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Resource Directed Management of Water Quality

MANAGEMENT INSTRUMENTS

Volume 4.3

Guideline on Monitoring & Auditing for Resource Directed Management of Water Quality

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PROLOGUE

MAKING MONITORING WORK FOR YOU

The core problem

In casual conversation, most managers readily agree that water resource monitoring is important. However, when faced with real human or financial resource constraints, some of those managers will all too readily sacrifice monitoring in favour of some other activity, at least to some extent.

It would appear that some managers think they are supposed to say that monitoring is important (perhaps because they have been told it often enough). However, the evidence suggests that, deep down, they are unconvinced. Apparently, the advantages just don't seem that advantageous.

Why monitoring gets a raw deal

Some honest reflection on what is generally important to managers (and perhaps politicians, who managers need to be seen to be aligned with) suggests the following factors may play a role (not in any particular order). An assessment is also made as to whether they work for or against water resource monitoring.

- **Legislation and policy**. Not aligning oneself to existing legislation and/or policy can often boil down to, at least, not following due process or, at worst, simply breaking the law. Managers cannot afford this. Their jobs are at stake. The National Water Act (36:1998) requires monitoring of water resources. It has to be done. This is definitely "for monitoring". However, the real issue is the extent of monitoring required to satisfy the requirements of the Act. The Act is not clear on this. So while "legislation and policy" are perceived as important, the lack of clarity does not focus monitoring practices. (*The Act is for, but the vagueness is against, monitoring*.)
- **The need for simple rules and procedures**. When much of your time is spent "fire fighting", it seems unfair that you are expected to think as well. Simple rules and procedures are great once a monitoring programme is up and running. But designing is simply not simple. It often requires specialist input to really get it right. (*On balance, against monitoring*).
- **Affordability**. Nobody doubts that, in the end, information has to be paid for. When budgets are tight, compromises are inevitable. And monitoring can be expensive. "Value for money" is often low compared with many of the other kinds of information that are important to managers (political, social, economic, legal, administrative, and so on). (*Against monitoring*.)
- **Avoiding "egg on face"**. Nobody, especially managers and politicians, can afford to look inadequate. Can monitoring help to avoid "egg on face"? In some circumstances, yes (like preventing you confronting a water user about high fluoride or nitrate in the water when it is actually naturally high because of the local geology). In others, it may cause it (like when it exposes your own inadequate water resource management). (*For or against monitoring*.)
- **Having sound scientific/technical information**. Such information is useful. For example, managers and politicians can quote impressive facts that convey powerful messages ("quotable information"). But data assessments must not only be done soundly, they must communicate effectively. If they do not, the monitoring will be perceived to be useless. (*Largely for monitoring, if communicated effectively*.)

In summary, water resource monitoring can be difficult to design, and, even if you get it right, can expose inadequate management (i.e. cause "egg on face"), is almost always relatively expensive, and can sometimes be difficult to interpret. And, no matter what monitoring you are doing, it is easy to justify as implementing the Act.

It is not surprising that monitoring often gets a "raw deal" and doesn't achieve its full potential.

The positive perspective: Knowledge is power

One can turn the above factors around and use monitoring to one's advantage. The following are some examples.

- What you want to achieve in your water resources should intimately determine how water users are managed. Some water users have a very sophisticated knowledge of water quality. Managers have to negotiate face-to-face with such water users. Monitoring can provide both parties with a sound understanding of the current status and trends of the resource. The manager will be seen to be competent. He/she can negotiate more effectively from this position of knowledge.

> *"Knowledge itself is power"*
> Francis Bacon (1561-1626)

- As an aside, it may be tempting to use the precautionary principle when knowledge of the behaviour of a resource is lacking (*e.g.* because you haven't done enough monitoring). However, applying it is usually subjective and therefore prone to debate and dispute. This is not a position of power. It can also place unnecessary and sometimes unfair demands on water users. Monitoring could avoid this.
- On the other hand, the vast majority of water users will not be sophisticated. In a spirit of transparent governance, the Department or CMA has a responsibility to ensure that such users are suitably informed. To do this, managers must understand the behaviour of the water resource themselves. This can be achieved through effective monitoring.

> *"Honesty is the best policy"*
> R Whately (1787-1863)

- Some might argue that, in the long-term, the single most important principle of good governance is transparency. Being seen to be transferring knowledge (based on sound monitoring) in an honest and open manner could be a powerful positive basis for participatory water resource management. Specifically, this can lay the groundwork for the establishment of catchment management agencies.
- The current political climate demands implementation and service delivery. Prominent government officials are being held more accountable for their actions (or inaction, as the case may be). Monitoring is one powerful way of quantitatively demonstrating effective service delivery.

> *"Knowledge may give weight, but accomplishments give lustre,*
> *and many more people see than weigh"*
> PD Stanhope (1694-1773)

- Conscientious managers can use monitoring to quantify and prioritise the real problems. Annual budgeting will be more focused, be seen to be more cost-effective, and therefore more powerfully motivated.
- The greater the depth of knowledge about what lies behind a monitoring report (even an individual datum point), the more sensibly a manager can use that report (or datum). Getting into the field is not only good fun and stimulating. Seeing the samples being taken, experiencing the difficulties first hand, as well as understanding laboratory quality control and statistical analysis (and its flaws and assumptions), all provide powerful insights into monitoring that cannot be obtained in any other way.

- Much pressure is being placed on the Department and CMA to indicate whether or not they are “moving towards sustainable development”. To many, these requests remain vague and difficult to answer and can therefore be ignored as futile wish-lists. However, monitoring specific variables (or indicators) can provide an insightful way of understanding how a resource is changing over time or beyond its limits – ultimately providing a clearer picture of its sustainability into the future.

But don't ignore the problems

More detailed guidance is necessary on precisely what monitoring should be achieving in South Africa. High-level thinking is going on in the Department (5-year resource quality monitoring plans and strategic frameworks). These need to link clearly with detailed monitoring designs, the individual needs of managers and water users, and more especially, a sound supporting institutional environment.

With a little careful thought, the costs of monitoring can be minimised:

- Designers should (a) be as clear as possible about what the managers really need, and (b) think creatively to maximise information while minimising costs.
- Monitoring results do not always need to be reported with very high certainty. Compromising certainty can often greatly reduce costs. Situations in which this is acceptable should be identified and the uncertainty reported. As long as the manager (a) understands that there is uncertainty, and (b) knows (preferably quantitatively) what this uncertainty is, the manager is able to make informed decisions.
- Sampling costs (of visiting monitoring sites on a regular basis) often contribute significantly to overall costs. Making sure that, where appropriate, sampling costs are shared with other programmes that sample at the same monitoring site can significantly reduce costs. However, be careful that sharing such resources does not compromise, in any significant way, the ability of the programme to achieve its own objectives.

Acquiring the data is only half the battle. Assessing it so that it addresses real needs is usually not trivial. In essence, data assessment and reporting must:

Keep it simple. Keep it sound. Keep it significant.

Conclusion

Some (though not all) perceive that monitoring does not give value for money. This has worked against monitoring. However, when properly implemented, monitoring provides tremendous power. This power can be brought to bear in:

- Negotiations (inside and outside the Department);
- Facilitating effective stakeholder engagement (transparency, in particular, being a significant "force for good");
- Demonstrating successes (service delivery); and
- Motivating budgets.

But it will not all be plain sailing. There are problems and they must be addressed explicitly. If any one issue stands out - it is that designers must focus explicitly on minimising costs, paying particular attention to the relationship between costs and uncertainty.

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ACRONYMS

CMA	Catchment Management Agencies
DEAT	Department of Environmental Affairs & Tourism
DPSIR	Driving force-Pressure-State-Impact-Response
DWAF	Department of Water Affairs & Forestry
ISO	International Standards Organisation
NEMP	National Eutrophication Monitoring Programme
NWA (36:1998)	National Water Act
POPs	Persistent Organic Pollutants
PSIR	Pressure-State-Impact-Response
PSPs	Professional Service Providers
RDM	Resource Directed Measure
RDMWQ	Resource Directed Management of Water Quality
RQO	Resource Quality Objective
RWQO	Resource Water Quality Objective
SDC	Source Directed Control
SoE	State of Environment
WARMS	Water Authorisation and Registration Management System
WMA	Water Management Area
WMS	Water Management System
WRC	Water Research Commission

SECTION 1: INTRODUCTION

PHOTO: K MURRAY

The purpose of this document is to provide general guidance for designing monitoring programmes related to resource water quality which collectively ensure useful statements can be made about the water quality in water resources and sustainable development.

1.1 Goal and objectives

Target audience

This document is aimed at the following people:

- Managers who are responsible for national planning related to water quality monitoring (so that they may understand just what it takes to do it effectively);
- Regional managers who are directly responsible for water quality monitoring (so that they may better understand how to make the most of the information derived from monitoring); and

Those who actually do the monitoring (so that they may better understand the bigger picture).

Management tool

This document provides guidelines for the monitoring that is required for resource directed management of water quality. It is one of many essential management tools required to implement the resource directed management of water quality strategy (DWAF, 2005a). The strategy, in turn, is aimed primarily at implementing the resource directed management of water quality policy ("the Policy") (DWAF, 2005b).

Regional perspective

Although there are top-down Departmental initiatives (described below), there is also a desperate need for better direction, standardisation and integration at a regional level. This document deliberately takes a regional bottom-up perspective with the intention that this will constructively feed into the top-down initiatives.

Policy vision

In its simplest sense, monitoring should be seen as measuring progress in order to provide useful management information. In the current context of resource directed management of water quality, this specifically means measuring the progress towards the ultimate vision of effective water quality management. The vision of the Policy is to ensure that "*the water quality in South African water resources enables an equitable and sustainable balance to be achieved between its use by society and its protection as a critical component of a natural system so that the quality of life of all South Africans is improved and sustained in the long-term*". Since the current context is "resource directed", the focus is on how this can be done through giving effect to resource directed measures (RDM).

Objectives

The monitoring related to resource directed management of water quality is focussed primarily on the spatial scale of water management areas. The objectives are as follows:

Objectives of monitoring for Resource Directed Management of Water Quality

To measure, assess and report on a regular basis the status and trends broadly relating to water quality in water resources, and their management, in a manner that will support balanced decision-making and planning in the contexts of fitness for use and aquatic ecosystem integrity, in the Catchment Management Agency's quest to promote sustainable development.

1.2 Sustainable development

Sustainable development

Sustainable development is defined in the resource directed management of water quality policy ("the Policy") (DWAF, 2005b) as follows:

"*Sustainable development endeavours to ensure that future generations can meet their own basic water needs while promoting socio-economic development and improved quality of life for all in the current generation. This should be done in a manner that uses water resources in general, and water quality in particular, within the ability of the ecosystems to satisfy such needs now and in the future.*"

The Policy also notes six enabling principles:

- Protection of water resources.
- Optimal water use.
- Equity between generations.
- Current equitable access.
- Environmental integration.
- Good governance.

Resource management class

In specific situations there may be some degree of tension (if not conflict) between the principles (typically between protection of water resources and optimal water use or current equitable access). One of the tasks of a water resource manager is to balance these in an equitable way. First and foremost, this is done by designating, attaining and then sustaining a resource management class. This class is intended to reflect the optimum balance between the above principles.

> ***The resource management class is the "first line of defence" against development that is not sustainable. In particular, it balances the way that a water resource is used with an appropriate degree of protection of that resource.***

Need for more than resource quality objectives

Resource quality objectives (RQOs) and Resource Water Quality Objectives (RWQOs) are the most important management objectives against which monitoring data will be assessed. This will indicate whether the management class is being maintained. In general, RQOs will be the most important sustainability indicators for water resource management. **However, they will not necessarily provide all the information required for holistic management.** For example, on what should water resource management and the associated source management (including corrective actions) be based if the RQOs are not being achieved? They can only be based on a broader knowledge of the water resource, including the following (neither of which is addressed by RQOs):

- Information on what might be causing the problems. This helps focus source directed controls.
- Information on the nature and extent of the impacts of inadequate water quality (not only on other components of the water resource, like biota, but also on socio-economic enhancement). This facilitates cost-effectiveness by enabling sensible priorities to be set.

> ***Managers will need more holistic information than just resource quality to properly manage (a) the resource, (b) those impacting on the resource, and (c) those impacted by the resource.***

Environmental integration

This will also demonstrate the application of the "environmental integration" principle enabling sustainable development.

Besides these more practical management objectives, in order for the Department to demonstrate it is striving for sustainable development, it is important that the principle of "environmental integration" be applied. In the current water quality context, this requires consideration of all possible interactions with, and within, ecosystems and water quality in particular. Achieving the above objectives will therefore necessarily include monitoring, or at least an understanding, of:

- Causes of inadequate water quality.
- Actual water quality.
- Impacts of inadequate water quality.
- Decisive societal responses to inadequate water quality.
- Water quality management performance.

RDM and SDC

This is well aligned with the concept that the resource directed measures (RDM) determine the most appropriate source directed controls (SDC). Monitoring the water quality and the impacts of water quality on the water resource provide information on the most appropriate RDM. These determine the best SDC that relate to the causes of deteriorating water quality.

Monitoring in the even broader context of impacts on social and economic development, and associated societal responses, completes the "environmental integration" necessary to facilitate sustainable development.

1.3 Guiding principles for monitoring

The Policy

The principles that guide the manner in which monitoring is carried out are described in the Policy (DWAF, 2005b). They are listed here for convenience. Readers are particularly encouraged to examine all the enabling principles of sustainable development in the Policy. The monitoring described herein is intended ultimately to facilitate sustainable development. The long-term vision is to include elements of the biophysical, social and economic systems.

Relevant principles

- Sustainable development (enabled by protection of water resources, optimal water use, equity between generations, current equitable access, environmental integration and good governance);
- Adaptive management;
- Sound financial management;
- Prudent pragmatism; and
- General legislative alignment.

1.4 Document guide

Table 1.1: Quick reference guide to using this document.

If you want to …	Then …
Concentrate on water quality monitoring that is **relevant now and in the immediate future**	*Go to* Section 3: *Designing a water quality monitoring programme.*
See a **future vision** for monitoring	*Go to* Section 4: *A monitoring vision: Beyond water quality.*
Understand the necessary **supporting environment** for successful regional monitoring	*Go to* Section 2: *Institutional environment.*
See the **overall process** for designing a water quality monitoring programme	*Go to* Section 3.2.1: *Overall design process*.
Understand what **design documentation** is important (and see a suggested structure)	*Go to* Section 3.2.2: *Documentation*.
Get general advice on **how to monitor effectively** (no matter what specific water quality programme you may be designing)	*Go to* Section 3.2: *How to be effective*.
See some **suggested designs** for regional water quality monitoring	*Go to* Section 3.3: *Designing for the immediate future.*
Understand how this all connects with **sustainable development**	*Go to* Section 1.2: *Sustainable development, and* *Go to* Section 4.2: *The PSIR framework and sustainable development.*
See the overall **implementation strategy** once a programme is designed.	*Go to* Section 3.2.7: *Implementation strategy (making the plan reality)*.
See **definitions** of some technical terms	*Go to* Section 6: *Glossary*.

SECTION 2: INSTITUTIONAL ENVIRONMENT

2.1 Introduction

Crippling constraints

Without an institutional environment that is appropriately focused on supporting regional monitoring, effective monitoring is impossible. No degree of wishful thinking or careful scientific design can overcome the crippling constraints of inadequate human capacity and lack of a common vision of the future. The following sections briefly examine the Department's top-down vision and how this might be constructively influenced from the bottom-up.

An effective institutional environment that truly supports water quality monitoring is essential.

It is the most important current priority.

