CHAPTER 1: BACKGROUND

1.1 INTRODUCTION

This document presents the current state of thinking in the design of the National Toxicity Monitoring Programme (NTMP). It will evolve into a final report that will record the design process and, in particular, why certain decisions were taken. It will therefore provide background to, and complement, the formal implementation manual of the NTMP.

The NTMP will involve measurements of toxicity to selected organisms and the concentration of selected toxicants. For reasons given in subsequent chapters, these toxicants have been initially restricted to the so-called persistent organic pollutants (POPs). Other toxicants can be included in future. The intention is to complement other national monitoring programmes by reporting on the status and trends of toxicity in South African inland surface water resources. It is also the intention to extend the degree to which "response-based" monitoring is performed in South Africa (by monitoring toxicity) while also adopting the traditional "stressor-based" approach of monitoring some toxicant concentrations directly.

The overarching framework for the current work is the "Strategic Framework for National Water Resource Quality Monitoring Programmes" [DWAF, 2004a]. This provides general design guidelines and a framework for capacity building.

The current design is specifically restricted to inland surface waters. The intention is to extent this design in future to groundwater and estuaries.

1.2 NEEDS ASSESSMENT

A needs assessment was for the NTMP was performed [DWAF, 2003b]. It recognised a number of reasons why the NTMP was necessary:

- South Africa is a signatory of various international agreements and conventions that mean that such monitoring is necessary.
- The Department recognises a responsibility for keeping abreast of international trends.
- The Department also recognises a responsibility for initialising capacity creation upon which further regional capacity creation can be based.

Some of the issues (like the target users and objectives) are addressed explicitly in the following sub-sections. However, the following summarises other the key recommendations.

- The NTMP should address national issues while anchoring itself at catchment level (within catchment management agencies).
- The choice of toxicants should ideally be based on the following four major categories of information. (1) The nature of the monitoring variable. (2) The nature of potential occurrence (throughout South Africa). (3) The nature of the potential impact (on fitness for use). (4) Nature of the monitoring required.
- The choice of toxicity tests should be based on the outcome of the Water Research Commission funded project that will establish guidelines for the choice of toxicity tests to address the requirements of the National Water Act.

- The degree of assessment of raw data appearing in annual reports should be simple though scientifically sound. They should add value to the raw data, not be misinterpreted, and be as consistent as possible for toxicants and toxic effects.
- The NTMP should not be designed to explicitly establish the sources of toxicants or toxic effects.
- The reporting format should make use of easy-to-understand colour-coded maps that illustrate the status and trends of the nature and extent of toxicants and toxicity nationwide.
- The next phase (*i.e.* the current design phase) of this project should, resources permitting, focus on simultaneously producing monitoring designs for watercourses (including sediments), qroundwaters and estuaries.
- Careful consideration must be given to the capacity creation needs demanded by the ultimate choice of monitoring variables.
- The primary role player in future phases will be DWAF. It will have primary management responsibility but will delegate some of this responsibility to catchment management agencies (CMAs). However, specialist consultant expertise is likely to be necessary to supplement that existing in DWAF. An international funding agency is also likely to be a role player for the pilot study phase.
- The overall project should be planned and executed in a modular way while at the same time being holistic.

As will become evident in the following chapters, all of these issues except one are addressed as recommended. The one exception is that this design phase is restricted to inland surface water resources.

1.3 TARGET USERS

It is important that the ultimate users of the target users ("clients") of the information provided in reports produced by the NTMP are (a) clearly identified and (b) kept in mind at all times during the design of the monitoring programme.

The needs assessment for the NTMP identified the following target users [DWAF, 2003b].

Primary users:

- The Minister of Water Affairs and Forestry
- Water Resource Managers and Water Quality Managers (at DWAF Head Office and Regional Offices, CMAs and Water User Associations)

Secondary users:

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

The primary users are necessarily those that have a direct voice in monitoring design decisions. The secondary users are regarded as having an indirect voice because they may use and benefit from the information generated.

1.4 REVISED OBJECTIVES

Objectives of the NTMP were proposed in the needs assessment [DWAF, 2003b]. Slight changes of emphasis described elsewhere in this document, and a need to be more specific about the scope of the water resources addressed in this phase, have resulted in the following re-wording:

National Toxicity Monitoring Programme
DWAF National Objectives

To measure, assess and report on a regular basis
on the status and trends of the nature and extent of,

first, the potential for toxic effects to selected organisms, and,
secondly, potentially toxic substances
in South African inland surface water resources

in a manner that will
(A) support strategic management decisions
in the context of (1) fitness for use of those water resources
and (2) aquatic ecosystem integrity, and
(B) be mindful of financial and capacity constraints, yet,
be soundly scientific.

