South African National Water
Quality Monitoring
Programmes Series

National Microbial Monitoring Programme for Surface Water

Implementation Manual

Department of Water Affairs and Forestry

Second Edition
2002

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Monitoring Programme Series

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for

Surface Water

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EXECUTIVE SUMMARY

South Africa does not currently have a central source of information for assessing the potential health risks associated with natural waters contaminated with faecal pollution. With numerous dense settlements (both formal and informal), increasing urbanisation and other factors, South Africa's water resources are coming under increasing threat from faecal contamination.

The Department of Water Affairs and Forestry (DWAF) is responsible (in terms of the National Water Act) for the operation and maintenance of national water quality monitoring and assessment programmes.

Because microbes behave in a non-conservative manner in water, a national grid of monitoring sites (like that used for monitoring chemical water quality variables) is both undesirable and impractical. This document is the culmination of five years of work towards creating a National Microbial Monitoring Programme (NMMP) that overcomes this problem. This programme has the following objectives:

NMMP Objectives

i To provide information on the status and trends of the extent of faecal pollution, in terms of the microbial quality of surface water resources in priority areas.

i To provide information to help assess the potential health risk to humans associated with the possible use of faecally polluted water resources.

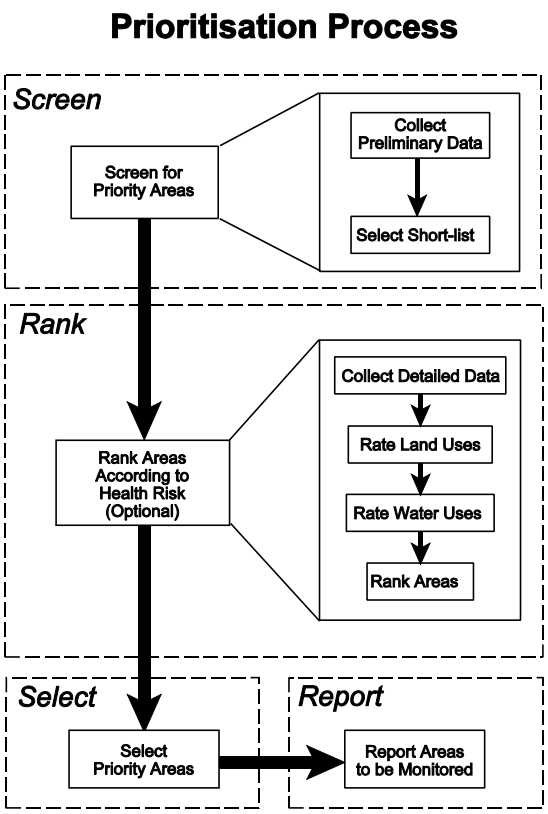
It is emphasised that these objectives are primarily national, not regional. That is, it is not the intention that the individual causes and impacts of faecal pollution are identified by the programme.

This document aims to facilitate the successful implementation of the programme nationally. Although the primary responsibility for implementation rests with DWAF, many organisations and people will necessarily be involved. They range from the sampler to the Minister of Water Affairs.

A glossary of terms, a list of references and a reproduction of Chapter 14 of the National Water Act also enable ready access to some of the more technical aspects.

Prioritisation Process

Given (a) the distinct non-conservative behaviour of microbes in water and (b) the essential need to use resources as cost-effectively as possible, a process has been developed that ranks priority areas. This is based on the identification of problematic land uses and water uses sensitive to microbial quality. The process is a desk study only, not involving actual monitoring.



Land uses that can result in significant faecal pollution include settlements that have no sanitation infrastructure or one that is inadequate. Intensive livestock farming without sound waste handling practices is also problematic. Settlements that result in high runoff after rainfall events (and hence contamination of surface waters) are also considered.

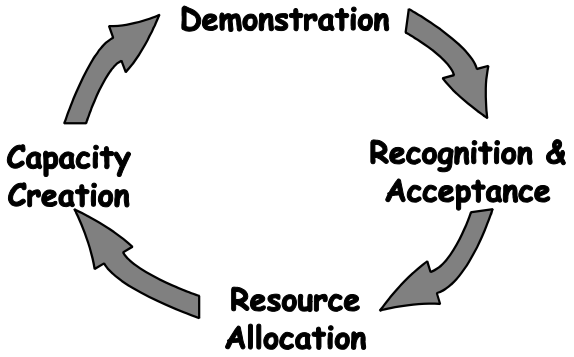
There is only a health risk when people are actually exposed to faecally contaminated water. Particularly sensitive water uses include drinking of untreated or partially treated surface waters. Full or partial external contact with water (such as from swimming or washing) also exposes people to significant health risk. The irrigation of crops that are ultimately eaten raw (like lettuce and tomatoes) is likewise a serious problem.

The prioritisation process involves an initial screening phase based on relatively simple criteria. The resulting short-list will often be sufficient for managers to choose from when initialising microbial monitoring. If a more objective (and quantitative) process is necessary then the next ranking and selection phases can be carried out. The overall process will facilitate a phased implementation of the programme. The areas with highest risk are earmarked for individual monitoring programmes.

National Implementation Process

Creating national coordination is important in a nationwide implementation process. A single person, ideally within DWAF, should be assigned this role. This person should facilitate in whatever way possible both national and regional implementation.

The general implementation model is based on the "Demonstration-for-Resource Allocation Spiral" approach used successfully by the River Health Programme (a national biomonitoring programme). This involves choosing a few priority areas and implementing the NMMP full scale in those areas. The results of this exercise can then be presented to other potential concerned parties in order to demonstrate success, create buy-in and hence willing allocation of resources for further implementation.



The "Demonstration-for-Resource Allocation Spiral " model of the River Health Programme [Roux, 1997].

An annual national assessment report will also be produced that summarises the situation in all areas being monitored. This report presents the information in a way that communicates well with the water resource managers, for example by using colour maps. It will indicate the potential health risk of the four most sensitive water uses at all sampling sites. It will also present an overall potential health risk index for the year (which can be compared with equivalent values for previous years).

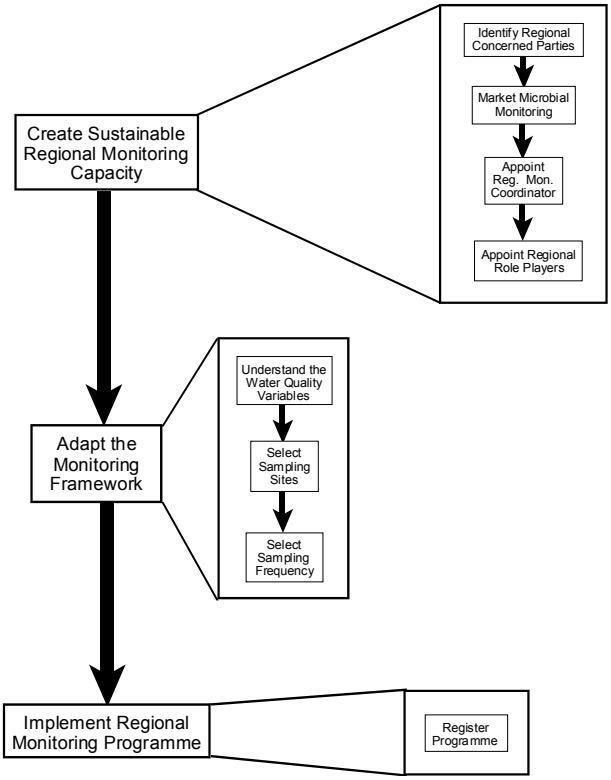
Regional Implementation Process

Once an area is identified as a priority area by the prioritisation process, a regional monitoring programme must be established that meets the national objectives of the NMMP. Although the primary responsibility rests with DWAF, the regional concerned parties that can benefit from a local monitoring programme must be identified and approached. These include, among others, the Department of Health, catchment management agencies, water user associations, major industry and so on. Ideally, their involvement should be a 'win-win' situation.

To achieve this, it will be necessary to 'market' microbial monitoring. A wide range of tools is presented in this document for doing this. These include various diagrammatic representations of issues, processes and how information flows from sampler to Minister. Tables are presented that summarise information, including resources required.

A regional monitoring coordinator must be appointed. That person must identify and appoint the various other regional role players and decide where sampling should take place. Sampling frequency is proposed to be weekly (based on a statistical analysis of the results of the pilot studies) though this can be changed if justified. Once the regional monitoring programme is formally registered with DWAF, sampling can begin.

Microbial Monitoring Programme
Regional Implementation Process



Monitoring Roles

Monitoring programmes involve the collection of data and converting this to useful information. The overall structure of data and information flow has been carefully considered in this document (and is presented diagrammatically). Individual roles have also been identified and described in detail. This structure will facilitate a clear definition of these roles and buy-in to the process by ensuring each individual role player understands where he or she fits into the overall picture.

The following diagram illustrates the roles and information flow. The following table identifies typical role players for each role.

National Microbial Monitoring Programme Roles and Information Flow

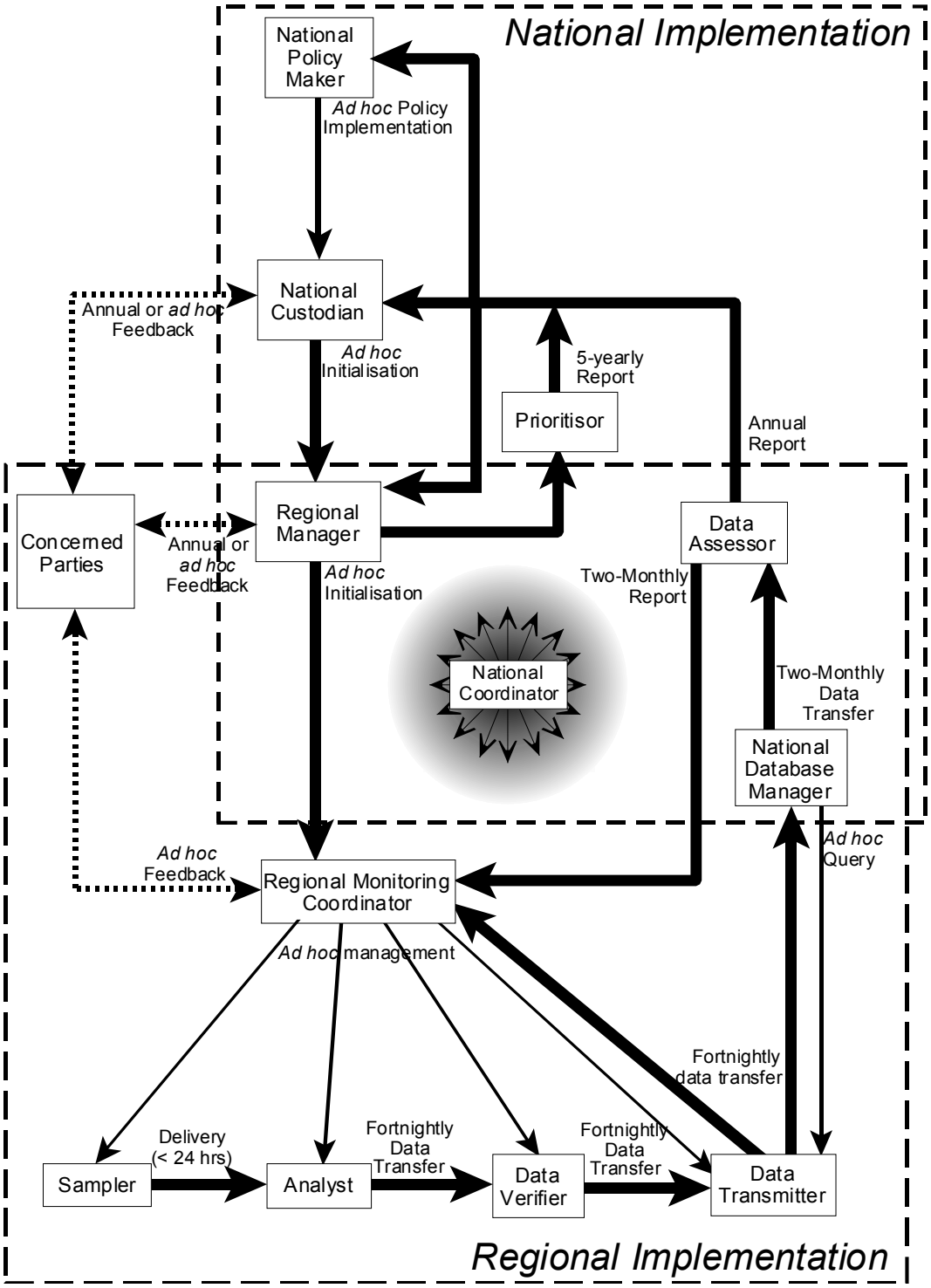


Table 1. Summary of roles and typical role players.

Role	Typical Role Players
National Policy Maker	Minister of Water Affairs and Forestry, Minister of Health.
Concerned Parties	Any person or organisation with an interest in microbial water quality or that might be affected by deteriorating microbial water quality.
National Coordinator	A single person from the Department of Water Affairs and Forestry (DWAF).
Prioritisor	The Department of Water Affairs and Forestry (DWAF) and/or appointee. (Possibly the National Coordinator.)
National Custodian	Department of Water Affairs and Forestry (DWAF) Directors or Chief Directors.
Regional Manager	Water Quality Managers of Department of Water Affairs and Forestry (DWAF) Regional Offices or appointed representative of the relevant catchment management agency. (Possibly the Regional Monitoring Coordinator.)
Regional Monitoring Coordinator	Typically a representative of the relevant catchment management agency or a DWAF Regional Office.
Data Assessor	Microbiologist with experience in the behaviour of faecal coliforms in environmental waters. Typically in the Department of Water Affairs and Forestry (DWAF).
National Database Manager	The Department of Water Affairs and Forestry (DWAF).
Data Transmitter	Laboratory.
Data Verifier	Laboratory microbiologist with experience in the behaviour of faecal coliforms in environmental waters.
Analyst	Laboratory.
Sampler	Laboratory, DOH environmental health officers, water board or local authority.

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Mr U Looser	Department of Water Affairs and Forestry
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LIST OF ABBREVIATIONS

DEAT	Department of Environmental Affairs and Tourism
DOH	Department of Health
DWAF	Department of Water Affairs and Forestry
I&AP	Interested and Affected Party
IWQS	Institute for Water Quality Studies
SoE	State of the Environment
WHO	World Health Organisation
WRC	Water Research Commission

GLOSSARY

Aquaculture. The production of protein for human consumption in an aquatic environment under controlled or semi-controlled conditions. It includes the production of fish, shell-fish, crustaceans and plants.

Assessment Endpoint. An explicit expression of the environmental value that bears directly on the management of resources (for example, "human health risk"). The assessment endpoint is based directly on values of the measurement endpoint (by adding value to it).

Autoclave. An apparatus for sterilising objects by the use of steam under pressure.

Catchment. The area that receives the rain that flows into a particular watercourse.

Catchment Management Agency. A statutory body established by the Minister of Water Affairs to delegate water resource management to a local level and to involve local communities. They may be established for specific geographical areas, after public consultation, on the initiative of the community and stakeholders concerned.

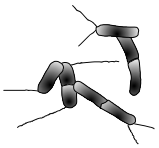
***Coliforms*:** Bacteria that are members of the *Enterobacteriaceae* family with the ability to ferment lactose. These bacteria make up about 10% of the intestinal microorganisms of human and other animals.

Diffuse-source Pollution. Pollution that comes from a wide area, such as fertilisers draining off farmlands or pollutants in the runoff from urban areas.

Disinfection. The killing, inhibition, or removal of microorganisms that may cause disease.

Ecosystem. The total community of living organisms and their associated physical and chemical environment.

Faecal Coliforms. Thermotolerant (max 44.5EC) coliforms derived from the intestines of warm-blooded animals, including man. For a water to be considered potable, faecal coliforms must not be present.



E. coli

Filtration. The process whereby suspended solid particles are removed by passing a liquid through a porous material (the filter) so that the liquid portion passes through the filter and the solid particles are retained by the filter.

Floc. Small masses formed in water through coagulation, agglomeration of fine suspended particles.

Flocculation. The bringing together of fine particles to form flocs.

Groundwater. Water found underground, typically supplying wells, boreholes, and springs.

Infrastructure. The basic structure of an organisation, system, etc.

Measurement Endpoint. The attribute of the water resource actually measured (for example, faecal coliforms).

Microbes. Microscopic organisms, especially disease-causing organisms.

Microbiology. The study of organisms that are usually too small to be seen with the naked eye. Special techniques are required to isolate and grow them.

Microorganisms. Microscopic biological organisms such as bacteria, viruses, protozoa, etc. some of which cause diseases.

Morbidity Rate. The number of individuals who become ill as a result of a particular disease within a susceptible population during a specific time period.

***Nutrient*.** Substance that supports growth and reproduction.

***Pathogen*.** An organism that causes disease. Derived from the Greek *Patho* (meaning disease) and *gen* (meaning giving rise to).

***Potable*.** Drinkable.

***Point-source Pollution*.** Pollution that comes from a single source, such as a pipe, that is usually easily quantifiable.

Prioritisation. The process of establishing an order of things based on the degree to which they require special attention.

***Runoff*.** Water that does not filter into soil but flows over the surface and into natural surface waters.

***Sanitation*.** Practical measures for preserving public health. Typically associated with the reduction of the microbial population to levels judged safe by public health standards.

Sanitation Services. The collection, removal, disposal or purification of human excreta, domestic waste-water, sewage and effluent resulting from the use of water for commercial purposes.

***Sedimentation*.** The process by which suspended solids settle downwards.

***Settlement*.** A permanently populated area of high population density.

***Site-specific*.** Conditions that are unique or specific to a certain locality.

***Sterilisation*.** The process by which all living cells, viable spores, viruses, viroids are either destroyed or removed from an object or habitat.

***Surface Water*.** Water above the ground surface in lakes, dams and rivers.

***Suspended Solids*.** Inorganic or organic matter, such as clay, minerals, decay products and living organisms, that remains in suspension in water. In surface waters it is usually associated with erosion or runoff after rainfall events.