2.2 Important Departmental initiatives

2.2.1 5-year water resources quality monitoring plan

Goal and objectives

A document exists that is intended to inform management within the Department of a 5-year plan for resource quality monitoring (DWAF, 2004a). The overall goal is to achieve "an effective and efficient national information service". This entails achieving:

- User focus and value for money.
- Ease of access for users (one point of entry).
- One version of the truth (no duplication).
- Sharing of data acquisition and management.
- Integrated information systems (as far as is realistically possible).
- Appropriate capacity (expanded and multi-skilled capacity).

Key interventions

The following interventions have been identified to achieve the overall goal:

- *Umbrella programme*. Probably based on the objectives of the "US Water Information Co-ordination Programme".
- *Monitoring governance model*. There is a pressing need for clear governance structures and processes.
- *Integrated monitoring plans for each water management area (WMA)*.
- *Business plans for individual programmes*. A business approach to monitoring has become essential.
- *Water use monitoring feasibility study*. If feasible, this should be followed by a business plan.
- *Aquatic ecosystem health monitoring business plan*. This should also address how it can contribute to ecological Reserve monitoring.

- *Guidelines and standards for all levels*. Chapter 14 of the National Water Act mandates the development of guidelines and standards needs to be formalised and coordinated. This can form the basis of sharing of monitoring actions and outsourcing.
- *Development of auditing responsibility*. Water resources monitoring will be a major business process. This will require auditing. It has been suggested that ISO 9002 quality control system may suffice.
- *Scoping of technology for monitoring*. This is important given the growing importance of monitoring and the number of stakeholders.
- *Cost-benefit analysis for monitoring*. This should address the uncertainty that exists regarding the overall investment required by monitoring, including the degree of delegation and outsourcing.
- *Convergence of Information Technology systems*. These include HYDSTRA (surface water), NGA/REGIS (groundwater), WMS (water quality), GIS (spatial) and WARMS (Water Authorisation and Registration Management System).
- *Capacity building for monitoring*. Capacity creation required to meet the overall goal is seen as the most significant bottleneck, particularly in the Regions. The FETWATER programme could play an important role.
- *Pilot implementation*. To test the practicality of the overall 5-year plan, full rollout in one pilot area is seen as important.

2.2.2 National reporting system

Formalised national reporting system

A critically important aspect of effective monitoring is information generation and dissemination. The dissemination (*e.g.* reporting) explicitly exposes the target users to the results of the monitoring. The very wide variety of monitoring that currently occurs, and that will occur in South Africa in future, and the fact that the Department produces over 70 reports annually, has prompted the development of guidelines for reporting on the status of the South African water sector (DWAF, 2004c). The slogan of the Water Sector Report is proposed to be "*ensuring sustainable water use and water resource protection*".

Considerations

Work on a conceptual design for a national reporting system to facilitate the production of such a report has started and has been based on the following considerations:

- A regularly updated inventory of required reports.
- An agreed framework for each report.
- An agreed set of indicators for each report.
- Identified line functionaries who are responsible for policy, key performance areas, etc., and for ensuring appropriate monitoring is taking place, which measures performance of their functional area against the set indicator.
- Regular contributions by a water sector "think tank" or strategic planning team, with representation from relevant line functions and sector role players (e.g. agriculture, health, energy, environment, local government).
- A depository for standardised inputs that can be shared by various reports.

Indicator development

The following framework has been suggested for choosing monitoring indicators:

- *Factual indicators.* These describe the current status.
- *Policy and strategy objectives indicators*. These address the situation described by the factual indicators.
- *Policy and strategy implementation indicators*. These are associated with licensing, meeting of targets for compliance, resources allocated and performance.
- *Outcome indicators.* These address how policy, strategy or programmes address identified issues.

2.3 Resource quality monitoring strategic framework

Strategic framework

A strategic framework has been compiled specifically for national resource quality monitoring programmes (DWAF, 2004b). The framework emphasises the necessity for monitoring programmes to deliver useful information to water resource managers, planners and other stakeholders.

Hierarchy of information requirements

Information requirements can vary considerably. They depend on, among other factors, the spatial scale of interest (*e.g.* as illustrated in Figure 2.1).

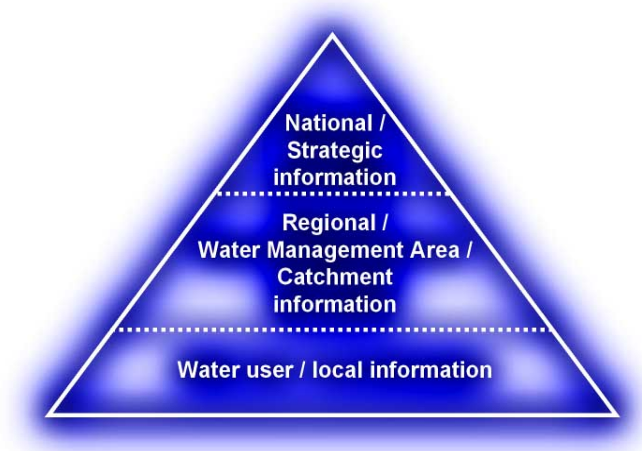

Figure 2.1: Hierarchy of information requirements for water resource management.

Principle components

The strategic framework identifies three principle functional components of a monitoring programme:

- Data acquisition.
- Data storage and management.
- Information generation and dissemination.

These should be seen as the more technical aspects, all of which fall within an overall management component that is required for successful implementation.

Portfolios of programmes

The framework also identifies a number of portfolios of programmes based on the responsible institution:

- Department of Water Affairs and Forestry (DWAF): DWAF Policy and Regulation will typically take responsibility for "national" programmes with strategic objectives.
- Catchment Management Agency (CMA): CMAs will implement programmes focussed on water resource management within their water management areas.
- Local water users: These are typically compliance or impact assessment monitoring programmes, and relate to source directed controls.

2.4 A supporting environment: a regional perspective

2.4.1 Introduction

Bottom-up

The above 5-year plan, reporting framework and strategic framework comprise the current top-down perspective. Although admirable, regional offices are not currently operating in an institutional environment that is adequately supportive for sound water quality monitoring. Even with a perfectly scientifically designed monitoring programme, it is doomed to failure if adequate institutional support is not provided. The following are some of the critical issues required to facilitate the creation of an appropriate supporting environment.

2.4.2 Financial support

Communicate clear objectives

Regional monitoring budget proposals should keep the following in mind:

- Ensure monitoring objectives are clear and relevant.
- Understand and communicate the "value for money" of monitoring.
- Ensure the most cost-effective budget is proposed.

2.4.3 Cost-effectiveness

Optimum use of resources

Optimising the use of resources is easy to say, but is often difficult to achieve. It requires careful thought about all aspects of the resources being used and exactly how these help to achieve monitoring objectives.

- Examine previous budgets and identify those tasks that were most expensive. Look for ways in which these can be made more cost-effective.
- Use local knowledge. Rely heavily on local people, inside and outside the Department, for advice on how best to optimise activities.
- Integrate with other existing monitoring programmes (as long as your own objectives are not compromised). Consider especially linking up with the national monitoring programmes that have, because of their national scale, been designed with cost-effectiveness in mind.
- Consider carefully the degree of confidence you require in your monitoring assessments. Compromising on confidence may often be quite acceptable and result in enormous savings.

2.4.4 Human resource management

Career building

Career building among those involved in monitoring addresses a critical requirement of all monitoring, namely continuity. Lack of continuity can lead to, at least, inconsistencies in procedures and, at worst, missing data. These play havoc with data assessments and obviously can seriously compromise achieving the monitoring objectives. Staff turnover also places enormous pressures on more experienced staff and others who are responsible for training.

Dedicated posts

Dedicated posts concentrating on monitoring can also greatly increase overall effectiveness. This provides for depth rather than breadth.

Incentives and rewards

One aspect of career building can be provision of rewards for outstanding work. People with pride in their work are likely to go that extra mile (for themselves and the Department/CMA). For some further thoughts on a rewards system see the Chapter: The Business of Monitoring in the National Eutrophication Monitoring Programme Implementation Manual (DWAF, 2002).

Mentorship

Continuity in monitoring can be significantly affected when an experienced person leaves. Mentorship programmes for new staff can greatly mitigate this, and generally facilitate sound knowledge transfer.

Training of local service providers

Training should go beyond Departmental/CMA staff to include appropriate local professional service providers (PSPs). All of these PSPs should be accredited and then used effectively so that they maintain a sufficiently high standard.

Analytical continuity

Continuity in the analytical laboratories used can be important. Besides the administrative demands of tendering and appointing new laboratories, changes in analytical methods (and quality control) that may result can cause step changes in the measured data that can confuse and confound data assessments.

2.4.5 Data management

Water Management System

The Water Management System (WMS) is the Department's designated central database for water quality data. The existence of a centralised user-friendly data management system is a critically important supporting function for effective water quality monitoring. For it to be effective, it must be remotely accessible both for data capture and retrieval (for assessment and reporting). The resources required for these two tasks should not be underestimated. Specialist posts should be created for these purposes.

Every effort should be made to increase the pace at which convenient access to WMS is achieved. If this is not achieved, data management will remain fragmented, non-standard and inefficient, and water quality monitoring will never reach its full potential.

SECTION 3: DESIGNING A WATER QUALITY MONITORING PROGRAMME

3.1 Introduction

Assumption that supporting environment exists

This and subsequent sections address the technical and scientific aspects of water quality monitoring design. It is assumed that the institutional supporting environment is in place. As noted above, if this is not the case, then these sections will be rather academic.

These sections assume that a reasonable institutional supporting environment is in place.

Effective monitoring is not easy

Monitoring "effectively" (*i.e.* producing the greatest amount of information that is genuinely useful to water resource managers for minimum cost) is not easy. Some might argue that even doing ineffective monitoring is difficult.

Careful design

Monitoring requires careful upfront thinking ("design"). This must focus attention primarily on what water resource managers really need. It must then focus on the most cost-effective way to provide that information.

The following sub-sections make a series of recommendations that aim to ensure that water quality monitoring is effective.

3.2 How to be effective

3.2.1 Overall design process

Need for holistic thinking

Figure 3.1 shows the steps of the ideal process for designing a water quality monitoring programme. Note that although the process is indicated as a series of sequential steps, at each step one must simultaneously consider all subsequent steps as well. For example, when deciding on the monitoring variables, also think about the frequency of monitoring, where samples will be taken, through to how the results will best be reported (graphically, in tables, etc.).

Design first and then, only if appropriate, integrate with other existing monitoring programmes later. This ensures that your design and implementation remains focused on your objectives. (Other programmes may not be implemented in the best way for your objectives.)

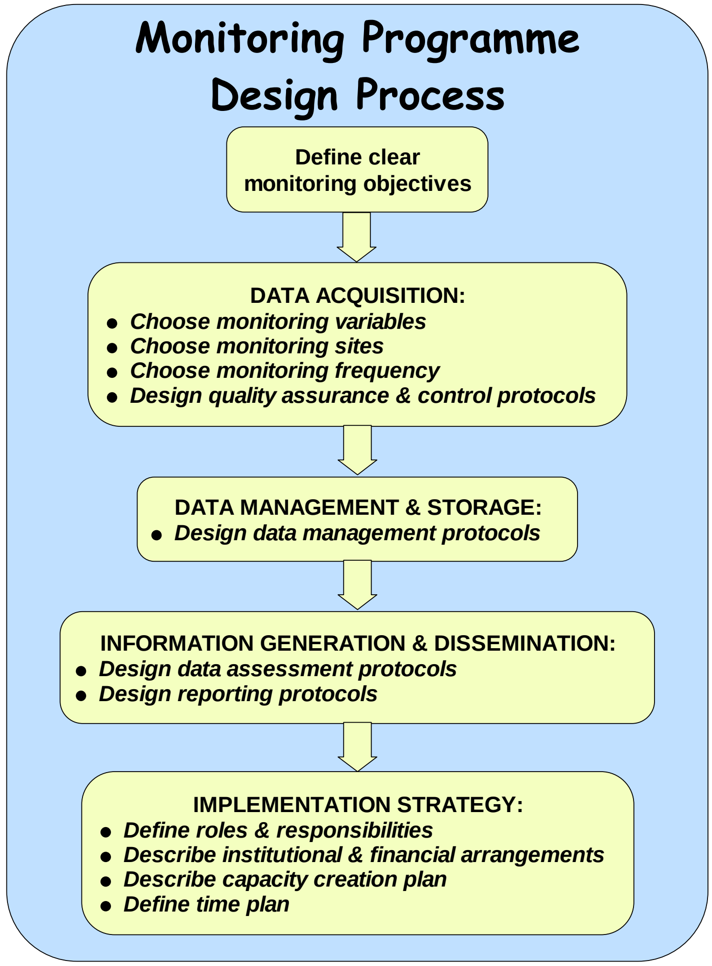

Figure 3.1: Generic monitoring programme design process.

Guidelines

The Departmental document on monitoring (DWAF, 2004d) should be consulted for some more detailed recommendations on monitoring design (including sampling procedures).

3.2.2 Documentation

Accountability

A wide variety of people is likely to be involved in a programme for monitoring water quality. These vary from samplers, analytical staff, data management staff, through to the managers that receive the monitoring reports. The roles and responsibilities of each need to be defined and well coordinated to ensure cost-effectiveness. Documenting the design of the programme helps to ensure that everyone is (a) working towards a common purpose, and (b) knows what he/she is accountable for (*i.e.* what needs to be done).

Thinking ahead

The effectiveness of any initial design needs to be assessed at periodic intervals so that improvements can be imposed. Under these circumstances, it is important to have on record why the particular initial design was chosen in the first place.

How to do it versus why to do it

The design of a monitoring programme should deliver two reports:

- *Implementation manual.* This should describe how the programme will be implemented.
- *"Record of decision" report*. This records why certain monitoring design decisions were taken. For example, why the chosen variables were selected, why the monitoring sites were selected in the way they were, and why the chosen monitoring frequency was selected.

The structure of the record of decision report will depend on the nature of the decisions taken. However, sections could simply correspond to those in the implementation manual, a possible structure for which is given below. The section on monitoring objectives should include a thorough analysis of information requirements of those for whom the monitoring reports are intended. (In certain circumstances some of the proposed sections may not be relevant).

Excessive detail is not necessary.

Simply record the most important factors.

Manual title

For water quality programmes the following general title could be used:

**WATER QUALITY MONITORING PROGRAMME:
IMPLEMENTATION MANUAL
(UPPER VAAL WATER MANAGEMENT AREA)**

Proposed structure

INTRODUCTION
- Need for monitoring
- Stakeholders
- Monitoring objectives

MONITORING FRAMEWORK
- Monitoring variables/indicators
- Monitoring site selection
- Monitoring frequency
- Sampling procedures
  - Equipment
  - Sampling protocol
  - Sample preparation
  - Sample delivery and analysis
- Data management
- Data assessment and reporting
- Quality assurance and quality control

IMPLEMENTATION STRATEGY
- Roles and responsibilities
  - Monitoring Coordinator
  - External stakeholders
  - Analysts
  - Samplers
- Institutional and financial arrangements
- Capacity creation plan
- Implementation time plan
- Review

3.2.3 Monitoring objectives

Objectives = why (not how)

Objectives of a monitoring programme should be summarised in one or two sentences. Objectives should describe why (not how) the monitoring will be done. For example:

***Objectives of impact & licence compliance monitoring*: To measure, assess and report on a regular basis the degree to which individual water users are (a) complying with the "end-of-pipe" conditions defined in their water use licence (if any), and (b) impacting on the local water resource water quality.**

The objectives must be considered explicitly at every step in the design process.

Monitoring is usually expensive. Sampling and laboratory analysis will often account for the greatest costs. Well-defined objectives maximise cost-effectiveness.

Generic objectives are proposed below for various kinds of regional monitoring (section 1.3.3).

