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A GUIDE TO CONDUCT WATER QUALITY CATCHMENT ASSESSMENT STUDIES:
In support of the Water Quality Management Component of a Catchment Management Strategy

Department: Water Affairs and Forestry

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PREFACE

Reform of South African water resource management has been a key focus of the Department of Water Affairs and Forestry (DWAF) for a number of years. This reform process has already seen a number of highlights, prime amongst which was the formulation of a new National Water Policy in 1997 and promulgation of a new water statute, the National Water Act (Act No. 36 of 1998). These developments established, *inter alia*, a formal process of integrated water resource management according to 19 water management areas (WMAs). At the national scale, this process of integrated management is now structured by a National Water Resource Strategy (NWRS), while evolving Catchment Management Strategies (CMS) provide an integrated management framework at the catchment scale.

Sound strategies for catchment management require relevant information about the *water-related* natural attributes, infrastructure developments, human and ecological needs, human impacts, issues and economic development in a catchment. The process of collating, processing and interpreting such information in a water-related context is now generally called a “catchment assessment study”. Although various forms of catchment assessments (sometimes called “situation analyses” or “basin studies”) have been common-place in South African water resource planning for some time, a number of diverse approaches have been followed which have not necessarily been of comparable standard and consistency. Furthermore, the particular mix of information needs that statutory strategy development invokes, brings new challenges in the field of water resource decision support.

In such a new and evolving management environment, consistency and acceptable standards of both strategy development and supporting information might easily suffer. Therefore, a clear need has arisen for guiding procedures to support the processes and decisions involved. (It should also be noted that Section 10(1) of the National Water Act enables the establishment of such “guidelines” for the preparation of catchment management strategies.) DWAF has responded to this need by initiating processes to develop a range of guideline documents in the integrated water resource management and catchment management fields. This document is one of a trio of inter-related documents specifically aimed at the domain of *water quality management*:

- *A Conceptual Introduction to the Nature and Content of the Water Quality Management and Assessment Components of a Catchment Management Strategy*
- *A Guideline to the Water Quality Component of a Catchment Management Strategy*
- *A Guide to Conduct Water Quality Catchment Assessment Studies.*

The development of these documents was informed by interviews with knowledgeable professionals operating in the water resource management field, as well as by the proceedings and outcomes of two dedicated Technical Workshops. The development process was guided by a Steering Committee under my chairmanship and with the support of the Director: Catchment Management. A series of three Training Workshops, using an early draft of these documents, were also conducted with Regional Office staff in three different regions of the country. Valuable comments and insights, contributed by the Training Workshop participants, were incorporated in the documents.

Comments from those using these three documents in the future will assist their revision and ongoing improvement. The documents will also be used for continuing capacity building and training and for conceptual and technical support to the unfolding implementation of the National Water Act.

JLJ van der Westhuizen
Director: Water Quality Management

DOCUMENT INDEX

Reports as part of this Sub-Series:

Sub-Series No.	Report Title
MS 8.1	A Conceptual Introduction to the Nature and Content of the Water Quality Management and Assessment Components of a Catchment Management Strategy
MS 8.2	A Guideline to the Water Quality Management Component of a Catchment Management Strategy
MS 8.3	**A Guide to conduct Water Quality Catchment Assessment Studies: In support of the Water Quality Management component of a Catchment Management Strategy (this document)**

Other relevant DWAF Reports:

- RSA Department of Water Affairs and Forestry, 2001.
  Integrated Water Resource Management Series, Sub-Series No. MS 6.1, *Guidelines on the Establishment and Management of Catchments Forums: in support of Integrated Water Resource Management*. Pretoria.

- RSA Department of Water Affairs and Forestry, 2001.
  Integrated Water Resource Management Series, *Generic Framework for Catchment Management Strategies* (Draft). Pretoria.

- RSA Department of Water Affairs and Forestry, 1999.
  DWAF Report No. WQP 0.1. *A Framework for Implementing Non-Point Source Management under the National Water Act.* Pretoria.

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ABBREVIATIONS AND ACRONYMS

CA	- catchment assessment
CARP	- conservation of agricultural resources plan
CAS	- catchment assessment study
CBD	- central business district
CBO	- community based organisation
CCWR	- computing centre for water research
CEC	- committee for environmental coordination
CMA	- catchment management agency
CMS	- catchment management strategy
DISA	- daily irrigation and salinity analysis (model)
DWAF	- Department of Water Affairs and Forestry
DWAF HO	- DWAF: Head Office
DWAF RO	- DWAF: Regional Office
EIP	- environmental implementation plan
EMF	- environmental management framework
EMP	- environmental management plan
GIS	- geographic information system
GNP	- gross national product
GPS	- global positioning system
GRP	- gross regional product
GWMP	- general waste management plan
HIS	- hydrological information system
HOD	- heads of departments committee
HSPF	- hydrological system program fortran
HWMP	- hazardous waste management plan
IDP	- integrated development plan
IMPAQ	- Impoundment/river management and planning assessment tool for water quality simulation
IWRM	- integrated water resources management
LDO	- land development objectives
MSDF	- metropolitan spatial development framework
NGO	- non-governmental organisation
NWA	- National Water Act (Act No 36 of 1998)
NWRS	- national water resource strategy
POLMON	- pollution monitoring system
QA/QC	- quality assurance/quality control
RDM	- resource directed measures
RQ	- resource quality
RQOs	- resource quality objectives
RWQOs	- resource water quality objectives
SCS	- soil conservation service
SDI	- spatial development initiative
SEA	- strategic environmental assessment
SMO	- source management objective
TDS	- total dissolved salts
TLC	- transitional local council
TRC	- transitional regional councils
USLE	- universal soil loss equation
WMA	- water management area
WMI	- water management institution
WMS	- water management system

WQCAS	- water quality catchment assessment study
WQCMS	- water quality catchment management strategy
WQMFP	- water quality management framework plan
WQMIP	- water quality management implementation plan
WQT	- name of a model
WSDP	- water services development plan
WSI	- water services institution
WRC	- Water Research Commission
WRM	- water resources management
WRPM	- water resources planning model
WRYM	- water resources yield model
WSA	- water services authority
WSP	- water services provider
WUA	- water user association

EXECUTIVE SUMMARY

Background

Reform of South African water resource management has been a key focus of the Department of Water Affairs and Forestry (DWAF) for a number of years. This reform process has already seen a number of highlights, prime amongst which was the formulation of a new National Water Policy in 1997 and promulgation of a new water statute, the National Water Act (Act No. 36 of 1998). These developments established, *inter alia*, a formal process of integrated water resource management according to 19 water management areas (WMAs). At the national scale, the process of integrated management is now structured by a National Water Resource Strategy (NWRS), while evolving Catchment Management Strategies (CMS) provide a management framework at the regional and catchment scale. Resource directed measures (RDMs) comprising a Resource Management Classification system, implementation of a "Reserve" and the setting of Resource Quality Objectives (RQOs) underpin this framework. The "Reserve" is that quantity and quality of water required for basic human needs, as well as that quantity and quality required to sustain aquatic ecosystems. RQOs are time-related management goals reflecting a path leading to an agreed future state for the catchment, as specified by the Resource Management Class.

Important components of these new approaches are the over-arching requirements to ensure sustainable use of water resources and the equitable use[1] of the resource for the "optimum social and economic benefit" of the country. Coupled with these are the need for a transparent and participative approach to water resources management and the redress of inequitable access to water resources caused by past policies.

These policy principles must underlie the approach to water resource management on a catchment basis. Catchment water quality management is a component of this process, and as such is subject to these policy principles.

Sound strategies for catchment management require relevant information about water-related conditions, issues and developments in a catchment. The process of collating, processing and interpreting such information is now generally called a "Catchment Assessment Study". Although various forms of catchment assessments (sometimes called "situation analyses" or "basin studies") have been common-place in South African water resource planning for some time, a number of diverse approaches have been followed which have not necessarily been of comparable standard. Furthermore, the particular mix of information needs that statutory strategy development invokes, brings new challenges in the field of water resource decision support.

In such a new and evolving management environment, consistency and acceptable standards of both strategy development and supporting information might easily suffer. Therefore, a clear need has arisen for guiding procedures to support the processes and decisions involved. (It should also be noted that Section 10(1) of the National Water Act enables the establishment of such "guidelines" for the preparation of catchment management strategies.) DWAF has responded to this need by initiating development of a number of guideline documents. This document is one of a trio of inter-related documents specifically aimed at the domain of water quality management, that have been developed by the Directorate: Water Quality Management:

[1] Most importantly, "Use" as defined in the National Water Act includes *inter alia* the consumptive use of the resource, as well as use of the resource to carry water that contains waste.

- *A Conceptual Introduction to the Nature and Content of the Water Quality Management and Assessment Components of a Catchment Management Strategy*
- *A Guideline to the Water Quality Component of a Catchment Management Strategy (this document)*
- *A Guide to Conduct Water Quality Catchment Assessment Studies.*

Why does this Document address only Water *Quality*?

Water resource management occurs within a highly integrated environment, where water quality, water quantity and the aquatic ecosystem are all interlinked and interdependent. This integration is achieved at a national level by the National Water Resource Strategy (NWRS), and by Catchment Management Strategies (CMS) at a catchment or water management area (WMA) level. These strategies link together the management elements required by the water quality, water quantity and aquatic ecosystem components of the water resource into a coherent approach that aims to secure the beneficial, equitable and sustainable use of the water resource.

However, while it is important to integrate the management of these components, the complexities of the water environment usually require that they be addressed by different parts of the same water management institution (for example the different directorates of DWAF). Pragmatism therefore dictates that water quality, water quantity and the aquatic ecosystem are also likely to be managed somewhat independently at a catchment level. It is nevertheless still important to integrate these components in some way. This document provides guidelines and procedures for integrating the *water quality management component* to yield IWRM at a catchment level. It should be noted that the approaches developed are largely generic, and should also be appropriate for the *quantity* components of IWRM.

Purpose and Target Audience of this *Guide to Conduct Water Quality Catchment Assessment Studies*

The objectives of this Guide are to:

- provide a comprehensive overview of the information categories and decision support that the water quality component of a catchment management strategy might require;
- be conceptually consistent with the Act and the National Water Policy;
- be a technical synthesis of the collective wisdom about support information needed for the water quality component of water resource management in South Africa, and
- be a potential capacity building tool.

The target audience of this Guide are:

- water quality managers and pollution control officers in statutory catchment management structures and DWAF's Regional and National Offices;
- practitioners in the water resources field, particularly among emerging professionals, and
- general stakeholders participating in catchment management processes.

What is a Catchment Assessment Study (CAS)?

A CAS is undertaken to provide information on a catchment for use in IWRM. A CAS describes the water-related natural resources in a catchment, the human use of and impacts on those resources, the human needs regarding those resources and the socio-economic and institutional development of that catchment. But, a CAS is more than merely an assembly of information. A CAS also identifies water-related stakeholders and elicits inputs and feed-backs from them regarding concerns, issues, problems and opportunities in the water resource field. A CAS, furthermore, prepares and implements predictive techniques that can be used to estimate the state of the water resources in a catchment for different future development scenarios.

Why Perform a Catchment Assessment Study?

A CAS enables the understanding, in water-related terms, of the natural catchment, of the way humans are changing it, and what the human and environmental needs are, so that sound and wise water resource management can ensue. A varied range of objectives may underlie a CAS:

- to provide an information/knowledge system suitable to *support and sustain development of a CMS* for a specific catchment, *i.e.* to enable the requirements of Section 9 of the NWA to be met;
- to provide an information/knowledge system suitable to *support source-specific* management interventions, and
- to *inform the NWRS* in an iterative manner over time.

Variable Character of Catchment Assessment Studies

In order to be sound, the management of a catchment would have to be both *problem/ issue-driven* (more local, more immediate) and *strategic* (more general, longer-term). These two-fold imperatives imply that any particular CAS, or some of its elements, may have the following variability in character:

- the boundaries of the CAS, or some of its elements, may vary from minor sub-catchments to full basins;
- the spatial scale and temporal resolution of a CMS may vary from coarse to fine across the catchment in which an assessment needs to be undertaken; thus, the scale and resolution of such assessment tasks would need to reflect a similar variability;
- the level of management focus may vary from an interest in broad trends and aggregated or averaged comparisons of resources, impacts and needs, to detailed analyses of underlying natural and developmental processes so that management strategies and action plans can be prioritised, and
- assessment tasks may be iterative - *e.g*. initially, a scoping exercise of existing understanding is undertaken, which then indicates where or which detailed assessments, including modelling, should follow; this, in turn, leads to further iterations according to the information/ knowledge requirements of the unfolding CMS establishment process.

The Links between the WQM Components of the CMS and the CAS

The links between the WQM components of the CMS and the CAS can be unpacked in generic detail by considering the information/ knowledge requirements of the CMS according to the following steps:

- Formulate generic management-related “**Questions**” that arise during CMS development:
  i.) *What is the water-related status of the study area and how did it get to this point?*

ii.) Who are the water-related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages and roles?
iii.) What are the study area's water-related issues, concerns, problems and opportunities?
iv.) Where might the water-related status of the study area be heading in the future?
v.) What are the appropriate priority water-related management options?
vi.) Has catchment management achieved its objectives?

- Formulate generic "**Tasks**" that would provide answers to the management-related Questions:

i.) Characterisation of the current situation and historical trends.
ii.) Engagement of the water-related institutions and stakeholders in the CAS process.
iii.) Formulate and record water-related issues, concerns, problems and opportunities.
vii.) Projection of impacts of future water-related development scenarios on water resources.
iv.) Formulate and prioritise catchment management options.
v.) Monitor and audit the implementation of catchment management options.

- Derive information/ knowledge "**Outputs**" that constitute the "answers" to the management-related Questions:

i.) A CAS can generically be partitioned into two distinct phases:

Phase One: Describing and understanding the catchment

Phase Two: Supporting catchment management decision-making

ii.) The respective Outputs, for the WQM component of the CAS, are listed in the Table below.

Layout of this Guide

The Guide has been partitioned into three: a contextualising Part One, a procedural Part Two and a general referencing Part Three. Part One provides the statutory background to Water Quality CMS development and the consequent Water Quality CAS needs and explains the rationale behind the Guide. Part Two details each Water Quality CAS Output Component that the Water Quality CMS development and implementation process requires. This detail is given under the following headings:

- Context
- Purpose
- Prerequisite Output Components
- Outputs
- How to attain Outputs
- Sources
- Checklists
- Display and presentation options

Part Three presents information on reports of historical catchment assessments performed for a range of South African catchments, as well as individual references which the reader may consult for elucidation on particular elements of the assessment process or the NWA implementation process.

OUTPUT COMPONENTS OF A WATER QUALITY CAS

OUTPUT COMPONENT NO.	OUTPUT COMPONENT TITLE	PHASE NO.**
0	Summary of existing understanding, knowledge and past studies with regard to water quality in the catchment	One
1	Details of physical, developmental and administrative attributes and characteristics of the catchment relevant to water resources management	One
2	Requirements of the National Water Resource Strategy and Resource Directed Measures	One
3	Water use and conservation	One
4	Overview of adequacy of water availability	One & Two
5	Water quality requirements and constituents of concern	One & Two
6	Water quality of streamflow, reservoirs, estuaries, wetlands and groundwater	One
7	Point source waste discharges and source characteristics	One
8	Non-point source water quality loadings and impacts	One
9	Configured and calibrated water quality predictive tools / models	One & Two
10	Reconciliation: catchment sources and water quality patterns	One & Two
11	Status report on monitoring, physical data and characterisation information	One & Two
12	Stakeholder details and participation processes	One
13	Water-interest institutional arrangements and linkages	One & Two
14	Record of water quality issues and their origins	One & Two
15	Catchment management implications of water quality issues	One & Two
16	Vision (or long-term resource objectives) for water quality management	One & Two
17	National, regional and local plans and projections of future water demands and catchment development	One & Two
18	Predicted future water quality at sites of management focus	Two
19	Management units and assessment spatial and temporal resolution	One & Two
20	Priority water quality management options	One & Two
21	Monitoring and auditing the implementation of management options	One & Two

** **Phase One*****: Describing and understanding the catchment***

Phase Two***: Supporting catchment management decision-making***

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PART 1: RATIONALE AND KEY CONCEPTS

1 INTRODUCTION

This Chapter provides some general introductory information to place this Guide for catchment assessment studies in South Africa in perspective, by:

- Outlining the background and rationale for its development.
- Describing what its purpose is and whom it is aimed at.
- Outlining the document's structure.
- Referring to other studies that offer important additional material relevant to this Guide.

1.1 Background

Reform of South African water resource management has been a key focus of the Department of Water Affairs and Forestry (DWAF) for a number of years. This reform process has already seen a number of highlights, prime amongst which was the formulation of a new National Water Policy in 1997 and promulgation of a new water statute, the National Water Act (Act No. 36 of 1998). These developments established, *inter alia*, a formal process of integrated water resource management on a catchment basis. At the national scale, the process of integrated management is now structured by a National Water Resource Strategy, while evolving Catchment Management Strategies provide a management framework at the catchment scale. More detail on these and other water-relevant statutory changes and their operational implications are provided in Section 2 below.

Sound strategies for catchment management require relevant information about water-related conditions, issues and developments in a catchment. The process of collating, processing and interpreting such information is now generally called a "catchment assessment study". Although various forms of catchment assessments (sometimes called "situation analyses" or "basin studies") have been common-place in South African water resource planning for some time, a number of diverse approaches have been followed which have not necessarily been of comparable standard. Furthermore, the particular mix of information needs that statutory strategy development invokes, brings new challenges in the field of water resource decision support.

In such a new and evolving management environment, consistency and acceptable standards of both strategy development and supporting information might easily suffer. Therefore, a clear need has arisen for guiding procedures to support the processes and decisions involved. This document is one of a number of responses by DWAF to this need for guidance. It should be noted that Section 10(1) of the National Water Act enables the establishment of such "guidelines" for the preparation of catchment management strategies.

This Guide is one of a trio of inter-related DWAF documents specifically aimed at the domain of *water quality management*:

- *A Conceptual Introduction to the Nature and Content of the Water Quality Management and Assessment Components of a Catchment Management Strategy* (Water Quality Management Series, Sub-Series No. MS 8.1)
- *A Guideline to the Water Quality Component of a Catchment Management Strategy* (Water Quality Management Series, Sub-Series No. MS 8.2)
- ***A Guide to Conduct Water Quality Catchment Assessment Studies: In support of the Water Quality Management Component of a Catchment Management Strategy*** (Water Quality Management Series, Sub-Series No. MS 8.3).

1.2 Objective and Target Audience of this Guide

The objectives of this Guide are to:

- provide a comprehensive overview of the information categories and decision support that the water quality component of a catchment management strategy might require;
- be conceptually consistent with the National Water Act (Act 36 of 1998) and the National Water Policy;
- be a technical synthesis of the collective wisdom about support information needs for the water quality component of water resource management in South Africa, and
- be a potential capacity-building tool.

The target audience of this Guide are:

- water quality managers and pollution control officers in statutory catchment management structures and DWAF's Regional and National Offices;
- practitioners in the water resources field, particularly among emerging professionals, and
- general stakeholders participating in catchment management processes.

1.3 Why does this Document address only Water Quality?

Water resources management occurs within a highly integrated environment, where water quality, water quantity and aquatic ecosystems are all interlinked and interdependent. The National Water Act (Act No. 36 of 1998) (NWA) makes provision for this by promoting *integrated* water resources management (IWRM). This is done both at a national level by the National Water Resource Strategy (NWRS), and by catchment management strategies (CMS) at a catchment/ water management area/ regional level. These strategies pull together the water quality, water quantity and aquatic ecosystem components of the water resource into a coherent management approach that aims to secure the beneficial, equitable and sustainable use of the water resource.

However, while it is important to integrate the management of these components, the complexities of the water environment usually demand that they be addressed by different parts of the same water management institution (for example the different Directorates of DWAF). Pragmatism therefore dictates that water quality, water quantity and the aquatic ecosystem are also likely to be managed somewhat independently at a catchment level. It is nevertheless still important to integrate these components in appropriate ways. This document provides guidelines and procedures for integrating the *water quality management component* into IWRM at catchment and regional levels.

However, the approaches developed are largely generic, and should be appropriate to the quantity/ecosystem components of IWRM.

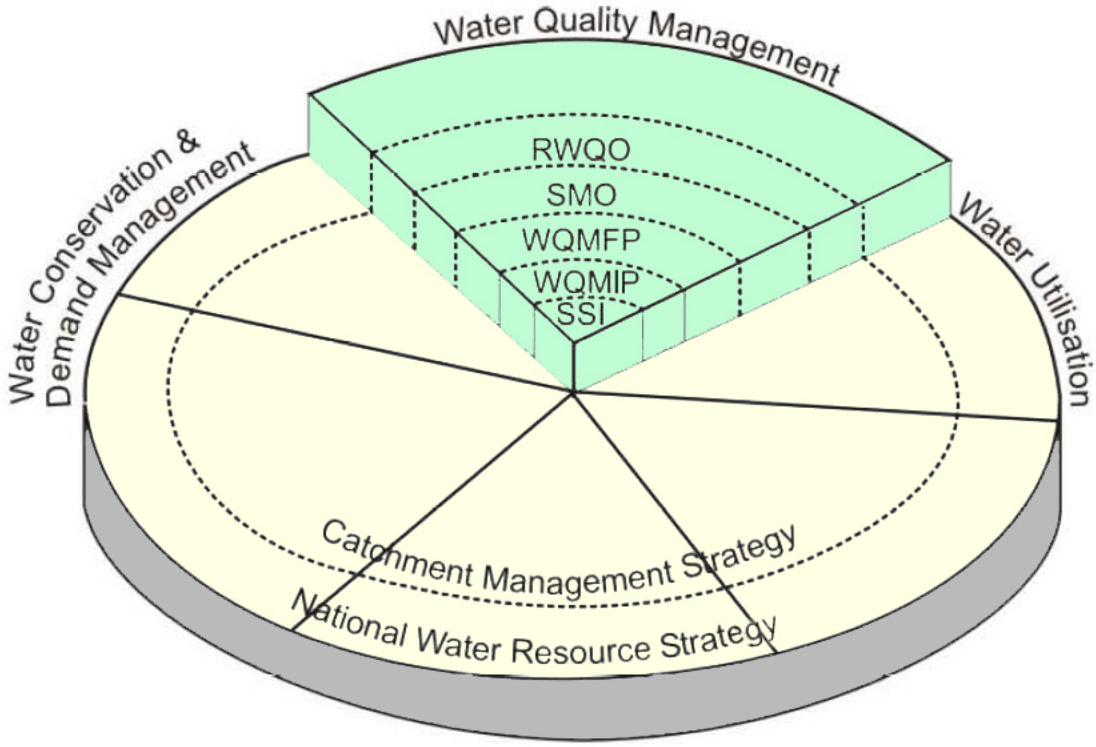

Figure 1: An illustration of the relationship between a catchment water quality management strategy, the NWRS and other IWRM strategies

1.4 Anatomy of this Document

This document has three primary parts: the conceptual and statutory context, the Guide itself, and supporting information. The first-time user of the Guide is encouraged to read Part 1 with close attention before tackling Part 2, as the former provides direct insight into the development process of the water quality component of the catchment management strategy. Such insight will facilitate understanding of the role catchment assessment studies should play in support of strategy development.

1.5 The Legacy of Preceding and Parallel Studies

Much innovation and synthesis has preceded this Guide in related studies undertaken in support of catchment management implementation under the National Water Act. These ground-breaking studies were commissioned by Directorate: Water Quality Management and Directorate: Catchment Management of DWAF, as well as the Water Research Commission. This Guide has benefited enormously from the legacy of these studies. Among the primary outputs from these studies are the following documents:

- *The Philosophy and Practice of Integrated Catchment Management: Implications for Water Resource Management in South Africa*, 1996. Report commissioned by DWAF and the Water Research Commission, Pretoria.
- *Guidelines for Catchment Management to support integrated water resource management in South Africa*, 1998. WRC Report No KV 108/98 by Görgens A, Pegram GC, Uys M, Grobicki A, Loots L, Tanner A, Bengu R.
- *A Strategic Plan for the DWAF to Facilitate the Implementation of Catchment Management in South Africa*, 1998. WRC Report No KV 107/98, Commissioned by DWAF and the Water Research Commission, Pretoria.
- *A Framework for Implementing Non-Point Source Management Under the National Water Act*, 1999. WRC Report No TT 115/99 and DWAF Report No WQP 0.1, commissioned by DWAF and the Water Research Commission, Pretoria.
- *Generic Framework for Catchment Management Strategies*, 2001 (in draft). Report commissioned by D: Catchment Management, DWAF, Pretoria.

2 A BACKGROUND TO CATCHMENT MANAGEMENT IN SOUTH AFRICA

This Chapter provides a background to catchment management in South Africa by:

- Outlining the overarching policy principles for water resource management.
- Highlighting the constraints imposed by the NWRS, and Resource Directed Measures.
- Outlining the requirements of the National Water Act with respect to the definitions of "Resource Quality" and "Water Use".
- Highlighting the institutional and process requirements of formulating a Catchment Management Strategy (CMS).

2.1 The Overarching Policy Principles for Catchment Management

One of the most important milestones in the revision of the Water Law in South Africa was the publication of the *White Paper on a National Water Policy for South Africa*. This document highlighted the overarching policy considerations for water resources management, which were later taken up into the National Water Act (NWA) (Act 36 of 1998). The most important components of these were the requirements to ensure sustainable use of water resources and the equitable use[2] of the resource for the "optimum social and economic benefit" of the country. Coupled with these were the need for a transparent and participative approach to water resources management, and the need to provide for a "Reserve". The "Reserve" is that quantity and quality of water required for basic human needs, as well as that quantity and quality required to sustain aquatic ecosystems.

These overarching policies must underlie the approach to water resources management on a catchment basis. Catchment water quality management is a component of this process, and as such is subject to these policy principles. These principles have therefore been integrated into the *Guideline for the Water Quality Management Component of a Catchment Management Strategy,* the sister-document to this one (Sub-Series No. 8.2). These principles should consequently be considered as inherent to all the steps proposed in that document, even where not explicitly stated as such.

2.2 The National Water Resource Strategy

Chapter 2 of the National Water Act (NWA) makes provision for the development of a national water resource strategy (NWRS). The NWRS gives effect to integrated water resources management at a national strategic level, by providing a framework for water resources management between and within Water Management Areas (WMAs). The NWRS therefore makes provision for the water quality and quantity requirements of strategically important water users. The NWRS is established in law and may consist of a number of functional and/or issue-based strategies for the protection, use, development, conservation, management and control of water resources.

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[2] Most importantly "Use" as defined in the National Water Act includes *inter alia* the consumptive use of the resource, as well as use of the resource for the discharge of water that contains waste.

The development of the NWRS is still in a provisional mode and the form and content of the associated strategies, objectives, plans, guidelines and procedures is as yet evolving. However, the NWRS must "state the objectives in respect of water quality to be achieved through the classification system" *[Section 6(1)(i)].* Together, the quantity-related aspects of the NWRS and resource protection (see below) provide the constraints for water quality management within a WMA.

Catchment Management Strategies (CMSs) must give effect to the NWRS within WMAs, and the NWRS thus provides the framework within which a CMS should be developed. The NWA also indicates that all water resources management activities must give effect to these strategies.

2.3 Resource Protection

The NWA is grounded in the *resource protection* approach, based upon resource directed measures and source directed controls, which are not prescribed by law, but have to be developed through Department of Water Affairs and Forestry (DWAF) policies. Resource directed measures aim to provide an appropriate level of protection for different water resources. This system allows for the ecological classification of water resources into four Classes, describing relatively pristine to highly degraded (ecologically dysfunctional) resources. These ecological Classes may be combined with the socio-economic importance of the resource to formulate management classes reflecting the required level of protection. These Resource Management Classes will focus management attention on sensitive or degraded systems, and may indicate standards and practices required to control pollution at source. In some cases, they will highlight the need for remediation, either of the water resource itself, or the sources causing water quality problems.

The classification system will also establish Resource Quality Objectives (RQOs) for each water resource. These RQOs specify numeric and narrative objectives that may relate to quantity, quality, habitat, biota or instream / land-based activities for different water bodies. This is done in terms of the requirements of the "Reserve", and in terms of the needs of other users. These RQOs therefore set the "line in the sand" with respect to water quality management goals, and shift the emphasis of water resource protection into the water resource. Most importantly, the National Water Act requires that all water resource management practices "give effect" to these RQOs and the water resource classification system.

The water resource classification system may **[Section 12(2)b]**:

(i) *establish procedures for determining the Reserve;*

(ii) *establish procedures which are designed to satisfy the water quality requirements of water users as far as is reasonably possible . . .;*

(iii) *set out water uses for instream or land-based activities which must be regulated or prohibited in order to protect the water resources.*

The determination of a Water Resource Management Class, the RQOs and the Reserve for a water resource occurs outside of the NWRS (although the results are reflected in the NWRS). Similarly, Classification can proceed outside of the formulation the CMS (although the CMS must give effect to the Classes). However, Classification of water resources, when at least done in parallel with the formulation of the CMS, will add value to both the Classification and Catchment Management processes.

2.4 Water Use

Water use is broadly defined in Section 21 of the NWA to include:

- *(a) taking water from a water resource;*
- *(b) storing water;*
- *(c) impeding or diverting the flow of water in a watercourse;*
- *(d) engaging in a stream flow reduction activity contemplated in section 36;*
- *(e) engaging in a controlled activity identified as such in section 37(1) or declared under section 38(1);*
- *(f) discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;*
- *(g) disposing of waste in a manner which may detrimentally impact on a water resource;*
- *(h) disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process;*
- *(i) altering the bed, banks, course or characteristics of a watercourse;*
- *(j) removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people; and*
- *(k) using water for recreational purposes.*

Those that are particularly relevant for catchment water quality management are **Sections 21(e), 21(f), 21(g), 21(h)** and **21(j)** while **Sections 21(d), 21(i), 21(k)** relate particularly to instream and riparian activities.

2.5 Resource Quality and Water Quality

The National Water Act defines Resource Quality (RQ) as **[Section 1(xix)]**:

....the quality of all the aspects of the water resource including –

- *(a) the quantity, pattern, timing, water level and assurance of instream flow;*
- *(b) the water quality, including the physical, chemical, biological characteristics of the water;*
- *(c) the character and condition of the instream and riparian habitat; and*
- *(d) the characteristics, condition and distribution of the aquatic biota.*

This definition extends the conventional interpretation of water resources to represent the entire aquatic ecosystem, rather than mere water quantity and quality. Accordingly, the *interrelationships* between the four elements of RQ are as important as the elements themselves. As such, the concept of RQ is a keystone of integrated water resource management (IWRM), and hence of Catchment Management.

Management of Resource Quality requires management of water quantity, water quality and aquatic ecosystem quality. Functionally, water quantity and quality have been separated in the DWAF. While this document has been prepared as a Guideline for the water quality component of a CMS, the approaches outlined are appropriate for managing the water quality requirement of the habitat and biotic components, and could be integrated with the quantity component of a Catchment Management Strategy.

2.6 Institutional Arrangements

The White Paper on a National Water Policy states that the National Government is "custodian of the nation's water resources and its powers in this will be exercised as a public trust". DWAF is the primary agency responsible for water resources management. In exercising its mandate, DWAF must reconcile, integrate and coordinate diverse and often conflicting interests of different stakeholders, within the framework of sustainable and equitable utilisation of South Africa's water resources.

The new policy also provides for the phased establishment of Catchment Management Agencies (CMAs) to undertake IWRM in defined WMAs. CMAs will be responsible for implementing the statutory provisions of the Act, as well as developing CMSs in their WMA, in line with the NWRS. However, only the Minister and DWAF can establish institutions, delegate powers, or promulgate statutory authorisations, requirements or strategies. Many of the personnel in these CMAs may initially not be highly skilled, due to the human resource limitations in South Africa. This reinforces the need to adopt streamlined approaches for water resources management.

2.7 The Catchment Management Process

The process of catchment management has been outlined by Görgens *et al* (1998). Stakeholder consultation and participation underlies the entire process and is therefore not explicitly identified as a stage of catchment management. This is a critical component of the development of a CMS, and must ensure "buy-in" and "ownership" by the stakeholders. However, consultation around water quality management issues must be part of the entire CMS development process, and should link to the processes of CMA establishment and/or operation.