It is envisaged that the NTMP will fulfil an auditing function as well as be a basis of communication for informing the public.

1.5 RELEVANT INITIATIVES

1.5.1 Introduction

There are many initiatives within the Department and in other organisations that have a bearing, one way or another, on the design of the NTMP. The following sub-sections summarise some of these, their current status and briefly how they relate to the current design.

1.5.2 Guidelines for toxicity tests

1.5.2.1 Purpose

A project funded by the Water Research Commission entitled "Guidelines for the Selection of Toxicity Tests in Support of the National Water Act (NWA)" is nearing completion. The purpose of this initiative is to provide a facility to the Department and other stakeholders in water resource management that will allow for the objective choice of appropriate toxicity tests in a series of specific NWA contexts.

1.5.2.2 Approach

The management contexts identified are as follows:

Resource Directed Measures

- Classification and Resource Quality Objectives

- Reserve determination – basic human needs
- Ecological Reserve Determination
- Monitoring ecosystem health
- Monitoring compliance with Resource Quality Objectives
- National status and trends monitoring

Source Directed Controls

- Pollution prevention
- Emergency incidents
- Licence conditions

Inland water resources and estuaries are the two water resource types considered. The water body, sediment or groundwater zone can also be chosen. Both fresh and brackish waters are considered for inland water resources.

Only tests considered to be "well established" and reliable are included.

Generic management criteria relating to the following were specified for each management context in collaboration with the Department.

- Legal defensibility
- Effect period (short-term or long-term)
- Target kingdom (animal or plant) – the kingdom to be afforded protection
- Maximum days turnaround time – how quickly results of tests can be obtained
- Maximum costs (low, medium or high)

The facility is embodied in an Excel spreadsheet. The user specifies the nature of the resource of interest and the most relevant management context. The spreadsheet then indicates the suite of toxicity tests that satisfy the criteria. This "shortlist" of tests becomes the point of departure for the final choice of tests most appropriate for the circumstances using other requirements such as the specific organism, the physical nature of the test, analytical and infrastructure requirements, toxicity test endpoint, and so on.

1.5.2.3 Status

The first version is likely to be released in mid-2005 for formal testing.

1.5.2.4 Relevance

Although being more broadly based than only national status and trends monitoring, this facility will almost certainly provide essential input into the design of the NTMP. In particular, it will provide an initial shortlist of applicable toxicity tests that can be further refined (shortened) by imposing other more demanding criteria. These criteria may relate to the following:

- Suitability for nationwide decentralised capacity creation
- Simplicity of application
- Simplicity of assessment of results (in terms of the NTMP objectives)
- Costs
- The degree to which direct analysis of chemical toxicants can be practically undertaken

1.5.3 Environmental Water Quality

1.5.3.1 Introduction

"Environmental Water Quality" (EWQ) is a concept that focuses on understanding how chemical, microbiological, radiological and physical characteristics of water (the "water quality") link to the responses of living organisms and ecosystem processes (the "environment") [Palmer *et al*., 2003]. There are three kinds of information that underpin this integrated picture:

- The physico-chemical characteristics of water (obtained from chemical and physical analysis).
- The presence, absence and abundance of biota in an ecosystem (obtained from biomonitoring).
- The responses of specific biota to specific concentrations or mixture of components (obtained from ecotoxicology).

1.5.3.2 Integrated Water Resource Management (IWRM)

Strategic Adaptive Management is at the core of IWRM. This involves a cyclical process of four steps: Plan, Implement, Monitor and Adapt.

The "plan" typically involves a catchment assessment study the ultimate purpose of which is to feed into the catchment management strategy. This requires setting the basic human needs Reserve and the ecological Reserve. The latter requires setting the requirements of the ecosystem (the "ecospecs") and the requirements of users (the "userspecs"). EWQ plays a role in a number of contexts:

- Water quality ecospecs can be explicitly based on the EWQ concept.
- The characteristics of a catchment can be described in terms of the above three kinds of information underpinning EWQ.
- This integrated picture can contribute to a better understanding of a catchment during stakeholder engagement and catchment visioning processes.
- The three components of EWQ can contribute directly to the resource classification process since each class can be defined in terms of physico-chemistry, biomonitoring and ecotoxicology.

The "implementation" step focuses on Source Directed Controls (SDCs) that aim to ensure the objectives set for a water resource (the Resource Quality Objectives, RQOs) are achieved. This involves formally authorising (*i.e.* licensing) users for defined water uses, encouraging self-regulation and imposing economic incentives and penalties. All three components of EWQ can be used as licence conditions.

The "monitoring" step can include monitoring the resource and auditing end-of-pipe discharges. All three aspects of EWQ are applicable.