3.2.4 Data acquisition (collecting the data)

Water quality variables

The water quality variables are those attributes that change over time and space, and whose measurement provides some of the raw data upon which the assessment and reporting of the monitoring programme is based.

Importantly, the monitoring variables chosen must be genuinely useful to managers. As a simple test answer the following question (truthfully):

"Why do I want to know what value that variable has (or how that variable is changing)?"

This forces one to consider how one might interpret monitoring data and, in particular, assess the benefits of monitoring against the costs. See Figure G3 for lists of some of the factors that should be considered.

The following are some particular points:

- *Be relevant.* Choose variables that are relevant to the local or regional situation and the monitoring objectives. For example, choose variables that are being impacted on by water users (e.g. sulphate or pH in the case of coal mines). If there are important ecosystems that need protection, choose variables upon which that ecosystem's integrity depends (e.g. dissolved oxygen).
- *Think beyond chemical variables*. Remember that chemical variables are not the only variables of importance. If human health is an issue (e.g. water may be used directly from the resource for domestic use), then include microbiological variables (such as *E. coli*, which is an internationally used indicator of faecal pollution).
- *Consider toxicity tests.* In certain special circumstances where toxic substances are suspected or known to be discharged into a resource, consider using toxicity tests on organisms like fish, Daphnia (an invertebrate) or even algae. Get advice from an aquatic toxicologist.

- *Make sure there are guidelines.* There must be guidelines or criteria (such as the South African Water Quality Guidelines (DWAF, 2001), RQOs or RWQOs, effluent targets, standards, etc.) available against which measurements can be assessed. If this is not the case, it will be difficult to know how "good" or "bad" a measurement is.

Complex ecological systems are usually driven by only a handful of factors. Water users are also typically heavily dependent on only a few critical parameters.
The challenge is to find out what these are.
For water quality, do your best to identify those variables.
These should be your "essential" list.

Further reading: Roux DJ, PL Kempster, CJ Kleynhans, HR van Vliet and HH du Preez 1999. Integrating stressor and response monitoring into a resource-based water quality assessment framework. *Environmental Management*, **23**(1): 15-30.

Monitoring sites

When selecting monitoring sites, there are macro considerations (large spatial scale) and micro considerations (local scale) (see Figure 3.2). The macro factors depend heavily on the chosen objectives of the programme. The micro considerations refer to precisely where the sample will be taken:

- *Health and safety.* Sites must be chosen that ensure that samplers are safe from any danger, such as wild animals and even hijackings.
- *Accessibility.* Inaccessible monitoring sites (e.g. chosen from a map without on-site inspection of accessibility) may not only be dangerous or impossible to reach, but they may make the sampling round very time-consuming and expensive.
- *Spatial correlation.* Ensure that monitoring sites are not located so close to each other that the way in which water quality changes at one site is closely related to how it changes at an adjacent site. If this happens, the water quality at the two sites is "correlated" and, as such, can waste valuable resources and compromise the quality of the data for statistical analyses.
- *Mixing zone.* Samples must be taken well beyond the mixing zone that is located immediately downstream of a known or suspected pollution source, to ensure that samples are representative of the water resource. For a practical procedure to establish the extent of the mixing zone in a river see USEPA (1991).
- *Existing monitoring sites*. Sites at which sampling already takes place (for other monitoring programmes) may allow sharing of sampling resources and hence greater cost-effectiveness. However, these sites must be situated in locations that enable the objective of the current monitoring programme to be achieved.

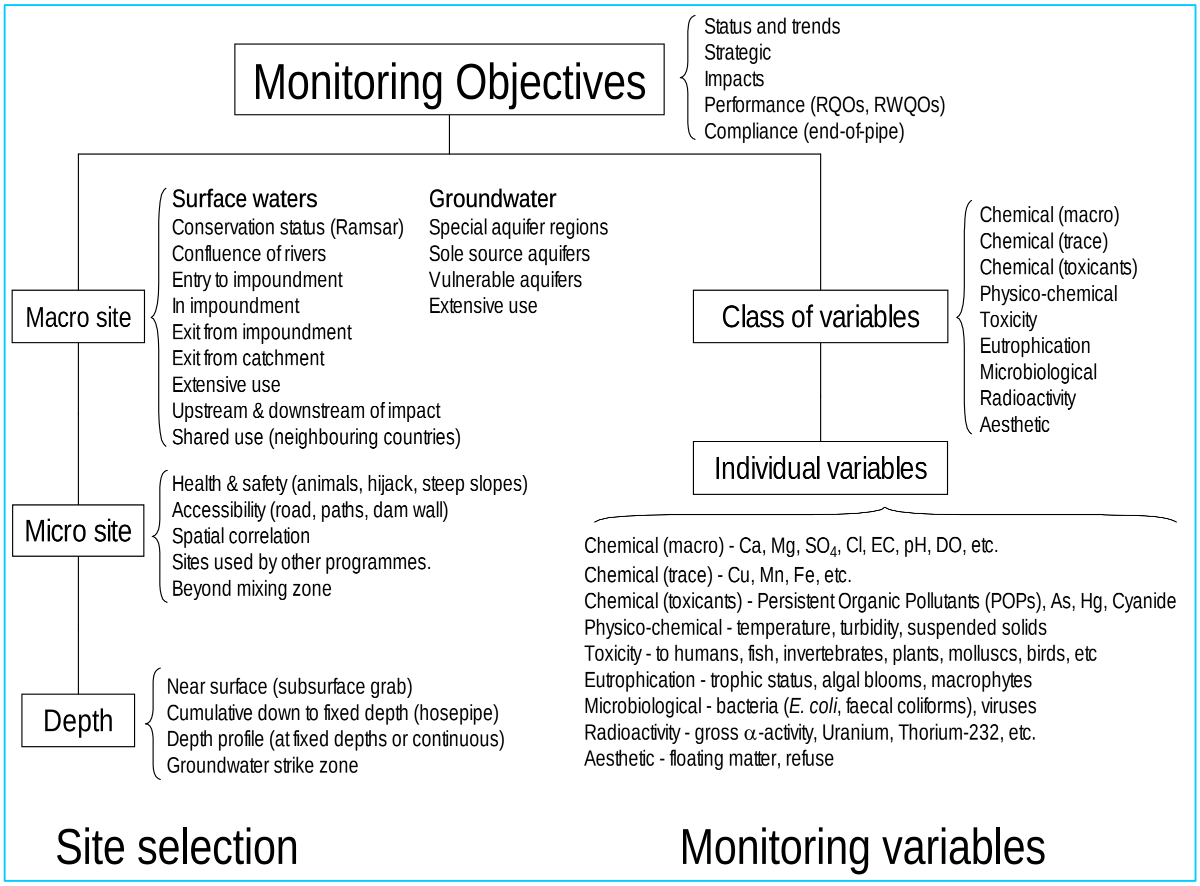

Figure 3.2: Some site selection and monitoring variable factors to be considered.

Monitoring frequency

The following tend to <u>increase</u> the monitoring frequency (*i.e.* decrease the time between successive sampling trips):

- *High random experimental variability.* The greater the random (unavoidable) variability in the experimental techniques (from sampling to analysis), the higher the frequency may need to be.
- *High natural variability.* Natural changes in the water quality attribute being monitored also result in variability. If this is high, and such changes as seasonality cannot be removed from the data, increased frequencies are also likely. Water quality changes in groundwater usually occur relatively slowly so less frequent monitoring is acceptable.

The following factors tend to <u>decrease</u> the monitoring frequency (*i.e.* increase the time between sampling trips):

- *Available resources.* The frequency of sampling is a major factor in determining the overall costs of a monitoring programme. For this reason the sampling frequency should be kept as low as possible.
- *Temporal correlation.* Samples that are collected on successive sampling trips should be independent of each other (because sufficient time has lapsed between sampling trips). If this is not the case, resources are being wasted and the quality of the data may be compromised if subsequent statistical analyses are intended. (See Table 3.2. for typical frequencies.)

Overall a balance needs to be achieved between the factors that increase the frequency and those that decrease it. If possible, consult a statistician.

Statistical methods are very useful; some would say essential. Be wary of drawing conclusions from a visual assessment of graphically presented data. It is often not easy to draw sound scientific conclusions on this basis. Monitoring frequency is a particularly important design decision that affects this.

Sampling and analytical methods

Sampling and analytical methods must be carefully chosen. They must ideally be well established and straightforward to implement in order to minimise:

- Initial capital and capacity creation costs; and
- The chances of inconsistent application (by different samplers in the field or by different laboratories).

See WRC (2000) for more detail on sampling techniques.

Choose laboratories that are accredited for the selected methods. If necessary, ask these laboratories for advice on the detailed sampling and sample preservation procedures. Be particularly careful to avoid sample contamination (*e.g.* by unclean hands) when sampling for microbial analysis.

Quality assurance and control

Quality assurance and quality control (see Glossary) are contentious, and often ignored, components of water quality monitoring in South Africa. This is particularly so because the management climate is one in which (a) the fundamental usefulness of monitoring is sometimes questioned and in which (b) lack of financial and human resources are frequently used to justify monitoring cutbacks or lack of progress. ("Basic monitoring is expensive enough without further strain being put on limited resources by invoking formal quality assurance and quality control protocols".)

The critical question that managers should ask is:

"How much confidence do I need to have in the monitoring data, and their assessment, to be able to make the decisions I need to make?"

The Department places considerable emphasis on the concept of "confidence" in visioning, determining the Reserve, the management class and resource quality objectives. Although the question is seldom easy to answer, managers are encouraged to answer the question to the best of their abilities in the current context. (Also, if possible, consider consulting a statistician and focus clearly on the objectives of the programme.

Unfortunately, statisticians often bear the brunt of inadequate data quality reflected in an inability to draw firm conclusions.

Furthermore, if a formal documented design is not available for the overall monitoring programme, it is impossible to specify a design for effective quality assurance and quality control.

Quality management

The standard SANS 9001 / SABS ISO 9001:2000 should be used to establish an overall management system that ensures that target readers of monitoring reports can have confidence that documented methods were followed. This is a general standard and each of the principles to which it ascribes should be carefully considered when setting up the overall quality management system.

These principles are:

- *Customer focus*. This will refer to the target readers of the monitoring reports.
- *Leadership*. This will refer at least to the coordinator of each programme but also refer to those to whom he/she reports.
- *Involvement of people*. All people associated with the monitoring should be fully committed.
- *Process approach*. Activities and related resources should be managed as a process.
- *System approach to management*. Managing interrelated processes well contributes to overall efficiency and effectiveness.
- *Continual improvement*. This should be a permanent objective.
- *Factual approach to decision making*. This acknowledges that effective decisions are soundly based on the analysis of data and information.
- *Mutually beneficial supplier relationships*. This emphasises the importance of the relationship between those involved in the actual monitoring and the target readers of the final reports.

Laboratory quality control

Although quality control goes beyond laboratory practices, it must be ensured that the laboratories that are chosen to perform certain analyses are properly accredited for those methods. The ISO 17025 system is particularly rigorous in this respect.

3.2.5 Data management and storage (handling the data)

Data capture

Primary data capture can potentially occur in at least two conceivable circumstances:

- Capture of experimental results in the laboratory; and
- Capture of these laboratory results on a centralised database.

In either case, ensure that the probability of human error is minimised by automating such actions as far as possible, including data transmission mechanisms.

Use software that automatically performs simple checks on the entered data to confirm that they are reasonable. For example, a pH value must be between 0 and 14.

Data management

Make sure that clear and robust protocols exist to ensure the data, once captured on a centralised database, are stored in such a way as to facilitate subsequent efficient access and processing. In particular, ensure that all data are stored so they can be made available under at least the following circumstances:

- A reasonable request for data is received from any stakeholder or interested party. The data should be provided, at reasonable charge if necessary, in line with the Access to Information Act (Act No. 2 of 2000) and the National Water Act (Act No. 36 of 1998).
- For the production of reports that constitute the formal and regular information dissemination mechanism of the programme.

3.2.6 Information generation and dissemination (reporting)

Data assessment do's and don'ts

Data assessments should:

- Be appropriate for the target readers of the report.
- Add (scientifically sound) value to the raw monitoring data.
- Be relatively straightforward to perform.
- Be understandable by all readers.
- Ensure misinterpretation is avoided.

Assessment criteria

A raw datum (such as the measured value of any water quality variable) is useless unless it can be compared with criteria that put it into context. This kind of assessment of data is the simplest way of adding value to produce "information". Two important kinds of criteria exist:

- *Regulatory criteria*: These are sometimes called "standards" and are often based on widely accepted guidelines. They have a legal status that facilitates their enforcement. Resource quality objectives will be regulatory criteria.
- *Guidelines*: These are usually widely (sometimes internationally) accepted threshold levels or ranges associated with certain effects relevant to the fitness for use of the water. National guidelines are usually generic (*i.e.* do not take into account site-specific situations). However, they are often a very useful starting point that gives an approximate indication of the possibility of effects occurring.

The following are some specific sources of water quality guidelines.

- DWAF, 2001. *South African Water Quality Guidelines for Fresh Water (2nd edition, 1996) and Coastal Marine Waters (1st edition, 1995).* Compact Disk. Water Quality Management Series. Department of Water Affairs and Forestry, Pretoria, South Africa.
- WRC, 1998. *Quality of Domestic Water Supplies. Vol. 1 Assessment Guide.* Department of Water Affairs and Forestry, Department of Health, Water Research Commission Report No. TT 101/98. Pretoria, South Africa.
- WHO, 2004. *Guidelines for Drinking-Water Quality. 3rd edition.* World Health Organisation, Geneva.

Statistical methods

DWAF (2003b) can be consulted for more information on some statistical methods that can be used. However, these must necessarily be consistent with the statistical methods used in the initial design (*e.g.* the choice of monitoring frequency).

False negatives and false positives

Be aware of the issues associated with reporting so-called "false negative" and "false positive" results. Let a "positive" result mean "there is a water quality problem" (whatever it might be). Then:

- A false negative result reports that there is NOT a problem when there actually is a problem with the water quality.
- A false positive result reports that there IS a problem when there is actually not a problem with the water quality.

The following table shows some causes and consequences of these errors.

In essence, an excessive number of false negative results can impact negatively on the achievement of sustainable development. An excessive number of false positive results impact negatively on the cost-effectiveness of the monitoring programme.

Table 3.1: Summary of some causes and consequences of false negative and false positive errors (adapted from DWAF, 2005f).

	FALSE NEGATIVES	FALSE POSITIVES
	CAUSES	
Sampling method	Snapshot water sampling that may miss peaks	
Sensitivity	Toxicity test organism is less sensitive to stressor than organisms in the water resource	Toxicity test organism is more sensitive to stressor than organisms in the water resource
Bias	Guideline value very lenient	Guideline value highly precautionary
	CONSEQUENCES	
Ecosystem integrity	Inadequate protection of water resources	Decreased cost-effectiveness of monitoring programme
Fitness for use	Increased likelihood of negative impacts on water users (and socio-economic enhancement and optimal water use)	

Reporting frequency

Distribute monitoring reports to target readers at a frequency that suits them. Annual reports will often suffice. However, it may be necessary in some circumstances to introduce more frequent reporting to provide feedback to some local stakeholders on a more regular basis (possibly with only limited data assessment). Reporting to selected stakeholders when certain "thresholds of concern" are reached should also be considered. This may be necessary in order to prompt a specific management response (like warning water users of potential problems when water quality deteriorates to a particularly unacceptable level).

Reporting format

The following are some general suggestions:

- *Targeted but easy to produce.* The format of the monitoring report should try to satisfy the requirements of the target readers. However, try to keep the resources required to produce such a report as limited as possible. For example, use facilities built into the database software (being used to store the data) as far as possible.
- *Be visual when possible.* Use visual presentations (like maps and graphs) whenever possible. However, use icons with care. In particular, ensure that they cannot be misinterpreted.
- *Watch your units.* Pay very careful attention to the units of monitoring variables. It is easy to make mistakes with units and cause considerable confusion as a result.

