been successfully used in a number of rural applications, and is very cost effective due to the availability of the raw materials. Flocculation with alum is limited to reducing the fluoride content to about 15 mg/l, which is still excessive for drinking water. However, it could be utilised as a first step when the natural fluoride content is very high.

c. Desalination (brackish waters)

A number of rural areas in Southern Africa are endowed with saline groundwater resources. A few methods are available for desalinating water, even in rural areas.

The age-old greenhouse type solar still has been tried and tested in many parts of the world. In particular the greenhouse type still has shown considerable potential for rural areas due to its simplicity. However, this still does suffer from problems of low efficiency and relatively high capital costs. Subsequently the cost per litre of fresh water obtained is relatively high. In an attempt to produce a small scale unit with lower capital cost, a solar still was developed by the CSIR for household applications. Further development is continuing in South Africa, also by other institutions.

Reverse osmosis membrane systems have been developed for small scale and household use. The so-called “tap water” units which rely on a low pressure to desalinate are not suited to the high salinity waters (3000 mg/l and more) generally encountered in the

problem regions. The alternative reverse osmosis (RO) systems for desalinating brackish water sources require some additional pumping mechanism to pressurise the water on a continuos basis to 15 bar or more. To date, only a few RO units have been installed in South Africa for rural water treatment plants, amongst them the Bitterfontein municipal plant in the Northern Cape. However, such units are fairly widely used in countries where brackish water problems are more severe, such as India.

d. Algae removal

Simple treatment methods are available to treat algae laden waters. These methods are low cost and low maintenance alternatives which are well suited to rural areas. Six methods of interest are presented here, these being slow sand filtration, horizontal roughing filtration, sedimentation, flotation, in-line filters and oxidation with chlorine.

Algae entering a slow sand filter with the raw feed water will be captured in the *Schmutzdecke* and upper sand layer. The algae may also proliferate in the supernatant water. These algae will be beneficial to the treatment process if they are in moderate numbers. Algae add oxygen to the water and filter out certain nutrients and even some metals.

Techniques to prevent or control troublesome algae growth in slow sand filters include pre-treatment, shading, chemical treatment, biological methods and manual removal.

Algae is removed to a large extent in a horizontal roughing filter (HRF). It is also not necessary to cover or shade a HRF as the water remains within the gravel and is not exposed to the surface.

Sedimentation and flotation provide effective means of removing algae (Haarhoff and Van Vuuren, 1993).

NOTE!
While flotation provides an effective means for algae removal, cognisance should be taken that operation of flotation systems requires more attention and skills

In-line cartridge filters and filter screens which are commercially available can be very effective in removing algae, particularly filamentous algae. However, the filters will block fairly rapidly under conditions of high algae loads, and the replacement of cartridges or the cleaning of screens may be expensive and tedious.

Chlorine and other oxidants can be used to inactivate algae cells by attacking the cell walls and reacting with the internal contents. Having inactivated the cell it is more easily removed from the water by conventional or other treatment processes. The use of chlorine for algae control may result in the formation of unpleasant tastes or odours in the water when certain species of algae are present.

e. Organics removal (pesticides, etc.)

The method most suitable for organics removal is activated carbon adsorption. The water is passed through a bed of carbon granules where adsorption of the organics into the fine pores of the carbon particles, takes place. The capacity of the carbon to adsorb organics depends on a number of factors, including the type of carbon used and the type of organics present.

Other methods for removing organics include the desalination methods described above, ultrafiltration (similar to reverse osmosis but using a membrane with larger pores) and oxidation. Oxidation methods will not remove organics, but rather convert the existing organics to other more acceptable compounds.

6.5.8 Package treatment plants

A number of package type treatment plants are commercially available. The conventional plants usually include the following unit processes combined into a complete and compact unit: coagulation and flocculation, filtration and disinfection.

Other package treatment systems which have been developed for small scale water treatment include crossflow microfiltration systems, diatomaceous earth filtration plants, ceramic microfiltration plants and membrane ultrafiltration plants.

These package treatment plants are available in standard modular sizes and hence the capacity of the treatment plant can be built up by incorporating a number of modules in parallel. It is important to assess the operation and maintenance requirements for such plants to ensure that the community utilising the plant will reasonably be able to operate and maintain it.

Because of the variety of package treatment systems that have been developed, Umgeni Water undertook a WRC funded project to evaluate the systems according to a number of criteria relating to its appropriateness for use as treatment system for small communities. A report giving the results of this evaluation of South African package plants has been published and provides guidance in the selection of a suitable package treatment system (WRC Report No. 450/1/97 "Package Water Treatment Plant Selection").

The main findings of the report is as follows :

a. <u>Water treatment performance</u>

- Disinfection : Adequate disinfection was obtained where sufficient chlorine contact time was provided.

- Turbidity and Aesthetics : Excellent turbidity removal, beyond that required for potable water was achieved with the two microfiltration units. The dual media and upflow filter systems produced water with a turbidity well below 1 NTU for most of the evaluation period.

- Sludges and Effluents : Most of the plants produced effluents containing various combinations of suspended solids, water treatment chemicals, filter media and cleaning chemicals. Provision for handling and disposal of these waste products must therefore be included in the design phase of water supply schemes where package water treatment plants will be used.

- Robustness and Reliability : In general, the choice of materials in all plants was satisfactory and no failures due to inappropriate materials occurred during the evaluation period.

- Potential for upgrading capacity : The only system in which significant potential for increasing the treatment capacity exists is the crossflow microfiltration unit. The purchase and installation of additional crossflow modules represents a relatively inexpensive method of increasing plant capacity. In all the other systems, significant increases require the purchase of additional package units.

- Control systems : Six of the systems were manually controlled, two were partially automated and two were fully automated. On the whole, the control systems were effective but in many cases, inexpensive modifications were required to improve the overall reliability of the process and reduce the operating workload. Since most manufacturers have attempted to minimize the capital costs, there is a lack of alarm systems or automated cut-outs which shut off the plants when an alarm condition arises. The addition of automated cut-outs for high filter pressures or low chemical tanks levels will remove the requirement for the plant to be continually manned while in operation and will decrease the risk of mechanical failurer or contamination of the treated water supply.

b. Maintenance requirements

Regular maintenance is essential to ensuring that package water treatment systems function correctly. Most of the spares and consumables required for the units that were evaluated are available locally.

c. Operation and operator training requirements

Proper operation of package water treatment plants is essential if a reliable supply of potable quality water is required. The ten systems under investigation were rated in terms of cmplexity of operation on a scale which varied from simple to expert. Recommendations are made for each system with respect to the skills and training that an operator would require. This is an important aspect that will provide a guide as to the level of operator skill required for any of the systems. Recommendations for the content of package plant operating manuals are also provided.

6.5.9. Point-of-entry (POE) units

Point-of-entry (POE) units treating water for an entire household can be an alternative to centralised treatment technology for small systems. The POE water treatment industry is growing rapidly, also in South Africa. It can be an cost-effective solution to very small systems and individual homeowners, eliminating some of the problems small systems face when attempting to finance and operate central treatment facilities. However, the assurance of long-term maintenance and monitoring of POE technology and its performance remains the main problem to be dealt with. It is therefore not applicable or recommended for small water systems in the context of this report.

NOTE!

It is important to note that bacteriological contamination of the filtration media in point-of-entry systems can take place during prolonged use, which may result in deterioration of the microbiological quality of the treated water.

6.6 PROCESS SELECTION

When designing a water treatment plant for a particular water source, three aspects are important.

Firstly, the designer should have a clear picture of the deficiencies of the water to be treated for potable use; not only after analysis of one or two grab samples, but also of the variations in raw water quality likely to occur, taking into account the physical circumstances surrounding the source.

Secondly, the designer should have a clear understanding of the abilities and constraints of the various unit processes is water treatment.

Thirdly, the designer should ascertain the likely level of skills and dedication available for operation and maintenance of the works, so that an unrealistically high degree of sophistication will not be expected from the operator.

With respect to the third aspect above, it should be noted that once coagulation is incorporated as a unit process, pH control is required. This implies the use, calibration and maintenance of a pH meter, as well as carrying out of flocculation tests from time to time to establish optimum conditions.

For the development of a design rationale, the characteristics of waters from various sources as well as the most likely unit processes to be utilized, will first be discussed.

6.6.1 Ground water

a) <u>From "clean" environment</u>

The water would need to be abstracted from a borehole or well which is completely sealed with no chance of surface water inflow, and no refuse or septic tank effluent disposal in the vicinity of the abstraction point. Note that a distance between a specific point of pollution and the abstraction point is not stipulated, because this will depend on the geological strata and the likely direction of ground water flow. In doubtful cases the advice of a geologist should be sought; backed up by bacteriological sampling. A distance of 500 meters may be regarded as a practical minimum. The appearance of the water should generally be clear without colour or turbidity.

If the water also has a fresh taste and smell, it may be regarded as potable without any treatment. Regular bacteriological samples should however be taken.

If the water has a stuffy smell, cascading will be required. Note that this does not apply to a hydrogen sulphide smell, in which case expert advice should be sought.

Groundwater sometimes contains iron and manganese in solution, which may form a brownish/blackish precipitates when ecposed to air; and would also cause brown and black spots to form on white surfaces. Removal of iron and manganese requires sophisticated treatment processes which falls outside the scope of these guidelines.

b) From a suspect environment

If at any time indications of bacteriological pollution are found, or a known source of pollution is present, the water should be disinfected on a continuous basis, and steps taken to remove the source of pollution.

