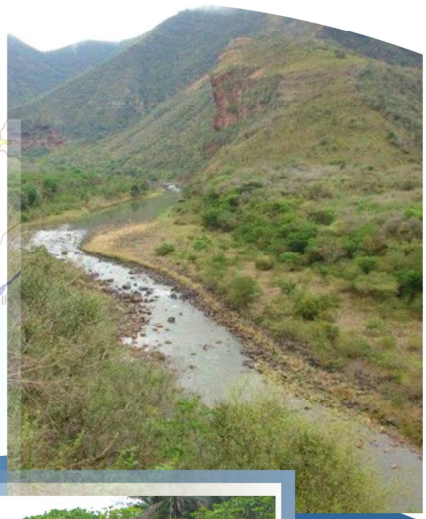
REPORT NUMBER: RDM/WMA11/00/CON/CLA/0715

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

PROJECT NUMBER: WP 10679

IMPLEMENTATION REPORT

SEPTEMBER 2015



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Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

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REFERENCE
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Department of Water and Sanitation, South Africa, September 2015. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Implementation report. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Authored by Pieter van Rooyen, Delana Louw, Patsy Scherman, Lara van Niekerk, Susan Taljaard, Shael Koekemoer, Piet Kotze, James Mackenzie, Karim Sami. DSA Report: RDM/WMA11/00/CON/CLA/0715.

DOCUMENT INDEX

Index Number	DWS Report Number	Report Title
1	Report Number: RDM/WMA11/00/CON/CLA/0112	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Inception Report**
2	Report Number: RDM/WMA11/00/CON/CLA/0113	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Status Quo assessment, IUA delineation and Biophysical Node identification**
3	Report Number: RDM/WMA11/00/CON/CLA/0213	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **River Resource Units and EWR sites**
4	Report Number: RDM/WMA11/00/CON/CLA/0313	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Desktop Estuary EcoClassification and EWR**
5	**Rivers EWR report volumes**	
5.1	Report Number: RDM/WMA11/00/CON/CLA/0114	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 1: EWR estimates of the River Desktop Biophysical Nodes**
5.2	Report Number: RDM/WMA11/00/CON/CLA/0214	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 2: EcoClassification and EWR assessment on the Mtamvuna, Lovu, uMngeni, Karkloof and uMnsunduze Rivers**
5.3	Report Number: RDM/WMA11/00/CON/CLA/0314	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 3: EcoClassification and EWR assessment on the uMkhomazi, uMngeni and Mvoti Rivers**
6	Report Number: RDM/WMA11/00/CON/CLA/0212	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **BHNR**
7	Report Number: RDM/WMA11/00/CON/CLA/0414	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Water Resource Analysis Report**
8	**Operational Scenario and Management Class report volumes**	
8.1	Report Number: RDM/WMA11/00/CON/CLA/0514	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 1: Supporting Information on the Determination of Water Resource Classes – River Ecological Consequences of Operational Scenarios**
8.2	Report Number: RDM/WMA11/00/CON/CLA/0614	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 2a: Supporting Information on the Determination of Water Resource Classes – Mvoti (U4) Estuary EWR and Ecological Consequences of Operational Scenarios**

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	Report Number: RDM/WMA11/00/CON/CLA/0614	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 2c: Supporting Information on the Determination of Water Resource Classes –Mhlali (U30E) Estuary EWR and Ecological Consequences of Operational Scenarios**
	Report Number: RDM/WMA11/00/CON/CLA/0115	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 2d: Supporting Information on the Determination of Water Resource Classes –Ecological Consequences of Estuaries in T4, U2, U3, U5, U6, U7 and U8 of Operational Scenarios**
8.3	Report Number: RDM/WMA11/00/CON/CLA/0714	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 3 Supporting Information on the Determination of Water Resource Classes – Estuary specialist appendices (electronic information only)**
8.4	Report Number: RDM/WMA11/00/CON/CLA/0814	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 4: Supporting Information on the Determination of Water Resource Classes - Economic Consequences of Operational Scenarios**
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8.6	Report Number: RDM/WMA11/00/CON/CLA/1014	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 6: Supporting Information on the Determination of Water Resource Classes – User Water Quality Consequences of Operational Scenarios**
8.7	Report Number: RDM/WMA11/00/CON/CLA/1114	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 7a: Recommended Water Resource Classes for the uMkhomazi (U1) and Mvoti (U4) River Systems**
	Report Number: RDM/WMA11/00/CON/CLA/0215	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 7b: Recommended Water Resource Classes for the T4, T5, U2, U3, U5, U6, U7 and U8 secondary catchments**
9	**Resource Quality Objectives report volumes**	
9.1	Report Number: RDM/WMA11/00/CON/CLA/0315	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 1: River RQOs**

Index Number	DWS Report Number	Report Title
9.2	Report Number: RDM/WMA11/00/CON/CLA/0415	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 2: Wetland RQOs**
9.3	Report Number: RDM/WMA11/00/CON/CLA/0515	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 3: Groundwater RQOs**
9.4	Report Number: RDM/WMA11/00/CON/CLA/0615	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Volume 4: Estuary RQOs**
10	**Report Number: RDM/WMA11/00/CON/CLA/0715**	**Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Implementation Report**
11	Report Number: RDM/WMA11/00/CON/CLA/0815	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Main Report**
12	Report Number: RDM/WMA11/00/CON/CLA/0116	Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: **Closing Report**

DEPARTMENT OF WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

IMPLEMENTATION REPORT

Approved for RFA by:

…… ***……***

Delana Louw
Project Manager

Date

DEPARTMENT OF WATER AND SANITATION (DWS)
Approved for DWS by:

…… ***……***

Chief Director: Water Ecosystems

Date

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- Mr James Mackenzie: Riparian vegetation
- Dr Patsy Scherman: Rivers - Water quality
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Report Editor: Shael Koekemoer
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REPORT SCHEDULE

Version	Date
First draft	September 2015
Second draft	December 2015
Final draft	March 2015

EXECUTIVE SUMMARY

INTRODUCTION

This task is associated with step 5 and 6 of the Water Resource Classification System. The report focuses on describing the principles of an implementation plan as part of National Water Resource Classification (NWRC), the actions required as well as a timeline for the implementation of the RQOs. Monitoring to measure whether the RQOs are being achieved is also provided.

IMPLEMENTATION BUILDING BLOCKS AND COMPONENTS

The Resource Quality Objective (RQO) implementation plan consists of three components:

- Firstly activities ensuring that the RQOs determined are adhered too (e.g. releasing or transferring water usually from storage).
- Secondly, monitoring (measuring) various aspects in order to determine whether or not the required RQOs are met or the resulting ecological health objectives are achieved.
- Lastly, if the intended outcomes are not observed from the monitoring process, adaptive management needs to take place in order to rectify the situation such that the desired RQOs are met. The Figure below presents a simplified schematic of these three components, indicating a circular flow of information.

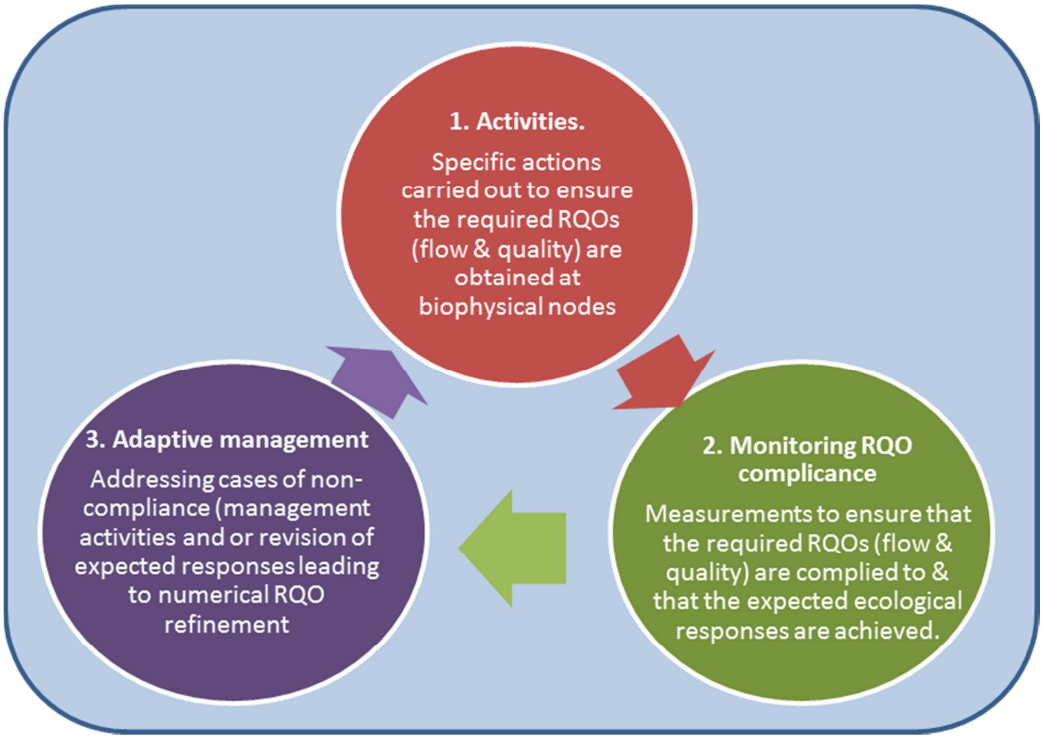
This is best demonstrated through what is needed for the flow RQOs:

- Activity: Release flow from a dam according to set rules.
- Monitoring: Record the flow at flow gauges and compare against Ecological Water Requirement (EWR) flow EWR at a downstream site as well as monitoring related to wastewater discharges affecting the estuaries.
- Adaptive Management: Inform operator to increase flow if target levels are not achieved.

Where the above cycle would typically be carried out at weekly or monthly frequencies a similar process would be followed for ecological variables, however, the cycle period could be annually of once every three years.

Important aspects that should be managed as part of this cycle are the flow of information including recorded (raw) data and information such as reports, meeting proceedings and decisions. This is to build up a history (record) of the implementation process as well as identify “lessons learnt” to strengthen success and improve or adjust activities to achieve the desired results.

Some of the activities needed to fulfil the requirements of the RQO implementation relate to functions that are currently performed by different Directorates in Department Water and Sanitation (DWS) or even other institutions. Coordination among these institutions is essential and the uptake of particular responsibilities relating to these actions need to be formalised and added to their respective business plans. For example, institutions that will typically be involved are water users (e.g. Water Authority Associations and Municipalities) and DWS water resource operating personnel and active conservation bodies. This coordination may be formalised in an appropriate structure similar to a System Operating Forum (SOF) (as set up by DWS in various catchments across the country). Alignment with the activities of the Catchment Management Forums (CMFs) also needs to be established. All these role players need to contribute to the plan by, for example, sharing information and executing their assigned activities.



Core building blocks of the implementation

A RQO implementation must function within the existing environment of water resource management as well as existing monitoring programmes. While the regulation and control of the required RQOs are the responsibility of DWS, CD: WE, certain aspects that could cause violations of the required RQOs may relate to legislation managed and implemented by other Directorates within DWS, or even other government departments. Examples of this are pollution, fisheries management, abstraction and erosion control. It is not the intention of the implementation actions leading to a plan to either duplicate or replace existing legislation and/or institutions that already manage aspects affecting the RQOs, but to rather harness these and inform the relevant authorities that can take action using existing Acts and legislation. The implementation information should therefore allow for the linkages that will initiate the appropriate actions to enforce compliance in accordance with procedures already in place. An example of an important links is with the Estuarine Management Plans.

Implementation of the RQOs to achieve the Water Resource Class (hereafter referred to as the Class) consists of the following primary components:

- Implementing the operating rules in terms of the key driver (hydrology) to ensure that the releases required by users and the ecology are met in time and place. This may consist of operation of dams, abstractions and other infrastructure as well as management through licensing and implementation of restrictions amongst other measures.
- Compliance hydrological monitoring based largely on the continuous monitoring at a network of flow and water level gauges.
- Compliance geohydrological monitoring based on monitoring low flow flows and water levels at gauging weirs and boreholes.
- Implementing water quality source control measures through operation and management of Waste Water Treatment Works (WWTW) and monitoring of effluent quality and volume entering rivers and estuaries, for example. If dam releases are relevant, factors such as releases through multi-level outlets to maintain water quality would be relevant.
- Compliance water quality monitoring based largely on monitoring at gauges and other key points as well as monitoring through implementing agents and municipalities (often by the

developers themselves as part of license conditions) amongst others. Water quality RQOs at EWR sites and associated Resource Units (RUs) are described through Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) for rivers. For estuaries, EcoSpecs and TPCs for water quality are set for river inflow into the estuary, as well as for zones in the estuary.

- Implementation of catchment and non-flow related measures to achieve the Class: In some cases, non-flow (other than quality) related measures are required to achieve the Class's catchment configuration. As these measures may not be the responsibility of DWS to implement and manage, RQOs are provided at a broad level. These measures most often relate to protection of the riparian buffer zone, alien vegetation control and control of erosion and sedimentation.
- Response monitoring (also called resource monitoring in Estuary Management framework) of biota and habitat to determine whether the expected responses described as part of the Reserve and Classification assessments are being achieved. The responses are described at different levels of detail depending on the available information and priority level of the different river reaches. Generally the biota and habitat RQOs are described through EcoSpecs and TPCs where detailed numerical information is available at high priority river reaches (RUs) which contain EWR sites. In the case of estuaries, EcoSpecs and TPC are usually set for all estuaries in a WMA, albeit at different levels of confidence (e.g. EcoSpecs and TPCs set as part of desktop or rapid level assessments are usually of low confidence, while EcoSpecs and TPCs set as part of intermediate or comprehensive level assessments are of medium to high confidence). Where insufficient data is available to set EcoSpecs and TPCs, it is indicated as such. Also note that the response monitoring is dependant on information on the hydrology and water quality compliance monitoring.

Note that the Reserve is encapsulated within the Class and RQOs. The Class and catchment configuration provides the associated EcoStatus for every river reach in the system. The EWRs associated with the accepted Class become the Ecological Reserve. The hydrology, water quality, habitat and biota RQOs therefore include the Reserve requirements. The response monitoring above directly refers to the monitoring of the EcoStatus and therefore by default the Ecological Reserve.

PROPOSED IMPLEMENTATION TO GIVE AFFECT TO THE RQOs

In its most basic form the implementation information tries to answer the following three questions:

- **What** activities are required? i.e. the actions and work that has to be performed and at what intensity or level of detail these should be carried out at.
- **When** should the activities take place? i.e. the frequency of work of activity; and
- **Who** is responsible for ensuring the work or activity are carried out?

It was recognised that the implementation information should take account of the varying characteristics of the river reaches across the Study Area, availability and need for monitoring information, the ability (currently and in the future) to regulate flow in the river reaches as well as the existing water resource management activities taking place or being planned.

The overarching approach to be followed in the execution of the implementation is that a sequence of activities needs to be introduced to accommodate proposed future infrastructure developments, rollout of ongoing water resource management activities such as the verification of the lawful water use as well as seeking alignment with the progressive implementation of the DWS Reconciliation Strategy and the strategies of the Provincial and Local Authorities.

The tables below lists all the activities required for RQO implementation.

Activities milestones and related processes

ID	Activity	Description
1	**Resource Quality Objectives and Class**	
2	Legal Notice.	Published in Gazette and comment period.
3	Promulgation.	Approved by Minister of Water and Sanitation.
4	**Monitoring**	
5	Flow (continuous recordings).	Maintain flow gauges.
6	Water quality (continuous from current activities).	▪ Maintain current DWS and other (e.g. Umgeni Water) water quality monitoring activities. ▪ Identify and maintain monitoring programmes other than DWS and that of Umgeni Water. Ensure that all data are captured in the DWS Water Management System (WMS) database, including microbial data. ▪ Link with the DWS National Microbial Monitoring Programme (NMMP) and ensure that faecal coliform and *E.coli* data can be sourced by the programme.
7	Water quality.	Initiate and maintain additional water quality monitoring points as specified.
8	Fish and macro-invertebrates (every 2 - 3 years).	Standard fish and macro-invertebrate surveys and an update of the Fish Response Assessment Index (FRAI) and Macro Invertebrate Response Assessment Index (MIRAI) to determine any changes in Ecological Category (EC). If TPCs are triggered, the required actions must be undertaken.
9	Diatoms (twice a year).	Diatom analysis to feed into the water quality monitoring programme.
10	Riparian vegetation (every 3rd year).	Specific surveys to determine whether TPCs have been exceeded as well as an update of the Vegetation Response Assessment Index (VEGRAI) to determine any changes in EC. If TPCs are triggered, the required actions must be undertaken.
11	Groundwater monitoring.	▪ Water level monitoring: Monthly to quarterly at existing and (new) monitoring boreholes. ▪ Abstraction monitoring (for large groundwater users): Continuous or aggregated monthly to annually. ▪ Baseflow monitoring continuously at gauging stations and aggregated monthly to provide annual volumes. ▪ Groundwater quality monitoring: quarterly at existing and (new) monitoring sites.
12	**Institutional arrangements**	
13	Establish RQO implementation structures (committee).	Design and establish the institutional structures. This could be in the form of a standalone committee or may be linked to other initiatives.
14	Develop reporting procedures, method and communication products.	This must be linked to the monitoring information and should be concise focussing on reporting compliance with meeting the RQOs.
15	Meetings / compliance reports / adaptive measures.	Application of what is defined in Item 19.
16	**Review RQO and Implementation Plan**	
17	Evaluate effectiveness of activities and	Key activity to ensure the RQO implementation

ID	Activity	Description
	monitoring.	remains relevant.
18	Review RQOs and recommend changes	Recommend when RQOs need to be revised.
19	**Related Parallel Water Resource Management Processes**	
20	Operating Analysis.	
21	Update: Water requirements, maintenance schedules, operational risk analysis.	The information must feed into the water resource model.
22	System Operating Forum – uMngeni System and stand-alone systems.	DWS to continue with forums for operational planning including drought management.
23	Continuation and maintenance of the Reconciliation Strategy.	Revise the timeframes for implementation of water resource development interventions to account for prevailing water balances.

Note: Blue shaded activities are in progress or have been completed for the study area.

Implementation Plan Management Committee

It is recommended that an Implementation Plan Management Committee (IPMC) be formulated to oversee the roll out of the actions of the plan. Since there are already several forums and committees functioning in the study area, it is suggested that the proposed functions of the IPMC be discussed at the existing forums to determine the most suitable institutional arrangements.

The committee's activities will entail coordination of monitoring activities among institutions, evaluation of monitoring information against RQO specifications as well as making recommendation on the required adaptive management measures where noncompliance occurs.

It is anticipated that the majority of the communication amongst the committee members take place electronically, with a meeting held once a year. The meeting will discuss monitoring results obtained in the previous year, as well as set goals and targets to achieve the RQOs for the upcoming year.

DOCUMENTATION

It is necessary to keep record of the implemented actions, monitoring and adaptive management and it is suggested that this take place on an annual basis. The annual implementation plan document will typically include a summary of the previous years' monitoring results. Where deviations occurred, explanations of the adaptive management or corrective measurements should be given. System changes that took place in the previous year should also be documented, as well as specific system operational aspects.