Reports can also highlight corrective and other management actions if appropriate.

3.2.7 Implementation strategy (making it happen)

The business of monitoring

Once the design decisions have been taken and documented, the actual monitoring programme must be initialised, implemented and carefully managed. It is useful to think about running a monitoring programme as you would about running any business. The following are some simple generic management reminders (Manning, 2004):

Management reminders

- Apply yourself to the right things.
- Keep things simple.
- Communicate.
- If you don't make a difference, you don't matter.
- Focus on the right stakeholders, improve their perception of the value you offer and drive down your costs.
- Think about the 7Ps: Purpose, Philosophies, Positioning, Partners, Processes, People, and Products.
- All businesses depend on social interaction to get things done.
- Embrace paradoxes by identifying opportunities.
- Provide good leadership.
- Give teams clear direction, simple rules and intense conversation.
- Facilitate creative thinking.

Tony Manning's Management Toolkit (Manning 2004)

Roles & responsibilities

Identify the various roles that are required to initialise and sustain the monitoring programme. These are likely to include the following:

- *Monitoring Coordinator*. A single person should be assigned the primary responsibility to coordinate all of the activities required to initialise the programme and ensure its continuity.
- *External stakeholders*. Identify those parties that may have a vested interest in the monitoring results. Ensure that their roles and responsibilities are clear defined and understood.
- *Analyst*. Identify appropriate laboratories that are accredited for the kinds of analyses required, and that are able to handle the number of samples likely to be delivered to them.
- *Samplers*. Identify organisations or individuals that have the capacity to perform the necessary sampling, sample preservation and sample delivery.
- *Reporter*. Identify who will be responsible for preparation and dissemination of final reports.

Institutional arrangements

Ensure that all necessary institutional arrangements are appropriate to the identified roles and responsibilities. For example:

- *Update job descriptions*. Ensure Departmental/CMA job descriptions are clear and formal.
- *Request tenders for, and then appoint, samplers and laboratories*. It is advisable to enter into formal contracts with analytical laboratories and samplers (following prescribed Departmental tendering procedures) to ensure that neither side can unilaterally change agreed protocols. This can be an important factor in ensuring continuity and standardisation of methods.

Financial arrangements

Clarify financial arrangements with all parties so that everyone involved understands and agrees to what they are likely to receive, and are likely to need to contribute, to ensure the success of the programme.

Tools: Two related costing spreadsheets are available from the Department (Resource Quality Services). These were developed for national status and trends monitoring. These can be used for any scale of monitoring programme as a relatively simple template for (a) identifying associated costs, and (b) developing detailed 5-year projected annual implementation costs. One spreadsheet is available for costing a single local programme (multiple monitoring sites in one local area). The other allows an overall regional (*e.g.* water management area) costing to be developed, based on a specified annual increase in the number of such local programmes over five years.

Capacity creation

The broadest goal of capacity building is to inform and improve decision-making in support of sustainable development of water resources (DWAF, 2004b). It focuses on enhancing the quality of the outcomes of monitoring programmes and hence the resultant decision-making. It covers all aspects of monitoring, including fostering collaboration between institutions and building human and social capital (DWAF, 2004b). As such it is the overarching quality assurance initiative. Creating capacity is more than just training samplers and analysts. It is ensuring that the entire institutional environment is geared towards maximising the effectiveness of the monitoring. (See Section: Institutional Environment above.)

Accordingly, carefully consider all activities and functions that will affect achieving the objectives of the monitoring and ensure that all are appropriately aligned.

Further reading: DWAF, 2004b. *Strategic Framework for National Water Resource Quality Monitoring Programmes.* [Compiledby DC Grobler and M Ntsaba]. Report No. N/0000/REQ0204. ISBN 0-621-35069-9. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

Time plan

Define an achievable timetable that implements the planned monitoring in a phased manner. For large-scale (*e.g.* strategic status and trends) programmes, initialise the programme in those areas in which:

- Monitoring data is most urgently needed; and
- Obvious problems (*e.g.* logistical and capacity-related) are minimal.

Then, in subsequent phases, when experience has increased through implementation in pilot areas, tackle the other areas that are less urgent or that are likely to be more challenging.

Review

Specifically state a reasonable period after which the overall effectiveness of the monitoring programme will be reviewed. This should not be longer than five years, though it may be much shorter initially (say three years). This auditing function should examine (a) the appropriateness of the programme's objectives, and (b) whether or not they are being achieved.

This should result in corrective actions if necessary to improve the programme's cost-effectiveness and focus on objectives.

3.3 Designing for the immediate future

3.3.1 What the future holds

Transition

The Department remains in a state of transition. Two particularly important aspects are relevant:

- *Decentralisation to catchment management agencies (CMA).* Although this process has started, it will be many years before the CMAs are firmly established. In the interim, this affects accountability for monitoring, clarity of mandate and resources available.
- *Introduction of the resource classification system.* Technically, this will be the most important initiative determining resource management by the Department and CMAs.

Management class

The management class is a resource directed measure (RDM) that will entail important water resources being assigned a "desired future state", typically encapsulated in the catchment vision. This will specifically be defined by resource quality objectives (RQOs) that define limits for specified characteristics of the resource, including water quality. Once designated, the management class will enable one to determine whether the resource is currently stressed (i.e. the RQOs are not being met) or unstressed (i.e. the current state falls within the limits defined by the RQOs). The degree to which RQOs are being complied with will therefore determine the nature of the management of current water users.

The degree to which the management class is being attained or maintained provides one important perspective on the degree to which sustainability goals are being achieved.

All monitoring will eventually need to provide information in direct support of water resource and water user management in the context of attaining or maintaining the management class (i.e. complying with RQOs) and complying with the Reserve.

Regional perspective

From a regional perspective, resource directed water quality monitoring should comprise a series of programmes with distinct objectives. Monitoring related to General Authorisations is not considered here because this typically does not involve monitoring of the water resource. Levels 1-4 refer to how the Upper Vaal catchment management agency categorises their current monitoring (Figure 3.3).

- ***Impact & licence compliance monitoring.*** This typically entails (a) upstream and downstream monitoring of sources of impact ("Level 3"), and (b) monitoring of effluent discharges to monitor compliance with authorisation conditions relating to "end-of-pipe" ("Level 4").
- ***Strategic status and trends monitoring.*** This can include major watercourses ("Level 1") and major tributaries of those watercourses ("Level 2"). This kind of monitoring is conceptually aligned with the objectives of the existing national water quality monitoring programmes. However, on a regional and local scale this should ultimately be aligned with the management class and RQO.
- ***Reserve monitoring.*** This monitors whether or not water quality meets the requirements of the Reserve.
- ***Performance monitoring (RQO and RWQO).*** When RQOs and RWQOs become established, it will be the CMA's responsibility to comply with these objectives (conceptually, this is in the same way that water users have to comply with licence conditions).

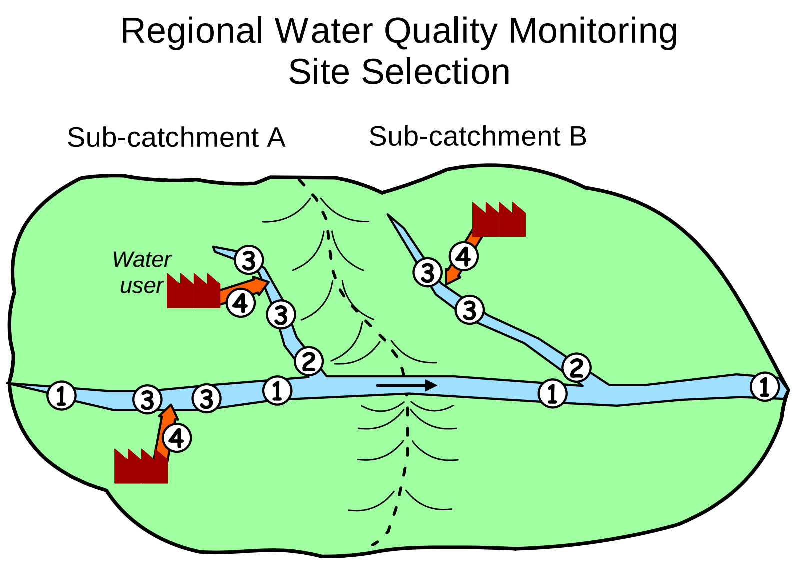

Figure 3.3: Illustration of four levels of regional water quality monitoring.

National perspective

A series of national water quality monitoring programmes exist, and others that are intended to be implemented, that have a strategic national (and international) perspective in their objectives. Strategic regional monitoring programmes can benefit considerably from these monitoring programmes. A typical design framework for national programmes is given below so that their perspective can be better understood.

Design frameworks

The following sub-sections suggest design frameworks for specific contexts. These expand on some of the issues noted above in the generic design process, interpreting them within the specific contexts.

3.3.2 Impact & licence compliance monitoring

3.3.2.1 Introduction

Generic objectives

To measure, assess and report on a regular basis the degree to which individual water users are (a) complying with the "end-of-pipe" conditions defined in their water use licence (if any), and (b) impacting on the local water resource water quality.

(Although monitoring end-of-pipe conditions is not directly resource directed, this monitoring has been included here for completeness).

Target users

The primary users of the monitoring information include the following:

- *The water user*. The information will indicate to the water user the extent to which adequate measures have been taken to limit and control the likely impacts on the water quality of the local water resource. Non-compliance can indicate the need for pro-active corrective actions by the water user.
- *The relevant authority*. The information will indicate whether or not the water user is complying with the conditions of the water licence. Non-compliance may lead to a number of possible actions in order to ensure compliance.

Management responsibility

There are two perspectives:

- *The water user*. The primary responsibility for licence compliance monitoring lies with the individuals or organisations whose water use is being monitored. Licence conditions typically stipulate upstream and downstream monitoring and monitoring of any discharge of water containing waste (if any).
- *The relevant authority*. The authority has the responsibility to audit these results by performing their own sampling and analysis.

3.3.2.2 Data acquisition

Water quality variables

- *The water user*. For an overview of the choice of monitoring variables see Section 6.2. In the interim, variables should be chosen that are (a) significantly affected by the particular water use, and (b) important to downstream water users and ecosystems (including the Reserve). Once RQOs are in place, these should give explicit guidance on what variables are important.
- *The relevant authority*. The authority should use the same variables for auditing.

Monitoring site selection

- *The water user*. For an overview of the monitoring site selection see Section 6.3.
- *The relevant authority*. The authority should monitor at the same sites for auditing.

Monitoring frequency

- *The water user.* The frequency of monitoring carried out by the water user should depend on available resources, how consistent the quality of discharged water containing waste is over time (if this exists), and the potential severity of impact. Consider imposing a higher monitoring frequency initially, at least until the behaviour of the discharged water containing waste and the resource are better understood. Only then permit the user to apply for a lowering of this frequency, if this is appropriate.
- *The relevant authority.* The authority's monitoring frequency should be determined by available resources and can be at a lower frequency than that used by the water user. For example, if the water user is monitoring monthly, a three-monthly interval might be adequate for the authority.

Sampling and analytical methods

The formal nature of compliance monitoring will require well-established standard methods to be used for sampling, sample preparation, sample transport and analyses (whether in the laboratory or on-site). Laboratories should be formally accredited for the chosen methods to ensure adequate data quality is achieved.

3.3.2.3 Information generation and dissemination

Data assessment

In the interim, General or Special Effluent Standards can be used to assess effluent data. South African water quality guidelines (among others) can be used to assess instream measurements (DWAF, 2001). When RQOs and RWQOs are established, these should be sensibly back calculated to effluent targets (see DWAF, 2005h).

Reporting frequency

The reporting frequency must be chosen in such away that corrective actions can be invoked in good time should problems be detected. Reporting may simply involve perusal of monitoring results received directly from the laboratory. However, if targets involve annual statistics, these statistics should be determined on an annual basis and compared with the target.

Reporting format

The reporting format should be simple and suit the requirements of both licensee and licensor.

3.3.3 Regional status and trends monitoring (strategic)

3.3.3.1 Introduction

Generic objectives

To measure, assess and report on a regular basis the status and trends relating to water quality in major water resources, in a manner that will support strategic management decisions in the water management area (WMA) in the context of fitness for use of water resources and aquatic ecosystem integrity.

Responsibility

The responsibility for funding and implementing this monitoring will lie with the CMA. However, considerable overlap is possible with national water quality monitoring programmes (see below). Funding and implementation of the latter programmes is the responsibility of the Department (Policy and Regulation).

Less confidence

The objective of this kind of monitoring is not as demanding as assessing authorisation compliance or performance monitoring. This means that less confidence in your results is acceptable as long as the objectives are achieved and managers can make informed decisions.

3.3.3.2 Data acquisition

Water quality variables

- *In the interim*. As a point of departure, it is sensible to choose the kinds of variables being used in the national water quality monitoring programmes. If there are other variables that are of particular concern to the WMA, these can be included.
- *When RQOs or RWQOs exist*. These should give further explicit guidance on what variables should be considered important.

Monitoring site selection

- *In the interim.* Monitoring sites should be chosen along main watercourses and major tributaries that can be regarded as strategically representative of those water resources. Take into account, if possible, the kinds of issues considered for determining RWQOs (i.e. ecological and water user requirements, etc.). Specifically, a desktop or rapid determination of RWQOs could be carried out (DWAF, 2005g).
- *When RQOs or RWQOs exist.* These will typically define where compliance is required. If these sites are of a sufficiently important strategic nature, use them. However, they may not exist at a sufficient number of sites to provide the WMA with the necessary resolution. In such a case, as above, take account of the kinds of issues considered for determining the RWQOs.

Also consider augmenting the sites that may exist for national monitoring programmes to provide a resolution that is more suitable for the WMA (Figure 3.4).

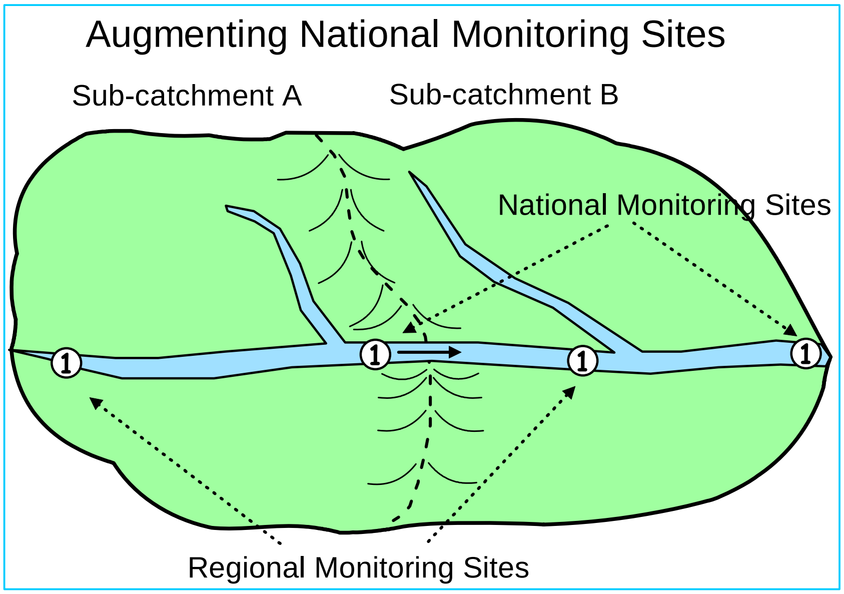

Figure 3.4: Augmenting national monitoring sites.

Monitoring frequency

In the interim. The following frequencies are recommended as "points of departure" in the types of water indicated and should be tailored to local circumstances.