The Catchment Management process generally involves the following stages, although these are characterised by significant overlap and iteration:

- *initiation*: of the catchment management process, triggered by one or more water-environment related issues;
- *assessment*: to provide understanding of the water, social, economic and institutional environments;
- *planning*: for catchment management in that area, resulting in a catchment management strategy;
- *implementation*: of the actions and procedures detailed in catchment management strategy;
- *administration*: of the catchment in terms of the catchment management strategy, including fine-tuning;
- *monitoring*: and processing of data and information collected in the catchment; and
- *auditing*: of catchment management against performance indicators, and regular review of the strategy.

2.8 What are possible Components of a CMS?

This section unpacks the statutory and pragmatic requirements of a catchment management strategy (CMS), and its implications for the water quality management component.

The *Generic Framework for Catchment Management Strategies* (DWAF, 2001) provides an interpretation of the nature and content of a CMS. This is taken as the point of departure for this document and the associated guidelines, together with the minimum requirements of a CMS outlined in Section 9 of the NWA.

Each catchment management agency (CMA), or the DWAF Regional Office acting as a CMA where one is not yet functional, is required to progressively establish a catchment management strategy and review it at least every five years.

Section 9 of the National Water Act (Act No. 36 of 1998) states the requirements of a CMS. However, it is useful to reorder these requirements, in order to provide some structure and facilitate interpretation. A possible paraphrased reordering is as follows:

Given the...:
- *Requirements and constraints of the national water resource strategy (Section 9b);*
- *Requirements of the water resource management class, resource quality objectives, the Reserve and international obligations (Section 9a);*

The national water resource strategy and resource directed measures are developed externally to the CMS, also through a process of stakeholder consultation. They provide the framework and constraints within which water resources in a Water Management Area (WMA) will be managed (in other words, the context in which the CMS will be developed). In particular, the CMA must give effect to the requirements and objectives outlined in the NWRS and the resource directed measures (namely the class, Reserve and RQOs).

And considering the...:
- *Natural and anthropogenic character of a WMA, ie. geology, land use, etc (Section 9d);*
- *National and regional plans, including water services development plans (Section 9f);*
- *Needs and expectations of existing and future water users (Section 9h);*

These provide the background to and must be reflected in the CMS, but are not necessarily the focus of the CMS. However, they represent the basis of the catchment assessment supporting the development of the CMS. The linkage to other plans is important in terms of cooperative governance and coordinated planning for the CMA, while the needs and expectations of users is important in terms of public participation in water resources management.

The CMS must set out the...:
- *Strategies, objectives, plans, guidelines and procedures of the CMA (Section 9c);*
- *Allocation plan, reflecting the principles for authorising water use (Section 9e);*
- *Institutions to be established (Section 9i);*

This is the core of the CMS, as required by the National Water Act. However, other components that are not specified may also be core components of the Act, as outlined below in this document.

The first bullet represents the main vehicle for setting out the approach to water resources management in a WMA. These strategies, objectives, plans, guidelines and procedures should focus on the requirements for giving effect to the resource directed measures (RDM) and the national water resource strategy (NWRS). They may address technical management issues, as well as stakeholder participation, institutional development and resource allocation for water resources management.

The allocation plan represents an important water resources management component of the CMS. It should take cognisance of water quantity, water quality and habitat-biotic issues, thereby providing the linkage between RDM and water use. The allocation plan is usually narrowly interpreted as addressing the allocation of water quantity. However, with the broad interpretation of water use under the NWA, a similar plan should be formulated for the allocation of water quality related uses. This may be referred to as a *water quality use allocation plan*, and should provide the basis for statutory authorisation of point and nonpoint sources. The formulation of these allocation plans must give effect to the allocation provided for in the NWRS, taking account of the principles for water use authorisation presented in Section 27 of the Act[3].

The institutional arrangements should reflect the water resource management needs in the catchment, including the specific functional requirements for managing water quality in the WMA. In setting out the institutions, some indication of their organisational development must be provided, and thus the strategy provides the link between priority water resources issues and institutions required for their management. This requirement implies that the CMS represents a “business plan” for water resources management in a WMA[4]. Is should include the development of institutions to facilitate the participation of stakeholders in water resources management decisions within a WMA.

To enable the...:

- *Public to participate in managing water resources in their WMA (Section 9g);*

This is central to the purpose of catchment management as described by the CMS, and is a key objective of the establishment of CMAs and associated institutions. However, in the interests of integrated water resources management, it must not be separated from the general stakeholder participation and consultation associated with the development of a CMS, nor the stakeholder involvement in the establishment of a CMA. This requires adoption of the concept of stakeholder involvement, participation and consultation in any catchment management process, as being the core of an institutional development capacity building process.

For the water resource...:

- *Protection, use, development, conservation, management and control (Section 9c).*

[3] This requires an interpretation of the social, economic and ecological imperatives that must be addressed in allocating water.

[4] The concept of a “water resources management business plan” should not be confused with the statutory requirement of an annual business plan for particular water management institutions, such as catchment management agencies or water user associations.

These six activities[5] represent the main purpose of catchment management as outlined by the CMS, namely to ensure integrated water resources management (IWRM) at a catchment level.

Note

A Catchment Management Strategy may be established in a phased and progressive manner, based on the water resources management priorities in different parts of a WMA. The first strategy may therefore only include parts of a comprehensive strategy, but should provide a framework (or programme) for the development of future strategies. These parts may be geographically-based (in priority sub-catchments) or issue-based (for priority water resources management problems). Similarly, the catchment assessment study may reflect this phasing.

[5] The exact interpretation and differentiation of these management activities is not actually important, rather they should be seen together as representing all integrated water resources management.

3 A FRAMEWORK FOR CATCHMENT WATER QUALITY MANAGEMENT

This Chapter develops a generic framework for developing the Water Quality Component of a Catchment Management Strategy within the constraints outlined in the previous Chapter. This framework provides the basis for the rest of the document, and as such the Chapter also outlines the Roadmap for the water quality components of the CMS (WQCMS) and introduces the domain of the catchment assessment study as input to the WQCMS.

3.1 Why Develop a Common Framework for Catchment Management?

The NWA is not only based on securing the beneficial, equitable and sustainable use of the resource, but also on the need to ensure stakeholder participation in this process. The NWA therefore devolves management of the resource to a regional and catchment level *via* CMAs. These Agencies must include stakeholders in both the ongoing development of the CMS, and in giving effect to the Strategy. The reason for this is straight-forward - local communities or water user sectors are more likely to be able to identify their needs with respect to use of the resource, and to ensure local actions to realise these requirements. Furthermore, the NWA specifically requires public consultation for the development of strategies and the application thereof.

However, water flows over long distances within the catchment, and may even be transferred from one catchment to another. Local use of the water resource therefore affects users across the whole catchment, and potentially in neighbouring catchments. This makes it difficult to realise the benefits of local management of the water resource without a common framework within which to balance local actions with their catchment-wide and regional implications. The framework following below is proposed as a means for reconciling the often-diverging needs of water users within a common goal for the water resources of the catchment and of the WMA.

3.2 How large must a Catchment be to justify IWRM-based Catchment Management?

In terms of IWRM needs, a catchment may be any size, from a few square kilometers, to something like the Orange-Vaal River catchment, which dominates the larger portion of Southern Africa and is shared by three countries. IWRM may occur at any of these scales, from small common-interest groups aiming to protect a short stretch of river or local groundwater, to the national or even international goals of the NWRS. Economies of scale, nevertheless, dictate that CMAs, which must be economically viable, will have to operate at fairly large scales, i.e. the WMA scale. Furthermore, RQOs are set at a relatively coarse spatial resolution.

However, given the frequent lack of human resources, and the requirements for participative management in the NWA, the CMS cannot ignore catchment management efforts that occur at a smaller scale. Be this as it may, management efforts that occur at smaller scales must be compatible with the overall objectives of the CMS. The framework outlined below enables integration of water quality management efforts that occur at different scales into the formulation of the water quality component of the CMS.

3.3 The Framework for Catchment Water Quality Management

As stated earlier, catchment water quality management must be informed by the requirements of the Water Resource Management Class, RQOs, the Reserve, and the NWRS. Together these establish the water quality, water quantity and aquatic ecosystem attributes that are required to ensure a given level of protection for the resource, to meet basic human needs, and to meet the requirements of strategically important water users. The framework proposed below is based on identifying the stakeholders' needs with respect to use of the water resource over and above these requirements. This is attained through following an iterative and incremental process that answers four generic questions, as outlined below:

What are the goals for water quality management?

a. Establish *resource water quality objectives* for use of the resource to meet the requirements of the users and to dispose of water containing waste, based on the needs expressed by the stakeholders.

How must water quality loads change to achieve the goals?

b. Determine *source management objectives* to meet these needs.

How will this be managed across the WMA?

c. Formulate a WMA-wide *water quality management framework-plan* that indicates the management priorities, requirements, CMS linkages, sectoral responsibilities and programme to achieve these objectives.

How, where, by whom and when will this be implemented?

d. Develop individual *water quality management implementation plans*, which may be source-, issue- or sector-specific, or even, multi-sectoral, to give effect to the water quality management framework-plan.

Together, these make up the framework for the water quality management component of the CMS. They will be revised and updated on a five-yearly basis to accommodate the ongoing development of the WMA, and are aimed at securing a gradual and phased realisation of the stakeholders' goals for individual catchments in the WMA. These four steps may occur at any scale, and the results could be fed into the formulation of the wider CMS. In these cases, the CMS would have to ensure the compatibility of these processes with allied upstream and downstream processes and approaches. How this could be done, is outlined in the following chapters.

Figure 2 shows conceptually how these four steps allow for the gradual realisation of the stakeholders' goals - according to individual sub-catchments, or spatial *"Management Units"* - in the WMA, by harnessing the collective resources available at a local level.

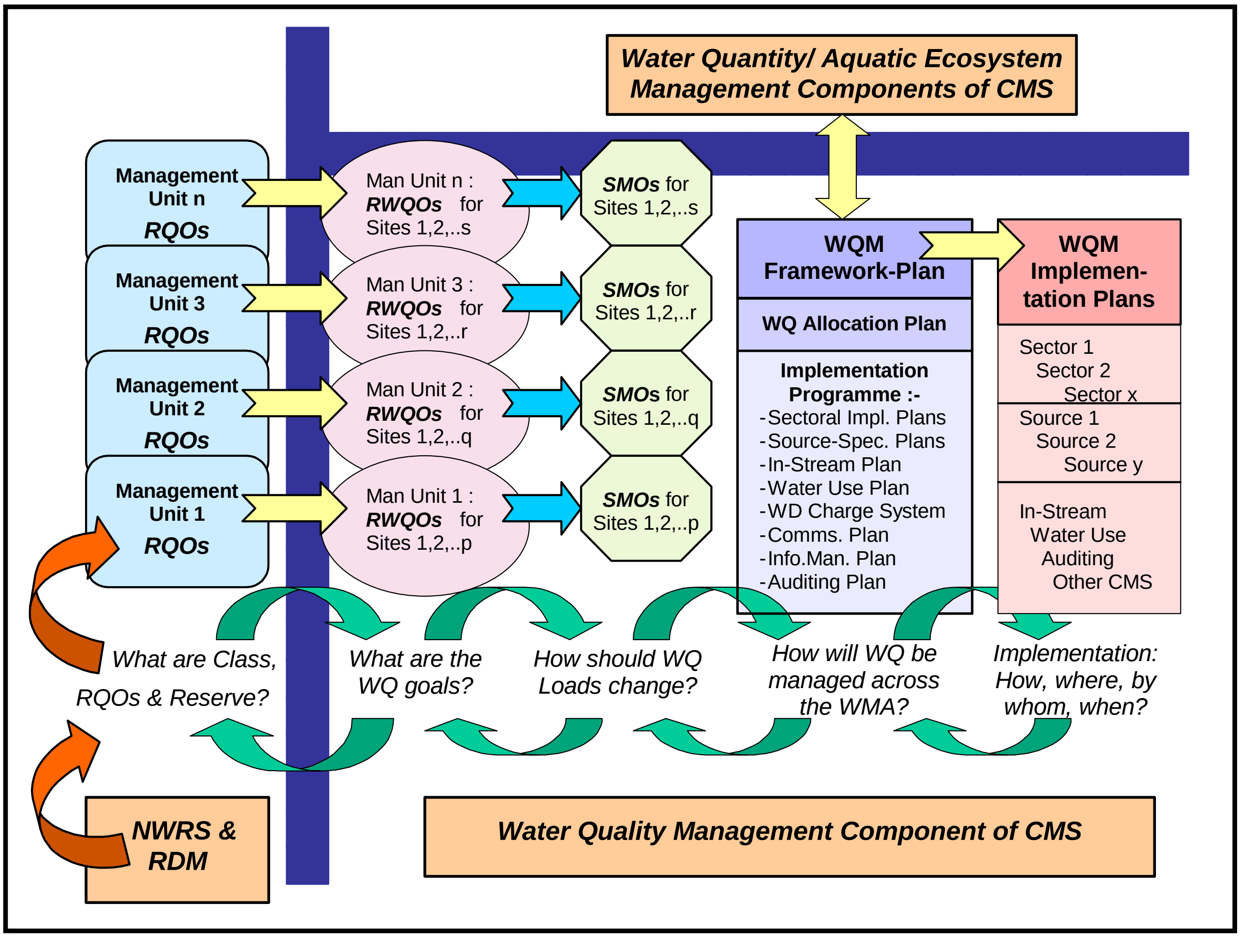


Figure 2: Conceptual Framework for Catchment Water Quality Management

3.4 Roadmap to the Water Quality Component of a CMS and its Links to the Water Quality Catchment Assessment Study

The "Roadmap" in Figure 3 below details the stages of the water quality component of the CMS (WQCMS). It also highlights the inputs required for, and outputs of, the process. *These inputs are derived from the outputs of the water quality catchment assessment study (WQCAS) procedures* described in this Guide.

The conceptual context of the WQCAS is described in Section 4 below.

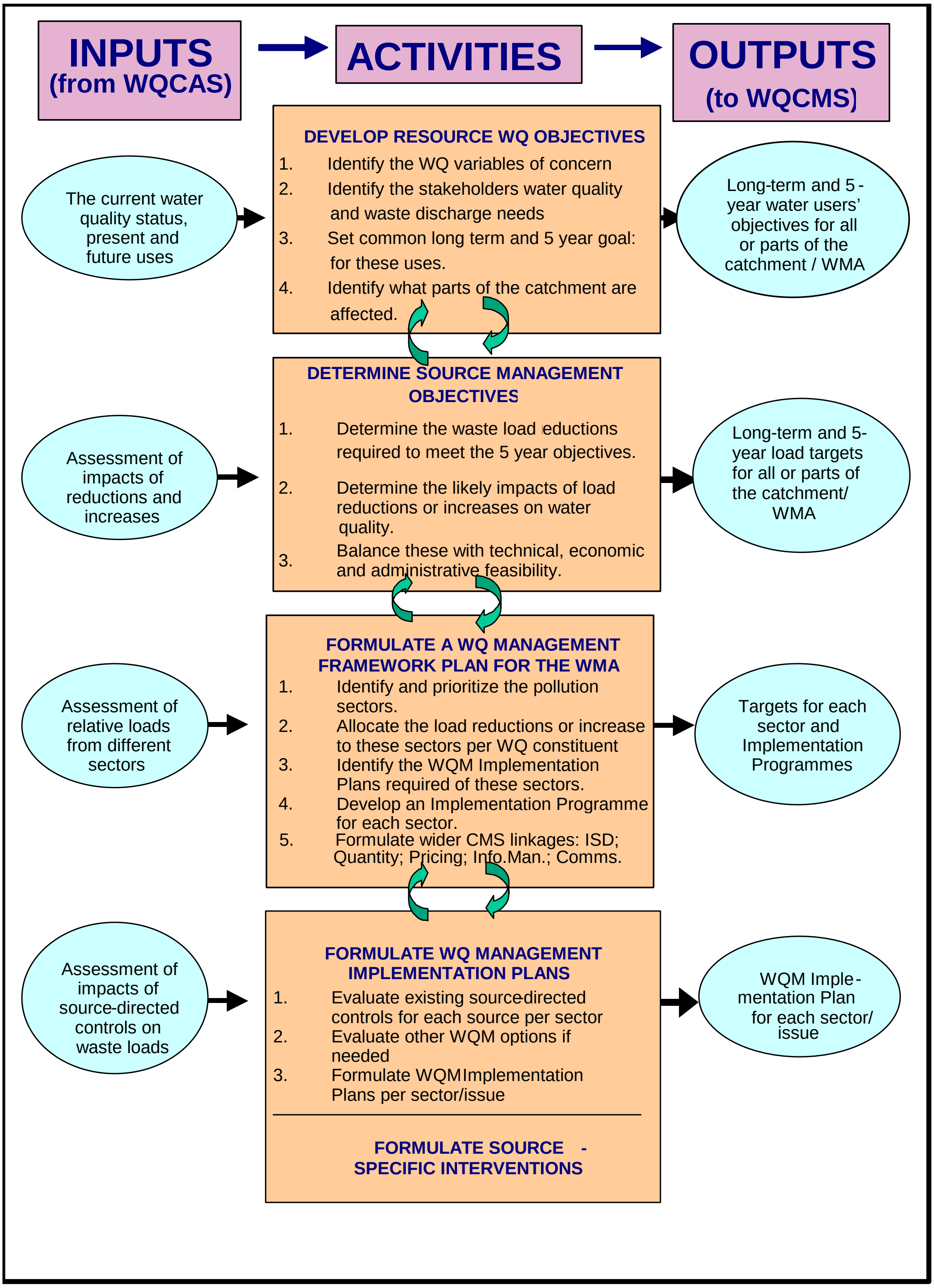


Figure 3: Roadmap to Detailed Stages of the Water Quality Component of the Catchment Management Strategy

4 WHAT IS A CATCHMENT ASSESSMENT STUDY (CAS)?

This Chapter provides content to the concept of a CAS by:

- Providing a generic definition that would be applicable across a range of circumstances.
- Describing what the purpose of a CAS is and whom it is aimed at.
- Outlining the way CASs might differ under different circumstances.
- Outlining the way a CMS process is supported by a CAS.
- Underlining the importance of public consultation during the CAS process.

4.1 A Generic Definition

A CAS deals with water-related natural resources in a catchment, with human impacts on those resources and with human needs regarding those resources.

In formal terms it can be stated that a Catchment Assessment Study (CAS) is the…

- systematic assembly and processing of *appropriate* data and information…
- to yield a *knowledge system*, including predictive tools/models, with regard to…
- all *water-relevant* physical, developmental and administrative *attributes and characteristics* and…
- in consideration of all *water-related issues and problems,*…
- to be used in integrated water resources management (*IWRM*) in a catchment.

4.2 Why Perform a Catchment Assessment Study?

A CAS enables the understanding, in water-related terms, of the natural catchment, of the way humans are changing it, and what the human needs are, so that sound and wise water resource management can ensue.

In more formal terms, it can be seen that varied objectives may underlie a CAS:

+ to provide an information/knowledge system suitable for *support of development of a CMS* for a specific catchment, i.e. to enable the requirements of Section 9 of the NWA to be met
+ to provide an information/knowledge system suitable to *sustain implementation of a CMS* for that catchment
+ to provide an information/knowledge system suitable to *support source-specific* management interventions
+ to *inform the NWRS* in an iterative fashion, i.e. as the CAS upgrades the level of understanding of catchment resources, pollution sources and human and environmental needs, earlier versions of the NWRS would need to be modified.

4.3 Variable Character of Catchment Assessment Studies

The discussions in sections 2 and 3 suggest that, in order to be sound, the management of a catchment would have to be both problem/issue-driven (more local, more immediate) and strategic (more general, longer-term). These two-fold imperatives imply that any particular CAS, or some of its elements, may have the following variability in character:

- the boundaries of the CAS, or some of its elements, may vary from minor sub-catchments to full basins;
- the spatial scale and temporal resolution of a CMS may vary from coarse to fine across the catchment in which an assessment needs to be undertaken; thus, the scale and resolution of such assessment tasks would need to reflect a similar variability;
- the level of management focus may vary from an interest in broad trends and aggregated or averaged comparisons of resources, impacts and needs (requiring information at a "scoping"-level), to detailed analyses of underlying natural and developmental processes so that management strategies and action plans can be prioritised (requiring information at a "cause-effect" level), and
- assessment tasks may be iterative - e.g. initially, a scoping exercise of existing understanding is undertaken, which then indicates where or which detailed assessments, including modelling, should follow; this, in turn, leads to further iterations according to the information/knowledge requirements of the unfolding CMS process.

NB: The reader is reminded that the CAS process must meet certain minimum information/knowledge requirements of the CMS, as prescribed by Section 9 of the NWA. These are contextualised in section 2.8 of this document.

4.4 What are the Links Between the Water Quality Management Components of the CMS and the CAS?

The WQCMS development process schematic in Figure 2 and the "Roadmap" schematic in Figure 3 suggest the information input requirements of the WQCMS. For this Guide the links between the water quality components of the CMS and the CAS have been unpacked in more generic detail by reinterpreting the forementioned CMS "Roadmap" in terms of information/knowledge requirements according to the following steps:

- Formulate generic management-related "Questions" that arise from the "Roadmap". These Questions are:
  - *i.)* *What is the water-related status of the study area and how did it get to this point?*
  - *ii.)* *Who are the water-related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages and roles?*
  - *iii.)* *What are the study area's water-related issues, concerns, problems and opportunities?*
  - *iv.)* *Where might the water-related status of the study area be heading in the future?*
  - *v.)* *What are the appropriate priority water-related management options?*
  - *vi.)* *Has catchment management achieved its objectives?*
- Formulate generic "Tasks" that would provide answers to the management-related Questions. These Tasks are:

i.) *Characterisation of the current situation and historical trends.*

ii.) *Engagement of the water-related institutions and stakeholders in the CAS process.*

iii.) *Formulate and record water-related issues, concerns, problems and opportunities.*

iv.) *Projection of impacts of future water-related development scenarios on water resources.*

v.) *Formulate and prioritise catchment management options.*

vi.) *Monitor and audit the implementation of catchment management options.*

- Describe information/knowledge "Outputs" that constitute the "answers" to these Questions.

  i.) *These Outputs are described, for the water quality component of the CAS, in Part Two of this Guide.*

This exercise revealed that a CAS can generically be partitioned into two distinct phases, where the first phase is about "describing and understanding the catchment" and the second phase is about "providing decision-support for catchment management". In terms of the water quality component of the CMS, these phases can be linked to the CMS development process through the basic questions formulated in section 3.3, as follows:

- **Phase One: Describing and understanding the catchment*:***

  The first Phase encompasses Questions and Tasks (i) – (iv) and addresses the CMS development process of section 3.3 in terms of the questions:

  - "*What are the goals for water quality management?*" – Resource Water Quality Objectives
  - "*How must water quality loads change to achieve the goals?*" (partly) – Source Management Objectives.

- **Phase Two: Supporting catchment management decision-making:**

  The second Phase encompasses Questions and Tasks (v) and (vi) and addresses the CMS development process of section 3.4 in terms of the questions:

  - "*How must water quality loads change to achieve the goals?*" (rest of) – Source Management Objectives
  - "*How will this be managed across the WMA?*" – Water Quality Management Framework-Plan
  - "*How, where, by whom and when will this be implemented?*" – Water Quality Management Implementation Plans.

The respective Outputs that are required from the two Phases of the WQCAS are described in Part Two of this Guide.

4.5 What are the Public Consultation Requirements for a CAS?

Section 9 of the NWA makes it clear that one of the core purposes of a CMS is to enable the public to participate in decision-making regarding the management of water resources in their WMA. Furthermore, as the CMS needs to be issue-driven, it is important to engage stakeholders to record such issues and concerns. Often, inhabitants of catchments, as well as water users in those catchments are custodians of valuable data, information and insight regarding their catchments. It is clear, therefore, that stakeholder consultation, through organised forums, through public meetings, and through the media, is needed for adequate information-gathering and feed-back under a CAS. Such consultation ought to be iterative and should include reflecting back to the stakeholders the unfolding outputs of the CAS for comment and to engender and facilitate capacity-building among the stakeholder ranks.

PART 2:

A GUIDE TO CONDUCT WATER QUALITY CATCHMENT ASSESSMENT STUDIES

Part 2 of the Guide contains a set of practical procedures to equip the user to conduct a catchment assessment study with a water quality focus, or to apply the conceptual information provided in Part 1 to localised water quality studies. The procedures are formulated from the perspective of the information inputs that are required to develop and update the water quality component of a Catchment Management Strategy (WQCMS). Such information is usually gathered as part of the catchment assessment study, or during particular localised water quality studies, and forms the output of the catchment assessment study, or of such localized studies.

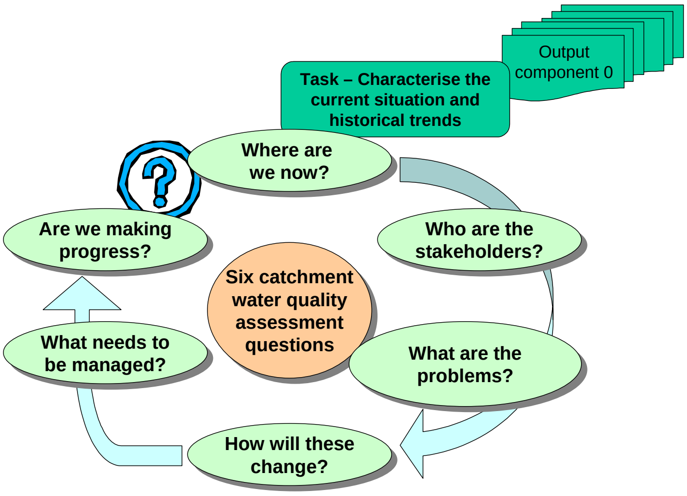
Introductory material consists of an overview of Part 2 and the rationale of its layout; how to use the Guide; the chronology and overlaps of different components of a catchment assessment; and a Route Map to steer the user to particular components. The rest of Part 2 comprises the individual detail components of water quality focused catchment assessment studies, broadly grouped according to two discrete phases and under six generic management questions that constitute the primary building blocks of a WQCMS process. The two phases are:

- Phase One: "*Catchment description and understanding*"
- Phase Two: "*Catchment management decision support"*.

HOW TO USE THIS GUIDE

Rationale of the Layout

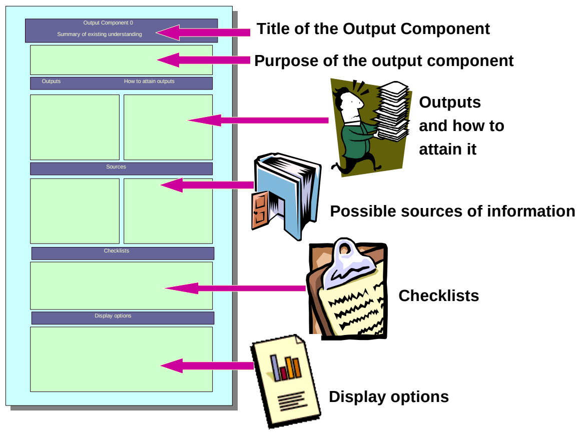
The primary building blocks of the Guide are six generic management questions about the water quality status in a catchment or the study area (as illustrated on the right). For each question, a primary task has been formulated to answer the question. Each primary task is then subdivided into a number of output components that need to be addressed in order to satisfy the requirements of the task. The six generic questions, the primary tasks and output components are listed in Table 1.



Layout of each output component

Each output component consists of six parts (as illustrated on the right):

- The title of the output component
- A description of the context and purpose of the output component
- A description of what outputs to be produced and how this can be attained
- A description of possible sources of information
- Checklists that can be used in the preparation of the outputs
- Some options on how the output results can be displayed



Display and Presentation Options

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The maps and graphs in the following sections are used to illustrate different ways of displaying information. They are conceptual and should not be regarded as being prescriptive or conforming to DWAF GIS or data display standards applicable at the time of preparing this report.

TABLE 1: CHRONOLOGY OF A WATER QUALITY CATCHMENT ASSESSMENT

OUTPUT COMPONENT NO.	OUTPUT COMPONENT TITLE	PHASE NO.**	TIMING OF ACTIVITIES LEADING TO OUTPUT (DURING NOMINAL INCREMENTS OF 10% OF TOTAL DURATION)									
MANAGEMENT QUESTION 1: *WHAT IS THE WATER-RELATED STATUS OF THE STUDY AREA AND HOW DID IT GET TO THIS POINT?* ***TASK 1:*** *CHARACTERISATION OF THE CURRENT SITUATION AND HISTORICAL TRENDS*												
0	Summary of existing understanding, knowledge and past studies with regard to water quality in the catchment	One										
1	Details of physical, developmental and administrative attributes and characteristics of the catchment relevant to water resources management	One										
2	Requirements of the National Water Resource Strategy and Resource Directed Measures	One										
3	Water use and conservation	One										
4	Overview of adequacy of water availability	One & Two										
5	Water quality requirements and constituents of concern	One & Two										
6	Water quality for streamflow, reservoirs, estuaries, wetlands and groundwater	One										
7	Point source waste discharges and source characteristics	One										
8	Non-point source water quality loadings and impacts	One										
9	Configured and calibrated water quality predictive tools / models	One & Two										
10	Reconciliation: catchment sources and water quality patterns	One & Two										
11	Status report on monitoring, physical data and characterisation information	One & Two										

OUTPUT COMPONENT NO.	OUTPUT COMPONENT TITLE	PHASE NO.**	TIMING OF ACTIVITIES LEADING TO OUTPUT (DURING NOMINAL INCREMENTS OF 10% OF TOTAL DURATION)									
MANAGEMENT QUESTION 2: *WHO ARE THE WATER-RELATED STAKEHOLDERS AND INSTITUTIONS IN THE STUDY AREA AND WHAT ARE THEIR RESPECTIVE JURISDICTIONS, RELATIONSHIPS, LINKAGES, AND ROLES?* ***TASK 2:*** *ENGAGEMENT OF WATER-RELATED INSTITUTIONS AND STAKEHOLDERS IN CAS PROCESS*												
12	Stakeholder details and participation processes	One										
13	Water-interest institutional arrangements and linkages	One & Two										
MANAGEMENT QUESTION 3: *WHAT ARE THE STUDY AREA'S WATER QUALITY ISSUES, PROBLEMS, CONCERNS AND OPPORTUNITIES?* ***TASK 3:*** *FORMULATE AND RECORD WATER QUALITY ISSUES, CONCERNS, PROBLEMS, AND OPPORTUNITIES*												
14	Record of water quality issues and their origins	One & Two										
15	Catchment management implications of water quality issues	One & Two										
16	Vision (or long-term resource objectives) for water quality management	One & Two										
MANAGEMENT QUESTION 4: *WHERE MIGHT THE WATER QUALITY STATUS OF THE STUDY AREA BE HEADING IN THE FUTURE?* ***TASK 4:*** *PROJECTION OF WATER QUALITY IMPACTS OF FUTURE WATER-RELATED DEVELOPMENT SCENARIOS*												
17	National, regional and local plans and projections of future water demands and catchment development	One & Two										
18	Predicted future water quality at sites of management focus	Two										

OUTPUT COMPONENT NO.	OUTPUT COMPONENT TITLE	PHASE NO.**	TIMING OF ACTIVITIES LEADING TO OUTPUT (DURING NOMINAL INCREMENTS OF 10% OF TOTAL DURATION)										
MANAGEMENT QUESTION 5: *WHAT ARE THE APPROPRIATE (PRIORITY) WATER QUALITY MANAGEMENT OPTIONS?* ***TASK 5:*** *FORMULATE AND PRIORITISE WATER QUALITY MANAGEMENT OPTIONS*													
19	Management units and assessment spatial and temporal resolution	One & Two											
20	Priority water quality management options	One & Two											**Etc.**
MANAGEMENT QUESTION 6: *HAS WATER QUALITY MANAGEMENT ACHIEVED ITS OBJECTIVES?* ***TASK 6:*** *MONITORING AND AUDITING OF IMPLEMENTATION OF WATER QUALITY MANAGEMENT OPTIONS*													
21	Monitoring and auditing the implementation of management options	One & Two											**Etc.**

** **Phase One**: ***Describing and understanding the catchment***

Phase Two: ***Supporting catchment management decision-making***

Route Map of the Guide

You are here

Management question 1

What is the study area's status in water - related terms and how did it get to this point?

Output 0: Summary of existing understanding, knowledge and past studies with regard to water quality in the catchment

Output 1: Details of natural, developmental and administrative attributes and characteristics of the catchment relevant to water resources management

Output 2: Requirements the National Water Resource Strategy and Resource Directed Measures

Output 3: Water use and conservation

Output 4: Overview of adequacy of water availability

Output 5: User water quality requirements and constituents of concern

Output 6: Water quality of streamflow, reservoirs, estuaries, wetlands and groundwater

Output 7: Point source waste discharges and source characteristics

Output 8: Non-point source water quality loadings and impacts

Output 9: Configured and calibrated water quality predictive tools / models

Output 10: Reconciliation: catchment sources and water quality patterns

Output 11: Status Reports on monitoring, physical data and characterization information

Management question 2

What are the water - related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages and roles?