MONITORING

Effective implementation of the Classes and RQOs relies on the availability of relevant monitoring information for tracking progress, evaluating compliance and to identify if and when revisions of the specified stipulation (target criteria) need to be considered. Monitoring requirements are therefore a key component of the plan

MONITORING PROGRAMME FOR THE STUDY AREA

Hydrological compliance monitoring

The DWS has approximately 43 functional flow gauges on the online HYDSTRA database for the study area. There are also numerous flow gauges which have been closed over the years. It is

important that flow monitoring takes place at the EWR sites. Where applicable, gauges that are no longer monitored should be reinstated. Monitoring exists for two main purposes namely:

- Monitoring to confirm whether the required flows at a certain point are being achieved.
- Monitoring to activate a specific action (request for release) should the flows be non-compliant.

Water level monitoring at estuaries

The DWS has eight functional estuary water level recorders on the online HYDSTRA database for the study area (see Table 4.2). It is important that were water levels are being monitored flow gauging also takes place above the estuary. This is only the case for about four of the systems at present ((Mvoti, uMkhomazi, uThongathi and uMdloti (Table 4.1)). Monitoring exists for three main purposes namely:

- Gather information on estuary mouth behaviour and increase confidence in/ the mouth state-flow relationship.
- The monitoring of estuary mouth state to confirm whether the required volume of freshwater inflow is entering the estuary.
- Verify artificial breaching levels.

Groundwater monitoring

Groundwater monitoring timing is as follows:

- Water level monitoring: Water level monitoring is required monthly to quarterly.
- Abstraction monitoring: Abstraction monitoring is by nature continuous, or aggregated monthly to annually.
- Baseflow monitoring: Baseflow monitoring is undertaken continuously at gauging stations and aggregated monthly to provide annual volumes. During wet periods, baseflow can be derived from hydrograph separations.
- Groundwater quality monitoring: Water quality is required quarterly.

A groundwater monitoring plan has been provided that indicates what type of monitoring is essential and the priority.

Water quality compliance monitoring

Water quality monitoring is undertaken monthly or as specified by the current DWS or other (e.g. Umgeni Water) monitoring programme. Monitoring focussing on water quality and diatoms are specific to High Priority river sites (EWR and 3WQ[1] sites for water quality monitoring) and estuaries, but could be applied at any of the RUs or estuaries with lower Priority Ratings (2) where water quality has been identified as an indicator.

Monitoring details for water quality and diatom sampling providing the actions, temporal and spatial scales have been provided below.

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
All variables measured as standard by DWS as a minimum requirement. Umgeni Water sties to continue as current, as a	Include additional variables in the formal DWS and other monitoring programmes as indicated by water	1. Monthly, or as determined by current DWS or other monitoring programme per monitoring	1. Relevant water quality monitoring point or gauging weir. 2. Institute a monitoring

[1] Water quality (WQ) hotspots (designated Priority Rating - 3WQ).

broader range of variables is monitored as compared to DWS sites. Note that temperature and dissolved oxygen should be monitored at all EWR sites as no baseline currently exists for these parameters and they are strongly linked to biotic responses. No data or numeric DWS guidelines exist for turbidity, although Umgeni Water routinely monitors turbidity. Turbidity should be measured where specified and a turbidity database developed. Although *E. coli* and faecal coliforms are not strictly part of ecological monitoring, data should be collected where specified due to current and potential impacts on users. This variable is again monitored by Umgeni Water.	quality RQOs, specifically periphyton chlorophyll-a and diatoms. Include toxics monitoring if specifically mentioned; otherwise cover only if indicated by biotic responses. Include *E. coli* and faecal coliform monitoring as part of the NMMP or other health monitoring programmes, as required and indicated in the Implementation Report.	point. 2. Institute bi-monthly (i.e. twice a month) monitoring if required at High Priority water quality sites with no water quality gauging weir or other monitoring point in place. 3. Institute monthly monitoring of the standard suite of DWS variables, if specified in the Implementation Report, at Moderate Priority RUs where water quality has been identified as an indicator and an existing water quality gauging weir or monitoring point is in place. If not, institute bi-monthly (i.e. twice a month) monitoring as outlined in point 2. 4. *E. coli* and faecal coliform monitoring must be conducted at the frequency required by the NMMP.	point downstream of a High Priority water quality site or at the lower end of a Moderate Priority RU where water quality has been identified as an indicator, if no water quality gauging weir or monitoring point is in place for use. 3. Institute a monitoring point just upstream of estuaries (where this is not covered by an existing monitoring point or where the monitoring point is too far upstream from the estuary.
Diatoms	Collect baseline data to develop EcoSpecs and TPCs.	Six monthly.	All EWR sites and sites were WQ hotspots have been identified.

Although it is recommended that monitoring activities outlined above be conducted at all High Priority and EWR sites as specified, it is understood that the pressure on resources may require prioritization of sites for monitoring purposes. This is particularly important if an information database has to be built before the implementation of RQOs can take place.

Habitat and biota monitoring for estuaries

This monitoring is at lower frequency and usually requires field work. The focus for this monitoring will be at high priority estuaries.

In the table below, a monitoring programme for these activities is provided.

Estuary monitoring programme

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
Sediment dynamics (Estuary)			
Bathymetric surveys:	Series of cross-section profiles and a longitudinal profile collected at fixed 200 - 500 m intervals, but in more detail in the mouth (every 100 m). The vertical accuracy	Every 3 years	Entire estuary

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
	should be about 5 cm.		
Sediment grab samples	Set sediment grab samples (at cross section profiles) for analysis of Particle Size Distribution (PSD) and origin (i.e. using microscopic observations)	Every 3 years (with invert sampling)	Entire estuary
Water quality (Estuary)			
Longitudinal salinity and temperature profiles (in situ)	Collected over a spring and neap tide during high and low tide at: ▪ End of low flow season (i.e. period of maximum seawater intrusion). ▪ Peak of high flow season (i.e. period of maximum flushing by river water).	Seasonally every year	Entire estuary (3 - 10 stations)
Water quality measurements (i.e. system variables, and nutrients)	Take measurements along the length of the estuary (surface and bottom samples).	Seasonal surveys, every 3 years or when significant change in water inflows or quality expected	Entire estuary (3 - 10 stations)
Organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments	Measurements along length of the estuary, where considered an issue.	Every 3 - 5 years	Focus on sheltered, depositional areas
Water quality (e.g. system variables, nutrients and toxic substances)	Measurements on near-shore seawater.	Use available literature	Seawater adjacent to estuary mouth at salinity 35
Microalgae (Estuary)			
Phytoplankton Benthic microalgae	Conduct water column chl-a measurements and counts of dominant phytoplankton groups (incl. flagellates, diatoms, dinoflagellates, chlorophytes and cyanobacteria). Conduct intertidal and subtidal benthic chl-a measurements.	Summer and winter survey every 3 years	Entire estuary (3 - 10 stations)
Macrophytes (Estuary)			
Plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations. Plant cover. Depth	Develop ground-truthed maps. Record number of community types etc. documented during a field visit. Record percentage plant cover, salinity, water level, sediment moisture content and turbidity on a series of permanent transects along an elevation gradient. Take measurements of depth to water table and ground water salinity in supratidal marsh areas.	Summer survey every 3 years	Entire estuary
Invertebrates (Estuary)			
Zooplankton Benthic invertebrates	Record species and abundance of zooplankton, based on samples collected across the estuary at each of a series of stations along the estuary; Record benthic invertebrate	Summer and winter survey every 3 years	Entire estuary (3 - 10 stations)

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
	species and abundance, based on subtidal and intertidal grab samples at a series of stations up the estuary, and counts of hole densities. Measures of sediment characteristics at each station		
Fish (Estuary)			
Species diversity Abundance of fish	Seine net and gill net sampling.	Summer and winter survey every 3 years	Entire estuary (3 - 10 stations)
Birds (Estuary)			
Birds	Full count of all water associated birds, covering as much of the estuarine area as possible, from a boat and on foot.	Annual winter (Jul/Aug) and summer (Jan/Feb) surveys	Entire estuary

1 South African Scoring System version 5.

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ACRONYMS AND ABBREVIATIONS

CD: WE	Chief Directorate: Water Ecosystems
CMF	Catchment Management Forum
CWAC	Coordinated Waterbird Counts
D:RQIS	Directorate: Resource Quality Information Services
DAFF	Department of Agriculture Forestry and Fisheries
DEA	Department of Environmental Affairs
DSS	Decision Support System
DWA	Department Water Affairs (Name change from DWAF applicable after April 2009)
DWAF	Department Water Affairs and Forestry
DWS	Department Water and Sanitation (Name change from DWA applicable after May 2014)
EC	Ecological Category
EcoSpec	Ecological Specification
EFZ	Estuary Functional Zone
EIS	Ecological Importance and Sensitivity
EMP	Estuarine Management Plan
EWR	Ecological Water Requirements
EWRM	Ecological Water Resources Monitoring
FFHA	Fish Flow Habitat
FIFHA	Fish Invertebrate Flow Habitat Assessment
FRAI	Fish Response Assessment Index
ICM	Integrated Coastal Management
IPMC	Implementation Plan Management Committee
IWRM	Integrated Water Resource Management
MIRAI	Macro Invertebrate Response Assessment Index
MMTS	Mooi-Mgeni Transfer Scheme
NBA	National Biodiversity Assessment
NEMA	National Environmental Management Act
NEMP	National Estuarine Management Protocol
NMMP	National Microbial Monitoring Programme
NWRC	National Water Resource Classification
PAR	Photosynthetic Active Radiation
PES	Present Ecological State
PESEIS	Present Ecological State and Ecological Importance -Ecological Sensitivity
PSD	Particle Size Distribution
PTV	Pollution Tolerant diatom Valve
RC	Reference Condition
REC	Recommended Ecological Category
REMP	River EcoStatus Monitoring Programme
RHAMM	Rapid Habitat Assessment Method and Model
RIVDINT	River Data Integration
RQO	Resource Quality Objective
RU	Resource Unit
SANBI	South African National Biodiversity Institute
SASS5	South African Scoring System version 5
SFR	Stream Flow Reduction
SOF	System Operating Forum
SPI	Specific Pollution sensitivity Index
SQ	Sub Quaternary

TDI	Trophic Diatom Index
TEC	Target Ecological Category
TPC	Threshold of Potential Concern
VEGRAI	Vegetation Response Assessment Index
WMA	Water Management Area
WMS	Water Management System
WQ	Water Quality
WWTW	Waste Water Treatment Works

1 INTRODUCTION

1.1 BACKGROUND

There is an urgency to ensure that water resources in the Mvoti to Umzimkulu Water Management Area (WMA); now known as the Pongola to Umzimkulu WMA (however for the purposes of this study the WMA will refer to the original delineation) are able to sustain their level of uses and be maintained at their desired states. The determination of the Water Resource Classes of the significant water resources will ensure that the desired condition of the water resources, and conversely, the degree to which they can be utilised is maintained and adequately managed within the economic, social and ecological goals of the water users (DWA, 2011). The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study during 2012 for the provision of professional services to undertake the Comprehensive Reserve, classify all significant water resources and determine the Resource Quality Objectives (RQOs) in the Mvoti to Umzimkulu WMA.

1.2 STUDY AREA OVERVIEW

The study area encompasses a total catchment area of approximately 27,000 km^2 and is situated within Kwazulu-Natal. A small portion of the Mtamvuna River and the upper and lower segments of the Umzimkulu River straddle the Eastern Cape, close to the Mzimvubu and Keiskamma WMA in the south (DWA, 2011).

The WMA extends from the town of Zinkwazi, in the north to Port Edward and on the south along the KwaZulu-Natal coastline and envelopes the inland towns of Underberg and Greytown also incorporating the Drakensberg escarpment. The WMA spans across the primary catchment “U” and incorporates the secondary drainage areas of T40 (Mtamvuna River in Port Shepstone) and T52 (Umzimkulu River). Ninety quaternary catchments constitute the water management area and the major rivers draining this WMA include the Mvoti, uMngeni, uMkhomazi, Umzimkulu and Mtamvuna (DWA, 2011).

Two large river systems, the Umzimkulu and uMkhomazi rise in the Drakensberg. Two medium-sized river systems the uMngeni and Mvoti rise in the Natal Midlands and have been largely modified by human activities, mainly intensive agriculture, forestry and urban settlements. Several smaller river systems (e.g. Mzumbe, uMdloti, uThongathi, Fafa, and Lovu Rivers) are also present within the WMA (DWAF, 2004). Several parallel rivers arise in the escarpment and discharges into the Indian Ocean and the water courses in the study area display a prominent southeasterly flow direction (DWA, 2011). The WMA is very rugged and very steep slopes characterise the river valleys in the inland areas for all rivers and moderate slopes are found but comprise only 3% of the area of the WMA (DWAF, 2004).

1.3 INTEGRATED STEPS APPLIED IN THIS STUDY

The integrated steps for the National Water Classification System, the Reserve and RQOs are supplied in Table 1.1.

Table 1.1 Integrated study steps

Step	Description
1	Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s).
2	Initiation of stakeholder process and catchment visioning.
3	Quantify the Ecological Water Requirements and changes in non-water quality ecosystem.
4	Identification and evaluation of scenarios within the Integrated Water Resource Management process.
5	Evaluate the scenarios with stakeholders and determine Water Resource Classes.
6	**Develop draft RQOs and numerical limits.**
7	**Gazette and implement the class configuration and RQOs**.

1.4 PURPOSE AND OUTLINE OF THIS REPORT

The report focuses on providing information that can be used towards implementation as part of National Water Resource Classification (NWRC). **It must be noted that an implementation plan should form part of Integrated Water Resource Management and as such, the information provided in this report does not constitute an implementation plan but information that can be used for implementation. Focus will be on actions and steps that should form part of an implementation plan** Monitoring information to be used in monitoring programmes to measure whether the RQOs are being achieved is also provided.

The intention is to provide information that will guide the development of detailed business plans of relevant DWS directorates incorporating the availability of budgetary and human resources to define and schedule activities and set execution priorities.

A key factor for successful implementation will be to establish appropriate coordination mechanisms among all relevant institutions involved in water resource management to ensure efficient utilisation of existing resources and prevent the duplication of aspects such as monitoring. DWS will take the leading role in formalising the appropriate links with the institutions. Since the exact outcomes of the institutional structures will only follow from these engagements it will be premature to provide prescriptive details on what the institutional arrangements should be at this stage.

The report outline is provided below.

Chapter 1: Introduction
This Chapter provides general background to the project.

Chapter 2: RQO Implementation: Generic
This chapter discusses in general the context and components of an RQO implementation actions and information generated as part of NWRCS.

Chapter 3: RQO Implementation actions for the Study Area
The generic implementation actions presented in Chapter 2 is applied to the Study Area and presented in this chapter. The different components of the plan are provided, the linkages as well as a proposed conceptual timeline for the applications of the actions included in the Implementation Plan.

Chapter 4: Hydrological and Groundwater and Estuarine Water Level monitoring
The hydrological, groundwater and estuarine hydrodynamic requirements for the Study Area are presented.

Chapter 5: Water quality monitoring
The water quality monitoring programme linked to two different levels of monitoring detail is presented.

Chapter 6: Estuaries Habitat and Biota monitoring
This section describes the principles of a monitoring programme that measures the Ecological Categories (ECs) as signed off as part of the Water Resource Class. The focus of this chapter is on the biological monitoring specific to the high priority estuaries.

Chapter 7: References

Chapter 8: Appendix A: Report Comments
Comments from reviewers are listed.

2 RQO IMPLEMENTATION: GENERIC

2.1 CONTEXT OF RQO IMPLEMENTATION

The RQO implementation actions will function within the current Integrated Water Resource Management (IWRM) and regulatory environment and therefore integration of activities with existing processes should be an overarching principle for developing an implementation plan. This will prevent duplication of functions aimed at efficient utilisation of human, infrastructure and financial resources.

The relevant elements of this environment are:

- Water resource management functions performed by DWS and other institutions.
- Regulatory and control functions relating to both the water and ecological environments.
- Legal framework within which the above functions.

Integrated Water Resource Management in this context encompasses planning, operational and maintenance of the water resource systems, where the following activities have links with the RQO implementation:

- **Water resource development planning informed by:**
  - Reconciliation Strategies (planning of interventions to increase availability and reduce water use through loss control and efficiency measures).
  - Feasibility studies and construction of infrastructure options; and
  - International agreements and treaties.
- **Operational planning an implementation:**
  - Operating Analysis providing decision support information;
  - The planning and execution of infrastructure maintenance activities influences operational decisions and feeds into the above function; and
  - Operation and control of infrastructure on a daily basis. This is particularly relevant to achieve required flow regime specified in the RQO.
- **Maintenance (planning and execution)** of infrastructure influences operational decisions and feeds into the operational functions (monitoring is an important component that needs to feed into this process).
- **Regulatory and control functions** can loosely be grouped as those carried out by DWS and other national and local authorities.

The DWS regulatory functions are:

- Water use (all types) abstraction control and enforcement.
- Water pollution prevention, control and enforcement; and
- Monitoring, Auditing and reporting.

The Department of Environmental Affairs (DEA) regulatory aspects (with some of these functions devolved to provincial agencies) relating to RQO implementation are:

- Environmental Impact Assessments (National Environmental Management Act - NEMA).
- Estuarine Management Planning (Integrated Coastal Management (ICM) Act).
- Conservation planning (Biodiversity Act); and
- Protected Areas (Protected Areas Act).

The Department of Agriculture Forestry and Fisheries (DAFF) regulatory aspects (with some of these functions devolved to provincial agencies) related to RQO implementation are:

- Fisheries management, control and enforcement.
- Mariculture.
- Agriculture.

The district and metropolitan municipality regulatory aspects related to ROQ implementation are:

- Recreational water quality (National Health Act 2003).

The legal framework or mandates within which the RQO implementation will exist are provided by the Water and Environmental resources acts that stipulate the responsibilities of the government departments as well as how water users and developers are regulated when performing certain activities. These regulating processes and their compliance enforcement procedures will be methods of how corrective measures can be enforced.

2.2 COMPONENTS OF A RQO IMPLEMENTATION ACTIVATES TOWARDS IMPLEMENTATION

The RQO **implementation plan** consists of three components namely:

- Firstly activities ensuring that the RQOs determined are **adhered** too (e.g. releasing or transferring water usually from storage).
- Secondly, **monitoring** (measuring) various aspects in order to determine whether or not the required RQOs are met or the resulting ecological health objectives are achieved; and
- Lastly, if the intended outcomes are not observed from the monitoring process, **adaptive management** needs to take place in order to rectify the situation such that the desired RQOs are met. Figure 2.1 presents a simplified schematic of these three components, indicating a circular flow of information.

This is best demonstrated through what is needed for the flow RQOs:

- Activity: Release flow from a dam according to set rules.
- Monitoring: Record the flow at flow gauges and compare against Ecological Water Requirement (EWR) flow EWR at a downstream site as well as monitoring related to wastewater discharges affecting the rivers and estuaries.
- Adaptive Management: Inform operator to increase flow if target levels are not achieved.