Table 3.2: Monitoring frequencies that can be used as "points of departure".

Type of resource	Frequency	No. of samples per year
River / stream / spring etc.	2-weekly	26
Impoundment	Monthly	12
Borehole	6-monthly	2

Also take guidance from the national monitoring programmes. However, if a greater frequency is required, consider augmenting the monitoring done for the national monitoring programmes (see Figure 3.5).

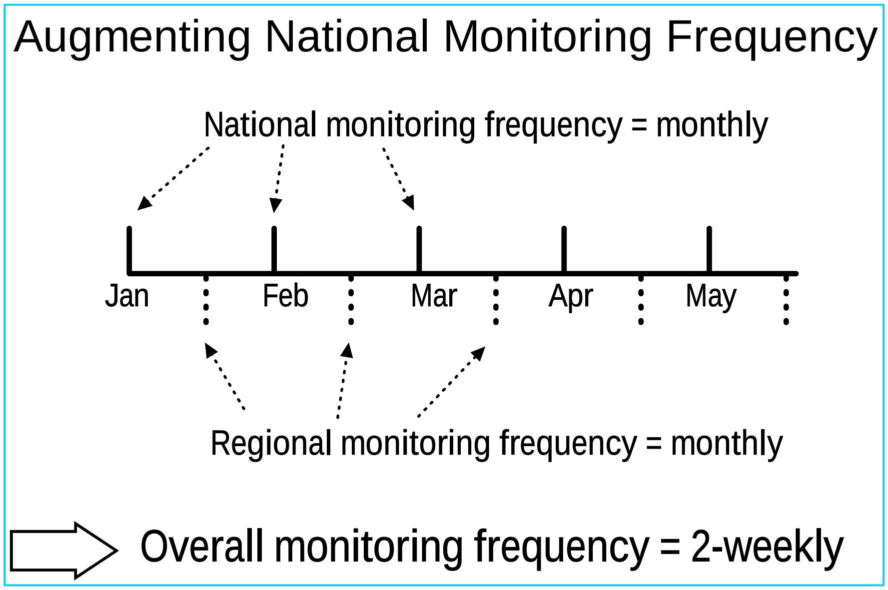

Figure 3.5: Augmenting national monitoring frequency.

If human and financial resources permit, seriously consider using a higher frequency (than recommended above) for the first year. Once the full year's data are available, submit the data to a statistician in order to determine whether or not the chosen frequency is satisfactory. They can examine whether or not temporal (or spatial) correlation exists. On this basis, change the frequency and/or the monitoring sites if necessary.

When RQOs or RWQOs exist. These are likely to define the required monitoring frequency. However, less confidence (than for performance monitoring) is acceptable so less frequent monitoring may be possible.

3.3.3.3 Information generation and dissemination

Data assessment

- *In the interim*. Take guidance from the national monitoring programmes.
- *When RQOs or RWQOs exist.* The RQOs and RWQOs will be the criteria against which measurements should be assessed.

3.3.4 Performance monitoring (Reserve, RQOs and RWQOs)

3.3.4.1 Introduction

Generic objectives

To measure, assess and report on a regular basis:

- ***The degree to which the resource water quality complies with the requirements of the determined ecological Reserve, and***
- ***The degree to which present resource water quality conforms to (a) resource quality objectives (RQOs) relating to water quality, and / or (b) resource water quality objectives (RWQOs), and hence***
- ***Whether a water resource is within its designated management class (in respect of water quality).***

RQOs and RWQOs

RQOs are quantitative or descriptive goals for resource quality (ecosystem health, water quantity, water quality, etc.), within which a water resource must be managed to maintain its designated management class and hence move towards the catchment vision. These have a formal legal, and hence regulatory, status (by being published in the *Government Gazette*).

RWQOs are similar but (a) relate only to water quality, and (b) do not have the legal status of RQOs (*i.e.* are not published in the *Government Gazette*). They may have a higher spatial and temporal resolution than the RQOs.

Management responsibility

The primary responsibility for management and implementation of performance monitoring programmes, and compliance with the Reserve and RQOs, will lie ultimately with CMA.

3.3.4.2 Data acquisition

Water quality variables

The Reserve determination will define the monitoring variables.

In respect of RQOs, the monitoring variables must relate directly to the RQO chosen for the designated management class for each water resource (DWAF, 2005g). If the RQO is expressed in terms of specific water quality attributes (e.g. pH must be between 6 and 9), then the chosen monitoring variable is self-evident (for this example, pH).

However, RQOs may be more narrative in nature and may not be explicitly expressed in terms of traditional water quality monitoring variables. In this case, these RQOs may need to be interpreted and a choice made regarding what water quality attribute is best monitored to enable an assessment of whether the RQOs are being achieved or not (if this cannot be achieved by the RQOs relating directly to water quality).

RWQOs, since their purpose is to give effect to the RQOs, should comprise the same variables as the RQOs.

Monitoring site selection

The Reserve determination and the RQOs will specify explicitly where they should apply and hence indicate where sampling should take place.

Similarly, RWQOs, since they will be determined in an equivalent way to the RQOs, will also inherently specify where they apply.

Monitoring frequency

The Reserve determination will give some indication of an appropriate monitoring frequency.

Since RQOs will have a formal status (by being published in the Government Gazette), particular care must be taken to ensure that data of adequate quality are collected. One aspect of this quality is that sufficient data must exist over the designated period (typically annual) to enable an accurate statistic to be determined that can be compared with a particular RQO. The factors described above will determine the optimum monitoring frequency.

The same applies to the RWQOs.

Sampling and analytical methods

The formal nature of the Reserve and RQOs will also require well-established standard methods to be used for sampling, sample preparation, sample transport and analyses (whether in the laboratory or on-site). Laboratories should be formally accredited for the chosen methods to ensure adequate data quality is achieved at all times.

The somewhat less formal nature of RWQOs means that the same level of analytical rigour need not be applied. However, it must be ensured that all methods are sufficiently standardised so that their purpose and interpretation is not compromised.

3.3.4.3 Information generation and dissemination

Data assessment

Because the Reserve and RQOs have a significant legal status, the confidence with which results are reported should be as high as possible. The most important issue is the relationship between the present state of the resource and its designated management class. The RQOs themselves are the objectives against which monitoring data are assessed.

Assessments of RWQOs need not be as formal, although it will be sensible to perform the same kinds of assessments as RQOs (since these protocols will exist anyway).

3.3.5 National status and trends monitoring (strategic)

3.3.5.1 Introduction

Generic objectives

To measure, assess and report on a regular basis the status and trends relating to water quality in South African water resources, in a manner that will support strategic management decisions in the context of fitness for use of water resources and aquatic ecosystem integrity.

Strategic nature

"Strategic" is used here in the sense of being large in scale, both spatially and temporally. The spatial scale is national and the temporal scale for reporting would typically be annual.

National design responsibility

As noted above, the Department (Policy and Regulation) has the responsibility for funding and implementing national monitoring programmes (DWAF, 2004b).

Where monitoring is already occurring for such national purposes, it is important that regional monitoring does not duplicate this. It should rather use the national data for its own purposes and supplement this (*e.g.* at more sites or more frequently at the national sites) to better meet regional objectives.

National target users

The users of the monitoring information are specifically those that are interested in a more strategic (national and long-term) perspective on the state of water quality in water resources. Target users go beyond just the CMA. However, the CMA can (and, indeed, should) benefit directly from the information contained in national reports.

Cost-effectiveness

The enormous spatial and temporal scale of national monitoring programmes has meant significant emphasis is given to cost-effectiveness. Specifically this means maximising the information provided to water resource managers while minimising the costs. Creative thinking has been necessary to achieve practical designs for these large-scale monitoring programmes. In particular, it has emerged that fundamentally different designs have been necessary for the different types of national monitoring (surface water versus groundwater, microbiological versus chemical, etc.).

These can be useful lessons for a CMA that must also monitor different attributes of water quality and different types of water resources, sometimes over large spatial scales. The national implementation manuals can be consulted for insights likely to be useful in designing monitoring programmes for a CMA.

Current national water quality monitoring programmes

The following national programmes relating directly to water quality are either in place or are envisaged fir future implementation (for a little more detail on each programme see DWAF, 2004a):

- ***National Chemical Monitoring Programme (NCMP).*** Monitors the status and trends of major inorganic ions and attributes such as pH, electrical conductivity, etc. Many sampling points exist throughout the country. In operation for many years.
- ***National Microbial Monitoring Programme (NMMP).*** Monitors the status and trends of either faecal coliforms or E. coli. Surface water monitoring has been implemented in some water management areas for a few years. The design for groundwater microbial monitoring is currently being tested prior to implementation.
- ***National Eutrophication Monitoring Programme (NEMP).*** Monitors the status and trends of mainly chlorophyll a and total phosphorous in impoundments only and determines their trophic status (oligotrophic, mesotrophic, trophic, hypertrophic). Also monitors algae and cyanobacteria. The programme has been implemented for a few years.
- ***National Toxicity Monitoring Programme (NTMP).*** Currently being designed. Will monitor status and trends of (a) toxic effects on selected organisms (algae, invertebrates and fish), and (b) selected individual toxicants in water (including some persistent organic pollutants (POPs)).

- ***National Radioactivity Monitoring Programme (NRMP***). Currently being designed. Will monitor the status and trends of radioactivity.
- ***Ecological Reserve Determination and Monitoring***. Currently being designed. Will monitor the status and trends and compliance of those variables important to the ecological Reserve.

3.3.5.2 Data acquisition

Water quality variables

Status and trends programmes choose monitoring variables that address various issues of national concern. These include the following:

- International responsibilities (that are not normally covered by performance monitoring).
- Keeping abreast of international Capacity creation upon which further region-specific capacity creation can be based when CMAs become operational.

The kinds of variables currently in use are indicated above.

Monitoring site selection

Monitoring sites are typically chosen at a fairly low spatial resolution but at strategically important sites from a national point of view.

Monitoring frequency

Monitoring frequency is typically relatively low (mainly to minimise costs) though it is sufficient to provide, for example, annual statistics with adequate confidence to meet the national objectives.

3.3.5.3 Information generation and dissemination

Data assessment & reporting formats

Data assessment protocols tend to be specific to the type of monitoring programme. For some national programmes (*e.g.* microbial and toxicity), guidelines have been developed specifically for these programmes.

3.3.5.4 Guidelines

Microbial monitoring (surface water)

Murray K, M du Preez, AL Kühn and H van Niekerk 2004. *A Pilot Study to Demonstrate Implementation of the National Microbial Monitoring Programme*. Water Research Commission Report No. 1118/1/04. Pretoria, South Africa. (Annexure contains implementation manual).

Microbial monitoring (groundwater)

Murray K, M du Preez, MB Taylor, R Meyer, R Parsons, E van Wyk, AL Kühn, H van Niekerk and MM Ehlers 2004. *National Microbial Monitoring Programme for Groundwater. Prototype Implementation Manual*. Water Research Commission Report No. 1277/2/04. Pretoria, South Africa.

Murray K, M du Preez, MB Taylor, R Meyer, R Parsons, E van Wyk, AL Kühn, H van Niekerk and MM Ehlers 2004. *National Microbial Monitoring Programme for Groundwater. Research Report*. Water Research Commission Report No. 1277/1/04. Pretoria, South Africa.

Eutrophication monitoring

DWAF, 2002. *National Eutrophication Monitoring Programme: Implementation Manual.* Department of Water Affairs and Forestry, Pretoria, South Africa. [Compiled by K Murray, M du Preez and CE van Ginkel].

Toxicity monitoring (surface water)

DWAF, 2004. *National Toxicity Monitoring Programme for Surface Waters: Draft Conceptual Design Framework and Record of Decision Report*. Department of Water Affairs and Forestry, Pretoria, South Africa. [Compiled by K Murray].

SECTION 4: A MONITORING VISION: BEYOND WATER QUALITY

4.1 Long-term perspective

Also useful now

Achieving sound water quality monitoring, as outlined above, is by far the most pressing need in respective of regional monitoring. The following sub-sections outline a more ambitious perspective on monitoring. Although this is only likely to be implemented in the long-term, the new paradigm introduced here can nevertheless also help authorities to understand and present the results obtained by the current monitoring programmes.

4.2 The PSIR framework and sustainable development

4.2.1 The thinking framework

DPSIR framework (precursor to PSIR)

The Driving force-Pressure-State-Impact-Response (DPSIR) framework was developed by the European Environment Agency. According to this framework, social and economic activities (driving forces) exert pressure on an ecosystem, and as a consequence, the state of that ecosystem changes. This change in state leads to various impacts (*e.g.* on socio-economic enhancement). These impacts can result in responses from society that ultimately aim at mitigating these impacts by directly addressing the driving forces, pressures, the state, or impacts. (The River Health Programme uses this framework).

Focus on PSIR

As driving forces are often difficult to manage, the DPSIR framework is sometimes adjusted to focus more on pressures rather than on the driving forces behind them. This is called the PSIR (Pressure-State-Impact-Response) framework.

Resource directed management of water quality is a very specific application in which responsibility for management of driving forces typically lies outside the mandate of the Department. For example, obvious driving forces include the multitude of land use practices that impact directly on water quality (such as agriculture and mining). It is considered more appropriate to focus monitoring efforts on identifying the pressures that result from these driving forces (such as non-point source agricultural runoff polluting water with pesticides). This is more directly relevant to the Department.

Beyond water resources

RQOs will be the most important sustainability indicators. However, they will not be sufficient on their own. Management of water resources must support decision-making that will facilitate using water resources in a way that ensures future generations can meet their basic water requirements while promoting socio-economic development and improved quality of life for all in the current generation. To do this effectively, water resource managers must think beyond water quality, and indeed even beyond water resources.

A number of frameworks that facilitate such thinking have been applied to state of environment (SoE) reporting. One in particular, PSIR, has already been successfully used in South Africa, including in the Department of Environment Affairs and Tourism (DEAT) National Environmental Indicators Programme (DEAT, 2002).

Applying the PSIR framework to resource directed management of water quality will enable managers to take monitoring beyond simply water quality to a level at which it can more usefully inform sustainable development.

Advantages

The PSIR framework has the following advantages:

- It facilitates the development of a balanced suite of sustainability indicators.
- It guides data and information collection processes (also identifying gaps).
- It helps managers to understand cause-and-effect relationships.
- It helps to structure reports and group related information.

4.2.2 PSIR categories defined

PSIR categories

The four PSIR categories (Figure 4.1) can be interpreted in the context of resource directed management of water quality as follows:

Beware of the following PSIR-related terminology. The words Pressure, State, Impact and Response are commonly used to mean other things as well. Be sure that you understand the context in which they are being used in this document.

- ***Pressure***. This refers to those wide-ranging human activities that can directly cause negative impacts on water quality in a water resource. The National Water Act (Act No. 36 of 1998) Section 21 water uses provide a series of obvious categories of likely immediate pressures on water quality.
- ***State***. In the current context, the state of water quality in water resources (surface water, groundwater and estuaries) is the specific focus. This includes concentrations or loads of chemicals or microbiological attributes as well as biological responses like toxicity.
- ***Impact***. Deteriorating water quality can impact directly on ecosystem health and on fitness for use (*e.g.* domestic, recreational, agricultural, industrial) and hence impact on quality of life and socio-economic enhancement. Impact in the current context therefore means "impact of changes in the state of water quality on the water resource, socio-economic enhancement or quality of life".
- ***Response***. This refers to decisive reactions of society, including government, to these negative impacts, that aim to solve or mitigate water quality problems. These can directly address the pressures (*e.g.* through regulation), state or impacts (*e.g.* through rehabilitation).