Management question 3

What are the study area's water quality issues, problems, concerns and opportunities?

Management question 4

Where might the water quality status of the study area be heading in the future?

Management question 5

What are the appropriate (priority) water quality management options?

Management question 6

Has water quality management achieved its objectives?

Management Question 1:

WHAT IS THE STUDY AREA'S STATUS IN WATER-RELATED TERMS AND HOW DID IT GET TO THIS POINT?

Task 1: Characterisation of the current situation and historical trends

OUTPUT COMPONENT 0
Summary of Existing Understanding, Knowledge and Past Studies with regard to Water Quality in the Catchment

PURPOSE

Context

No catchment is a clean slate in terms of information or knowledge about it. Some experienced-based understanding of the functioning of at least some parts of a catchment is usually present among some of the long-standing inhabitants of a catchment, as well as among state officials or professionals active in water-related matters in it. Similarly, the existence of water-related issues and problems is often common knowledge. In many instances, particular water-related studies have historically been conducted in the catchment under consideration.

Purpose

The purpose of this component is to provide the CMS development process at an early stage with a provisional overview of *readily available* water-related knowledge and information, and of existing perspectives on issues, problems and opportunities relating to water in the catchment. Such an overview may be used as an inception document to bring all stakeholders and interested parties to a similar level of informedness, to guide discussion among such persons, to elicit issue-identification and to provide an early focus on acute problems that may need urgent attention in the CMS implementation.

OUTPUTS	HOW TO ATTAIN OUTPUTS
A brief overview document giving a summary description of the physical, developmental, and administrative attributes of the catchment relevant to water resource management, using only *readily available information* from past studies, or from interested persons with relevant knowledge.	Assemble all reports on relevant past technical and scientific studies and summarise the primary aspects mentioned under *Checklists* below. Identify relevant interested persons by publicising this study and by public participation events, and then capture their knowledge through public responses, interviews and correspondence.
A scoping report on real or perceived problems, issues, challenges and opportunities that are water-related, with special focus on the water quality aspects. [See Output Component 15 for a Checklist of possible issues, etc.]	Summarise the issues, problems, challenges and opportunities that are contained in reports on past studies. Elicit further inputs from knowledgeable persons and the general public through publicising, public participation events, interviews and correspondence.

SOURCES

◊ Reports with the following themes: *Catchment Description; Hydrology; Land Use; Water Resources; Water Quality Situation Analysis; System Analysis; Water Demands; Institutional Description, Water Scheme Design Reports*, etc.	*Address*: Director: Water Resources Planning or Director: Project Planning, Department of Water Affairs and Forestry (DWAF), Private Bag X313, Pretoria. Tel: 012 336 7500 Fax: 012 324 6592
◊ Reports with the following themes: *Water Quality Situation Analysis/ Study; Waste Load Allocation; Water Quality Management Plan*, etc.	*Address*: Director: Water Quality Management, DWAF, Private Bag X313, Pretoria. Tel: 012 336 7500 Fax: 012 324 6592

Output 0: *Existing Understanding*

◊ Reports with the following themes: *Catchment Management; Catchment Management Plans*; etc.	*Address*: Director: Catchment Management, DWAF, Private Bag X313, Pretoria. Tel: 012 336 7500 Fax: 012 324 6592 *AND/OR*: Various Metropolitan or Local Councils.
◊ Reports with the following theme: *In-stream/ Environmental Flow Requirements (IFRs) of Rivers and Estuaries*; etc.	*Address*: Director: Resource Directed Measures, DWAF, Private Bag X313, Pretoria. Tel: 012 336 7500 Fax: 012 324 6592

CHECKLISTS

The provisional overview reports should typically summarise the following, *at coarse scales*, with a focus on water quality: *climate, surface water and groundwater resources; demography; water use and demands; land use; water quality; return flows; Ecological Reserve, water balance, water-related infrastructure; water management institutions; water-related issues, problems and opportunities*.

DISPLAY AND PRESENTATION OPTIONS

The format of the output would typically be similar to that of a scoping report and the focus would be inclined towards water quality. Information should preferably be presented graphically or in map form (with GIS support), while text should be limited to significant observations only. See Output Component 1 for particular display and presentation options.

OUTPUT COMPONENT 1

Details of Physical, Developmental and Administrative Attributes and Characteristics of the Catchment Relevant to Water Resources Management

PURPOSE

Context

Every human being lives in a catchment. Therefore, one of the challenges of integrated water resource management at the catchment scale is to be able to recognise and accommodate the many mutual interdependencies among the natural processes that give the water resource its particular character as well as the overlay of human impacts and developments in the catchment. A description of these natural and human-related elements and their linkages is therefore a fundamental prerequisite for the development of a catchment management strategy.

Purpose

The purpose of this output is to provide the CMS development process with accessible technical details about

- ◊ the natural attributes of the catchment
- ◊ the extent of human impacts and development
- ◊ socio-economic profile
- ◊ water-related infrastructure and monitoring
- ◊ administrative arrangements

which are relevant to water resources management. This information serves as a *baseline* for both technical assessment tasks and consultative/ public participation tasks; therefore, the information needs to be spatially organised, with three levels of output:

- in map form for easy visualisation (for consultative tasks),
- in numerical/ tabular form with explanatory text (for consultative and technical tasks),
- in data base storage form (for technical tasks).

Prerequisite Output Components

This is the most fundamental Output Component and therefore does not have prerequisites.

OUTPUTS	HOW TO ATTAIN OUTPUTS
User-friendly GIS coverages and tables, as well as detailed data base storage sets of the following information:	Method of information assembly to attain the corresponding outputs in the left-hand column:
▪ *natural attributes* such as geological formations, soil types, rainfall isohytes, iso-evaporations, selected contours, aquifer boundaries and characteristics, vegetation, sediment production potential	◊ use available GIS coverages or digitise from available maps or aerial photos; if detailed maps are not available, then required features can be derived from available point data, through interpolation and regionalisation
▪ *river system details* such as main stem channels and tributaries (primary, secondary, tertiary, and quaternary, as the need arises), wetlands, estuaries and (sub-) catchment boundaries	◊ use available national coverage from DWAF, CMA, or local authority, or digitise from existing maps

Output 1: *Catchment Characteristics*

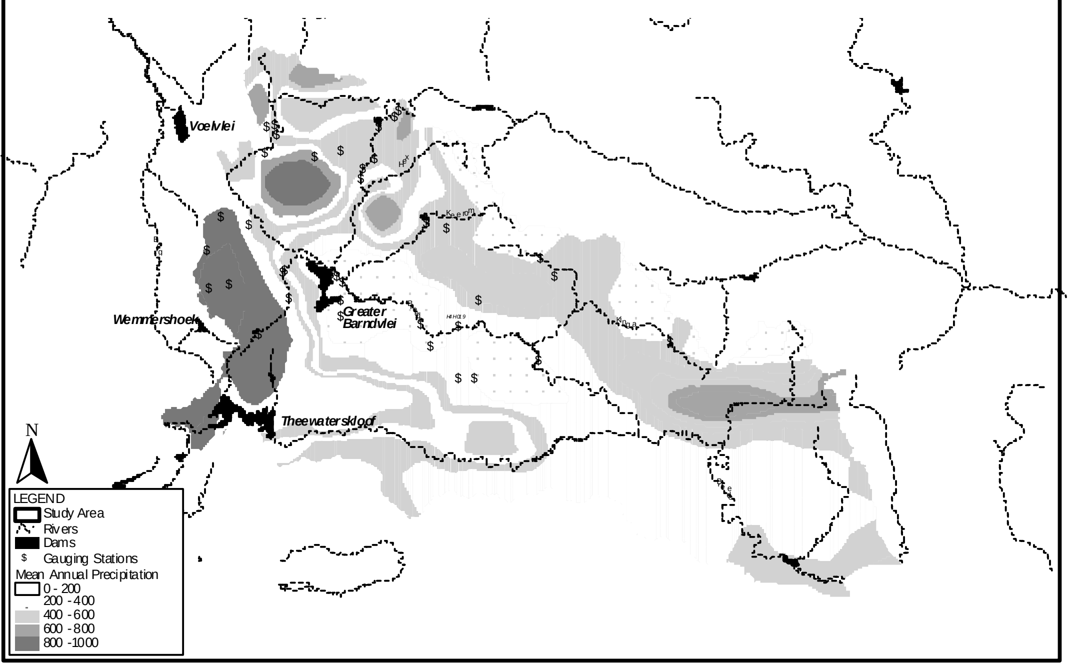
▪ *monitoring locations and type*; this would include stations for water quality sampling of rivers and effluent streams, flow gauging stations, rainfall stations, evaporation stations, weather stations	◊ locate via latitudes and longitudes obtained from data custodians, or determine with the aid of maps, aerial photos or a GPS
▪ *infrastructure* locations and dimensions, such as storage dams, balancing reservoirs, irrigation scheme components, water transfer schemes, water and wastewater treatment works, major roads and railways	◊ locate via latitudes and longitudes, obtained from scheme or infrastructure owners, or their consultants, or digitise from maps or aerial photos
▪ *demographic distribution* in the catchment	◊ obtain base data from demographic studies and projections, which might form part of this study, or be available through regional studies, or through the national census
▪ *land use (current and past)*, such as different categories of human settlements; commercial and industrial areas; different categories of irrigation activities; commercial and other plantations; dryland agriculture; mining details; solid waste sites; nature reserves; indigenous veld and forests	◊ use existing GIS coverages available from custodians of remotely sensed data, based on interpretation of satellite imagery, aerial photographs and orthophotos; alternatively, perform land use identifications from aerial photographs supported by ground-truthing in the field
▪ *socio-economic profile*, such as the types and extent of economic outputs per management unit, in terms of absolute values as well as proportion of GNP, GRP and per capita.	◊ consult appropriate economic databases, the National Department of Economic Affairs and Trade and Industry and the Development Bank of Southern Africa.
▪ boundaries and magnitudes *of areas of jurisdiction*, such as water management institutions, water services institutions, municipal, magisterial, provincial and international	◊ use existing GIS coverages available from DWAF, CMAs and municipalities, or digitise from appropriate maps
▪ boundaries of water resource *management units* (see Output Component 19 below)	◊ this is one of the outputs from the consultative tasks in a catchment assessment (see Output Component 14) and would usually follow physiographic boundaries; digitised from maps
SOURCES	
◊ Maps, aerial photographs and orthophoto maps.	▪ Chief Directorate: Surveys and Mapping, Department of Land Affairs - present in all major cities ▪ Map Office & municipal offices – All major cities

◊ GIS coverages ◊ Water Management System (WMS)	▪ Director: Geomatics, Department of Water Affairs & Forestry, Private Bag X313, Pretoria , 0001 Tel: 012 336 7500 Fax: 012 324 6592 ▪ CSIR, PO Box 395, Pretoria, 0001 Tel: 012 336 2911 ▪ Large Municipalities ▪ CMA Offices
◊ Institutional boundaries	▪ Director: Community Water Supply and Sanitation, Department of Water Affairs & Forestry, Private Bag X313, Pretoria, 0001 Tel: 012 336 7500 Fax: 012 324 6592
CHECKLISTS	
▪ *Human settlements*: Urban formal; urban informal; small holdings; rural semi-formal; rural informal ▪ *Irrigation activities*: Summer crops; winter crops; perennial crops, irrigation technology – centre-pivot, sprinkler, micro, drip and flood ▪ *Afforestation and Plantations*: Pines, eucalypts, wattles, indigenous forests, sugar cane, woodlots ▪ *Dryland agriculture*: Summer crops; winter crops; perennial crops, subsistence crops ▪ *Institutional boundaries*: Magisterial districts, district councils, metropolitan councils, local councils, WMAs, water boards, government water control areas, provincial and international.	

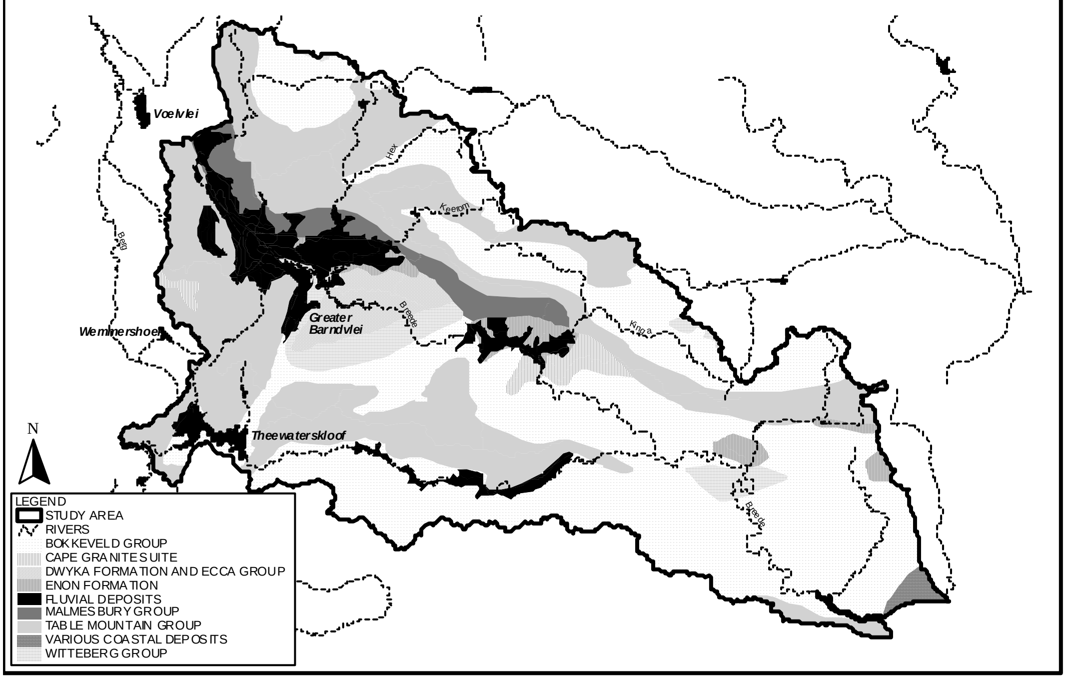
Output 1: *Catchment Characteristics*

DISPLAY AND PRESENTATION OPTIONS

MEAN ANNUAL PRECIPITATION IN THE BREEDE RIVER BASIN



GEOLOGY IN THE BREEDE RIVER BASIN



OUTPUT COMPONENT 2

Requirements of the National Water Resource Strategy and Resource Directed Measures

PURPOSE

Context

The National Water Resource Strategy (NWRS) and Resource Directed Measures (RDM) place specific constraints on the development of catchment management strategies and plans.

The ***National Water Resource Strategy*** (NWRS) provides the implementation framework for the National Water Act, 1998 (No. 36 of 1998) and the first edition was published for comment in August 2002. This national strategy is being progressively developed to set out policies, strategies, objectives, plans, guidelines, procedures and institutional arrangements for the protection, use, development, conservation, management and control of the country's water resources. The NWRS will be reviewed and published at five-yearly intervals. The NWRS provides the following:

- A national framework for managing water resources;
- A framework for the preparation of catchment management strategies in a nationally consistent way;
- Provision of information in line with current legislation regarding transparent and accountable public administration; and
- The identification of development opportunities and constraints with respect to water availability (quantity and quality).

The NWRS takes cognisance of the social, economic and ecological needs with respect to the water resources in South Africa at a national and regional scale, and balance these with international obligations and resource availability, in order to ensure their sustainable development of water resources.

The NWRS was given further impetus through the development of Internal Strategic Perspective (ISP) documents for the 19 water management areas. These documents present more detail on the Department's strategic perspective on how it wishes to protect, allocate usage, develop, conserve, manage and control water resource in the WMA's until the functions have been delegated to Catchment Management Agencies (CMA's).

Resource-Directed Measures (RDM) focus on the quality and the overall health of water resources. Resource quality includes water quantity and water quality, the character and condition of in-stream and riparian habitats, and the characteristics, condition and distribution of the aquatic biota. Resource-directed measures include the following elements:

- A National Classification System;
- Determination of the Management Class of specific water resources;
- Establishment, for each significant water resource, of resource quality objectives and determination of the Reserve in accordance with the Management Class of the resource.

The Reserve includes the water quantity and quality required to meet basic human needs, and to protect aquatic ecosystems. It has priority over all water uses, and the requirements of the Reserve must be met before water quantity and quality can be allocated for other uses.

Purpose

The purpose of this component is to document the constraints imposed by the NWRS by compiling data and information, at a WMA level, on the availability of water and priority water quality problems, that may affect strategies for the study area. The RDM provides information on whether any of the resources in the study have been classified and whether quantity and quality reserves have been determined for these resources.

Prerequisite Output Components

Geographical boundaries of the study area (Output Component 1) would inform this Component.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Description of the NWRS and ISP strategies that would affect the development of a catchment management strategy. GIS maps showing key features and transfers in and transfers out of water.	Contact the Director: Strategic Planning for information on the NWRS or obtain the document from the DWAF web site. Contact the Director: Water Resources Planning for more detailed information on the ISP for the study area.
Description of the Management Class, water quantity and quality reserve and resource quality objectives for each significant resource in the study area. GIS maps showing river reaches where Reserve determinations have been done.	Contact the Director: Resource Directed Measures for information.
SOURCES	
Information on the National Water Resource Strategy can be obtained from the Directorate: Strategic Planning.	Director: Strategic Planning Private Bag X313, Pretoria 0001 Tel: 012 336 7500 Fax: 012 324 6592 Web site: www.dwaf.gov.za
Information on the Internal Strategic Perspectives (ISP's) for the study area can be obtained from the Directorate: Water Resources Planning	Director: Water Resources Planning Private Bag X313, Pretoria 0001 Tel: 012 336 7500 Fax: 012 324 6592 Web site: www.dwaf.gov.za
Information on Resource Directed Measures in the study area can be obtained from the Directorate: Resource Directed Measures	Director: Resource Directed Measures Private Bag X313, Pretoria 0001, Tel: 012 336 7500 Fax: 012 324 6592 Web site: www.dwaf.gov.za
Information on the planning estimate of the ecological importance and sensitivity, present ecological class and future ecological class.	Director: Institute for Water Quality Studies Private Bag X313, Pretoria 0001 Tel: 012 808 0374 Fax: 012 808 0338 Web site: www.dwaf.gov.za

CHECKLISTS	
National Water Resource Strategy	Relevant information at WMA and sub-WMA scale: • Mean annual runoff & ecological Reserve • Available yield from natural resources (surface and ground water) and usable return flows (irrigation, urban, mining & bulk industrial) • Water requirements (irrigation, urban, rural, mining & bulk industrial, power generation, afforestation) • Reconciliation of water requirements and availability for different time and growth scenarios (local yield, transfers in, local requirements, transfers out) • Broad policy statements on water quality management approaches • Key elements of the broad strategic perspectives for each WMA.
Internal Strategic Perspective documents An ISP document will include more detailed strategies for a WMA or sub-WMA that are aligned with the NWRS, and is designed to provide the baseline from which a CMA can develop a catchment management strategy. The ISP has ten main strategies and each main strategy has one or more sub-strategies. Each strategy has the following elements: • Background information • Management objectives • Motivation • Actions required to implement the strategy • Interfaces with other strategies • Responsibilities for implementing the strategy • Programme • Priorities	The main strategies and sub-strategies that could affect the development of the water quality component of a CMS, include: • Water Resource Reconciliation Main Strategy (Resource availability strategy, Effluent re-use strategy) • Resource Protection Main Strategy (Reserve and resource quality objectives strategy, Water quality management strategy) • Water Use Management Strategy (General authorisations strategy, Licensing strategy, Pricing strategy, Sectoral use strategy) • Monitoring Strategy (Monitoring networks and data capture strategy) • Information Strategy (Information management strategy)

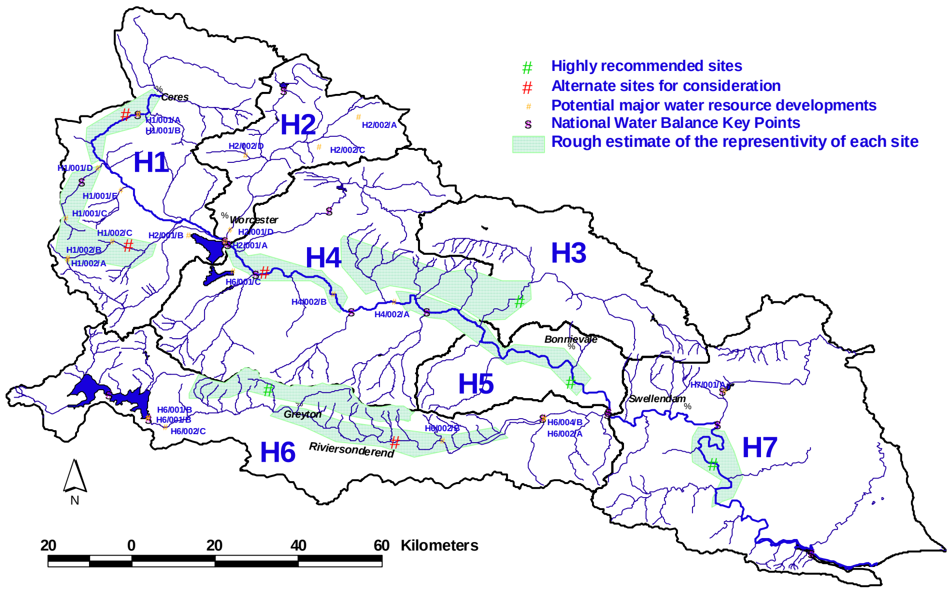
Reserve and resource management class

The Director-General has authorised a number of preliminary reserves and resource management classes.

The following information would appear in a preliminary reserve document:

- Description of the water resource and the ecological category.
- Description of the water quantity reserve in terms of a percentage of the MAR maintenance and drought low flows and maintenance high flows as well as the monthly distribution of the recommended reserve flows.
- Description of the water quality reserve in terms of major inorganic salts, major ion concentration, nutrients, physical constituents and toxic substances.

DISPLAY AND PRESENTATION OPTIONS



Example of a GIS map showing areas where reserve determinations have been done in the Breede River catchment

OUTPUT COMPONENT 3
Water Use and Conservation

PURPOSE

Context

Rapidly increasing *water use* for basic human and domestic needs, development and recreation is the reason why water resource management has a high priority in South Africa. Water use inevitably results in the discharge of water containing waste and return flows, and reduces assimilative capacity in streamflow. Therefore, a geo-referenced record of all water use, both current and historical, provides one of the *basic templates* for structuring the water quality assessment of a catchment. It is only when a clear picture emerges of all the different types of water uses, of the relevant categories of water users, and of their location in a catchment, that the water quality assessment can be focused on relevant constituents of concern and on appropriate locations. This information allows the fitness-for-use of the currently available water resources in the catchment to be seen in perspective. Historical water use trends are important to help explain the current water quality status, as well as for providing crucial input data to enable water quality model calibration.

A description of w*ater conservation* measures and their outcomes is needed to explain historical water use trends and to allow assessment of their impacts on the water quality status. For example, reduced domestic and industrial abstraction through conservation should lead to reduced return flows from waste water treatment plants, which in turn should impact water quality positively.

Purpose

Water users are primary stakeholders in the catchment management process. Therefore, the output from this component will help to focus CMS development in terms of who and where the primary stakeholders are, where the potential impacts associated with water use might be and where remediation and control should be aimed.

It should be borne in mind that the National Water Act (Section 21) defines water use very broadly: abstracting and storing water, activities which reduce streamflow, waste discharges and disposals, altering a water course, removing groundwater, certain potentially detrimental controlled activities, and recreation. The outputs from this Component should encompass all the Section 21 elements that may have a bearing on water quality. Return flows (waste discharges and disposals), because of their potentially direct impact on the water quality status, are highlighted by a separate treatment as Output Component 7.

Prerequisite Output Components

Output Components 1 and 5 would inform this Component in various ways.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Geo-referenced time series records/ estimates of all water abstractions, summarised by sub-catchment/ management unit (see Output Component 19) and by water use category (see Checklist below). These outputs should be linked to water quality via the constituents of concern (see Output Component 5).	Assemble all water abstraction or bulk water delivery records from relevant sources. In many instances irrigation abstractions will need to be estimated. The abstraction water quality is sourced from monitoring records, or else the abstracted water quality may be simulated with a calibrated model (see Output Component 9).

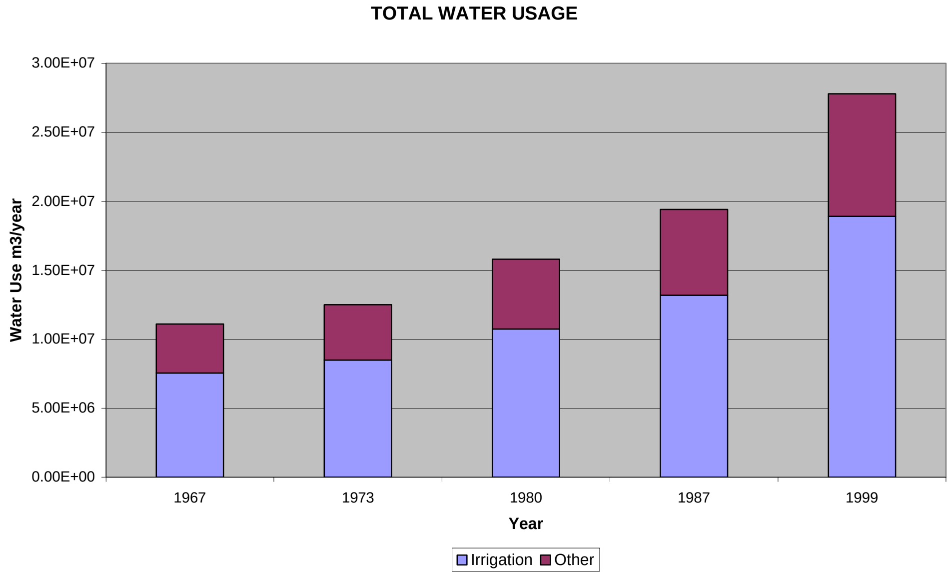
Output 3: *Water Use*

Geo-referenced time series estimates of all streamflow reductions, summarised by sub-catchment/ management unit and by category.	Estimate streamflow reductions attributable to commercial plantations, sugarcane and alien vegetation infestations. These estimates may already be available from the water resource quantity assessment.
Geo-referenced time series records/ estimates of all the discharge of water containing waste and return flows, summarised by sub-catchment/ management unit and by category.	Because of their importance to the water quality status, these are treated separately as Output Component 7.
Geo-referenced time series records/ estimates of all groundwater abstractions, summarised by sub-catchment/ management unit.	Assemble groundwater abstraction records from relevant sources, or make estimates based on the type of use. These estimates may already be available from the water resource quantity assessment.
Information tables of recreational water use, organised by sub-catchment/ management unit and/ or by river reaches or surface water bodies.	Assemble information via forums and stakeholder/ public participation activities, as well as through local authority administrations.
Information tables of "controlled activities" relevant to water quality, organised by sub-catchment/ management unit.	Assemble licence information on controlled activities, as well as records via compliance monitoring, from DWAF or the licensee.
Information set of water conservation measures, organised by sub-catchment/ management unit.	Assemble conservation plans and their outcomes from relevant sources.
GIS coverages displaying each of the above water use summaries in appropriate detail.	Combine with activities under Output Component 1.
A record of contact details for all water use management institutions or groupings. (Output component 13)	Assemble information via DWAF Regional Office, CMAs, forums and stakeholder/ public participation activities, as well as through local authority administrations.
SOURCES	
◊ Water abstraction or delivery records	Available from DWAF (Directorates: Water Utilisation; Hydrology), WUAs, CMAs, Water Boards, mines and municipalities.
◊ Data base on afforested, alien infested and sugarcane areas	Output Component 1.
◊ Groundwater abstraction records	Available from DWAF (Directorate: Geohydrology), WUAs, CMAs, Water Boards, mines and municipalities.
◊ Controlled activity licences	Available from DWAF (Chief Directorate: Water Use and Conservation), Regional Office, or CMAs.
◊ Water conservation plans	Available from DWAF (Directorate: Water Conservation), municipalities, WUAs.

CHECKLISTS

- *Water use categories*: domestic; irrigation; industrial; power generation; mining; livestock
- *Streamflow reduction categories*: commercial timber plantations (pines, eucalypts, wattles); range of classes of alien vegetation; dryland agricultural crops (at least sugar cane).

DISPLAY AND PRESENTATION OPTIONS



Output 4: *Water Availability*

OUTPUT COMPONENT 4
Overview of Adequacy of Water Availability

PURPOSE

Context

A sound understanding of the adequacy of water quantity availability in a catchment is a pre-requisite to the understanding of water quality issues and appropriate management responses to them. At the heart of certain water quality issues lie inadequate or unreliable supplies of fresh water, needed for dilution, flushing, assimilative capacity, river channel maintenance, or as alternative supplies to existing supplies that have problematic quality.

Purpose

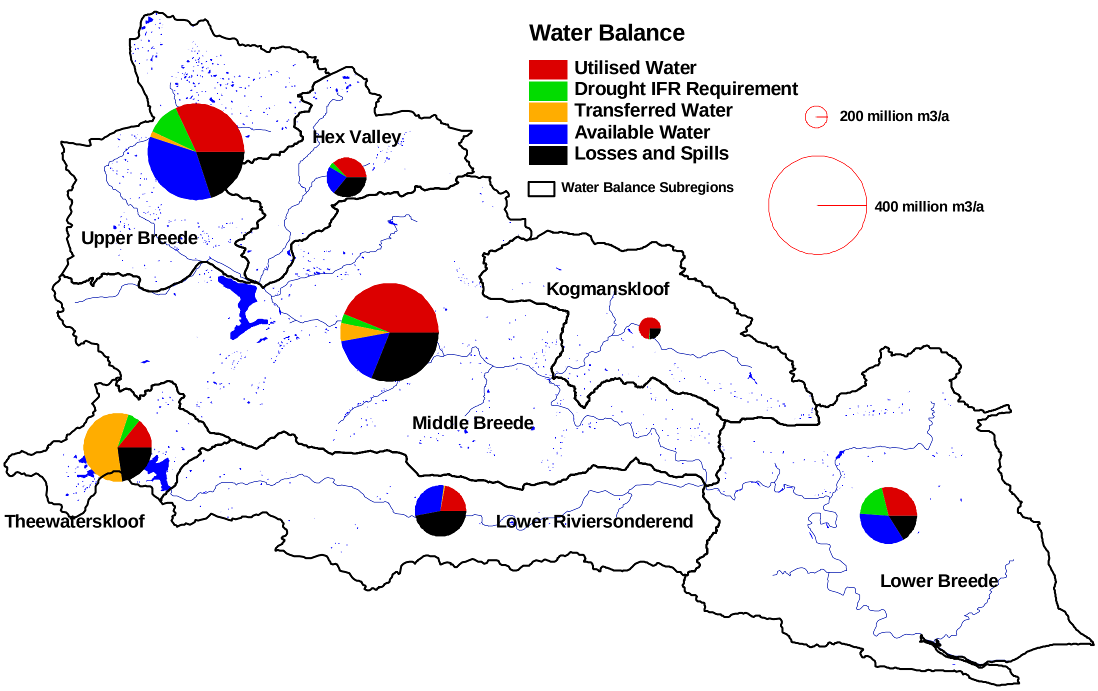
This component provides the CMS development process with an integrated picture of how much surface water and groundwater is available *at particular assurances/ reliabilities* at key locations in the catchment, and how this availability balances the demand for water (Output Component 3). If possible, this balance assessment should encompass not only the current water use situation, but also projected future water demands. Water quality issues that arise in areas of potential supply shortfall obviously need different management responses to those in areas of supply surplus. Assurance of surface water supply is usually a function of the availability of storage. If possible, this overview should include supplies not only from existing, but also from potential future impoundments or groundwater development schemes, so that derivation of management options can be fully informed about supply possibilities.