Where the above cycle would typically be carried out at weekly or monthly frequencies a similar process would be followed for ecological variables, however, the cycle period could be annually of once every three years.

Important aspects that should be managed as part of this cycle are the flow of information including recorded (raw) data and information such as reports, meeting proceedings and decisions. This is to build up a history (record) of the implementation process as well as identify “lessons learned” to strengthen success and improve or adjust activities to achieve the desired results.

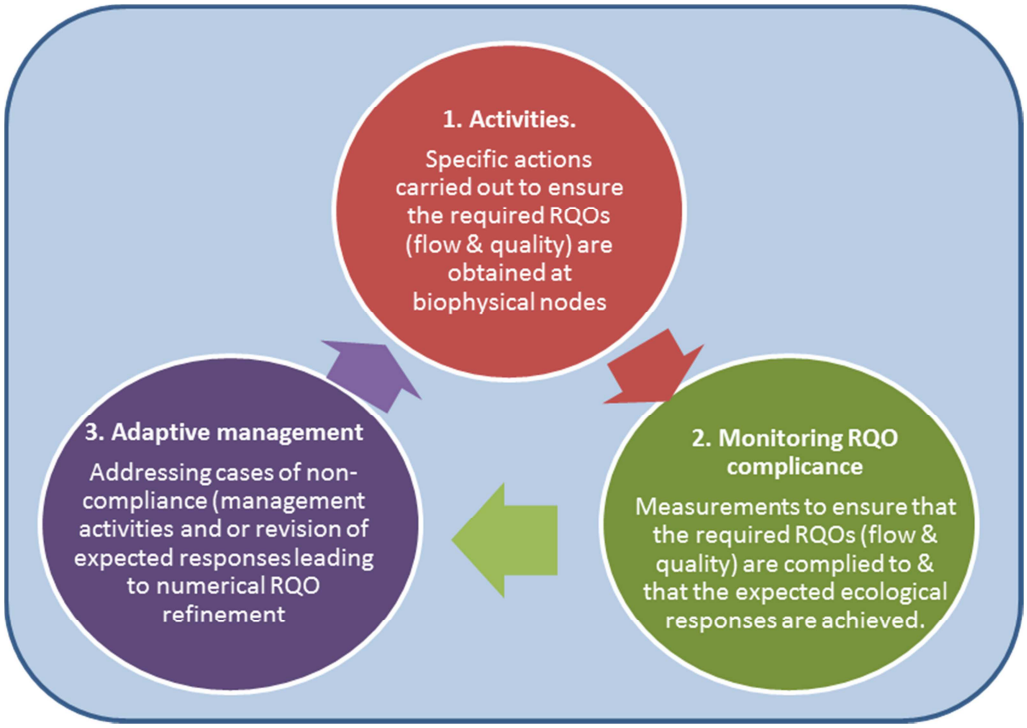

Figure 2.1 Core building blocks of the implementation

Some of the activities needed to fulfil the requirements of the RQO implementation relate to functions that are currently performed by different Directorates in DWS or even other institutions. Coordination among these institutions is essential and the uptake of particular responsibilities relating to these actions need to be formalised and added to their respective business plans. For example, institutions that will typically be involved are water users (e.g. Water Authority Associations and Municipalities) and DWS water resource operating personnel and active conservation bodies. In the case of the estuaries, coordinated managed is further facilitated through the development of individual estuary managed plans and the establishment of estuary forums. This coordination may be formalised in an appropriate structure similar to a System Operating Forum (SOF) (as set up by DWS in various catchments across the country). Alignment with the activities of the Catchment Management Forums (CMFs) also needs to be. All these role players need to contribute to the plan by, for example, sharing information and executing their assigned activities.

The monitoring of estuary RQOs is supported by the DWS National Estuarine Monitoring Programme. The objective of the programme is to measure, assess and report on a regular basis on the status and trends of the nature and extent of the condition of South African estuaries in a manner that will support strategic management decisions to ensure sustainable use of estuaries and ensure ecosystem integrity, being mindful of financial and capacity constraints, yet be soundly scientific. The programme aims to collect relevant, consistent and reproducible long-term data to facilitate information generation and dissemination for the future integrated national, regional and local management of South African estuaries. It will also strive to inform the Estuary Heath Index used on a national scale within the Classification context. Eventually the programme will compare the health of South African estuaries on a temporal and spatial scale. The programme has three tiers. Tier 1 focuses on basic abiotic data, Tier 2 makes use of the methods used for determining estuarine freshwater inflow requirements while Tier 3 is usually of a short temporal scale and dependent on the issue at hand such as a sewage spill or fish kill.

RQO implementation must function within the existing environment of water resource management as well as existing monitoring programmes. While the regulation and control of the required RQOs are the responsibility of DWS CD: WE, certain aspects that could cause violations of the required RQOs may relate to legislation managed and implemented by other Directorates within DWS, or even other government departments. Examples of this are pollution, fisheries management, abstraction and erosion control, mining activities, forestation etc. It is not the intention of the implementation activities to either duplicate or replace existing legislation and/or institutions that already manage aspects affecting the RQOs, but to rather harness these and inform the relevant authorities that can take action using existing acts and legislation. The plan should therefore allow for the linkages that will initiate the appropriate actions to enforce compliance in accordance with procedures already in place. In the light of this and the important link between Classification and RQO implementation for the water resources in this CMA, background and detail are provided regarding Estuarine Management Plans.[2]

2.2.1 Estuary Management Plans

Estuarine Management Plans as mandated by the ICMA (Act 24, 2008), the act provides the platform for an integrated approach to protect and manage estuaries on a local scale and is an important means towards implementation of RQO related to estuaries. South Africa's estuaries have a diversity of management requirements, often unique to individual systems, and are governed by a variety of authorities, from national to local level. Therefore, estuary management must allow for a dynamic process that facilitates integrated cross-sectorial planning and implementation including stakeholders involved in land-use planning, management of freshwater and marine resources, amongst others.

Consequently, it was necessary to develop a flexible, but legally defensible National Estuarine Management Protocol (NEMP) providing guidance to estuarine managers at all levels to develop sound management plans to suit individual systems. South Africa's NEMP was published in May 2013. The NEMP sets out to:

- Determine a strategic vision and objectives for achieving effective integrated management of estuaries.
- Set standards for management of estuaries.
- Establish procedures and provide guidance regarding how estuaries must be managed and how the management responsibilities are to be exercised by different organs of state and other parties.
- Establish minimum requirements for estuarine management plans.
- Identify who must prepare estuarine management plans and the process to be followed in doing so; and
- Specify the process for reviewing estuarine management plans to ensure that they comply with the requirements of the ICM Act.

In the case of estuaries, protection is not only effected by localised management actions but also through ensuring adequate quantity and quality of freshwater flows into the estuary. Future flows into an estuary will be decided on the basis of its Target Ecological Category (TEC) determined under the National Water Resources Classification System. The outcome of the Classification process therefore informs and supports other estuary planning initiatives, and products developed as part of this process are aligned as much as possible with other management initiates. In turn,

[2] Note that no such plans exist for rivers.

the interventions required to achieve a TEC and the monitoring actions required to measure if such targets are achieved, will be taken up in individual Estuary Management Plans.

The NEMP provides a list of key management standards that must be adhered to in the management of any estuary. These must be considered as the Objective setting phase, specifically in terms of the management objectives and associated activities. These management standards are as follows:

- Estuarine management must aim at best practice in term of the use, management and protection of estuaries based on **principles of ecological sustainability and co-operative governance.**
- Estuarine management planning must consider the predicted impacts of climate change and management of potential disasters including pollution events.
- Integration of land use planning and natural resource management outcomes with estuarine management outcomes must be promoted.
- Management actions (or activities) should be based on sound scientific evidence and where lacking the precautionary approach should prevail.
- An estuary must be managed to **avoid, minimise or mitigate significant negative impacts that include, but are not limited to, reduced water flows and loss of habitat or species**;
- An **estuary must be maintained in its ecological category as determined in the 2011 National Biodiversity Assessment (NBA) and subsequent updates** in order to meet biodiversity targets, and to take into account the recommended extent of protection and recommended ecological health category.[3]
- **The classification and setting of the Ecological Reserve and RQO of an estuary must take into account current ecological health status, recommended extent of protection and recommended ecological category in order to meet the biodiversity targets as set in the 2011 NBA and the subsequent updates.**

2.2.2 Estuary institutional structures for implementation of EMPs

The *Guidelines for the Development and Implementation of Estuarine Management Plans in terms of the National Estuarine Management Protocol* (DEA, 2015) recognises that effective institutional structures and arrangements are crucial support elements for the successful implementation and coordination of activities in and around estuaries as set out in individual Estuarine Management Plan (EMP). The individual EMPs should, in turn, encapsulate the findings and recommendations of this study. In this light the Protocol requires that the EMP includes details on the institutional capacity and arrangements that will be required for managing the various elements of an EMP, taking into account different departmental mandates.

Chapter 5 of the ICM Act provides direction on institutional arrangements that would contribute to cooperative coastal governance in South Africa. According to the ICM Act, the embodiment of cooperative coastal governance is vested in coastal committees that are established at national, provincial and municipal levels. The Protocol does not propose new institutional arrangements specifically aimed at estuarine management. Rather the Protocol states that provincial and municipal coastal committees shall serve as the forums for monitoring the implementation of EMPs and reporting of progress and achievements related to EMPs. While coastal committees are suitable forums for monitoring the implementation of EMPs and reporting on progress and achievements related to these plans, successful implementation and coordination of management activities do require detailed technical coordination and cooperation amongst responsible

[3] It is acknowledged that this bullet is contradictory to the other bullets as well as to the aims of Classification.

authorities and other key role players. In the above context, it remains crucial that the estuarine management authorities provide specific details on the institutional arrangements that they propose, specifically dealing with the technical cooperation and coordination in estuarine management.

An institutional model that can be considered for stronger technical coordination and cooperation is the National Estuaries Management Sub-Committee (an advisory body to Working Group 8). This Working Group provides government authorities (and other key role players) with management responsibilities, the opportunity to coordinate activities and to address disputes or uncertainties that may arise during implementation. Also, it provides a platform through which to optimise the use of limited resources in the execution of the management actions as set out in the EMP. When addressing details on these institutional arrangements for a specific estuary, it is also critical that capacity constraints (both in terms of capacity and skills) be highlighted and that proposed solutions to address those constraints are explored.

Continuous stakeholder engagement will remain critical even during the Implementation phase of the EMP as local stakeholders fulfil the important role of being watchdogs or custodians. The Protocol recognizes existing estuary forums. These are regarded as informal advisory bodies towards the effective facilitation and implementation of project plans (to be developed as part of the Implementation Phase). Also, they foster continuous stakeholder engagement. It is strongly recommended that the management authority considers the continuation or establishment of an advisory stakeholder body in their area to fulfil the above role in the spirit of participatory, cooperative governance promoted by NEMA and the ICM Act.

2.3 IMPLEMENTATION COMPONENTS

Implementation of the RQOs to achieve the Water Resource Class (hereafter referred to as the Class) consists of the following primary components:

- Implementing the operating rules in terms of the key driver (hydrology) to ensure that the releases from infrastructure required by users and the ecology are met in time and at EWR site. This may consist of the operation of dams, abstractions and other infrastructure as well as management through licensing and implementation of restrictions amongst other measures.
- Compliance hydrological monitoring based largely on the continuous monitoring at a network of flow and water level gauges.
- Compliance geohydrological monitoring based on monitoring low flow flows and water levels at gauging weirs and boreholes.
- Implementing water quality source control measures through operation and management of Waste Water Treatment Works (WWTW) and monitoring of effluent quality and volume entering rivers and estuaries, for example. If dam releases are relevant, factors such as releases through multi-level outlets to maintain water quality would be relevant.
- Compliance water quality monitoring based largely on monitoring at gauges and other key points as well as monitoring through implementing agents and municipalities (often by the developers themselves as part of license conditions) amongst others. Water quality RQOs at EWR sites and associated Resource Units (RUs) are described through Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) for rivers. For estuaries, EcoSpecs and TPCs for water quality are set for river inflow into the estuary, as well as for the longitudinal zones in the estuary.
- Implementation of catchment and non-flow related measures to achieve the Class: In some cases, non-flow (other than quality) related measures are required to achieve the Class's

catchment configuration. As these measures may not be the responsibility of DWS to implement and manage, RQOs are provided at a broad level. These measures most often relate to protection of the riparian buffer zone, alien vegetation control and control of erosion and sedimentation.

- Response monitoring (also called resource monitoring in Estuary Management framework) of biota and habitat to determine whether the expected responses described as part of the Reserve and Classification assessments are being achieved. The responses are described at different levels of detail depending on the available information and priority level of the different river reaches. Generally the biota and habitat RQOs are described through EcoSpecs and TPCs where detailed numerical information is available at high priority river reaches (RUs) which contain EWR sites. In the case of estuaries, EcoSpecs and TPC are usually set for all estuaries in a WMA, albeit at different levels of confidence (e.g. EcoSpecs and TPCs set as part of desktop or rapid level assessments are usually of low confidence, while EcoSpecs and TPCs set as part of intermediate or comprehensive level assessments are of medium to high confidence). Where insufficient data is available to set EcoSpecs and TPCs, it is indicated as such. Also note that the response monitoring is dependant on information on the hydrology and water quality compliance monitoring.

Note that the Reserve is encapsulated within the Class and RQOs. The Class and catchment configuration provides the associated EcoStatus for every river reach in the system. The EWRs associated with the accepted Class become the Reserve. The hydrology, water quality, habitat and biota RQOs therefore reflect Reserve requirements. Response monitoring directly refers to the monitoring of the EcoStatus and therefore by default the Ecological Reserve.

More details are provided in the section below. The chapters that follow discuss the implications and requirements for the water resources within the study area.

2.4 HYDROLOGICAL IMPLEMENTATION

The hydrological implementation relates to achieving the required temporal and spatial flow as specified by the RQOs. This requires a complete understanding of the water balances, hydrology and water resource infrastructure as it relates to the specific characteristics of the water resource system.

A broad categorisation of river reaches (including the river reach just above an estuary) is made to inform the development of an implementation plan and to identify what key activities are needed for implementation. The flow regime needed to achieve the ecological conditions defined by the recommendations, Class and Ecological Category (EC) at each biophysical node is the result of a combination of the following influences:

- Upstream water use including river abstractions with or without restriction rules, return flows (discharges), transfers into and out of the catchment, streamflow reduction, and regulating storage dams.
- Release rules from dams to support water abstractions along the river reach.
- Release rules from dams to support downstream dams.
- Releases in addition to the above, specifically to achieve the stipulated ecological conditions. These are from existing dams as well as proposed dams that were part of the recommended scenario.

Since flow measurements are often limited, simulation models are used to generate representative flows in tributaries and at all identified biophysical nodes including EWR sites. Models therefore

play an essential role in the hydrological component of the RQO implementation plan. Such a simulation model should be applied as an active decision support tool in order to manage releases and abstractions, typically on a monthly time scale where necessary. Using a combination of actual flow data and modelling results is key to both the operational flow management as well as to ensuring the integrity of the model to represent the physical system as close as possible.

2.5 HYDROLOGICAL COMPLIANCE MONITORING

Two main forms of monitoring need to be carried out in order to ensure that set hydrological flows are complied with, namely: monitoring of flows in the rivers and metering of abstractions from the rivers. This is not always possible in all categories of river reaches and is highly dependant on the locations of existing flow gauges. The water resources simulation model can assist in determining impacts on flows for various changes in landuse (e.g. increased irrigation abstractions upstream of a biophysical node) in cases where flow measurements are not available. Should the model results indicate substantial deviations from the target flows, recommendations for additional ecological monitoring can be made to ascertain if adaptive measures are required.

2.6 WATER QUALITY IMPLEMENTATION

For rivers the implementation of RQOs at this level includes activities independent of flow or not affected by flow, although it is understood that polluting activities are exacerbated by lower flows. This level of implementation would therefore not include meeting water quality RQOs through the initiation of a particular flow release, but rather a change in polluting activity which could or would result in meeting a RQO. However for estuaries, water quality RQOs can include both flow and non-flow related activities. For example, salinity penetration in estuaries are strongly influenced by flow, while nutrient enrichment is typically associated with non-flow related activities such as WWTW effluent, agricultural return flow or contaminated urban stormwater runoff.

In the case of point source pollution source (e.g. WWTW effluents), actions to meet water quality (WQ) RQOs can be addressed through discharge licenses or permits (e.g. issued under the National Water Act [rivers] or the ICM Act [estuaries]). These licenses or permits set quantitative limits for effluent volume and composition, e.g. *Escherichia coli,* faecal coliform. Meeting such limits may mean meeting instream objectives, for example specified as risk levels used by SA's National Microbial Monitoring Programme (NMMP). In the same way reducing inorganic nutrient (e.g. nitrogen and phosphate) levels in effluent discharges may mean meeting the instream RQO set downstream driven by aquatic ecosystem requirements.

This level of implementation may also include activities which are linked to non-point pollution sources. For example, a quarry in the riparian zone of a river may cause increases in instream turbidity levels and silting of instream habitats during rain events. If a turbidity RQO had been identified for the downstream reach, it may not be met most of the time. Closure of this quarry is a management activity or intervention which would then result in possibly meeting the RQO. Note that a turbidity database and detailed guidelines are not yet available in South Africa for rivers or estuaries, meaning that turbidity RQOs are often not immediately applicable on a numerical basis.

As RQOs are set at specific points in the river and for different zones in the estuary, it means that all polluting activities upstream of the monitoring point may contribute to not meeting an instream RQO. However, if license or permit conditions are met by all point source discharges and the RQO is still not met, it is likely that non-point source pollution may be taking place (e.g. agricultural return flow or contaminated urban stormwater runoff) or that the RQO is unrealistic and has to be revised. The latter scenario is possible as RQOs are often set even though baseline data were not available

for consideration, particularly at High priority RUs in rivers that are driven by water quality importance and are not EWR sites, or are estuaries where RQOs were set as part of a low confidence desktop or rapid EWR assessment.

High and low frequency monitoring for rivers has therefore been defined, as well as the timing of the applicability of RQOs. If a site has been identified as a High Priority RU from a water quality perspective due to water quality importance (referred to as a 3WQ site), e.g. Mbokodweni (U60E-04792), Manzimtoti and the Little aManzimtoti (U70F-04845 and U70F-04893), with measurable water quality RQOs specified but no current instream monitoring taking place, the RQOs set for this RU could be separated into first phase vs. second and third phase monitoring activities if the site is prioritized for monitoring.

First phase (short-term) activities would include setting up a monitoring programme for specified RQOs (as outlined in the monitoring programme), with data collection stretching into the medium-phase, and measurement against the RQOs being the long-term phase. The priority level of the site would also determine when monitoring would be initiated to develop a database of information.