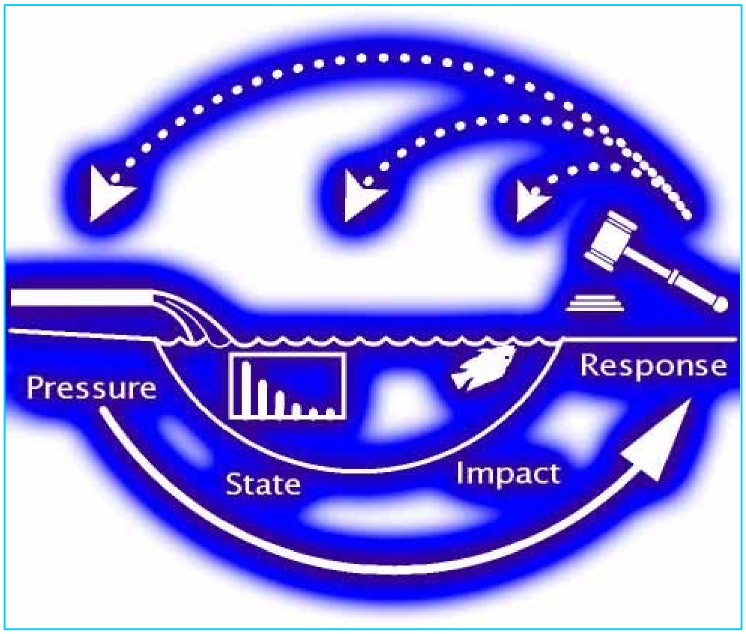

Figure 4.1: Illustration of the PSIR framework in a water quality monitoring context.

PSIR addresses sustainable development principles

Each of the four PSIR categories provides a particular kind of information that helps to determine the degree to which the six enabling principles of sustainable development (Section 1.2) are being achieved (DWAF, 2005b).

- *Pressure monitoring*. This provides some information relating to socio-economic enhancement (*e.g.* by quantifying the pressures put by polluters on water quality and by helping to quantify the degree of efficient water use). This information can also inform equitable allocation initiatives and hence achieving current equitable access. This monitoring is directly related to the management of water users.
- *State monitoring*. This provides direct information on the degree of protection of water resources and will also inform equitable allocation (by enabling quantification of allocatable water quality) that in turn informs the degree of current equitable access. This monitoring is directly related to monitoring the resource water quality and hence resource directed measures (fundamental to sustainable development).
- *Impact monitoring*. This measures both socio-economic and ecological impacts. Socio-economic impact data can help to quantify the degree of socio-economic enhancement that, in turn, enables optimal water use. Ecological impacts include those of deteriorating water quality on other resource quality attributes. Monitoring this contributes to a broader understanding of the degree of protection of water resources in general (beyond just water quality).
- *Response monitoring*. This supplements the information from impact monitoring by providing more specific information on the nature of societal needs. This can directly inform initiatives to achieve current equitable access and optimal water use (as well as, in some instances, the degree of protection of water resources).

Effective responses by the Department will require good governance (another enabling principle of sustainable development) since solutions to problems will frequently require close co-operation with other government departments and stakeholders.

Any monitoring that provides information relating to current equitable access and protection of water resources inevitably provides information that is relevant to equity between generations (a sustainability principle).

Furthermore, once all four kinds of monitoring are in place, only then can one confidently claim that the enabling principle of environmental integration is being addressed.

PSIR, catchment assessment and catchment visioning

Catchment visioning is about creating a common vision of the future aspirations of stakeholders in a catchment (DWAF, 2005e). The processes of (a) defining the vision, and (b) striving for that vision, depend heavily on catchment assessments to supply the quantitative data upon which sensible decisions can be based (DWAF, 2003b). The PSIR framework provides an excellent structure for focusing these assessments and thereby ensuring that catchment visioning is suitably comprehensive and holistic.

4.2.3 Issues-based indicators

Indicators depend on the issues

The framework itself does not provide any detailed guidance on what indicators should actually be measured. In order to identify the most appropriate indicators, a list of relevant issues can be compiled. The Policy, in particular, identifies many issues of national concern. These, supplemented with local catchment priority issues (*e.g.* identified through catchment visioning), can be used as a basis for identifying specific individual indicators.

Indicators can also be adapted from those that are used in similar applications of the PSIR framework in other countries. However, these will need to be carefully examined for their applicability to the South African context.

Policy issues

The Policy identifies a number of national issues relating to water quality (DWAF, 2005b) that can influence the choice of appropriate PSIR indicators:

- Quality of life;
- HIV/Aids;
- Poverty; and
- Racial and gender inequities.

Software decision support tool

A software decision support tool is available for assessing the probability that a licence should be issued (DWAF, 2005d). It is based on an assessment of each of the Section 27 considerations ((a) to (k)), using a multi-criteria decision support algorithm. A series of indicators are used upon which the assessment is based. Some of these could also be used for PSIR monitoring.

Applying this interpretation of the PSIR framework will ensure that resource directed management of water quality, through a careful choice of indicators, can be explicitly related to sustainable development and national, regional and local issues.

4.3 Monitoring programmes that support PSIR

Supporting programmes and data sources

As described in more detail in the following sub-sections, monitoring programmes that already exist (or that are envisaged) can provide useful support for Pressure, State, Impact and Response monitoring. Importantly, these "supporting programmes" exist in their own right and are designed to meet their own well-defined objectives. However, their data and results can be assessed within the PSIR framework. Figure 4.2 illustrates this.

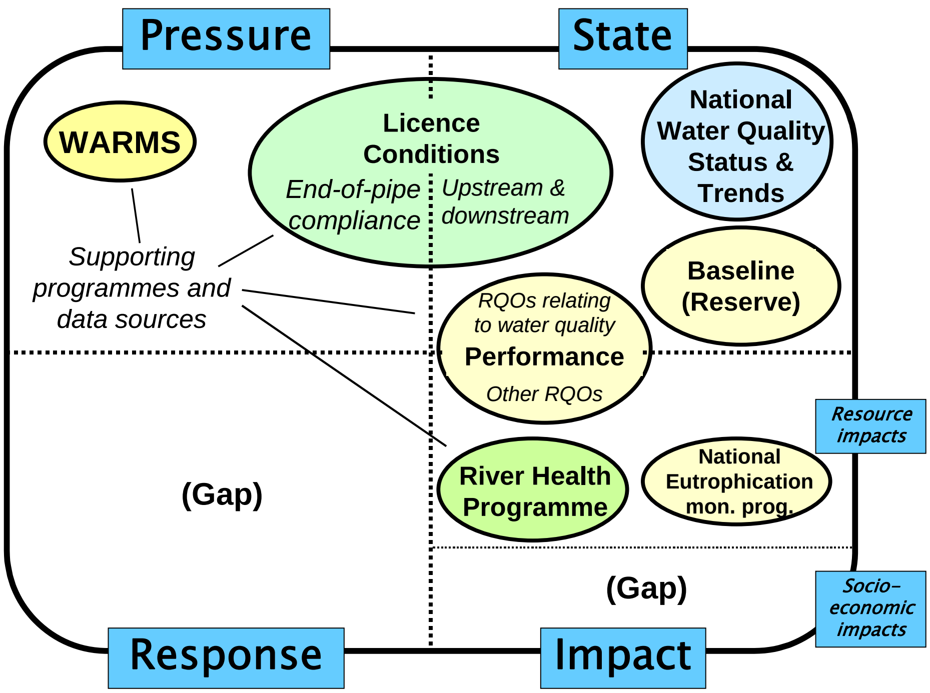

Figure 4.2: Illustration of some supporting programmes and data sources for PSIR-based monitoring.

Gaps

Figure 4.2 also illustrates that there are no existing standardised supporting programmes for socio-economic impacts and response monitoring. These gaps are addressed below.

4.4 PSIR monitoring

4.4.1 Introduction

Emphasis on indicators

This section describes in general the essential components of PSIR monitoring. Whereas the water quality monitoring described above measures specific water quality variables, PSIR monitoring tends to place greater emphasis on "indicators".

4.4.2 Documentation

Manual titles

For the same reasons as for water quality monitoring, a PSIR monitoring programme should have a "record of decision" report and an implementation manual. The title of the manual could be as follows:

PSIR MONITORING PROGRAMME: IMPLEMENTATION MANUAL

(UPPER VAAL WATER MANAGEMENT AREA)

Proposed structure

The structure of the manual can be based on that proposed for water quality monitoring (Section 3.2.2). Note, however, that "variables" will now typically be referred to as "indicators".

4.4.3 Monitoring objectives

Importance

Well-defined objectives for any monitoring programme are essential. They should be summarised into one or two sentences that make it clear why (not how) the monitoring will be done.

Specific objectives are proposed for pressure, state, impact and response monitoring programmes in the design frameworks below (section 1.4.5).

Target users

In general, the users of monitoring information that is related to resource directed management of water quality include the following:

Primary users:

- Water resource managers, water quality managers and water resource planners (in catchment management agencies, water use managers, water user associations and Department Head Office and Regional Offices).

Secondary users:

- Other national, provincial and local government authorities.
- Non-Government Organisations.
- All industrial sectors.
- Public.
- Any other interested party.

4.4.4 Data acquisition

Choice of indicators

The choice of indicators should be driven by national and catchment priority issues. Indicators may often be some statistic obtained from a raw data series. An indicator might also simply be an annual average or be a more complicated aggregation of data or other indicators.

It is preferable to choose indicators for which either national or international criteria exist against which they can be assessed. However, if such criteria do not exist, it may still be possible to perform a simple comparative assessment, either from one time period to the next or between different spatial areas. Such indicators may need to be normalised (*e.g.* per capita, per unit area, per unit volume, etc.).

***Further reading*:** Walmsley JJ, M Carden, C Revenga, F Gagona and M Smith, 2001. Indicators of sustainable development for catchment management in South Africa – Review of indicators from around the world. *Water SA*, **27**(4): 539-550.

DEAT, 2002. *National Environmental Indicators Programme*. Department of Environment Affairs and Tourism, Pretoria, South Africa.

Field data collection

Whatever the nature of the field data that need to be collected (including, for example, data on the incidence of waterborne diseases that may need to be collected from remote clinics), the factors mentioned above for water quality monitoring are important.

Monitoring frequency

When collecting data, from whatever source, carefully consider the variability of the data, available resources and temporal correlation (similar to monitoring water quality, as noted above). This is particularly so if the data are to be analysed statistically.

Quality assurance and control

Carefully consider quality assurance and quality control (see Glossary). If data are to be collected from data sources whose compilation has been outside your control, then the level of confidence that you can reasonably associate with these data may be lower than you may wish. Accordingly, any assessment of such data should be conducted with caution.

4.4.5 Data management and storage

Human error

Data manipulation at any stage of the process must be designed to minimise the possibility of human error (*i.e.* unintentional mistakes). The greater the number of times that data must be re-typed, the greater is the likelihood of mistakes. Process data electronically as far as possible.

Databases

Ensure that databases that store the raw data, or the indicators obtained from the data, are effectively designed to simplify the following:

- Data capture;
- Long term storage (with frequent backups);
- Data retrieval; and
- Transfer to other databases.

4.4.6 Information generation and dissemination

Assessment criteria

Raw data should ideally be compared with criteria or guidelines that add value and place the data in context in a way that produces useful "information".

Reporting frequency

The frequency with which reports are disseminated depends primarily on the needs of the target readers. However, periods between successive reports should not be longer than one year.

Reporting format

The format of the report must satisfy the requirements of the target readers. Visual presentations (such as maps and graphs) are encouraged with careful use of icons, if necessary (with due attention given to possible misinterpretation of icons).

4.4.7 Implementation strategy

Management

See the management and implementation strategy section for water quality monitoring, described above.

Modularity

In order to be consistent with the Department's hitherto modular approach to monitoring programme design and implementation, it is proposed that four separate monitoring programmes be envisaged for Pressure, State, Impact and Response monitoring (and yet another for management performance monitoring). Catchment management agencies are encouraged to ensure that all types of monitoring programmes are in place.

This modular approach allows a degree of flexibility in implementation and more focussed thinking in each instance.

Integration

A potential disadvantage of such a modular approach is that an individual programme may be designed and implemented in a way that does not take sufficient account of the others. This must be avoided to ensure that the products of all of the separate programmes are appropriately complementary and hence allow a truly integrated overall assessment to be performed when all are eventually fully implemented.

Phased implementation

It is important that a phased approach be taken to implement the PSIR monitoring programmes. Accordingly, the following are recommended in order of decreasing priority for the initial stages of implementation:

- *State monitoring*. This is by far the most important monitoring that should be initiated in a water management area. Once in place, the results of this will inevitably drive the more detailed design of the remaining monitoring programmes.
- *Pressure monitoring*. This will quickly become important once a good picture is obtained of the state of water resources. This will allow more focussed source directed controls to be imposed by providing an overview of those activities that are causing the state of resource water quality to change.
- *Impact monitoring*. This information will begin to provide a broader spectrum of information that can facilitate the holistic thinking required to achieve sustainable development.

- *Response monitoring*. This will provide greater insight into (a) the impacts on society, (b) the real needs and priorities of society, (c) measures that may need to be enforced, and (d) successes or failures of responses (*e.g.* of rehabilitation efforts). This can be the last to be implemented.

4.5 Design frameworks

Basis for detailed design

The following sub-sections present frameworks that should form the basis of the design of the four PSIR monitoring programmes. Development of detailed designs can be highly resource intensive. It requires specialist input and should deal with all aspects of implementation from higher-level management, through the choice of monitoring variables to the lowest level technical specifications, if appropriate (such as sampling and analytical methods). The following sections only provide generic frameworks that can be used to guide these more detailed design processes.

4.5.1 "Pressure" monitoring

4.5.1.1 Introduction

Generic objectives

To measure, assess and report on a regular basis, the nature and extent of immediate pressures on water quality in the catchment in a manner that will contribute to an understanding of the causes of deteriorating water quality.

4.5.1.2 Data acquisition

Pressure indicators

The causes of deteriorating water quality will often be highly site-specific. Most of the water uses defined in the National Water Act (36:1998), Section 21, can potentially affect water quality; some to a greater and more obvious extent than others. (It can be assumed that any water use has potential for changing water quality in some way, albeit this may be minimally in some cases). The Section 21 water uses are the following (more or less arranged in decreasing order of general potential for significantly impacting on water quality):

(f) Discharging waste or water containing waste into a water resource.

(g) Disposing of waste in a manner that may impact on a water resource.

(h) Disposing of water containing waste from, or which has been heated in, any industrial or power generation process.

(e) Engaging in a controlled activity (including irrigation using waste or water containing waste, modification of atmospheric precipitation, power generation that alters flow regimes, and aquifer recharge using waste or water containing waste).

(k) Using water for recreational purposes.

(a) Taking water from a resource.

(d) Engaging in a stream flow reduction activity (commercial afforestation is the only activity currently declared as such an activity).

(j) Removing, discharging or disposing of water found underground for the efficient continuation of an activity or for the safety of people.
(i) Altering the bed, banks, course or characteristics of a watercourse.
(b) Storing water.
(c) Impeding or diverting the flow of water in a watercourse.

Pressure indicators appropriate to the current context would need to be closely related to the above activities, in particular, the extent to which they occur.

Link to management class

Focus on a choice of indicators that relate to important catchment issues. In particular, ensure that the indicators can be sensibly related to the RQOs and RWQOs associated with the designated management class and vision.

Examples of pressure indicators

Pressure indicators can include measures of water supply, water demand and waste and pollution. Examples include:

- Frequency and nature of non-compliance with water use licence conditions;
- Levels of water abstraction relative to water availability; and
- Number and volume of pollutant discharges from point and non-point sources relative to river flow.

Sources of data

The following sources of relevant data can be used:

- The WARMS (Water Authorisation and Registration Management System) database.
- Data collected from monitoring of end-of-pipe discharges, in particular discharge volumes and concentrations (and hence loads).