Prerequisite Output Components

Output Component 3 (Water use and Conservation) and the provisional version of Output Component 20 (Management Options) would inform this Component in various ways.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Overview chapter on surface water availability-reliability characteristics at key locations, such as at major (existing and future) impoundments and abstraction points, or per management unit. Availability is usually expressed as "*yield in* 10^6 m^3 *per year at 1:XX year recurrence interval of failure*", where, say, XX=50 implies a failure of one year in 50 years.	The required water availability information is sourced from reservoir and system yield analyses. The execution of such water resources analyses does not usually form part of a water quality management assessment, and should precede or be conducted simultaneous to it.
Overview chapter on groundwater availability-reliability characteristics at key locations, such as per geohydrological zone, aquifer, or management unit.	The required groundwater availability information is sourced from borehole and aquifer yield surveys. The execution of such groundwater studies does not usually form part of a water quality management assessment, and should precede it, or be conducted simultaneously.
Overview chapter on (current and future) balance of available water supplies and demands, organised according to any or all of: ◊ geographical grouping of water demands ◊ management units ◊ user sectors ◊ major sub-catchments.	These water balances are derived by combining the previous two outputs with due attention to the *varying assurances/reliabilities that are attached to different water use sectors*. The water balance exercise does not usually form part of a water quality management assessment, and should precede it, or be conducted simultaneous to it.

Summary of options for demand management, water conservation and water supply augmentation.	Cross-referencing to Output Components 3 (Water Use and Conservation) and 20 (Management Options).
SOURCES	
◊ Planning or Design Reports with the following themes: *Hydrology; Water Resources; System Analysis; Water Demands; Water Supply Augmentation Scheme Design*; *Groundwater Studies; Geohydrology; Demand Management*; etc.	*Address*: Director: Water Resources Planning, Director: Project Planning, or Director: Geohydrology, Department of Water Affairs and Forestry, Private Bag X313, Pretoria. Tel: 012 336 7500 Fax: 012 324 6592 *AND/OR*: Relevant Metropolitan or Local Councils.
◊ Reports with the following themes: *Catchment Management; Catchment Management Plans*; etc.	*Address*: Director: Catchment Management, Department of Water Affairs and Forestry, Private Bag X313, Pretoria. Tel: 012 336 7500 Fax: 012 324 6592
CHECKLISTS	
Apply checklists of Output Components 3 and 20.	
DISPLAY AND PRESENTATION OPTIONS	



OUTPUT COMPONENT 5
Water Quality Requirements and Constituents of Concern

PURPOSE

Context

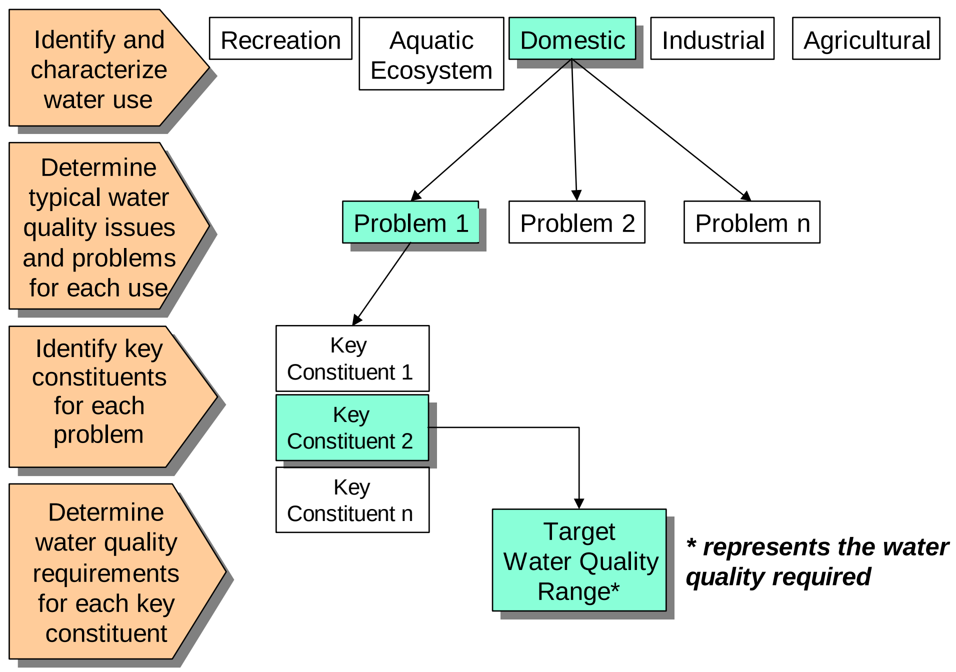
Not all the user sectors have the same water quality requirements or are concerned about the same water quality constituents. For example, domestic water users are more concerned about safe water supplies (bacteriological water quality) while irrigation farmers are more concerned about the build-up of salts in the irrigated soils (salinization).

Purpose

The purpose of this component is to describe the water quality requirements for each water user. The description should contain at least the Target Water Quality Range as specified in the South African Water Quality Guidelines. However, where appropriate, the requirements should be made site specific to account for local conditions such as crops cultivated (salt sensitive or salt insensitive, irrigation method used) or geological formations (old marine deposits etc.)

In summary this involves (see diagram below):

- identifying and characterise the main water uses
- determining the typical water quality issues or problems experienced by the main water users,
- identifying the water quality constituents associated with the each problem or issue, and
- specifying a target water quality range for each of the key constituents.



Prerequisite Output Components

- The initial scoping and background information (Output Component 0), reserve water quality requirements (Output Component 2), water users in the study area (Output Component 3) would inform this component in various ways. The water quality issues identified in Output Component 15 should be used to review this Component.

<table>
<tr><th>OUTPUTS</th><th>HOW TO ATTAIN OUTPUTS</th></tr>
<tr><td>Inventory of the specific water quality issues and problems of concern to different water users</td><td>Public participation process

Check list of typical water quality problems associated with different users (Component 15)</td></tr>
<tr><td>Inventory of water quality constituents and target water quality ranges for different uses</td><td>1. Summarize the target water quality guidelines for the key water quality constituents for the different water uses using the South African Water Quality Guidelines.

2. Develop site-specific water quality guidelines where the SA Water Quality Guidelines are not appropriate for local conditions.

3. Summarize the water quality reserve for aquatic ecosystems.

If a water quality reserve for aquatic ecosystems does not exist yet, develop an initial water quality reserve using the rapid reserve determination methodology.</td></tr>
<tr><th colspan="2">SOURCES</th></tr>
<tr><td colspan="2">The primary sources of information on user requirements for water uses in South Africa are the South African Water Quality Guidelines and the Assessment Guide for Domestic Water Supply.</td></tr>
<tr><td>South African Water Quality Guidelines:

Volume 1 : Domestic water use
Volume 2 : Recreational water use
Volume 3 : Industrial water use
Volume 4 : Agricultural water use: Irrigation
Volume 5 : Agricultural water use: Livestock watering
Volume 6: Agricultural water use: Aquaculture
Volume 7: Aquatic ecosystems
Volume 8: Field guide</td><td>Can be obtained from the Department of Water Affairs and Forestry:

Director: Water Quality Management
Department of Water Affairs & Forestry,
Private Bag X313, Pretoria 0001
Tel: 012 336 7500 Fax: 012 324 6592
Web page: www.dwaf.gov.za</td></tr>
<tr><td>Quality of domestic water supplies. Volume 1: Assessment Guide. Second edition.

Water Research Commission Report TT 101/98</td><td>Can be obtained from:

The Librarian
Water Research Commission
Private Bag X03, Gezina 0031
Tel: 012 330 0340 Fax: 012 3311136
or order directly from the WRC publications web site
Web page: www.wrc.org.za</td></tr>
</table>

Output 5: User Requirements

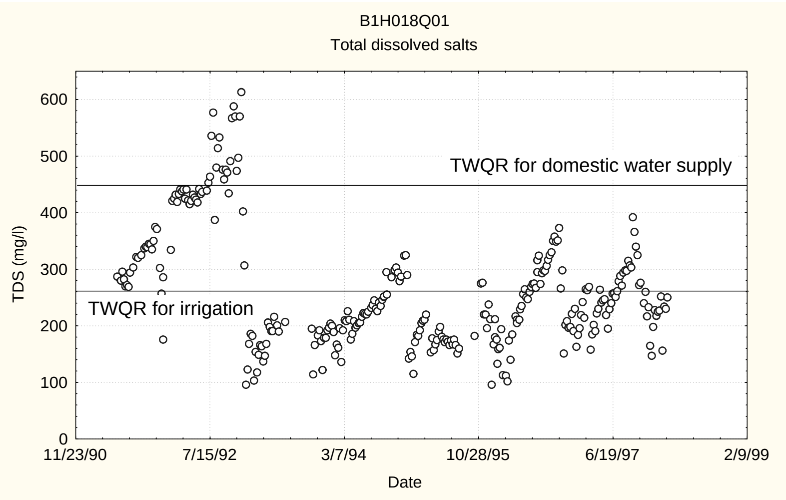
Resource Directed Measures for Protection of Water Resources. Volume 3: River Ecosystems. (This source is only required if no water quality reserve or resource quality objectives have been determined for the catchment under investigation)	The Resource Directed Measures documents can be obtained from the Department of Water Affairs & Forestry: Director: Resource Directed Measures Department of Water Affairs & Forestry Private Bag X313, Pretoria 0001 Tel: 012 336 7500 Fax: 012 324 6592 or download the documents from the DWAF web site at: www.dwaf.gov.za
South African sources of information that can be used to supplement the Guidelines are:	
Summarized Water Quality Criteria	Kempster, P.L., Hattingh, W.H.T. and van Vliet, H.R. (1980). Hydrological Research Institute, Technical Report TR108 Available from the DWAF Library
South African Bureau of Standards: *Specifications for domestic supplies*	South African Standard 241-1984 Available from SABS Library
Water quality criteria in South Africa	Aucamp, P.J. & Vivier, F.S. (1990) Technology South Africa, June 1990, pp 21-30
Water quality for aquatic ecosystems: tools for evaluating regional guidelines. Final report	Dallas, H.F.,Day, J.A., Musibono, D.E., Day, E.G. (1998). Water Research Commission Report 626/1/98 Available from the Water Research Commission Web site: www.wrc.org.za
International sources that can be used to supplement the South African Water Quality Guidelines include (only those which can be accessed via the Internet are listed here):	
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (1999)	Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of Australia and New Zealand http://www.environment.gov.au/science/water/index.html
USEPA Water Quality Criteria	USEPA Water Quality Standards Section http://www.epa.gov/OST/standards/
Canadian Water Quality Guidelines	Environment Canada http://www.ec.gc.ca/water/en/manage/qual/e_qual.htm
Guidelines for Drinking Water Quality	World Health Organisation http://www.who.int/water_sanitation_health/GDWQ/

CHECKLISTS	
Key water uses to consider	Domestic water use • Drinking water (health & aesthetic considerations) • Food preparation • Bathing • Laundry • Household appliances Industrial water • Leather & tanning industries • Pulp & paper industries • Power generation industries (for steam generation and cooling water use) • Textile industries Agricultural water use • Irrigation water supply • Livestock watering Recreational use Aquatic ecosystems
Water quality constituents Water quality constituents will generally fall into one of the following groups	Physical properties • pH, conductivity, temperature, suspended solids, turbidity Major cations • Sodium (Na), Potassium (K), Magnesium (Mg), Calcium (Ca) and Ammonia (NH_4) Major anions • Sulphate (SO_4), Chloride (Cl), Nitrate (NO_3), Heavy metals • Iron (Fe), Manganese (Mn), Aluminium (Al), Zinc (Zn), Copper (Cu), Nickel (Ni), Chromium (Cr), Cobalt (Co), Lead (Pb) and Selenium (Se) Other inorganic constituents • Boron (B), Silica (Si), Fluoride (F) Organic constituents
Water quality problems or concerns	See *Checklist* at Component 14 for a description of common water quality problems and the constituents associated with the problem.

DISPLAY AND PRESENTATION OPTIONS

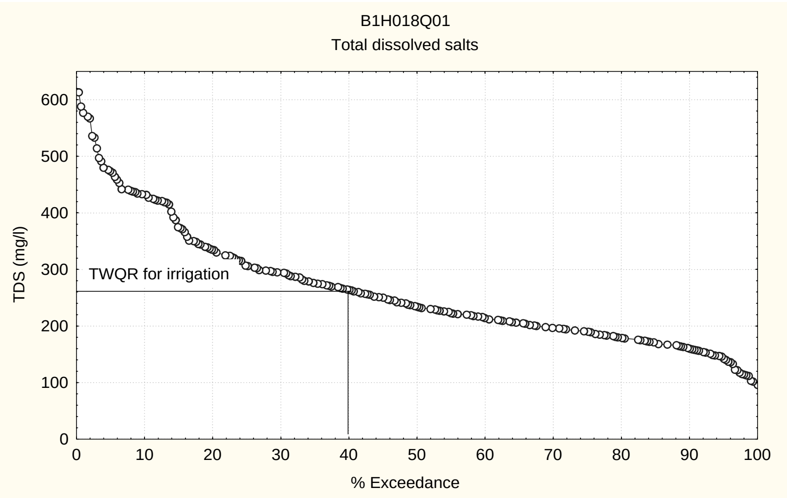
Time series plot

A time series plot like the example shown here can be used to indicate the acceptability of the water quality, for different users, at one location, over time.



Exceedance diagram

An exceedance diagram can also be used to illustrate the acceptability of water quality, at one location, for different users. In the example it can be seen that the target water quality range for irrigation is exceeded for 40% of the time (or observations made).



Summary Tables of target water quality ranges

Example showing only target guideline ranges for two key water uses and five constituents.

Constituent	Water Use		
		Agricultural	
	Domestic	Irrigation	Livestock
pH	6 – 9		
Electrical conductivity (mS/m)	< 70	< 40	< 154
Chloride (mg/l)		< 105	< 3000
Total hardness (mg/l)	< 100		
Fluoride (mg/l)	< 1.0		< 2.0
Etc.			

OUTPUT COMPONENT 6

Water Quality of Streamflow, Reservoirs, Estuaries, Wetlands and Groundwater

PURPOSE

Context

The present water quality status needs to be described in order for the CMA and/or the Department and other stakeholders to make informed decisions on how to manage water quality in a specific catchment. An analysis of water quality data needs to provide information on the present water quality status, how the status may possibly change over time if current trends continue and, by comparing it to the user water quality requirements, determine whether user requirements are met or not.

Purpose

The purpose of this component is to obtain water quality data and information for the study area from appropriate sources and to analyse the data to describe:

- water quality in the catchment at an overview level
- spatial trends in water quality constituents of concern
- temporal trends in water quality constituents of concern
- the fitness of water resources for key water uses in the study area

Prerequisite Output Components

To undertake this component, the following information should be available:

- Output Components 1 (Catchment description)
- Output Component 3 (Water use and conservation)
- Output Component 5 (User water requirements, and constituents of concern).

Output 6: *Water Quality*

OUTPUTS	HOW TO ATTAIN OUTPUTS
Inventory of water quality data sources for the study area	Identify the key sources of data and information for the study area using the national, provincial, water service providers, local authorities and other institutions listed in the *Sources* section as guideline. For each data source list the following: • Name of the monitoring programme • Name of the institution responsible for the monitoring programme • Key objectives of their monitoring programme Note: *A detailed assessment of each monitoring programme is described in Component 11.*
Inventory of key water quality reaches in the study area[6]. Key water quality reaches are the most impacted sections of the resource.	• List the geographical boundaries and describe the key water quality reaches • Compile a GIS map showing the location of the water quality reaches
Temporal trends in key water quality constituents	• Describe and illustrate the temporal trends, at specific key points in the study area, for specific water quality constituents, using the presentation and display options listed below. Use a statistical package or WMS to assess whether the trend is significant or not. • Use a statistical software package (such as WQStat or Statistica) and the Kruskal-Wallis test for seasonality to determine whether there is seasonality in the data. Illustrate seasonality with monthly box-and-whisker plots (See display options below)
Spatial trends in key water quality constituents	• Describe and illustrate spatial water quality trends long the length of key water quality reaches. • Use a statistical software package or WMS to confirm significant spatial trends.

[6] The Water Management System (WMS) of DWAF will provide essential support for these tasks (http://www.dwaf.gov.za/Projects/WMS_Overview/index.htm)

Water quality assessment report	Compile a water quality assessment report which addresses the following aspects: • Overview of water users in the study area (refer to detailed descriptions in Component 12). • Overview of the water quality problems experienced by main users (refer to detailed descriptions in Component 5 and 15) • List of water quality constituents investigated (refer to detailed descriptions in Component 5 and 15) • Temporal trends of key water quality constituents • Spatial trends of key water quality constituents
SOURCES	
Water quality information in a catchment is available from a number of sources. The Department of Water Affairs & Forestry operates the most comprehensive water quality monitoring programme in the country. Other potential sources include water service providers such as water boards, local authorities, metropolitan councils as well as research institutions. The list of potential data sources is by no means complete and is presented here to serve as a guide of the types of organizations involved in collecting water quality data. It is up to the study team to identify the key sources of water quality data and information in the catchment under investigation.	
National government data sources	
Department of Water Affairs & Forestry (Surface Water Quality)	Director: Hydrology Private Bag X313, Pretoria 0001 Tel: 012 336 7500 Fax: 012 324 6592 Web site: www.dwaf.gov.za
Department of Water Affairs & Forestry (Groundwater quality)	Director: Geohydrology Private Bag X313, Pretoria 0001 Tel: 012 336 7500 Fax: 012 324 6592 Web site: www.dwaf.gov.za
Department of Water Affairs & Forestry (Flow data)	Director: Hydrology Private Bag X313, Pretoria 0001 Tel: 012 336 7500 Fax: 012 324 6592 Web site: www.dwaf.gov.za

DWAF Regional Offices Water Quality Management (Compliance monitoring data)[7]	Contact details for individual regional offices are available on the DWAF web site Web site: www.dwaf.gov.za/ContactRegions.htm
Catchment Management Agencies	DWAF is in the process of establishing a number of Catchment Management Agencies. These agencies may in future undertake monitoring of water resources in their area of responsibility and act as sources of water quality data.
Provincial government	
Provincial nature conservation departments, in general, do not operate long-term routine water quality monitoring programmes. They do, however, collect project specific information during surveys of rivers and reservoirs in the province.	Contact the relevant provincial nature conservation department about water quality data would be available from them.
Examples of water service providers and water user associations involved in water quality monitoring	
Rand Water Rand Water has an extensive monitoring network in the Vaal Dam catchment as well as its area of supply (the Pretoria Witwatersrand Vereeniging complex)	Manager: Water Environment Rand Water PO Box 1127, Johannesburg 2000 Tel: 011 862 0481 Fax: 011 862 0733 Web site: www.randwater.co.za
Umgeni Water Umgeni Water has an extensive monitoring network in the Umgeni River catchment and their area of supply	Director: Scientific Services Umgeni Water P O Box 9, Pietermaritzburg 3200 Tel: 033 341 1164 Fax: 033 341 1177 Web site: www.umgeni.co.za
Water user associations (WUA's), such as former Irrigation Boards or Water Conservation Boards, have in the past collected user specific water quality data, for example to assess the fitness for irrigation.	WUA's are too numerous to list in this document and it is recommended that WUA's in the study area be identified and contacted about the availability of water quality data.

Output 6: *Water Quality*

[7] All pollution monitoring data is being transferred onto the Water Management System (WMS) and will in future be accessible via the Internet. More information about the development of WMS and progress on the project can be obtained from the DWAF web site:
http://www-dwaf.gov.za/Projects/WMS_Overview/index.htm

Examples of local government organisations involved in water quality monitoring	
Cape Metropolitan Council	Director: Scientific Services Cape Metro Council – Scientific Services PO Box 16548, Vlaeberg 8018 Tel: 021 637 9090 Fax: 021 638 5083 Web site: www.capetown.gov.za
Durban Metropolitan Council	Head of Laboratory Durban Metro Water Services Laboratory Tel: 031 302 4793 Fax: 031 302 4747 e-mail: tonyb@dmws.durban.gov.za Web site: www.durban.gov.za
Greater Johannesburg Metropolitan Council	Director: Scientific Services Tel: 011 407 6669 Fax: 011 339 1276 or Tel: 011 728 7373 Fax: 011 728 5444 Web site: www.johannesburg.gov.za
Examples of other organizations involved in water quality monitoring	
CSIR Division of Water, Environment and Forestry Technology (Estuary water quality data and information)	The Director: Environmentek, CSIR PO Box 320, Stellenbosch 7999 Tel: 021 888 2494 Fax: 021 888 2693 Web site: www.csir.co.za/environmentek/estuaries
Universities and Technikons sometimes collect project specific water quality data.	Contact the natural sciences departments at Universities and Technikons in the study area to find out whether they have undertaken any water quality data collection that would be relevant for the catchment assessment study.

DISPLAY AND PRESENTATION OPTIONS

Introduction

Analyse the water quality constituents that are relevant to the water uses and key water quality issues in the catchment. Graphical and statistical procedures for analysing and reporting water quality data are described in:

- Harris, J., M. van Veelen & T.C. Gilliland (1992). *Conceptual design report for a National River Water Quality Assessment Programme*. Water Research Commission, Report No. 204/1/92, Pretoria, South Africa.
- Ward, R.C., J.C. Lofts & G.B. McBride (1990) *Design of Water Quality Monitoring Systems*. Van No strand Reinhold, New York, NY, USA
- Gilbert, R.O. (1987). *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold, New York, NY, USA

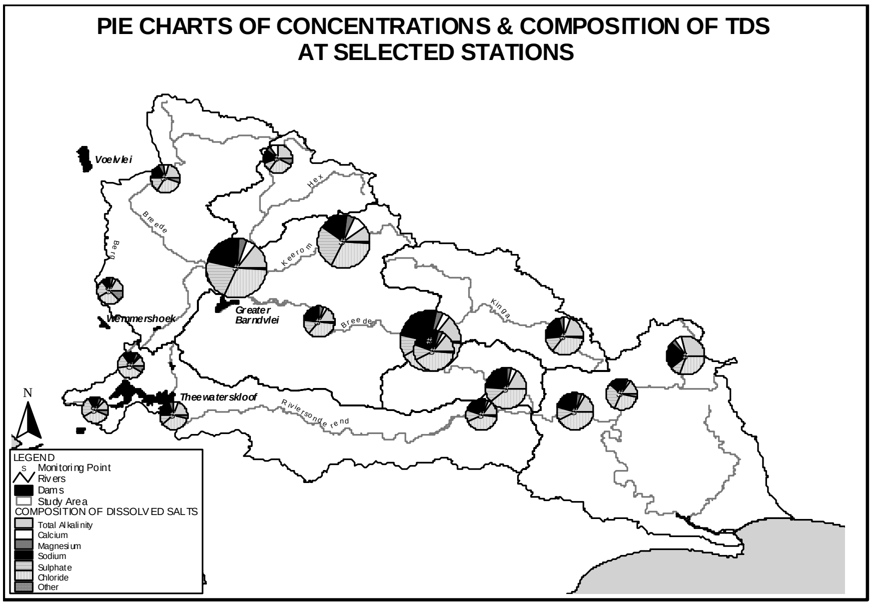
Summary statistics

Summary statistics provide a good overview of the order of magnitude of concentrations recorded for different constituents in the study area. Summary statistics can include the average, median, minimum, maximum, standard deviation and number of samples over a specified time period.

GIS maps for synoptic overviews[8]

GIS maps of the study area can provide a good synoptic overview of water quality in a catchment. The purpose of the maps is to illustrate spatial trends in water quality rather than actual values. The values on which the map information is based can be summarized in tabular format. A good example of presenting water quality information on a map can be found in:

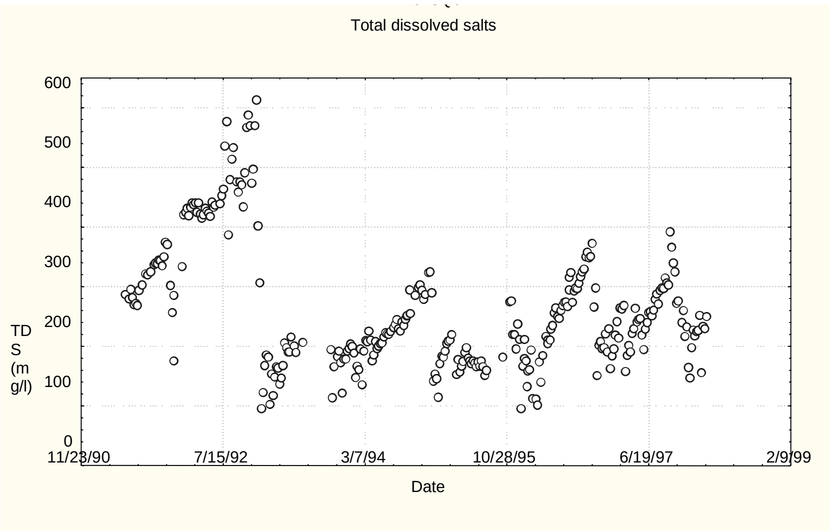
- DWAF (1999) Zwartkops River Water Resource Management Plan: Situation Assessment and Development of a Catchment Water Quality Monitoring Programme. Report number N/M100/REQ/0896.



[8] In future, the DWAF Water Management System (WMS) would be able to produce the required GIS maps.

Time series plot

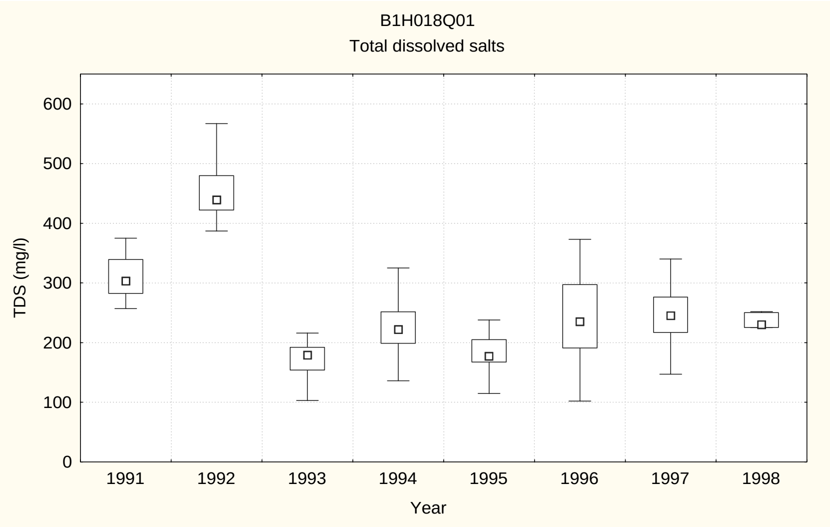
A plot of the water quality variable against time. A visual examination of the time series plot can show suspect outliers as well as some indication of seasonal or longer-term trends.



Annual box-and-whisker plot

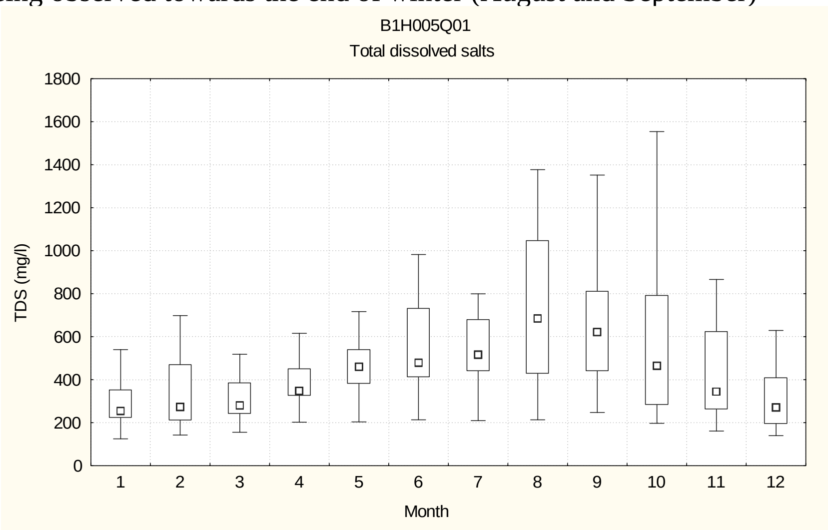
A box-and-whisker plot is based on a five number summary consisting of the 95th, 75th, 50th, 25th and 5th percentiles. The box is enclosed by the 75th and 25th percentile and contains the 50th percentile (also called the median). The whiskers join the box to 95th and 5th percentiles.

An annual box-and-whisker plot is obtained by plotting the data collected during a specific year as a box-and-whisker graph. An examination of an annual box-and-whisker plot would indicate water quality differences between different years.



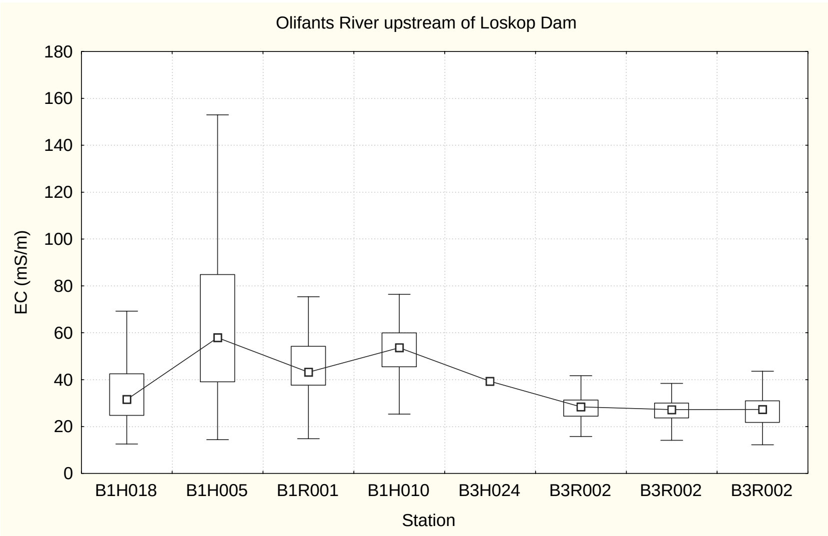
Seasonal box-and-whisker plot

A seasonal box-and-whisker plot is obtained by plotting all the data collected during a specific month as a box-and-whisker graph. An examination of a monthly box-and-whisker plot can give an indication of seasonal differences in the data. This can be confirmed with statistical tests for seasonality. For example, this box-and-whisker plot shows strong seasonality with higher TDS concentrations being observed towards the end of winter (August and September)



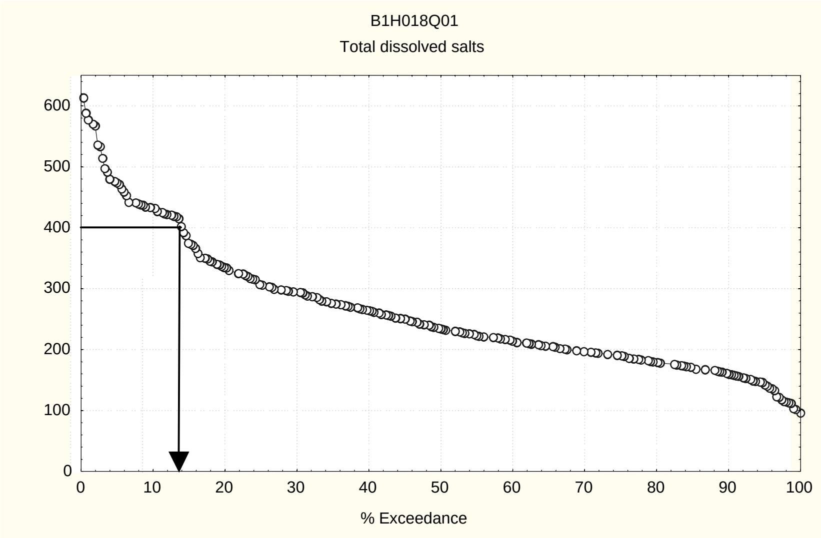
Spatial box-and-whisker plot

A spatial box-and-whisker plot is compiled by arranging the sampling stations according to its downstream position in the river. An examination of a spatial box-and-whisker plot can give an indication of the water quality changes along the length of a river. For example, this spatial box-and-whisker plot shows a sharp increase in TDS concentration in the second sampling station and a general decrease from there onwards as tributaries discharge a better quality water into the main stem river.