To summarize, implementation of RQOs over a medium to long-term will be valid under a number of circumstance, e.g. where no or little instream data exists and additional monitoring is required, or where instream objectives cannot be immediately met. The former may refer to specific areas (as indicated in the RQO report), and is normally the case with variables such as turbidity, toxic substances, faecal coliforms and *E.coli*, while the latter may refer to areas under high impact, e.g. the Sterkspruit (U60C-04556) part of the upper uMlazi, where industries and a range of other land-use activities have resulted in a highly impacted water quality state. It is acknowledged that the immediate implementation of water quality RQOs in a highly stressed and economically important area such as this would not be feasible over a short period, and that improvement over time would be needed. Problem areas have therefore not been included in the immediately applicable list of RQOs to be gazetted.

The TEC is a D Category for the Sterkspruit Sub Quaternary (SQ) reach, and the implementation of water quality RQOs would need to ensure that further degradation below the D Category does not take place. Note that instream monitoring is also required in a number of areas to test the validity of the RQOs that have been set. Due to the dearth of water quality data in some areas, and a general lack of Reference Condition (pre-impacted sate) data, RQOs have been set based on best available information and stakeholder input. Monitoring over time may also indicate that a revision of the RQO may be needed.

2.7 WATER QUALITY COMPLIANCE MONITORING

2.7.1 Rivers

Monitoring for water quality compliance is focussed at the level of the EWR sites for rivers, where detailed EcoSpecs and TPCs have been provided through the Reserve process. This detail is usually only available at RUs containing, or associated with EWR sites. As water quality is a driver, implementation of RQOs is also linked to habitat and biotic response monitoring. The monitoring programme will also indicate if monitoring for certain variables, e.g. a particular toxic, should only take place in response to biotic indicators, where already being assessed as part of the existing DWS programme, or where a specific toxic has been mentioned in the water quality RQOs.

Compliance monitoring will normally take place at an existing monitoring point linked to an EWR site, e.g. a DWS gauging weir, but as databases do not exist for all variables even at these points, short-term vs. medium and long-term monitoring activities against RQOs may still be specified. The collection of riverine data to set up a database is generally linked to the following water quality variables for which little data often exists - turbidity, toxics, faecal coliforms and *Escherichia coli* – although not limited to these variables. Note that these variables are generally monitored at Umgeni Water monitoring points, but not DWS gauging weirs.

Note the following should new monitoring points need to be set up: All existing monitoring points (not only those linked to the DWS chemical monitoring programme) should be identified before new monitoring points are set up, as existing points, e.g. linked to compliance monitoring for an industry or municipality, could be used as long-term points. New monitoring points are generally linked to 3WQ or Moderate Priority sites where water quality has been identified as an issue, as data from DWS gauges have been used for the present state assessment at EWR (High Priority) sites, and should therefore be used for compliance monitoring at these points. Additional monitoring might be flagged at EWR sites as not all variables are monitored at the same intensity. Points used by the NMMP as an indicator site should also be identified, in case of overlap with identified sites for faecal coliforms / *E. coli* monitoring.

Medium and long-term activities may be linked to a specific proposed activity in an area, e.g. the building of a dam, which would be expected to affect water quality state, or a current activity (e.g. industrial or urban impacts) known to have a significant impact on water quality state which would need long-term intervention for improvement. These RQOs would therefore only be implemented once the dam becomes operational, or be treated as longer-term goals for heavily impacted areas where water quality improvement could only be achieved over time. This principle would apply to all sites affected by the activity, and would not be restricted to only EWR sites.

An important aspect of water quality monitoring is methods and data quality, including the length of data records used for compliance monitoring. Although the use of percentiles of water quality data is acceptable practise for statistically summarizing data, it is necessary to define data quality and length of an acceptable data record when calculating percentiles. When compliance to a percentile is evaluated, it is important to know the associated statistical confidence of the data, and therefore the confidence in the result. Detail is provided in Section 3.2 of the Rivers RQO Report around data confidence. Guidelines regarding data frequency and hence quality are taken from DWAF (2008).

The general rule for data selection is the following:
Select the RC (or Reference Condition/natural state) data as the ***first*** *3 - 5 years (****minimum of 60 data points for high confidence, 25 samples for moderate confidence and 12 samples for low confidence****) of the data record, and the PES (or Present Ecological State) as the* ***last*** *3 - 5 years of data (again a minimum of 60, 25 or 12 data points for difference confidence levels). The monitoring point suitable for RC must therefore either be in an unimpacted tributary (this can be in an adjacent catchment, but in the same Level II EcoRegion) or a very early data record (e.g. from the 1960s – early 1980s). It is possible to use the same monitoring point for RC and PES data, if the appropriate data record is available. Note that although a low confidence desktop assessment can be run using 12 data points, these points should preferably be spread across the hydrological cycle. Alternatively, weekly monitoring over a 60 day period can be undertaken.*

Note that data collected for compliance monitoring at EWR sites must be taken from the same site used for the Reserve study. In most instances in this study area, data should be collected from Umgeni Water monitoring points, as they routinely analyse for a wide range of variables (including turbidity).

2.7.2 Estuaries

For estuaries, monitoring for water quality compliance focuses on river inflow near the head of an estuary, as well as a selection of stations along the length of an estuary. Detailed EcoSpecs and TPCs have been provided for river inflow, as well as zones in the estuary through the Reserve process. These are typically prepared for all selected estuaries in a WMA, albeit at different levels of confidence (e.g. EcoSpecs and TPCs set as part of desktop or rapid level assessments are usually of low confidence, while EcoSpecs and TPCs set as part of intermediate or comprehensive level assessments are of medium to high confidence).

Monitoring of river inflow (together with monitoring of point source discharges into estuaries) comprises the basic components of water quality compliance monitoring in estuaries, typically undertaken at weekly to monthly intervals. Quality of river inflow normally takes place at an existing monitoring point upstream of the estuary, e.g. a DWS gauging weir, typically collected at monthly intervals. However, in several cases existing gauging weirs are too far upstream to represent inflow to the estuary or are not in existence. Currently, monitoring at existing river inflow stations do not include all relevant water quality variables, such as suspended solids, toxic substances and microbiological indicators (e.g. *Escherichia coli*) – although not limited to these variables. Therefore, monitoring activities to expand river inflow monitoring stations, as well as to collect data on variables currently not measured at such stations – both existing and future - may still need to be specified.

Water quality compliance monitoring in estuaries (estuarine monitoring) can vary from seasonally to every three years (as dictated by the DWS National Estuarine Monitoring Programme). Estuarine monitoring is currently not a routine activity of the DWS, nor other national departments (e.g. DEA). Where routine estuarine monitoring activities do occur it is undertaken by management authorities (e.g. SANParks), provincial authorities (e.g. Western Cape Province Environmental department) or local authorities (e.g. eThekwini Municipality), but including only a limited selection of water quality variables. More recently the DWS (Directorate: Resource Quality Information Services (D:RQIS)) commenced with the role out of a national estuarine water quality monitoring programme, initially including a limited selection of systems across the country. Therefore, implementation of water quality compliance monitoring activities in estuaries still needs to be specified by the DWS, in collaboration with other responsible authorities (e.g. management authorities, DEA, and provincial and local authorities). It is strongly recommended that the estuarine management planning process (a requirement under the ICM Act), be used as a vehicle to coordinate the implementation of these compliance monitoring activities.

The general rule for data selection is the following:
Select the RC (or Reference Condition/natural state) data as the ***first*** *3 - 5 years (****minimum of 60 data points for high confidence, 25 samples for moderate confidence and 12 samples for low confidence****) of the data record, and the PES (or Present Ecological State) as the* ***last*** *3 - 5 years of data (again a minimum of 60, 25 or 12 data points for difference confidence levels). The monitoring point suitable for RC must therefore either be in an unimpacted tributary (this can be in an adjacent catchment, but in the same Level II EcoRegion) or a very early data record (e.g. from the 1960s – early 1980s). It is possible to use the same monitoring point for RC and PES data, if*

the appropriate data record is available.

Note that although a low confidence desktop assessment can be run using 12 data points, these points should preferably be spread across the hydrological cycle. Alternatively, weekly monitoring over a 60 day period can be undertaken.

2.8 IMPLEMENTATION OF THE CLASS THROUGH NON FLOW-RELATED MEASURES

Some desktop biophysical nodes in rivers require improvement in the ecological status to achieve the Recommended Ecological Category (REC). This improvement is based on a high Ecological and/or Socio-Cultural importance. Specific to this section, are those RUs that require improvement through non flow-related measures. These relate to catchment activities other than flow or water quality changes that impact on the riparian zone. Impacts can be directly in the riparian zone, such as removal of vegetation for e.g. fire wood or to create fields for planting crops, alien vegetation infestation or indirectly through e.g. agricultural practices or other activities that result in erosion, sedimentation etc. Water quality from outside sources as well as irrigation return flows can also be seen as non-flow related measures, but are dealt with under water quality.

The actions required to achieve the improvement are identified at a broad level only due to the desktop level information that is available at these nodes. This information as well as the largely narrative RQOs that have been determined can then be conveyed to the appropriate authorities if outside of DWS for the necessary action to be undertaken, possibly following more detailed studies.

It is acknowledged that some of the catchment management actions required are difficult to implement and would require the efforts of various institutions.

Similarly, some estuaries require improvements in the ecological status to achieve the TEC, based on either a high ecological or socio-economic (e.g. recreational use) importance. Specific to this section, are those estuaries that require improvement through non flow-related measures.

The following types of non-flow related interventions were identified as important requirements in meeting the objectives of estuaries and are all relevant for this study area:

- Water quality interventions include the management of stormwater and agricultural return flow and improving or reducing the quality and quantity of WWTW discharges (see Chapter 2).
- A number of estuaries showed the need for interventions by provincial and local authorities' authority that deals with land-use planning to apply and enforce estuary set-back lines (e.g. Estuary Functional Zone (EFZ)) to ensure protection of estuary riparian zone. This includes the need for rehabilitation of estuarine riparian area and flood plains to ensure estuarine functionality.
- Some of the medium to larger size estuaries were highlighted as in need of control/reduction in fishing pressure through fisheries management initiatives (e.g. ban on night fishing, increase compliance monitoring, improved zonation).
- The regulation of artificial breaching by provincial authorities to ensure that premature breaching do not interrupt natural estuary cycles, e.g. nursery function in winter.

Similarly, wetland problems are mostly associated with destruction of habitat and not with changes in flow in these catchments.

2.9 HABITAT AND BIOTA RESPONSE MONITORING

2.9.1 Introduction: The relationship between EcoSpecs, habitat and biota RQOs

RQOs and EcoSpecs are specified and both are relevant for monitoring. For the purpose of RQO determination and monitoring, the following differentiation is made between biota and habitat EcoSpecs and RQOs:

- EcoSpecs are associated with the Ecological Reserve process and are provided at EWR sites. EWR sites are situated in High priority RUs and therefore detailed RQOs must be provided.
- EcoSpecs are seen as detailed or numerical RQOs as they are quantifiable, measurable, verifiable and enforceable and therefore ensure protection of all components of the resource, which together define ecological integrity.
- As EcoSpecs are presented in a numerical quantitative format, it can be used for monitoring and compliance.
- When setting EcoSpecs, the work is usually based on field surveys that have been undertaken. A monitoring baseline is therefore available and monitoring to determine whether the specifications are being achieved (or TEC) can be undertaken.

Biota and habitat RQOs are defined as:

- Usually determined for the Moderate Priority RUs in narrative format rather than as EcoSpecs as they are broad or less detailed than EcoSpecs at High Priority RUs. Field work is usually not undertaken in Moderate Priority RUS and hence a monitoring baseline is not available. Numerical RQOs or EcoSpecs can therefore not be determined.
- Monitoring at Moderate Priority RUs will therefore be of lower priority than at EWR sites in High Priority RUs.
- Broad objectives can be provided for the EC (As sufficient data is not available to set specifications).
- RQOs in this format cannot be used for monitoring as is, monitoring to develop a baseline must be undertaken if monitoring is required at these RUs. Objectives can then be translated into EcoSpecs based on field surveys and the establishment of a monitoring baseline.

It is also acknowledged that limited resources are likely to prevent extensive monitoring and that the focus will have to be on the High Priority RUs and even these may require prioritisation. All RQOs and EcoSpecs for High Priority RUs will however be provided as one cannot at this stage be certain of the scale of monitoring that will be implemented now and in the future.

The rest of this Section defines EcoSpecs and TPCs and describes the principles of a monitoring programme which will be relevant for the High Priority RUs.

A monitoring programme must be designed according to the principles of adaptive management to provide guidance on how to address issues and implement corrective action if the EcoSpecs and TPCs (Rogers and Bestbier, 1997) are exceeded. The broad objectives of monitoring are to:

- Set EcoSpecs and TPCs for rivers, estuaries and wetlands.
- Provide a monitoring programme to measure the responses and effectiveness in terms of trend and change in EC.

The following report sections are modified from DWAF (2009a), DWA (2010) and ORASECOM (2013).

2.9.2 Ecological monitoring

Ecological monitoring is the collection and analysis of repeated observations or measurements to evaluate changes in the condition of the resource and the progress towards meeting the management objective (Elzinga *et al*., 1998). In terms of Ecological Water Resources Monitoring (EWRM), it is the measurement of EcoSpecs to determine if the EC is attained (Kleynhans *et al*., 2009). EWRM operates within the following concepts (based on Elzinga *et al*., 1998):

- The reference condition which is the natural or unimpaired condition of the system.
- The monitoring baseline which is a series of measurements taken before the initiation of the impact or management activity and used for comparison with the series of measurements taken afterwards.
- **Response (or resource) monitoring occurs at a particular detail, frequency and intensity as guided by the Ecological Importance and Sensitivity (EIS) of the resource. Response monitoring results are evaluated by analysis within a management objective framework. This allows measurement of how the resource is changing over time, i.e. to measure the trend.**
- Implementation (or compliance) monitoring assesses whether the activities are carried out as designed. Implementation monitoring can also identify which variables are most likely to be causing a change in the resource, and help eliminate from consideration some potential causes of change (Kershner, 1997; Elzinga *et al*., 1998). This would, inter alia, refer to whether flows are released as was specified for the attainment of a particular EC and is described in 2.2 to 2.7 above)
- **Effectiveness monitoring measures whether the EC (in terms of EcoSpecs) are attained by following the particular management scenario (Kershner, 1997).**

If the EC decreases over a period of time and the cause is unknown, more intensive monitoring or research may be initiated. If a cause for decrease is suspected, appropriate management intervention may be indicated (Elzinga *et al*., 1998).

EWRM should be undertaken within a structured framework following the principles of adaptive management. This will provide a decision framework within which monitoring results can be interpreted in terms of the attainment of objectives set for the condition and integrity of the resource. This relates directly to EcoSpecs and TPCs (Rogers and Bestbier, 1997) formulated to assess attainment of an EC. Conclusions emanating from the Decision Support System (DSS) will provide guidance on the management of the resource (Cormier and Suter, 2008).

2.9.3 EcoSpecs and Thresholds of Potential Concern

EcoSpecs must be quantifiable, measurable, verifiable and enforceable to ensure protection of all components of the resource, which make up ecological integrity. The critical components of the EcoSpecs include:

- Requirements for water quantity. Maintenance of spring and baseflow in rivers and other ecological features are also considered.
- Biological criteria and habitat criteria that are derived from EcoSpecs are clear and measurable specifications of ecological attributes (flow, physico-chemical attributes and biological integrity that reflect the health, community structure and distribution of aquatic biota).

- EcoSpecs therefore define the EC.

TPCs are upper and lower levels along a continuum of change in selected environmental indicators and are used and interpreted according to the following guidelines (Rogers and Bestbier, 1997):

'When a TPC level is reached (or when modelling predicts it will be reached), it prompts an assessment of the causes of the extent of the change. Assessment of the causes provides the basis for deciding whether management actions are needed or if the TPC needs to be recalibrated. TPCs provide management with strategic goals or endpoints within which to manage the system'.

'TPCs form the basis of an inductive approach to adaptive management, and are invariably hypotheses of limits of acceptable change in ecosystem structure, function and composition. The validity and appropriateness of TPCs are always open to challenge and they must be adaptively modified as understanding and experience of the system being managed increases'.

'It follows that more detailed monitoring surveys would increase the confidence in the validity of a TPC (i.e. narrow the uncertainty). This principle is built into the DSS by considering different levels of monitoring surveys'.

2.9.4 Principles of Ecological Water Resources Monitoring, Ecological Specifications and Thresholds of Potential Concern

Monitoring in this section focuses on measuring the ecological state, i.e. the EC. EcoSpecs and TPCs therefore describe the PES and / or the REC for each of the biota and habitat indicators. The key principles and concepts are the following:

- Data collated during field surveys during the EWR study or at the onset of the monitoring programme form the baseline.
- Future monitoring must compare conditions to the baseline.
- For rivers the EcoSpecs and TPCs therefore describe the baseline so monitoring can determine whether one is maintaining the PES, further degrading the system, or achieving the REC if different from the PES.
- Monitoring should be initiated soon after the baseline data has been collated to ensure that this data represents the recent baseline.
- Monitoring must be applied within an adaptive management framework.
- The concept of the TPCs provides the basis of a DSS. When TPCs are exceeded, management actions will be necessary.

Management actions are designed to maintain, or attain (if different from the PES) the REC. These management actions relate to the management objectives which are described in terms of the flow and quality (water quality) EcoSpecs. Additional land use objectives may also be described if non-flow related aspects are contributing to the PES of the system. One must therefore clearly distinguish between setting management objectives in terms of habitat to achieve/maintain certain ECs, and defining EcoSpecs for the biophysical responses that describe the ECs.

In essence, during an EWR study, flow requirements (i.e. the main habitat driver) that could result in a certain ecological state are defined through an EC. These flow requirements inform the management objectives supported by the other habitat driver components. Note that the word 'could' is used as the biological responses to habitat driver conditions are all predicted and must be tested through monitoring.

Monitoring the ecological responses will test the predictions made during an EWR study. It furthermore will test whether adjustments to the EcoSpecs and TPCs are required and whether the overall management objective in terms of the REC is being achieved. It is therefore crucial that monitoring be driven by objectives as it forms the foundation of a monitoring project (cf. Elzinga *et al*., 1998).

2.9.5 Different levels of monitoring

The design of a cost-effective monitoring programme is based on different levels of monitoring:

- Level 1: Analysis of data at a high frequency (e.g. physical parameters such as flow and water quality).
- Level 2: Surveys and specialist analysis at low frequency (e.g. every three years).

If Level 1 monitoring indicates that TPCs are exceeded, Level 2 monitoring surveys may need to be initiated to determine the management actions required to address potential problems or more frequent monitoring undertaken. There could be additional levels required and this is dependant on the monitoring programme and monitoring decision support system. In this report, further reference to the levels will not be made although there will high frequency monitoring activities will be identified.

2.9.6 General

It is recommended that different biomonitoring programmes must be aligned to existing programmes such as the DWS River EcoStatus Monitoring Programme (REMP). The following information on the REMP has been provided by Dr CJ Kleynhans (D:RQIS, DWS).