The "adapt" step refers to assessing the results of the monitoring to determine whether the original plan is on track (*i.e.* the RQOs, and hence the assigned management class, is either being maintained or movement towards their achievement is as planned). If indications are otherwise, then changes (*i.e.* management interventions) are required to ensure this happens.

1.5.3.3 Status

Many water use licences involve monitoring the physico-chemistry of water. Some water use licences exist at this time (2004) that require biomonitoring. However, far fewer exist that include toxicity testing. A particular current drawback is that guidelines and standards do not yet exist for toxicity tests so such testing is only recommended, not mandatory.

However, biomonitoring is being carried out in many water management areas.

1.5.3.4 Relevance

Monitoring toxicants directly produces information on the chemical characteristics of the water. Monitoring effects on biota (through toxicity tests, biomarkers or bioaccumulation measurements) provides responses of biota to the presence of chemical components.

The EWQ concept is relevant to the NTMP but only in the context of chemical components. (Microbiological and radiological components, for example, are excluded from the NTMP.) It is particularly relevant at the higher level of providing a framework for thinking when considering how information from the NTMP could complement, for example, the river health programme (which uses biomonitoring). The same kind of thinking could be applied to how the inorganic chemicals national monitoring programme might complement the river health programme.

1.5.4 Resource Directed Measures

1.5.4.1 Introduction

The National Water Act stipulates that the following be defined for each appropriate unit of water resources. Each should be defined through effective stakeholder engagement that is given effect and focus through a catchment visioning process [DWAF, 2003a].

Resource management class

Defining a management class for a water resource can be regarded as the "first line of defence" that ultimately aims at ensuring sustainable development. It captures the most desirable balance between protection of water resources, optimal water use, equity between generations and current equitable access [DWAF, 2003a].

Basic human needs Reserve

The basic human needs Reserve provides for the essential needs of individuals (*e.g.* drinking, food preparation and personal hygiene) served by the water resource in question. It specifically does not include any volume of water for small- or large-scale productive uses.

Ecological Reserve

The ecological Reserve is the quantity and quality of water required to protect aquatic ecosystems of water resources. The specifications of the water quality component of the ecological Reserve on an individual variable basis are called "ecospecs". The degree of “protection” actually afforded to aquatic ecosystems by the Ecological Reserve will depend on the desired degree of protection and the ability of the Department or CMAs to actually ensure that this volume is delivered consistently and in accordance with the requirements laid down in the ecospecs.

Resource Quality Objectives (RQOs)

RQOs are either numerical or narrative expressions of the desired water quality, water quantity and overall resource quality for the management class chosen for a particular water resource.

Resource directed water quality management policy

A draft operational policy exists that is heavily principle-based [DWAF, 2003a]. It proposes hierarchies of enabling principles for all the important principles that underpin resource directed

water quality management. Examples are sustainable development, effective stakeholder engagement, various management and governance principles and integrated water resource management. The policy provides a strategic national perspective as well as specific policy statements on all important resource directed issues. These include catchment visioning, catchment assessment, resource directed measures, catchment management strategies and monitoring and auditing.

1.5.4.2 Status

The Class, Reserve and RQOs for each resource unit will be published in the *Government Gazette*. This makes them legally enforceable. However, the Department remains preoccupied with developing appropriate procedures for classification, Reserve determinations and setting RQOs. These efforts are also more heavily focussed on surface water resources than other resources (groundwater, estuaries, wetlands, and impoundments).

It is also the Department's policy to set either narrative or quantitative resource water quality objectives (RWQOs) that are spatially and temporally incremental water quality targets [DWAF, 2003a]. These are management targets that will guide Source Directed Controls and ultimately allow a realisation of the catchment vision in general and the RQOs in particular. However, until RQOs are defined, individual RWQOs necessarily remain undefined. However, procedures for their definition (linking RQOs and effluent discharge licence conditions) are being developed.

Draft recommendations currently exist for many variables comprising the water quality component of the ecological Reserve [Rossouw, 2004]. However, while toxicity tests are acknowledged as being an important biological response variable, methods for their inclusion have not been developed. Methods for categorising the present state of a resource as Natural, Good, Fair or Poor are provided for 15 individual substances (some as a function of hardness) for which South African Water Quality Guidelines for Aquatic Ecosystems are available [DWAF, 1996g]. These are aluminium, ammonia, arsenic, atrazine, cadmium, free chlorine, chromium(III), chromium(VI), copper, cyanide, endosulfan, fluoride, lead, mercury and phenol. Note that only three organic compounds are addressed (atrazine, endosulfan and phenol).