4.5.2 "State" monitoring

4.5.2.1 Introduction

Generic objectives

To measure, assess and report on a regular basis the degree to which the designated management classes in the catchment are being attained or maintained in respect of water quality, in a manner that will contribute to an understanding of the status and trends in water quality.

Management class

The most obvious focus relating to the "state" category will inevitably be whether or not a water resource is within its designated management class. As noted in the Policy, the resource management class is the "first line of defence" against unsustainable development. In other words, ensuring all water resources attain and maintain their designated management classes is the very least that should be achieved to be able to claim any degree of facilitation of sustainable development.

This strongly suggests individual indicators could be associated with answering two basic questions:

- Is the resource in its designated management class (in respect of water quality)?
- If not, is the trend towards or away from the designated class?

4.5.2.2 Data acquisition

State indicators

The high priority issues in a catchment must drive the choice of indicators. Consider the causes of water quality problems and the likely impacts of changes in water quality (on the water resource and socio-economic development) and choose state indicators related to these. For example, if human health is an important issue, consider microbiological variables. If there are sensitive ecosystems, identify those water quality variables to which those ecosystems will be most sensitive.

Data could come from the following supporting monitoring programmes (see Figure 4.1), in order of decreasing likely relevance:

- Performance monitoring of RQOs relating to water quality (see Section 3.3.4).
- National and regional water quality status and trends monitoring programmes. These typically provide a more strategic perspective of water quality (see Sections 3.3.3 and 3.3.5). However, if carefully designed, they also provide information directly related to the management class.
- Monitoring of impacts and licence conditions. Upstream and downstream monitoring of points of impact should be an important aspect of the licence conditions of water users that are likely to have significant impacts on water quality (see Section 3.3.2). See Section 6.3 for more details.

4.5.2.3 Data storage and management

Responsibility of supporting programmes

Since state monitoring can probably rely totally on the existence of other supporting monitoring programmes, all data storage and management is likely to be the responsibility of these other programmes.

4.5.2.4 Information generation and dissemination

Assessment criteria

The main assessment criteria will be the RQOs and RWQOs that define the limits of the designated management class. However, formal RQOs may not exist relating to other variables of concern. In this case, criteria will need to be developed and based preferably on nationally or internationally accepted guidelines. This task may require specialist expertise.

4.5.3 "Impact" monitoring

4.5.3.1 Introduction

Generic objectives

To measure, assess and report on a regular basis the impacts of deteriorating water quality in the catchment on (a) aquatic ecosystem integrity, and (b) socio-economic enhancement and quality of life, in a manner that will contribute to an understanding of the effects of inadequate water quality on aquatic ecosystems and water users.

Impact categories

Typically, impacts can be grouped into two main categories:

- *Relating to the principle of protection of water resources*. Impacts would be reflected in changes in the health (integrity) of aquatic ecosystems.
- *Relating to the principles of optimal water use and current equitable access*. Impacts would be reflected in the quality of life and the level of socio-economic enhancement and equitable access achieved, particularly relating to those water uses that areheavily dependent on water quality.

Indicators related to protection of water resources

The level of protection and the current and future uses should be identified in a catchment visioning process. The most desirable balance between protection and use will (ideally) have been captured in the designated management class. Therefore, to some extent, certain "impacts" (relating to water quality) may automatically appear in some indicators chosen to be RQOs. In particular, these may be RQOs <u>not involving water quality directly</u> (*i.e.* they are not water quality attributes such as concentrations, loads or biological effects like toxicity), but nevertheless show a significant degree of dependence on water quality. Since these are <u>resource</u> quality objectives, they are likely to reflect impacts of water quality on the resource. This means these can be interpreted in the context of impacts on "protection of water resources".

The River Health Programme already determines a number of indicators that relate to ecosystem integrity (*e.g.* riparian vegetation index, fish index, SASS5, etc.).

Indicators related to use (socio-economic)

On the other hand, use-related indicators would need to be quality of life or socio-economic indicators that reflect impacts on society, which do not measure anything in the water resource *per se*. The impacts considered here must refer to the kinds of, and degree of, impacts on users related to the catchment vision (and hence consistent with the designated management class). These may include any of the user sectors: domestic, recreational, irrigation, stock watering, aquaculture, and industrial.

4.5.3.2 Data acquisition

Indicators of socio-economic impacts

Socio-economic indicators could be associated with the following:

- Incidence of waterborne diseases. This relates directly to quality of life and is also affected by the prevalence of HIV/Aids. An example related to recreational use could be exposure of the population to contaminated recreational water through water sports.
- Impacts of water fluoridation (*e.g.* costs associated with dental fluorosis, immune and thyroid system disturbance or kidney damage).
- Irrigation of food (like fruit) exported to the European Union. The issues concern microbial and chemical contamination of irrigation and washing water in this agricultural industry.
- Blockage of irrigation systems (relating to suspended solids and algae). An indicator could be the financial losses incurred.
- Eutrophication (trophic status, economic impacts on water boards).

Supporting programmes

In respect of impacts on the water resource, performance monitoring programmes, such as the River Health Programme and the National Eutrophication Monitoring Programme (NEMP), could supply much relevant information directly.

Socio-economic information could be obtained from the Department of Health (particularly information on notifiable water-borne diseases such as cholera and typhoid). Economic impacts associated with blockage of irrigation systems and contamination of exported food may be obtained from the Department of Agriculture. It is also possible that data could be sought from *ad hoc* projects (*e.g.* carried out by universities or other stakeholders).

Socio-economic data acquisition

The following actions will be necessary to develop socio-economic indicators:

- *Incidence of waterborne diseases.* The Department will need to work closely with the Department of Health to establish the extent to which data are available to develop such an indicator. If available, mechanisms will need to be developed that facilitate data collection.
- *Irrigation (fruit export).* The Department may need to liaise closely with the Department of Trade and Industry and appropriate stakeholder organisations such as agricultural boards.
- *Irrigation system blockages.* The Department itself is extensively involved in this issue and should be able to provide some data on the extent of the problem.

4.5.3.3 Data storage and management

Supporting programmes

As supporting programmes with the necessary socio-economic data may not exist, it will be the Department's responsibility to ensure that appropriate data storage and management protocols are developed for the raw data that are needed to compile "Impact" indicators.

4.5.3.4 Information generation and dissemination

Data assessment

Data assessment should be kept simple and should be understandable by non-experts. Linkages with the following should be made as explicit as possible:

- The extent to which socio-economic enhancement is being hampered by inadequate water quality (the "burden of disease").
- The impact of inadequate water quality on those suffering from HIV/Aids because of their immune deficiency.
- Effects on general quality of life.
- The economic impacts of inadequate water quality within development sectors.

Assessment criteria

Preferably use criteria that are internationally accepted. However, when such criteria are not appropriate for South African conditions, more appropriate criteria should be developed that are meaningful in the local context.

4.5.4 "Response" monitoring

4.5.4.1 Introduction

Generic objectives

To measure, assess and report on a regular basis the decisive reactions of society, government or a catchment management agency to deteriorating water quality in the catchment, in a manner that will further contribute to a better understanding (by all stakeholders) of (a) the effects of inadequate water quality, (b) the desires of stakeholders in respect of water quality, (c) measures that may need to be enforced and (d) the successes or failures of response efforts.

Decisive societal responses

Decisive societal responses in order to achieve improvements in water quality may occur because:

- An aquatic ecosystem has been negatively impacted (leaving it with a diminished capacity to provide its goods and services). This may leave the immediate users of such products and services with no option but to respond decisively to a situation they regard as untenable to regain the use of those ecosystem goods or services. Or,
- The water cannot be productively used (whether for domestic, social, agricultural or industrial purposes). This may occur because increased costs have to be incurred to treat the water before it can be used. Responses occur when such users respond decisively to what they regard as an untenable situation in order to improve that situation.

In either case, the responses are often likely to be related to deviations from, or an apparent inability to attain, the designated management class and the associated catchment vision.

4.5.4.2 Data acquisition

Response indicators

Response indicators need to reveal the extent to which society is reacting to inadequate water quality. These responses may be reactive or even precautionary. In particular, they must demonstrate the efforts of society and decision-makers to resolve water quality issues. Possible response indicators may relate to the following:

- Resources allocated to regional offices for state monitoring.
- Relationship between Departmental water quality management posts available and the number of those posts that have been filled.
- Extent of enforcement in mitigation of existing impacts on water quality.
- Extent of remediation of existing impacts on water quality.
- Extent of cleaner production initiatives aimed at reducing pressures on water quality.
- Degree to which ISO-based self-regulation is encouraged.

4.5.4.3 Data storage and management

Supporting programmes

As supporting programmes with the necessary socio-economic data may not exist, it will be the Department's responsibility to ensure appropriate data storage and management protocols are developed.

4.5.4.4 Information generation and dissemination

Data assessment

Data assessment should be kept simple and should be understandable by non-experts. It should also be acknowledged and carefully considered, that a societal response can also be due to perceptions that the water quality is inadequate (while it may not actually be so).

Assessment criteria

Preferably use criteria that are internationally accepted. However, when such criteria are not appropriate for South African conditions, more appropriate criteria should be developed that are meaningful in the local context.

SECTION 5: MANAGEMENT PERFORMANCE MONITORING

Management performance monitoring

Management performance monitoring ensures that role players with identified responsibilities (relating to resource directed management of water quality) are held accountable for their actions (or inaction). In one sense, this is monitoring for quality control, but in a management context. It determines whether or not managers are executing their assigned tasks.

It is important that management performance monitoring, although serving an end in itself, should be designed to be adaptive and responsive to the results of water quality monitoring. It should also be closely aligned with any institutional goals that may comprise the "objectives hierarchy" of a catchment visioning process (DWAF, 2005e).

Resource water quality = ideal overall indicator

The ultimate overall indicator of management performance in the current context is the resource water quality. When management classes are designated for water resources, and associated RQO are defined, the degree to which these are being complied with (or movement towards such compliance is occurring) will also indicate overall management performance.

Generic objectives

To measure, assess and report on a regular basis the degree to which water resource managers in resource directed management of water quality are fulfilling the responsibilities associated with their respective roles.

DWAF, 2003. *Initial Review Report: In Support of an ISO 14001 based Management System for Water Quality Management*. Water Quality Management Series, Sub-Series No. MS 5.3.1. Department of Water Affairs and Forestry, Pretoria, South Africa.

DWAF, 2002. *Human Resource Handbook – A Guideline*. Department of Water Affairs and Forestry, Pretoria, South Africa.

SECTION 6: WATER USE LICENCE CONDITIONS

6.1 Introduction

Introduction

Resource directed management of water quality depends heavily on effective monitoring. Licence conditions can, and should, impose requirements on water users to contribute to such monitoring. Monitoring can be expensive and time-consuming. Therefore, it must be as cost-effective as possible. The following sub-sections provide some basic guidance on how to choose the most appropriate monitoring variables and where to locate monitoring sites.

6.2 Variables of concern

Factors affecting choice of variables of concern

In essence, the water quality variables of concern in any specific case, depend on the following:

- The nature of the water use being authorised.
- The nature of downstream water use.
- The degree to which healthy aquatic ecosystems must be maintained.
- The resource quality objectives (giving effect to the management class that in turn gives effect to the catchment vision).

Each is associated with different sets of variables. The important variables of concern for licence conditions are illustrated in Figure 6.1.

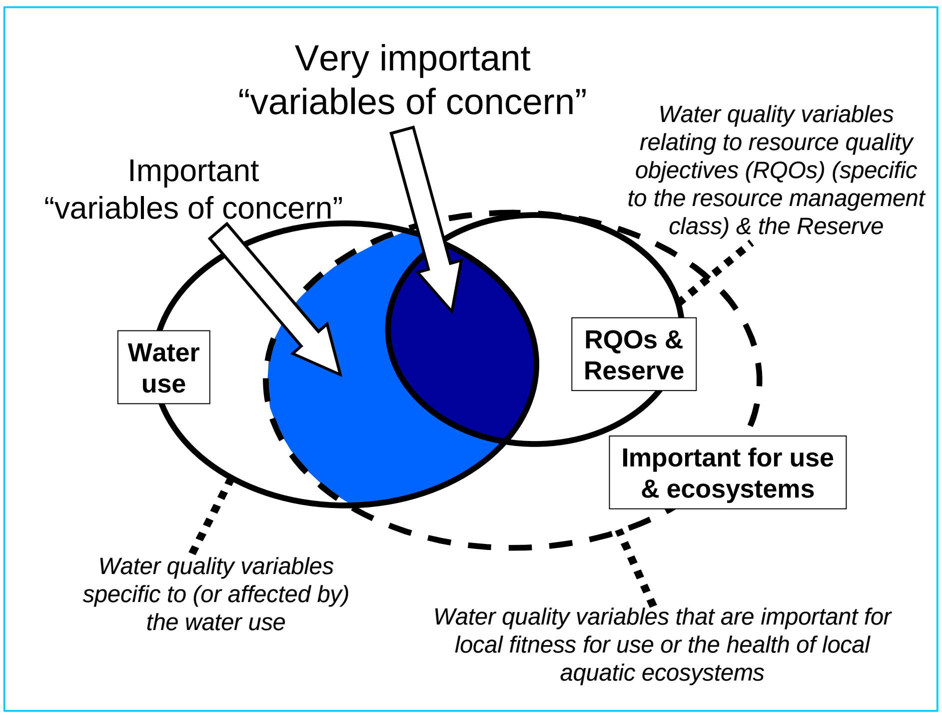

Figure 6.1: Illustration of appropriate water quality variables for licence conditions.

Nature of the water use

Different water uses can affect different water quality variables. For example, the concentrations of problematic chemicals or micro-organisms in a waste discharge would be regarded as the variables specific to that particular water use. These may not be the same as those for another local waste discharge whose chemistry or microbiology may be quite different.

Nature of downstream water use

Abstraction of water may decrease the allocatable water quality of the resource for downstream users. Variables of concern will therefore be those considered important to the downstream users. Importantly, downstream users can include:

- Users using the potentially impacted water directly (i.e. using the same surface water or groundwater) (Figure 6.2); and
- Users using a surface water impacted by a contaminated groundwater because of a significant contribution to the surface water's base flow (Figure 6.2 (a)); and
- Users using a groundwater impacted by contaminated surface water because of significant recharge to the aquifer from the surface water (Figure 6.2 (b)).

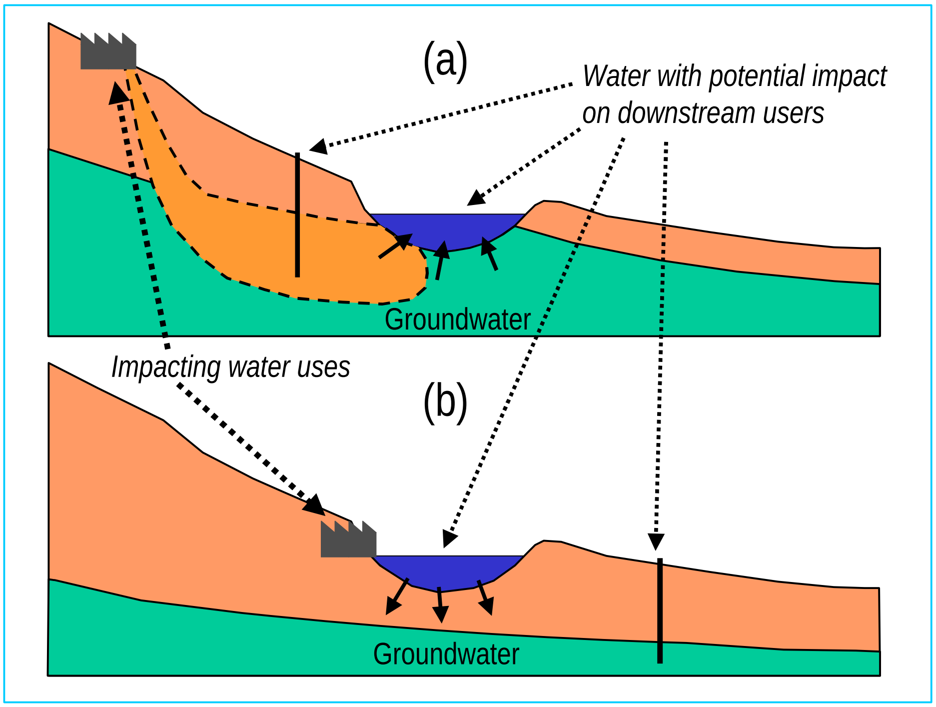

Figure 6.2: Illustration of downstream water users that depend on either surface water resources or groundwater resources.