- *The River Health Programme (RHP) has evolved into the River EcoStatus Monitoring Programme (REMP). The REMP replaces the RHP and is a component of the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP).*
- *The REMP focuses on the monitoring of the ecological conditions in River ecosystems as it is reflected by the system drivers and biological responses (instream and riparian).*
- *The basis of the REMP is the establishment of a relative reference condition (i.e. usually a natural or close to natural condition) derived from the best available information.*
- *In its formulation and characterization the relative reference condition considers:*
    - *The characteristics of the abiotic drivers of the system (hydrology, geomorphology and physico-chemical conditions) that determine the habitat template for instream and riparian biota.*
    - *The characteristics of the instream and riparian biota as a response to the system drivers.*
- *The determination of baseline (current for the time it was established) conditions (i.e. represented within a defined spatial and temporal context; this can refer to either a river reach or a specific site) provides a fixed point against which future changes can be measured and compared.*
- *The Ecological Category (desired condition) of the reach (or site as representative of a reach) is determined by assessing the PESEIS[4] information for the resource, or any more detailed information (i.e. species or assemblages of particular concern). This would include the Ecological Category that is required (or implied) to attain the status or integrity of instream biota and riparian components. The overall Ecological Category of the resource as*

[4] Present Ecological State and Ecological Importance -Ecological Sensitivity

well as the constituent Ecological Categories required for the abiotic and biotic components is viewed as targets (i.e. A - D) that is quantifiable in terms of the index values as well as specific indicators at a finer scale where relevant. It follows that Thresholds of Probable Concern (TPCs) can be defined as an early warning that resource quality be degrading (or if time series data are available, that there is a degrading trend).

- *The level to which the specified Ecological Category is attained, is determined by monitoring on a scale and frequency determined by the abiotic and biotic components of the system. This relates to the ecological importance and sensitivity of the system, anthropogenic pressures on the system as well as its baseline condition.*
- *The **REMP** is built upon the use of particular models that incorporates existing approved EcoStatus models:*

*River Data Integration (**RIVDINT**): Assessment is done on a Quaternary Reach level and includes use of the Index of Habitat integrity model (Instream and Riparian), Fish Condition, Invertebrate condition, Vegetation (Riparian) condition. Based on the available and approved RQOs, Targets for the various components are set (as well as TPCs) for a Sub-Quaternary reach (or a subdivision of the SQR where necessary). Where RQOs for a SQR has not been set according to the EWR-site approach, it is still possible to set ecological targets based on specific ecological considerations. The eventual result of this process is the Fish, Invertebrate, Vegetation and integrated EcoStatus for a SQR. The RIVDINT has been developed as data storage and retrieval system that allows the comparison of various components over time. The model includes the development of relative reference conditions for all components. The first detailed assessment of a SQR will be considered the baseline against which future assessments will be evaluated.*

*Rapid Habitat Assessment Method and Model (**RHAMM**): Assessment is done on a site level where a site should be representative of a SQR or a subdivision thereof. EcoStatus models are incorporated into the RHAMM: IHI, FRAI, MIRAI, VEGRAI and the Integrated EcoStatus. Specific information for setting targets for indicator fish spp. (in terms of FRAI) and invertebrate taxa (e.g. in terms of SASS5) are provided for. The formulation of relative reference conditions is provided for in the RHAMM. Targets and TPCs can be set for available and approved RQOs (i.e. at EWR sites) in terms of biota and habitat requirements (also including the use of cross sections and habitat measurements). Where EWR-site data is not available, biological targets and TPCs can still be set for the site. Only a very limited number of physico-chemical measurement are included in the RHAMM.*

*Fish Invertebrate Flow Habitat Assessment (**FIFHA**): This model originates from the Fish Flow Habitat (FFHA) model that was used in some applications of the HFSR. The primary aim of the FIFHA is not to do instream flow requirements per se, but to use the data generated by the HFSR model (e.g. Hydrology and HABFLO) and the categories and flows that were set during the HFSR process to establish a basis for rapid assessment of fish and invertebrate habitat conditions at a EWR cross section. It follows that the FIFHA can only be used where a EWR site with the necessary hydraulic and hydrology are available.*

It is evident from this explanation that the REMP logically include the monitoring of ecological and specific biological components that have been established and approved (i.e. Gazetted) as RQOs.

In the line of the above and as requested by DWS, no further details with regards to the monitoring of riverine biota (specifically fish, macro-invertebrates and riparian vegetation) has been provided.

2.10 BASIC PRINCIPLES OF A GROUNDWATER MONITORING PROGRAMME

Because of the contribution of groundwater to surface water flow in the upper parts of the catchment, the volume of groundwater that could be abstracted, or the extent of stream flow reduction activities permitted without impacting the ability of the groundwater to sustain or contribute to the surface water Reserve has to be monitored by assessing the contribution to baseflow. It is also necessary to control the amount of water abstracted to protect the reliability of the resource and protect the terrestrial ecosystems dependent on the groundwater supplies.

Several variables can be measured to monitor groundwater, each of which has uncertainties:

1. Groundwater levels: The water levels at any one point may not reflect stresses in another point of the aquifer if outside the radius of influence of an abstraction zones. Boreholes in hydraulic connection with a surface water body may not exhibit as severe a drawdown as boreholes located away from surface water bodies as they are recharged by surface water if water levels drop below the level of the surface water body. A relatively dense network is required to identify the extent of stressed regions
2. Abstraction: Although a critical variable to compare volumes abstracted against recharge, abstraction is rarely monitored and needs to be monitored at every abstraction point, hence its monitoring is problematical. Generally it is estimated via secondary measures such as hectares irrigated, number of people supplied and level of service, pumping hours, size of reservoirs etc.
3. Baseflow: Baseflow in catchments in hydraulic connection with surface water bodies can be monitored in dry months at gauging stations and at a point summarises the level of depletion of aquifer storage via declining baseflow volumes and contributions to the EWR.
4. Water quality can be quantitatively and directly measured in the field, however, it can be quite variable due to natural and anthropogenic activities, and hence a dense monitoring network is required to assess regional trends.

2.10.1 Water level monitoring

Water level monitoring at an aquifer scale involves monitoring dedicated monitoring boreholes located away from localised abstraction so the water level variations reflect regional rather than localised trends of local overexploitation. Trends in the water level time series are monitored and:

- Water level trends over succeeding dry periods are evaluated for trends; and/or
- Water levels during wet periods are evaluated to ensure no trend in declining water level peaks is observed.

If water level declines are observed, water levels need to be related to rainfall patterns to distinguish between declining water levels in dry years from those due to over abstraction.

2.10.2 Abstraction monitoring

Abstraction monitoring involves the use of flow meters on individual boreholes, or lumped inflows into or out of reservoirs from a wellfield. It can also be estimated from operating hours of pumps if the head discharge relationship of a borehole system is known.

Abstraction volumes need to be related to aquifer recharge to identify stress levels.

2.10.3 Baseflow monitoring

Rivers that are groundwater fed supply water to meet the surface water EWR, and may also sustain groundwater dependant riparian vegetation (if not dependent on bank storage from the

river recharged during floods). The volume groundwater flowing into a river can be derived from dry season flows at gauging weirs, and trends in declining dry season flows are indicative of over abstraction. When over abstraction occurs near river channels, borehole water levels may not be indicative of over abstraction as water levels are maintained by losses of water from the river channel and interception of groundwater flowing to the river which would otherwise contribute to baseflow. Hence baseflow monitoring is important in catchments where groundwater sustains low flow flows.

Baseflow monitoring determines cumulative impact of all upstream impacts and surface water abstractions. Declining baseflow implies that the identification of the cause, whether increased river abstraction, groundwater abstraction or an increase in Stream Flow Reduction (SFR) activities is responsible.

2.10.4 Water Quality Monitoring

Water quality monitoring involves temporal monitoring of indicator parameters like Electrical Conductivity, which is indicative of rising salinity from a host of possible sources, or nitrates, which could be indicative of sanitation contamination or the removal of vegetation.

3 RQO IMPLEMENTATION FOR THE STUDY AREA

3.1 INTRODUCTION

This chapter presents what aspects need to be considered for the implementation of the recommended Classes and RQOs in the Study Area. In its most basic form an implementation plan tries to answer the following three questions:

- **What** activities are required? i.e. the actions and work that has to be performed and at what intensity or level of detail these should be carried out at.
- **When** should the activities take place? i.e. the frequency of work of activity; and
- **Who** is responsible for ensuring the work or activity are carried out?

It was recognised that implementation should take account of the varying characteristics of the river reaches across the Study Area, availability and need for monitoring information, the ability (currently and in the future) to regulate flow in the river reaches as well as the existing water resource management activities taking place or being planned.

The overarching approach to be followed in the execution of an implementation plan is that a sequence of activities needs to be introduced to accommodate proposed future infrastructure developments, rollout of ongoing water resource management activities such as the verification of the lawful water use as well as seeking alignment with the progressive implementation of the DWS Reconciliation Strategy and the strategies of the Provincial and Local Authorities.

3.2 ACTIVITIES REQUIRED FOR IMPLEMENTATION

Table 3.1 lists all the activities required for RQO implementation.

Table 3.1 Activities milestones and related processes

ID	Activity	Description
1	**Resource Quality Objectives and Class**	
2	Legal Notice.	Published in Gazette and comment period.
3	Promulgation.	Approved by Minister of Water and Sanitation.
4	**Monitoring**	
5	Flow (continuous recordings).	Maintain flow gauges.
6	Water quality (continuous from current activities).	▪ Maintain current DWS and other (e.g. Umgeni Water) water quality monitoring activities. ▪ Identify and maintain monitoring programmes other than DWS and that of Umgeni Water. Ensure that all data are captured in the DWS Water Management System (WMS) database, including microbial data. ▪ Link with the DWS NMMP and ensure that faecal coliform and *E.coli* data can be sourced by the programme.
7	Water quality.	Initiate and maintain additional water quality monitoring points as specified.
8	Fish and macro-invertebrates (every 2 - 3 years).	Standard fish and macro-invertebrate surveys and an update of the Fish Response Assessment Index (FRAI) and Macro Invertebrate Response Assessment Index (MIRAI) to determine any changes in EC. If TPCs are triggered, the required actions must be undertaken.
9	Diatoms (twice a year).	Diatom analysis to feed into the water quality

ID	Activity	Description
		monitoring programme.
10	Riparian vegetation (every 3rd year).	Specific surveys to determine whether TPCs have been exceeded as well as an update of the Vegetation Response Assessment Index (VEGRAI) to determine any changes in EC. If TPCs are triggered, the required actions must be undertaken.
11	Groundwater monitoring.	▪ Water level monitoring: Monthly to quarterly at existing and (new) monitoring boreholes. ▪ Abstraction monitoring (for large groundwater users): Continuous or aggregated monthly to annually. ▪ Baseflow monitoring continuously at gauging stations and aggregated monthly to provide annual volumes. ▪ Groundwater quality monitoring: quarterly at existing and (new) monitoring sites.
12	**Institutional arrangements**	
13	Establish RQO implementation structures (committee).	Design and establish the institutional structures. This could be in the form of a standalone committee or may be linked to other initiatives.
14	Develop reporting procedures, method and communication products.	This must be linked to the monitoring information and should be concise focussing on reporting compliance with meeting the RQOs.
15	Meetings / compliance reports / adaptive measures.	Application of what is defined in Item 19.
16	**Review RQO and Implementation Plan**	
17	Evaluate effectiveness of activities and monitoring.	Key activity to ensure the RQO implementation remains relevant.
18	Review RQOs and recommend changes	Recommend when RQOs need to be revised.
19	**Related Parallel Water Resource Management Processes**	
20	Operating Analysis.	
21	Update: Water requirements, maintenance schedules, operational risk analysis.	The information must feed into the water resource model.
22	System Operating Forum – uMngeni System and stand-alone systems.	DWS to continue with forums for operational planning including drought management.
23	Continuation and maintenance of the Reconciliation Strategy.	Revise the timeframes for implementation of water resource development interventions to account for prevailing water balances.

Note: Blue shaded activities are in progress or have been completed for the study area.

3.3 IMPLEMENTATION PLAN MANAGEMENT COMMITTEE

It is recommended that an Implementation Plan Management Committee (IPMC) be formulated to oversee the roll out of the actions of the plan. Since there are already several forums and committees functioning in the study area, it is suggested that the proposed functions of the IPMC be discussed at the existing forums to determine the most suitable institutional arrangements.

The committee's activities will entail coordination of monitoring activities among institutions, evaluation of monitoring information against RQO specifications as well as making recommendation on the required adaptive management measures where noncompliance occurs.

It is anticipated that the majority of the communication amongst the committee members take place electronically, with a meeting held once a year. The meeting will discuss monitoring results

obtained in the previous year, as well as set goals and targets to achieve the RQOs for the upcoming year.

An important link that must be made and liaison required is with the institutional structure that exists for Estuarine Management Plans. See Section 2.2 above for more detail.

3.4 DOCUMENTATION

It is necessary to keep record of the implemented actions, monitoring and adaptive management and it is suggested that this take place on an annual basis. The annual implementation plan document will typically include a summary of the previous years' monitoring results. Where deviations occurred, explanations of the adaptive management or corrective measurements should be given. System changes that took place in the previous year should also be documented, as well as specific system operational aspects.

3.5 MONITORING

Effective implementation of the Classes and RQOs relies on the availability of relevant monitoring information for tracking progress, evaluating compliance and to identify if and when revisions of the specified stipulation (target criteria) need to be considered. Monitoring requirements are therefore a key component of the plan as outlined in the subsequent chapters.

4 HYDROLOGICAL, GROUNDWATER AND ESTUARINE WATER LEVEL MONITORING

4.1 HYDROLOGICAL MONITORING

4.1.1 Catchment and river characteristics

As described in Section 2.4, four categories of river reaches were defined for the Inkomati study area:

(a) Upstream water use including river abstractions with or without restriction rules, return flows (discharges) and regulating storage dams.
(b) Release rules from dams to support water abstractions along the river reach.
(c) Releases or transfers from dams to support downstream dams.
(d) Releases in addition to the above, specifically to achieve the stipulated ecological conditions. These are from existing dams as well as proposed dams that were part of the recommended scenario.

The flow regime in most tributaries of the Study Area area is a result of the factors listed in category (a). There is therefore no specific release rule (deliberate operational management actions) needed to achieve the specified conditions for these type of river reaches. In these cases the implementation activities revolve around compliance monitoring and enforcement of the upstream influences which is abstraction, storage and discharges.

River reaches where categories (b) and (c) are applicable (usually (a) is also present) are where current operating rules are in place and where releases are made from storage for the intended purposes. In these cases there are no additional releases needed to achieve the ecological objectives in the river reach. Implementation in these rivers require, as is in (a), compliance monitoring of abstraction, storage and discharge plus the releases to satisfy the downstream users and/or for releases to support a downstream dam (essentially the operation of the river reach should remain as it was carried out in the recent past, i.e. present conditions). Since the release rules for (b) and (c) originate from existing (current) operations the implementation (continuation) of the existing rules is what is required.

In river reaches where specific releases need to be made for the ecology, as for category (d), there are particular management activities that have to be implemented. Such as the releases required form Inanda Dam.

4.1.2 River reach operation definitions

This section describes the operating rules for the indicated river reaches that need to be implemented to comply with the volumetric (flow) regime to achieve the Class and RQO.

4.1.2.1 River reaches influenced by major dams and transfer schemes

Transfer from Mooi-Mgeni River Transfer Scheme (MMTS)
Transfer of water to be operated in accordance with the derived operating rule determined based on risk analysis and implemented by Umgeni Water.

Midmar Dam
Minimum release of 0.9 m^3/s defined as a compensation release for downstream uses.

Albert Falls Dam
Releases are in accordance with the system operating rules, supporting the abstractions from Nagle Dam.

Nagle Dam
Regulating structure which diverts water into large aqueducts providing water for eThekwini Metropolitan Municipality. There is a minimum release of 0.7 m^3/s into the downstream river reach.

Inanda Dam
Minimum release of 1.5 m^3/s defined for the downstream river reach.

Hazelmere Dam
The releases from Hazelmere Dam it to be managed in accordance with the following three stages based on the indicated future planning phases:

- *Stage 1:* Current operation is to provide releases to supplement the downstream irrigation users. (It is expected that over time the irrigation land used will be replaced by urban developments).
- *Stage 2:* Following the raising of Hazelmere Dam the releases from the dam will initially be only to supplement the downstream irrigation water requirement until augmentation from an alternative source is implemented (such as reuse or implementation of a water resource development in the Mvoti River System).
- *Stage 3:* Once an augmentation option has been implemented the releases from Hazelmere Dam should comply with the flows needed to maintain the PES, set at an EC of a D for the downstream river reach.

4.1.2.2 River reaches influenced by proposed future major dams

uMkhomazi River System (Proposed Smithfield Dam)
The release requirements from the proposed Smithfield Dam will be in accordance with the recommended scenario (DWS, 2014a) which will achieve the TECs of C, B and C for the three primary EWR sites; Mk_I_EWR1, Mk_I_EWR2 and Mk_I_EWR 3 respectively.

The recommended scenario (MK21) entails providing releases from Smithfield Dam to supply the total Ecological Water Requirements at the EWR 2 river site identified as Mk_I_EWR2. The flow requirements are in accordance with the definitions for the REC defined for the site.

Mvoti River System (Proposed Isithundu Dam or alternative)
The release requirements from a proposed dam on the Mvoti River (such as the proposed Isithundu Dam) will be in accordance with the recommended scenario (DWS, 2014a) which will achieve the TEC of C at the EWR site; Mv_I_EWR1.

The recommended scenario (MV42) entails providing releases from Smithfield Dam to supply the low flow Ecological Water Requirements at the EWR 2 river site identified as Mv_I_EWR2. The flow requirements are in accordance with the definitions for the low flows for the REC defined for the site.

It should be note that scenario MV43 (total Flows for January, February and March and Low Flows for the remaining months set to achieve the REC) resulted in a ranking that is very close to scenario MK42. It is therefore consider prudent to consider both these scenarios when further feasibility investigations are undertaken in the Mvoti River System.

- The recommended procedure to implementing the EWRs in these systems would involve the following: Develop and apply river hydrodynamic of the river reach downstream of the dams to determine the release requirements from the dams that will comply with the flow requirements at the EWR site.
- Develop and implement an Ecological Release Operating Model and associated processes that will provide the information to manage the releases from the dams. A description of an example of such an operating system can be found in DWA (2009a).

4.1.2.3 River reaches in tributary catchments

Other river reaches in tributary catchments (not discussed specifically in the above sections) falls into the category where the flow is influenced by "Upstream water use, return flows (discharges) and regulating storage dams and/or farm dams". There are no releases made from upstream dams and the flow in the recommended scenario will be maintained as long as the abstractions, return flows and regulating storage structures remain as were in the recommended scenario.

The primary implementation requirements for these river reaches are therefore to follow the normal compliance, monitoring and enforcement processes applied by DWS.