6.6.2 Water from springs and roofs

If the spring is covered and the water piped without exposure to possible sources of pollution, it may be regarded in the same category as ground water. On the other hand, if the spring is open to the environment so that birds and other animals have access to it; but protected from turbid surface water influx, disinfection will suffice. Steps should however be taken to prevent access by animals.

Water from roofs, as is often utilised in small communities, is subject to pollution from bird droppings, and should also be disinfected before use.

Once water from springs and fountains has been stored in open reservoirs or dams, the risk of pollution by animals and humans greatly increases, and the water should be regarded as surface water. (See next sections)

6.6.3 Clear surface water

This would be water abstracted from clear mountain streams, or originating from springs and used directly or stored in open reservoirs before use. The water would generally have colour of less than 20 parts and turbidity between 1 and 10 parts, but be suspect with regard to bacteriological quality on account of exposure to the environment.

A suitable treatment plant would consist of slow sand filters, followed by disinfection.

6.6.4 Turbid or coloured surface water

This would typically be waters from the middle or lower reaches of rivers, after extensive exposure to the environment so that it would have acquired turbidity in excess of 10 parts and/or colour in excess of 20 parts. It would however not be enriched and therefore not contain appreciable numbers of alge (it would not appear green to the eye).

The unit processes flocculation (including pH control), rapid filtration and disinfection will be required. pH correction before distribution may also possibly be required, because the optimum pH for coagulation is often too low for distribution.

6.6.5 Eutrophied surface water

This would be waters enriched with nitrogen and phosphorus by purified sewage discharges, or from diffuse sources. The water would be green to the eye on account of the algae present, and would also exhibit typical algal smells (muddy, grassy, earthy, fishy) which will not be removed by any of the unit processes described in this document; and which smells are enhanced by the addition of chlorine.

6.7 PROCEDURE FOR ESTABLISHING A WATER PURIFICATION WORKS

As described above, water purification installations can vary from the use of one or two simple processes which will operate with very little supervision, to fairly complex works where the unit processes need careful design and supervision. Whilst the simple units may be designed and constructed by people with relatively low skills, it is always advisable to acquire the services of a technologist or engineer to assist with an evaluation of all the relevant factors, as well as the selection and design of appropriate unit processes.

The preparation of a design and supervision of construction (except for very small and simple works) fall in the ambit of a professional engineer, normally one with a civic engineering background. Water purification works differ from normal civil engineering projects, in as much that a significant portion of the project often entails work of a mechanical and electrical engineering nature; thereby making it an inter-disciplinary project.

In South Africa, the water industry has developed along the lines of engineering consultants doing the background investigation as well as process design of treatment plants; commercial companies supplying and installing the equipment needed (pumps, meters, valves, chlorinators, filtration equipment, electrical installation, etc); and civil engineering contractors, undertaking earthworks, concrete works, road works, etc. Even for a relatively small water treatment works, two contractors whose operations need to be co-ordinated, are therefore often involved.

There is of course a considerable degree of expertise present in the commercial companies, who often do their own process designs. In the conception of a scheme, engineering consultants will be well advised to draw on this source of knowledge.

The procedure for establishing a water treatment plant will roughly proceed along the following lines:

a. Make sure that the community has a legal right to the water source,and verify according to normal engineering practice that the source is adequate.

b. Estimate the water demand of the peak day; decide on the number of operating hours for the works, and calculate the average hourly flow that must pass through the works. This is the design flow.

c. Decide on the various unit processes to be employed. This may have to be preceded by chemical and bacteriological analyses of the raw water as well as flocculation tests by a chemical laboratory. For the rest of this section it is assumed that a turbid surface water is to be treated.

d. Calculate the sizes of the various structures required e.g. the chemical store, the number and sizes of the containers for chemical solutions, the rapid mix unit, the flocculation channel, the sedimentation tank, the filters, the chlorination contact channel and the sludge lagoon.

e. Prepare a lay-out of the works on the ground, taking care to prevent floc break-up by pumping or excessive turbulence.

f. Decide on the mechanical equipment required (typically mixers, dosing pumps, dry feeders, rapid filter equipment, pumps, and a chlorinator); write a specification for these and ask for tenders. For small works, it is customary to include the electrical engineering work in this section. For larger installations, the electrical engineering work would be designed by an electrical engineer and be the subject of a separate tender.

g. In the mean time, prepare a civil engineering design, including all earthworks, pipework and structures. Prepare a specification and ask for tenders.

h. Once the tenders have been adjudicated and awarded, the contracts will follow the normal procedure; due care being taken to co-ordinate the activities of the two contractors.

i. When the installations have been completed and all mechanical equipment tested, it is the responsibility of the designer to initiate the purification process in collaboration with the equipment supplier, set the dosing equipment and ensure that the process functions satisfactorily.

k. Finally, an operations manual should be prepared and made available to the operator.

6.8 WATER SUPPLY UNDER EMERGENCY CONDITIONS

Emergency conditions, albeit due to natural circumstances (earth quake, flood, etc), or man made actions (war, civil unrest, wilfull damaging of property, etc), often goes hand in hand with the disruption of normal water supply services; and the attendant threat of outbreak of disease. Engineers may under such circumstances be called upon to advise people on procedures to follow with respect to safeguarding their water, and to establish emergency water supplies.

The same principles as for normal water treatment would apply. Firstly, the best possible source under the circumstances should be located. In this case, however, aesthetic aspects like colour of tubidity could be ignored in favour of the absence of pollution by sewage or wastes form human or animal origin. For example, the turbid water from a river in flood would be a better raw water source than clear seepage water from below an emergency settlement without proper sanitation. Swimming pools would also be an acceptable raw water source. Also, pollutants with only long term negative effects like trihalomethanes, would be of little consequence under emergency conditions.

Secondly, purification should be aimed primarily at the elimination of pathogenic organisms. On a very small scale, boiling of the water is an excellent way to eliminate pathogens. On a somewhat larger scale, and if it is available, chlorine could be used for disinfection. Chlorine would normally be available in communities in the form of household chlorine compounds (bleach solutions, and chlorine granules for use in swimming pools).

CHAPTER 7

INDIGENOUS WATER TREATMENT TECHNOLOGIES

People have traditionally used both plants and soil materials for domestic treatment of highly turbid water. For example, horse beans, lentils and helba have been used as coagulants. Also used are ful masri (*Faba vulgaris*), doleb (palmfruits of *Borasses* sp.) and oshar shrub (*Calotrpis procera*), while ground nuts are being used with a clarifying clay soil (these are powdered seeds of *Moringa oleifera).* The juice from the leaves of *Moringa oleifera* has also been found to inhibit the growth of *E.coli*, *Micrococcus pyogenes*, and *Bacillus subtilis.* This has been attributed to the absorption capacity of the montmorillonite composing the material.

The drawback of using these coagulants is the ignorance about their constituents and their general effect on hygiene, as well as their scientific application, *i.e.* dose required, pH influence, degree and time of mixing, ect. which are not very well known.

7.1 INTRODUCTION

A great variety of both natural and synthetic materials is available to aid in the clarification of water. The correct application of these coagulant aids may improve the settling characteristics and toughness of the floc which in turn permit shorter sedimentation periods and higher rates of filtration. More important, however,such aids may significantly reduce the required dosage of the primary coagulant (*e.g.* alum), which is beneficial to those developing countries that must import coagulants. A number of synthetic chemicals (*e.g.* catronic, antonic, and ampholytic polyclectrolytes) that can successfully cope with certain types of coagulation-flocculation problems (especially those arising from seasonal changes in water quality and ambient temperature) have been developed by chemical manufacturers in the United States and Europe. In general, however, the use of these chemicals in developing countries is inappropriate, because of the need for importation, careful monitoring and regulation, and their high cost. Continued supply may be questionable. A reasonable alternative, then, is natural coagulant aids that are available at low cost in most developing countries.

Natural coagulant aids fall into two categories, namely, (1) adsorbents-weighting agents, and (2) natural polyelectrolytes, both of which are discussed below.

7.2 ABSORBENTS AND WEIGHTING AGENTS

Bentonitic clays, fuller's earth, and other adsorptive clays are used to assist in the coagulation of waters containing high colour or low turbidity. They supply additional suspended matter to the water upon which flocs can form. These floc particles are then able to settle rapidly due to the high specific gravity of the clay. Some clays swell when added to water, and can produce a floc when used alone or with a limited dosage of alum. Practical experience has shown that does of clay ranging from about 10 to 50 mg/l result in good floc formation, improved removal of colour and organic matter, and a broadening of the pH range for effective coagulation (American Water Works Association, 1971). For low turbidity raw waters (less than 10 NTU), the addition of adsorptive clays may often reduce the dosage of alum required.

Powdered-calcium carbonate (limestone) is also effective as a weighting agent and, in addition, supplies alkalinity to the water upon dissolving. It is a common construction material (known as whiting in the building industry) and is easily stored, handled, and applied. A dosage of about 20 mg/l is sometimes used to treat low turbidity waters *(Cox, 1964).*

7.3 NATURAL POLYELECTROLYTES

Polyelectrolytes are either derived from natural sources or synthesized by chemical manufacturers. In both instances, their structure consist of repeating units of small molecular weight, chemically combined to form a large molecule of colloidal size, each carrying electrical charges or ionizable groups. Polyeletrolytes are often classified by the type of charge they carry. Thus, polymers possessing negative charges are anionic, those possessing positive charges are cationic, and those that carry both positive and negative charges are *ampholytic.* A wide variety of ampholytic polymers is derived from natural sources.