***Thermotolerant*.** Tolerant of high temperatures.

***Turbidity*.** A measure of the light-scattering ability of water. It indicates the concentration of suspended solids in the water.

***Urbanisation*.** The migration of an increasing proportion of rural people to cities.

***UV Radiation*.** Ultraviolet radiation of shorter wavelength than visible light (about 10 to 400 nm) and higher energy.

***Virus*.** An infectious agent having a simple acellular organisation with a protein coat and a single type of nucleic acid, lacking independent metabolism, and reproducing only within living host cells.

Water Board. An organ of state established or regarded as having been established in terms of the Water Services Act (No. 108 of 1997) to perform, as its primary activity, a public function.

***Waterborne Disease*.** A disease resulting from infection from water that contains pathogens. Many important human pathogens are maintained in association with living organisms other than humans, including many wild animals and birds. Some of these bacterial and protozoan pathogens can survive in water.

***Watercourse*.** A river or spring; a natural channel in which water flows regularly or intermittently; a wetland, lake or dam into which, or from which, water flows.

Water Management Area. An area established as a management unit in the national water resource strategy within which a catchment management agency will conduct the protection, use, development, conservation, management and control of water resources.

Water Management Institution. A catchment management agency, a water user association, a body responsible for international water management or any person who fulfils the functions of a water management institution in terms of the National Water Act (Act No. 36 of 1998).

Water Resource. Includes a watercourse, surface water, estuary or aquifer.

Water Services Institution. A water services authority, a water services provider, a water board

or a water services committee.

Water User Association. Cooperative associations of individual water users who wish to undertake water-related activities for their mutual benefit. Their primary purpose is *not* water management.

Wetland. Land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil.

1. BACKGROUND

This chapter should be read by anyone wanting a brief background to the events leading up to the monitoring design in this manual or an overview of the manual.

CHAPTER CONTENTS

1.1 THE NEED FOR MICROBIAL MONITORING

There have been rapid and extensive demographic changes in South Africa in recent decades. Many areas lack appropriate sanitation facilities. This has resulted in South Africa's water resources coming under increasing threat from faecal pollution. Using such contaminated water for drinking, recreation or irrigation poses serious health risks. In particular, contracting such waterborne diseases as gastroenteritis, salmonellosis, dysentery, cholera, typhoid fever and hepatitis, becomes increasingly likely.

Increasing faecal pollution ...

Most waterborne diseases are caused by pathogens associated with faecal contamination of water. However, pathogens excreted into water from healthy skin or hair, wounds, urine, mucus, saliva, etc. can also be transmitted, particularly by recreational exposure. Some waterborne pathogens are excreted by healthy carriers (*i.e.* infected persons, in many cases children, who show no clinical symptoms of disease) [DWAF, 1996a].

...increases health risks.

The risk of infection is greatest when the contaminated water is used for drinking purposes. The guidelines for faecal coliforms (which are used as indicator organisms) note that less than 10 counts per 100 mℝ may cause infections in some sensitive groups. Up to 100 counts per 100 mℝ will commonly cause infections, even after a single consumption [DWAF, DOH and WRC, 1998]. It is clear that even very low concentrations can be significantly problematic.

Cholera is a waterborne disease that was confined to Asia (mainly India) until the early 1800s. Then epidemics occurred at intervals throughout Europe and America during the 19th and early 20th centuries. Outbreaks continue to occur every year in different parts of the world. In particular, they have occurred in countries to the north of South Africa, particularly in Mozambique, and a number of imported cases are identified each summer in South Africa [Klugman, 1999].

Cholera is caused by a bacterium, *Vibrio cholerae*, that invades the intestines causing acute diarrhoea. If present in a surface water, it will be due to faecal pollution.

By using the presence of faecal coliforms as an indicator of recent faecal pollution, the National Microbial Monitoring Programme not only helps prevent disease associated with faecal coliforms but will also help prevent outbreaks of cholera.

DWAF must ensure water is fit for use ...

The Department of Water Affairs and Forestry (DWAF) is the primary custodian of South Africa's water resources. As such it must ensure that waters remain fit for use on a sustainable basis. A number of national monitoring programmes are already in place. The chemical water quality monitoring programme has been operational for many years. A national biomonitoring programme is currently being implemented. However, given the serious human health risks associated with surface waters exposed to faecal pollution, there is a pressing need to implement a national programme that focuses on microbial water quality.

Water resource managers and various other role players involved in maintaining the quality of South Africa's water resources will be the main users of information from a national microbial monitoring programme.

... and is bound by the National Water Act to establish monitoring systems.

There are basic statutory requirements for establishing monitoring systems in South Africa. Monitoring, recording, assessing and disseminating information on water resources are critically important for achieving the objectives of the National Water Act (Act No 36 of 1998). The Act provides for establishing national monitoring systems and national information systems on water resources. It also deals with accessibility of this information.

See National Water Act Chapter 14 Section 137.

This document describes a national monitoring programme.

This document describes an implementation strategy for a national programme. The objective of the programme is to provide general information on the status and trends in the microbial water quality in priority areas, as well as to give an indication of the potential health risk associated with the use of surface water in those areas. The data could be used to give some general indication of the effectiveness of measures taken to protect water resources against faecal pollution. Ground water resources are not included in the present design, nor are marine waters because they are specialist fields best dealt with separately.

1.2 OBJECTIVES THAT SATISFY THE NEEDS

In order to satisfy the various national needs, the following are adopted as the specific objectives of the national microbial monitoring programme.

NMMP Objectives

i To provide information on the status and trends of the extent of faecal pollution, in terms of the microbial quality of surface water resources in priority areas.

i To provide information to help assess the potential health risk to humans associated with the possible use of faecally polluted water resources.

The objective is not to quantify the effect of individual activities on the microbiological water quality, nor to determine the potential health risk to specific water users at specific points of abstraction or contact. The latter would require a local monitoring programme which would need to reconsider such design aspects as sampling frequency, sampling variables, and selection of sampling sites.

1.3 FACTORS DICTATING PROGRAMME DESIGN

Microbial water quality and the potential health risk associated with faecal pollution are not geographically evenly distributed. Combined with the non-conservative nature of microbial pollution, this makes an evenly distributed grid of monitoring sites undesirable and impractical.

Therefore, the programme focuses on priority areas only. These areas are identified by the following general criteria:

- Land-uses that are typically associated with faecal pollution of water resources;
- The number of people likely to be impacted by exposure to water of poor microbial quality as a consequence of the way they use the water.

There are a number of problematic land uses and various ways in which people can be exposed to faecally contaminated water. These are summarised diagrammatically in a formal systems model (a set of interacting issues) in **Figures 1.1** and **1.2**.

1.4 THE PROGRAMME THUS FAR

Many organisations in South Africa have been involved in the monitoring of faecal pollution for many years. However, there had been no previous attempt to collate information in a coordinated and focused way to provide a nationwide picture of faecal pollution. The design of a National Microbial Monitoring Programme was initiated in 1994. This was driven by DWAF since such projects form part of its official function. The underlying research upon which the programme is based is described by du Preez *et al.* (1999). Further research reports that describe the basis of various aspects of the design are also available [du Preez *et al.* (2001), du Preez *et al.* (2002)].

The following table summarises some of the events henceforth.

Table 1.1. Summary of events in the design of the National Microbial Monitoring Programme.

Date	Event	Comments
1994	IWQS (DWAF) starts project to design a NMMP	
1995	Monitoring system product specification expectations established	Input from various water resource managers
Apr 1996	Report: *Design Framework for a National Microbiological Monitoring Programme to Assess the Faecal Pollution of SA Surface Water Resources*	By: Environmentek, CSIR Purpose: Draft specification of conceptual design framework for NMMP
Jul 1996	Report: *A National Microbiological Monitoring Programme to Assess Faecal Pollution of South African Water Resources: Conceptual Monitoring Programme Design*	By: IWQS (DWAF) and Environmentek, CSIR. Detailed design approach
Jan 1997	WRC project starts. Objectives: Select high risk areas, initiate pilot scale monitoring, recommend procedures	Joint IWQS (DWAF) and CSIR venture (with Rand Water and Umgeni Water doing the pilot scale monitoring)
Oct 1997	NMMP News No. 1	First newsletter, IWQS (DWAF)
Mar 1998	Article in CSIR's "Envisage" newsletter	M du Preez, 1998a
Apr 1998	Article in *Engineering News*: Plan to Monitor Water Quality	M du Preez,1998b
May 1998	WISA Conference presentation: *National Microbiological Water Quality Monitoring Programme for South Africa*	Kühn *et al.*, 1998
Jun 1998	IAWQ Conference presentation: *A Method for the Prioritisation of Areas Experiencing Microbial Pollution of Surface Water.*	Venter *et al.*, 1998
Jun 1999	NMMP Implementation Manual produced including recommended procedures.	K Murray 2000
May 2000	WISA Conference presentation: *Identification of Areas with Faecally Polluted Surface Water Sources in South Africa.*	Kühn *et al.*, 2000
Aug 2001	Progress report: A pilot study to demonstrate implementation of the national microbial monitoring programme	du Preez *et al.*, 2001
Sep 2001	River Basin Management Conference presentation, Wales: *Implementation of a catchment based national microbial water quality monitoring programme in prioritised high health risk areas.*	van Niekerk *et al.*, 2001
Jan 2002	Research report: A pilot study to demonstrate implementation of the national microbial monitoring programme	du Preez *et al.*, 2002
Feb 2002	Updated NMMP Implementation Manual	K Murray *et al.*, 2002

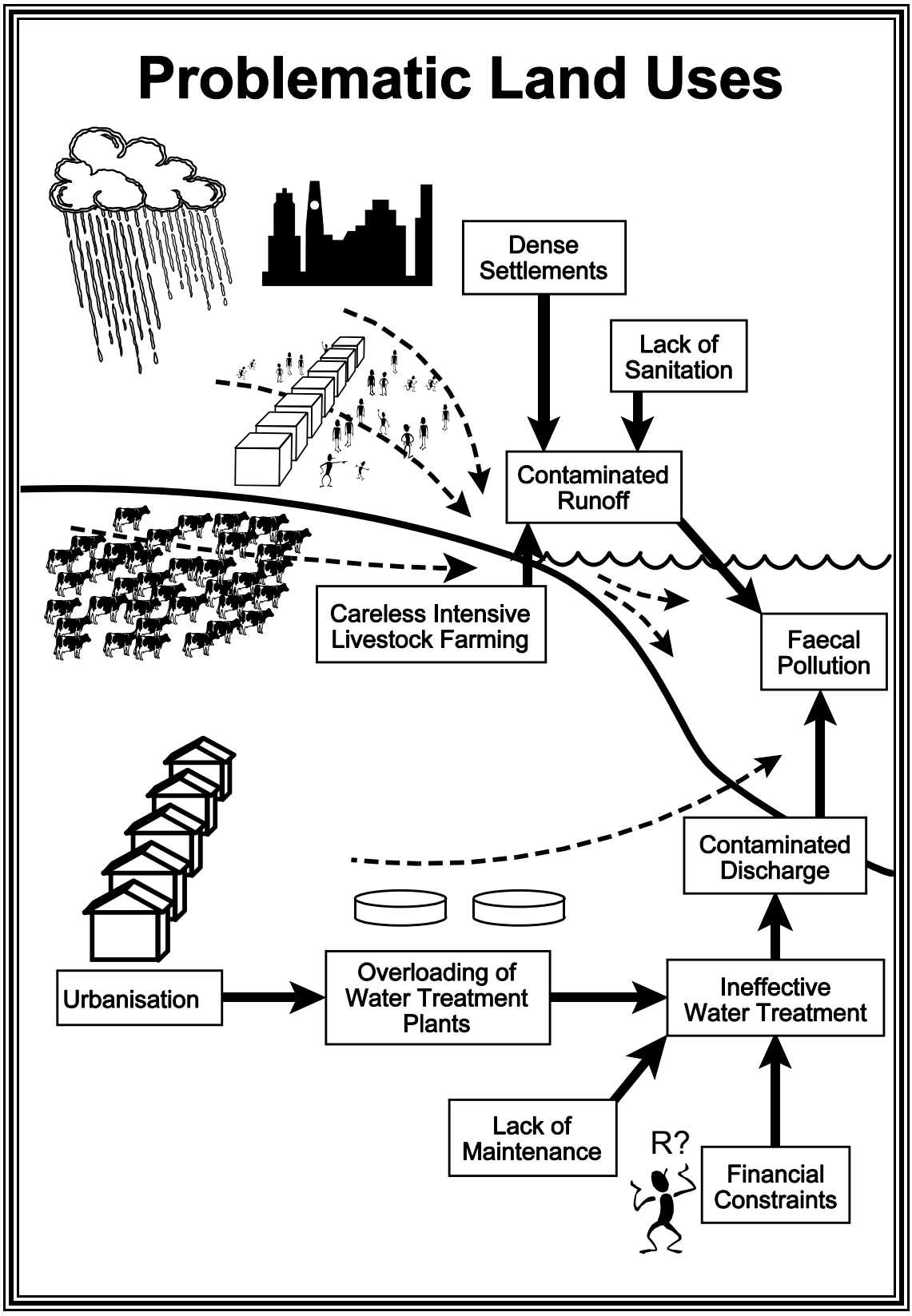


Figure 1.1. Schematic illustration of problematic land uses.

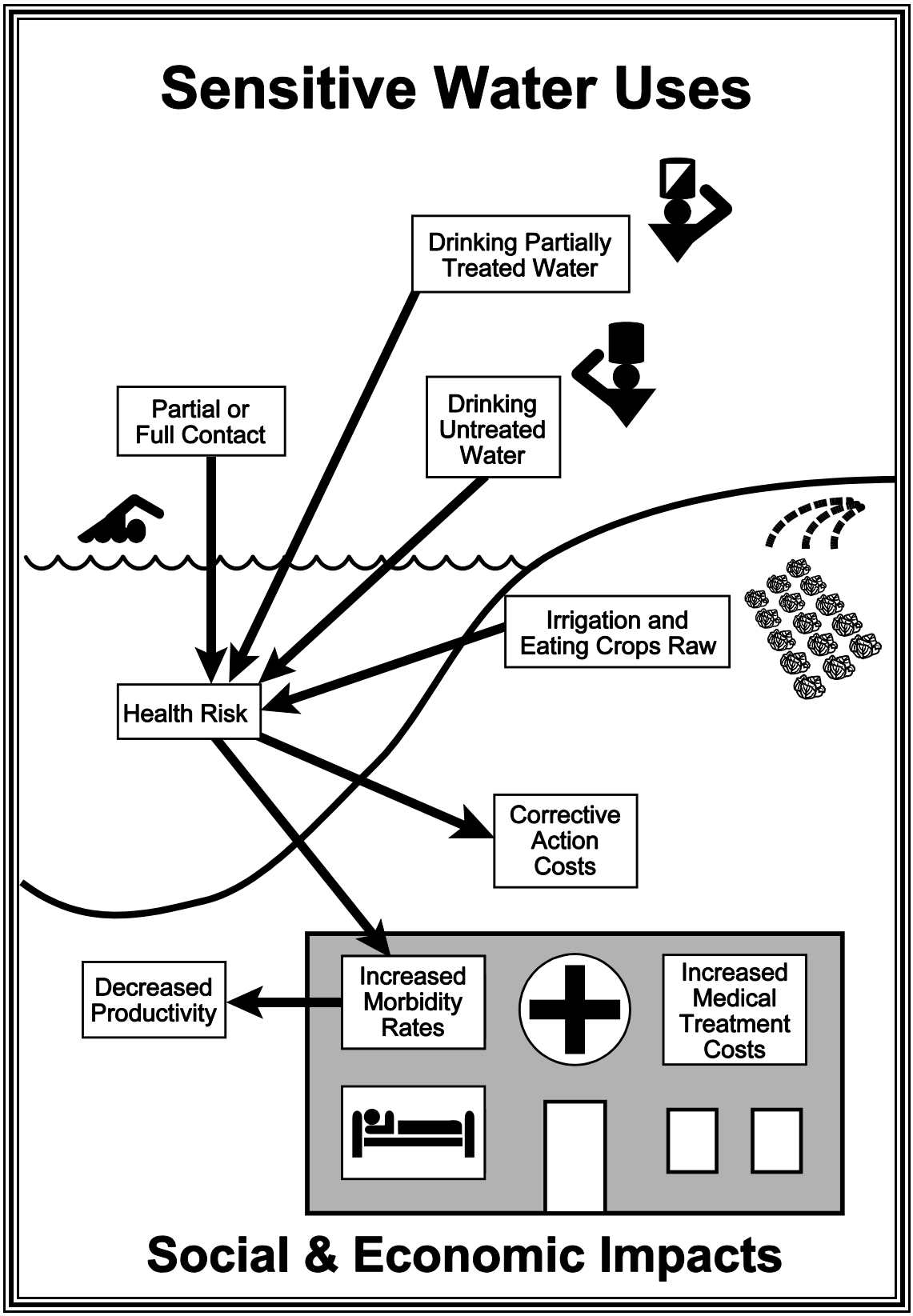


Figure 1.2. Schematic illustration of sensitive water uses and impacts of health risk.

1.5 THE STRUCTURE OF THIS DOCUMENT

Chapter Two describes how priority areas should be identified

The chapter following this one describes the prioritisation process used for identifying priority areas. This is a desk study not involving sampling The purpose is to create a short-list of areas in which a microbial monitoring programme should be established. The chapter describes the screening and, if necessary, ranking, selecting and reporting of the final results.

Chapter Three describes a national implementation strategy

Chapter three describes the overall national implementation strategy. In particular it deals with national coordination and creating public awareness. It also describes the national assessment that should be performed annually.

Chapter Four describes how to implement regionally

Chapter four deals with the process of implementing the national programme in a region (Water Management Area). It addresses creating capacity and adapting the existing framework to the point of registering the monitoring programme formally with DWAF.