4.1.3 Available hydrological flow gauges

The DWS has approximately 43 functional flow gauges on the online HYDSTRA database for the study area. There are also numerous flow gauges which have been closed over the years. It is important that flow monitoring takes place at the EWR sites. Where applicable, gauges that are no longer monitored should be reinstated. Monitoring exists for two main purposes namely:

- Monitoring to confirm whether the required flows at a certain point are being achieved.
- Monitoring to activate a specific action (request for release) should the flows be non-compliant.

Tables 4.1 present a summary of the EWR sites and estuaries and the respective flow gauges (if present) where monitoring should take place.

Table 4.1 Flow gauges associated with EWR sites and IUAs

IUA	Water Resource Class	EWR Site	River	Flow Gauge Nr	Comment
T4: Mtamvuna River Catchment					
T4-1	II	Mt_R_EWR1	Mtamvuna	Require gauge for monitoring	
T5: Umzimkulu River Catchment					
T5-1	I	-	-	T5H004	Observation[1]
T5-2	II	MzEWR2i	Umzimkulu	-	Require gauge for monitoring[2]
		MzEWR9r	Pholela	-	Require gauge for monitoring
		MzEWR8r	Ngwangwane	-	Require gauge for monitoring
		MzEWR3i	Umzimkulu	-	Require gauge for monitoring
		MzEWR17i	Mzimkhulwana	T5H012	Monitoring
T5-3	I	MzEWR14r	Bisi	T5H002	Monitoring
		MzEWR6i	Umzimkulu	-	Require gauge for monitoring
U1: uMkhomazi River Catchment					
U1-2	II	Mk_I_EWR1	uMkhomazi	U1H005	**Monitoring**
U1-3	I	Mk_I_EWR2	uMkhomazi	**-**	Require gauge for monitoring

IUA	Water Resource Class	EWR Site	River	Flow Gauge Nr	Comment
					(downstream of proposed Smithfield Dam)
U1-4	II	Mk_I_EWR3	uMkhomazi	U1H009	Monitoring
U2: uMngeni River Catchment					
U2-1	II	Mg_R_EWR1	uMngeni	U2H013	Monitoring
U2-2	III	Mg_I_EWR2	uMngeni	U2H048	Monitoring
		Mg_I_EWR3	Karkloof	U2H008	Monitoring
U2-3	III	-	-	U2H005	Observation
U2-4	II	-	-	U2H022	Observation
U2-5	III	Mg_I_EWR5	uMngeni	U2H055	Monitoring
U2-6	III			U2H054	Observation
U3: uMdloti and Tongati River Catchments					
U3-1	III	-	uMdloti	U3H005	Observation
U3-2	II	-	uThongathi	U3H001	Observation
U4: Mvoti River Catchment					
U4-3	II	Mv_I_EWR2	Mvoti	-	Require gauge for monitoring (downstream of proposed Isithundu Dam)
U4-1	II	Mv_I_EWR1	Heinespruit		Require gauge for monitoring
U6: uMlazi and Mbokodweni					
U6-1	III	-	uMlazi	U6H003	Observation
U6-2	III	-	uMlazi		See estuary monitoring requirements
U6-3	I	-	Mbokodweni		See estuary monitoring requirements
U7: Lovu River Catchment					
U7-1	III	Lo_R_EWR1	Lovu	Require gauge for monitoring	
U8: Mtwalume and Mzumbe River Catchment					
U8-1	I	-	Mzumbe		Require gauge for observation
U8-2	II	-	Mtwalume		Require gauge for observation

1 At least one flow gauge is required in an IUA in order to have a record of flow **observations** that can be used in future to verify if the required WRC of the IUA is being maintained.
2 The need for continuous flow recording and frequent **monitoring** of recorded flows against the flow requirements at EWR sites are recommended.

4.2 HYDRODYNAMIC (WATER LEVEL) MONITORING

The DWS has eight functional estuary water level recorders (see Table 4.2 below) on the online HYDSTRA database for the study area. It is important that where water levels are being monitored flow gauging also takes place above the estuary. This is only the case for about four of the systems at present (Mvoti, uMkhomazi, uThongathi and uMdloti (Table 4.1)). Monitoring exists for three main purposes namely:

- Gather information on estuary mouth behaviour and increase confidence in/ the mouth state-flow relationship.
- The monitoring of estuary mouth state to confirm whether the required volume of freshwater inflow is entering the estuary.
- Verify artificial breaching levels.

Tables 4.2 presents a summary of the estuary water level recorders where continuous monitoring takes place at present.

Table 4.2 Estuary water level recorders

Station	Stations name	From	Period (years)	Type
T4T001	Mapenjati Estuary	09/04/2014	< 1	Water levels
T5T001	Umzimkulu Estuary	09/03/2011	3	Water levels
U1T008	Mkhomazi Estuary	17/01/2002	12	Water levels and flow
U2T001	Blue Lagoon	25/03/2014	< 1	Water levels
U3T008	Tongaat Estuary	11/08/2005	9	Water levels and flow
U3T009	Umdloti Estuary	01/09/2005	9	Water levels and flow
U3T010	Umhlanga Estuary	11/08/2005	9	Water levels
U4T011	Umvoti Estuary	01/09/2005	9	Water levels and flow

In addition to the above, the following estuaries also require that their water levels and baseflow be monitored:

- Mtamvuna
- Kandandhlovu
- Kongweni
- Vungu
- Zotsha
- Mbango
- Damba
- Koshwana
- Intshambili
- Mzumbe
- Fafa
- uMuziwezinto
- Mzimayi
- Mahlongwa
- Mahlongwane
- Umgababa
- Msimbazi
- Lovu

4.3 GROUNDWATER MONITORING

4.3.1 Timing of groundwater monitoring

- Water level monitoring: Water level monitoring is required monthly to quarterly.
- Abstraction monitoring: Abstraction monitoring is by nature continuous, or aggregated monthly to annually.
- Baseflow monitoring: Baseflow monitoring is undertaken continuously at gauging stations and aggregated monthly to provide annual volumes. During wet periods, baseflow can be derived from hydrograph separations.
- Groundwater quality monitoring: Water quality is required quarterly.

4.3.2 Groundwater monitoring programme

Based on existing and future groundwater use, identified zones of localised poor water quality, and the contribution of groundwater to surface flows, the following monitoring programme needs to be implemented.

Table 4.3 Groundwater monitoring plan

Quat	Groundwater Monitoring				
	Abstraction	**Baseflow**	**Water Level**	**Water Quality**	**Priority**
IUA: T4					
GRU 1 T40A-C	Groundwater underutilised. Monitoring not essential.	Due to the impacts of afforestation and AIPs, monitoring of baseflow is required. Low flows at T4H001 should be maintained at a minimum of 35.78 Mm^3/a	Groundwater underutilised. Monitoring not essential.	No water quality issues exist. Quarterly monitoring of TDS is sufficient.	High. Baseflow reduction in T40B = 72%
GRU 2 T40D-E		Due to the low groundwater use, monitoring not required		Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes and quality monitored.	Moderate
IUA T5-1					
GRU 4 T51A-B T51D-G	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential.	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride.	Low
GRU 5 T51C T51H-J				No water quality issues exist. Quarterly monitoring of TDS is sufficient.	
IUA T5-2					
GRU 6 T52A-C T52E-G	Groundwater underutilised. Monitoring not essential	Due to the impacts of afforestation and AIPs, monitoring of baseflow is required. Low flows at T5H002 should be maintained at a minimum of 72.75 Mm^3/a Low flows at T5H007 should be maintained at a minimum of 131.7 Mm^3/a	Groundwater underutilised. Monitoring not essential.	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride.	High due to Current PES < target EC and baseflow reduction = 28%
GRU 7 T52D T52H		Due to the impacts of afforestation and AIPs, monitoring of baseflow is required in T52D. A gauging station is required.		Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride.	Moderate
IUA T5-3					
GRU 7 T52J-K	Groundwater underutilised. Monitoring not essential	Due to baseflow reduction, monitoring of baseflow is required in T52K. Low flows at T5H012 should be maintained at a minimum of 2.47 Mm^3/a.	Groundwater underutilised. Monitoring not essential.	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride.	Moderate

Quat	Groundwater Monitoring				
	Abstraction	Baseflow	Water Level	Water Quality	Priority
				The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes and quality monitored.	
GRU 8 T52L		Due to the impacts of afforestation, sugar cane and AIPs, monitoring of baseflow is required. A gauging station is required.		No water quality issues exist. Quarterly monitoring of TDS is sufficient. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes and quality monitored.	Moderate
GRU 9 T52M		Due to the low groundwater use, monitoring not required		Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride and TDS.	Moderate
IUA U1-1					
GRU 10 U10-A-D	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient	Low
GRU 11 U10E-F					
IUA U1-2					
GRU 11 U10G-K	Groundwater underutilised. Monitoring not essential	Due to the impacts of afforestation, and AIPs, monitoring of baseflow is required. A gauging station is required.	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient	High due to Current PES < target EC and baseflow reduction = 17% in U10G
IUA U1-3					
GRU 12 U10L	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride and nitrates. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes and quality monitored.	Moderate
GRU 13 U10M				Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for	

Quat	Groundwater Monitoring				
	Abstraction	**Baseflow**	**Water Level**	**Water Quality**	**Priority**
				Fluoride, salinity and nitrates.	
IUA U2-1					
GRU 14 U20A-C	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient	High due to Current PES < target EC and baseflow reduction = 15% in U20B.
IUA U2-2					
GRU 14 U20D-E	Groundwater underutilised. Monitoring not essential	Due to the impacts of afforestation, sugar cane and AIPs, monitoring of baseflow is required. Low flows at U2R003 should be maintained at a minimum of 69.53 Mm^3/a	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient	Moderate
IUA U2-3					
GRU 15 U20F-G	Groundwater underutilised. Monitoring not essential	Due to the impacts of afforestation, and AIPs, monitoring of baseflow is required. Low flows at U2H012 should be monitored but an EWR has not been set.	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes and quality monitored.	Moderate
IUA U2-4					
GRU 14 U20H	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient	Low
GRU 16 U20J				Natural water quality problems exist in the catchment and boreholes for domestic use should be tested for compliance to drinking water standards The potential exists for contamination. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes.	Moderate
IUA U2-5					
GRU 15 U20K	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes and quality monitored.	Moderate

Quat	Groundwater Monitoring				
	Abstraction	**Baseflow**	**Water Level**	**Water Quality**	**Priority**
GRU 17 U20L				Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride.	Moderate
IUA U2-6					
GRU 18 U20M	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes and quality monitored.	Moderate
IUA U3-1					
GRU 19 U30A	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient	Low
IUA U3-2					
GRU 21 U30B	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes.	Moderate
IUA U3-3					
GRU 20 U30C	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes and quality monitored.	Moderate
IUA U3-4					
GRU 21 U30D	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required.	Groundwater underutilised. Monitoring not essential	The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes.	Moderate

Quat	Groundwater Monitoring				
	Abstraction	**Baseflow**	**Water Level**	**Water Quality**	**Priority**
IUA U4-1					
GRU 2 U40A-B	Groundwater moderately utilised for water supply. Monitoring of major use suggested	Due to the impacts of afforestation, sugar cane and AIPs, monitoring of baseflow is required. A gauging station is required. Low flows at U4H002 should be maintained at a minimum of 6.41 Mm^3/a	Due to the moderate groundwater use, monitoring is required around major users to ensure water levels do not exhibit a declining trend	No water quality issues exist. Quarterly monitoring of TDS is sufficient.	High due to moderate groundwater use of 20% of the aquifer recharge. Water level monitoring of major groundwater users required. Baseflow reduction is 77% and 57% in U40A and B respectively.
GRU 23 U40C	Groundwater underutilised. Monitoring not essential	Due to the impacts of afforestation, sugar cane and AIPs, monitoring of baseflow is required. A gauging station is required.	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes.	Moderate
GRU 24 U40D		Due to the low groundwater use, monitoring not required		No water quality issues exist. Quarterly monitoring of TDS is sufficient. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes.	Moderate
IUA U4-2					
GRU 23 U40F	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes.	Moderate
GRU 24 U40E U40G				Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes and quality monitored.	Moderate

Quat	Groundwater Monitoring				
	Abstraction	Baseflow	Water Level	Water Quality	Priority
IUA U4-3					
GRU 24 U40H	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride.	Moderate
GRU 25 U40J				The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes.	Moderate
IUA NCC					
GRU 21 U30E	Groundwater underutilised. Monitoring not essential	Monitoring not required. Aquifers discharge into the ocean	Groundwater underutilised. Monitoring not essential	The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes.	Moderate
GRU 26 U50A	Groundwater moderately utilised for water supply. Monitoring of major use suggested		Due to the moderate groundwater use, monitoring is required around major users to ensure water levels do not exhibit a declining trend	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride and salinity. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes	High due to moderate groundwater use of 36% of the aquifer recharge. Water level monitoring of major groundwater users required.
IUA U6-1					
GRU 27 U60A	Groundwater underutilised. Monitoring not essential	Due to the impacts of afforestation, and AIPs, monitoring of baseflow is required. An EWR has not been set to define a baseflow volume to monitor at U6H002	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient.	Moderate
GRU 28 U60B		Due to the impacts of afforestation, and AIPs, monitoring of baseflow is required. Low flows at U6H003 should be maintained at a minimum of 5.92 Mm^3/a		No water quality issues exist. Quarterly monitoring of TDS is sufficient.	High. Baseflow reduction is 54%
GRU 29 U60C		Due to the low groundwater use, monitoring not required		No water quality issues exist. Quarterly monitoring of TDS is sufficient. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes	Moderate
IUA U6-2					
GRU 29	Groundwater	Due to the low groundwater use,	Groundwater underutilised.	Localised water quality issues exist.	Moderate

Quat	Groundwater Monitoring				
	Abstraction	**Baseflow**	**Water Level**	**Water Quality**	**Priority**
U60D	underutilised. Monitoring not essential	monitoring not required	Monitoring not essential	Water quality monitoring of new and existing boreholes required for Fluoride, nitrate and salinity. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes	
IUA U6-3					
GRU 29 U60E	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes	Moderate
IUA U7-1					
GRU 30 U70A	Groundwater underutilised. Monitoring not essential	Due to the impacts of afforestation, and AIPs, monitoring of baseflow is required. Low flows at U7H001 should be maintained at a minimum of 2.75 Mm^3/a	Groundwater underutilised. Monitoring not essential	No water quality issues exist. Quarterly monitoring of TDS is sufficient.	High. Baseflow reduction is 75%
GRU 31 U70B					Moderate
GRU 32 U70C		Due to the low groundwater use, monitoring not required		Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for Fluoride. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes	Moderate
GRU 33 U70D					
IUA CC					
GRU 29 U60F	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for salinity. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes	Moderate
GRU 33 U70E				Insufficient data exists and a water quality monitoring network is required The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50	Moderate
GRU 34 U70F					

Quat	Groundwater Monitoring				
	Abstraction	Baseflow	Water Level	Water Quality	Priority
				m from water supply boreholes.	
IUA U8-1					
GRU 35 U80B-C	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for fluoride.	Moderate
IUA U8-2					
GRU 35 U80E-F	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for fluoride. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes	Moderate
IUA SC					
GRU 3 T40F-G	Groundwater underutilised. Monitoring not essential	Due to the low groundwater use, monitoring not required	Groundwater underutilised. Monitoring not essential	Localised water quality issues exist. Water quality monitoring of new and existing boreholes required for fluoride. The aquifer is of high vulnerability. Activities that could cause groundwater contamination should be restricted 50 m from water supply boreholes	Moderate
GRU 35 U80A, D, G-K					
GRU 36 U80L					

5 WATER QUALITY MONITORING

This section describes the principles of a monitoring programme that measures the ECs as signed off as part of the Water Resource Class. The focus of this chapter is on water quality monitoring activities for rivers and estuaries. The monitoring is specific to the river High Priority RUs i.e. RUs with a 3 (rivers) and 4 (estuaries) priority rating; and should therefore be applied at EWR sites and at WQ hotspots (designated Priority Rating - 3WQ) (DWS, 2015), and High Priority estuaries.

5.1 MONITORING OF HIGH PRIORITY WATER QUALITY SITES

Water quality monitoring is undertaken monthly or as specified by the current DWS or other (e.g. Umgeni Water) monitoring programme. Monitoring focussing on water quality and diatoms are specific to High Priority river sites (EWR and 3WQ sites for water quality monitoring) and estuaries, but could be applied at any of the RUs or estuaries with lower Priority Ratings (2) where water quality has been identified as an indicator.

Monitoring details for water quality and diatom sampling providing the actions, temporal and spatial scales have been provided in Table 5.1.

Table 5.1 Water quality and diatom monitoring programme

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
All variables measured as standard by DWS as a minimum requirement. Umgeni Water sties to continue as current, as a broader range of variables are monitored as compared to DWS sites. Note that temperature and dissolved oxygen should be monitored at all EWR sites as no baseline currently exists for these parameters and they are strongly linked to biotic responses. No data or numeric DWS guidelines exist for turbidity, although Umgeni Water routinely monitors turbidity. Turbidity should be measured where specified and a turbidity database developed. Although *E. coli* and faecal coliforms are not strictly part of ecological monitoring, data should be collected where specified due to current and potential impacts on users. This variable is again monitored by	Include additional variables in the formal DWS and other monitoring programmes as indicated by water quality RQOs, specifically periphyton chlorophyll-a and diatoms. Include toxics monitoring if specifically mentioned; otherwise cover only if indicated by biotic responses. Include *E. coli* and faecal coliform monitoring as part of the NMMP or other health monitoring programmes, as required and indicated in the Implementation Report.	1. Monthly, or as determined by current DWS or other monitoring programme per monitoring point. 2. Institute bi-monthly (i.e. twice a month) monitoring if required at High Priority water quality sites with no water quality gauging weir or other monitoring point in place. 3. Institute monthly monitoring of the standard suite of DWS variables, if specified in the Implementation Report, at Moderate Priority RUs where water quality has been identified as an indicator and an existing water quality gauging weir or monitoring point is in place. If not, institute bi-monthly (i.e. twice a month) monitoring as outlined in point 2. 4. *E. coli* and faecal coliform monitoring must be conducted at the frequency required by the NMMP.	1. Relevant water quality monitoring point or gauging weir. 2. Institute a monitoring point downstream of a High Priority water quality site or at the lower end of a Moderate Priority RU where water quality has been identified as an indicator, if no water quality gauging weir or monitoring point is in place for use. 3. Institute a monitoring point just upstream of estuaries (where this is not covered by an existing monitoring point or where the monitoring point is too far upstream from the estuary.

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
Umgeni Water.			
Diatoms	Collect baseline data to develop EcoSpecs and TPCs.	Six monthly.	All EWR sites and sites were WQ hotspots have been identified where there are potential nutrient problems.

Although it is recommended that monitoring activities outlined above be conducted at all High Priority and EWR sites as specified, it is understood that the pressure on resources may require prioritization of sites for monitoring purposes. This is particularly important if an information database has to be built before the implementation of RQOs can take place.