The application of synthetic polyelectrolytes as coagulant aids in water treatment is appropriate only in the industrialized countries or in the largest cities in countries such as Brazil, Argentina, Colombia, and India, which have reasonably developed water supply infrastructures that are able to regulate and monitor the manufacture and dosage of those chemicals.

A report published by the IRC (1973) summarizes the health aspects of using synthetic polyelectrolytes in water treatment; this report outlines procedures for their control that have been adopted and have proven effective in the United States and England. Nevertheless, in most developing countries, natural coagulant aids are preferable, because they do not require such regulatory control and are usually less costly.

Interestingly, natural polyelectrolytes have been used for many centuries in developing countries for clarifying water. Sanskrit writings from India reported that seeds of the nirmali tree (*Strychnos potatorum*), were used to clarify turbid river water 4 000 years ago. In Peru, water has been traditionally clarified with the mucilaginous sap of "tuna" leaves obtained from certain species of cacti (Kirchmer, Arboleda, and Castro, 1975). Jahn (1979) reports that in several countries in Africa (Chad, Nigeria, Sudan, and Tunisia) indigenous plants are added to drinking water by rural villagers to remove turbidity or unpleasant tastes and odors. Thus, the clarifying powers of natural polyelectrolytes are known to the rural inhabitants of numerous developing countries. At the same time, though, these substances have also been proven effective as coagulant aids in community water treatment, based on practical expierence with such aids in Great Britain and research undertaken in several developing countries.

The British were among the first to use natural polyelectrolytes as coagulant aids in urban water supplies (Manual of British Water Engineering Practice, 1969; Packham, 1967). Sodium alginate, a natural polymer extracted from brown seaweed, has been employed by a number of water authorities at doses of 0.4 to 0.5 mg/l as an aid to alum, particularly during periods of low temperatures. Sodium alginates are widely used as thickening and stabilizing agents in the food, textile printing, and paper industries. Other natural polymers that have been used successfully in England are hydroxyethyl cellulose (HEC) and Wisprofloc, a derivative of potato starch. Starch products, cellulose derivatives an alginates are all used in food processing.

7.4 NIRMALI SEEDS

The effectiveness of crushed nirmali seeds as a coagulant was verified in jar test studies conducted at Johns Hopkins University, Baltimore, Maryland (Kazoyoshi Kawata). The test runs involved six samples of 500 ml of turbid water (4,5 NTU) that were made using a suspension of bentonite clay in water. Crushed nirmali seeds were added to the six samples in doses ranging from 0 to 70 mg/l, and then the samples were subjected to rapid mixing for 1 minute, followed by gentle stirring for 2 to 3 minutes and settling for 15 minutes. About 50 – 75% reduction in turbidity was achieved. A check on alkalinity and pH before and after the additions of the crushed nirmali seeds showed no appreciable change.

7.5 MORINGA OLEIFERA SEEDS

Laboratory studies conducted in the Sudan (Jahn and Dirar, 1979) revealed that seeds from the moringa oleifera tree act as a primary coagulant, and compare favourably with alum with respect to reaction rates and turbidity reduction in the raw water. The results from jar testing showed that alum gave only a further 1% reduction in turbidity.

The efficiency of several plant materials (including moringa oleifera and nirmali seeds) as natural coagulants in comparison with alum have been studied experimentally by several investigators.

7.6 CHITOSAN

A remarkable cationic polyelectrolyte called chitosan acts faster than any known coagulant from plant materials (Jahn, 1981). It is derived from chitin, which is the organic skeletal substance in the shells of crustacea such as shrimp, prawns, and lobster. The yield of chitosan varies from about 35 to 40% of the weight of shrimp shells. Chitosan is produced from the partial deacctylation of chitin in concentrated alkali solutions at 135 to 150°C. Chitosan has been given interim approval for doses up to 10 mg/l by the U.S.-Environmental Protection Agency for use in drinking water treatment plants. A patent has been issued for its use as a water treatment coagulant aid (Peniston and Johnson, 1970). In Japan, chitosan has been used as a coagulant aid since about 1950 (Kawamura).

A pilot filter study conducted to develop design criteria for a new water treatment plant on the island of Maui, Hawaii showed that chitosan in conjunction with alum coagulation was very effective in reducing turbidity and colour (Kawamura). At a filtration rate of 17.9 m/hr, the combination of alum at 8.8 mg/l and chitosan at 0.22 mg/l removed 75% of the influent turbidity (from 19.4 to 4.8 NTU) and 90% of the colour (from 90 units to 10 units). Alum at 8 mg/l and chitosan at 0.5 mg/l removed 98% of the influent turbidity and about 90% of the colour, yielding an effluent turbidity of 0.25 NTU. On the other hand, 75 mg/l of alum alone removed. 97% of the influent turbidity and about 90% of the colour, yielding an effluent turbidity of 0.38 NTU.

The local production of chitosan for water treatment applications should be considered in coastal areas with large seafood industries where shells are a waste product, particularly if alum is costly.

A potentially deleterious side-effect of some natural polyelectrolytes is their propensity for increasing the growth of bacteria in the water being treated. Independent studies conducted in India and the Sudan showed that seeds from the nirmali and moringa trees, when used a coagulant aids, initially removed bacteria from the water, but after several hours the bacteria count rose slightly (Jahn, 1979). This phenomenon was attributed to the organic material present in the seeds, which was thought to provide additional substrate for the growth of bacteria. However, proper disinfection of the treated water will kill microbiological organisms, including bacteria.

Other potential problems associated with natural polyelectrolytes are their wide spread use as foodstuffs, which may make them difficult to procure without causing local scarcity; their quality tends to deteriorate in time, and therefore they should not be stored over three months. Chitosan, however, has been shown to be stable indefinitely in dilute solutions (Kawamura); there was no sign of bacterial activity or degradation in a five year old solution of chitosan.

CHAPTER 8

DESIGN GUIDELINES FOR SMALL WATER TREATMENT SYSTEMS FOR RURAL COMMUNITIES

Once a selection of a treatment process or processes has been made, it will be necessary to size the unit systems and specify its outlay and materials of construction, all based on sound engineering principles. This should be done to ensure that the treatment plant as a whole, and the unit processes individually, will be able to produce the required quantity of water of a quality complying with the needs for health and hygiene, aesthetics and stability.

This chapter provides the design considerations and guideline values to be used when sizing unit treatment processes for small water systems, consisting of coagulation and flocculation, sedimentation, filtration, disinfection and stabilisation.

The following design manuals and guideline documents were used in compiling this chapter:

Guidelines on the Technology for and Management of Rural Water Supply and Sanitation Projects.
Report to the Water Research Commission by the Appropriate Technology Group, Water Care Programme, Division of Water Technology, CSIR. WRC Report No. 231/1/93. December 1991

Water Purification Works Design.
F A van Duuren (Editor). Water Research Commission. 1997

Design Guidelines for Small Water Purification Works.
Report to the Water Research Commission by WM Malan, Department of Civil Engineering, University of Stellenbosch, Stellenbosch. Draft Final Report. December 1997

Coagulation and Flocculation.
Bratby, John. Upland Press Ltd, Croydon, England. 1980

Guidelines on Hydraulic Flocculation.
Division of Water Technology, CSIR Technical Guide by Felipe Solsona. October 1990

Surface Water Treatment by Roughing Filters : A Design, Construction and Operation Manual.
Martin Wegelin. Swiss Centre for Development Cooperation in Technology and

Management. October 1996

Guidelines for the Upgrading of Existing Small Water Treatment Plants.
Report to the Water Research Commission by Chris Swartz Water Utilization Engineers. WRC Report No. 738/1/00. 2000

Guidelines for the Treatment of Cape Coloured Waters.
Report to the Water Research Commission by the Division of Water Environment and Forestry Technology, CSIR. WRC Report No. 534/1/98. 1998

Manual on Water Purification Technology.
National Institute for Water Research, CSIR. CSIR Technical Guide K73 1995

8.1 PRE-TREATMENT

8.1.1 Screening

It is customary to use a screen at the point of water abstraction from a surface source to prevent the ingress of twigs, leaves, fish, frogs, etc. into the purification works. Where applicable, a simple sieve with 5 to 15 mm apertures, and a flow through area giving a velocity not exceeding 0,5 m/s will normally suffice.

8.1.2 Aeration

Water drawn from the bottom of a dam or from deep boreholes some times has a stuffy smell. A simple cascade where the water falls through a total distance of 1 to 2 m is normally sufficient to dissipate such offending odours. Odours caused by hydrogen sulphide will not be removed in this way, and require exposure to the atmosphere for at least 48 hours in an open reservoir. In the case of the tastes associated with algal blooms in surface waters, no degree of aeration or exposure will be of any use, and adsorption on activated carbon will be required. This is a specialised field.

8.2 COAGULATION AND FLOCCULATION

In general, water treatment processes making use of chemicals are not the best option for small community water supplies, and should be avoided where possible. Chemical coagulation and flocculation should only be used when the required treated water quality cannot be achieved with an alternative non chemical treatment process (for example slow sand filtration).