Chapter Five defines the individual roles

The final chapter defines each of the roles from the sampler to the minister. It notes typical role players (*i.e.* organisations capable of executing the role), their individual tasks and resources required.

Chapter 14 of the National Water Act (Monitoring: Assessment & Information) is reproduced as an appendix

2. PRIORITISATION PROCESS

This chapter should be used by the person appointed to perform the prioritisation process to obtain a detailed description of how to prioritise surface water resources.

CHAPTER CONTENTS

2.1 WHY A PRIORITISATION PROCESS?

Microbial water quality indicators such as faecal coliforms are non-conservative. This means that levels can change independently of how much was originally added to the surface water. It is not feasible (logistically and financially) to set up a nationwide uniform grid of sampling sites (as is possible for normal chemical variables). With 278 tertiary catchments in South Africa, DWAF (who is responsible for the prioritisation

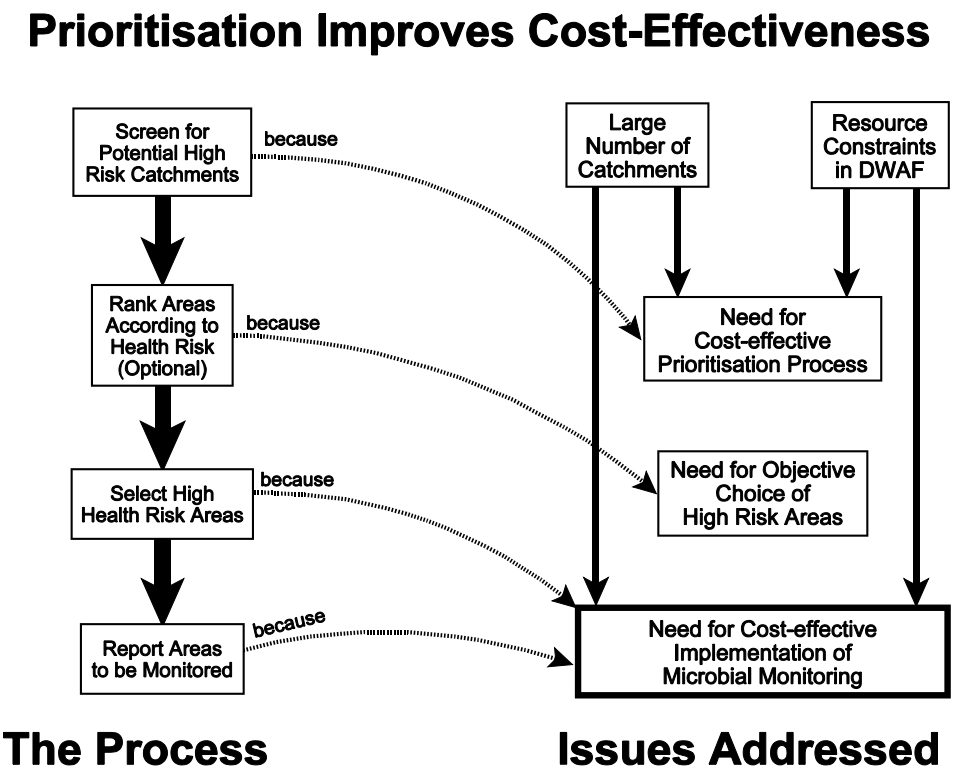


Figure 2.1. An illustration of some of the issues addressed directly by the major steps in the prioritisation process for microbial monitoring.

process) has a daunting task. The need for cost-minimisation is critical. Therefore, resources should focus on those areas most in need of monitoring. This prioritisation process helps identify those areas. The adjacent figure illustrates some of the issues that individual steps in this prioritisation process address.

2.2 OVERVIEW OF PROCESS

The prioritisation process is a quantitative desk study that identifies catchments (throughout South Africa) in which problematic land uses and sensitive water uses are most likely to result in a significant health risk due to faecal pollution. (It does not involve any actual sampling of waters.) Areas within these catchments become candidates for a microbial monitoring programme. The process is summarised in

Figure 2.2. The figure is referred to in the following sections which give details of the individual steps.

The first complete prioritisation process has been performed and was very comprehensive. Many tens of areas were identified as requiring a monitoring programme. The primary purpose of any follow-up prioritisation process will be to identify whether *new* areas have arisen which rank very highly (in terms of potential health risk).

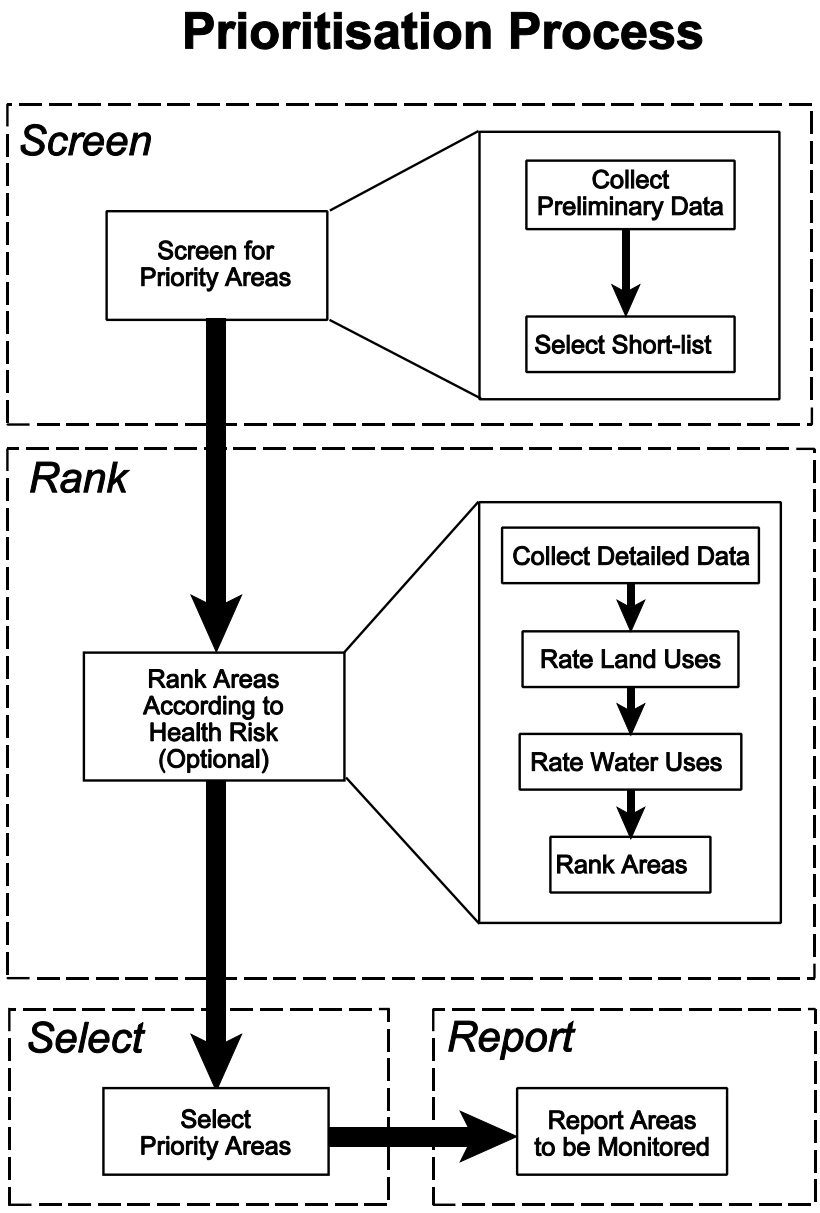
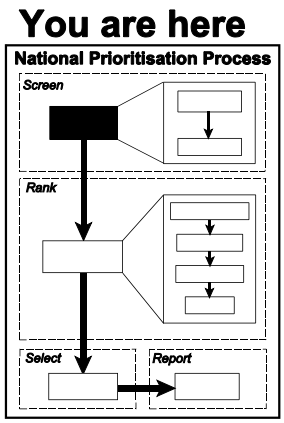


Figure 2.2. Overall Prioritisation Process.

2.3 SCREEN FOR PRIORITY AREAS



Monitoring is costly. Therefore only those catchments posing a significant potential risk to water users should be monitored. The first screening step involves creating a short-list of catchments most likely to exhibit a major health risk based on non-quantitative preliminary data. Those with no potential or actual microbial problems are excluded.

It is recommended that this screening be done on tertiary catchments.

2.3.1 Collect Preliminary Data

One is likely to be able to obtain the necessary information from the water resource managers in the regions. For each region, contact the DWAF Regional Director or local agent (*e.g.* Catchment Management Agency) first, typically by phone. Explain the purpose of the prioritisation process. Then contact other people in that region and obtain as much information as possible. It is advisable that the people contacted have copies of a map of each tertiary catchment in their region during discussions.

A catchment is included in the short-list if *any* of the following is true:

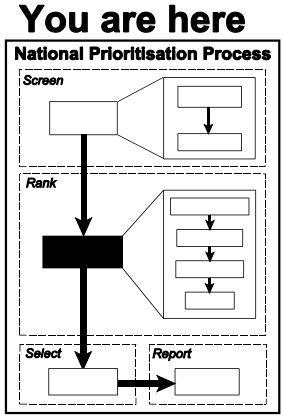
1. Microbial water quality problems have been experienced in the catchment.
2. A high incidence of waterborne diseases is evident in communities in the catchment.
3. Some people in the catchment use untreated or partially treated surface water from the catchment for domestic use.
4. Settlements (or parts thereof) in the catchment (or upstream of the catchment) do not have the necessary sanitation infrastructure to ensure effective disposal of human waste.

It should be borne in mind that if *any* of the above criteria is met, the catchment is included in the short-list. Only these questions should be addressed. It is a waste of your time and that of any respondent to request data that is unnecessary at this stage.

2.3.2 Select Short-list

In most cases, the list of catchments obtained above will be sufficient to create a short-list which regional managers can choose from when initialising microbial monitoring in their areas. However, if a more objective (and quantitative) prioritisation is necessary, then proceed to the next step.

2.4 RANK AREAS ACCORDING TO HEALTH RISK (OPTIONAL)



The purpose of this second main step is to quantitatively rank areas in the catchments (on the above short-list) according to their likely health risk. Because it is time-consuming, this should only be done if it is deemed necessary to be totally objective in the selection of those areas which should be subjected to actual monitoring. Frequently, such objectivety is not necessary because final decisions on what catchments are monitored initially also depend on factors other than simply which has the highest potential health risk. The most common factors are available finances and capacity.

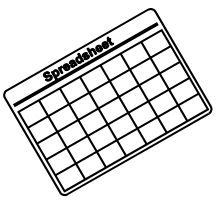
In summary, to perform the quantitative prioritisation process, <u>for each settlement in each catchment</u>, you need to do the following:

1. Quantify whether the land uses are likely to contribute to a health risk (if people are exposed to downstream surface water).
2. Quantify whether the way the water is used exposes an unacceptable number of people to major health risk.
3. Finally, combine these two factors to establish the overall ranking. The higher the ranking, the higher the health risk.

The details on how to perform these tasks follow.

2.4.1 Collect Detailed Data

The way the data is obtained and ultimately processed creates a number of basic requirements. First, some of the data can be obtained directly from the DWAF Water Supply and Sanitation Database. You need to be able to import this data directly (*i.e.* electronically). You also need to obtain data by personal communication. It is useful to be able to show others what you are looking for. Of course, you also need to be able to process the data in various ways to calculate the final ratings. You can achieve all of these if you use a spreadsheet.



Set up this spreadsheet in such a way that you can print out the pages conveniently. If you wish to obtain data from anyone else, it is always

best to provide that person with some background. The more they are informed about the reasons for the process, the more likely you are to get the right information from them. In particular, provide the following:

1. A copy of the diagram showing the issues addressed by the prioritisation process (**Figure 2.1**). (This will show them the reasons for the exercise.)
2. A copy of the overall process diagram (**Figure 2.2**). (This will show them where they fit into the overall prioritisation process.)
3. Pages printed from the spreadsheet showing the various column headings of data required. (This will show them what data is needed.)
4. A copy of the two tables of the land and water use attributes, with explanations on each attribute, **Tables 2.1** and **2.2**. (This will define each attribute exactly and explain why it is important.)
5. A map of each tertiary catchment. (This will help orient the choice of settlements and spatially link the data and information being obtained.)

Information sources ...
DWAF Water Supply and Sanitation Database
Agricultural Research Council
Regional Deputy Directors, Water Quality Management
Regional Water Quality Managers
Water User Associations (including large Water Boards)

Obtain as much data as possible directly from the DWAF Water Supply and Sanitation Database. Identify each settlement that occurs either totally or partially within the catchment in the above short-list. (This information can be obtained from regional DWAF offices.) A settlement is necessarily an area with a relatively high concentration of people. Note that you will also need to be able to identify intensive livestock farming units in rural areas.

It is best not to simply send the above information to respondents and ask them to fill in the data and return them. Rather do the following:

1. Phone each person likely to have data (the “respondent”) and say that you will be sending some information (and why).
2. Post or fax the above diagrams, tables and maps to each respondent. This will enable them to get an overview of the data required and why it is necessary.
3. Make an appointment to either meet or phone each respondent at a particular time. This enables both you and the respondent to choose the best time with the minimum of likely interruptions.
4. Begin the interview by making it clear what the objectives are. (Refer to the diagrams.)
5. Go through the spreadsheet with the respondent. Fill in the responses yourself. Ensure that the respondent understands each issue and the possible implications

of responses he/she makes.

6. If the respondent needs to obtain data from elsewhere, immediately make another appointment to visit or phone to get the data at a later time.
7. Finally, when you have completed the spreadsheet, send a copy to the respondent for confirmation. This is an important validation step, the purpose of which is to ensure that all numbers “look reasonable”.

New appointees to posts may not know the catchments well enough to be able to provide all the necessary information. In such a case, you may need to speak to more than one person to get what is required.

Table 2.1. Summary of information required to determine land use ratings.

No.	Land Use Attribute	Background
1	The number of individuals, **N**, with no sanitation infrastructure **(weight=53)***	These are individuals who do not have easy access to sanitation facilities. This can give rise to significant faecal pollution.
2	The number of individuals, **N**, with sanitation infrastructure that is either inefficient, poorly maintained (or operated) or inappropriate **(weight=43)***	These are individuals affected by sanitation facilities which are (i) poorly maintained, or (ii) not able to cope with the present population or (iii) not appropriate for the local situation. This includes wastewater treatment works that do not meet the relaxed microbiological effluent standard of 1 000 *E. coli* / 100 mR.
3	Average population density, **N** **(weight=1)***	The population density is used here as an indicator of the surface area covered by solid surfaces that are impermeable to rain. These include roads, pavements, buildings, and so on. This data gives an indication of the extent of storm water runoff that might occur as a result of rainfall events. This runoff usually enters surface waters, taking with it faecal and other contaminants.
4	Intensive livestock farming with no waste handling practices in place (small, medium or large) **(weight=3)***	This attribute includes such farming as aquaculture, dairy farming, pig farming, cattle feedlots, poultry farming and ostrich farming. Enterprises are classified as intensive when substantial capital and labour inputs are required per unit area. Use the following ranges to estimate the relative size of intensive farming units:

Unit	Numbers	Size
Cattle feedlot	< 5 000 cattle	**Small**
Piggery	< 500 pigs	
Cattle feedlot	5 000-10 000 cattle	**Medium**
Piggery	500-2 000 pigs	
Cattle feedlot	> 10 000 cattle	**Large**
Piggery	> 2 000 pigs	

* see Section 2.7 “Rationale Behind the Relative Priorities”.

Table 2.2. Summary of information required to determine water use ratings.

No.	Water Use Attribute	Background
1 	The number of individuals, **N**, without appropriate or reliable water supply infrastructure, that have to rely on untreated surface water for drinking **(weight=50)***	This typically includes people who need to physically collect water or who have to rely on surface water as an additional supply.
2 	The number of individuals, **N**, supplied with surface water from the catchment for drinking after limited treatment **(weight=10)***	Limited treatment means "not conventional treatment". Conventional treatment means all of flocculation, sedimentation, filtration and disinfection.
3 	The maximum number of people per month, **N**, that have full or partial contact with surface water in the catchment **(weight=25)***	This includes such activities as swimming, washing of laundry, wading across streams and so on. Typically, the maximum number of people using surface waters for recreation will be reached in summer.
4 	The area in hectares, **ha**, with vegetables that are irrigated with surface water from the catchment **(weight=15)***	Of primary interest are those crops that are spray irrigated and that may be consumed raw (carrots, lettuce, tomato, sweet potatoes and so on). However, these data are difficult to obtain, therefore the total area of vegetables being irrigated is used as an indicator.

* see Section 2.7 "Rationale Behind the Relative Priorities".

2.4.2 Rate Land Use

Particular care must be taken that data for parts of settlements that occur outside the catchment are not included in the analysis. For each settlement all data should be obtained for the following attributes. The values for these attributes can be summed over all settlements in an area and the final priority rating calculated using the formulae in the following table.

Table 2.3. Determination of the total land use rating for an area.

No.	Land Use Attribute (whole area)	Priority Rating (PR)
1	The number of individuals, **N**, with no sanitation infrastructure	**(N/100 000) x 100 x 53**
2	The number of individuals, **N**, with sanitation infrastructure that is either inefficient, poorly maintained (or operated) or inappropriate	**(N/100 000) x 100 x 43**
3	Average population density, **N**	**(N/20 000) x 100**
4	Intensive livestock farming with ...	
	... no waste handling practices in place	
	Small-scale Unit	**90**
	Medium-scale Unit	**180**
	Large-scale Unit	**300**
	... all units with appropriate waste handling practices in place	**0**
	Total Land Use Rating for Area =	**Sum**

For example ...