5.1.1 Water quality

This section of the report covers water quality monitoring at EWR sites and High Priority water quality sites (e.g. the Mbokodweni), but can be applied to Moderate Priority RUs where water quality has been identified as an indicator and as specified in this document. Moderate Priority RUs or High Priority water quality sites that are not EWR sites may not have water quality monitoring points in place with no regular monitoring by DWS or organisations such as Umgeni Water. Even at High Priority sites, regular monitoring should only be initiated as required, as baseline monitoring will need to be undertaken if a suitable water quality gauging weir or monitoring point is not present that is being currently monitored. Guidelines to where baseline monitoring should be initiated, is covered in Section 5.2 of this report regarding site prioritization.

For example, the Mbokodweni (U60E-04792) High Priority water quality site (3WQ) has the following measurable water quality RQOs specified:

Narrative RQO	Numerical RQO		
Ensure that toxics and salt levels are within appropriate limits for intended use, e.g. industrial use	Numerical limits can be found in DWAF (1996) (Industrial use: driver).		
Ensure that nutrient levels are within Tolerable limits.	50^{th} percentile of the data must be less than 0.075 mg/L PO_4-P (Aquatic ecosystems: driver). 50^{th} percentile of the data must be less than 2.5 mg/L TIN-N (Aquatic ecosystems: driver).		
Meet faecal coliform and *E. coli* targets for recreational / other (full or partial contact) use*	Potential health risks in terms of counts / 100 ml (SA NMMP guidelines).		
	Low	**Medium**	**High**
	< 600	600 – 2 000	> 2 000

* Guidelines are provided in the absence of data or knowledge of recreational activities in the area.

Note that due to the industrial nature of this area, and industry being an acknowledged user, toxics and salts has been specified within industrial use guidelines. This area is also upstream of an estuary flagged as problematic. Meeting specified RQOs should assist in achieving instream estuarine water quality objectives. However, as nutrients are not currently part of an existing monitoring programme, nutrient RQOs are only provisional and monitoring is required before RQOs can be applied (see Table 5.2).

As no water quality monitoring programme is currently in place, bi-monthly (i.e. every two weeks) monitoring of electrical conductivity, nutrients, faecal coliforms/*E. coli* should take place if required, so as to build up a water quality baseline against which compliance to RQOs can be measured. Note that this monitoring should be instituted depending on the prioritisation level of the site.

At sites where a toxics problem may exist (e.g. pesticides), but the toxic itself cannot be specified and a database of information does not exist, it is recommended that toxics monitoring be best achieved through toxicity testing of water samples to a range of organisms in the first instance. Should toxicity then be detected, identification of toxicants through more detailed sampled and chemical analyses, e.g. a metals scan or identification of biocides used in the area, can be undertaken.

The range of organisms that are recommended for toxicity testing include the following:

- Crustaceans, e.g. a 24 and 48 hr *Daphnia magna* acute toxicity screening test.
- Fish, e.g. a 96 hr *Poecilia reticulata* acute toxicity screening test.
- Algae, e.g. a 72 hr *Selenastrum capricornutum* growth inhibition screening test.

Note that these recommended tests are short-term (or acute) screening tests. Should toxicity be determined, additional tests, e.g. chronic or sub-chronic tests or tests using additional organisms can be undertaken to determine causes of effects seen. This may then be followed or replaced by detailed analytical tests such as screening for metals. Acute testing should be initiated on at least a quarterly basis to ascertain at a screening level whether toxicity exists. It is assumed that these tests will be accompanied by biological monitoring as biotic response is the main indicator of toxicity.

Note that before toxicity testing is initiated, all monitoring data in the area must be sourced. There are a number of organizations that do regularly monitor water quality in different parts of the WMA, e.g. Umgeni Water and eThekwini Municipality among others, and that include toxics monitoring on a site-specific basis.

Detail is provided in Section 3.2 of the RQO Report regarding methods and approaches for riverine water quality, with a distinction being made between RQOs that are *immediately applicable* (and will therefore be gazetted), i.e. those sites and variables where monitoring is currently taking place, and other RQOs that are *provisional* and can only be evaluated and confirmed once adequate monitoring data are available. The list of *immediately applicable* sites for the EWR and High Priority water quality sites is provided here as an indication of where monitoring is taking place at the moment, and what variables can immediately be monitored as part of a current monitoring programme. Tables 5.2 and 5.4 relate to EWR sites and High Priority water quality sites respectively. Note that monitoring data to be collected for measurement against RQOs that are immediately applicable and gazetted, should be collected from the monitoring sites as identified in the water quality Reserve documentation. Sites to be used for data collection during compliance or other monitoring are shown in Tables 5.2 and 5.4 below.

Table 5.2 River EWR sites and variables where water quality RQOs are immediately applicable

Component/ Indicator	TEC	RQO
IUA T4-1: MTAMVUNA RU EWR MT_R_EWR 1 (T40E-05601, T40C-05520, T40D-05537, 05584, 05707)		
Water quality	**A/B**	Maintain the target EC (>88%). Ensure that **turbidity or clarity levels** stay within Acceptable limits: A moderate change from present with temporary high sediment loads and turbidity during runoff events (Aquatic ecosystems: driver). **MONITORING POINT: DWS gauging weir T4H001Q01**
IUA U1-2: MIDDLE uMKHOMAZI RU MK_I_ EWR 1 DS (U10F-04528 DS)		
Water quality	**A/B**	Maintain the target EC (>88%). Ensure that **turbidity or clarity levels** stay within Acceptable limits: A moderate change from present with temporary high sediment loads and

Component/ Indicator	TEC	RQO
		turbidity during runoff events (Aquatic ecosystems: driver). **MONITORING POINT: Mkomazi at weir U1H005 Lundys, UW site RMK002**
IUA 1-3: uMKHOMAZI GORGE RU MK_I_ EWR 2 (U10J-04679, U10JH-04638, 04675)		
Water quality	**A/B**	Maintain the target EC (>88%). Ensure that **nutrient levels (phosphate)** are within Acceptable limits: 50th percentile of the data must be less than 0.015 mg/L PO_4-P (Aquatic ecosystems: driver).
		Ensure that **electrical conductivity (salt) levels** are within Ideal limits: 95th percentile of the data must be less than or equal to 30 mS/m (Aquatic ecosystems: driver). **MONITORING POINT: Mkomazi at Josephine Bridge, UW site RMK004**
IUA U1-4: LOWER uMKHOMAZI RU MK_I_ EWR 3 (U10M-04746, U10J-04807, 04799, 04833, U10K-04838)		
Water quality	**A/B**	Maintain the target EC (>88%). Ensure that **nutrient levels (phosphate)** are within Acceptable limits: 50th percentile of the data must be less than 0.015 mg/L PO_4-P (Aquatic ecosystems: driver).
		Ensure that **electrical conductivity (salt) levels** are within Acceptable limits: 95^{tn} percentile of the data must be less than or equal to 55 mS/m (Aquatic ecosystems: driver). **MONITORING POINT: DWS gauging weir U1H009Q01 or U1H006Q01**
IUA 2-1: uMNGENI UPSTREAM MIDMAR DAM RU Mg_R_ EWR 1 (U20A-04253, U20C-04275)		
Water quality	**B**	Maintain the target EC (>82%). Ensure that **nutrient levels (phosphate)** are within Acceptable limits: 50th percentile of the data must be less than 0.015 mg/L PO_4-P (Aquatic ecosystems: driver).
		Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: Mgeni @ Petrus Stroom, UW site RMG001**
IUA 2-2: uMNGENI, MIDMAR TO ALBERT FALLS RU Mg_I_ EWR 2 (U20E-04243, U20E-04221)		
Water quality	**C/D**	Maintain the target EC (>58%). Ensure that **nutrient levels (phosphate)** are within Tolerable limits: 50th percentile of the data must be less than 0.075 mg/L PO_4-P (Aquatic ecosystems: driver).
		Ensure that **nutrient levels (Total Inorganic Nitrogen; TIN)** are within Acceptable limits: 50th percentile of the data must be less than 0.85 mg/L TIN-N (Aquatic ecosystems: driver).
		Ensure that **electrical conductivity (salt) levels** are within Ideal limits: 95^{tn} percentile of the data must be less than or equal to 30 mS/m (Aquatic ecosystems: driver).
		Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: Mgeni @ Morton's Drift, UW site RMG008**
RU Mg_R_ EWR 3 (U20E-04170)		
Water quality	**B**	Maintain the target EC (>82%). Ensure that **nutrient levels (phosphate)** are within Acceptable limits: 50th percentile of the data must be less than 0.015 mg/L PO_4-P (Aquatic ecosystems: driver). **MONITORING POINT: DWS gauging weir U2H006Q01**
IUA 2-5: uMNGENI DS uMNSUNDUZE CONFLUENCE TO INANDA DAM RU Mg_I_ EWR 5 (U20L-04435, U20M-04396)		
Water quality	**C/D**	Maintain the target EC (>58%). Ensure that **nutrient levels (phosphate and Total Inorganic Nitrogen; TIN)** are within Tolerable limits: 50th percentile of the data must be less than or equal to 0.075 mg/L PO_4-P (Aquatic ecosystems: driver). 50th percentile of the data must be less than or equal to 4.0 mg/L TIN-N (Aquatic ecosystems: driver).
		Ensure that **electrical conductivity (salt) levels** are within Acceptable limits: 95^{tn} percentile of the data must be less than or equal to 55 mS/m (Aquatic ecosystems: driver).
		Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: DWS gauging weir U2H055Q01**
IUA 4-1 AND 4-2: MVOTI RU MV_I_ EWR 1 (U40B-03770, HEINESSPRUIT)		
Water quality	**C**	Maintain the target EC (>62%). Ensure that **nutrient levels (phosphate and Total Inorganic Nitrogen; TIN)** are within Tolerable limits: 50th percentile of the data must be less than 0.125 mg/L PO_4-P (Aquatic ecosystems: driver). 50th percentile of the data must be less than 2.5 mg/L TIN-N (Aquatic ecosystems: driver).
		Ensure that electrical conductivity (salt) levels are within Ideal limits: 95th percentile of the

Component/ Indicator	TEC	RQO
		data must be less than or equal to 30 mS/m (Aquatic ecosystems: driver).
		Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: Heinespruit@Mispah, UW site RMV005**
IUA 4-3: LOWER MVOTI RU MV_I_ EWR 2 (U40H-04064)		
Water quality	**C**	Maintain the target EC (>62%). Ensure that **nutrient levels (phosphate)** are within Tolerable limits: 50th percentile of the data must be less than 0.125 mg/L PO_4-P (Aquatic ecosystems: driver). **MONITORING POINT: Hlimbitwa River upstream of the EWR site, UW site RHB001**
IUA 7-1: LOVU RU LO_R_ EWR 1 (U70C-04859)		
Water quality	**B/C**	Maintain the target EC (>78%). Ensure that **turbidity or clarity levels** stay within Acceptable limits: A small change from present with minor silting of habitats and turbidity loads (Aquatic ecosystems: driver). **MONITORING POINT: Nungwane Nungwane inflow, UW site RNW001**

* Note that all river faecal coliform and *E. coli* targets for full and partial contact are presented in terms of SA NMMP guidelines and health risks in terms of counts/100 ml, as follows:

Low	Medium	High
< 600	600 - 2 000	> 2 000

Guidelines are provided in the absence of data or knowledge of recreational activities in the area.

Note that the only EWR site not listed in Table 5.2 is RU Mg_R_EWR 4 on the uMnsunduze River (Monitoring point: UW site RMD019). The overall target for this system is to improve it to a D EC, which would mean in improvement of water quality from an overall E/F category. The RQO table for this site is shown below, with RQOs that need to be improved to improve water quality state shown in bold red text.

Narrative RQO	Numerical RQO		
Ensure that nutrient levels are within Tolerable limits.	**50th percentile of the data must be less than 0.075 mg/L PO_4-P (Aquatic ecosystems: driver).** 50th percentile of the data must be less than 2.5 mg/L TIN-N (Aquatic ecosystems: driver).		
Ensure that periphyton chl-a levels are within Tolerable limits.	**50th percentile of the data must be less than 52.5 mg/L periphyton chl-a (Aquatic ecosystems: driver).**		
Ensure that electrical conductivity (salt) levels are within Ideal limits.	**95th percentile of the data must be less than or equal to 30 mS/m (Aquatic ecosystems: driver).**		
Ensure that turbidity or clarity levels stay within Acceptable limits.	A moderate change from present with increased turbidity levels expected (Aquatic ecosystems: driver).		
Ensure that toxics are within prescribed limits to improve present state	**Note that ammonia (NH_3-N), copper, cadmium and lead already exceed Acceptable or Tolerable levels for aquatic ecosystems, although background levels (natural state) are not known. Levels should be improved to meet Tolerable limits (see DWAF, 2008 for limits).**		
Ensure that dissolved oxygen levels are within Acceptable limits.	**5th percentile of the data must be greater than 6 mg/L dissolved oxygen (Aquatic ecosystems: driver).**		
Improve faecal coliforms and *E. coli* levels.*	**Move from a High to Medium risk level (SA NMMP guidelines).**		
	Low	**Medium**	**High**
	< 600	600 – 2 000	> 2 000

* Guidelines are provided in the absence of data or knowledge of recreational activities in the area.

Table 5.3 River High Priority water quality sites and variables where water quality RQOs are immediately applicable

RU	SQ	Water quality RQOs
IUA T5-2: UMZIMKULU		
MRU MzA	MzEWR2i T51C-04760	Ensure that **electrical conductivity (salt) levels** are within Ideal limits: 95th percentile of the data must be less than or equal to 30 mS/m (Aquatic ecosystems: driver). Ensure that **nutrient levels (phosphate)** are within Acceptable limits: 50th percentile of the data must be less than 0.025 mg/L PO_4-P (Aquatic ecosystems: driver). **MONITORING POINT: DWS gauging weir T5H004Q01**
MRU MzB	MzEWR3i T52C-04960 T52D-04948 T52D-05137	Ensure that **electrical conductivity (salt) levels** are within Ideal limits: 95th percentile of the data must be less than or equal to 30 mS/m (Aquatic ecosystems: driver). Ensure that **nutrient levels (phosphate)** are within Acceptable limits: 50th percentile of the data must be less than 0.025 mg/L PO_4-P (Aquatic ecosystems: driver). **MONITORING POINT: DWS gauging weir T5H007Q01**
IUA U2-3: uMNGENI		
RU uMn7	U20F-04131 U20F-04204 U20F-04224 U20G-04194 U20G-04215	Ensure that **nutrient levels (phosphate)** are within Acceptable limits: 50th percentile of the data must be less than 0.025 mg/L PO_4-P (Aquatic ecosystems: driver). Ensure that **turbidity/clarity or TSS levels** stay within Acceptable limits: A moderate change from present with temporary high sediment loads and turbidity during runoff event (Aquatic ecosystems: driver). Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: Mgeni @ Morton's Drift, UW site RMG008**
MRU uMnC	U20G-04240 U20G-04259 U20G-04385	Ensure that **nutrient levels (phosphate)** are within Tolerable limits: 50th percentile of the data must be less than 0.075 mg/L PO_4-P (Aquatic ecosystems: driver). Ensure that **turbidity/clarity or TSS levels** stay within Acceptable limits: A moderate change from present with temporary high sediment loads and turbidity during runoff event (Aquatic ecosystems: driver). Ensure that **toxics (ammonia, iron, manganese)** are within Ideal limits or A categories: 95th percentile of the data must be within the TWQR for toxics (DWAF, 1996c) or the upper limit of the A category in DWAF (2008b). Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: Mgeni weir upstream Nagle Dam, UW site RMG013**
IUA 2-4: uMNSUNDUZE		
RU uMn8	U20J-04461 U20J-04488	Ensure that **turbidity/clarity or TSS levels** stay within Acceptable limits: A moderate change from present with temporary high sediment loads and turbidity during runoff event (Aquatic ecosystems: driver). Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: Slangspruit upstream Duzi confluence, UW site RSL003**
MRU Duze D	U20J-04459	Ensure that **turbidity/clarity or TSS levels** stay within Acceptable limits: A moderate change from present with temporary high sediment loads and turbidity during runoff event (Aquatic ecosystems: driver). Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: Duzi @ Eddy Hagan Drive, UW site RDM024**
IUA U2-6: uMNGENI		
RU uMn10	U20M-04625 U20M-04639 U20M-04642 U20M-04649 U20M-04653 U20M-04659 U20M-04682	Ensure that **nutrient levels (phosphate)** are within Tolerable limits: 50th percentile of the data must be less than 0.075 mg/L PO_4-P (Aquatic ecosystems: driver). Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: Mgeni weir downstream Inanda Dam, UW RMG022, in SQ U20M-04396**
IUA U3-1: uMDLOTI		
RU U3.1	U30A-04228 U30A-04363 U30A-04360	Ensure that **turbidity/clarity or TSS levels** stay within Acceptable limits: A moderate change from present with temporary high sediment loads and turbidity during runoff event (Aquatic ecosystems: driver). Ensure that **nutrient levels (phosphate)** are within Acceptable limits: 50th percentile of the data must be less than 0.025 mg/L PO_4-P (Aquatic ecosystems: driver). Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: eThekwini monitoring point Ogunjini ww-RAW (SQ U30A-04360)**

RU	SQ	Water quality RQOs
IUA U4-1 AND U4-2: MVOTI		
RU Mv1	U40B-03708 U40B-03740 U40B-03832	Ensure that **nutrient levels (phosphate)** are within Acceptable limits: 50th percentile of the data must be less than 0.025 mg/L PO_4-P (Aquatic ecosystems: driver). Ensure that **electrical conductivity (salt) levels** are within Ideal limits: 95th percentile of the data must be less than or equal to 30 mS/m (Aquatic ecosystems: driver). **MONITORING POINT: Mvoti River @ Mvoti Poort, UW site RMV001**
IUA U6-1: UPPER UMLAZI		
RU U6.1	U60A-04533 U60B-04614 U60C-04555	Ensure that **turbidity/clarity or TSS levels** stay within Acceptable limits: A moderate change from present with temporary high sediment loads and turbidity during runoff event (Aquatic ecosystems: driver). Ensure that **nutrient levels (phosphate)** are within Tolerable limits: 50th percentile of the data must be less than 0.075 mg/L PO_4-P (Aquatic ecosystems: driver). Ensure that **electrical conductivity (salt) levels** are within Tolerable limits: 95th percentile of the data must be less than or equal to 85 mS/m (Aquatic ecosystems: driver). Ensure that **toxics (ammonia)** are within Tolerable categories: 95th percentile of the data must be within the D category according to DWAF (2008). Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: Mlazi @ end Shongweni inflow, UW site RML009**
RU U6.2	U60C-04556	Ensure that **turbidity/clarity or TSS levels** stay within Acceptable limits: A moderate change from present with temporary high sediment loads and turbidity during runoff event (Aquatic ecosystems: driver). Ensure that **nutrient levels (phosphate)** are within Tolerable limits: 50th percentile of the data must be less than 0.075 mg/L PO_4-P (Aquatic ecosystems: driver). Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: Sterkspruit Shongweni inflow, UW site RSS008**
IUA U6-3: MBOKODWENI		
RU U6.6	U60E-04792	Ensure that **electrical conductivity (salt) and toxics levels** are within appropriate limits for intended use, e.g. industrial use: Numerical limits can be found in DWAF (1996e) (Industrial use: driver). Meet **faecal coliform and *E. coli* targets** for recreational / other (full or partial contact) use*. **MONITORING POINT: appropriate eThekwini monitoring point on the Mbokodweni (either 04 or 05 recommended)**

* Note that all river faecal coliform and *E. coli* targets for full and partial contact are presented in terms of SA NMMP guidelines and health risks in terms of counts/100 ml, as follows:

Low	Medium	High
< 600	600 - 2 000	> 2 000

Guidelines are provided in the absence of data or knowledge of recreational activities in the area.