Coagulation and flocculation will usually be required when the suspended solid load would cause filters to block too rapidly, when flocculation facilities have already been provided, when space limitations preclude the use of slow sand filters, or when the colloidal matter present in the water is too fine to be removed even by slow sand filters. Some plants have been designed to dose coagulants only when the incoming turbidity is greater than some predetermined value.

8.2.1 Rapid mixing

Rapid mixing aims at the immediate dispersal of the entire dose of chemicals throughout the mass of the raw water. To achieve this, it is necessary to agitate the water violently and to inject the chemical in the most turbulent zone, in order to ensure its uniform and rapid dispersal. The requirement for rapid mixing is based on the property of the coagulant which results in very rapid hydrolysis of the coagulant (within a few seconds). Coagulants which have hydrolysed are less available to destabilise the colloids which the treatment process is aimed at removing. The destabilization of colloids is also very rapid, and hence optimum results are obtained when the coagulant is mixed with the water very rapidly (within one or two seconds).

Utilization of a hydraulic jump downstream of a Parshall flume is one of the most practical methods used in rural areas. This provides the additional advantage of flow measurement in the Parshall flume. Rapid mixing may also be achieved by feeding the chemicals at the suction side of pumps. With a good design, an hydraulic mixer can be as effective as a mechanical mixing device.

> **RAPID MIXING**
> Agitate water violently and inject the chemical in the most turbulent zone very rapidly (within one or two seconds)

8.2.2 Flocculation

The energy input for flocculation (as measured by the velocity gradient G) must be high enough to achieve the particle contacts necessary to promote aggregating and floc growth. However, they must not be so high as to lead to floc shear or floc break-up. Floc produced by organic polymers may be stronger than those produced from Fe (III) and Al (III) salts, and can withstand higher shearing stresses. In the case of floc rupture, reaggregation is more likely to occur for Fe (III) and Al (III) flocs than for polymer flocs, because the polymer segments that become detached may fold back and restabilise the particle.

The optimum velocity gradient depends on the coagulant used. For Fe (III) and Al (III) experience has shown that gradients between 20 and 70 s^{-1} gives best results.

The detention time in a flocculation basis is also an import parameter because it determines the amount of time that particles are exposed to the velocity gradient and gives a measure of contact opportunities in the basin. A detention time of 20 - 30 minutes is usually considered satisfactory, but for certain types of water 10 minutes may suffice.

FLOCCULATION
$G = 20 - 70\ s^{-1}$
t = 10 - 30 minutes

Guidelines regarding the design and construction of baffled channel flocculators are given below:

A. Around-The-End (Horizontal Flow)

1. Distance between baffles should not be less than 45 cm to permit cleaning.
2. Clear distance between the end of each baffle and the wall is about 1½ times the distance between baffles; should not be less than 60 cm.
3. Depth of water should not be less than 1,0 m.
4. Decay-resistant timber should be used for baffles; wood construction is referred over metal parts.
5. Avoid using asbestos-cement baffles because they corrode at the pH of alum coagulation.

B. Over-and-Under (Vertical Flow)

1. Distance between baffles should not be less than 45 cm.
2. Depth should be two to three times the distance between baffles.
3. Clear space between the upper edge of a baffle and the water surface, or the lower edge of a baffle and the basin bottom, should be about 1½ times the distance between baffles.
4. Material for baffles is the same as in around-the-end units.
5. Weep holes should be provided for drainage.

Further information on the design of hydraulic flocculation systems is given in the Division of Water Technology, CSIR guide: ◘ Guidelines On Hydraulic Flocculation◘, as well as the handbook by John Bratby, ◘Coagulation and Flocculation◘.

8.2.3 Choice of coagulant/flocculant

Extensive tests should be carried out on the raw water in order to ensure that the coagulant(s) and/or flocculant(s) that are selected will indeed give the best results. Such tests should preferably be carried out over a period of one year, in order to assess that quality of the raw water during all seasons of the year.

In deciding which coagulant(s)/flocculant(s) would be most desirable, the following factors should be considered:

- transport and handling costs
- volume of sludge produced
- length of filter runs.

8.2.4 Coagulant dosage and coagulation pH

For good coagulation, the optimal dose of coagulant should be fed into the water and properly mixed with it. The optimal dose will vary depending upon the nature of the raw water and its overall composition. It is not possible to compute the optimal coagulant dose for a particular raw water. A laboratory test called the "jar test" is generally used for the periodic determination of the optimal dose. It is also used to determine (less frequently) what the optimum pH range is for good floc formation.

8.3 SEDIMENTATION

In water treatment plants, sedimentation is used to remove readily settleable particles, flocculated or coagulated impurities, and precipitated impurities from softening operations.

The following factors influence sedimentation:

a. Size, shape and density of the floc.
b. Temperature and hence viscosity of the water.
c. Effective average period available for sedimentation.
d. Effective depth of the basins.
e. Basin surface area.
f. Surface overflow rate.
g. Velocity of flow.
h. Inlet and outlet design.

8.3.1 Retention time

The retention time in a tank is the time required to fill the tank at the normal rate of flow; for instance, a tank of 100 m^3 capacity would provide a retention period of 4 h at a flow of 25 m^3/h. Unfortunately, it is a poor parameter, and often bears little resemblance to the actual displacement period because of short-circuiting through the tank.

Some regulatory agencies have arbitrarily required water plant clarifier detention periods of as much as 6 h. Some texts suggest 2 to 4 h, which is not too unreasonable when compared with 6 h. Sedimentation tanks should not be designed on the basis of retention period.

RETENTION TIME
This parameter should not be used as the basis for design of a settling tank

8.3.2 Upward flow velocity

This is expressed in metres per hour or in unit volume per unit area per day. The establishment norms are based on the rate of sedimentation of floc. Well-formed dense floc settles at the rate of about 3 m/h. The upward flow velocity should not exceed one half of this value; *i.e.* 1,5 m/h upward velocity or 36 $m^3.m^{-2}.d^{-1}$. This rate when related to a basin of 3 m, gives a retention period of 2 h.

In practice, factors of safety are provided by selecting lower rates. For instance, an upward velocity of 0,75 m/h or a rate of 18 $m^3.m^{-2}.d^{-1}$ provides a retention period of 4 h and a velocity of approach to outlet weirs low enough to avoid carrying fine floc over in the effluent, provided that the length of the outlet weir is selected accordingly.

Allowable upflow verlocities depend on the type of floc being formed, because some flocs are heavier than others. The following are general guidelines:

Floc Type	**Upflow velocity (m/h)**
Floc from turbid waters (clay floc)	0,8 – 1,5
Floc from coloured waters	0,4 – 0,7

8.3.3 Weir loading rate

Water leaving the sedimentation tank should be collected uniformly across the width of the tank to prevent high velocities of approach and consequent lifting of the settled sludge over the weir.

Combinations of clarified water orifices ahead of the submerged weir provide efficient outlet arrangements and reduce short-circuiting. A useful, empirical parameter for the weir loading rate is 6,25 m^3/m length of weir/h.

In general, the weir trough group should be distributed from the clarified water end to about halfway toward the influent end. The low flow requires that the weirs be level so as to ensure distribution of the water over their full length. Distribution is facilitated by using 90^0 V-notches about 15 cm apart and 5 cm depth.

In stead of open launders with surface overflow, pipes or channels with subsurface openings are sometimes used. This system is not recommended, because floating material is retained in the sedimentation tank which leads to unsightliness.

WEIR LOADING RATE
Must be less than 6,25 m^3/m weir length/h

8.3.4 Inlet arrangements

Many tanks have no provision at their inlets for evenly distributing flocculated water, such as an influent channel with openings spaced across the tank. This is serious, as high entering velocities tend to destroy well-formed floc and lead to short-circuiting or turbulent flow. A transverse baffle may be installed to dissipate the energy of a concentrated inlet current, but the best procedure is to use a transverse baffle and also to install a stilling wall at the inlet end of the tank.

Sometimes a false wall having open, checkered brickwork is built into the influent end to provide good lateral distribution. The spacing and net amount of openings must be designed correctly and for one flow rate. There must be enough head loss for good distribution but not enough to cause floc break-up.

8.3.5 Tank depth

Tank depth is not a primary design parameter, and is determined by practical considerations like sludge storage space. A practical minimum depth is 2 to 3 m.

8.3.6 Desludging

For sludge to slide down an incline under water, an angle of not less than 65° with the horizontal is required for sludges resulting from turbidity (clay colloids), and 45° for sludges resulting from colour removal. Sludge hoppers or troughs with these minimum side slopes should therefore be provided at the bottom of the tank, where sludge may collect and from which it may be withdrawn. Keep in mind that for a square hopper, the angle in the corner is less than the angle in the middle of the side slope. For this reason square tanks are not favoured. If clay sludge is not withdrawn at least every second day, it will consolidate to such an extend that it will no longer slide down a 65 ° incline. Ideally, the bottom of a horizontal flow sedimentation tank should consist of hoppers, each with its own desludging pipe into which holes have been drilled. It is essential that the total area of the holes should not be more than 50 % of the pipe sectional area, so that equal discharges through each hole are ensured. See figure 4.11

8.4 FILTRATION

8.4.1 Slow sand filtration

In order to guarantee good microbiological filtration in a slow sand filter, attention should be paid to ensuring:

- favourable conditions for biological activity in the water above the sand (including the *Schmutzdecke*), *i.e.* no disinfectants.
- slow filtration rate (0,1 $m^3/m^2/h$); and
- favourable raw water quality (pretreated by sedimentation only, no chemical additives like coagulants, chlorine, etc.)

a. Filter media

To prevent penetration of suspended material, the media must be fine and must not be evenly graded. Typical specifications for sand for slow sand filters are as follows:

- effective grain size : 0,15 - 0,30 mm
- size range : 0,1 - 4 mm
- uniformity coefficient : <3

b. Summary of design criteria for slow sand filters

Design parameters for slow sand filters are given in the table below.