No:	*1*	*2*	*3*	*3*
Settl A	***1 000***	***10 000***	***3 000***	***90***
Settl B	***8 000***	***5 000***	***2 000***	***180***
Settl C	***5 000***	***1 000***	***3 000***	***0***
Settl D	***7 000***	***3 000***	***8 000***	***0***
Total	***21 000***	***19 000***	***16 000***	***270***

Therefore, the total land use rating for the area is (21 000/100 000)x100x53 + (19 000/100 000)x100x43 + (16 000/20 000)x100 + 270 = 1113 + 817 + 80 + 270 = 2 280.

2.4.3 Rate Water Use

Values for the following attributes should be obtained for all settlements in an area. The final priority rating is then calculated using the formulae in the following table.

Table 2.4. Determination of the total water use rating for an area.

No.	Water Use Attribute (whole area)	Priority Rating
1 	The number of individuals, **N**, without appropriate or reliable water supply infrastructure, that have to rely on untreated surface water for drinking	**(N/100 000) x 100 x 50**
	The number of individuals, **N**, supplied with surface water from the catchment for drinking after ...	
2 	... limited treatment	**(N/100 000) x 100 x 10**
	... conventional treatment	**0**
3 	The maximum number of people per month, **N**, that have full or partial contact with surface water in the catchment	**(N/10 000) x 100 x 25**
4 	The area in hectares, **ha**, with vegetables that are irrigated with surface water from the catchment	**ha x 15**
	Total Water Use Rating for Area =	**Sum**

For example ...

No:	*1*	*2*	*3*	*4*
Settl A	*12 000*	*5 000*	*1 000*	*20*
Settl B	*10 000*	*3 000*	*500*	*50*
Settl C	*3 000*	*2 000*	*5 000*	*0*
Settl D	*5 000*	*1 000*	*400*	*300*
Total	*30 000*	*11 000*	*6 900*	*370*

Therefore, the total water use rating for the area is (30 000/100 000)x100x50 + (11 000/100 000)x100x10 + (6 900/10 000)x100x25 + 370x15 = 1 500 + 110 + 1 725 + 5 550 = 8 885.

2.4.4 Rank Areas

The task now is to use the land and water use ratings to identify the high risk areas in the catchment. It is very useful to display the data on a map of the catchment. One can then spatially link and understand the data more easily.

Bear the following basic principles in mind when interpreting a map:

- *A particular set of land and water uses can only be considered to be part of the same area if those land uses are the ones that have impacts on those water uses. Equivalently, water uses upstream of the most upstream land use in the catchment should be ignored.*

- *As a general rule of thumb, the distance between a land use and the water use which it might have an impact on should not be more than 100 km. However, site-specific conditions may overrule this. These include topography, vegetation (e.g. vegetated flood-plains) and flow patterns (such as narrow fast-flowing streams or impoundments and wetlands which limit water movement).*

- *Large water impoundments (such as dams) often decrease the effect of upstream land uses on water uses downstream of the impoundment and hence could be appropriate boundaries for the areas chosen.*

An area containing a number of problematic settlements is a likely high risk area. Identify an area that contains a set of impacted water uses (*i.e.* with high priority ratings) that seem likely to be associated with high risk land uses (*i.e.* again with high ratings). Such an area should have an overall priority rating calculated for it as follows.

Overall Area Rating =

0.4 x (Total Land Use Rating for Area) +
0.6 x (Total Water Use Rating for Area)

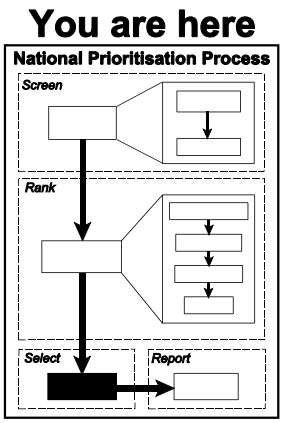
This overall area rating (or priority assessment) is the value that quantitatively represents the degree of health risk associated with the area.

For example ...

Overall Area Rating = 0.4x2 280 + 0.6x8 885 = 6 243

When the overall area rating for each area has been calculated, the areas should be ranked by sorting into decreasing order of overall rating.

2.5 SELECT PRIORITY AREAS

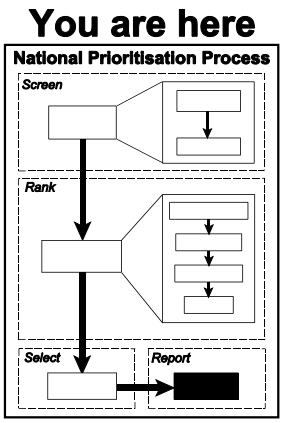


The areas with the highest overall ratings will be those that have the most urgent need for attention. As a rough guide, areas with a rating of above 200 000 should automatically be flagged as requiring a monitoring programme. However, this does not mean that areas with lower ratings do not have serious problems. For the purposes of this prioritisation exercise, this cutoff value is deemed appropriate, based on experience gained during pilot studies.

As noted above, a number of factors other than this rating will determine whether a monitoring programme is actually initiated. These include the existence (or creation) of the necessary capacity and finance. This is dealt with in more detail elsewhere (see Chapter 4).

2.6 REPORT AREAS TO BE MONITORED

See National Water Act Chapter 14 Sections 140 & 142.



A brief report of the results of the prioritisation process should contain the following:

1. A brief description of the background of the prioritisation process.
2. A clear reference to this manual for further details.
3. A map of the whole of South Africa highlighting those areas that are high risk. The areas should be colour coded according to the overall area rating.

The format used in the 1999 report should be used as a template for future reports.

This report should be sent to the following:

1. Water Advisory Council.
2. DWAF, Directorate Project Planning.
3. All DWAF Regional Directors.
4. DOH.
5. DEAT.
6. National Coordinator.
7. Any Concerned Party that has expressed an interest in obtaining the report.

2.7 RATIONALE BEHIND THE RELATIVE PRIORITIES

2.7.1 The Objective

The formulae used to calculate total land and water use ratings for a settlement involve numbers that take account of the relative importance (priorities) of the various attributes. For example, individuals that have to use untreated water are exposed to a greater health risk than those using water after limited treatment. Values are necessary that describe their relative contribution *quantitatively*.

Use was made of the Simple Multi-Attribute Rating Technique (SMART) as described by Goodmin and Wright (1991). The objective is to "identify high risk areas where severe faecal pollution due to land use activities could pose a health risk to water users". Two main attributes, namely land use and water use, were identified that could be used to measure the performance of areas in this regard. Each attribute was then further sub-divided into sub-attributes.

This section describes how the relative values for the attributes and sub-attributes were chosen.

2.7.2 Relative Land Use Priorities

The sub-attributes chosen for land use are shown in the following table. The weights were chosen by a technical team and normalised so that their sum equalled 100.

Table 2.5. Land use attributes and assigned weights.

Land use attribute	Normalised weight
No sanitation infrastructure	53
Sanitation infrastructure that is either inefficient, poorly maintained (or operated) or inappropriate	43
Average population density	1
Intensive animal farming enterprises	3
	100

Each of the above sub-attributes requires a means of measurement.

Sub-attributes 1 and 2 (relating to no or ineffective sanitation infrastructure) were chosen to be quantified by the number of individuals, N, that fell into the category. A value of **(N/100 000) x 100** was assigned.

The population density (people/km^2), N, is used as indicator of the surface area covered by solid surfaces (like roads, etc.). The latter data are difficult and time consuming to

obtain, therefore population density was chosen instead. A value of **(N/20 000) x 100** was assigned.

An intensive animal farming enterprise was rated as a function of its size. The following table shows the values assigned.

Table 2.6. Measurement values chosen for intensive farming enterprises.

Intensive Farming Enterprise	Measurement Value
All units with appropriate waste handling practices in place	0
No waste handling practices in place ...	
Small-scale unit	30
Medium-scale unit	60
Large-scale unit	100

The relative sizes of feedlots and piggeries were based on the opinion of DWAF pollution control officers. These are summarised in **Table 2.1**.

2.7.3 Relative Water Use Priorities

The sub-attributes chosen for water use are shown in the following table. The relative weights were again chosen by a technical team.

Table 2.7. Water use attributes and assigned weights.

Water use attribute	Normalised weight
Drinking untreated water	50
Full or partial contact	25
Irrigation of crops	15
Drinking after limited treatment	10
Drinking after conventional treatment	0
	100

Each of the above sub-attributes requires a means of measurement.

The attributes associated with drinking water that has been subject to either no or limited treatment were chosen to be measured in terms of the number of individuals in each category. In each case a value of **(N/100 000) x 100** was assigned. If the water was subject to conventional treatment, a value of 0 was assigned.

The attribute associated with full or partial contact was assigned a value of 0 when

nobody came into either full or partial contact with water. A value of **(N/10 000) x 100** was assigned otherwise.

Various assumptions had to be made regarding the sub-attribute of irrigation of crops. Originally the primary concern was those crops that would be eaten raw. Furthermore, those crops spray irrigated were of most concern. However, partly because of practices such as crop rotation, this is difficult to estimate. The calculation of the potential number of people that could be exposed was based on figures for the production of lettuce. This was regarded as a worst case scenario as the exposure risk during ingestion of other produce (such as cabbage or tomato) was regarded as less.

The average lettuce production figure used was 15 000 kg/ha or 30 000 lettuces when a weight of 500 g was assumed. (Information was supplied by the Vegetable and Ornamental Plant Institute, Agricultural Research Council.) If it is assumed that on average an individual or 4 people would be exposed per lettuce, 1 ha corresponds to the exposure of 120 000 people. In addition, it was assumed that 25% of the total area (all vegetable types) under irrigation could be associated with crops that could be eaten raw.

Therefore, a value of 0 was assigned to the situation when nobody would be exposed to vegetables irrigated with surface water. The actual water use priority was assumed proportional to the hectares under irrigation: **ha x 100**.

2.7.4 Water Use Relative to Land Use

The technical team decided that water uses rate higher than land uses. The following table summarises the normalised weights.

Table 2.8. Relative water and land use weights.

Main attribute	Normalised weight
Water uses	60
Land uses	40
	100

These normalised weights are used in the calculation of the overall area ratings (each reduced by a factor of 100, *i.e.* 0.6 and 0.4).

2.8 RESOURCES REQUIRED

The following table provides rough estimates of the time required for execution of the main steps in the overall process.

Costing Time: The time actively involved in the task.
Elapsed Time: The time from start to end of the task (taking account of inevitable delays such as waiting for others to provide information, lack of immediate availability of people and so on).

Table 2.9. Estimates of times required to perform individual steps in the prioritisation process.

Step	Costing Time	Elapsed Time
Screen for Potential High Risk Catchments	2 weeks	1 month
Rank Areas According to Health Risk	2.5 months	5 months
Select High Risk Areas	1 day	2 days
Report Areas to be Monitored	1 week	2 week
Approximate Total:	3.25 months	6.5 months

3. NATIONAL IMPLEMENTATION PROCESS

This chapter should be used primarily by the National Coordinator for overall guidance on the implementation process of the NMMP at a national level.

CHAPTER CONTENTS

3.1 CREATING NATIONAL COORDINATION

See National Water Act Chapter 14 Section 138.

There are general statutory requirements in respect of coordinating the monitoring of water resources in South Africa. For the programme to be well coordinated nationally, everyone must be clear on the objectives. It is reiterated here that the primary purpose of the programme is to monitor the extent of faecal pollution in priority areas on a national basis. Note that there is particular focus on high risk areas (primarily to ensure cost-effective use of resources). This means that, at least initially, those areas exposed to moderate (but nevertheless significant) faecal pollution may not be included. Furthermore, it is not the primary purpose to identify the precise causes of the faecal pollution.

Department of Water Affairs and Forestry (DWAF) has a mandate under the National Water Act (Act No 36 of 1998) to monitor water resources. However, although the DWAF is primarily responsible for the implementation of national microbial monitoring, the Department of Health also has an important role to play. Both will benefit from the programme and both have resources that can contribute to it.

A single person from DWAF should be formally assigned the role of **National Coordinator**. (See Roles and Responsibilities chapter for more detail.)

3.2 CREATING PUBLIC AWARENESS

The Department of Health would typically develop national public awareness campaigns for conveying generic health-related messages to water users. The National Microbial Monitoring Programme has an important role to play in this by providing information on where the worst problems exist. The results of the 1997 prioritisation process can also be used to focus resources cost-effectively in any such campaign.

A public awareness campaign will have a number of benefits.

1. It will contribute to avoiding health problems when water is faecally contaminated.
2. It will contribute to minimising future faecal pollution because users will be aware of the consequences.
3. It may create an awareness sufficient to mobilise pressure on polluters and relevant local authorities to deal with the problem.

3.3 AN IMPLEMENTATION MODEL

The National Aquatic Ecosystem Biomonitoring Programme (NAEBP) (or River Health Programme) is implementing a so-called "Demonstration-for-Resource Allocation Spiral" model. A similar approach should be adopted for the National Microbial Monitoring Programme.

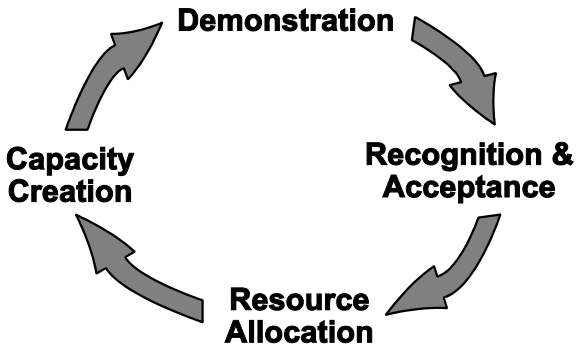


Figure 3.1. The "Demonstration-for-Resource Allocation Spiral " model of the River Health Programme [Roux, 1997].

In the case of the NAEBP, small-scale demonstration of the role of biomonitoring in water resource assessment and management led to a recognition of its usefulness. This recognition, and the acceptance of a need for the technology, resulted in the further allocation of resources (financial and human). Basically, this approach assumes that demonstrating good results leads to increased support.

The National Microbial Monitoring Programme must choose at least two local areas which it can use to demonstrate the usefulness of microbial monitoring. However, a failed attempt could have disastrous consequences and delay ultimate implementation significantly. Therefore, the Programme must "get it right first time". Accordingly, the areas chosen should satisfy at least the following criteria:

1. ***Existing capacity.*** There must be existing capacity in the area. This means there must already exist players who have the capacity to adopt the roles from **Sampler** to **Data Assessor** and preferably **Regional Monitoring Coordinator**.
2. ***Local willingness.*** The local players should reap well-defined benefits from an involvement in the local programme. That is, there should be an inherent willingness to get involved.
3. ***Real issues.*** The area should be experiencing significant microbial contamination of surface waters. (Preferably the area should have been rated as high risk in the prioritisation process.)
4. ***Suitability for demonstration.*** It should be remembered that one purpose of this exercise is to demonstrate success. Factors other than those identified here which may enhance or impede the chances of success will need to be identified and carefully considered.

The above criteria essentially make initial implementation as easy as possible by removing many of the most obvious difficulties. A successful implementation of microbial monitoring in, say, two areas will help in a number of ways. First, success can be demonstrated and hence more resources motivated. Secondly, technical and managerial problems (which will inevitably exist, notwithstanding the above criteria) will

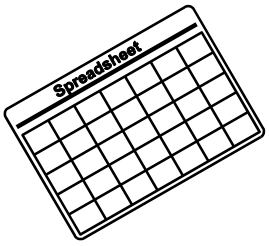
be identified and overcome. This will increase the chances of future successes in areas in which implementation is inherently more difficult.

3.4 ANNUAL NATIONAL ASSESSMENT

See National Water Act Chapter 14 Sections 140 & 142.

Frequency: Annual
Elapsed Time: 1 week
Costing Time: 8 hours

After one year of local monitoring, annual assessments of each area must be performed and combined into a single report. This section illustrates the process.



The complete Annual National Assessment calculation (with instructions) is available from DWAF as a Microsoft Excel spreadsheet. It requires only that the raw data be entered.

To maintain consistency and minimise the chances of human error, this spreadsheet should always be used to produce the necessary information for the maps.

Step 1: Each datum from each sampling site over the past year should be assigned a low, medium or high potential health risk (based on the guidelines in Table 3.1).

Table 3.1. Guidelines for assessing the potential health risk for the four water uses. (Note that these guidelines were developed specifically for use in the NMMP and were not tested in other contexts.)

	Potential Health Risk		
	Low	**Medium**	**High**
Water use attribute	**Faecal coliform or *E. Coli* counts/100 mℝ**		
1. Drinking untreated water	0	1-10	> 10
2. Drinking water after limited treatment (see explanatory note* below)	< 2 000	2 000-20 000	> 20 000
3. Full or partial contact	< 600	600-2 000	> 2 000
4. Irrigation of crops to be eaten raw	< 1 000	1 000-4 000	> 4 000

* Note: In this case, the water is used (*i.e.* for drinking) after limited treatment though the guidelines necessarily refer to the raw water before such treatment. For example, raw water with < 2 000 counts/100 mℝ subjected to limited treatment *and then used for drinking*, will be associated with a low potential health risk. "Limited treatment" means not conventional treatment. Conventional treatment means all of flocculation, sedimentation, filtration and disinfection.

For example ...

Assume the following (fictitious) annual data (Faecal coliforms/100 mℓ) had been collected at three sites A, B and C. (Although weekly data is usually used, for the purposes of this example the table only shows monthly data.) The second table shows the potential health risk (Site A only) associated with full or partial contact.

Faecal coliforms/100 mℓ		
Site A	*Site B*	*Site C*
9667	*14667*	*2600*
1111	*1889*	*433*
23333	*73333*	*3000*
14667	*4000*	*600*
11333	*1778*	*211*
17788	*667*	*60*
3000	*883*	*880*
421	*3700*	*2100*
733	*2889*	*6200*
30000	*1593*	*933*
2700	*13667*	*1600*
890	*667*	*1000*
Geometric Mean		
4377	*3237*	*934*

Site A: Full/partial contact		
Potential Health Risk		
Low	*Medium*	*High*
		H
	M	
		H
		H
		H
		H
		H
L		
	M	
		H
		H
	M	
Total		
1	*3*	*8*

Step 2: Tabulate the total counts (lows, mediums and highs) for each site and each water use.