A stakeholder engagement and catchment visioning process would result in the desired state *of the aquatic ecosystem* being expressed as Natural, Good or Fair. Benchmark tables for individual substances (salts, pH, the above toxicants, etc.) translate this desired category into desired numerical ranges of concentration. That is, attaining and maintaining the variables within these ranges (or better) is regarded as ensuring the desired (or better) level of aquatic ecosystem integrity is attained or maintained. (Equivalently, "reserving" these ranges ensures the desired aquatic ecosystem integrity.)

In practice this usually means that upper limits on concentrations are specified. For example, if the desired state in "Natural", then the arsenic concentration would be need to be kept below, say, 0.02 mg/l (unless this benchmark value has been otherwise calibrated because of naturally higher levels). However, the desired state may only be "Fair" (since the water resource may have been accepted by all as being a "working resource" whose ecosystem integrity can be sacrificed to some degree because of other, typically socio-economic, advantages). Then the upper limit may be, say, 0.13 mg/l.

1.5.4.3 Relevance

The RQOs are the ultimate expression of fitness for use of any particular resource (agreed as so by all relevant stakeholders). The objectives of the NTMP state that the monitoring should "support strategic decisions in the context of fitness for use". Some practical connection between the NTMP and RQOs is therefore essential.

There should also ideally be compatibility between the approaches used in the NTMP and those used for specifying the ecological Reserve.

1.5.5 Source classification

1.5.5.1 Purpose

A classification system at national and water management area level has been proposed for sources of pollution [DWAF, 2003d]. Source classification is defined as the "categorising of sources according to the level of threat or risk posed by the source to the water resource". The primary purposes are the following:

- To enable water quality management efforts to be focussed on those pollution sources that pose the greatest risks. In particular, the water use authorisations and the development of Best Practice guidelines can be prioritised.
- To ensure that those sources with the greatest impact (or potential impact) are subjected to scrutiny in respect of the principles of efficiency (*i.e.* wasting of water is minimised) and differentiation (*i.e.* catchment-specific conditions are considered).

1.5.5.2 National level classification

The approaches recognises five main sectors, namely mining, industry, agriculture, settlements (urban and rural/dense) and national infrastructure (*e.g.* contaminated land, railway and shipping activities and natural processes). Each is divided into sub-sectors that are further categorised into activities and processes of similar nature. These are then classified on the basis of the risk or threat posed to water resources, *i.e.* the potential of the source to have a serious detrimental impact on the water quality of the resource.

Various source management options are proposed that depend on the class (A, B or C) assigned to each activity. These options refer to requiring Best Practice guidelines, the degree of co-governance, whether licensing is required or whether a general authorisation suffices, or whether an exemption is appropriate.

1.5.5.3 Water Management Area classification

Classification at this level will be used to ensure the Source Management Plan of the catchment management strategy of each catchment management agency is appropriately focussed. An inventory of sources will be compiled with a description of the relevant processes, substances or activities. These will then be the basis of estimating the risk to the water resource (based on either or both of expert opinion and a semi-quantitative risk-based approach).

A risk-ranking matrix is suggested as one approach. It involves estimating the probability of a problem occurring on a six-point scale (from "not expected to happen" to "expected to occur") and classifying the likely consequences also on a six-point scale (from "very low " to "catastrophic"). The ranking matrix then provides a score from 1 to 20 that is regarded as the level of risk.

1.5.5.4 Status

Full implementation of the source strategy nationwide is only envisaged by 2014 [Bredenhann, 2004, personal communication].

1.5.5.5 Relevance

National status and trends monitoring is traditionally performed on the basis of priority areas. "Priority areas" in the current context are areas in which either (a) the actual water quality is

significantly impacted by toxicants or (b) there is a significant risk of such impacts. The source classification approaches have the potential to provide useful information on likely priority areas.

1.5.6 Direct Estimation of Ecological Effect Potential (DEEEP)

1.5.6.1 Approach

Traditional substance-specific assessments of wastewater discharges have limitations. Accordingly, a new approach to assessing the toxicity of whole effluents has been proposed [DWAF 2003c]. Effect-based hazard assessments of effluents can provide insight into the combined effects of both known and unknown hazardous substances (and their interactions, either synergistic or antagonistic) in a mixture.

1.5.6.2 Status

Only the general methodology has been proposed and released for comment [DWAF, 2003c]. Specific tests have not yet been proposed.

1.5.6.3 Relevance

Although the DEEEP approach tests effluents and not water resources, it seems sensible to ensure some degree of compatibility between the two initiatives for a number of reasons:

- Capacity creation could possibly be focussed on satisfying the requirements of both initiatives simultaneously. This could result in considerable cost savings.
- Data assessments from each initiative are more likely to facilitate establishing cause-effect relationships between discharge and resource quality though this is not a deliberate intention of either initiative.