Design criteria for slow sand filters in rural water supply

Design criteria	Recommended level
Design period	10 to 15 years
Period of operation	24 h/d
Filtration rate in the filters	0,1 to 0,2 m/h
Filter bed area	5 to 200 m^2 per filter, minimum of two units
Depth of sand layer: Initial Minimum	0,8 to 0,9 m 0,5 to 0,6 m
Specification of sand: Effective size Uniformity coefficient	 0,15 to 0,30 mm <3
Height of underdrains including gravel layer	0,3 to 0,5 m
Maximum height of supernatant water	1 m

8.4.2 Rapid filtration

For the design of a rapid filter, three parameters need to be selected:

- grain size of the filter material
- depth of the filter bed
- rate of filtration

These parameters may often be more easily selected by comparison with existing plants treating the same or a comparable water, or by carrying out pilot scale experimental evaluations. Design equations do exist but cannot always be relied upon because of the wide difference in the quality and type of solids found in the waters to be treated.

a. Filter media

The underdrain system is usually made of perforated laterals covered with graded layers of gravel, broken stones or hard bricks chipped to the desired size. The sand to be used in the main filter bed should be graded using suitable sieves to give a uniformity coefficient of 3.0 or less. Effective grain sizes for sand filters used as prefilters or final filters should be 0,8 mm to 1,2 mm; and 1,0 mm to 1,5 mm for iron and manganese removing filters. For prefilters and final filters the sand bed thickness should be 1,0 to 1,2 m and for iron and manganese removing filters 1,5 In the event that sand cannot be obtained, similar materials may be used, such as crushed stones or bricks, crystalline calcium-carbonate, dolomite, etc. These should be graded to a size about 40 % larger than the sizes mentioned above. Before the filter is commissioned it should be back-washed for about half an hour to clean the filter material.

b. Backwashing

If possible, filtered water should always be used for back-washing. Filtered water can be stored in an elevated tank for this purpose, or the filtered water from other operating filter units of the filtration plant can be used directly(▫self-wash arrangements▫). The velocity of the upward water flow should be sufficient to produce an expansion of the filter bed. For a filter bed of sand (S.G. = 2,65) typical back-wash rates giving about 20% expansion are given in the table below.

Cleaning of the bed is achieved by backwashing with water, preceded by air scouring to loosen the trapped materials from the sand grains. In order to distribute air and water evenly, the floor of the filter normally contains a sophisticated system of distribution pipes and nozzles at a density of 35 to 40 nozzles/m². Furthermore, air blowers and backwash pumps need to be provided, as well as controls to operate the system.

Application rates are typically:

Air: 25 to 30 m/h for 2 to 3 minutes

Water: 30 to 35 m/h for 5 to 10 minutes

Recent research to improve the efficiency of backwashing of rapid sand filters has been aimed at minimizing the shear velocity (force) of backwashing to the point where the bed just starts to expand, say at 5%, and that air is used together with water for backwashing. Considerable work is also directed into the improvement of nozzle design, and selection of the correct type of nozzle for a particular application.

Backwash-rates for different filter media in rapid sand filters

BACKWASHING RATES IN m/h FOR DIFFERENT EFFECTIVE GRAIN SIZE									
Temp (^oC)	Effective grain size (mm)								
	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,1	1,2
10	12	17	22	28	34	40	47	54	62
20	14	20	26	33	40	48	56	64	73
30	16	23	30	38	47	56	65	75	86

8.4.3 Pressure filters

Filtration rates of 5 m/h are recommended, but in practice higher rates are frequently used because water can be forced through the beds by means of pumps.

This is however poor practice and should not be done. It is permissible to allow somewhat higher head losses in pressure filters than in gravity filters, and so obtain slightly longer filter runs. It is seldom economical to operate at head losses in excess of 3 to 4 m.

IMPORTANT!
Pressure filters should be sized so that filtration rates under normal operating conditions do not exceed 5 m/h

Typical sand gradings pressure filters are given below.

Typical sand gradings for pressure filters

Material	Thickness (mm)	Grain size (mm)
Sand	500	0,9 - 1,1
Gravel	100	5
Pebbles	100	10
Stone	100	25
Stone	150	50

8.4.4 Multi-media filters

These filters are intended to provide greater void space for incorporation suspended particles than is the case with rapid gravity sand filters. As described earlier, the additional void space is made available by using a material (*e.g.* anthracite) that is lighter than ordinary sand on top of the sand bed. Typical criteria for dual media filters are given below.

Typical design criteria for dual media filters

Material	Depth (m)	Effective grain size (mm)
Anthracite	0,5 - 1,0	1,6 - 2,5
Sand	0,5 - 1,0	0,4 - 1,0
Coarse sand	0,1	1,3 - 2,4 size range
Small pebbles	0,1	2,5 - 6,0 size range
Large pebbles	0,1	6 - 12 size range

8.4.5 Roughing filtration

Design criteria are given in the table on the next page. Although turbidity removal will depend on local conditions, particularly on the type of turbidity, it will generally be greater than 70% and values of 90% have been reported. The suspended solids removed from the raw water will slowly build up in the filter. After some time, this will reduce the efficiency of the filter and ultimately lead to complete clogging. Efficiency can be restored by fully opening the underdrain system, and flushing out the deposits by fast drainage and a water spray on the surface. Nevertheless, some solids may remain and make subsequent fast drainage less effective and it may therefore become necessary to clean the filter material after several years. Cleaning can be carried out by removing and washing the filter material, and then replacing it.

Design guidelines for horizontal-flow roughing filters

Parameter	Average suspended solids concentration in raw water	
	High (>150 mg/l)	Medium (100-150 mg/l)
Horizontal flow (m/h)	0,5 - 0,75	0,75 - 1,5
Depth (m)	1,0 - 1,5	1,0 - 1,5
Width (m)	1,0 - 5,0	1,0 - 5,0
Length of filter media (m):		
First compartment (15 - 25 mm)	3,0 - 5,0	3,0 - 4,0
Second compartment (8 - 15 mm)	2,0 - 4,0	2,0 - 3,0
Third compartment (4 - 8 mm)	1,0 - 3,0	1,0 - 2,0

More detailed information on the design of roughing filters can be found in the guidelines document by Wegelin (1996).

8.5 DISINFECTION

The following factors influence the efficiency of the disinfection process:

- The nature and number of the organisms to be destroyed.
- The type and concentration of the disinfectant used.
- The temperature of the water to be disinfected (the higher the temperature the more rapidly will disinfection take place).
- The time of contact (the disinfection process becomes more complete when the disinfectant remains for a longer period in contact with the water). The minimum period is 10 to 15 minutes, but should preferably be several hours because the shorter the contact time the higher the dosage of free available chlorine required to ensure effective disinfection.
- The nature of water to be disinfected (if the water contains particulate matter especially of a colloidal and organic nature, or other chemical components which react with the disinfectant used *i.e.* exerts a demand, the disinfection process will be hampered).
- The pH (acidity/alkalinity) of the water; if chlorine is used, it is considerably more

effective a pH 7 than at pH 9.

- Mixing (good mixing ensures proper dispersal of the disinfectant throughout the water, and so promotes the disinfection process).

DISINFECTION WITH CHLORINE

The minimum contact time is 10 to 15 minutes, but should preferably be much longer

Methods of chlorinating small water supplies

The most suitable chlorination equipment to use depends on each particular case. However, the following points should be considered when choosing equipment:

The person who is responsible for the equipment must be reliable and must be properly trained in how to operate and maintain the equipment correctly. The person must also make sure that there is always enough chlorine product available. This is very important because other people rely on this person to make sure that the water supply is always safe to drink.

- The chlorine product that the equipment uses must be readily available at a reasonable cost.
- The equipment must be properly designed, strong, easy to operate require little maintenance. It must be made of materials that will not be corroded (eaten away) by chlorine.
- The equipment must be suitable for the particular use, taking account of the water flow rate, whether the flow rate is constant or varies, the quantity of water used per day, whether the chlorine is dosed into a pressurised pipeline and whether electricity is available.
- The equipment must always dose enough chlorine to disinfect the water, but not too much so that it gives the water a bad taste.

It is necessary to have a large water tank after the chlorinator so that there is enough time for the chlorine to react with the water before people drink the water. The size of this tank depends on the water flow rate, but it should have at least one hour◘s storage volume.

Dosing of chlorine

A number of different ways of dosing chlorine are set out in the CSIR booklet ◘Disinfection for Small Water Supplies◘ (1990).

The following are important points that must be taken into consideration in designing and controlling chlorine dosing systems:

- uninterrupted dosing
- uniform distribution to all parts of the water mass
- adjustment of the dosage to the chlorine demand of the water being treated
- control of the dosage to produce safe water without spoiling the taste.