For example ...

The following total counts are obtained at each site for each water use.

Water Use	Site A				Site B				Site C			
	L	M	H	Sum	L	M	H	Sum	L	M	H	Sum
1	0	0	12	12	0	0	12	12	0	0	12	12
2	4	6	2	12	6	5	1	12	8	4	0	12
3	1	3	8	12	0	6	6	12	3	5	4	12
4	3	3	6	12	3	6	3	12	6	5	1	12
Total:	8	12	28	48	9	17	22	48	17	14	17	48

[[[

Number of high risk incidents

Step 3: Tabulate (1) the overall yearly assessment (using the geometric means) and (2) the number of high risk incidents for each water use at each site.

For example ...

The following yearly assessments (from geometric means) and numbers of high risk incidents are obtained at each site for each water use.

Water Use	Site A		Site B		Site C	
	Yearly assessment	High Risk Incidents	Yearly assessment	High Risk Incidents	Yearly assessment	High Risk Incidents
1	High	12	High	12	High	12
2	Medium	2	Medium	1	Low	0
3	High	8	High	6	Medium	4
4	High	6	Medium	3	Low	1

Step 4: Calculate the potential health risk indices.

This is based on the percentage of incidents associated with high risk over all water uses at each site in the area.

Potential Health Risk Index =
100 x (3(all high risk incidents))/(total number of incidents)

Use the following guidelines to interpret the calculated index.

Table 3.2. Guidelines for interpretation of the potential health risk index.

Index Range	Interpretation
Index # 30	Limited faecal pollution of surface water
30 < Index # 60	Moderate faecal pollution of surface water
Index > 60	Heavy faecal pollution of surface water

For example ...

The following numbers of high risk incidents are obtained at each site for each water use.

Site A		*Site B*		*Site C*	
High Risk Incidents	***Total Incidents***	***High Risk Incidents***	***Total Incidents***	***High Risk Incidents***	***Total Incidents***
28	***48***	***22***	***48***	***17***	***48***

Potential Health Risk Index = 100x(28+22+17)/(48+48+48) = 46.5

This indicates <u>Moderate Faecal Pollution of Surface Water</u>

The equivalent index should be calculated for each water use. Use exactly the same formula as above except restrict to each of the water uses in turn. The necessary data appear in the table under step 2. For example, for drinking after limited treatment (water use 2), the index would be 100x(2+1+0)/(12+12+12) = 8.333 which should be rounded to the nearest integer, namely 8.

Step 5: Report results.

This brief annual report should contain the following.

1. A brief background on the Programme.
2. A clear reference to this manual for further details.
3. A colour map for each Water Management Area. Each map must show
   a. the sampling sites,
   b. the yearly assessment for each water use at each site (with icon colours reflecting the yearly assessment - low, medium or high, based on the geometric means)*,
   c. a sliding scale (bar) showing the annual assessment of the potential health risk per water use for the area as a whole for the current and previous year,
   d. a sliding scale (bar) showing the annual assessment of the potential health risk for the area as a whole for the current and previous year.

* Care should be taken with the interpretation of the individual health risks represented by these four indices. When the first such report is produced, careful consideration should be given to the way these indices are interpreted by the various concerned parties. If deemed necessary, special steps should be taken to ensure any incorrect interpretations are avoided.

The report should be sent to the following:

4. Each DWAF Regional Director in whose region a monitoring programme exists.
5. DWAF, Directorate Project Planning.
6. National Policy Maker.
7. National Coordinator.
8. DOH.
9. Each Regional Manager.
10. Any Concerned Party that has expressed an interest in obtaining the report.

4. REGIONAL IMPLEMENTATION PROCESS

This chapter should be used primarily by the Regional Monitoring Coordinator for guidance on the overall implementation process of the NMMP in a Water Management Area.

CHAPTER CONTENTS

4.1 OVERVIEW

A “regional implementation process” is that series of actions required to set up and sustain a successful microbial monitoring programme in a region (defined as a Water Management Area) so that the national objectives of the programme are realised.

The primary responsibility for regional implementation is likely to be delegated to a Catchment Management Agency. Coordination can be expected to be guided by the national coordinator (see Chapter 5 on “Monitoring Roles”). Regional resources will need to be mobilised.

It needs to be mentioned that if the detailed causes of faecal pollution in a local area need to be identified, the responsibility for this monitoring becomes that of the region. It is not within the scope of this document to deal with regional responsibilities under these conditions. However, it can be mentioned that this is likely to have a number of ramifications. The number of sampling sites is likely to increase (with associated costs and logistical problems). It may be necessary to include other water quality variables in the analysis. The selection of sampling sites requires considerably more care. The frequency of sampling may also differ from that of the national programme (*i.e.* most likely be more frequent).

The following figure shows the steps in the regional implementation process. The sections that follow refer to this figure and give details of the individual steps.

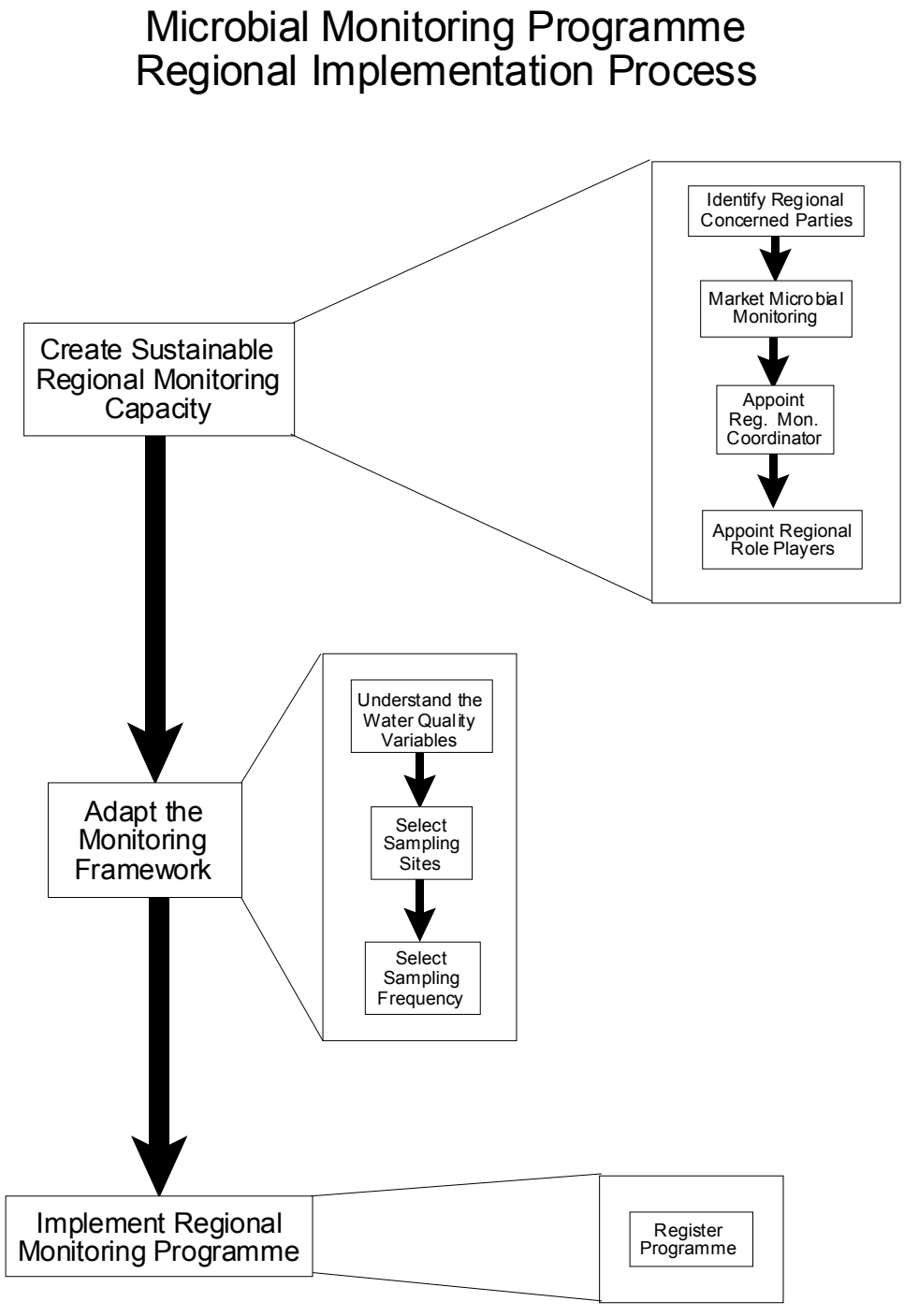
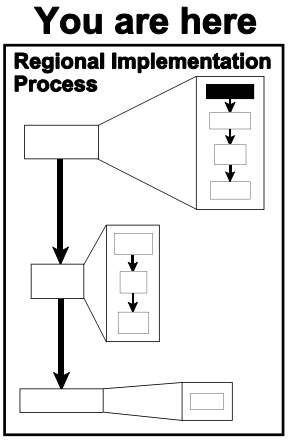


Figure 4.1. Overall Regional Implementation Process

4.2 CREATE REGIONAL MONITORING CAPACITY

4.2.1 Identify Regional Concerned Parties

It is the primary responsibility of DWAF to implement a national microbial monitoring programme for surface waters. However, the involvement of regional concerned parties is likely to be to the advantage of all involved.



Specific water management institutions may already exist in an area. If so, they may well have interests that overlap with those of the national microbial monitoring programme. Alternatively, such organisations could be established so that one of their functions is the implementation of the microbial monitoring programme in the area.

In general, a guiding principle is to identify those concerned parties that would have an inherent vested interest in a monitoring programme. That is, their involvement in the regional programme would be a “win-win” situation.

The following are typical organisations that could be regarded as concerned parties and even as role players.

4.2.1.1 Catchment Management Agencies

See National Water Act Chapter 7 & Schedule 3.

A catchment management agency (CMA) is a statutory body established at the discretion of the Minister to delegate water resource management to a local level and to involve local communities. It may be established for specific geographical areas, after public consultation, on the initiative of the community or stakeholders concerned. The proposal and procedure for its establishment and its powers and duties are detailed in the National Water Act. Its main functions are

- to investigate and advise on the protection, use, development, conservation, management and control of the water resources in its water management area,
- to develop a catchment management strategy, and
- to coordinate the related activities of the water management institutions within its water management area.

Schedule 3 of the National Water Act deals with the powers and duties of a CMA which are aimed at controlling the permitted water use by users.

Before these agencies come into being in any particular area, DWAF will act as agent in the meantime for the necessary water resource management. The process of

establishing them is time-consuming. This is partly because a cautious bottom-up approach is being adopted involving public participation and consultation. The aim is to do more than just consult but rather engage interested parties [Karodia, 1999, DWAF].

A number of "forerunner" regions have been identified as water management areas. These have been proposed in the Government Gazette and comment was invited before 31 March 1999.

See Government Gazette No 19641, 31 December 1998

It is likely that CMAs will be the primary agent for regional implementation of the NMMP.

4.2.1.2 Department of Health

The Department of Health has a significant role to play in the successful implementation of the National Microbial Monitoring Programme. They should also be contributing to establishing overall direction. The possibility of regional environmental health officers playing a role in sampling should be investigated.

4.2.1.3 Water User Associations

A water user association (WUA) is a cooperative association of individual water users who wish to undertake water-related activities for their mutual benefit. The purpose of WUAs is to represent specific water users relating to specific water use activities. It is not to undertake overall water resources management aimed at sustainability.

See National Water Act Chapter 8 & Schedule 5.

A water user association for a particular purpose would usually be established following a proposal to the Minister by an interested person, but such an association may also be established on the Minister's initiative. The functions of a water user association depend on its approved constitution. The following are a few examples that might typically be associated with a water user association:

4. To protect water resources.
5. To prevent any unlawful act likely to reduce the quality of water in any water resource.
6. To exercise general supervision over water resources.
7. To regulate flow.
8. To provide management services, training and support to rural communities and water services institutions, and to provide catchment management services on behalf of responsible authorities.

4.2.1.4 Water Boards

The primary activity of a water board is to provide water services to other water services institutions within its service area.

See Water Services Act (Act No 108 of 1997) Chapter VI & X.

A water board must achieve a balance between (among other aspects) (i) striving to provide efficient, reliable and sustainable water services, (ii) striving to be financially viable, (iii) taking into account national and provincial policies, objects and developments, (iv) complying with health and environmental policies, and (v) taking reasonable measures to promote water conservation and water demand management, including promoting public awareness of these matters.

The Water Services Act further requires that a national information system of water services be established. One purpose is to record and provide data for the development, implementation and monitoring of national policy on water services. Another is to provide information to water services institutions, consumers and the public.

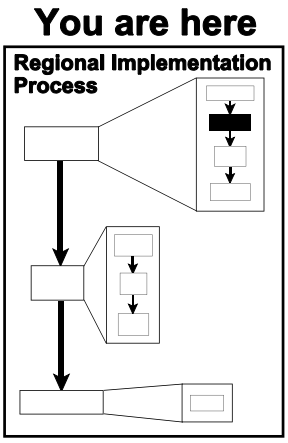
Therefore, water boards (among others) may well wish to involve themselves in a monitoring programme. It is usually in their interests to ensure that the quality of raw water that they use for purification and distribution is of consistent quality. Any major deterioration in quality may require changes to their process which could be costly for them. The larger water boards usually also have the necessary sampling and laboratory facilities.

The National Water Act provides for the restructuring of water boards as water user associations.

4.2.1.5 Major Industries

A number of major industries in South Africa take a pro-active role in ensuring (and demonstrating) minimal impacts on their local environments. This is also appropriate in the context of microbial pollution. In the first place, they can convincingly demonstrate a social responsibility to downstream users of the water. Secondly, they can ensure that their own staff are not exposed to faecally polluted surface water. This not only prevents disease but minimises production losses due to sickness. They can also contribute by (i) creating an awareness among staff of potential health risks and (ii) how to minimise risks by treating (*e.g.* boiling) water suspected to be contaminated.

4.2.2 Market Microbial Monitoring



It may be necessary to "sell" (or at least explain) the concept of microbial monitoring to prospective concerned parties. This may initially be the responsibility of DWAF. However, it may also become the responsibility of the regional monitoring coordinator in order to sustain interest and the necessary support.

Various tools can be used, depending on the specific audience. The following are contained in this document.

1. The systems model/illustration of problematic land uses and sensitive water uses. (This provides an overall picture of typical causes of the problem and a summary of those most likely to experience problems if contaminated water is used. This diagram contains a formal connection between many important issues as well as a pictorial representation of them, each of which communicates with a different level of audience.)
2. References to the National Water Act (Act No. 36 of 1998) and the Water Services Act (Act No. 108 of 1997). Many such references are made in this document. (These will explicitly convey the statutory requirements of people and organisations associated with water, *i.e.* what they have to do by law.)
3. The diagram entitled "Prioritisation Improves Cost-Effectiveness". (This enforces the general impression that the national programme is focussed on using resources as wisely as possible.)
4. The diagram showing the "Prioritisation Process". (This will demonstrate the broad steps that were followed that resulted in an area being identified as priority area.)
5. The diagram showing the "Regional Implementation Process". (This will demonstrate the steps required to get a new regional programme off the ground.)
6. The diagram illustrating "Microbial Water Quality Variables". (This shows some detail on what will be measured and why. This information is required to make an appropriate assessment of the raw data.)
7. The diagram showing the overall "Information Flow" from sampler to national policy maker. (This will illustrate all the necessary roles and allow each role player to see exactly where they "fit into the picture". This creates a sense of belonging and hence buy-in to the overall implementation.)
8. Brief descriptions of any specific role for which more information is required. (These summarise each role and details the tasks. They can be sent to prospective role players as broad "terms of reference".)
9. A summary of the funding requirements. (This will enable prospective role players to assess accurately the likely financial impacts.)

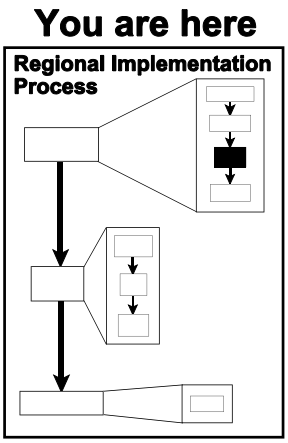
Besides specific tools within this document, the following reports can be used in future.

1. Results of a prioritisation process. (This will demonstrate the high risk areas

identified and enable comparison with the rest of the country.)

2. An annual report of the national implementation process. (This will show annual results for existing programmes. It will demonstrate how the results are presented and hence facilitate a better understanding of how they can be used.)

4.2.3 Appoint Regional Monitoring Coordinator

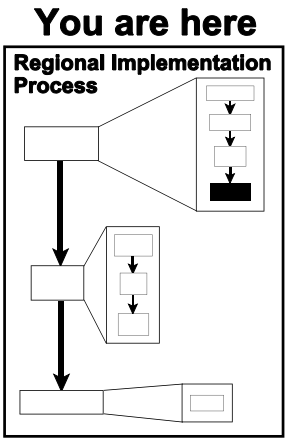


Having identified the concerned parties in the region, it is necessary to appoint one or more people (typically from one of the concerned parties) to take responsibility of being the regional monitoring coordinator. The associated tasks are described elsewhere in this document. One person is considered sufficient to implement and manage a monitoring programme in one area.

The appointment should be contractually based and the choice of regional monitoring coordinator should be based on the following criteria:

1. The candidate should have sufficient time and capacity to carry out the tasks. The percentage of time and other resources required should be estimated.
2. The candidate's superiors should be completely satisfied with the allocation of the regional monitoring coordinator's time and other resources to the monitoring programme.
3. The candidate should have sufficient expertise and experience to enable successful implementation and ongoing management of the regional programme.