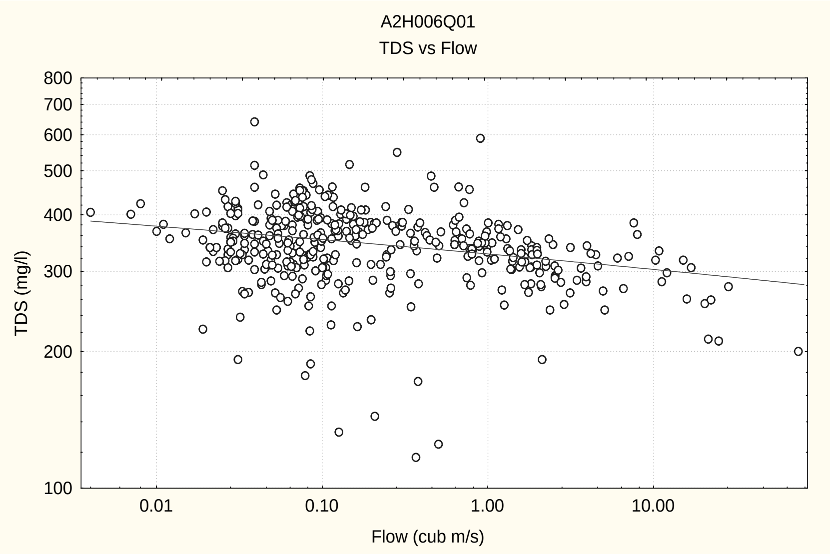
Exceedance diagram

An exceedance diagram shows the percentage of time a specific concentration was exceeded in the data recorded. This is obtained by ranking the data from large to small and calculating the plotting position as the rank divided by the total number of data +1. For example, this exceedance diagram shows that a concentration of greater than 400 mg/l TDS was only observed for about 14% of the time in the data record.



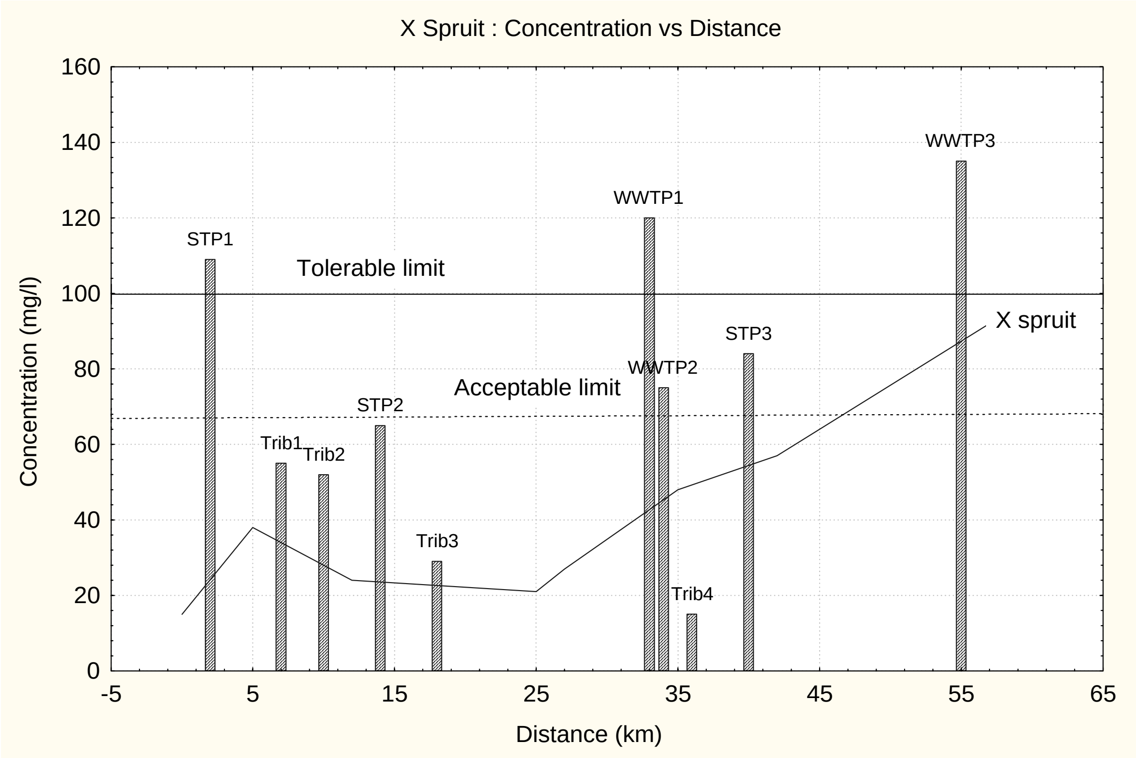
Flow – concentration plots

A flow-concentration plot is compiled by plotting the constituent concentration against the average daily flow (or instantaneous flow). By fitting a line trough the data points, an indication can be given whether there is a strong or weak, positive or negative, relationship between flow and constituent concentration.



Concentration vs. Distance Diagram

A concentration vs. river distance diagram can provide valuable information on spatial changes in water quality especially when reconciling source water quality data with in-river data. The example below illustrates the effect of sampling the river, tributaries and point sources on a specific day and then plotting the concentrations as a function of river distance. This type of graph can be used to assess whether the changes concentration can be explained with data from the known point sources in the catchment. A more accurate estimate can be obtained for catchment processes if concentrations are replaced with constituent loads.



OUTPUT COMPONENT 7
Point Source Waste Discharges and Source Characteristics

PURPOSE

Context

Wastewater treatment works or industrial plants usually discharge their effluents to stream channels or surface water bodies through conduits such as outfall pipes, ditches or canals. Such "end-of-pipe" sources of pollutant loading of surface water bodies are known as *point sources*, and the effluent is often called "return flows". In the case of groundwater, a point source is likely to be a holding pond for waste discharges from which concentrated seepage and deeper percolation takes place, usually unintentionally.

The quality of waste discharges must conform to standards prescribed in licences or other forms of authorisations. Such specific or general waste discharge quality standards are intended to safeguard the fitness-for-use of the receiving waters. However, in many river reaches across South Africa, the cumulative effects of point sources have, despite these standards, contributed to deteriorating fitness-for-use in terms of the requirements of specific water users. Consequently, the assessment of contaminant load contributions to streamflow and other water bodies originating from point sources is a prerequisite for understanding of water quality patterns and problems in catchments.

Unlike non-point (diffuse) sources, point sources are, in principle, relatively easily quantifiable. Discharge authorisation conditions usually include regular (albeit low-frequency) sampling and flow rate monitoring. Unfortunately, unlicensed discharging, or periodic dumping of effluents by authorised dischargers in excess of prescribed conditions, does occur. Point source assessment therefore does not only comprise the processing of available effluent stream records, but may also include scrutiny of streamflow water quality records to identify unknown contaminant loadings, which may signify unauthorised discharges.

Purpose

This Component assists understanding and interpretation of the water quality characteristics and patterns in a catchment by yielding both detailed and aggregated information on the location and magnitude of primary impactors on ambient water quality. For instance, by subtracting known point source waste discharge loadings from cascading incremental load balances (by constituent) at flow gauging/ water quality observation (or simulation) points in a river, non-point loadings, and unauthorised point sources, along intervening reaches can be identified/ quantified. The land uses or water uses from which these loadings emanate can then be brought into the ambit of management consideration and action.

The configuration and calibration of water quality simulation models for use in water quality assessments (see Output Component 9) and investigation of management options, require quantified point sources as essential inputs. Not only the current day point source waste discharges, but also historical waste discharge records or trends are required for proper calibration of the models over a representatively long time period.

The development of the CMS itself is, inter alia, dependent on availability of a reasonably reliable record of both point and non-point sources and their constituent loadings in the Water Management Area. This record provides essential input to the development of a Water Quality Management Plan, a core component of any CMS. From a water balance perspective, waste discharges and return flows may be considered to be a significant part of the total available quantity of water. Therefore, these discharges need to be considered in the Water Allocation Plan component of the CMS.

Prerequisite Output Components

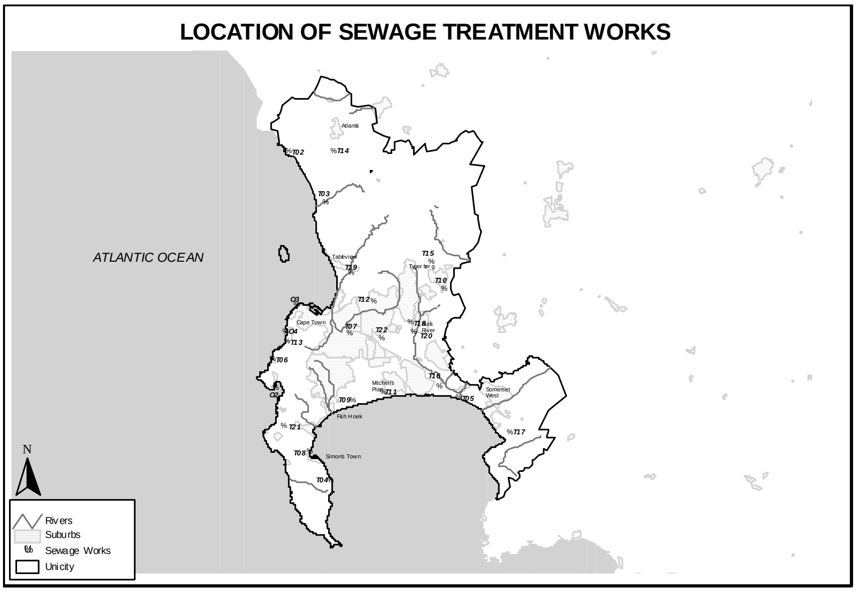
Output Components 1, 3 and 5 would inform this component in various ways.

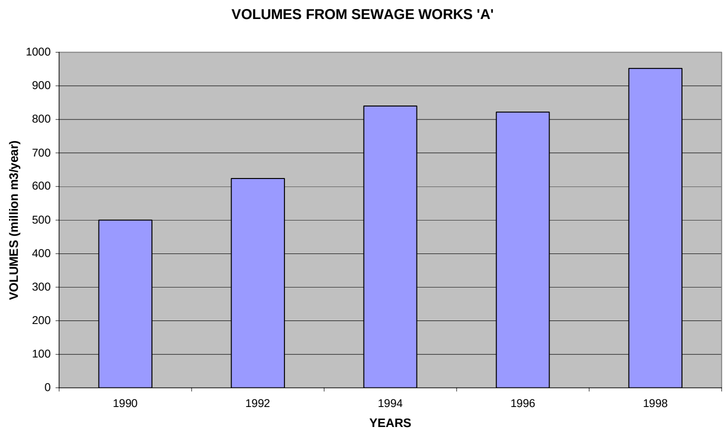
Output 7: *Point Sources*

OUTPUTS	HOW TO ATTAIN OUTPUTS
Summary Table with each individual waste discharge location, current annual discharge volume, current annual constituent loads, source type, primary activity involved, identity and position of accountable person, contact details, etc.	Current annual discharge volumes and loads are based on the monthly time series of historical discharges (the second output); all other information in this table is drawn from the register of water users, licences and personal contact with dischargers.
Monthly time series of historical waste discharge volumes and constituent loads.	These time series are developed by infilling or extrapolating the intermittent sample data (third output) using appropriate infilling methods. Sub-catchment scale information may be available from previous waste load allocation studies, sub-catchment assessments or the water quality phase of system analyses.
Database of raw information on waste discharge sample analyses and flow rates.	This raw data are assembled from the records kept by DWAF (or a CMA) as responsible authority, or from the discharger's own monitoring data. If a previously unknown discharger is identified during the catchment assessment, a customised site-specific waste monitoring exercise may be needed to characterise this particular discharge.
SOURCES	
◊ The DWAF Water Management System (WMS) was designed to store all water quality monitoring data collected for DWAF. It contains, *inter alia*, data on waste discharges, river water quality and reservoir water quality. Flow data is stored on HYDSYS (up to 2000, water quality data resided in various databases (POLMON & DBQUAL) and flow data was stored in HIS – Hydrological Information System)	WMS - Deputy-Director: Water Quality Management, at any of the Regional Office of DWAF. HYDSYS - Director: Hydrology, DWAF, Pretoria.
◊ Water quality-focused reports/ chapters in previous basin studies/ system analysis studies	Director: Water Resources Planning, DWAF.
◊ Reports on assimilative capacity/ waste load allocation studies for particular river reaches.	Director: Water Quality Management, DWAF, or Director: Institute for Water Quality Studies, DWAF
◊ Reports on environmental management or impact assessment in urban rivers.	Departments in Metro Councils dealing with environmental management or catchment management matters.
CHECKLISTS	
▪ *Source Types*: Sewage and wastewater treatment plants, canning and food-processing factories, pulp and paper mills, wineries and breweries, textile factories, tanneries, petro-chemical plants, animal feeding lots, dairy-related factories, mine de-watering sites, ore processing plants, quarries, etc.	

DISPLAY AND PRESENTATION OPTIONS

Typical display options for point sources of water containing waste and/or return flow data:





Output 8: *Non-Point Sources*

OUTPUT COMPONENT 8
Non-Point Source Water Quality Loadings and Impacts

PURPOSE

Context

NB: Output Component 9 and Output Component 8 should be considered and developed simultaneously, as there is strong overlap between them and their underlying processes.

Non-point sources represent *land use types, areas and activities* that result in the mobilisation and discharge of contaminants in any manner other than through a discrete or discernible conveyance. Non-point source pollution of surface waters in South Africa is largely caused by rainfall and the associated surface runoff or groundwater discharge. Non-point sources may be diffuse and intermittent, contributing to contamination of water resources over a widespread area, such as storm washoff and drainage from urban or agricultural areas. Alternatively, they may be concentrated, associated with localized high activity areas, such as mines, feedlots, landfills and industrial sites. Although non-point source impacts of surface washoff are relatively immediate, the non-point source impact of groundwater discharge is often delayed, due to the time taken for contaminants to mobilise and move through the soil matrix into the receiving surface water environment.

Although storm runoff and irrigation return flow are often collected into a discernable conveyance such as a pipe, canal, ditch or conduit, these are diffuse in nature (with the containment system representing a management practice) and are therefore included as non-point sources. Streamflow modification associated with land use change is also a type of non-point source pollution, which can adversely affect the physical and biological integrity of surface waters. The management of non-point sources is complicated by the dispersed and variable nature of the impacts, being primarily driven by hydro-meteorological events. The potential lag between polluting activity and effect also complicates non-point source management.

These characteristics obscure the impacts from different sources and restrict the opportunities for their measurement. Therefore, non-point source contributions can generally not be monitored directly, but have to be inferred by experience-based interpretation, mass balances against measured point source loadings, or simulation modelling. However, the importance of non-point source management is increasing as point sources are better controlled and catchments are developed. Thus, the only realistic way of obtaining adequate information to support non-point source management, is through non-point source assessment.

The nature of the water quality effect indicates the time period and time steps (i.e. resolution) required for an assessment, and thus the possible range of techniques which may be used for the analysis. Acute (short-term), transient or event-driven problems, with local impacts require sub-system analysis at finer spatial and temporal resolutions than what is required for cumulative (long-term) or relatively time-invariant problems with regional impacts.

Although land use is generally assumed to be the over-riding determinant of water quality impacts, there is generally more variation in loading within a land use category, than between categories. This implies that non-point source assessment should be based on the combination of hydro-meteorological and natural conditions, as well as the land use in an area; and the transition from one land use to another, generally as a progression from undisturbed land, through agricultural activities, to urbanised areas. It should be remembered that the combined characteristics of the non-point source types and areas within a catchment govern the water quality impacts on the receiving surface water environment.

Purpose

This Component together with Component 7 assists understanding and interpretation of the water quality characteristics and patterns in a catchment by yielding both detailed and aggregated information on the location and magnitude of primary impactors on ambient water quality. Because non-point source assessment might potentially be very complex because they relate to the whole hydrological cycle, this Component may be pitched at different management interest levels – each of which may entail a different quantification methodology. At a *scoping* level, it may simply determine whether, in a particular sub-catchment, non-point sources contribute more to water quality concerns than point sources, or which sub-catchment in a basin has the highest non-point loadings. At an *evaluation* level individual non-point source impacts are distinguished at the catchment level. At a *prioritisation* level the key source types, areas and activities are identified which require management attention.

Non-point source quantification occurs via various possible predictive methodologies. These are described in the WRC Report, "*A Guide to Nonpoint Source Assessment to Support Water Quality Management of Surface Water Resources in South Africa*," by G Pegram and A Görgens (2000). The configuration and calibration of these water quality predictive tools (see Output Component 9) require land-use and water use information as essential inputs. Not only the current day information, but also historical land use and water use trends are required for proper calibration of the models over a representatively long time period.

The development of the CMS itself is, *inter alia*, dependent on availability of a reasonably reliable record of both point and non-point sources and their constituent loadings in the Water Management Area. This record provides essential input to the development of a Water Quality Management Plan, a core component of any CMS.

Prerequisite Output Components

Output Components 1, 3, 4, 5, 6, 7, and 9 need to be substantially completed and 14, 15 and 16 reasonably progressed before this Output can be finalised.

OUTPUTS	HOW TO ATTAIN OUTPUTS
The methodologies referred to in this section are outlined in Output Component 9 and detailed in the Non-Point Assessment Guide referenced in the "Sources" section below:	
Scoping level: Aggregated (e.g. mean annual) loadings for constituents of concern at a relatively coarse scale, such as quaternary catchments, or coarser.	• Knowledge Based Approaches • Data Analysis Techniques • Potential and Hazard Maps • Unit Area Loading / Export Coefficients
Evaluation level (depending on the resolution required): Either time series or aggregated loadings for constituents of concern for individual land and water use categories at the scale of quaternary catchments.	• Unit Area Loading / Export Coefficients • Loading Functions and Potency Factors • Simple Process Models • Detailed Process Models
Prioritisation level: Identification of those sources that have the greatest existing or potential future impacts on the critical water quality concerns, the main processes causing the impacts from these priority sources, and how manageable the priority sources are.	The *Evaluation* task will indicate what resolution is required and which of the following techniques are needed. • Data Analysis Techniques • Unit Area Loading / Export Coefficients • Loading Functions and Potency Factors • Simple Process Models • Detailed Process Models

SOURCES

Current and historical land use and water use information.	Output Components 1,3, 5 6 and 7.
Non-point source assessment methodologies.	*A Guide to Nonpoint Source Assessment to Support Water Quality Management of Surface Water Resources in South Africa* by G Pegram and A Görgens (2000). Obtainable from the Water Research Commission, Pretoria (www.wrc.org.za)
Non-point source assessment case studies in South Africa.	*Case Studies of Non-Point Source Assessments in South Africa* by G Quibell, *et al* (2000). Obtainable from the Water Research Commission, Pretoria (www.wrc.org.za).

CHECKLISTS

◊ The non-point *source area* concept is reflected by separating a catchment or sub-catchment into areas with relatively homogeneous non-point source characteristics, based on:

- *land use*: natural, different types of agricultural, different types of human settlement, Central Business Districts, different types of industrial, etc;
- *natural features*: soils, topography, geology, natural vegetation, etc; and
- *climate*: rainfall, temperature, evaporation, seasonality, etc.

◊ Use Checklists under Output Component 1 as a guide.

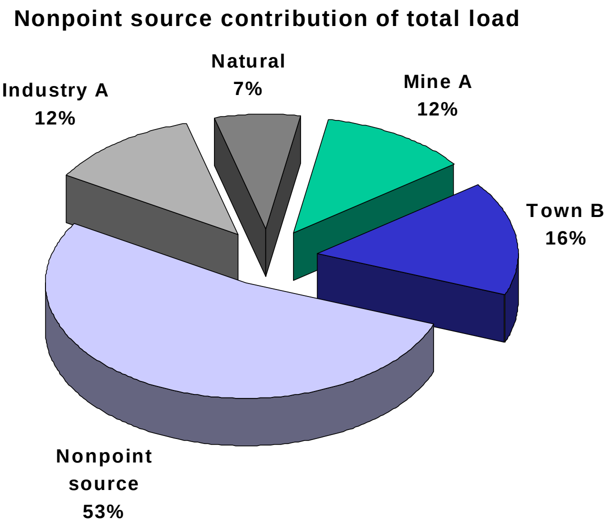
DISPLAY AND PRESENTATION OPTIONS

Catchment map showing location of known non-point sources

A map of the study area can be used to indicate locations of known point and non-point sources.

Non-point source contribution to known loads

Constituent loads can be calculated at a known location in the study area (e.g. water quality monitoring point). If the known point source loads and natural background loads can be accounted for, the remainder can be assumed to originate from non-point sources. This information can then be displayed in a pie diagram as displayed below on its own or on a map.



OUTPUT COMPONENT 9
Configured and Calibrated Water Quality Predictive Tools/ Models

PURPOSE

Context

NB: Output Component 9 and Output Component 8 should be considered and developed simultaneously, as there is strong overlap between them and their underlying processes.

The heart of the water quality component of the CMS is the "water quality use allocation plan", i.e. the allocation of the available discharge load, defined by management objectives, to different water user groups/ sectors, and the sectoral (or source-specific) WQM Implementation Plans to achieve these loads (see the sister-document: *Guideline to the WQM component of a CMS, Sub-series MS No. 8.2).* These implementation plans may relate to point source discharges, non-point source discharges and in-stream management, including suitable reservoir release operation, in-stream rehabilitation and environmental needs. Application of predictive tools/ models play a central role in this process, as described below:

◊ Sound management decisions may rely on the ability to predict the outcomes of streamflow and water quality along different river reaches and for different scenarios of land use and water use in the catchment. Various predictive approaches are available for water quality-focused management questions, ranging from process-based catchment models through rule-based methods to simple regression-based formulas.

◊ Similarly, models are also available for the prediction of the outcomes of different ways of operating an existing or planned river-reservoir system over an extended time period.

◊ Once the contributions of point sources to the water quality of streamflow and groundwater are quantified, the remaining causes of pollution evident from the applicable monitoring data, must be of a diffuse nature, i.e. they are non-point sources. The contextual discussion in Output Component 8, which outlines a range of approaches to non-point source assessment, is also relevant here. For their quantification, contributions by non-point sources have to be estimated, as, by their very nature, "waste discharges" from non-point sources cannot be measured directly. In effect therefore, a significant component of modelling support required during water quality-focused catchment assessments, relates to non-point source impacts.

◊ The high variability of rainfall and streamflow from year to year in South Africa dictates that, for sound management decisions, surface water availability and water quality patterns should be assessed via long-term characteristics, so that the inherent variability is adequately recognised. Unfortunately, the reality of water quality databases is that they are limited in duration and spatial representativeness and often comprise only intermittent samples. Mathematical predictive tools or "models" provide a way around this dilemma. Catchment modelling, driven by long sequences of rainfall, provides a useful approach to extend or infill streamflow and surface water quality time series synthetically, with the intention of capturing temporal and spatial variability better than the data do. Alternatively, simple empirical predictive tools/ models, driven by the statistics of long sequences of streamflow or based on heuristic interpretations of land-uses, may be used for estimation of long-term statistics of particular constituents of concern.

It needs to be noted that continuous simulation models are usually much more input resource intensive than simpler and qualitative assessment approaches. Consequently, in unstressed catchments, or for an "early-warning and -action" distinction between point and non-point loadings, simpler and qualitative approaches may be more appropriate.

Output 9: *WQ Predictive Tools*

Purpose

Configured and calibrated water quality predictive tools/ models can serve to:

+ indicate which of point or non-point source pollution is dominant, or which sub-catchments in a basin are dominant water quality load contributors, etc; in turn, this would help to prioritise certain types of management actions
+ estimate water quality constituent loadings from a range of land uses and water uses that result in non-point source pollution, and indicate which non-point sources are dominant
+ indicate the likely effects of pollution load increases or decreases on downstream water quality, or receiving waters
+ simulate water quality constituents at key points in river-reservoir systems in response to particular system operating rules
+ simulate water quality constituents at points of concern for different future scenarios of land use and water use
+ support prioritisation and appropriate selection of competing management options
+ extend, infill or simulate time series of water quality constituents at points of concern.

The CMS development process may be supported by predictive tools/ models during the following phases (see the sister-document: *Guideline for the WQM component of a CMS*):

+ development of Resource Water Quality Objectives, i.e. water quality goals that reflect the stakeholders' needs over and above those outlined in the NWRS and by the RDM, but include stakeholders' needs with respect to the discharge of waste to the resource
+ development of Source Management Objectives, i.e. pollution load reductions (stressed catchments), maintenance (threatened catchments), or increases (unstressed catchments)
+ development of the WQM Framework-Plan and the water quality use allocation plan
+ development of the individual sectoral or source-based WQM Implementation Plans that comprise the heart of the WQM component of the CMS
+ development of suitable interventions where a specific source (rather than a whole catchment) is the focus or cause of a specific water quality concern.

NB:

(i) The outputs which are specified in this section are predictive methods or tools, which have been made applicable to the particular catchment and constituents of concern. *Appropriate application of these tools depends on a reasonable degree of technical and scientific understanding of their nature, application procedures, dependence on other supporting tools, limitations and data preparation requirements.* It follows that a Guide such as this cannot even begin to describe this information - such understanding is best pursued by consulting the original source material on these tools, case study reports on their applications and specialised sources which compare them with other similar tools. Some of these sources are provided in the "Sources" section below.

(ii) Only those modelling tools or methods that have been operationally applied in South Africa and for which some degree of expertise may be locally available, are specified in this section.

(iii) Calibration is the process whereby the model coefficients or parameters (which control the processes in the model) are adjusted iteratively until model outputs correspond to the observed flows or loads according to selected goodness-of-fit criteria. Such observed loads are themselves often estimates based on grab-sample concentration records that have been infilled. Verification is the process whereby the calibrated model's reliability is determined via simulation of a period of observed values not used in the calibration process.

Prerequisite Output Components

Output Components 1, 2, 3, 5, 6 and 7 should be completed, or at least, well advanced, before substantial progress becomes possible with this Output Component.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Parameterised non-point source *Scoping* tools: • Knowledge Based Approaches • Data Analysis Techniques • Potential and Hazard Maps • Unit Area Loading / Export Coefficients	Follow the Non-Point Source Assessment Guide (Pegram and Görgens, 2000) (see "Sources" section below).
Calibrated and verified non-point source *Evaluation* and *Prioritisation* tools that produce aggregate loads (e.g. mean annual): • Unit Area Loading / Export Coefficients • Loading Functions and Potency Factors	Follow the Non-Point Source Assessment Guide (Pegram and Görgens, 2000) (see "Sources" section below).
(i) Simple Process Models:	Calibrate and verify these catchment water quality simulation tools so that load and concentration time series can be produced at all points of management interest.

- Monthly: Hydrosalinity Model (WQT). This is a *coarse-scaled* model for *salinity* production and transport in *large multi-use catchments*, specially designed to be driven by the same natural flows that drive the Water Resources Yield Model (WRYM) and Water Resources Planning Model (WRPM) system analysis models outlined in (iii) below. WQT is used to determine salinity parameters, which are then input to the WRPM model for multiple stochastic optimisation runs in large river systems.
- Monthly: IMPAQ (**I**mpoundment/river **m**anagement and **p**lanning **a**ssessment tool for water **q**uality simulations). This is a *medium-to-fine-scaled* model for *salinity*, *sediment and phosphate* production and transport in *large multi-use catchments*, specially designed to be driven by the same natural flows that drive the WRYM and WRPM system analysis models outlined in (iii) below. It has a washoff routine which uses SCS Curve Numbers to allow any mix of land-uses to affect sediment and phosphate production, which are derived from a combination of loading functions, potency factors and the USLE approach. Non-conservative processes are allowed to play a role in a channel transport module and a simple mixed reactor reservoir module. IMPAQ is used in conjunction with WRYM to generate very long sequences of monthly loads/concentrations of selected constituents in large river systems.
- Daily: ACRU. This is a *fine-scaled* model for *sediment and phosphate* production from *individual small catchments* with a limited range of agricultural land-uses. It is driven by daily rainfall and uses soil-moisture budgeting according to a discretisation based on soil texture classes and agricultural practices. It is recommended to investigate localised impacts of land-use and their related management options.
- Daily: NACL. This is a *medium-scaled* model for *salinity* production and transport in *large multi-use catchments*. It is built around the relatively black-box daily Pitman rainfall-runoff model, it allows urban washoff as well as operation of reservoirs, wetlands, and coarse irrigation activities. It is recommended as background support for WQT applications where certain parts of a multi-use catchment require more detailed treatment, or to assess salinity management options.

- Daily: DISA. This is a *fine-scaled* model for *salinity production and transport* through formalised irrigation schemes and allows operation of supply reservoirs, river channel transport, diversion devices, primary and secondary canals, balancing dams, artificial drainage, groundwater variability and a wide range of irrigation practices. It is driven by daily rainfall and uses soil-moisture budgeting according to a discretisation based on soil texture classes, location on the landscape, and agricultural practices. It is recommended as support for any of the other models to assess irrigation impacts of large or multi-offtake irrigation schemes, or to examine management options for salinity control.
- Sub-hourly to daily: HSPF (Hydrological Simulation Program Fortran). This is a *medium-to-coarse-scaled* model for *production and transport of salinity, temperature, sediment and a range of non-conservative constituents* in medium-to-large multi-use catchments. Its water quality chemical simulation components are comprehensive and it uses relatively black-box rainfall-runoff functions, different forms of hydrological channel routing and treats reservoirs as simple mixed reactors. It may be used to assess water quality outcomes of management and operational options in medium-to-large catchments.

(ii) Detailed Process Models: Detailed process models incorporate sophisticated processes, such as adsorption-desorption, decay and plant uptake, into the simulation of contaminant movement and transformation in soil and water. These contaminant processes are integrated with relatively complex hydrological and sediment models. NB: These models require specialised support and are not recommended for general use in catchment assessments. Their main function would be to optimise management options for site-specific water quality issues.	These models tend to be very data intensive and limited to areas for which there has been intensive data collection. The uncertainty of *a-priori* parameter estimates can lead to highly inaccurate output estimates in unmonitored catchments where calibration and verification are not possible. However, the model parameters often have physical interpretations and can be linked to observed catchment characteristics. The requirements of these models are not usually warranted in urban situations, so detailed process models are generally oriented towards rural, waste-related and agricultural land uses.
(iii) System Analysis Models: The following two models are used to optimise the allocation of water on a monthly basis throughout a large multi-use river system, according to a penalty structure, for a given time horizon of water demands and allowing stochastic variation: ➢ WRYM is used to calculate the long-term yield from a specific flow series, to examine operating rules or to develop yield-reliability curves. ➢ WRPM allows various sub-systems to support each other during deficit periods and is used as a planning tool to explore augmentation or restriction strategies.	Flow and demand sequences are supplied to the model for specific catchment development scenarios. This allows calculation of assurance or risk of failure of the water resource yield of the system as a whole or of any of its reservoirs. Model outputs can be used to indicate the required timing of augmentation measures and schemes to maintain given assurance levels. The impact of management options on reliability of supply can also be examined. Salinity management through freshening releases can be allowed to play a role in WRPM. The following two models discussed in (i) above support the above two system models to allow water quality simulations: WQT and IMPAQ.

(iv) Daily Reservoir Hydrodynamics Models: The following models have seen operational use in South Africa: ➢ CE-QUAL-W2 – a 2-D finite difference model that incorporates all primary hydrodynamic processes as well as a range of conservative and non-conservative water quality processes. ➢ DYRESM – a 1-D finite difference model using LaGrangian principles to simulate all energy and kinetic exchanges as well as salinity processes.	The models are configured according to the reservoir's specific depth-area-volume, spillway, and off-take characteristics. Daily inflow and relevant water quality values need to be provided, as is a range of meteorological variables. The hydrodynamics of these models require no calibration and are completely deterministic. The water quality process parameters of CE-QUAL-W2 do require calibration. If the primary interest of the simulation is stratification, then DYRESM is the more complete model in an energy balance sense. It should be noted that CE-QUAL-W2 does not perform its own mass balance, and needs outflows and spills as input.
(v) Sub-daily River Hydrodynamics Models: Three 1-D models have seen operational use in South Africa: MIKE11, ISIS and DUFLOW. All three models are based on a finite difference application of the full St Venant's flow equations to a series of cross-sections of the river channel and flood-plain. A range of conservative and non-conservative water quality routines are incorporated in all three models.	The basic requirements for applying these models are regular cross-sections of the river channel and its flood-plains, boundary conditions in the form of upstream and tributary inflow series (including water quality), and certain meteorological time series. Friction loss factors and water quality parameters are derived by calibration. This means that reasonable flow and water quality records of in-channel conditions are required. These models are useful to assess short-term downstream water quality impacts of upstream operations, or to examine management options related to localised water quality issues.