8.6 STABILISATION

One of the major problems experienced at the smaller treatment plants is the lack of stabilisation of the final water, and the aggressive attack on and corrosion of pipes, materials and fixtures containing these waters.

Because there appears to be a general lack of knowledge by the small treatment plant operating personnel about the need for stabilisation of water that is supplied to a community, a brief description of the effects of using an aggresive or corrosive water is given below, followed by guidelines on the use of chemical treatment to obtain a stabilised or partially stabilised water.

Aggression

Aggression is the designation given to the phenomenon whereby water attacks the cement matrix of cement and concrete lined structures. Two distinct aggressive processes have been identified:

- The water has chemical characteristics that cause dissolution of some of the minerals in the cement matrix

- The water contains sulphate species which might react chemically with some of the minerals in the cement matrix to form products which cause physical disruption of the matrix.

For chemical characteristics of aggressive waters, the terms *undersaturation, supersaturation and saturation* with respect to calcium carbonate describe chemical states in a water such that it respectively dissolves solid calcium carbonate (undersaturation), precipitates solid calcium carbonate out of solution (supersaturation) and neither precipitates nor dissolves calcium carbonate (saturation).

Corrosion

Corrosion of the metal components of pipes carrying water is the result of oxidation and reduction reactions at sites on the metal-water interface, by the formation of electro-chemical cells each with an anodic and cathodic area. At the anode metal molecules lose electrones to form metal ions which pass into solution. At the cathode the electrons (generated at the anode) pass from the metal (electron donor) to some chemical species (electron acceptor) in the water adjacent to the cathode; this is usually molecularly dissolved oxygen, if present. Depending on the circumstances, the reactions may cause continous dissolution of the metal into the water at the anode (corrosion), or may give rise to precipitation of minerals over the anode and cathode, thereby minimising the areas of the active electro-chemical sites and the rates of the reactions, and eventually stopping the corrosion completely (passivation of the surface).

Chemical treatment for stabilization

A stable water is essentially one the composition of which does not change when in contact with crystalline calcium carbonate, *i.e.* is saturated with respect to calcium carbonate, as described above. In the water treatment industry the term stabilization has, somewhat loosely, been broadened to describe the process of producing an over-saturated water in order to minimise it□s aggressive and corrosive tendencies.

Protection of concrete and fibre-cement pipes, the major consideration, is relatively easy to achieve and involves increasing calcium and/or alkalinity concentrations to values that give a small degree of super-saturation, say between 0,5 and 4 mg/l calcium carbonate precipitation potential. The computer program STASOFT, available from the Water Research Commission and in the process of being further developed, gives guidance in respect of concentrations required.

If the calcium content of the filtered water is low, the preferred treatment chemicals are slaked lime and carbon dioxide. However, the use of sodium carbonate to provide the necessary increases in alkalinity, pH and carbonic species may be considered where sufficient calcium is already present. This may be attractive for small plants where the ease of dosing a solution may outwigh any extra sodium carbonate cost - it is difficult to reliably dose small amounts of lime. The critical requirement here is that the settled or filtered water has a sufficient carbonic species content so that the final pH is not too high when enough sodium carbonate has been added for the required minimum alkalinity. There may be several ways of achieving this.

Small plants often have operational and cost constraints which influence the choice of chemicals but, given the size of the investment in distribution pipework, it should always be possible to find some combination which will provide the required result. With very small supplies or when current treatment only consists of disinfection, limestone beds, although not providing complete protection, will bring about an improvement.

Protection of steel pipes by over-saturating the water with calcium carbonate is more difficult to achieve as over-saturation is not the only requirement. High alkalinity values, at least 50 mg/l as $CaCO_3$ and probably much more, depending also on chloride and sulphate content, are needed. This approach is only considered economical and desirable in areas where the raw water has in any case nearly the right composition and where copper has not been extensively used as a plumbing material.

STABILISATION

Dose lime or sodium carbonate to the final water to obtain a chemical composition approaching the following:

Calcium carbonate precipitation potential : 4 mg/l as $CaCO_3$
Alkalinity : 50 mg/l as $CaCO_3$
Ca-hardness : 50 mg/l as $CaCO_3$

References

American Water Works Association – Partnership for Safe Water

Bond, P. Dor, G., Ruiters, G. (1999). Transformation in infrastructure policy from apartheid to democracy: mandates for change, continuities in ideology, frictions in delivery. In www.hsrcpublishers.co.za/e library/Infrastructure Mandate for Change 1994-1999/ Chapter 2.pdf

Chandler, D. (1986). Participation as process: what we can learn from Graneen Bank, Bangladesh. Oslo: NORAD, the Norwegian Ministry of Development Corporation.

Coetzee, J. (ed). (1986). Development is for people. Johannesburg: MacMillan.

Coetzee, J. & Hoffman, J.R.H. (1979) Die bedryf van watersuiweringsaanlêe. Universiteit van Pretoria Somerskool, 24 tot 26 Januarie

Department of Water Affairs and Forestry, (1997): *Water Services Act (No. 108 of 1997)*, South Africa.

Development Bank of southern Africa / Palmer Development Group (2002) Discussion Paper prepared for the World Summit on Sustainable Development, August

Division Of Water Technology, CSIR (1991) Part I: Guidelines on the Cost Effectiveness of Rural Water Supply and Sanitation Projects. WRC Report No. 231/1/93, December

Division Of Water Technology, CSIR (1991) Part II: Guidelines on the Technology for and Management of Rural Water Supply and Sanitation Projects. WRC Report No. 231/1/93, December

DWAF (2000) "Community based Organisations as Water Services Providers: Guidelines". DWAF: Pretoria.

DWAF (2002). "Draft White Paper on Water Services". DWAF: Pretoria.

DWAF (1997a). White Paper on a National Water Policy for South Africa. Pretoria.

DWAF (1997b). Framework for establishing rural water service providers[1].

DWAF (1999). Institutional and Social Development (ISD) Package for water projects.

Garn, M. (1998). Managing water as an economic good: the transition from supply-oriented to demand-responsive services. UNDP-World Bank Water and Sanitation Program. In www.wsp.org/English/focus/Conference/managing.html

Gollnitz, W.D. & Kittle, B. (1990) Operator Evaluation of Small Systems. Journal AWWA, August, pp. 40-45

Goodrich, J.A., Adams, J.Q., Lykins Jr., B.W. & Clark, R.M. (1992) Safe Drinking Water from Small Systems: Treatment Options. Journal AWWA, May, pp. 49-55

Government Gazette. National Water Act 36 of 1998. Cape Town.

Government Gazette. Water Services Act 108 of 1997. Cape Town.

IRC. (1988). Community self-improvement in water supply and sanitation. Training series, no. 5. The Hague: IRC International Water and Sanitation Centre.

Logsdon, G.S., Sorg, T.J. And Clark, R.M. (1990) Capability and Cost of Treatment Technologies for Small Systems. Journal AWWA, pp. 60-66

National Research Council Water Science and Technology Board: Safe Water from Every Tap. Improving Water Service to Small Communities (1997)

Robinson, R.B. & Collins, M.R. (1994) Survey of Research Needs for Small Water Systems. Paper presented at AWWA Annual Conference held in New York, AWWA Small System Research Committee

Sara, J., Garn, M., Katz, T. (1998). Some key messages about demand responsive approach on efficient water use in urban areas: innovative ways of finding water for cities. Proceedings of the International Symposium, Washington, USA, The World Bank.

Schultz, C.R., Okun, D.A. . (1984) Surface Water Treatment for Community Water Supplies. John Wiley & Sons, New York

Schoeman, J.J., Steyn, A. (2002) Treatment of high nitrate concentration in ground water with reverse osmosis in rural areas in South Africa. Water Institute of South Africa Biennial Conference, Durban, 2002.

Sims, D.C. (1986) Simple operational techniques for waterworks. 12th WEDC Conference: Water and Sanitation at mid-Decade. Calcutta pp. 238-242

Stephen, D.A. and Still, D.A., (2000): Performance Indicators used for a Rural Water Supply Scheme in KwaZulu-Natal, South Africa – A Case Study. Paper presented at 10th UAWS Congress, Durban, South Africa, February 2000.

Stephen, D.A., (2000): Appropriate Technology for Water Supply. Paper presented at 3rd ESAR/IWA Conference, Swaziland, October 2000.

Stephen, D.A., (2001): An Operation and Maintenance Report for Rural Water Schemes, Paper presented at 27th WEDC Conference, Lusaka, Zambia, August 2001.

Swartz, C.D. (2000) Guidelines for the Upgrading of Existing Small Water Treatment Plants, Water Research Commission Report No 738/1/00

The Mvula Trust. (1999). "Rethinking Community-Based O&M in South Africa: Lessons from the field". The Mvula Trust: Braamfontein.

The Mvula Trust. (2002). “Enhacing legal status of CBOs as WSPs”. The Mvula Trust: Braamfontein.

The Mvula Trust. (2000). “Report on Sustainability Evaluations of Rural Water Projects”. The Mvula Trust: Braamfontein.

Virginia Interactive Technology Assistance Network – Small water systems website.