4.2.4 Appoint Regional Role Players

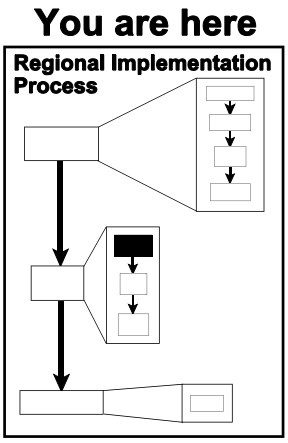


The regional monitoring coordinator, once appointed, needs to formally assign the appropriate organisations and people to each of the required roles. The details of each role are given in chapter 5 “Monitoring Roles”.

A critical aspect will be the choice of laboratories. They should preferably be accredited and their locations will need to be such that it is logistically possible to transport samples from the field to the nearest laboratory so that the analysis can be done within 24 hours. This is a demanding requirement. There are many laboratories with existing or potential facilities for microbial analysis, including those within DWAF and at water boards. Laboratories at tertiary education institutions could also be upgraded to provide the necessary analytical services.

4.3 ADAPT THE MONITORING FRAMEWORK

4.3.1 Understand the Water Quality Variables



It is impractical to measure pathogens directly ...

The overall purpose of the microbial monitoring programme is to assess and manage the health risk to water users due to faecal pollution of water resources. The true health risk to water users is best defined in terms of concentrations of pathogens. However, the measurement of all possible water-associated pathogens in a sample is complex and time-consuming. Furthermore, the low numbers of pathogens relative to the natural microbiological population make detection difficult. This makes direct detection of pathogens in a monitoring programme impractical.

... so the faecal coliform group is used as an indicator.

Therefore, the level of faecal pollution is assessed on the basis of the presence of “indicator” organisms. Two commonly used indicators are the faecal coliform group and *Escherichia coli* (one of the organisms that comprises the group). The use of the concentration of faecal coliforms in the assessment of water quality is considered to be acceptable (WHO, 1993) though recent trends are towards using *E. coli*.

Both faecal coliforms and *E. coli* can be measured directly and are the microbiological variables used for the NMMP.

For more details ...

CCREM, 1987
DWAF, 1996a
DWAF, 1996b
Gardiner and Zabel, 1989

The other water quality variables that must be measured are pH, temperature and turbidity. **Figure 4.2** illustrates how these variables play a role in determining the level of faecal coliforms. As an example, heavy rainfall creates runoff. Such runoff often carries with it suspended particles that make the water turbid. If, for example, there is a settlement upstream with inadequate sanitation facilities, the runoff may also be contaminated with faecal coliforms. A sudden increase in the faecal coliform levels as well as turbidity indicates that a recent rainfall event may have been the cause of the increased contamination. The presence of both nutrients and suspended solids can be problematic because nutrients adsorb onto particle surfaces. This can increase faecal coliform growth rates. Higher temperatures also increase growth rates while, on the other hand, extreme pH conditions increase the rate at which they decay.

For more details ...

Bowie et al., 1985
Crane and Moore, 1986
WHO, 1993
WHO, 1984

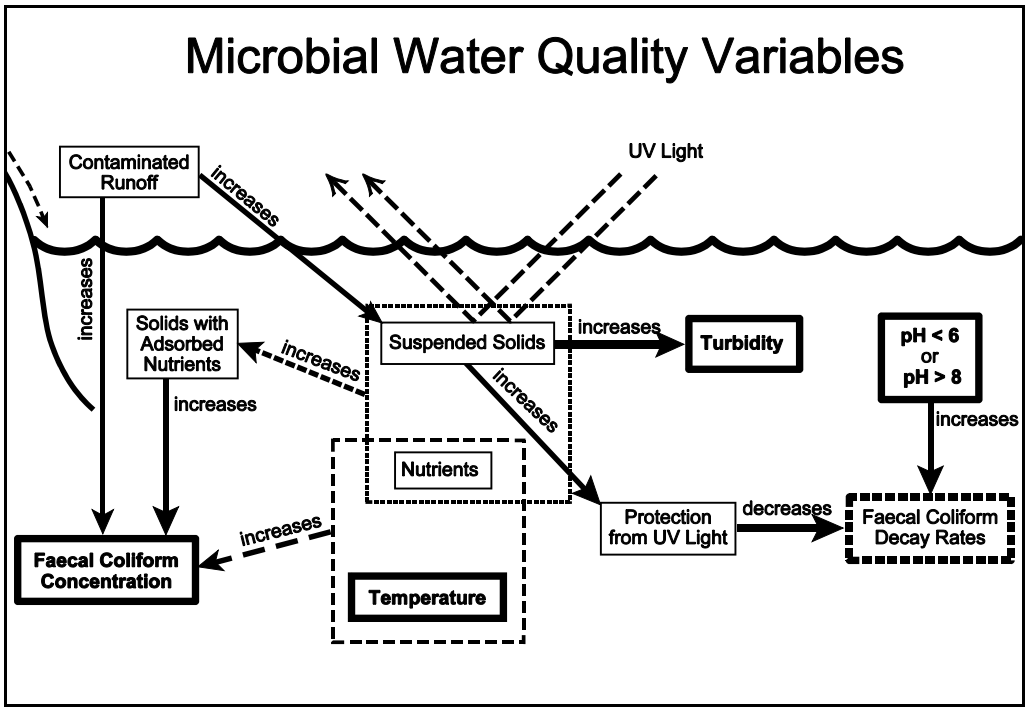


Figure 4.2. The microbial water quality variables and some of their interactions.

4.3.2 Select Sampling Sites

Elapsed Time: 2 weeks
Costing Time: 2 days

The location of sampling sites is always a critical aspect in the design of a monitoring network. Many factors influence the choice of sites, some specific to microbial monitoring.

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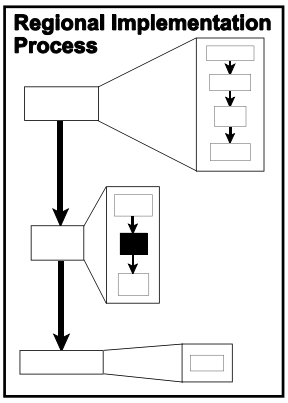


The location of sampling sites depends primarily on the national objectives, ...

It is appropriate to be reminded at this point of the specific objectives of the microbial monitoring programme. These are, nationally,

- i to provide information on the status and trends of the extent of faecal pollution, in terms of the microbial quality of surface water resources in priority areas;
- i to provide information to help assess the potential health risk to humans associated with the possible use of faecally polluted water.

The results of the prioritisation process are important in the initial choice of sampling sites. That is, areas regarded as having a potentially high risk should receive preferential treatment.

The fact that this programme is a national one and not primarily regional or local has significant implications for choice of sampling sites. For example, fewer sites are necessary for the purposes of the national programme than would be if the purpose was to identify the causes (*i.e.* the polluters) unequivocally.

... the fact that a non-conservative variable is being measured, ...

Another fundamental factor determining the choice of sampling sites is the fact that a microbial water quality variable (like faecal coliforms) is a non-conservative variable. This means that the concentration varies as a result of a number of processes (see section 4.3.1 “Understanding the Water Quality Variables”) causing it to change independently of how much was originally added to the water. (This is in stark contrast to conservative variables. Salts such as chloride, sodium and so on accumulate along the length of a watercourse in the direction of flow. Amounts added at the most upstream point are usually still present when the water passes the most downstream point. Their concentrations are only reduced by such mechanisms as dilution, adsorption or settling.)

A consequence of faecal coliforms being a non-conservative variable is that it is practically impossible (without large investment) to choose sampling sites to be on a uniform grid of representative positions countrywide.

... the proximity to sensitive water uses, ...

With the above in mind, choose sites in areas where the following water uses occur.

1. Where there are households without appropriate or reliable water supply infrastructure, that have to rely on untreated surface water.
2. Where there are households supplied with surface water from the catchment after limited treatment.
3. Where people have full or partial contact with surface water in the catchment.
4. Where crops to be consumed raw are irrigated with surface water from the catchment.

In particular, choose sites near settlements where one or more of the above water uses contributed significantly to the total water use rating for the settlement.

... the fact that samples must be analysed within 24 hours, ...

Another important factor in choosing sampling sites is that samples need to be analysed within 24 hours. The logistics of sampling in remote locations may preclude such sites simply because samples cannot reach the sample analyser in time.

Notwithstanding the above criteria which are specific to microbial pollution, there are a number of generic criteria associated with the choice of sites in any monitoring network. These are as follows.

For more details ...

Sanders et al., 1987
Ward et al., 1990

... the sample being characteristic of local conditions, ...

The site should provide information that is characteristic of the general local conditions. Remember that a “sample” should be representative, because it is being presented as evidence of the quality of the water body from which it is obtained.

... the water being completely mixed, ...

It is critically important that sampling occurs at a point in the watercourse where the water is completely mixed. That is, the microbial water quality should not vary with the

depth or width of the watercourse. Remember that complete mixing only occurs some distance downstream of a point discharge. The actual distance depends on local conditions. It may be necessary to take preliminary samples to test whether complete mixing has occurred.

... the site being accessible, ...

The site should be easily accessible to the person taking the sample. Valuable time and resources are wasted if this is not the case.

... sites not being spatially correlated, ...

Ideally, samples taken at different sites should not be "spatially correlated". This means that a sample at one site should not change in composition in a way that can be predicted from the composition of a sample taken at some nearby sampling site. This will occur if there is no significant change in conditions in the watercourse and if no additional pollution sources occur between the two points. If correlation occurs, resources are being wasted because the second sampling site is not providing information that cannot be obtained from the first site.

... account being taken of seasonal variations, ...

Sites should be chosen so that they take account of seasonal variations and other variations over time. Faecal pollution levels can vary seasonally. The flow of water in a watercourse is less in dry seasons so, for a constant pollution source, pollutant concentrations will be higher. On the other hand, wet seasons result in greater surface runoff. Therefore pollution arising from runoff will be greater. High rainfall events also cause sudden increases in pollution levels.

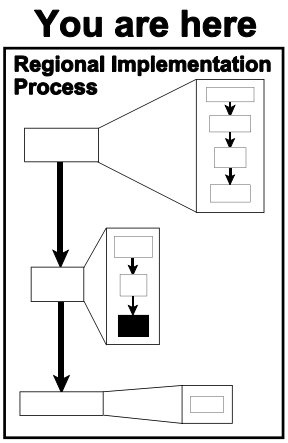
... and available funding.

Funding requirements will vary from area to area depending on the degree of existing infrastructure. A spreadsheet facility is available that enables detailed costing to be done for a single local area. This allows specification of operating and capital costs as well as human resource costs (as hours and hourly rates). It produces a five year cost projection based on various simple assumptions in respect of cost escalation, capital depreciation and so on. This should be used to agree on costs and the relative contributions of the various resource providers.

4.3.3 Select Sampling Frequency

Ideally, sampling should be done weekly.

Elapsed Time: 1 hour
Costing Time: 1 hour
(excluding travelling)



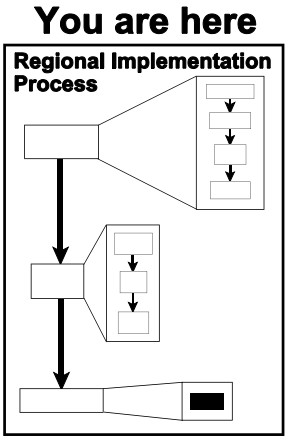
An analysis of the data collected during the pilot studies performed during the design phase of this monitoring programme suggested that an appropriate sampling frequency is weekly. This was determined statistically and should be adopted unless there are good reasons to change it. If it is changed, it should ideally be in favour of more frequent sampling rather than less frequent. (If regional monitoring is required that aims at identifying individual causes of faecal pollution, more frequent sampling is almost certainly required.)

Although less frequent monitoring may be all that is possible in certain circumstances, it must be realised that the usefulness of the data from such monitoring is significantly decreased. This is so for both national purposes and any regional management purposes. In such cases, both the national coordinator and the regional parties involved must explicitly acknowledge the potential information loss and, possibly, the greater risks that may be associated with this.

4.4 IMPLEMENT A REGIONAL MONITORING PROGRAMME

4.4.1 Register Programme

Elapsed Time: 3 weeks
Costing Time: 1 day



Each regional monitoring programme needs to be formally registered with DWAF. To do this, the regional monitoring coordinator should send the following to DWAF.

1. Completed **Monitoring Programme Registration** forms obtained from DWAF.
2. An A4 or A3 copy of a 1:50 000 scale map of the area. The photocopy must contain (i) the scale on the edge of the original map, (ii) the map number (e.g. 2734AB), (iii) the map name (written clearly if not on the photocopy), and (iv) each sampling site circled and numbered.

3. Information on all the sampling sites including sampling site number, description (so that someone else can find the site easily), name of water body, longitude, latitude, station number (if site is in an existing monitoring programme). An Excel spreadsheet is available from DWAF for this purpose if necessary.

Upon successful registration, DWAF will send a schedule to each sampler confirming exact sampling details (location, frequency, delivery, etc.). Sample bottles suitably tagged (again with sampling details) will also be provided by DWAF. Once the programme is registered, actual monitoring can begin.

4.5 RESOURCES REQUIRED

The following table provides rough estimates of the time required for execution of the main steps in the overall process.

Costing Time: The time actively involved in the task.
Elapsed Time: The time from start to end of the task (taking account of inevitable delays such as lack of immediate availability of people, waiting for others to provide information and so on).

Table 4.1. Estimates of times required to perform main steps in the regional implementation process.

Step	Costing Time	Elapsed Time
Creating Regional Monitoring Capacity	2 weeks	2 months
Adapting the Monitoring Framework	4 days	2 weeks
Implementing a Regional Monitoring Programme	1 day	3 weeks
Approximate Total:	3 weeks	3.25 months

5. ROLES AND RESPONSIBILITIES

This chapter should be used by any role player to establish the tasks required to be implemented by any of the role players in the NMMP.

CHAPTER CONTENTS

5.1 OVERALL INFORMATION FLOW

A monitoring programme involves analysing samples to obtain data which is assessed to create useful information. A multitude of parties are involved and many individual roles need to be smoothly executed for the overall programme to be successful. This chapter describes each individual role. The actual flow of data and information within the overall scheme is shown in the figures.

The roles cover the whole range from sampler to national policy maker. This approach has been adopted to ensure that each role player understands exactly where they fit into the overall picture. This should create buy-in to the process and hence facilitate initial implementation.

It should be noted that the identification of different roles does not imply that different people or organisations are required to execute those roles. On the contrary, a single person or organisation can be responsible for multiple roles.

Icons have been created for each role to improve visual communication and hence understanding.

National Microbial Monitoring Programme Roles and Information Flow

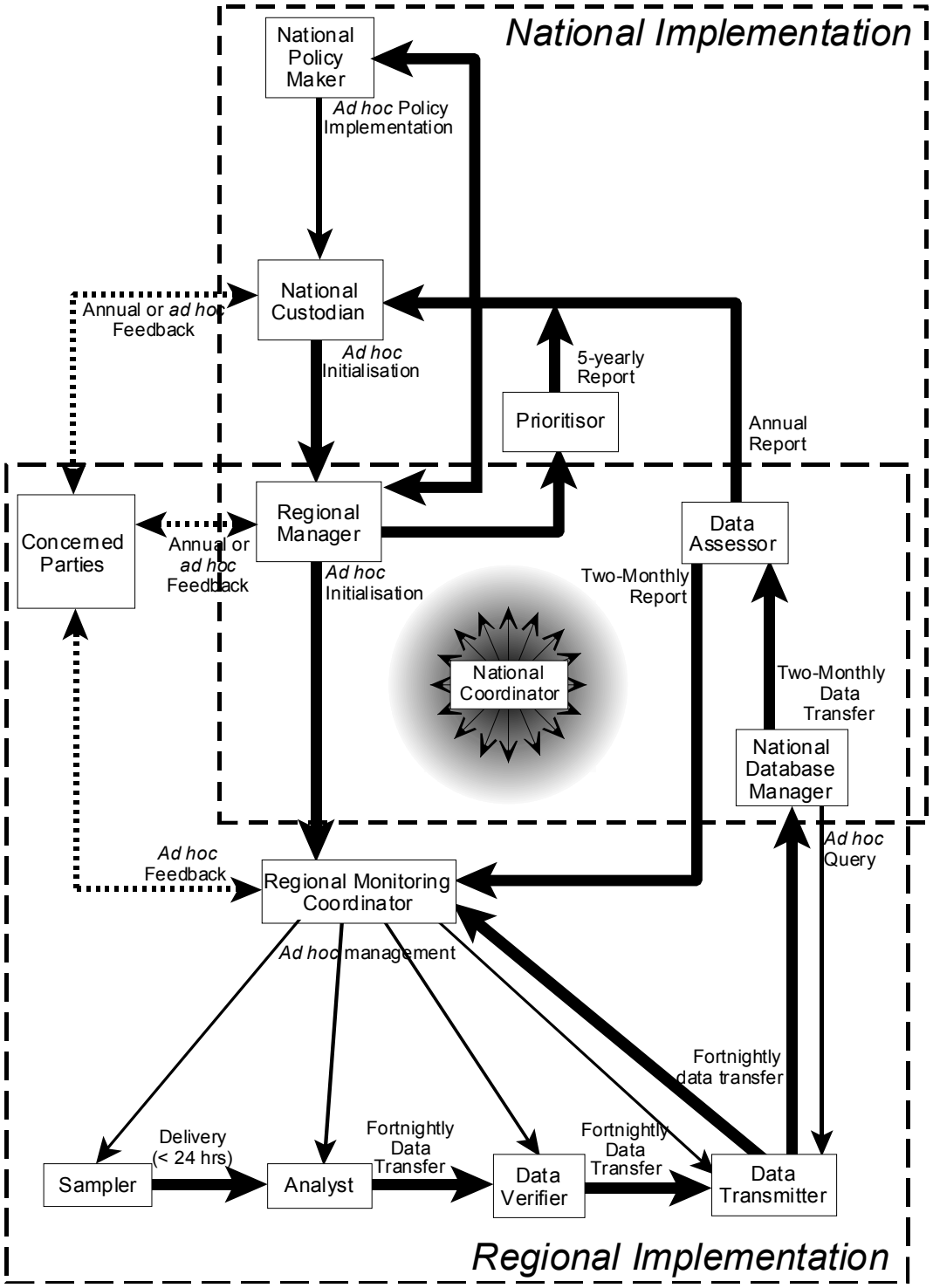


Figure 5.1. Formal roles and information flow.