SOURCES	
***Scoping and Evaluation Tools*:**	*A Guide to Nonpoint Source Assessment to Support Water Quality Management of Surface Water Resources in South Africa*. WRC Report by G Pegram and A Görgens, 2000. Obtainable from Mr HM du Plessis, Water Research Commission, Pretoria.
Simple Process Models:	
WQT	Allen, RB and CE Herold (1988) *Vaal River system analysis: Water quality modelling*. DWA Report No. P C000/00/7086, Pretoria
IMPAQ	Bath A, Reid C and Görgens A (1997) *Amatola Water Resource System Analysis: Water Quality Modelling.* DWAF Report No. PR 000/00/1798
NACL	Herold, CE (1981) *A model to simulate daily river flows and associated diffuse source conservative pollutants*. Hydrological Research Unit. Report 3/81. University of Witwatersrand. Johannesburg.
ACRU (Water Quality Version)	Lorenz, S (2000). Personal Communication. Also, Schulze, RE (1995) *Hydrology and Agrohydrology: A text to accompany ACRU 3.00 agrohydrological modelling system*, Department of Agricultural Engineering, University of Natal, Pietermaritzburg.

Output 9: *WQ Predictive Tools*

DISA	Görgens, AHM, V Jonker and H Beuster (2000) *The DISA Hydrosalinity Model*. Report to the Water Research Commission by Ninham Shand, Cape Town. Copies can be obtained from Mr HM du Plessis, WRC, Pretoria.
HSPF	Bricknell, BR, JC Imhoff, JL Kittle, AS Donigan and RC Johanson (1993) *Hydrological Simulation Program-Fortran: Users Manual*, Release 10, EPA Report 600/R-93/174, Athens.
System Analysis Models:	
WRYM and WRPM	DWAF (1994) *Vaal River System Analysis: Analysis procedures manual Addendum A.* DWAF Report No PC000/00/6986 by BKS Inc, Pretoria.
Reservoir Hydrodynamics Models:	
DYRESM and CE-QUAL-W2	Görgens A, A Bath, A Venter, K De Smidt, and G Marais (1994) *The applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa.* WRC Report No. 304/1/93. Bath A, K De Smidt, A Görgens and EJ Larsen (1997) *The applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa: Application of DYRESM and CE-QUAL-W2* . WRC Report No. 304/2/97
River Hydrodynamics Models:	
MIKE11	DHI (1992) *Mike11 Version 3.01. A micro-computer based modelling system for rivers and channels, Reference Manual*, Danish Hydraulic Institute Software.
ISIS	HR Wallingford (1997) *ISIS Flow, User Manual.* Halcrow/HR Wallingford, UK.
DUFLOW	STOWA/EDS (1998). *DUFLOW for Windows, Version 3.0.* EDS, Leidschendam, The Netherlands.

OUTPUT COMPONENT 10
Reconciliation: Catchment Sources and Water Quality Patterns

PURPOSE

Context

The patterns of water quality changes through space (say, along a river) are related to (a) the spatial variability of the natural background soil and geological materials and rainfall, and (b) the spatial location of point and non-point anthropogenic sources. Similarly, sustained temporal trends in water quality, over and above the usual "noise" caused by hydrometeorological variability, indicate that such anthropogenic sources have "kicked in" and/or are growing in impact. Output Component 6 (water quality data review) provides the basic information on patterns and trends.

Purpose

The purpose of this Output is diagnostic: it provides a knowledge-based interpretation and reconciliation of all spheres of information - land-use, water samples, model findings - relating to known sources that contribute to water quality loads. This interpretation represents a final "sweep" through the catchment to spot hitherto unsuspected sources. A simple example is as follows: if Component 6 shows that Electrical Conductivity of low flows jumps between Point X and Point Y (10 km apart) along a river, and no major tributary enters that reach, then a clandestine discharge of water containing waste or previously unsuspected irrigation return flow might need to be investigated, which would require management attention. A more complex example is: checking the presence of observed constituents against expected background water quality, or the expected impacts of known land-uses, and finding them discrepant.

Prerequisite Output Components

This Component can only be substantially completed if Output Components 1 and 6 have already been completed and Components 7 and 8 are quite advanced.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Diagnostic table of discrepancies in spatial patterns in terms of particular constituent concentrations.	Discrepant *point* discharges can be detected from (a) same-day sampling of low flows at sequential locations, (b) consistent differences between low flow concentrations at sequential locations from routine grab sampling over longer periods, (c) extraordinary model parameter values/settings required in order to achieve reasonable simulations, (d) systematic deviations of calibrated model outputs from observed values. Discrepant *non-point* contributions are more difficult to ascertain, as they are driven by rainfall-runoff events, which are highly variable and seasonal by nature. A powerful clue can be found in consistent under-estimation of spatially sequential concentrations or loads during simulation modelling of rainfall-runoff events in that catchment.
Diagnostic table of discrepancies in temporal trends in terms of particular constituent concentrations.	Abrupt steps or sustained trends in observed constituent values not explained by known trends in land- or water uses, provide a first clue. Trends in *moving averages* over a number of months or years smooth out the variability caused by climate and seasonality and buoy the underlying tendency. A powerful clue is offered when simulation modelling reveals a *systematically changing deviation* between observed and simulated concentrations or loads on a moving average basis. Trends in the *lowest few concentrations* per *wet* season would indicate non-point source change trends, while trends in the *highest few concentrations* per *dry* season would indicate point source change trends.

Output 10: *Sources & Patterns*

Diagnostic table of water quality constituents with unexpectedly high concentrations.	Interpret, on the basis of experience, values in grab-sample records in terms of the effluent constituents that might usually be associated with the known land- or water uses.

SOURCES

Information for these outputs is sourced from the prerequisite Output Components mentioned above.

CHECKLISTS

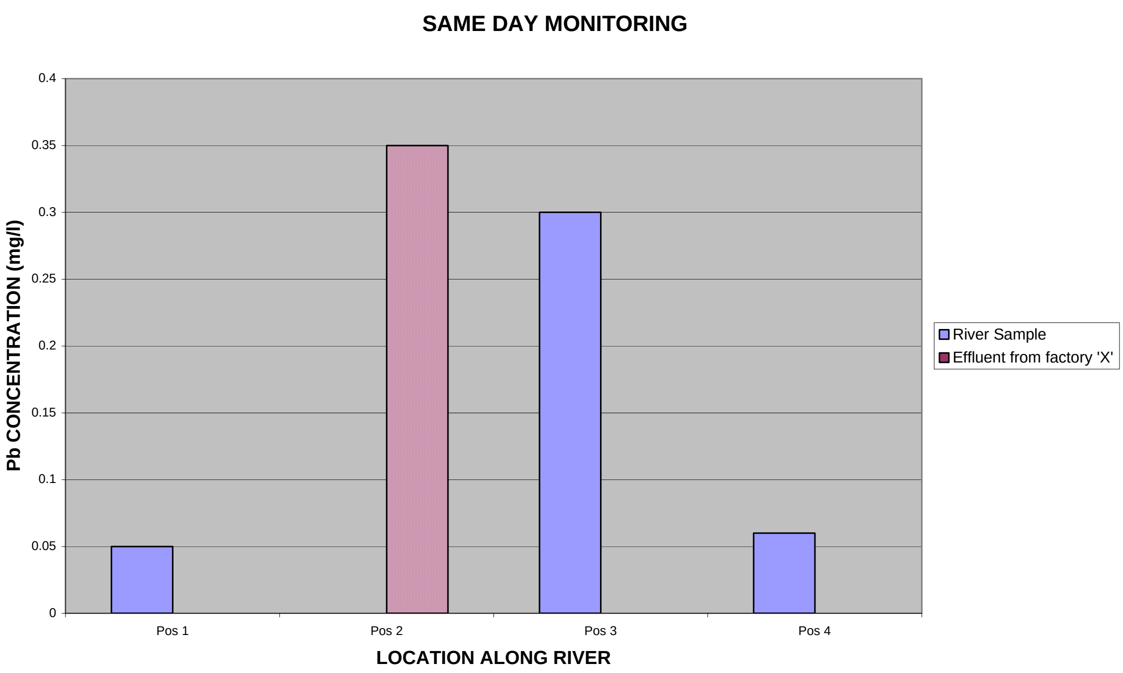
Diagnose against temporal trends or steps in constituent concentrations (sometimes, loads) as follows:

- ❑ dry season flow – flow-weighted mean per season, as well as moving average
- ❑ monthly flow-weighted means and their moving averages
- ❑ trends in lowest few wet-season values/season
- ❑ trends in highest few dry-season values/season
- ❑ trends against modelled values.

Diagnose against spatial steps or spatial trends in constituent concentrations (sometimes, loads) as follows:

- ❑ same-day sample concentrations
- ❑ consistent deviations between sequential spatial values over time with simulated values
- ❑ trends in lowest few wet-season values/season
- ❑ trends in highest few dry-season values/season
- ❑ trends against modelled values.

DISPLAY AND PRESENTATION OPTIONS



OUTPUT COMPONENT 11

Status Report on Monitoring, Physical Data and Characterization Information

PURPOSE

Context

A Catchment Management Agency may have to rely on a number of water quality data sources to assess the water quality status in the study area.

Purpose

The purpose of this component is to provide guidance on methods to assess the suitability of the data for the water quality assessment. A checklist is provided listing some of the common problems and shortcomings of water quality monitoring programmes and an evaluation sheet is also provided for summarizing the results for each monitoring programme.

Prerequisite Output Components

This Component is informed in various ways by Component 6 (Water quality of streamflow, reservoirs, estuaries, wetlands and groundwater), Component 7 (Point source waste discharges) and Component 9 (Non-point source water quality contributions and impacts).

OUTPUTS	HOW TO ATTAIN OUTPUTS
GIS map showing the location of monitoring points in the study area	• Compile a GIS map of the study area and plot the location of all the water quality monitoring points. • Use different symbols to differentiate between sampling points belonging to different monitoring programmes (or organizations). • Indicate which sampling points were used in the study to characterize the water quality status (Output 6).
Monitoring system assessment report for each of the data sources used in the assessment.	• Use the checklist and evaluation sheet described below to compile the monitoring system assessment report.
Conclusions and recommendations	• Conclude this component with an overall evaluation of the suitability of the monitoring programmes to meet the objectives of the CAS. • Identify shortcomings to existing monitoring programmes and make recommendations on how these can be redressed.

SOURCES

Techniques to evaluate the suitability of monitoring data for a water quality assessment, are described in the following publications:

Design of Networks for Monitoring Water Quality	Ward, R.C., Loftis, J.C. and G.B. McBride (1990) Van Nostrand Reinhold, New York, NY, USA 231pp.

Output 11: *Status Report*

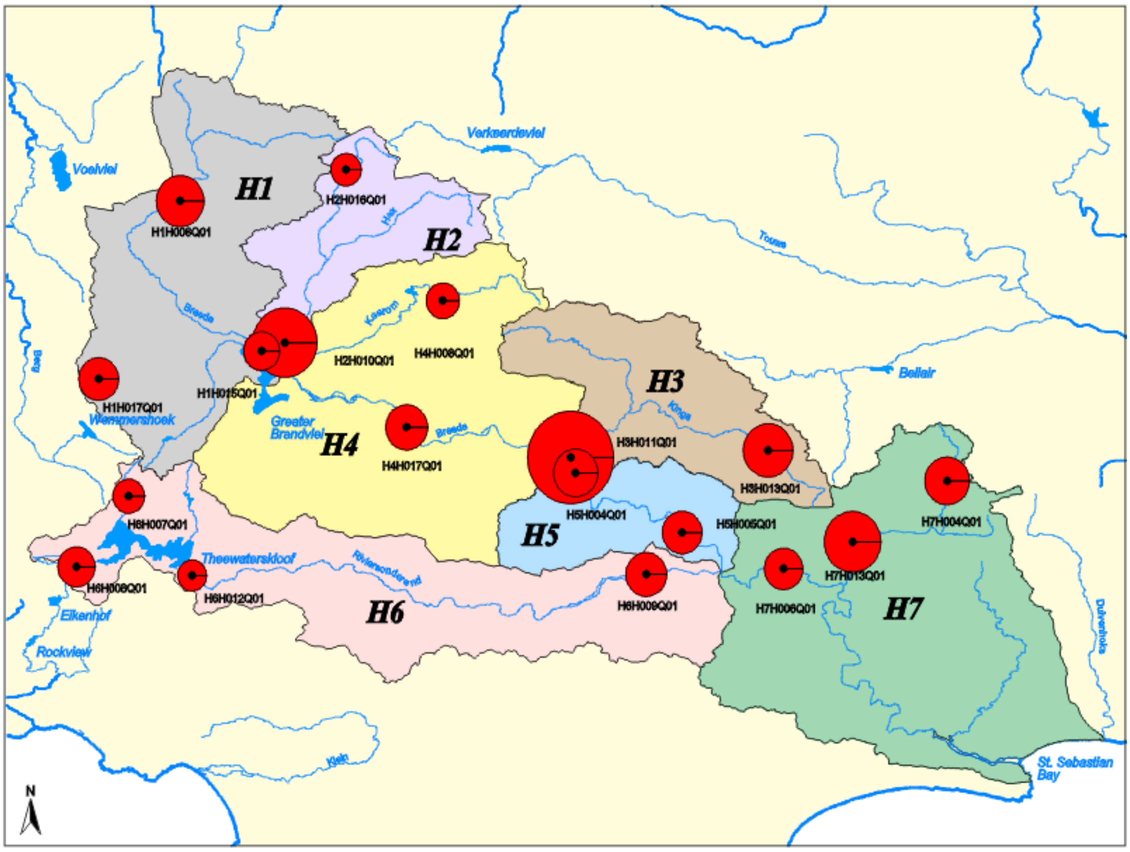
Conceptual Design Report for a National River Water Quality Assessment Programme.	Harris, J.M., van Veelen, M. and Gilfillan, T.C. (1992). Water Research Commission. Report No. 204/1/92. Available from : The Librarian Water Research Commission, PO Box 824, Pretoria 0001 Tel: 012 330 0340 Fax: 012 331 2565 Web site: www.wrc.org.za
CHECKLISTS	
Common limitations to monitoring data can be divided into two groups, namely limitations to the design of the monitoring system and limitations to the data records. The following can be used as a checklist for examining different limitations:	
Checklist for limitations in the design of the monitoring system	
Monitoring system design documentation There are several categories of monitoring systems. These include assessment monitoring, regional monitoring, compliance monitoring and water quality surveys. A good monitoring programme is well documented and it describes the purpose and information expectations of the programme, the statistical design criteria, the monitoring network, operating plans and procedures and information reporting procedures	Contact the data supplier to find out if documentation that describes the key components of the monitoring system exists.
Spatial distribution of sampling points The ideal situation is where monitoring points are distributed over the catchment to provide a balanced view of water quality changes. In many cases, monitoring points have been positioned to provide information on man-made impacts with little consideration being given to background or un-impacted state of a river or stream.	Plot the monitoring points on a GIS map and examine the distribution of monitoring points in relation to major features which impact on water quality such as confluences of tributaries, point sources, non-point sources, irrigation areas etc.

Sampling frequency The objective of a monitoring programme generally determines the frequency at which samples are collected.	If the sampling frequency is not specified in the monitoring system design documentation do the following. Use cross tabulation (QuatroPro) or pivot tables (Excel) to count the number of samples collected per year and month. Examination of the number of samples collected per month would indicate the predominant sampling frequency (Monthly, 2 weekly, weekly, daily, ad hoc).
Sampling depth Water samples are generally collected as grab samples from just below the water surface. However, in deep water bodies samples can be collected at specific depths or a depth-integrated sample can be collected using a hosepipe.	Examine the data record for an indication of sampling depth, or Contact the data supplier for information on the sampling depth.
Sample preservation Some water quality samples should be preserved. For example, samples for nutrient analysis should be preserved with a preservative like mercury chloride (HgCl) and samples for metal analysis should be preserved with nitric acid (HNO_3).	Examine the data records for an indication whether individual samples were preserved or not, or Contact the data suppliers for information on sample preservation.
Quality assurance /quality control procedures Some monitoring programmes have QA/QC procedures in place to ensure credible results from the sampling and analysing laboratory. Common QA/QC techniques are the inclusion of blanks, spiked samples, reference samples and replicate samples.	Contact the data suppliers to assess what quality control/quality assurance procedures are in place to ensure credible water quality data collection and analysis.
Analysing laboratory Individual analysis methods used at analysing laboratories are accredited by the South African National Accreditation Society (SANAS). The accreditation certifies that the laboratory has competent staff, equipment and quality control procedures to undertake specific analyses. The results from unaccredited methods should have a lower confidence.	Contact the data supplier to find out which methods are accredited at the analysing laboratory.
Data storage Analysis data can be recorded and stored in laboratory reports or it can be stored in electronic format in spreadsheets or databases.	Contact the data supplier to assess the data storage protocols.

Data conversions	
Some data is often derived from other observations. For example, in some laboratories, the total dissolved salts concentration (TDS) is derived from the measurement of individual cations and anions and in others it is merely calculated from the electrical conductivity values.	Contact the data supplier to assess whether there are data that are calculated from other observations.
Data availability and security	
Monitoring data collected by non-government organizations (industries, irrigation boards etc.) are in many cases regarded as confidential information. In the case of compliance monitoring, the data might be available on the POLMON database from DWAF.	Contact the data supplier to find out about the confidentiality and availability of the data.
Flow measurements	
If constituent loads have to be calculated, it is essential that flow data be collected at the same site or close to the water quality sampling point.	Contact the data supplier to find out whether flow data was collected at the same site or nearby.
Checklist for limitations to data records	
Outliers	
Outlying values can occur due to recording errors or when conditions in the water body changes in a dramatic way.	Outlying values should be removed from the data set. Diagnosing a value as an outlying value can be complex. The publication of Harris *et al* (1992) provides a comprehensive method for identifying outlying values.
Non-detects	
Non-detects refers to cases where values are less than or exceed the detection limit of the analytical technique used in the laboratory. These are then recorded as < (less than) detection limit or > (greater than) detection limit.	Enter smaller than non-detects as one half the detection limit. When available, the actual reading should be given.
Laboratory duplicates	
A laboratory may analyse a sample more than one time and record the results in a database.	All laboratory duplicates should be averaged to give one reading.
Missing data	
Some data suppliers use codes such as –99 to indicate missing data.	Replace missing values with blanks. Replacing it with zeros or unlikely values will confuse the statistical analysis.

DISPLAY AND PRESENTATION OPTIONS

Mapping the location of sampling points



Monitoring Programme Evaluation Sheet

The monitoring evaluation sheet presented in **Appendix A** provides the following information on each monitoring programme in the study area:

- The name of the monitoring programme
- Contact details of the owner of the monitoring programme
- Contact details of the analysing laboratory
- Information about the purpose of the programme and quality assurance procedures
- Location of sampling points and length of data records at each sampling point
- A qualitative assessment of the suitability of the data for assessing the water quality status

Route Map of the Guide

Management question 1

What is the study area's status in water- related terms and how did it get to this point?

↓

You are here

Management question 2

What are the water -related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages and roles?

Output 12: Stakeholder details and participation processes

Output 13: Water- interest institutional arrangements and linkages

↓

Management question 3

What are the study area's water quality issues, problems, concerns and opportunities?

↓

Management question 4

Where might the water quality status of the study area be heading in the future?

↓

Management question 5

What are the appropriate (priority) water quality management options?

↓

Management question 6

Has water quality management achieved its objectives?

Management Question 2:

WHO ARE THE WATER-RELATED STAKEHOLDERS AND INSTITUTIONS IN THE STUDY AREA AND WHAT ARE THEIR RESPECTIVE JURISDICTIONS, RELATIONSHIPS, LINKAGES, AND ROLES?

Task 2: Engagement of water-related institutions and stakeholders in CAS process

OUTPUT COMPONENT 12
Stakeholder Details and Participation Processes

PURPOSE

Context

The National Water Act requires that a CMS must "…enable the public to participate in managing the water resources within its water management area" [*s9(g)*] and "…take into account the needs and expectations of existing and potential water users" [*s9(h)*]. The Preamble of the Act recognises "…the need for ….the delegation of management functions to a regional or catchment level so as to enable everyone to participate". It follows that, in the assessment of the characteristics of the catchment, it would be important to record who would in fact be the "public", the "water users" and the "everyone", whom the Act refers to. In the context of this Guide, all these people are described as "water quality stakeholders". These are *any people* or institutions interested in water quality, or affected by water quality and the way it might be managed. It follows that one of the best ways of understanding water quality issues in catchments is by engaging the people and the institutions who perceive them, or who are affected by them! The "Checklists" section below provides guidance on what stakeholder groupings need to be considered.

Purpose

This Output will ensure that the primary groupings of people and institutions who have an interest in water quality issues, for whatever reason, will be recognised and given an opportunity to make inputs into the assessment. This information may simultaneously serve the CMA establishment process, as well as the CMS development process. The output from this Component is not only *stakeholder information*, but should also be seen as a *process*; i.e. the first stage of a stakeholder engagement and participation process that should continue seamlessly throughout the CMS development process to the long-term CMS implementation process.

Prerequisite Output Components

This Output Component starts simultaneously with Component 0 (inherent knowledge), as well as Component 5, but requires crucial information from Output Components 1, 5, 6 and 7 before it can be regarded as reasonably advanced.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Stakeholder database organised by sector and/or sub-catchment and cross-referenced for individuals' technical or scientific specialities.	Combine existing stakeholder databases or networks from existing forums and relevant organisations, relevant government agencies, consultants and researchers in the catchment. This should be expected to be an iterative process. It should be borne in mind that this database will also serve the CMS development process.
First stage of catchment management–related stakeholder participation processes.	It is important to view stakeholder participation during the CAS study as the beginning of a more long-term and profound process of participation that will culminate during the CMS development and implementation phases. Nevertheless, *pragmatism is required about the required extent of the participation process in the catchment description phase of the CAS.* For the catchment description phase, the minimum required output from the process is the identification of water quality issues and concerns. The formulation of a vision and management objectives for the catchment belongs to the management support phase of the CAS.

SOURCES	
Technical guide for public participation to support Integrated Water Resources Management.	Greyling T and S Manyaka (1999) *Appropriate Public Participation for Catchment Management Agencies and Water User Associations: Towards Cooperative Governance.* Technical Report to Directorate: Catchment Management, DWAF, Pretoria.
A guide to developing a management "vision" in catchments.	Rogers K and Bestbier M (1998) Development *of a Protocol for the definition of the desired state for riverine systems in South Africa*. Dept. of Environmental Affairs and Tourism, Pretoria.
CHECKLISTS	
Water Management and Water Services Institutions	CMAs and their catchment management committees, WUAs, and Water Boards, Water Service Authorities, Water Service Providers
Existing Forums and Steering Committees	Forums or Steering Committees that are related to any of Water Quality, Irrigation, Environment, Catchment Management, Conservancies, Land Care, Green Belts, Wetlands, Wildlife, Coastline and Bays, Estuaries.
NGOs	Those that are focussed on aspects of Development or the Environment
Civil Society	Community-based organisations (CBOs), residential organisations, traditional leaders, scientific organisations, professional organisations.
Agriculture and Forestry	Sector organisations and *relevant* individual professionals, researchers and academics in these sectors.
Conservation, Environment and Health	Sector organisations and *relevant* individual professionals, researchers and academics in these sectors.
Mining and Industry	Sector organisations and *relevant* individual professionals, researchers and academics in these sectors.
Government: Central, Provincial and Local	Government officials at relevant levels in government structures related to water resources, water services, agriculture, forestry, environment, conservation, mining, industry, health, and recreation.
Researchers and technical specialists	Relevant individuals who offer local scientific and technical experience and who may have gathered local data and information.

DISPLAY AND PRESENTATION OPTIONS

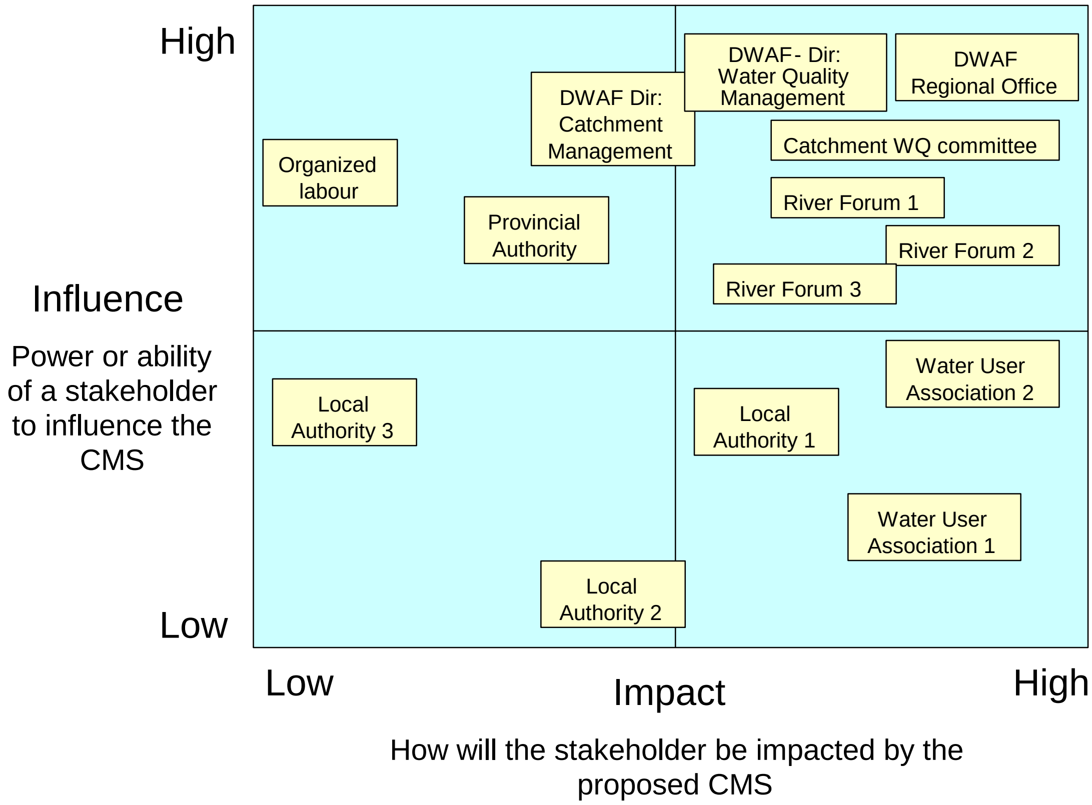
Stakeholder Table

A Stakeholder Table is a list of all the potential stakeholders in the study area, an identification of their interest in relation to the water quality CAS, an assessment of the likely water quality impact experienced by each stakeholder (positive, negative) and steps that can be taken to get stakeholder support and to reduce opposition. An example follows:

Stakeholder	Stakeholder interest in the CAS process	Assessment of impact	Potential strategies for obtaining support or reducing obstacles
Any'ol'Town Town Council			
Any'ol'River Forum			

Stakeholder Analysis Matrix

The stakeholder profile for a specific study area would be quite unique. A Stakeholder Analysis Matrix can be used to develop an understanding of the influence of stakeholders and the impact of the CMS on the stakeholder. Influence can be defined as the power or ability of a stakeholder to influence the CMS. Impact can be defined as how the stakeholder would be affected by the proposed CMS. Below is an example of how this can be illustrated.



OUTPUT COMPONENT 13
Water-Interest Institutional Arrangements and Linkages

PURPOSE

Context

Water quality in a catchment is closely dependent on the degree to which land-use and other physical developments have modified the condition of the land phase of the hydrological cycle. However, control over many land-uses and other physical developments lies outside the statutory domain of the NWA. Other laws, and organs of state other than DWAF or water management institutions, have jurisdiction over many of the activities that might somehow determine catchment water quality. Against this fragmented background, the development and, especially, the implementation of a CMS will therefore be highly dependent on a process of collaboration and joint undertakings between different organs of state, generally known as "cooperative governance". Furthermore, representative institutions from all water-interest stakeholder sectors in a catchment would also need to play a role and accept responsibilities in the processes surrounding the CMS. For these reasons it is imperative that the WQCAS should identify and describe all water-interest institutions in a catchment and clarify the linkages between them.

Purpose

The purpose of this Output is to provide the CMS process with an information base on water-related statutory institutions, their jurisdictions, functions, administrative structures and inter-institutional relationships. The CMS would especially be influenced by the nature of these relationships; i.e. whether or not each specific relationship is:

- ◊ statutory (powers and duties assigned or delegated under an Act)
- ◊ regulatory (one monitors and audits the other)
- ◊ cooperative governance based (collaboration amongst various organs of state with differing competencies and jurisdictions)
- ◊ contractual (performing catchment management functions (not statutory) on behalf of each other in return for a management or service fee)
- ◊ representative (between stakeholders -- particularly water user sectors -- and their representative water management structures, as well as politically accountable spheres of government).

Prerequisite Output Components

Output Components 0, 1 and 12 are prerequisites for this Component.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Outline description of all statutory water management and water services institutions in the catchment, their core functions and areas of jurisdiction or of operation.	Distinguish between CMAs, CMCs, Advisory Committees, WUAs, Water Boards, Water Services Committees, DWAF Regional Offices and local governments.
Schematic description of *internal* institutional relationships between the aforementioned statutory institutions with respect to water management interests.	Identify and briefly describe the relationships in terms of *regulatory*, *cooperative governance* and *contractual* mechanisms, management systems and procedures.
Schematic description of *external* statutory relationships, with respect to water management interests, between the water management sector and other organs of state in the different spheres of government.	Identify and briefly describe the relationships in terms of *regulatory*, as well as *cooperative governance* mechanisms, management systems and procedures.

Schematic description of *internal* and *external* "voluntary" relationships, with respect to water management interests, between stakeholders and the water management sector.	Identify and briefly describe the relationships in terms of *representative and contractual* mechanisms, management systems and procedures

SOURCES

◊ Pegram GC (1999) *The Catchment Management Agency Establishment Process,* Report to Directorate: Catchment Management, DWAF, Pretoria

◊ Görgens AHM (1999) *Catchment Management Agency Functions and Organisational Considerations,* Report to Directorate: Catchment Management, DWAF, Pretoria

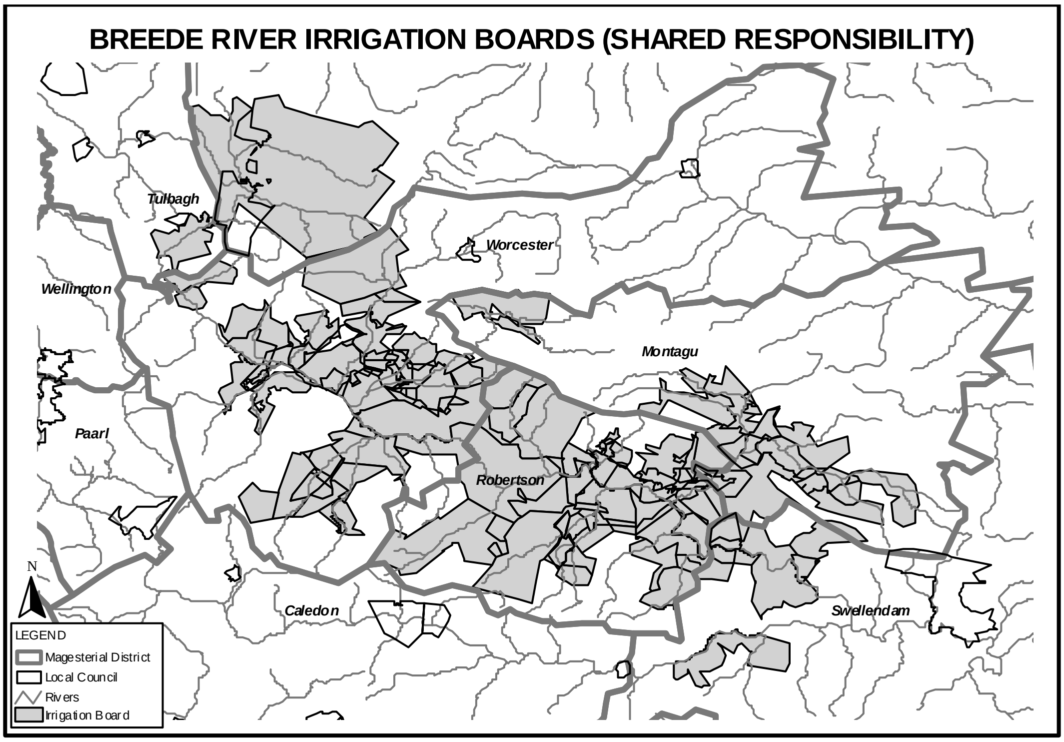
◊ Peart R and Masia M (1999) *Relationship Between Catchment Management Agencies and Other Institutions*. Report to Directorate: Catchment Management, DWAF, Pretoria

◊ Pegram GC and Palmer Development Group (2000*) Guidelines for Financing Catchment Management.* Report to the Water Research Commission, Pretoria.

CHECKLISTS

Refer to Checklists for Output Components 12 and 17.