WATER RESEARCH COMMISION REPORT NO. KV 58/94 (1994) Water Supply and Sanitation for Developing Communities: Research, Development, and Technology Transfer Issues. Proceedings of a Workshop held at WRC on 21 and 22 April, Compiled for the WRC by CSIR Environmental Services

WEDC: M Sohail (2002): Public Private Partnerships and the Poor. Halcrow management series

WEDC : Developing Private Sector Capacity (1994)

WEDC: Optimised Management of Water and Sanitation Services in Small Towns – Research project (October 2001)

Wegelin, M., . (1996) Surface Water Treatment by Roughing Filters. A design, Construction and Operation Manual. Swiss Centre for Development Cooperation in Technology and Management (SKAT), CH-9000 St. Gallen, Switzerland

White, A. (1981). ‘Community participation in water and sanitation. Technical Paper Series No. 17, IRC International Water and Sanitation Centre, The Hague, The Netherlands.

Whyte, A. (1986). Guidelines for planning community participation activities in water supply and sanitation projects. WHO Offset Publication no. 96. World Health Organisation, Geneva.

World Bank. (1993). Poverty reduction and the World Bank progress in Fiscal 1992. Washington DC: World Bank.

World Bank. (1998). Community Water Supply and Sanitation Conference, Water and Sanitation Program, Washington DC. May 1998. In www.worldbank.org

APPENDIX A

WORKSHOP ON THE SUSTAINABILITY OF SMALL WATER SYSTEMS IN SOUTHERN AFRICA

Birchwood Executive Hotel
JOHANNESBURG

22 – 23 August 2002

Workshop on

SUSTAINABILITY OF SMALL WATER SYSTEMS IN SOUTHERN AFRICA

22 - 23 August 2002

Birchwood Executive Hotel, Johannesburg International Airport

Water Research Commission **Department: Water Affairs and Forestry**

Department: Health **Water Institute of Southern Africa**

In an attempt to ultimately provide all households in South Africa with a supply of clean and safe drinking water, the National Government is giving the highest priority to water supply for all. To achieve this, a large number of small water treatment systems have been installed. Unfortunately, the majority of these small water systems are subject to failure prior to the end of the project lifetime, some even from the planning stages. There is, therefore, a major problem with the sustainability of existing small water systems and lack of conformity about sustainability to future (new) systems. There is a need for a structure, on a national and/or provincial level, to provide assistance and support for these small water systems. Among the important requirements, which are to ensure long-term sustainability of the systems, are technical ability, reliability, well-trained operators, community involvement, empowerment, availability of back-up systems and capacity building.

AIM OF THE WORKSHOP

The workshop aims at addressing these issues by firstly presenting the main problems and challenges facing the sustainability of small water treatment systems in Southern Africa, and to obtain inputs on how these problems can be remedied and the challenges met. The United States Environmental Protection Agency (USEPA) and the National Rural Water Association (proposed) will provide the input on how these problems are dealt with successfully in a number of countries, and will provide guidance on how their experiences can be used locally in the sub-continent.

The objective will be to adopt an approach and draw up a methodology for addressing the problem of sustainability of small water systems in Southern Africa through the formation of appropriate structures, which will be followed by a focus on individual problems that are commonly experienced. This will include an overview of treatment technologies and monitoring methods for small water systems, as well as considerations for upgrading and optimizing small systems.

WHO SHOULD ATTEND?

Planners, regulators and other officials from government, regional and local authorities; consulting engineers; NGO¤s; private institutions; water supply authorities; community representatives; manufacturers of water treatment plant and equipment; water project funding organizations.

WORKSHOP PROGRAMME
SUSTAINABILITY OF SMALL WATER SYSTEMS

DAY 1:Thursday 22 August 2002

08:30 – 09:15 Registration and Coffee

09:15 – 09:30 Introduction and Welcome *Dr Gerhard Offringa, Water Research Commission*
Mr Andrew Magadagela, DWAF

SESSION 1: SETTING THE SCENE: WHAT ARE THE ISSUES?

Chairperson: Dr Gerhard Offringa

09:30 – 10:00 Institutional arrangements for sustainable rural water schemes
Mr Bethuel Netshiswinzhe (Mvula Trust)

10:00 – 10:30 Why modern technology cannot ensure the sustainability of small water systems by itself *Mr Mike Marler (Development Bank of Southern Africa)*

10:30 – 11:00 **Morning Tea**

SESSION 2: WHAT IS NEEDED AND WHAT IS AVAILABLE?

Chairperson: Mr Charlie Crawford

11:00 – 11:30 Institutional Framework for water services provision in rural areas
Mr Abri Vermeulen (DWAF)

11:30 – 12:00 Support Services Agents: their role in achieving sustainability of rural water schemes
Mr David Stephen (Umgeni Water)

12:00 – 12:30 Sustainability of small water supplies: a recipe for success?
Mr James Rivett-Carnac (NCWSTI)

12:30 – 13:30 **Lunch**

SESSION 3: HOW IS IT DONE ELSEWHERE?

Chairpersons: Messrs Ian Pearson and Chris Swartz

13:30 – 15:15 Small Drinking Water Systems in the United States: Status and Challenges
Mr Ron Hoffer (USEPA)

Experiences with the Sustainability of Small Water Systems
Mr Andrew Tayong (Cameroon) Mr Brian Mathew (Zimbabwe) Mr Edward Bwengye (Uganda)

Experiences from South America, Africa and Asia based on David Brooks report on IDRC support *Derek Hazelton (TSE Water Services)*

15:15 – 15:30 **Afternoon tea**

SESSION 4: FORMATION OF A SOUTH AFRICAN ASSOCIATION FOR SMALL WATER SYSTEMS

Facilitator: Dr Gerhard Offringa

15:30 – 17:00 Round-table discussions, leading to the formation of appropriate structures for small water systems, with clear mission, aims and action plan. Facilitated discussion and planning session.

18:30 - **Braai Dinner Function and Networking Opportunity**

DAY 2:Friday 23 August 2002

08:00 – 08:30	**Early Morning Coffee**
SESSION 5:	**OVERVIEW OF SMALL WATER SYSTEMS AND TREATMENT TECHNOLOGIES** *Chairperson: Dr Gerhard Offringa*
08:30 – 09:00	Planning, design and operation of small water treatment systems *Mr Peter Thompson (Umgeni Water)*
09:00 – 09:30	Overview of disinfection technologies for small water systems *Mr Ian Pearson (WATSUP Development)*
09:30 – 10:00	The application of membrane technology for potable water production in developing communities *Dr Lingam Pillay (Durban Institute of Technology) and Dr Ed Jacobs (University of Stellenbosch)*
10:00 – 10:30	Technical and financial feasibility analysis in the selection of small water treatment systems *Mr Grant Mackintosh (CSIR Environmentek)*
10:30 – 11:00	**Morning Tea**
SESSION 6:	**ACTUAL NEEDS OF SMALL WATER SYSTEMS** *Chairperson: Mr Charlie Crawford*
11:00 – 11:30	Essential elements for sustainable small water treatment systems *Mr Chris Swartz (Chris Swartz Eng)*
11:30 – 12:00	The importance of community involvement and participation in water supply projects *Mr Xolile Daniel (Rural Support Services)*
12:00 – 12:30	Discussion session (with a.o. speakers from African countries)
12:45 – 13:30	**Lunch**
SESSION 7:	**UPGRADING AND OPTIMISING SMALL WATER SYSTEMS** *Chairperson: Mr Chris Swartz*
13:30 – 14:00	Demonstration of reverse osmosis technology in a rural area for the production of potable water *Dr Japie Schoeman (CSIR Environmentek)*
14:00 – 14:30	Upgrading and optimisation challenges for water treatment technologies *Mr Godfrey Mwiinga (Peninsula Technikon)*
14:30 – 14:55	General discussion on the way forward towards ensuring sustainability of small water systems
14:55 – 15:00	**Closure**

REQUIREMENTS FOR A SMALL WATER SYSTEMS ASSOCIATION

OBJECTIVES

Should it be advisory or implementational or lobbying?
Web page with e-mail capabilities for communication between members
Outcomes focussed
Representatives of users
Should facilitate rather than execute
Must be financially independent
Should have strategies for both water supply and treatment
Incorporate rural hygiene
Should put the needs of rural and urban poor first
Should address technical and social issues

ORGANISATION TYPE, ASSOCIATION & MEMBERSHIP

Affiliated to WISA
Should include all spheres of government and departments
Should be linked to and be acceptable to municipalities
Should be independent from WISA
Membership to include SWS operators
Should have wide municipal and community membership
Start with strong regional (provincial) basis

FUNCTIONS	COMMENTS
Establish and maintain a database of small water systems	requires continuous contact with the sector
Monitor and evaluate small water systems	similar to auditing, but more time consuming
Provide management assistance	requires program to implement action plans
Provide technical assistance	requires program to implement action plans
Develop guidelines for Small Water Systems	expert inputs required
Undertake training and capacity building	This requires special resources
Undertake auditing	Financial, technical, social, etc
Undertake certification of SWS and operators	links to auditing and training
Drive research projects	need a seat on WRC project steering committees
Identify range of small water service users	identify various target markets and appropriate channels
Identify requirements of small water service users	identify various target markets and appropriate channels
Establish a certification system for SWS	Do this first so that certification system can be implemented
Monitor and regulate norms and standards in the sector	requires time to evaluate 7 make recommendations
Identify research needs	outcome of monitoring & evaluation
Provide advisory service	requires call centre + knowledgable advisors in expected fields
Disseminiate information	identify various target markets and appropriate channels
Maintain links with education sector	requires coordination/liaison committee at right level
Establish links with education sector	requires meeting with stake holders
Liaise with central and local government	requires meeting with stake holders
Lobby/Influence central and local government	requires meeting with stake holders
Advise government on appropriate regulations	requires meeting with stake holders

APPENDIX B

CHECKLIST FOR DESIGN OF WATER TREATMENT PLANTS

CHECKLIST FOR DESIGN OF WATER-TREATMENT PLANTS

The purpose of this list is to assemble in an orderly manner the various items important in a water treatment plant designed to treat surface water. This permits utilizing the list as means of ensuring that essential points have not been overlooked, since in a preliminary or final design.