National Microbial Monitoring Programme Role Icons and Information Flow

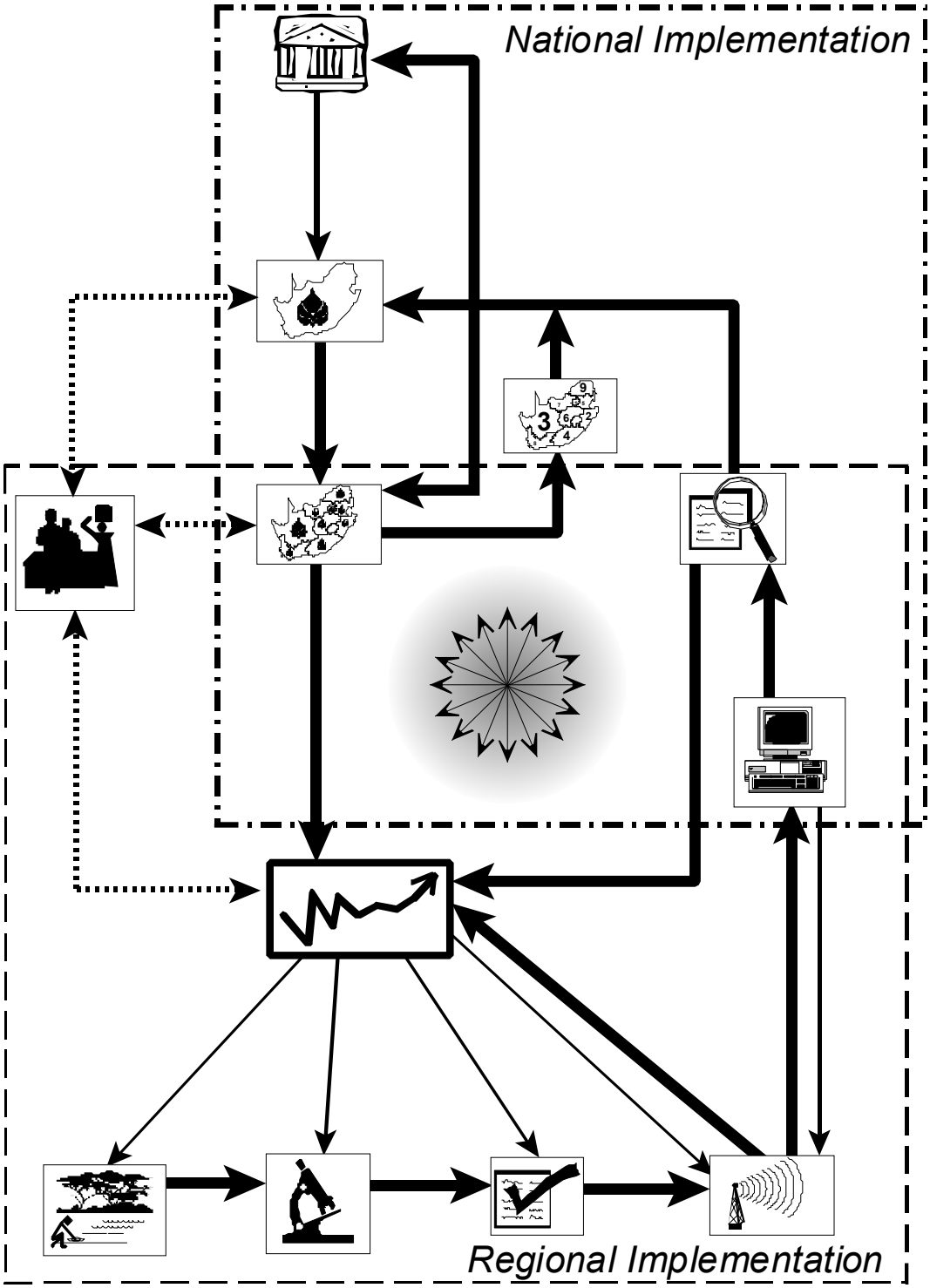


Figure 5.2. Role icons and information flow.

5.2 NATIONAL POLICY MAKER

5.2.1 Summary of Role

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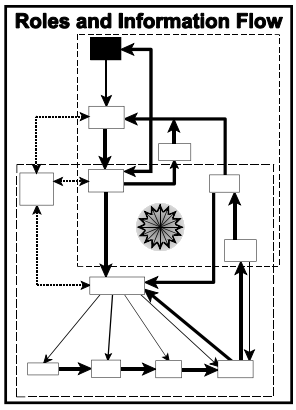

The **National Policy Maker** receives reports from the **Prioritisor** (every five years) and the **Data Assessor** (annually). These report on the national *status quo* in respect of faecal pollution in priority areas. It is the responsibility of the **National Policy Maker** to use this information to implement current policy and develop new policy for the national management of surface water resources.

5.2.2 Typical Role Player

Minister of Water Affairs and Forestry, Minister of Health.

5.2.3 Tasks

A Minister is generally responsible for the powers and functions assigned to him/her by the President. As a Member of Cabinet, he or she is accountable to Parliament for the exercise of these powers and the performance of their functions. A Member of Cabinet must (a) act in accordance with the constitution and (b) provide Parliament with full and regular reports concerning matters under his/her control.

The following extract from the National Water Act (Act No. 36 of 1998) summarises in general terms the ultimate responsibility of the Minister of Water Affairs and Forestry.

> ***Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act. National Government, acting through the Minister, is responsible for the achievement of these fundamental principles in accordance with the Constitutional mandate for water reform. Being empowered to act on behalf of the nation, the Minister has the ultimate responsibility to fulfil certain obligations relating to the use, allocation and protection of and access to water resources.***

5.3 CONCERNED PARTIES

5.3.1 Summary of Role

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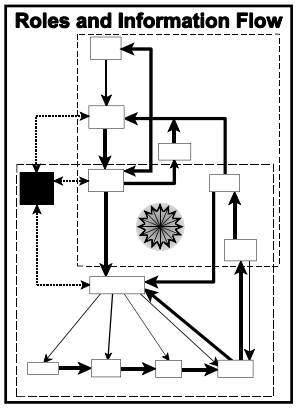


The **Concerned Parties** can receive information from a number of sources. These include the **Regional Monitoring Coordinator**, **Regional Manager**, **National Custodian**, **National Coordinator** or the **National Policy Maker**. This could be on an *ad hoc* or routine annual basis. The **Concerned Parties** can communicate directly with the **National Policy Maker**, **National Custodian**, or ideally with the **National Coordinator**.

5.3.2 Typical Role Player

Any person or organisation with an interest in microbial water quality or that might be affected by deteriorating microbial water quality. These may include the general public, business, lobby groups, water forums, community leaders, etc.

5.3.3 Tasks

5.3.3.1 Reporting Pollution Incidents

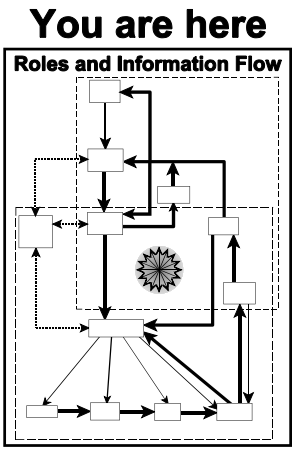
Pollution incidents (such as spills of hazardous substances or other pollution of surface waters) can be reported directly to the **Regional Manager** by any means.

5.3.3.2 Other Matters

The **Regional Manager** can be contacted on any matter concerning the microbial pollution of surface waters. The interests of **Concerned Parties** may be extremely diverse. They can become involved in water related issues using a number of formal structures. These include catchment management agencies, water user associations, water forums and so on. The functions and roles of these are summarised in section 4.2.

5.4 NATIONAL COORDINATOR

5.4.1 Summary of Role



The primary role is to facilitate the nationwide implementation of the national microbial monitoring programme so that the objectives are achieved. The **National Coordinator** will need to be familiar with all aspects of microbial monitoring and should be able to provide technical and managerial advice to the role players. The **National Coordinator** must ensure effective and efficient transfer of knowledge and experience gained by those involved in the programme.

5.4.2 Typical Role Player

A single person from the Department of Water Affairs and Forestry (DWAF).

5.4.3 Tasks

5.4.3.1 Facilitate National Implementation

The **National Coordinator** should be the driving force behind initial and ongoing implementation on a national basis. This will involve choosing appropriate areas for initial implementation. Details are provided in chapter 3 “National Implementation Process”.

5.4.3.2 Facilitate Regional Implementation

With the experience gained from implementation in other areas, the **National Coordinator** should facilitate the implementation of monitoring programmes in new priority areas. Details are given in chapter 4 “Regional Implementation Process”.

5.5 PRIORITISOR

5.5.1 Summary of Role

The **Prioritisor** screens, ranks, selects and reports the priority areas on a national basis when necessary. This report is submitted to the **Regional Manager**, the **National Custodian** and the **National Policy Maker**. This report summarises the national *status quo* and identifies new priority areas where new monitoring programmes should be initialised.

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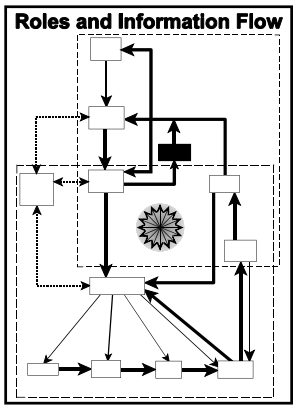


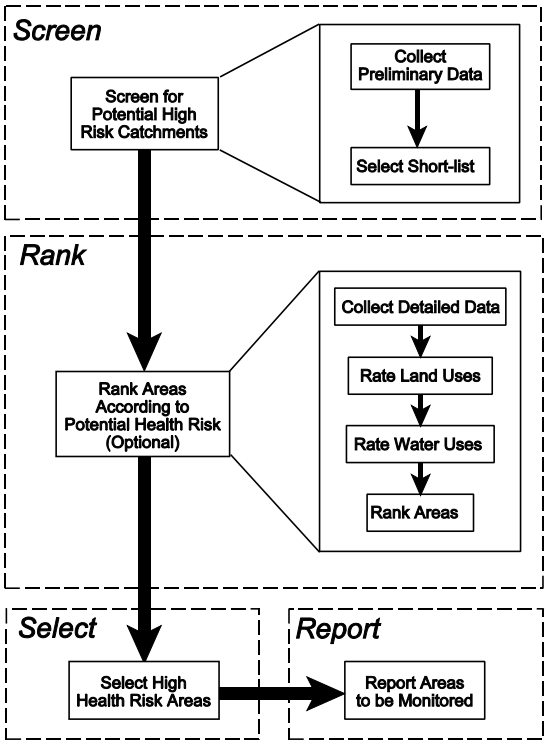
5.5.2 Typical Role Player

The Department of Water Affairs and Forestry (DWAF) and/or appointee. The **National Coordinator** may well take on this role.

5.5.3 Tasks

See chapter 2 “Prioritisation Process”.

Prioritisation Process



5.6 NATIONAL CUSTODIAN

5.6.1 Summary of Role

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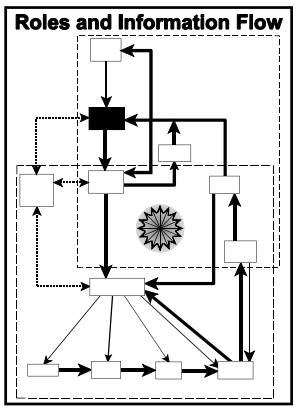

The **National Custodian** receives annual reports providing an assessment of each area in which a monitoring programme is in place. It will also receive instructions from the **National Policy Maker** in respect of policy implementation. The **National Custodian** initialises monitoring programmes in new priority areas by communication with the appropriate **Regional Manager** of the **National Coordinator**. It can also communicate directly with **Concerned Parties** routinely on an *ad hoc* or routine annual basis.

5.6.2 Typical Role Player

Department of Water Affairs and Forestry (DWAF) Director General.

5.6.3 Tasks

5.6.3.1 Initialisation of New Monitoring Programmes

Should a new high risk area be identified by the **Prioritisor**, the appropriate **Regional Manager** is notified as soon as possible. A regional monitoring programme is then established. See chapter 4 “Regional Implementation Process” for more details.

5.6.3.2 Communication with Concerned Parties

See National Water Act Chapter 14 Sections 140 & 145.

The **National Custodian** is bound by the Water Act to report to water management institutions, water users and the public. This can be done routinely every year by making annual assessment reports (see chapter “National Implementation Process”) available. This can also be done on an *ad hoc* basis using press releases, radio or DOH environmental health officers when the need for urgency arises.

5.7 REGIONAL MANAGER

5.7.1 Summary of Role

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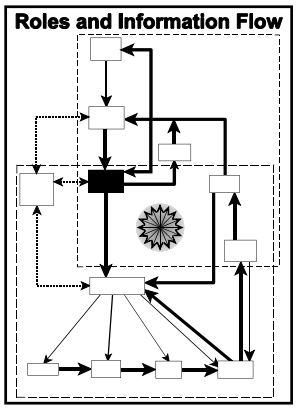

The **Regional Manager** receives a 5-yearly report from the **Prioritisor**. This report summarises the national *status quo* and identifies new priority areas where monitoring should be initialised. The **Regional Manager** also receives annual reports providing an assessment of each area in which a monitoring programme is in place. The **Regional Manager** can communicate directly with **Concerned Parties** routinely on an *ad hoc* or routine annual basis.

5.7.2 Typical Role Player

Water Quality Managers of Department of Water Affairs and Forestry (DWAF) Regional Offices or appointed representative of the relevant catchment management agency. The **Regional Monitoring Coordinator** may also take on this management role.

5.7.3 Tasks

5.7.3.1 Initialisation of a Monitoring Programme

When a new high risk area is identified by the **Prioritisor**, a **Regional Monitoring Coordinator** must be appointed (if one is not already in place) to initialise a microbial monitoring programme in the new high risk region. See chapter 4 “Regional Implementation Process”.

5.7.3.2 Communication with Concerned Parties

The **Regional Manager** should receive comments and information from **Concerned Parties** as well as provide them with regular reports or feedback, as deemed appropriate by both parties.

5.8 REGIONAL MONITORING COORDINATOR

5.8.1 Summary of Role

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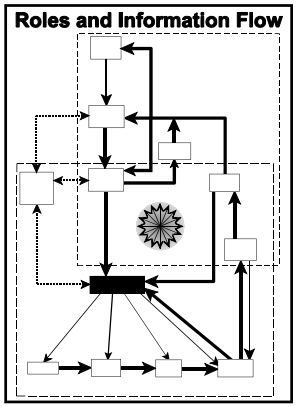


The **Regional Monitoring Coordinator** has many sub-roles. After the position is established when a new priority area is identified, the person is responsible for selecting sampling sites, ensuring that the appropriate training is carried out, implementing monitoring and managing day-to-day problems. The **Regional Monitoring Coordinator** receives a two-monthly report from the **Data Assessor** on the *status quo* of the faecal pollution in the area.

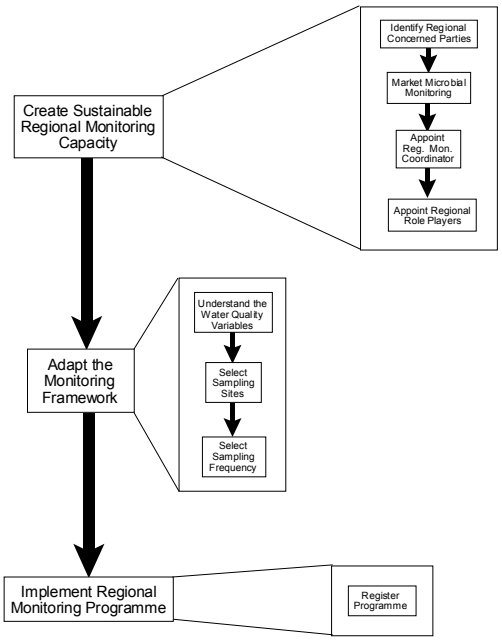
5.8.2 Typical Role Player

Typically a representative of the relevant catchment management agency or a DWAF Regional Office.

5.8.3 Tasks

Once appointed, the tasks of the **Regional Monitoring Coordinator** are to initialise, implement and coordinate the microbial monitoring programme in the identified high risk area. The individual tasks are given in detail in chapter 4 “Regional Implementation Process”.

Microbial Monitoring Programme
Regional Implementation Process



5.9 DATA ASSESSOR

5.9.1 Summary of Role

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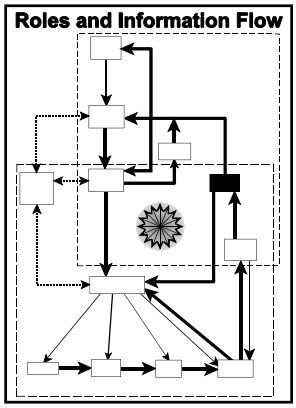


The **Data Assessor** receives data (for each area in which a monitoring programme is in place) from the **National Database Manager** every two months. The data should be assessed and the current status and trends of faecal contamination in the area should be reported to the **Regional Monitoring Coordinator** every two months. The **Data Assessor** also produces annual reports on all water management areas with monitoring programmes in place. The fundamental role is to add value to the numerical results for the benefit of the **Regional Monitoring Coordinator**.

5.9.2 Typical Role Player

Microbiologist with experience in the behaviour of faecal coliforms in environmental waters. Typically in the Department of Water Affairs and Forestry (DWAF).