Downstream aquatic ecosystems

The existence of downstream water-linked ecosystems will also influence the choice of variables of concern.

RQOs and RWQOs

Existing RQOs and RWQOs (which include objectives relating to the Reserve) provide the most obvious guidance for the choice of monitoring variables to be included in any licence condition. These are, by their very nature, resource-focused objectives. They arise directly from the management class designated for the resource. RQOs may be narrative, although quantitative RQOs will facilitate easier management. Some will explicitly relate to water quality. The remainder will refer to other aspects of resource quality (water flow, ecosystem integrity, etc.).

Variables of concern for licence conditions should comprise those that explicitly occur as RQOs or the Reserve (*e.g.* RQO = 6 < pH < 9, therefore monitor pH). However, they can also include those that are implicitly necessary to achieve the stated RQO or Reserve (*e.g.* RQO = 6 < pH < 9, therefore consider monitoring alkalinity or specific components that may significantly influence the pH).

Other important variables of concern

The essential water quality variables will usually be those variables that are directly related to RQOs and specific to (or affected by) the authorised water use (see Figure G10).

However, in some cases, there may be water quality variables specific to (or affected by) the authorised water use that is not associated with RQOs yet may still be problematic. Unusual chemicals (*e.g.* toxicants such as persistent organic pollutants (POPs) or radio nuclides) may not be obviously accounted for by RQOs. In this case, these are also important variables of concern.

Assessment guidelines

In all cases, when a variable is chosen it must be ensured that guidelines exist against which measured results can be assessed. These guidelines must be appropriate for the downstream water uses and ecosystems. Without guidelines a measured value is often useless. RQOs and RWQOs are, by definition, assessment guidelines (or specifically "objectives" in this case). However, if a variable is chosen that is not associated with an RQO or RWQO, then consider using the South African Water Quality Guidelines or other appropriate source.

National water quality monitoring programmes

The various national water quality monitoring programmes (mainly the responsibility of DWAF Directorate: Resource Quality Services) can sometimes provide further guidance for the variables of concern. Their monitoring variables will fall into the above "important" set of variables for fitness for use and ecosystem health. If RQOs are not in place, then the variables used in these national programmes can be chosen as the variables of concern for particular uses. Even if RQOs are in place, the national monitoring variables can supplement the list of variables of concern.

6.3 Monitoring sites

Upstream and downstream (surface water)

Frequently it is useful to monitor at sites located upstream of the most upstream point of impact and downstream of the most downstream point of impact. For some water uses, the impact on a surface water may be immediate (*e.g.* the reduction in allocatable water quality caused by an abstraction). However, for some uses (such as discharge of a water containing waste) there is a mixing zone immediately downstream of the initial point of impact in which a distinct concentration profile will exist across the cross-section of the water resource. Complete mixing is typically necessary for representative samples to be obtained (in order to properly assess likely impacts on downstream ecosystems and water users). Therefore, the downstream monitoring point must be located beyond this mixing zone. A fairly simple procedure for establishing the extent of this zone is available (USEPA, 1991).

Up-gradient and down-gradient (groundwater)

In the case of groundwater, the up-gradient monitoring borehole can be at any point up-gradient of the point or area of groundwater impact. However, care must be taken to ensure that samples are representative of the groundwater quality before any impact occurs caused by the use in question.

Typically a three-dimensional pollution plume is formed down-gradient of the initial point of impact. It is useful to monitor the extent and movement of this plume. Down-gradient boreholes therefore need to be sited by a competent geohydrologist in order to do this effectively.

Conservative versus non-conservative variables

A conservative variable is one whose original amount that entered the water resource remains essentially unaltered. Inorganic ions such as sodium, potassium, chloride (and even sulphate under oxidising surface water conditions) are commonly regarded as conservative. A non-conservative variable is one whose amount can change. Examples include ammonia (that can be oxidised) and all microbiological variables (like bacteria, viruses, etc.) that can die off.

Placing of monitoring sites is intimately dependent on the degree of conservatism. To monitor non-conservative variables, sites must be located relatively close to the initial point of impact. However, the cumulative impacts of conservative variables can often be detected far downstream.

Fate of substances

The fate of chemicals and micro-organisms must also be considered when deciding where to monitor and what medium (water column, sediments, biota, etc.) to monitor. Some migrate readily to sediments while others can volatilise into the atmosphere; still others bioaccumulate in biota. Many of the persistent organic pollutants (POPs) migrate over vast distances through the atmosphere, entering water resources, and though they may be only sparingly soluble in water, they end up accumulated in sediments and biota. Micro-organisms also adsorb readily onto the surfaces of suspended particles of sediment and detritus.

RQOs and RWQOs

If RQOs or RWQOs have been defined as applying everywhere in the resource unit, then monitoring of the variables of concern can be carried out at any point in the resource (subject to the usual conditions of accessibility, health and safety, logistics, resources required, etc.). However, if RQOs or RWQOs have been defined at specific sites in a catchment, then these sites can be used if they are sufficiently close to the points of impact of a water use (upstream and downstream).

In both cases, such monitoring can contribute directly to the "performance" monitoring required by the Department to monitor their achievement and compliance with RQOs.

National water quality monitoring programmes

The national water quality monitoring programmes (most of which are the responsibility of Resource Quality Services) usually have fairly well defined criteria for choosing monitoring sites. The location of these sites is focused on ensuring that the objectives of these national programmes are achieved. If the location of these sites is upstream or downstream of the licensee's point of impact and nearby, then the licencee may be able to contribute to the appropriate national programme by monitoring at these sites.

6.4 *Pro forma* licence conditions

Introduction

Table 6.1 provides some examples of licence conditions relating to monitoring of the resource and socio-economic impacts.

Table 6.1: Examples of licence conditions relating to resource monitoring.

Monitoring resource water quality	
Resource water quality monitoring. *The licensee shall implement a programme (approved by the Department) that monitors all water quality variables of concern. For surface water and groundwater resources this must include monitoring at sites (a) upstream of the most upstream / up gradient point of actual or potential impact of the water use, and (b) downstream / down gradient of the actual or potential impact of the water use.*	Early detection of resource water quality problems and monitoring of existing impacts and facilitation of identification of possible causes.
Variables of concern (RQO, Reserve & international obligations). *The licensee shall monitor at least those water quality variables that are (a) specific to, or affected by, the authorised water use and (b) included explicitly or implicitly in downstream resource quality objectives (RQOs), the Reserve or international obligations. Should water quality variables for the latter change, then the licensee shall modify the monitoring programme design to include such new water quality variables.*	To ensure that the most relevant monitoring variables are chosen.
Abstraction from a surface water resource. *The licensee shall monitor at points upstream and downstream of the point or area of water quality impact, at least those water quality variables in terms of which allocatable water quality is defined for (a) the authorised use and (b) all potentially impacted downstream users.*	Monitors degree to which the licensee does not exceed the allocated water quality and that the abstraction does not unacceptably reduce the dilution capacity for downstream users.
Seawater ingress into coastal freshwater aquifer. *The licensee shall monitor the salinity of the groundwater quality on the seaward side of the point(s) of groundwater abstraction at a frequency, site and depth determined by a suitably qualified geohydrologist.*	To backup the primary management of the aquifer (achieved by water level control) by detecting seawater ingress into the freshwater aquifer.
Artificial groundwater recharge. *The licensee shall monitor at frequent intervals (to be determined by a suitably qualified geohydrologist) the water quality of the water being used for the recharge (represented by the essential variables of concern) and, less frequently (also determined by such a geohydrologist) the water quality of the aquifer in boreholes sited to provide an adequate representation of the aquifer as a whole.*	Early detection of problems can help prevent irreversible impacts.

Mine dewatering (operations phase). *The licensee shall monitor, at appropriate intervals, sites and depths (to be determined by a suitably qualified geohydrologist), the water quality of the groundwater removed (represented by the essential variables of concern) and in appropriately placed boreholes at adequate intervals to reflect possible changes in the quality of the groundwater flowing in from surrounding aquifers.*	To detect potential changes in source aquifers from which the dewatered water is originating and hence detect potential impacts on other local water users or aquatic ecosystems.
Mine dewatering (post-closure phase). *The licensee shall monitor, at appropriate intervals, total period, sites and depths (to be determined by a suitably qualified geohydrologist), the water quality of the groundwater (represented by the essential variables of concern) to reflect the long-term water quality impacts of the mining operations on surrounding aquifers.*	To detect potential changes in aquifers that are currently being used, or that may be used in future, as the original water levels and groundwater flow regime is restored, and hence detect potential impacts on other local water users or aquatic ecosystems.
Groundwater acidifcation in dolomitic aquifers. *The licensee shall monitor, at appropriate intervals, sites and depths (to be determined by a suitably qualified geohydrologist), the water quality of the groundwater (represented at least by pH) to reflect the potential for dissolution of dolomite in the aquifers and hence the potential for subsidence.*	Early detection of problems can avoid catastrophic impact on aquifers, associated water-linked ecosystems and water users.
Persistent Organic Pollutants (POPs). *The licensee shall contribute to the National Toxicity Monitoring Programme (NTMP) by monitoring the water quality in the water resource in accordance with the specifications of the NTMP.*	Monitoring will contribute to (a) national status and trends monitoring, (b) local, regional and national management of the contaminants, and (c) fulfilling our international obligations (Stockholm Convention) in respect of these problematic pollutants.
Toxicity. *The licensee shall contribute to the National Toxicity Monitoring Programme (NTMP) by monitoring the water quality in the water resource in accordance with the specifications of the NTMP.*	Monitoring will contribute to (a) national status and trends monitoring, and (b) local, regional and national management of the contaminants.
Radioactivity. *The licensee shall contribute to the National Radioactivity Monitoring Programme (NRMP) by monitoring the water quality in the water resource in accordance with the specifications of the NRMP.*	Monitoring will contribute to (a) national status and trends monitoring, and (b) local, regional and national management of the contaminants.
Nutrients. *The licensee shall contribute to the National Eutrophication Monitoring Programme (NEMP) by monitoring the water quality in the water resource in accordance with the specifications of the NEMP.*	Monitoring will contribute to (a) national status and trends monitoring, and (b) local, regional and national management of the contaminants.
Monitoring resource quality (other than water quality)	
Positive ecological impact monitoring. *The licensee shall monitor the motivated ecological impact of the water use by providing a measure, at an appropriate time interval, of the following indicator(s). << Specify indicator(s) >>*	Ensures original claims of positive impacts on resource water quality are achieved.
Negative ecological impact monitoring. *The licensee shall monitor the potential ecological impact of the water use by providing a measure, at an appropriate time interval, of the following indicator(s). << Specify indicator(s) >>*	Ensures originally identified potential negative impacts on resource water quality are monitored to ensure that they remain within acceptable limits.
Variables of concern (ecosystem integrity). *The licensee shall contribute to the River Health Programme (RHP) by monitoring the resource in accordance with the specifications of the RHP.*	Monitoring will contribute to (a) national status and trends monitoring, and (b) local, regional and national management of the water resource use.
Monitoring socio-economic impacts	
Positive socio-economic impact monitoring. *The licensee shall monitor the motivated socio-economic impact (e.g. redress of past racial and/or gender discrimination) of the water use by providing a measure of said impact on an annual basis.*	Ensures original claims of positive impacts are achieved.
Negative socio-economic impact monitoring. *The licensee shall monitor the potential socio-economic impact of the water use by providing a measure of said impact on an annual basis.*	Ensures originally identified potential negative impacts on resource water quality are monitored to ensure they remain within acceptable limits.

SECTION 7: GLOSSARY

Data assessment. The evaluation or interpretation of raw monitoring data in a manner that adds value to the data in the sense of extracting useful information. (A common data assessment is comparison of raw data with guidelines).

Fitness for use. A scientific judgement, involving objective evaluation of available evidence, of how suitable the quality of water is for its intended use or for protecting the health of aquatic ecosystems.

Indicator. A simplified characteristic of a system that provides a means of conveying information about the presence or absence of change in that system.

Monitoring. The measurement, assessment and reporting of selected properties of water resources in a manner that is focussed on well-defined objectives. These monitoring objectives should also be linked clearly to water resource management objectives.

Monitoring design. The definition of all the aspects that are necessary for successful implementation of a monitoring programme. These include the monitoring variables, monitoring site selection, sampling methods, monitoring frequency, analytical procedures, data assessment, reporting formats, etc.

Monitoring variable. An attribute that changes over time and space, and whose measurement provides the raw data upon which a monitoring programme is based, and whose behaviour provides useful information to managers.

Principle. A statement providing guidance on what should be strived for, typically acknowledging an underlying values-based assumption.

Quality assurance. The implementation of all activities that minimise the possibility of quality problems occurring. These include amongst others, training, instrument calibration and servicing, quality control, producing clear and comprehensive documentation, and so on.

Quality control. The process of ensuring that recommended monitoring procedures are followed correctly by detecting and correcting quality problems when they arise, so that the accuracy of primary observations or measurements is (a) defined, (b) within acceptable limits and (c) recorded.

Resource quality. Includes all aspects of water quantity, water quality and aquatic ecosystem quality, the latter including the quality of in-stream and riparian habitats and aquatic biota.

Resource quality objectives (RQOs). Numeric or descriptive (narrative) goals for resource quality within which a water resource must be managed. These are given legal status by being published in a *Government Gazette*.

Resource water quality objectives (RWQOs). Numeric or descriptive (narrative) in-stream (or in-aquifer) water quality objectives that are typically set at a finer resolution (spatial or temporal) than RQOs, and that provide greater detail upon which to base prudent management of water quality.

Stakeholder. An individual, group or organisation that has an interest in, or is affected by, an initiative, and who may therefore affect the outcome of an initiative.

Stress, water quality. A state in which the water quality is inadequate for the desired water use. For many uses, water quality stress exists when there is no allocatable water quality.

Stressed water resource. A water resource for which the demand for benefits exceeds the supply. This can apply to either the quantity of water or to the allocatable water quality.

Sustainability indicator. An indicator conveying information about progress towards sustainable development.

Waste. Defined by the National Water Act as including any solid material or material that is suspended, dissolved or transported in water (including sediment), and which may be spilled or deposited on land or into a water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water resource to be polluted.

Watercourse. Defined by the National Water Act as 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, and any collection of water that the Minister may declare to be a watercourse. Furthermore, reference to a watercourse includes, where relevant, its bed and banks.

Water quality. The physical, chemical, radiological, toxicological, biological and aesthetic properties of water that (1) determine its fitness for use, or (2) that are necessary for protecting the health of aquatic ecosystems. Water quality is therefore reflected in (a) concentrations of substances (either dissolved or suspended), (b) physico-chemical attributes (e.g. temperature), (c) levels of radioactivity, and (d) biological responses to those concentrations, physico-chemical attributes or radioactivity.

Water resource. Defined by the National Water Act as including a watercourse, surface water, estuary or aquifer.

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