In general, the checklist is limited to the more commonly-used processes. An attempt has been made to separate the items into functional and operational considerations, as far as these apply. Items such as intakes and pumping stations, not included in this text, are covered for completeness.

PLANT AND BUILDING DATA

Plant site:
- Distance from community ______
- Access roads ______
- Rail siding ______
- Ground elevation ______
- Protection against flooding ______
- Size of property ______
- Fencing ______
- Landscaping ______
- Outdoor lighting ______
- Provision for future expansion ______

Building:
- Type of structure ______
- Size ______
- Exterior finish ______

Chemical storage:
- Lime ______
- Alum ______
- Iron ______
- Salt ______
- Other ______
- Unloading and handling methods ______

Facilities:
- Drinking water ______
- Toilet ______

- Locker room ____________________
- Washroom and shower ____________________
- Lunchroom ____________________
- Toolroom ____________________
- Shop ____________________

Laboratory:

Bacteriological:

- Refrigerator ____________________
- Incubator____________________
- Oven ____________________
- Microscope ____________________
- Balance ____________________
- Still ____________________

Chemical:

- Hood ____________________
- pH meter ____________________
- Colorimeter ____________________
- Residual chlorine ____________________
- Reagents ____________________
- Jar testing equipment ____________________

General:

- Glassware ____________________
- Sinks ____________________
- Hot water ____________________
- Vacuum ____________________
- Electricity ____________________
- Lighting ____________________
- Gas ____________________
- Air ____________________
- Safety shower ____________________
- Fir protection ____________________

Material storage:

- Existing ____________________
- Needed ____________________
- Provided ____________________
- How ____________________

WATER SUPPLY

Source:

- Expected yield of source: average ________________ m^3/day, safe yield in dry season _______________ m^3/day.

Population Served:

- Present ____
- Design ____

Water use:

- Present_________________ m^3/day
- Design__________________m^3/day
- Average ________________ m^3/day
- Maximum month__________ m^3/day
- Maximum day ____________m^3/day

Stream Flow:

- Average ________________ m^3/day
- Maximum _______________ m^3/day
- Minimum ________________m^3/day
- High water level ___________m
- Low water level ____________m

Reservoir:

- Area ____
- Depth ____
- High water level __________m
- Low water level ___________m

Range of Raw Water Quality:

- MPN ____
- BOD ____
- pH ____
- Total solids ____
- Turbidity ____
- Temperature ____
- Colour ____
- Taste and odor ____
- Alkalinity ____
- Hardness ____
- Algae ____

RAW WATER TRANSMISSION

Supply Line:

- Number____________________
- Size ____________________
- Material ____________________
- Length ____________________
- Capacity ______________ m³/day
- C= ____________________
- Gravity ____________________
- Pumping ____________________
- Pressure at plant ____________________
- Head pumped against ____________________
- Velocity in line for design flow ____________________
- Corrosion protection ____________________
- Interconnections ____________________
- Air relief valves ____________________
- Drains at low points ____________________
- Isolation of sections for repairs ____________________
- Access to right of way ____________________
- Is line metered? ____________________

Pumping Stations:

- Location ____________________
- Number of pumps ____________________
- Capacity of pumps ____________________
- Size of suction lines ____________________
- Size of discharge line ____________________
- Type of pumps____________________
- Efficiency ____________________
- Motive power ____________________
- Power requirements ____________________
- Flood protection ____________________

COAGULATION AND SEDIMENTATION

Chemicals:

- Kinds used ____________________
- Design dosages __________________mg/l

Rapid Mix:

- Number of units ____________________
- Type of mixer ____________________

- Volume ________________m^3
- Retention ______________seconds
- Point of chemical feed ____

Flocculator:

- Number of tanks ____
- Tank length __________________m
- Width ________________________m
- Depth ________________________m
- Retention ____________________min
- Type of mixer ____

Ports or Openings:

- Rapid mix to flocculator ____________m^2
- Velocity _________________________m/s
- Flocculator to sedimentation ________m^2
- Velocity _________________________m/s
- Weir or baffle adjustment possible ____
- Can tanks be drained? ____
- Are walkways and guard rails provided? ______________________________________

Feeders:

Dry:

- Number ____
- Capacity ________________________kg/hr

Liquid:

- Number ____
- Capacity _______________________kg/hr

Settling Tanks:

- Number ____
- Length ________________________m
- Width _________________________m
- Depth _________________________m
- Diameter _______________________m
- Retention time __________________hr
- Overflow rate ___________________m/day
- Flow line elevation _______________m
- Type of weirs (or launders)____
- Effluent pipe to ____
- Can tanks be drained? ____
- Where to? ____
- Are walkways and guard rails provided? ______________________________________

FILTERS

Units:

- Size ____
- Number of units ____
- Area ______________m²
- Rate of filtration __________m/hr
- Are walkways and guard rails provided? __________________________

Filter Media:

Fine medium:

- Material ____
- Effective size ___________mm
- Uniformity coefficient _____________________________________
- Depth ______________m

Coarse medium:

- Material ____
- Sizes ____

Undrainage:

- Type ____
- Range of head losses _____________________________________

Backwash:

- Rate _____________m/hr
- Water required _________m³/day
- Where from ____
- Lip elevation above filter surface _____________________________
- Surface wash? ____

Pump:

- Size ____
- Capacity ____________ m³/day

Washwater Tank:

- Capacity ____
- Elevation above filter _____m
- Size of outlet pipe _______________________________________
- Method of filling _______________________________________

Filter Controls:
- Type ______________________________
- Location ______________________________
- Sewer to where ______________________________
- Cross-connection possible? ______________________________

CHLORINATION

Chlorinators:
- Number ______________________________
- Type ______________________________
- Capacity ________________kg/day
- Where located ______________________________
- Point of chlorine application ______________________________
- Contact period provided ____________min
- Are chlorinators in separate building? ______________________________
- Is chlorine room isolated? ______________________________
- Scales ______________________________

Chlorine containers:
- Size ______________________________
- Storage for containers ______________________________
- Equipment for handling containers ______________________________

Safety precautions:
- Equipment provided ______________________________
- Adequate exhaust system ______________________________
- Louvers in door ______________________________
- Inside fixed window ______________________________
- Door opening outward ______________________________
- Light switch near door ______________________________

PLANT STORAGE AND PUMPING

Storage:

Clear well:
- Location ______________________________
- Capacity ______________m^3

Other low-level storage plant:
- Type ______________________________
- Capacity _____________m^3

Pumping:

- Where to? ______________________________
- Number of pumps ______________________________
- Sizes ______________________________
- Type ______________________________
- Drive ______________________________
- Controls ______________________________
- Standby power ______________________________
- Standby pump provided ______________________________
- Capacity ______________________________
- Power source ______________________________
- Disconnect switch for each pump? ______________________________

APPENDIX C

LIST OF SOUTH AFRICAN GUIDELINE DOCUMENTS AND PUBLICATIONS ON DRINKING WATER TREATMENT

WRC REPORTS:

WRC Report No. TT 53/92 : STASOFT III - **Computer Program for Chemical Conditioning of Low and Medium Salinity Waters**

WRC Report No. 571/1/94 : **Overview of Institutional and Financial Arrangements in Water Supply and Sanitation (with a focus on the urban areas in South Africa)**

WRC Report No. TT 68/95 : **Water and Sanitation Handbook for Community Leaders (Urban and Peri-Urban)**

WRC Report No. 449/1/95 : **Non-Conventional Disinfection Technologies for Small Water Systems**

WRC Report No. 450/1/97 : **Package Water Treatment Plant Selection**

WRC Report No. 354/1/97 : **Evaluation of Direct Series Filtration for the Treatment of South African Surface Waters**

WRC Report No. 649/1/98 : **An Assessment of Common Problems Associated with Drinking Water Disinfection in the Developing Areas**

WRC (1998) : **Water Purification Works Design, FA van Duuren (Editor)**

CSIR REPORTS:

National Institute for Water Research, CSIR : **Manual for the Operation of Small Water Works.** (1967)

National Institute for Water Research, CSIR : **Simple Control Tests for Operators of Small Wastewater Treatment Plants**. (1980)

National Institute for Water Research, CSIR : **Manual on Water Purification**

Technology. CSIR Technical Guide K73. (1985)

Division of Water Technology, CSIR : **Guidelines on Hydraulic Flocculation.** October (1990)

Division of Water Technology, CSIR : **Disinfection for Small Water Supplies**

Division of Water Technology, CSIR : **Education and Training for Community-Based Management of Water Supply Services**. (1992)