DISPLAY AND PRESENTATION OPTIONS



An example of a map showing the boundaries of different statutory institutions that should be considered in water management in a catchment (Breede River in this example)

Output 13: *Institutional Arrangements*

Route Map of the Guide

Management question 1

What is the study area's status in water - related terms and how did it get to this point?

Management question 2

What are the water - related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages and roles?

You are here

Management question 3

What are the study area's water quality issues, problems, concerns and opportunities?

Output 14: Record of water quality issues and their origins
Output 15: Catchment management implications of water quality issues
Output 16: Vision (or long –term resource objectives) for water quality

Management question 4
Where might the water quality status of the study area be heading in the future?

Management question 5

What are the appropriate (priority) water quality management options?

Management question 6

Has water quality management achieved its objectives?

Management Question 3:

WHAT ARE THE STUDY AREA'S WATER QUALITY ISSUES, PROBLEMS, CONCERNS AND OPPORTUNITIES?

Task 3: Formulate and record water quality issues, concerns, problems, and opportunities

OUTPUT COMPONENT 14
Record of Water Quality Issues and their Origins

PURPOSE

Context

Water quality issues are water quality related problems that users experience. These problems are based on perceptions of water users and may therefore be real problems or perceived problems. Matching a perceived problem with water quality data to assess whether the requirements of user groups are violated can identify an actual water quality issue. The link between causes and consequences or symptoms can then be investigated in more detail.

Purpose

The purpose of this component is to identify the key water quality issues or potential water quality problems in the study area. The objective is to first identify the water quality concern. A water quality concern can be excessive algal blooms or corrosion of household appliances. The next step is to identify and understand the processes that affect or influence the concern and then to identify the most relevant water quality indicator (or constituent) that should be measured to assess the current status.

Water quality issues typically involve a range of water quality constituents. Identifying a water quality issue and managing the negative impacts would ensure that the overall problem is addressed rather than individual water quality constituents as "symptoms". This approach will also ensure integration in managing the physical/ chemical/ biological aspects of water quality.

The following is a range of common water quality issues that have been grouped per water use sector. The list can be used as a checklist to guide the identification of water quality issues in a catchment assessment study.

Prerequisite Output Component

To undertake this component, all the Outputs of Task 1: *Characterization of the current situation and historical trends* must be completed.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Inventory of actual and/or perceived water quality problems, issues and causes and consequences.	Synthesis of information outputs from previous components by matching perceived water quality problems with users' requirements and observed data to assess whether the problems are real or merely apparent.

SOURCES

The primary sources of information on generic water quality problems in South Africa and the water quality constituents associated with them, are the South African Water Quality Guidelines and the Assessment Guide for Domestic Water Supply.

South African Water Quality Guidelines Volume 1 : Domestic water use Volume 2 : Recreational water use Volume 3 : Industrial water use Volume 4 : Agricultural water use: Irrigation Volume 5 : Agricultural water use: Livestock watering Volume 6: Agricultural water use: Aquaculture Volume 7: Aquatic ecosystems Volume 8: Field guide	The South African Water Quality Guidelines can be obtained from: The Director: Water Quality Management Department of Water Affairs & Forestry Private Bag X313, Pretoria 0001 Tel: 012 336 7500 Fax: 012 324 6592 Email: taa@dwaf.pwv.gov.za Web site: www.dwaf.gov.za

Quality of domestic water supplies. Volume 1: Assessment Guide. Second edition. Water Research Commission Report TT 101/98	The Assessment Guide can be obtained from: The Librarian Water Research Commission PO Box 824, Pretoria 0001 Tel: 012 330 0340 Fax: 012 331 2565 or order directly using the WRC web site: Web site: www.wrc.org.za

CHECKLISTS

Domestic water supply

Water used for domestic purposes include water for drinking, food & beverage preparation, hot water systems, bathing and personal hygiene, washing, laundry and gardening. Domestic water users can experience a wide range of water quality problems. These can be categorized as impacts on the health of consumers, aesthetic impacts and economic impacts.

Concerns	***Water quality constituents***
Health impacts that includes short and long-term effects on the health of consumers. This includes the effect of toxic substances that can be harmful even at low concentrations.	Algae, Aluminium, Ammonia, Arsenic, Asbestos, Atrazine, Cadmium, Chromium (VI), Copper, Fluoride, Indicators organisms, Lead, Magnesium, Manganese, Mercury, Radioactivity, Selenium, Trihalomethanes, Vanadium, Zinc
Aesthetic impacts that include changes in water taste, odour or colour or staining of laundry or household fittings and fixtures.	Algae, Chloride, Colour, Copper, Dissolved organic carbon, Iron, Manganese, Nitrate, Odour, pH, Phenols, Suspended solids, Sodium, Turbidity
Economic impacts that include increased treatment costs, scaling, corrosion or deposition of sediments in distribution systems or household appliances.	Calcium, Chloride, Corrosion, pH, Potassium, Total dissolved salts, Hardness, Turbidity

Industrial water supply

The water quality problems experienced in industries that have water using processes can be categorized in the following groupings:

- Potential damage to equipment, for example corrosion and scaling,
- Potential problems in the manufacturing process, for example precipitates and colour changes,
- impairment of product quality, for example taste or discolouration, and
- complexity of waste handling as a result of using available water.

The water quality constituents generally associated with industrial water quality problems are listed below.

Concerns	***Water quality constituents***
Corrosion	pH, Conductivity, Total hardness, Iron, Alkalinity, Sulphate, Chloride, Suspended sediment, Chemical oxygen demand
Scaling	pH, Conductivity, Total hardness, Iron, Alkalinity, Sulphate, Silica, Suspended sediment

<table>
<tr><td>Fouling</td><td colspan="2">Iron, Manganese, Suspended sediment, Chemical oxygen demand</td></tr>
<tr><td>Blockages</td><td colspan="2">pH, Conductivity, Total hardness, Iron, Manganese, Alkalinity, Sulphate, Silica, Suspended sediment, Chemical oxygen demand</td></tr>
<tr><td>Abrasion</td><td colspan="2">Sulphate, Suspended sediment</td></tr>
<tr><td>Embrittlement</td><td colspan="2">pH, Conductivity, Chloride</td></tr>
<tr><td>Discolouration</td><td colspan="2">pH, Iron, Manganese, Chemical oxygen demand</td></tr>
<tr><td>Resin blinding</td><td colspan="2">pH, Conductivity, Total hardness, Iron, Manganese, Alkalinity, Sulphate, Silica, Suspended sediment</td></tr>
<tr><td>Foaming</td><td colspan="2">pH, Alkalinity, Chemical oxygen demand</td></tr>
<tr><td>Sediment</td><td colspan="2">pH, Total hardness, Iron, Manganese, Sulphate, Suspended sediment</td></tr>
<tr><td>Gas production</td><td colspan="2">pH, Alkalinity, Sulphate, Chemical oxygen demand</td></tr>
<tr><td>Taste and/or odours</td><td colspan="2">pH, Conductivity, Iron, Manganese, Chloride</td></tr>
<tr><td>Precipitates</td><td colspan="2">pH, Conductivity, Total hardness, Iron, Manganese, Alkalinity, Sulphate</td></tr>
<tr><td>Turbidity</td><td colspan="2">pH, Iron, Sulphate, Suspended sediment, Chemical oxygen demand</td></tr>
<tr><td>Colour</td><td colspan="2">pH, Iron, Manganese, Chemical oxygen demand</td></tr>
<tr><td>Biological growth or biofouling</td><td colspan="2">pH, Iron, Manganese, Alkalinity, Sulphate, Suspended sediment, Chemical oxygen demand</td></tr>
<tr><td colspan="3">Agricultural water supply: Irrigation</td></tr>
<tr><td>Irrigation water users experience a range of impacts as a result of changes in water quality. These include:</td><td colspan="2">The key water quality constituents which can be linked to these water quality problems include:</td></tr>
<tr><td>Concerns</td><td colspan="2">Water quality constituents</td></tr>
<tr><td>• Reduced crop yield as a result of increased salinity or the presence of constituents that are toxic to plants
• Impaired crop quality as a result of inferior products or a health risk to consumers
• Impaired soil suitability as a result of degradation of soil properties and the accumulation of undesirable constituents or toxic constituents, and
• damage to irrigation equipment as a result of corrosion or encrustation</td><td>Aluminium
Arsenic
Beryllium
Boron
Cadmium
Chloride
Chromium (VI)
Cobalt
Coliforms
Copper
Fluoride
Iron
Lead
Lithium</td><td>Manganese
Molybdenum
Nickel
Nitrogen
pH
Scaling/Corrosion
Selenium
Sodium adsorption ratio
Sodium
Suspended solids
Total dissolved salts
Uranium
Vanadium
Zinc</td></tr>
</table>

Agricultural water supply: Stock watering

Water quality problems associated with the production of livestock depend on a number of factors such as the type of livestock, the type of livestock products and type of production system in use. If water quality does not meet requirements, a wide range of problems can be encountered. These can be categorized as:

- Problems associated with the consumption of water by livestock,
- Problems associated with the water distribution system to livestock, and
- Problems associated with the quality of livestock products.

Concerns	***Water quality constituents***	
Problems associated with the consumption of water by livestock • Toxicological effects • Palatability effects Problems associated with the livestock watering systems • Clogging • Corrosion • Encrustation • Scaling • Sediment Problems associated with livestock product quality • Consumer health hazards • Product quality	Water quality constituents that are potentially hazardous with a high incidence of occurrence	
	• Total dissolved solids • Chloride • Sulphate • Arsenic • Copper • Sodium	• Calcium • Fluoride • Molybdenum • Manganese • Nitrate and nitrite • Toxic algae
	Water quality constituents that are potentially hazardous but with a low incidence of occurrence.	
	• Cadmium • Chromium • Mercury • Lead • Zinc • Selenium • Boron • Aluminium	• Cobalt • Iron • Nickel • Vanadium • Manganese • Pesticides • Pathogens

Agricultural water supply: Aquaculture

Aquaculture refers to aquatic agriculture and it can be divided into several sectors:

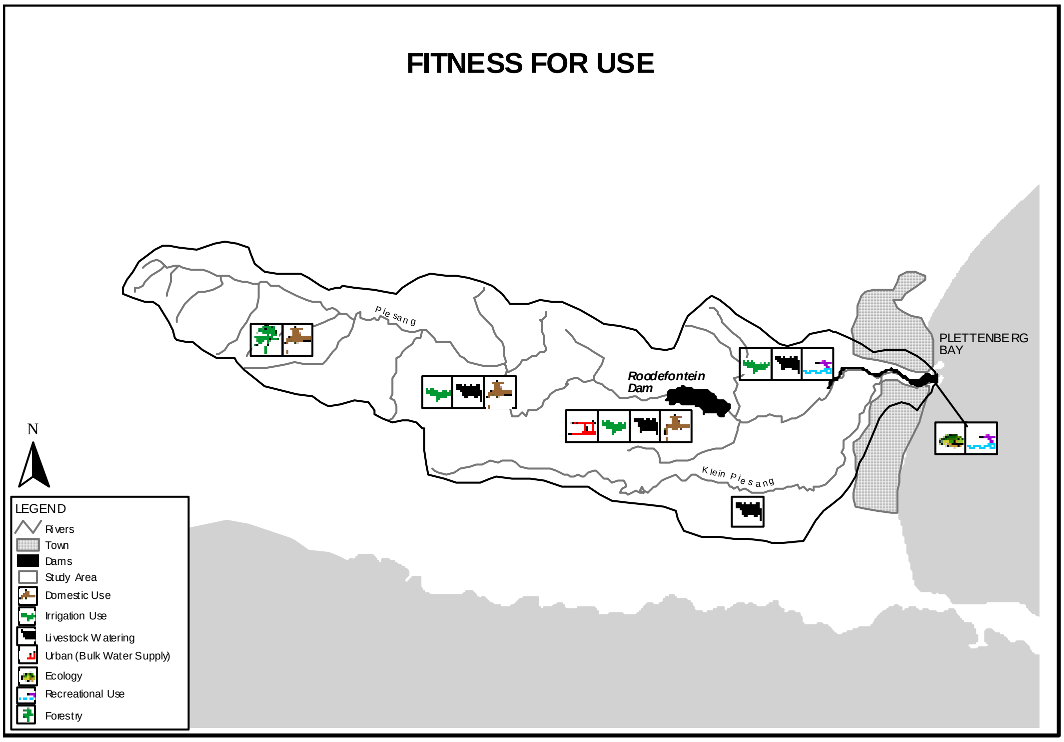
- breeding of fish in cages in dams and natural lakes (cage culture)
- extensive farming in small earthen farm dams
- extensive and semi-intensive fish farming in purpose designed fish ponds, and
- intensive farming in raceways and tanks.

Concerns	***Water quality constituents***
Concerns about low dissolved oxygen and eutrophication of the water	Algae, dissolved oxygen, carbon dioxide, nitrate & nitrite, ortho phosphate
Concerns about the presence of toxic compounds in the water	Algae, ammonia (NH_4), herbicides, arsenic (As), Cyanide (HCN), PCB's and pesticides
Concerns about water quality that affect the osmo-regulation of fish	Chloride, alkalinity, chlorine, pH, salinity and total hardness
Concerns about waterborne diseases to fish and other biota	Bacteria, parasites, viruses

Concerns about elevated metals and its effects on fish and other biota	Aluminium (Al), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), mercury (Hg), selenium (Se), and zinc (Zn)
Concerns about changes in temperature of the water	Temperature
Aquatic environment	
The Department of Water Affairs & Forestry considers aquatic ecosystems to be the base from which the water resource is derived. Man depends on many of the services provided by a healthy ecosystem. These include the ability to assimilate certain waste products, providing a pleasing environment for recreation, provide a livelihood for communities that depend on water bodies for food and maintaining biodiversity and habitats for the biota that depend on the ecosystem. Aquatic ecosystems must be protected to ensure the resource remain fit for all the other uses (Domestic, agriculture etc.) on a sustainable basis.	
Concerns	***Water quality constituents***
Toxic substances	Inorganic constituents such as aluminium, arsenic, cadmium, mercury and ammonia Organic constituents such as phenol and atrazine
System variables	Salinity, temperature, dissolved oxygen
Non-toxic inorganic constituents	Total dissolved solids (TDS) and total suspended solids (TSS)
Nutrients	Inorganic nitrogen such as nitrate, nitrite and ammonium and inorganic phosphates such as ortho-phosphate
Recreational water use	
Recreational water users experience a range of impacts as a result of changes in water quality and the type of recreation. Three types of recreation have been identified (i) Full contact recreation such as swimming and diving, (ii) intermediate contact recreation such as water-skiing and angling, and (iii) non-contact recreation such as picnicking and hiking next to a water body. Water quality impacts can be categorized as follows:	
Concerns	***Water quality constituents***
Human health impacts refer to concerns about waterborne diseases such as gastro-enteric diseases, skin and ear infections and carcinogenic risks.	Algae, chemical irritants, indicator organisms, pH
Human safety impacts refer to concerns about poor visibility, profuse plant growth and benthic microbial and/or algal growth.	Algae, clarity, floating matter, nuisance plants
Aesthetic impacts refer to concerns about taste, odour and colour of the water, discolouration and staining, objectionable floating matter and nuisance plants.	Algae, clarity, floating matter & refuse, nuisance plants, odour
Economic impacts refer to concerns about damage to equipment, increased treatment costs and increased cost due to scaling, corrosion or sedimentation in distribution systems.	Algae, pH, clarity, nuisance plants

DISPLAY AND PRESENTATION OPTIONS

An example of how water quality issues can be described:



Perceived problem	"Water is unsafe to drink, it has a brown colour which is probably due to pollution with sewage or something": Comment by local community.
User requirements	0 Faecal coliform (Counts/100 mL) in drinking water
Water quality data	0 Faecal coliform (Counts/100 mL) in drinking water
Explanations	This is a perceived problem. Analysis of the Faecal coliform data shows that the counts in the treated water conform to the guidelines. The perception is that the brown colour of the water is an indication of pollution that renders the water unsafe to drink. The brown colour is from naturally occurring humic acids present in the water and is a characteristic of all the mountain streams in this area. The drinking water treatment processes used by the local authority do not remove colour. It is impractical to remove colour due to high costs and sophisticated treatment technology required.
Water quality issue	This is not a water quality issue for further investigation and consumer concerns should be addressed through and a consumer education programme.
Perceived problem	"Yellow spots appear on the leaves of orange trees when we irrigate the trees using overhead irrigation. This is most noticeable early in summer. The agricultural extension officer says it is due to high chloride in the irrigation water": Comment from irrigation farmers.
User requirements	<100 mg/l Chloride
Water quality data	Mean = 89 mg/l Chloride by mean chloride for August and September are 120 and 136 mg/l respectively.

Explanations	Although the mean chloride concentration falls within the water quality guidelines, end winter and early summer concentrations exceed the guidelines.
Water quality issue	The elevated chloride concentrations observed at the end of winter and early spring should be investigated further to identify the causes and options to manage the problem.

OUTPUT COMPONENT 15
Catchment Management Implications of Water Quality Issues

PURPOSE

Context

The WQCMS development process is discussed in the sister-document to this Guide, *Guideline to the Water Quality Component of a CMS*. Chapter 3 of the *Guideline* describes a systematic iterative procedure to move from the statement of constituents of concern and user water requirements (Output Component 5), via examination of water quality issues (Output Component 14), to setting of medium-term Resource Water Quality Objectives (RWQOs) and agreement on a long-term vision (Output Component 16). In Chapter 4 the WQCMS development process description continues via the setting of Source Management Objectives (SMOs) for all management units to right-size existing or expected water quality loads so that RWQOs can be met. In Chapter 5 the *Guideline* deals with a WQM Framework-Plan that prioritises sectors and sources so that SMOs can be met across the whole WMA. In Chapter 6 WQM Implementation Plans on a sector-source-management unit basis are engaged.

Each water quality issue, problem, concern or opportunity (collectively called "issues") brought to the table under Output Component 14 potentially requires attention in one or more of the stages of the WQCMS development process. This creates an issue-focused bridge between the WQ-CAS and the WQCMS. By their nature it can be expected that issues will feature most prominently in the setting of RWQOs (Chapter 3 of the *Guideline*) and in WQM Implementation Plans (Chapter 6 of the *Guideline*). This process needs to include the potential for future water quality changes in response to potential catchment developments (see Output Component 18).

Purpose

The purpose of this Output Component is to record how each water quality issue, problem, concern, or opportunity should be linked to one or more of the phases of the WQCMS development process (as described in the *Guideline*) to ensure that it influences appropriate management decisions.

NB: (i) Ensuring that the CMS development process is issue-focused is ultimately the primary responsibility of the CMS development teams. This output is included as part of the WQCAS for the sake of completeness, but is not a primary ingredient of a CAS.

(ii) It should be borne in mind that the scoping information of Output Component 0 may already highlight urgent water quality issues, which may need ad hoc management attention, i.e. preceding the CMS development process.

Prerequisite Output Components

Completion of Task 1 and Output Components 14, 15 and 18 are prerequisites. Component 18 should be used to review the findings of this component.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Table and brief report that links water quality issues with one or more of the phases of the WQ-CMS development process.	Interpret inputs and feedback from stakeholder participation processes, as well as from examining the findings of predictive studies.
Table that provides conceptual management options for each water quality issue.	Obtain inputs during stakeholder participation processes and consult sectoral specialists.

OUTPUT COMPONENT 16
Vision (or Long-Term Resource Objectives) for Water Quality Management

PURPOSE

Context

The CMS development process kicks off with the setting of *medium-term* (5 years) RWQOs for the different management units that make up the catchment (see *Guideline to the Water Quality Management Component of a CMS*). RWQOs reflect the stakeholders' needs with respect to water quality over and above those outlined in the NWRS and by the RDM, but also include stakeholders' needs with respect to the discharge of waste to the resource. This process can be given a strong focus if it can unfold against the background of an "ideal", or a "vision", of the *long-term* future water quality desired by stakeholders, both for the whole catchment and also for its major components. Furthermore, the Water Resource Classification process that is required to implement the NWA, recognises the need to declare, on a provisional basis, a "desired future state" for each catchment. This preliminary vision needs to be converted to a long-term vision through iterative stakeholder engagement during the CMS development process.

Purpose

The purpose of this Output Component is two-fold:

+ to provide the initial stages of the CMS development process with a narrative description of, and motivation for the long-term future water quality status as provisionally foreseen by the Water Resource Classification process

+ to record, during all stages of the CMS development process, the desired long-term future water quality status, and the motivation for it, formulated by stakeholders.

NB: (i) It should be noted that, regardless of whether the Water Resource Classification process has already considered a particular catchment, the stakeholders in that catchment are likely to have a variety of ideals for the water quality in that catchment on the basis of intuitive understanding, experience or historical studies. Therefore, already during the preparation of Output Component 0, should it be possible to formulate a provisional "vision" on such a basis.

(ii) The tasks of vision formulation and RWQO determination belong to the CMS development process and are not usually the direct responsibility of the WQCAS teams. Nevertheless, these tasks are intertwined and should be undertaken as a single process.

Prerequisite Output Components

Output Components 0, 1, 5, 12, 13, 14 and 15 are pre-requisites for preparation of this output.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Descriptions of any pre-existing long-term visions for water quality at the start of the WQCAS.	Consult reports on historical water quality study, as well as selected participants in such studies.
Narrative description of, and motivation for, the long-term future water quality status as provisionally foreseen by the Resource Classification process.	Interrogate Water Resource Classification System and consult participants in the RDM process for the particular region.
Narrative description of, and motivation for, the long-term future water quality status declared desirable by stakeholders during the CMS development process.	Record relevant outcomes of stakeholder participation processes undertaken by CMS teams.

SOURCES

The Sources section of Output Component 12 is recommended for guidance on the process of vision formulation.

The Sources section of Output Component 20 is recommended for guidance on the format of vision formulations in specific catchments where water management plans have been developed.

CHECKLISTS

- The vision for water quality needs to be formulated in non-technical, stakeholder-friendly format in all official South African languages that are important to the stakeholders in that catchment.
- The vision may be idealistic, but should not be a “pie-in-the-sky” statement and should recognise the NWA injunction for beneficial and equitable use and the economic situation in the catchment.
- The vision would typically refer to the desired condition of the water resource, to its future use and to relevant socio-economic themes.
- Technical information on long-term water quality target requirements should back the vision up in fair detail, but do not form part of the stakeholder-friendly narrative.
- Vision is not to be confused with “mission” – the former is a target state, while the latter is a dynamic intention that drives a process, such as implementation of the CMS.

DISPLAY AND PRESENTATION OPTIONS

The following is an example of a brief vision for water quality: “*The Sabie River water quality shall sustain the current diversity of fish species forever.*”

The following is a more elaborate vision statement: “*The water quality of the Sabie River shall be suitable to sustain the domestic and agricultural needs of settlements upstream of the KNP, as well as the needs of aquatic and riparian ecosystems in the KNP, to the mutual benefit of conservation, tourism and rural community development.*”

Route Map of the Guide

Management question 1

What is the study area's status in water - related terms and how did it get to this point?

Management question 2

What are the water -related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages and roles?

Management question 3

What are the study area's water quality issues, problems, concerns and opportunities?

You are here

Management question 4

Where might the water quality status of the study area be heading in the future?

Output 17: National and regional plans and projections of future water demands and catchment development
Output 18: Predicted future water quality at sites of management focus

Management question 5

What are the appropriate (priority) water quality management options?

Management question 6

Has water quality management achieved its objectives?

Management Question 4:

WHERE MIGHT THE WATER-RELATED STATUS OF THE STUDY AREA BE HEADING IN THE FUTURE?

Task 4: Projection of future water-related development scenarios

OUTPUT COMPONENT 17

National, Regional and Local Plans and Projections of Future Water Demands and Catchment Development

PURPOSE

Context

Catchment management is part of a wider planning and development environment, which is affected by the fragmentation that characterises South Africa's water, land-use and environmental legislation and administration. In Output Component 13 the institutional linkages that are required to counter this fragmentation are addressed. Here, the focus is on the fragmented statutory arrangements for spatial, land-use and infrastructural development planning.

Obviously, all planning in South Africa occurs with recognition of future population growth; therefore development of a CMS should recognise demographic trends. Demographic projections are obvious prerequisites for such planning activities.

Purpose

This Output Component ensures that the CMS is aligned with national, provincial, regional and local planning initiatives by organs of state outside the water management sector, as far as spatial, land-use and infrastructural development patterns are concerned. Additionally, by being informed about such planning processes, the CMS may be oriented to influence them or their underlying development processes to the advantage of water quality management.

Furthermore, the CMS needs to be cognisant of demographic trends, which determine future water demand patterns, as well as spatial patterns of potential future water quality impacts.

Prerequisite Output Components

Output Components 0, 1, 3, 12, 13, and 15 would inform this Component in various ways.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Outline of available outputs from all national, provincial, regional and local planning processes. The "Checklist" section below provides examples of such outputs.	Obtain plans from all organs of state in all spheres of government that deal with: ◊ natural resource use (agriculture, environment, mining, water services, forestry) ◊ land-use and infrastructure development (local government, housing, transport, land affairs) ◊ spatial planning (provincial planning, land affairs, economic affairs)
Outline of demographic projections that are differentiated for different parts of the catchment.	This should not normally be the task of the water quality assessment and should be derived by preceding or simultaneous water resource planning studies. Derived by combining census results with alternative economic, health and social development scenarios. Best performed by economics professionals or social scientists.
Detail chapter on projections of future water demands due to population growth and potential physical developments in the catchment.	These should not normally be the task of the water quality assessment and should be derived by preceding or simultaneous water resources planning studies. However, projections of physical developments may require refinements under a water quality perspective.

Output 17: *Long-term Planning*

SOURCES
Planning Information: ◊ Planning Divisions of organs of state in all spheres of government, particularly the National Departments dealing with: water affairs, forestry, environment, agriculture, minerals and energy, transport, land affairs, health, trade and industry, economic affairs, constitutional development, housing, defence, labour. ◊ Secretariat of Provincial Heads of Departments (HOD) Committee and of the Provincial Directorate-General's Office. ◊ Secretariat of the Provincial Water Liaison Committee (formal interface between provincial government and DWAF Regional Offices). ◊ Secretariat for the Committee for Environmental Coordination (CEC) (created under the National Environmental Act to oversee the EIP and EMP processes).
Projections: ◊ Water resource planning or design reports with the following themes: *Water Resources, Water Demands, Demand Management, Water Supply Augmentation Scheme Design, Economics of Augmentation Scheme Options (*Obtainable from DWAF addresses provided under Output Component 4). ◊ Scientific institutions that specialise in demographic analyses and population projections, such as the Institute for Futures Studies and the Bureau for Economic Studies (both University of Stellenbosch), or the Human Sciences Research Council, Pretoria.
CHECKLISTS
National Departments: • Water Services Development Plans (WSDP) – Water Affairs and Forestry. • Integrated Development Plans (IDP) – Constitutional Development. • Land Development Objectives (LDO) – Land Affairs. • Hazardous Waste Management Plans (HWMP) – Environmental Affairs and Tourism. • Spatial Development Initiatives (SDI) – Trade and Industry. • Environmental Implementation Plans (EIP) – Environmental Affairs and Tourism, Land Affairs, Agriculture, Housing, Trade and Industry, Water Affairs and Forestry, Transport, Defence, Minerals and Energy, Health, Labour. • Environmental Management Plans (EMP) – Environmental Affairs and Tourism, Land Affairs, Water Affairs and Forestry, Minerals and Energy, Health, Labour.
Provincial Governments: • Environmental Implementation Plans (EIP) • Strategic Environmental Assessments (SEA) • Environmental Management Frameworks (EMF) • General Waste Management Plans (GWMP) • Spatial Development Initiatives (SDI) • Conservation of Agricultural Resources Plans (CARAP)

Local Authorities:

- Metropolitan Spatial Development Frameworks (MSDF)
- Urban Structure Plans
- Land Development Objectives (LDO)
- Town Planning Schemes

DISPLAY AND PRESENTATION OPTIONS

Projected Water Demands

Projected water demands can be displayed in tabular format as in the example below.

Catchment	Type	Name	Water consumption (Mm^3/a)					
			1980	1990	2000	2005	2010	2015
Upper Buffalo	Urban	King Williams Town	0.57	0.72	1.30	1.55	1.84	2.19
		Ginsberg	0.07	0.23	0.33	0.39	0.46	0.66
	Periurban	Tyutyu	-	0.04	0.04	0.07	0.08	0.08
		Skobeni	-	0.02	0.04	0.07	0.08	0.08
		Balasi	-	0.02	0.04	0.07	0.08	0.08
	Rural villages	Zone A – Frankfort area	-	0.10	0.22	0.24	0.27	0.59
		Zone B – Upper Buffalo Area	-	-	0.15	0.17	0.19	0.41
	General industrial	King Williams Town	0.19	0.98	0.94	0.99	1.04	1.09
	Water intensive industry	Da Gama (Zwel)	1.54	1.54	1.36	1.43	1.5	1.58
		King Tanning	0.32	0.23	0.11	0.12	0.13	0.13

Mapping Development Plans

Development plans lend themselves particularly well to mapping. All development plans would probably be based on maps showing the extent of current and future developments in a catchment. GIS-based maps can be used to indicate future development plans in a catchment.

OUTPUT COMPONENT 18
Predicted Future Water Quality at Sites of Management Focus

PURPOSE

Context

The WQ-CMS is aimed not only at current water quality issues, but particularly also to pre-empt issues arising from planned *future* water-related developments in the catchment. The information "mosaic", formed by the Output Components 14, 15, 16, 17, 19 and 9, of water quality issues, catchment management implications of those issues, long-term RWQOs, future development scenarios, the spatial discretisation of management units and configured decision support tools, allows a management-oriented analysis of potential future water quality trends in space and time. It should be borne in mind that, like all projections, various degrees of uncertainty would be present in the predictions of water quality and that a wide range of sensitivity analyses of the predictions in response to variations of controlling variables should form a standard part of such analyses.

Purpose

This Output Component ensures that the derivation of individual management options, which underpin the WQCMS, is not blinkered by current issues, but is also informed by an understanding of potential future water quality outcomes in the catchment. Additionally, by being thus informed, the CMS may be oriented to influence such planned development processes to the advantage of water quality management.

Prerequisite Output Components

Most Output Components from Tasks 1 to 4, as well as Output Component 19 would inform this Component in various ways. Cross-referencing of the predicted water quality issues with catchment management implications analysed under Output Component 15 is also important.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Time series, or significant statistics, of water quality constituents of concern on the spatial scale of management units or at sites of concern.	Suitable predictive tools, such as water quality catchment models, need to be configured with overlays of potential future developments and demand patterns in the catchment. Sensitivity analyses should be performed in terms of all primary development assumptions.
Matrix of potential water quality issues derived from the predicted water quality trends.	The predicted water quality trends need to be evaluated against the backdrop of the water quality requirements and constituents of concern for this catchment (Output Component 5), as well as of the vision for water quality (Output Component 16). This evaluation will allow identification of potential water quality issues.
Suitable inputs to the preparation of Output Component 15.	Analyse the links between the potential water quality issues and each of the stages of the WQCMS development process.

CHECKLISTS

Potential developments in all significant sectors need to be assessed, and both non-point and point impacts need to be considered. The assessment should include expansion in: *urbanisation, dense semi-formal settlements, industrial clusters, irrigation areas, mining, large water resource and wastewater infrastructure, afforestation, large transportation infrastructure, etc.*

DISPLAY AND PRESENTATION OPTIONS

The display and presentation options described in Output Components 6, 7 and 8 are applicable here.

Route Map of the Guide

Management question 1

What is the study area's status in water - related terms and how did it get to this point?

Management question 2

What are the water -related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages and roles?

Management question 3

What are the study area's water quality issues, problems, concerns and opportunities?

Management question 4

Where might the water quality status of the study area be heading in the future?

You are here

Management question 5

What are the appropriate (priority) water quality management options?

Output 19: Management units and assessment spatial and temporal solution

Output 20: Prioritised water quality management options

Management question 6

Has water quality management achieved its objectives?

Management Question 5:

WHAT ARE THE APPROPRIATE (PRIORITY) WATER-RELATED MANAGEMENT OPTIONS?