5.9.3 Tasks

It is the primary task of the data assessor to provide information on the "assessment endpoint" (the human health risk) based on the "measurement endpoint" (the measured values of faecal coliforms etc.).

5.9.3.1 Annual National Assessment

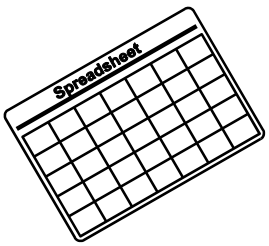
For details see chapter 3 "National Implementation Process".

Elapsed Time: 1 week
Costing Time: 8 hours
(per 10 areas assuming established methods)

5.9.3.2 Two-monthly Assessment to Regional Monitoring Coordinator

Elapsed Time: 1 hour
Costing Time: 1 hour
(per area)

The data (*i.e.* faecal coliform or *E. coli* counts, pH, turbidity and temperature) should be obtained from the database for each sampling site in the area being assessed. Trends need to be displayed, therefore the data should ideally be imported into a spreadsheet.



The complete Bi-monthly Assessment calculation (with instructions) is available from DWAF as a Microsoft Excel spreadsheet. It requires only that the raw data be entered.

To maintain consistency and minimise the chances of human error, this spreadsheet should always be used for the assessment.

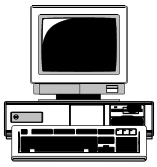
Each **Regional Monitoring Coordinator** simply wants to know what the current status is and what the trend is in the area under their jurisdiction. A spreadsheet format is sufficient for this purpose and is cost-effective. The bi-monthly assessment spreadsheet assigns low, medium and high potential health risks to each datum for each water use. It also automatically provides graphs showing how the data has changed over the period being assessed. The final assessment can either be transmitted to the **Regional Monitoring Coordinator** directly (by E-mail) or copies of A4 printouts of the spreadsheet pages can be faxed.

The following specific individual assessments can be done on the data (directly in the spreadsheet or on the fax cover page).

1. Individual high or low faecal coliform values can be commented on. For example, give possible reasons (if known) such as “high rainfall event on 1998-Feb-12”, “sewage spill at point X on 1999-Jan-5”, and so on. Often such local information is not immediately available to the **Data Assessor** since he/she is centrally based. If this is the case, unusually high values could be questioned simply to bring them to the attention of the **Regional Monitoring Coordinator**.
2. Include any other comments that will assist the **Regional Monitoring Coordinator** to understand the full implications of the data that have been measured in the area.

This report should be seen primarily as providing regular feedback to the **Regional Monitoring Coordinators** while also providing whatever assessment is possible.

5.10 NATIONAL DATABASE MANAGER



5.10.1 Summary of Role

The **National Database Manager** receives verified analytical data from the **Data Transmitter**. A database must be maintained so that data can be supplied to the **Data Assessor** monthly.

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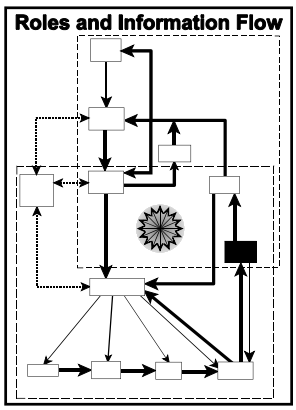

5.10.2 Typical Role Player

The Department of Water Affairs and Forestry (DWAF). Ideally a person associated with the Water Management System (WMS).

5.10.3 Tasks

5.10.3.1 Database Management

This includes all tasks typically associated with the data input and maintenance of computer databases.

5.10.3.2 Data Extraction on Demand

Upon demand from the **Data Assessor**, data should be provided in a format appropriate for the use intended. Automated data extraction procedures will need to be developed that provide the data in the most appropriate form.

Elapsed Time: <30 mins
Costing Time: < 30 mins
(per area)

5.11 DATA TRANSMITTER

5.11.1 Summary of Role

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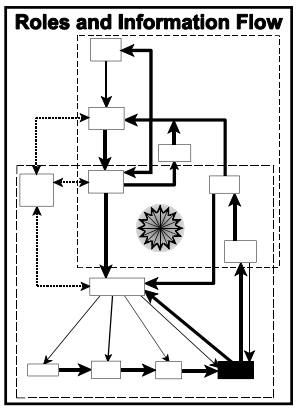

The **Data Transmitter** receives verified analytical data from the **Data Verifier**. The data must be electronically transmitted on a weekly basis, preferably as a comma delimited ASCII file attached to an E-mail, to the **National Database Manager** and the **Regional Monitoring Coordinator**.

5.11.2 Typical Role Player

Laboratory.

5.11.3 Tasks

Elapsed Time: <30 mins
Costing Time: < 30 mins
(per area)

Frequency: Supply the data to the **National Database Manager** and the **Regional Monitoring Coordinator** every two weeks if the transfer process is easy, otherwise on a monthly basis. It is important that data be transmitted regularly. If the **Regional Monitoring Coordinator** has the necessary expertise to play the role of the **Data Assessor,** data can be received directly from the **Data Transmitter** (and not via the **National Database Manager**).

Means of data transmission. The most important basic principle to bear in mind in respect of data transmission is that the amount of manual work (particularly repeated manual data entry) should be minimised. This will minimise the potential for mistakes (that can easily occur). Ideally, data should be entered manually only once.

If direct entry of the data into the IQWS Water Management System (WMS) is possible (*e.g.* using the interface Winterm), then this is preferable. If this is not possible, then data should be transmitted electronically as an E-mail attachment. A simple Excel spreadsheet interface is available from IWQS for this purpose. The interface performs a series of simple checks for obvious mistakes as the data are being entered.

If one does not have access to E-mail, it can be posted on a 3½" floppy disk to the **National Database Manager**. However, this is not ideal. There will be postal delays, it is more expensive and the risk of loss in the postal system is significant. It may also be possible to submit data on paper. Upon registration of the monitoring programme, the **National Database Manager** will provide the **Regional Monitoring Coordinator** with a schedule which will describe the format in which data should be transmitted.

Provision may be made in future for certain data transmitters (at perhaps the larger laboratories) to insert the data directly into the database via a direct line.

Data file type: If direct remote data entry is not possible, data should ideally be transmitted as the above Excel spreadsheet. Alternatively, the data can be transmitted as a Comma Delimited ASCII file. This can be produced by exporting a file of this type ("Saving As") from most spreadsheet software packages.

From Excel: Save As File Type: CSV (Comma delimited) (filename.csv)
From Quattro Pro: Save As File type: ASCII Text ("Comma delimited") (filename.txt)

Note, however, that commas in text strings can cause problems in comma delimited files. If they cannot be avoided, then rather produce a 'tab delimited' file.

If an electronic file is to be transmitted, *physically test the file* by sending it to the **National Database Manager** (and confirming receipt) to ensure that it can be read correctly.

5.12 DATA VERIFIER

5.12.1 Summary of Role

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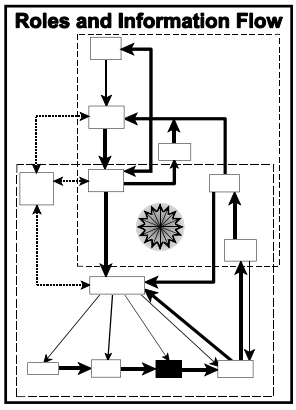

The **Data Verifier** receives analytical data from the **Analyst** every two weeks. This data includes sample site identification, faecal coliform counts, temperature, pH and turbidity. The data must be verified as "reasonable" and explanations must be found for unexpected results. Verification is then recorded as having been carried out. Verified data is then made available to the **Data Transmitter**.

5.12.2 Typical Role Player

Laboratory microbiologist with experience in the behaviour of faecal coliforms in environmental waters.

5.12.3 Tasks

Elapsed Time: <10 mins
Costing Time: < 10 mins (per area, possibly longer if unexpected results found)

The primary purpose of data verification is to ensure that the experimental measurements are not obviously wrong (*e.g.* are in the incorrect units). If the result is unexpected, an explanation must be found. Consider the following.

1. Previous trends;
2. High rainfall events (that may have resulted in a sudden increase in faecal coliforms);
3. Actions that may have been taken to minimise or contain the pollution source (that may have lowered the faecal coliform level);
4. The possible effects of any changes in temperature, pH and turbidity (see **Figure 4.2**).

5.13 ANALYST

5.13.1 Summary of Role

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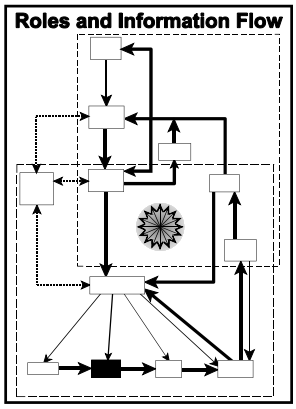

The **Analyst** receives samples from the **Sampler** at two-weekly intervals. The sample should be analysed for faecal coliforms, pH and turbidity. This data must be stored directly in the format that will ultimately be used by the **Data Transmitter** (prescribed by the **National Database Manager**). This is then made available to the **Data Verifier**.

5.13.2 Typical Role Player

Laboratory.

Elapsed Time: 24 hours
Costing Time: 1 hour
(10 samples, all analyses)

5.13.3 Tasks

5.13.3.1 Sample Preservation

Store samples at a temperature of less than 10EC (though not frozen). Analyse the sample within 24 hours of collection.

For more details ...

WRC, DWAF & DOH, 1999b

5.13.3.2 Faecal Coliform Analysis

The preferred method is the Faecal coliform membrane filter procedure. This uses commercial M-FC agar. Results are available within 24 hours. This is a well-described standard method.

For more details ...

Standard Methods, 1998
SABS method 221-1990
SABS method 221-1/1 NP (draft)

If the laboratory is not equipped to perform the membrane filter procedure or if the turbidity of the sample is high, the Faecal coliform MPN procedure can be used.

Report the result as Faecal coliforms/100 mR. Every effort should be made to report results as absolute counts, not using a 'greater than' symbol, >.

5.13.3.3 E. coli Analysis

E. coli should preferably be measured by the colilert method although other standard methods may also be used. However, if the laboratory does not measure *E. coli*, or does not have the resources to set this up, then faecal coliforms should be analysed, as described above

For more details ...

Standard Methods, 1998
SABS 241 Ed.5 2001

Report the result as *E. coli*,/100 mℝ. Every effort should be made to report results as absolute counts, not using a 'greater than' symbol, >.

5.13.3.4 Turbidity Analysis

Measure turbidity using the standard nephelometric method. Any apparatus based on this principle can be used. Report the result in nephelometric turbidity units (NTU).

For more details ...

Standard Methods, 1998

5.13.3.5 pH Measurement

Use a calibrated pH meter equipped with a temperature conversion device. Report in pH units.

For more details ...

Standard Methods, 1998

5.14 SAMPLER

5.14.1 Summary of Role

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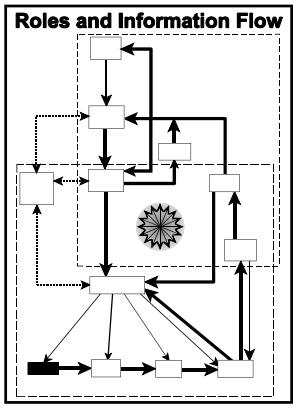


The **Sampler** physically travels to the designated sample sites at the required frequency (typically weekly), takes the samples in the specified way, marks the containers with the date and sample site identification and delivers the sample containers to the **Analyst** for analysis within 24 hours.

5.14.2 Typical Role Player

DWAF regional offices, laboratory, DOH environmental health officers, water board or local authority.

5.14.3 Tasks

5.14.3.1 Choice of Sample Containers

Wide-mouth glass or heat-resistant plastic bottles of a volume of at least 250 mℝ are ideal. The bottles and caps should not produce toxic or nutritional compounds when sterilised. Commercially available plastic bags intended for sterile sampling can also be used.

Clean all sample containers thoroughly and ensure that all traces of detergent are removed. Sterilise the containers in an autoclave at 121℃ for 15 minutes. Dry glassware can also be sterilised in a hot air oven at 170℃ for at least two hours.

For more details ...

Bordner and Winter, 1978
Standard Methods, 1998
WRC, DWAF & DOH, 1999a

5.14.3.2 Temperature Measurement

Measure the ambient water temperature in-stream at the sampling site.

5.14.3.3 Sampling Procedure

Elapsed Time: 1-8 hours
Costing Time: 1-8 hour

Samples could be collected either by hand or with a sampling device. A variety of sampling devices are available on the market and when used they should be operated according to the instructions of the manufacturer. Contact with the bank or stream bed should be avoided otherwise fouling of the sample may occur.

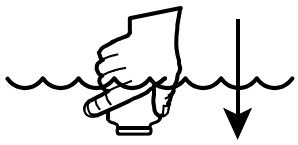
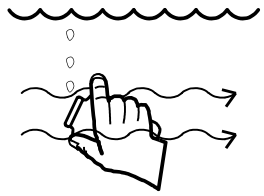
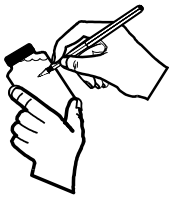
Sampling Procedure	
To take a grab sample by hand, hold the container close to the base with one hand (carefully avoiding touching the neck at all times) and plunge into the water with the mouth downwards. This avoids the introduction of surface scum into the sample. Take the usual precautions to avoid contact with skin.	
Point the submerged container towards the current or push to create a current if the water is static. Tilt the container slightly upwards to allow the air in the container to escape, and fill the container.	
If the water sample contains residual chlorine, add 1 mℝ of a 10% sodium thiosulphate solution for every litre of sample taken (Standard Methods, 1995).	
Ensure that an air space exists at the top of the sample before sealing the container with the stopper. This will allow the sample to be properly mixed before analysis.	
Fill in the necessary information on the tag on the container. Also, note the measured temperature.	
If the sample cannot be delivered to the **Analyst** and analysed within one hour after collection, store and transport the samples in iced coolers.	

Figure 5.1. Formal roles and information flow.
Figure 5.2. Role icons and information flow.

6. REFERENCES

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Appendix A:
National Water Act (Act No. 36 of 1998)
Chapter 14

(For the complete Act, see http://www.acts.co.za/ntl_water/index.htm)

CHAPTER 14

MONITORING, ASSESSMENT AND INFORMATION

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

Part 1: National monitoring systems

Establishment of national monitoring systems

137. (1) The Minister must establish national monitoring systems on water resources as soon as reasonably practicable.
(2) The systems must provide for the collection of appropriate data and information necessary to assess, among other matters -
(a) the quantity of water in the various water resources;
(b) the quality of water resources;
(c) the use of water resources;
(d) the rehabilitation of water resources;
(e) compliance with resource quality objectives;
(f) the health of aquatic ecosystems; and
(g) atmospheric conditions which may influence water resources.

Establishment of mechanisms to co-ordinate monitoring of water resources

137. The Minister must, after consultation with relevant -
(a) organs of state;
(b) water management institutions; and
(c) existing and potential users of water, establish mechanisms and procedures to co-ordinate the monitoring of water resources.

Part 2: National information systems on water resources

Part 2 requires the Minister, as soon as it is practicable to do so, to establish national information systems, each covering a different aspect of water resources, such as a national register of water use authorisations, or an information system on the quantity and quality of all water resources. The Minister may require any person to provide the Department with information prescribed by the Minister in regulations. In addition to its use by the Department and water management institutions, and subject to any limitations imposed by law, information in the national systems should be generally accessible for use by water users and the general public.

Establishment of national information systems

138. (1) The Minister must, as soon as reasonably practicable, establish national information systems regarding water resources.
(2) The information systems may include, among others -
(a) a hydrological information system;
(b) a water resource quality information system;
(c) a groundwater information system; and
(d) a register of water use authorisations.

Objectives of national information systems

139. The objectives of national information systems are -
(a) to store and provide data and information for the protection, sustainable use and

management of water resources;
(b) to provide information for the development and implementation of the national water resource strategy; and
(c) to provide information to water management institutions, water users and the public -
(i) for research and development;
(ii) for planning and environment impact assessments;
(iii) for public safety and disaster management; and
(iv) on the status of water resources.

Provision of information

141. The Minister may require in writing that any person must, within a reasonable given time or on a regular basis, provide the Department with any data, information, documents, samples or materials reasonably required for -
(a) the purposes of any national monitoring network or national information system; or
(b) the management and protection of water resources.

Access to information

142. Information contained in any national information system established in terms of this Chapter must be made available by the Minister, subject to any limitations imposed by law, and the payment of a reasonable charge determined by the Minister.

Regulations for monitoring, assessment and information

143. The Minister may make regulations prescribing -
(a) guidelines, procedures, standards and methods for monitoring; and
(b) the nature, type, time period and format of data to be submitted in terms of this Chapter.

Part 3: Information on floodlines, floods and droughts

Part 3 requires certain information relating to floods, droughts and potential risks to be made available to the public. Township layout plans must indicate a specific floodline. Water management institutions must use the most appropriate means to inform the public about anticipated floods, droughts or risks posed by water quality, the failure of any dam or any other waterworks or any other related matter. The Minister may establish early warning systems to anticipate such events.

Floodlines on plans for establishment of townships

144. For the purposes of ensuring that all persons who might be affected have access to information regarding potential flood hazards, no person may establish a township unless the layout plan shows, in a form acceptable to the local authority concerned, lines indicating the maximum level likely to be reached by floodwaters on average once in every 100 years.

Duty to make information available to public

145. (1) A water management institution must, at its own expense, make information at its disposal available to the public in an appropriate manner, in respect of -
(a) a flood which has occurred or which is likely to occur;
(b) a drought which has occurred or which is likely to occur;
(c) a waterwork which might fail or has failed, if the failure might endanger life or property;
(d) any risk posed by any dam;
(e) levels likely to be reached by floodwaters from time to time;
(f) any risk posed by the quality of any water to life, health or property; and
(g) any matter connected with water or water resources, which the public needs to know.
(2) The Minister may, where reasonably practicable, establish an early warning system in relation to the events contemplated in subsection (1).