Task 5: Formulate and prioritise water quality management options

OUTPUT COMPONENT 19
Management Units and Assessment Spatial and Temporal Resolution

PURPOSE

Context

The NWA states that the CMS "...may be established in a phased and progressive manner and in separate components over time…" [*s8(3)(a)*]. This statement refers not only to variable timing of aspects of the CMS, but also to spatial distinctions in the establishment of the CMS, i.e. that at any stage the CMS implementation may focus more intensely on some portions of a catchment and less so on others. These flexibilities are necessary to accommodate four "reality checks":

+ issues and problems are usually more acute in some sub-catchment areas compared with others; therefore greater urgency resides with those "stressed or threatened" areas and they offer higher returns on management investment
+ capacity to intervene is not limitless, due to limitations in human and financial resources, therefore the urgent problems should be tackled first
+ the sub-catchments upstream of some river reaches demand higher investment of management focus because they are important water supply points
+ information may be inadequate in some catchment areas to warrant detailed interventions.

These four factors may dictate that the degree of detail of the catchment management challenges, and, therefore, the required spatial and temporal resolution of the management plans, may vary among sub-catchments. From a pragmatic perspective, it would also make sense to treat certain sub-catchments as management "units", each with their own information base, management objectives, priorities, strategies and action plans.

If such a two-stage discretisation (sub-division) exercise underlies the CMS development and implementation process, then the structuring and spatial resolution of the WQCAS should reflect the outcome of this subdivision, and *vice versa*.

Purpose

The purpose of this Output Component is to provide to the CMS process with:

◊ a pragmatic but relevant spatial structure, and
◊ decisions on appropriate spatial and temporal resolutions for the WQCAS in each management unit

which reflect the aforementioned four "reality checks".

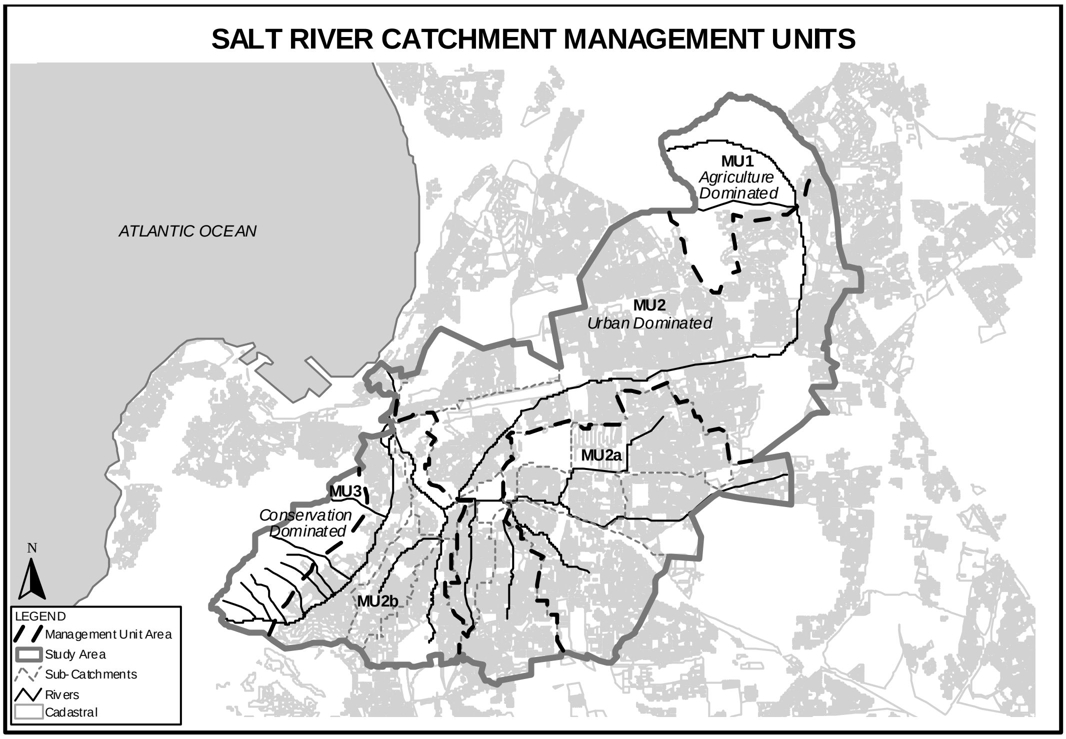
Prerequisite Output Components

Output Component 0 and early versions of Components 1, 3, 6, 7 and 8.

OUTPUTS	HOW TO ATTAIN OUTPUTS
GIS coverages and outline descriptions of, and motivations for, proposed management units.	Criteria that may be applied to identify particular management sub-catchments/ units: • upstream of primary water supply points • level of "water stress" • upstream/downstream of critical water quality problem sites • relatively low variability in bioclimatic and geophysical characteristics • relatively pristine or relatively degraded (the particular water resource class) • particular dominant user sectors or dominant land-uses. It should be noted that this exercise might require further iterations as the overall CAS yields additional relevant information.
Level of detail of the WQCAS in each management unit and motivation in each case.	Two levels of detail of the WQCAS are suggested: ◊ *Scoping*-level: Broad indications, at the quaternary scale or coarser, of water quality issues and the relative importance of non-point and point sources, and provisional identification of the most important sources of either variety. This is the preferred initial level for all sub-catchments. ◊ *Evaluation/prioritisation* level: Detailed quantification on a sub-area basis of priority point and non-point source impacts, and the key source types and areas requiring management. This is the preferred level only for those sub-catchments which are important existing water supply sources, which are known to be "water-stressed or threatened", or for which a scoping-level assessment indicates acute problems.
SOURCES	
Example: Scoping-level water quality CAS	NSI (1996) *Preliminary Assessment*. Mgeni Catchment Management Plan. DWAF Report WQ U200/00/0194. Pretoria.
Example: Evaluation-level water quality CAS	NSI (1996) *Pollution Sources*. Mgeni Catchment Management Plan. DWAF Report WQ U200/00/0193. Pretoria.
Example: Water quality assessment framework	Pegram GC, Görgens AHM and Ottermann A (1997) A framework for addressing the information needs of catchment water quality management. *Water SA*, Vol 23, No 1.
CHECKLISTS	
Not applicable.	

Output 19: *Management Units & Resolution*

DISPLAY AND PRESENTATION OPTIONS



Output 19: *Management Units & Resolution*

OUTPUT COMPONENT 20
Priority Water Quality Management Options

PURPOSE

Context

The WQCMS *Guideline* (Chapter 5) states that the WQM Framework-Plan prescribes a *sub-catchment/ Management Unit water quality load allocation to different sector/source types*, to achieve the specified RWQOs for water quality. The WQM Implementation Plans of the WQ-CMS (Chapter 6 of the *Guideline*) specifies the management actions, responsibilities, resources and timeframes *to mitigate or remediate the water quality impacts associated with priority sectors/sources within particular sub-catchment/management units (or across the WMA)*, to give effect to the load allocation specified in the WQM Framework-Plan.

In order to make the load allocations between sectors/sources, information or estimates are required about the relative load contribution from each source type (or each large source), both currently, and due to expected future development. Furthermore, the relative differences in water quality outcomes of different management options by which these allocations may be achieved, need to be estimated.

NB: (i) By this stage the WQCAS is heavily entwined with the WQCMS development process. There is so much overlap and iteration that for all practical purposes the two processes can be said to be fusing into one. It is important to note that this Output Component is usually driven by the CMS development team and is not the direct responsibility of the WQCAS team.

(ii) The design and detailed analysis of individual WQM actions that are allocated to responsible parties according to the WQM Implementation Plans are operational tasks and do not usually form part of the WQCAS. Such responsible parties may use practitioners of their choice to perform such design functions. However, it makes sense that such designers should interface with the WQCAS knowledge system, including its predictive tools.

Purpose

The purpose of this Output Component is to:

◊ provide quantification support of a “what if” variety for the development of the WQM Framework-Plan and the WQM Implementation Plans, using the decision support tools of Output Component 9

◊ provide support with the evaluation of the non-technical aspects of WQM Options.

Prerequisite Output Components

All Output Components from 0 to 19 are prerequisites to this Component.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Water quality loads and concentrations, which may result from, proposed management options as predicted for particular sub-catchments/ management units.	Apply the configured predictive tools and decision support methods produced as Output Component 9. Although accurate sector/source load estimates, based on detailed point and non-point source modelling (based on monitored data), would provide the best support for management decisions, simpler and qualitative assessment approaches may be used, particularly in unstressed situations. The selection of assessment approach should be based on a trade-off between the resources required to use a particular technique and the increase in accuracy and reliability of the results. The following additional WQCAS Output Components are relevant: + Components 7 (point) and 8 (non-point) provide the basic information about the relative (and absolute) water quality load contributions from different source types. + Components 17 and 18 provide an indication of future expected loadings. The process of identifying and evaluating WQM Options must consider the effectiveness of the options in achieving the allocated load. It may not be possible to define the absolute effectiveness of a WQM Option, because site-specific conditions have a considerable impact. However, it should be adequate to assess the relative effectiveness of different options.
An evaluation of the manageability of these sources and the technical feasibility of options for their management.	The manageability must be estimated in terms of the background constituent concentrations, the technical effectiveness of available technologies to use as management options, and the social and economic impacts of those management options.
Inventory of priority sources and options for their management by management unit.	Those source types or areas with the greatest total impact on a water quality concern should be a priority for management. However, those sources with the highest relative impact (e.g. per unit area or per capita loading) should also have a higher priority for management, because the interventions may be more effective in these areas. Similarly, the potential future impacts of these sources should be a major consideration, because these impacts may be more easily mitigated before they are fully realised.

SOURCES

The following sources contain useful examples of Management Options formulated under particular management strategies:

DWAF (1999). *Plettenberg Bay Water Resources Management. Part 1: Management Strategy.* Report by Sakaza and Ninham Shand to Directorate: Water Quality Management, DWAF, Pretoria.

DWAF (1999). *Catchment Management Strategy for the Modder & Riet Rivers. Phase 1: Situation Assessment & Draft Management Strategy*. Report by Ninham Shand to Directorate: Water Quality Management, DWAF, Pretoria.

DWAF/Umgeni Water (1997). *Mgeni Catchment Management Plan*. Report WQM U200/00/0196 by Ninham Shand to DWAF, Pretoria and Umgeni Water, Pietermaritzburg.

DWAF/WRC (1999). *A Framework for Implementing Non-Point Source Management under the NWA.* WRC Report No TT 115/99 and DWAF Report No WQP 0.1, DWAF, Pretoria.

CHECKLISTS

Management focus areas:

◊ point source discharges, such as municipal waste water, mining, industrial, manufacturing;

◊ non-point source discharges, such as irrigated agriculture, dry-land agriculture, settlements;

◊ in-stream management, including rehabilitation, minimum streamflows or operating rules.

Management approaches:

◊ Full compliance with the existing authorisation conditions, for which RWQOs would have been recognised according to the Resource Management Class.

◊ Statutory controls on water use, including more stringent authorisation conditions (through area-specific general authorisation or licences), or compulsory licensing of relevant water quality-based water users.

◊ Waste discharge charges used as an economic incentive to reduce loads to the required levels, together with funding of direct interventions to implement technologies and practices to manage loads from particular sources.

◊ In-stream management, through remediation of the water resource, reservoir system operation and/or ensuring adequate water quantity allocation to streamflow for dilution and assimilation of loads (possibly above the Reserve and RWQOs).

◊ Non-statutory options, particularly cooperative governance and capacity building to improve the effectiveness of land-use and infrastructure management that has an impact on water quality and to change human behaviour to mitigate impacts.

Sectors and Source Types:

◊ *Agriculture*: irrigated crops; dry-land crops; irrigated pastures; confined animal facilities, feedlots, livestock grazing, game farming.

◊ *Food Processing*: canning; dairy-related processing; wineries, breweries, abattoirs.

◊ *Forestry and Timber*: plantations; pulp and paper mills; sawmills.

◊ *Industry*: energy production; heavy industry; light industry; stockpiles; wastewater treatment plants.

◊ *Mining:* coal mining; metal extraction; mineral extraction; slimes dams and dewatering; quarrying and sand.

◊ *Municipal*: stormwater outfalls; wastewater treatment plants; informal settlements.

◊ *Transport*: highways and roads; airports, storage depots.

◊ *Waste Disposal*: general solid waste; hazardous waste; sludge disposal; effluent irrigation.

DISPLAY AND PRESENTATION OPTIONS

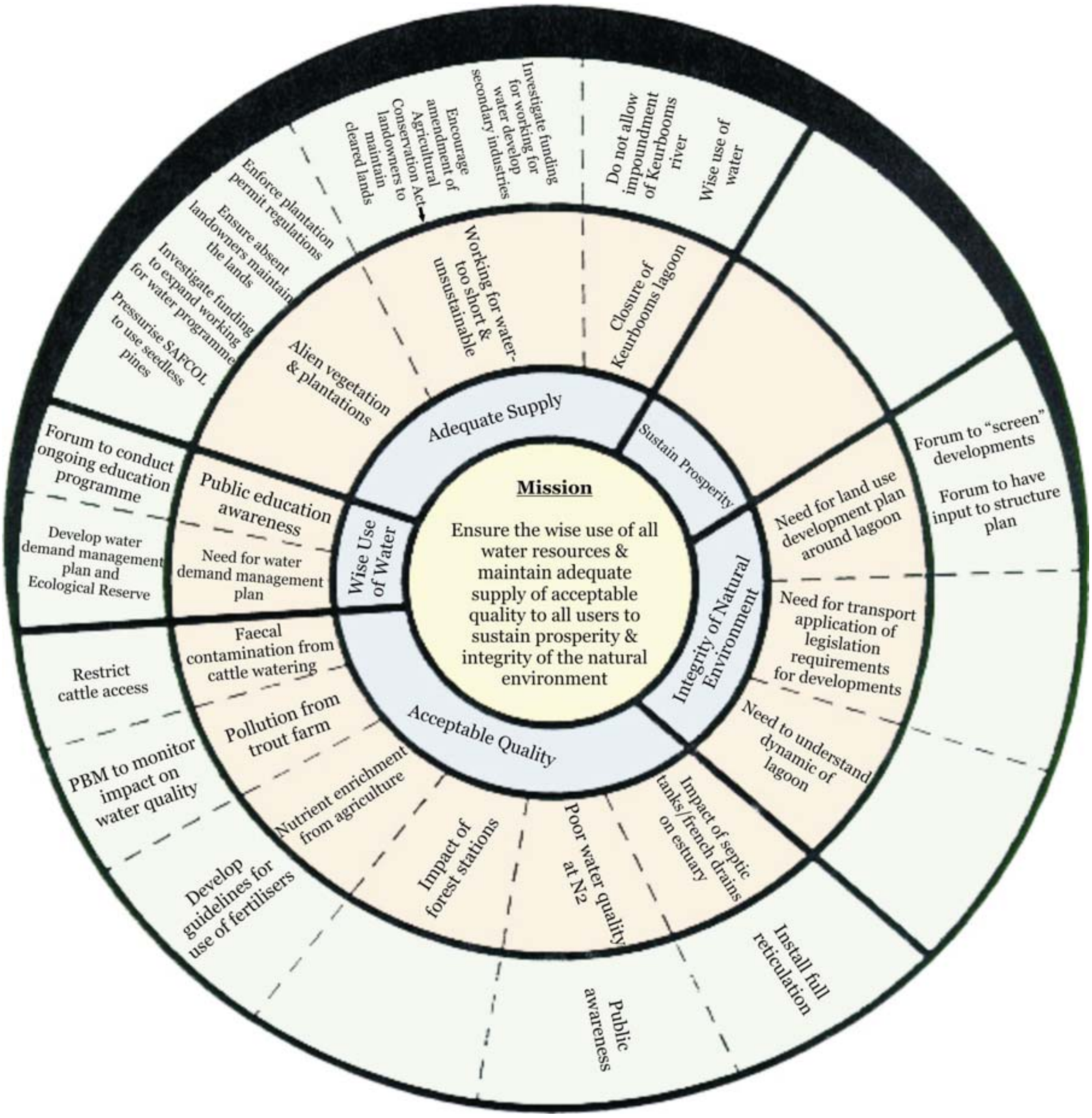
Table of Water Quality Management Options

Water quality management options can be summarized in a table. The Plettenberg Bay Water Resources Management study (DWAF, 1999) provides a good example of how these may be summarized (see the extract below):

Keurbooms River Management Issues & Actions (Extracted from the original report)

Problem	Perceived problem	Concern	Technical data	Guidelines for applicable criteria	Possible solutions	Possible actions
Faecal contamin-ation from cattle watering directly from the river	✔	✔	*E.coli* concentrations taken at Newlands between July 1996 and July 1998 50th percentile = 35 80th percentile 120 counts/100ml	*E.coli*: TWQR for full and intermediate contact recreation: 0-130, and 0-1000 counts/100ml respectively	1. Restrict cattle access	1. Fence grazing areas and restrict cattle from watering directly from the river
Impact of SAFCOL plantations on base flows	✔	✔	The % runoff reduction in the middle Keurbooms catchment as a result of plantations is approximately 2.5%	Reserve, still to be determined	1. Maintain natural riparian vegetation along streams and conservation programme	SAFCOL to improve their public image by educating the public regarding their efforts to minimize the impacts of plantations
Nutrient enrichment of river from fertilizer	✔	?	Avg PO_4 = 0.1 Avg NO_3 = 0.73 Avg NH_3 = 0.55	PO_4: Limit for eutrophication: 0.025 mg/l NO_3: Limit for eutrophication: 2.5 mg/l	1.Educate farmers 2. Create incentives to reduce use of fertilizers 3. Carry out mandatory independent soil evaluations at regular intervals	1. Undertake regular water quality monitoring 2. Inform farmers through the forum regarding the impacts of nutrient rich irrigation return flows 3. Investigate alternative irrigation practices

WQM “Options” for Plettenberg Bay Study



Output 20: *Priority WQM Options*

Route Map of the Guide

Management question 1

What is the study area's status in water - related terms and how did it get to this point?

Management question 2

What are the water -related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages and roles?

Management question 3

What are the study area's water quality issues, problems, concerns and opportunities?

Management question 4

Where might the water quality status of the study area be heading in the future?

Management question 5

What are the appropriate (priority) water quality management options?

You are here

Management question 6

Has water quality management achieved its objectives?

Output 21: Monitoring and auditing assessment

Management Question 6:

HAS WATER QUALITY MANAGEMENT ACHIEVED ITS OBJECTIVES?

Task 6: Monitoring and auditing of implementation of management options

OUTPUT COMPONENT 21
Monitoring and Auditing the Implementation of Management Options

PURPOSE

Context

Water quality monitoring is the planned, systematic collection of water quality data through a series of repetitive measurements. The monitoring programme is often specifically designed to collect data that can be used to review the effectiveness of a water quality management option.

Auditing water quality is a structured interpretation of the current water quality status. It involves the organisation and interpretation of water quality data to establish a record of change associated with the implementation of a water quality management option. It is a process of verification that measured water quality parameters are in compliance with performance limits (or goals) set for a water quality management option.

In Section 137 of the National Water Act it is specified that monitoring systems must be established to assess, among other matters, "(a) the quantity of water in the various water resources; (b) the quality of water resources; (c) the use of water resources (d) the rehabilitation of water resources; (e) compliance with resource quality objectives; (f) the health of aquatic ecosystems, and (g) atmospheric conditions which may influence water resources." Section 137 (d) & (e), which deals with monitoring the rehabilitation of water resources and compliance with resource quality objectives, probably have most in common with water quality catchment management strategies.

Auditing can also be undertaken to review and assess the effectiveness of the management systems, practices and procedures rather than the physical water quality status. This type of management performance assessment is essential but is not described in this *Guide*, where the focus is on tracking and assessing changes in physical water quality.

Purpose

The purpose of this section is to describe methods to monitor progress with the implementation of management options to maintain present status, rehabilitate water resources or the implementation of Management Options to meet RWQOs or SMOs.

Prerequisite Output Components

- Output components 1, 2, 3, 4 and 5 would inform this Component in various ways.

OUTPUTS	HOW TO ATTAIN OUTPUTS
Performance assessment - Meeting *operational* management objectives	Assess compliance with short-term operational management goals using monitoring information systems designed for each management option. Graphically and statistically compare the monitoring results of key water quality indicators with the management goals to assess whether management goals have been met during the past season.
Performance assessment - Meeting *strategic* management goals	Review the medium to long-term trends in key water quality constituents to assess how long-term water quality is changing in relation to long-term management goals. Statistical methods to assess water quality trends and the effect of management interventions on water quality, are described in the following publications: • Ward, R.C., Loftis, J.C. and G.B. McBride (1990) *Design of*

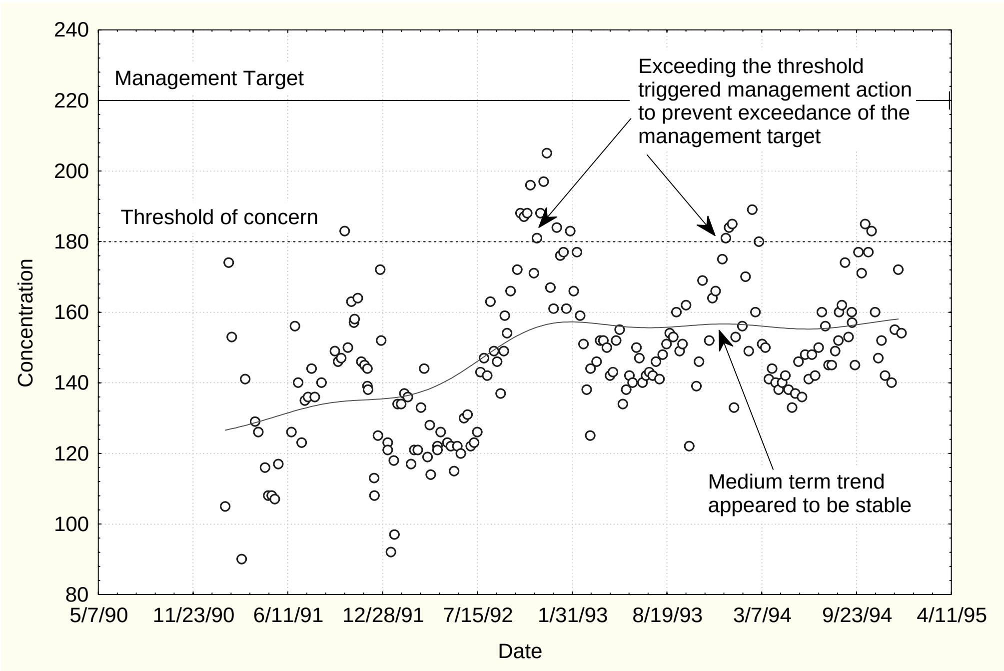
	Networks for Monitoring Water Quality. Van Nostrand Reinhold, New York, NY, USA 231pp. • Harris, J.M., van Veelen, M. and Gilfillan, T.C. (1992). *Conceptual Design Report for a National River Water Quality Assessment Programme.* Water Research Commission. Report No. 204/1/92
SOURCES	
Management information system	Water Resource Management Institution (Catchment Management Agency or DWAF Regional Office)
National, provincial, local and other data sources	Potential data sources were identified in Component 11.
CHECKLISTS	
Statistical analysis of the water quality data. Water quality data must be processed before statistical trends or comparisons over time can be made. • Outlying values must be identified and dealt with, and Data must be adjusted for missing values, non-detects, laboratory duplicates and field replicates.	Methods for pre-processing data are described in: Harris, J.M., van Veelen, M. and Gilfillan, T.C. (1992). *Conceptual Design Report for a National River Water Quality Assessment Programme.* Water Research Commission. Report No. 204/1/92
Independence of observations Statistical analysis should be done on independent observations.	Water quality taken at short intervals (daily or weekly) can be serially correlated, i.e. each observation repeating part of the information contained in the previous observation. Monthly observations should be used for analyses. Methods to derive independent samples are described in Harris *et al*. (1992).
Trend analysis It is difficult to detect a significant trend in less than 5 years of data if significant seasonality is present. Seasonality occurs when one part of the year tends to produce consistently higher or lower values than other parts of the year.	Significant seasonality should be removed from the data before trend analysis can be done. For more than 5 years of data, monthly box-and-whisker plots can be used to detect seasonality. For less than 5 years of data, quarterly box-and-whisker plots can be used. The Kruskal-Wallis test, at the 90% confidence level, can also be used to test for seasonality. For data sets longer that 5 years, the seasonal Kendall Tau test can be used to detect long-term trends (Harris *et al*., 1992). For data sets less that 5 years, the seasonality must first be removed and the Kendall Tau test can then be used to detect a trend.
Assessing changes after implementation of management options Two statistical tests can be used.	For same size data sets, the Wilcoxon signed rank test (Harris *et al*., 1992) can be used to determine whether the medians over the two data sets are similar. For data sets of unequal size, the Mann-Whitney or the Wilcoxon Rank Sum test (Harris et al., 1992) can be used to assess whether the medians of the two data sets are different. The data needs to be deseasonalised before the comparison is made.

Software for water quality data analysis	***General statistical software packages*** Statistica and QuickStatistica - http://www.statsoft.com/ SAS: http://www.sas.com/ Statgraphics Plus - http://www.manu.com/statgraphics/ ***Custom designed water quality statistical software*** WQStat Plus - http://www.idt-ltd.com/wqstat/WQStat.html

DISPLAY AND PRESENTATION OPTIONS

Meeting management targets

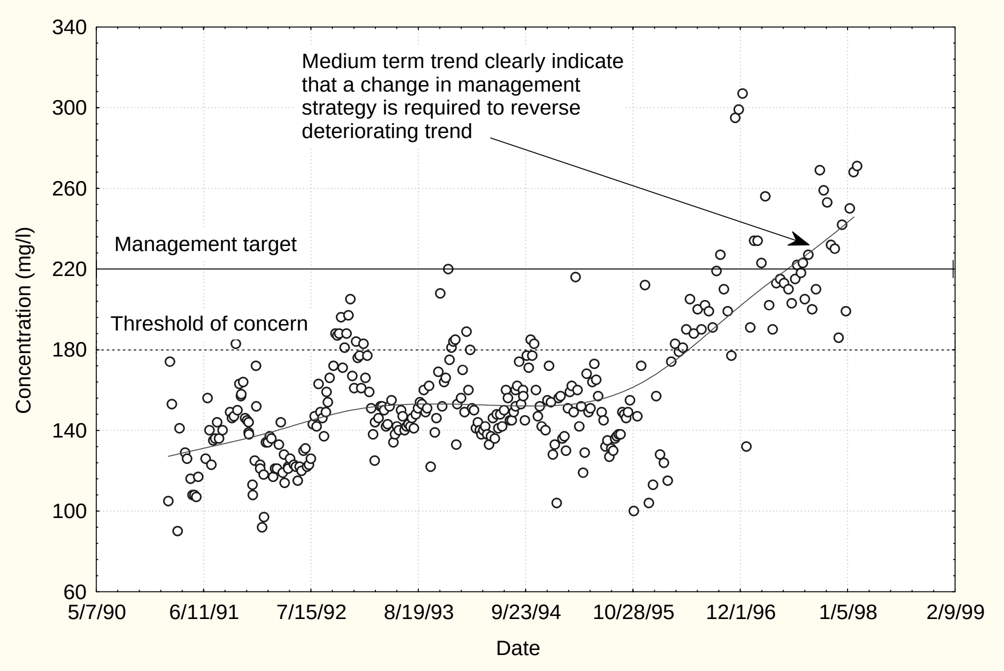
Monitoring the implementation of a water quality strategy involves setting a management target (which may be an interim resource water quality objective) to be maintained and setting a Threshold of Concern. The Threshold is a trigger for management action if water quality exceeds the threshold value and is a function of the response time of the catchment to management actions. These two values are monitored on a regular basis to evaluate changes in water quality and whether management actions are required. The medium term trend is evaluated when auditing is undertaken. In this example, no change in management strategy is required because the trend has stabilised.



Output 21: *Monitoring & Auditing*

Meeting strategic management goals

The medium term trend is tracked as part of the auditing process. If the trend changes negatively and short term management actions do not reverse the trend, the management *strategy* may need to be changed.



Output 21: *Monitoring & Auditing*

PART 3:

GENERAL SUPPORTING INFORMATION

Part 3 of the Guide presents two sets of general source information that could be used by the reader to elucidate particular aspects of the text:

◊ A list of and outline information on historical catchment assessments for a range of catchments in South Africa
◊ A bibliography of documents that have been cross-referenced in the text, and many of which contain seminal material on individual elements of the process of catchment assessments, or of the National Water Act implementation process, including the development of catchment management strategies.

SUMMARY OF PAST CATCHMENT ASSESSMENT/MANAGEMENT STUDIES

REF NO	STUDY	DATE	CLIENT	BY	REPORT NAMES
1	Plettenberg Bay Coastal Catchments Study, Phase 1	Feb 1996	DWAF, Plettenberg Bay Municipality & South Cape RSC	Ninham Shand	Water Quality Summary Assessment Volume 1: Main Report Volume 2: Appendices
	Plettenberg Bay Water Resources Management Strategy	June 1999	DWAF	Sakaza and Ninham Shand	Water Quality Management Series Part 1:Managemnt Strategy Part 2: Reference Document Piesang River Catchment Part 3: Reference Document Bitou River Catchment Part 4: Reference Document Keurbooms River Catchment Part 5: Reference Document Matjies, Sout and Groot River Catchment
2	Catchment Management Strategy for the Modder & Riet Rivers	March 1999	DWAF	Ninham Shand	Phase 1: Situation Assessment and Draft Management Strategy
3	Amatola Water Resources System Analysis Phase I	April 1995	DWAF	NS & HKS	Volume 2: Main Report Volume 13: Water Quality
	Amatola Water Resources System Analysis Phase II	April 1998	DWAF, Amatola DC, East London TLC, King WT TLC	NS and Gibb Africa	Water Quality Modelling Volume 3 Part 1: Monthly model configuration Part 2: Daily model configuration Part 3: WQT Hydro-salinity calibration model Volume 9: User manual for the Decision Support System

REF NO	STUDY	DATE	CLIENT	BY	REPORT NAMES
	Development of a Provisional Water Quality Management Strategy for the Amatola River System	November 1997	DWAF, Water Quality Management Directorate	Sigma Beta	Part 1: Quantification, Assessment and Prioritization of Contaminant Sources (proposal only - no report was produced - it is all on a CD) Part 2: Analysis and prioritization of management options (no report produced) Part 3: Develop and implement a process for the management of the water quality in the Amatola river systems (no report produced)
4	Mgeni Catchment Management Plan	(initiated in 1993) 1997	DWAF	Ninham Shand	Mgeni Catchment Management Plan: A Framework for an Integrated Water Management Plan for the Mgeni Catchment
5	Komati/Usutu Subsystem (Vaal river System Analysis Update)	March 1997	DWAF	BKS, Stewart Scott, NS	Requirements of Water Quality Models for the Komati and Usutu Subsystem
6	Swartkops River Basin Study	1992	Algoa Regional Services Council	CSIR	Phase 1: Water Quality Situation Analysis
	Zwartkops River Water Resources Management Plan	Dec 1996	IWQS	IWQS	Draft version of report
7	Lower Vet River	1996	WRC	Stewart Scott	Lower Vet River Water Quality Situation Analysis with Special Reference to the OFS Goldfields
8	Krokodilrivier (Wes-Transvaal) Opvanggebiedstudie: Watergehalte	Mei 1991	DWAF	SSO & BKS	Watergehalte situasie ontleding van die Jukseirivier

REF NO	STUDY	DATE	CLIENT	BY	REPORT NAMES
	Jukskei River Water Quality Management (Management Strategy)	April 1994	DWAF	BKS	Facts About the Jukskei River
		June 1994	DWAF	BKS	The Jukskei River and Environs*
		April 1995	DWAF	BKS	Sources of Pollution*
			DWAF	BKS	Preliminary Water Quality Guidelines
			DWAF	BKS	Geohydrological Assessment of Potential Groundwater Pollution
			DWAF	BKS	Water Quality Situation Assessment (not a separate report, covered by the reports marked * above)
			DWAF	BKS	Management Objectives

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APPENDIX A

Monitoring Programme Evaluation Sheet (Example)

Name of monitoring programme								
	Data source				Analyzing laboratory			Date
Organization				Organization				
Contact person				Contact person				
Postal address				Postal address				
Tel #				Tel #				
Fax #				Fax#				
Email				Email				
Web site				Web site				
Brief description of the objectives of the monitoring programme								
Documentation for the monitoring system			Yes/No/Unknown		Comments			
Quality assurance / Quality control procedures			Yes/No/Unknown		Comments			
Data security			Public domain / Restricted / No access / Unknown		Comments			
For each sampling point in the study area, list the following								
Station number	Description		Longitude	Latitude	Total number of samples	Date of first sample	Date of latest sample	Sampling frequency
For each sampling point used in the analysis, list the following								
Station number	Assessment Good/Moderate/Poor		Comments					