The first step with all other RQOs listed in this report (i.e. provisional RQOs) is to assess whether sites are part of a monitoring programme and whether the variable of interest is being monitored by that programme. If not, or if insufficient data are available to test compliance, a monitoring database must be developed before the RQO can be evaluated and applied.

For estuaries, high frequency water quality monitoring covers river inflow into estuaries.

5.1.2 Diatoms

The general confidence in data availability for the Rapid (DWA, 2014a) and Intermediate (DWA, 2014b) EWR sites were Moderate (2). During the Rapid assessment, diatom samples were taken during June and August 2013 at EWR sites in the Lovu, Karkloof and Mtamvuna. The uMngeni and uMnsunduze EWR sites were only sampled once during this period. Limited existing data were available at all sites and the only additional information that could be sourced was for the uMnsunduze and Lovu River (GroundTruth Consulting, 2006; 2010). During the Intermediate assessment, diatom samples were taken during June and August 2013 at EWR sites in the Mvoti, uMngeni, Heinespruit and uMkhomazi. Mv_I_EWR 1 in the Mvoti and Mk_I_EWR1 and

Mk_I_EWR 3 in the uMkhomazi, were only sampled once during this period. Limited existing data were available at all sites and the only additional information that could be sourced was for the uMngeni and uMkhomazi River (GroundTruth Consulting, 2006).

Although some historic data is available for the KwaZulu-Natal area, diatom data within the South African National Diatom Collection is generally depauperate for the specific areas where EWR sites are located. It is recommended that diatom sampling and analysis should be included as part of a monitoring programme on a six monthly basis with specific emphasis where nutrients are an issue, i.e. as an additional indicator of eutrophication. Additional baseline data is necessary in order to develop a monitoring baseline and then in future develop EcoSpecs and TPCs.

Within the context of this study diatoms should be used as a **water quality screening tool** to indicate if:

- A particular physico-chemical metric needs further monitoring to assess the cause of the extent of the change.
- Management action is needed.
- For diatoms to function as an effective water quality screening tool the results generated should:
    - Provide information on diatoms as an additional response variable to compliment the physico-chemical driver component of the monitoring programme.
    - Provide additional information and interpretive results, especially at sites were physico-chemical data availability was poor or of low confidence.
    - Give an indication of the current pollution levels at a monitoring site according to the defined water quality class limits of the Specific Pollution sensitivity Index (SPI; Coste in CEMAGREF, 1982).

Collection and analysis of further baseline data should be based on the following methods and approach

- Sampling methods and species identification as outlined in Taylor *et al*. (2007a; 2007b) should be followed and the European numerical diatom index, SPI (Coste in CEMAGREF, 1982) should be used to interpret results with the database programme OMNIDIA (Lecointe *et al*., 1993). The classification of ecological indicators and class ranking based on van Dam *et al*. (1994) can be used to define EcoSpecs and TPCs from baseline data for both the wet season (or periods when the flow is elevated) and the dry season (or when the flow is low)..
- Diatom data analysis should include the following data output or indicators:
    - Diatom based water quality score: Using the SPI to interpret results which include adjusted class limits.
    - Diatom based Ecological classification according to Van Dam *et al*. (1994).
    - The results from the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) should be included as this index provides the percentage pollution tolerant diatom valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.

The following physico-chemical metrics or variables should be considered for the development of EcoSpecs and TPCs based on the most important and frequent pollution related impacts encountered in South African rivers and discussed in detail in Dallas and Day (2004):

- pH.
- Salinity.

- Nutrients.
- Organics.

At this level of monitoring the emphasis would be on the general diatom community composition and the temporal and spatial changes exhibited by the community under different flow conditions. Key indicator species/genera that most frequently indicate problems relating to physico-chemical metrics under South African conditions and applicable to the specific EWR sites should be identified and considered when developing EcoSpecs and TPCs. The outcome of data analysis should focus on the general measure of system recovery of the River reach as well as indicating notable changes in selected metrics. These species can then be considered when developing EcoSpecs and TPCs at a later stage when sufficient baseline data becomes available.

Information on specific species that would influence the overall SPI score as well as pollution related events which would lead to an increase in these specific species should be used as indicator species. Although there are many species that could lead to a change in community composition and ultimately altered SPI scores, the selected indicator species should occur frequently in the samples, and should be specifically good indicators of deteriorated water quality conditions or indicate changes in community composition due to water quality changes at the specific EWR site. The diatom reports provided in DWA (2014a;b) provided a good basis for identifying indicator species.

The presence of valve deformities is an indication of possible metal toxicity that may be present within the aquatic system. According to Luís *et al*. (2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The general threshold for valve deformities is usually considered potentially hazardous if the valve deformities make up between 1 - 2% of the total count.

The presence of valve deformities should be monitored at the EWR sites as valve deformities were noted at most of the Rapid and Intermediate EWR sites with the exception of Mk_I_EWR1 in the uMkhomazi River and Mt_R_EWR1 in the Mtamvuna River.

5.2 PRIORITISATION OF SITES

Although it is recommended that high frequency monitoring be conducted at all High Priority, it is understood that the pressure on resources may require prioritization of sites for monitoring purposes. This is particularly important if an information database has to be built before the implementation of RQOs can take place. Prioritisation may be for a range of reasons, e.g. Mk_I_EWR3 on the uMkhomazi, requires water quality monitoring as this is an important ecological site and the data is needed to explain what may be seen biologically, while the Sterkspruit (U60C-04556) is prioritised because of the poor water quality state at this site. Prioritisation of sites is therefore conducted for the EWR sites and High priority 3WQ sites.

The recommended prioritisation of sites is shown in Table 5.2 for EWR sites, and Table 5.3 for High Priority WQ sites. Table 5.3 does not list every 3WQ site (as the list is extensive), but lists the highest priority sites for monitoring. Sites listed in Table 5.3 will require the identification of monitoring sites or existing monitoring programmes (other than DWS monitoring), as water quality databases will need developing BEFORE RQOs can be implemented, as specified in the RQO report for the study (DWS, 2015). The RQO tables will also specify which RQOs at EWR sites can

be immediately implemented, and which variables will first need database development before implementation.

Note that Table 5.2 and 5.3 do not list the sites in order of priority - from highest to lowest priority but rather lists all sites that are a priority in the study area.

Table 5.4 Prioritisation of EWR sites for water quality monitoring

Priority (Area)	EWR site (River)	Comment
1 (U1-3)	Mk_I_EWR3 (uMkhomazi)	Important site for measuring responses to water quality issues.
2 (U4-1 and U4-2-)	MV_I_WR1 (Mvoti)	Important site in the Heinespruit for assessing state in the upper Mvoti River.
3 (U2-2)	Mg_I_EWR2 (uMngeni)	An EWR site which may be impacted by operational scenarios. Water quality state also needs improvement to maintain the biota.
4 (U2-5)	Mg_U_EWR5 (uMngeni)	Low in the system and receiving the uMnsunduze quality problems.
Other EWR sites as required by developmental or other pressures.		

For estuaries, high frequency monitoring requires monitoring of river inflow to the estuary. Such monitoring sites should ideally be located in the inflowing river just upstream of the EFZ. For some systems, e.g. the uMkhomazi an existing DWS water quality monitoring station (U1H6) fulfil this requirement, but in most other estuaries in the WMA monitoring stations still need to be specified. Criteria for the selection of monitoring priority sites for estuaries include systems that reflected poor catchment water quality, as well as systems that received effluent from WWTW. Table 5.5 indicates the list of priority sites related to the monitoring of water quality in river inflow to estuaries (as indicated).

Table 5.5 Prioritisation of other sites for water quality monitoring (including sites representative of inflow into estuaries)

SQ	Estuary/River	Comment
	Tongazi	Inflow to estuary (include WWTW effluent).
	Mpenjati	Inflow to estuary (include WWTW effluent).
	Umhlangankulu	Inflow to estuary (Pollution from catchment).
	Kaba	Inflow to estuary (Pollution from catchment).
	Mvutshini	Inflow to estuary (include WWTW effluent).
	Uvuzana	Inflow to estuary (Pollution from catchment).
	Kongweni	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Vungu	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Mhlangeni	Inflow to estuary (include WWTW effluent).
	Zotsha	Inflow to estuary (Pollution from catchment).
	Boboyi	Inflow to estuary (include WWTW effluent).
	Mbango	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Koshwana	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Mhlabatshane	Inflow to estuary (include WWTW effluent).
	Sezela	Inflow to estuary (include WWTW effluent).
	Mpambanyoni	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Mahlongwana	Inflow to estuary (Pollution from catchment/WWTW effluent).

SQ	Estuary/River	Comment
	Mkomazi	Inflow to estuary (include WWTW effluent).
	Little aManzimtoti	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Manzimtoti	Inflow to estuary (Pollution from catchment).
	Mbokodweni	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Sipingo	Inflow to estuary (Pollution from catchment).
	Durban Bay	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Mgeni	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Mdloti	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Tongati	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Mhlali	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Mvoti	Inflow to estuary (Pollution from catchment/WWTW effluent).
	Nonoti	Inflow to estuary (include WWTW effluent).
U40J-03998	Mvoti	High water quality impact area.
U70F-04845 U70F-04893	Amanzimtoti Little Amanzimtoti	Impacted areas upstream of an estuary flagged for poor water quality.
U60A-04533 U60B-04614 U60C-04555 U60C-04555	uMlazi Mkuzane uMlazi Sterkspruit	Economically important area with water quality issues.
U60E-04792	Mbokodweni	Impacted area upstream of an estuary flagged for poor water quality.
U60F-04597 U60F-04632	Mhlatuzana Umbilo	High water quality impact area.
T40G-05616	Vungu	Poor water quality state upstream of the estuary.
U20J-04488	Mshwati	High water quality impact area.
Appropriate site in lower uMnsunduze		A suitable site on the lower uMnsunduze needs to be monitored to monitor instream water quality state and biotic responses. The site selected should be downstream of water quality impacts and link in with current biomonitoring activities if possible.

5.3 EWR SITE PRIORITISATION

As it is acknowledged that resources may not be available to undertaken monitoring at all the EWR sites, the EWR sites have been prioritised. Initial prioritisation based on the following criteria was undertaken as part of the scenario evaluation (DWS, 2014c).

- PES.
- EIS.
- Confidence in the EcoClassification results.
- Conservation importance.

Further prioritisation for monitoring purposes was undertaken by taking into account the position of the EWR site in the catchment as well as the length of river the site represents. For example, monitoring at the most downstream site will often be the most useful as all impacts and changes of upstream developments will impact on these sites.

The order of priority EWR sites for monitoring is provided in the sections below.

5.3.1 uMngeni River (U2) Catchment

The site weight (Table 5.6) indicates that the weight between the sites is similar. Mg_I_EWR2 carries the highest weight due to its PES and as it is situated in a private nature Reserve.

The weights are provided in the Table 5.6. The weight is based on the conversion of the PES and EIS to numerical values to determine the normalised weight.

Table 5.6 uMngeni River system: Weights allocated to EWR sites relative to each other

EWR site	PES	EIS	Locality in protected areas (0 - 5)	Confidence	Normalised Weight
EWR 2	C	Moderate	2	3.5	0.52
EWR5	D	Moderate	1	4	0.48

5.3.2 uMkhomazi River (U1) Catchment

As there are three sites on the uMkhomazi River, these need to be integrated based on a system of weighting the importance of the sites. MK_I_EWR3 is the most important site due largely to the long river distance which the site represents (Table 5.7).

Table 5.7 Weights allocated to EWR sites relative to each other

EWR site	PES	EIS	Locality in protected areas (0 - 5)	Distance	Normalised Weight
EWR 1	C	Moderate	1	0.08	**0.22**
EWR 2	B	High	3	0.32	**0.37**
EWR 3	C	Moderate	1	0.6	**0.41**

6 ESTUARIES HABITAT AND BIOTA MONITORING

A list of abiotic indictors that should always be included in long-term monitoring programmes to allow for proper identification of “cause and effect’ links, in particular links to river inflow and water quality are:

- Hydrology.
- Sediment dynamics.
- Hydrodynamics, and
- Water quality.

Biotic components that need to be addressed are:

- Microalgae.
- Macrophytes.
- Invertebrates (including zooplankton, benthic invertebrates and macro crustaceans).
- Fish (Ichthyofauna), and
- Birds (Avifauna).

As monitoring on the individual estuary basis is very costly it is recommended that the ecological surveys of critical biological components – plants, invertebrates, fish and birds - be repeated every three years in summer and winter (in the case of the open/closed estuaries it should be during the closed mouth periods) on a regional scale as one concerted survey. This will reduce cost and contribute significantly to a regional overview to the state of the regions estuaries.

In the event where the recommended baseline studies cannot be implemented fully due to, for example budgetary constraints, it must be recognised that the reduced baseline programme will result in a poorer understanding of the functioning of the systems in question and lower confidence. Further to this it could also influence the reaction time to respond to interventions required if the estuarine health is on a negative trajectory. Critical minimum indicators must be selected to be measured at a higher frequency level to act as a check after which more intensive monitoring can be introduced if negative triggers are detected. This baseline monitoring should be done in partnership with the CMF, municipalities and other organs of state who has environmental protection mandate.

6.1 PRIORITIZATION OF ESTUARIES FOR MONITORING

As it is not possible to initiate monitoring programmes on all the estuaries instantaneously the systems were prioritised based on the following criteria: PES, degree of current and future pressure on them and estuarine Importance. A scoring system was used to identify the hotspot estuaries with 4 being allocated to the estuaries with the highest priority and 1 to the lowest. Levels 3 and 4 will therefore be the highest priority estuaries for management (Table 7.1). In addition to identifying the “Hotspot” estuaries, priority monitoring components were prioritised with red circles indicating the highest priority, orange medium priority and green the lowest priority.

Table 6.1 Prioritisation of estuaries for long-term monitoring

ESTUARY	PES	REC	TEC	Importance: Conservation	Importance: Estuary (Biodiversity)	Importance: Fish Nursery	Pressure: Hotspot Rating	Pressure: Flow	Pressure: Water Quality	Pressure: Non-Flow	Monitoring Components: Flow	Monitoring Components: Mouth State	Monitoring Components: Sediment dynamics	Monitoring Components: Water Quality	Monitoring Components: Microalgae	Monitoring Components: Macrophytes	Monitoring Components: Invertebrates	Monitoring Components: Fish	Monitoring Components: Birds
Mtamvuna	B	A/B	A/B	5	4	5	2												
Zolwane	B	B	B	1	1	1	3												
Sandlundlu	C	C	C	1	2	1	2			X									
Ku-Boboyi	B	B	B	1	1	1	3												
Tongazi	B/C	B/C	B/C	1	2	1	3		X	X									
Kandandhlovu	B	B	B	1	2	3	4		X	X									
Mpenjati	B/C	B	B	5	3	3	3		X	X									
Umhlangankulu	C	C	C	1	3	3	2		X	X									
Kaba	C	C	C	1	2	1	3		X	X									
Mbizana	B	B	B	1	3	1	2			X									
Mvutshini	B/C	B/C	B/C	1	1	1	3		X	X									
Bilanhlolo	C	C	C	1	3	3	2		X	X									
Uvuzana	C	C	C	1	1	1	2		X	X									
Kongweni	D/E	D	D/E	1	2	3	2	X	X	X									
Vungu	B	B	B	1	2	1	4		X										
Mhlangeni	C	C	C	1	2	1	2		X	X									
Zotsha	B/C	B	B	5	3	3	4		X	X									
Boboyi	B/C	B/C	B/C	1	2	1	3		X	X									
Mbango	E	D	E	1	2	1	3	X	X	X									
Umzimkulu	B	B	B	5	4	5	3												
uMthente	C	C	C	1	3	1	2	X	X	X									
Mhlangamkulu	C	C	C	1	1	3	2	X		X									
Damba	D	C	D	5	2	1	2	X		X									
Koshwana	C/D	B	C	5	2	1	3	X	X	X									
Intshambili	C	B	C	5	2	1	3	X	X	X									
Mzumbe	C/D	C	C	1	3	1	2		X	X									
Mhlabatshane	B/C	A/B	A/B	5	2	3	3			X									
Mhlungwa	C	C	C	1	2	1	2		X	X									
Mfazazana	C	B	C	5	3	1	3		X	X									
Kwa-Makosi	B/C	B	B	5	3	1	3		X	X									
Mnamfu	C	C	C	1	2	1	2		X	X									

ESTUARY	PES	REC	TEC	Importance: Conservation	Importance: Estuary (Biodiversity)	Importance: Fish Nursery	Pressure: Hotspot Rating	Pressure: Flow	Pressure: Water Quality	Pressure: Non-Flow	Monitoring Components: Flow	Mouth State	Sediment dynamics	Water Quality	Microalgae	Macrophytes	Invertebrates	Fish	Birds
Mvuzi	C	C	C	1	2	1	3		✕	✕	●	●	●	●	●	●	●	●	●
Fafa	C/D	C	C	1	4	3	2	✕	✕	✕	●	●	●	●	●	●	●	●	●
Mdesingane	D	D	D	1	1	1	2		✕	✕	●	●	●	●	●	●	●	●	●
Sezela	C	C	C	1	3	1	3		✕	✕	●	●	●	●	●	●	●	●	●
Mkumbane	C	C	C	1	2	1	3		✕	✕	●	●	●	●	●	●	●	●	●
uMuziwezinto	C/D	C/D	C/D	1	3	1	3	✕	✕	✕	●	●	●	●	●	●	●	●	●
Nkomba	B/C	B/C	B/C	1	1	1	2		✕	✕	●	●	●	●	●	●	●	●	●
Mzimayi	C/D	C/D	C/D	1	2	1	2	✕	✕	✕	●	●	●	●	●	●	●	●	●
Mpambanyoni	C	C	C	1	2	1	2		✕	✕	●	●	●	●	●	●	●	●	●
Mahlongwa	C	B	B	5	2	1	3		✕	✕	●	●	●	●	●	●	●	●	●
Mahlongwane	C	B	B	5	3	1	3		✕	✕	●	●	●	●	●	●	●	●	●
uMkhomazi	C	B	B/C	5	4	5	4	✕	✕	✕	●	●	●	●	●	●	●	●	●
Ngane	C	C	C	1	2	1	3		✕	✕	●	●	●	●	●	●	●	●	●
Umgababa	C	B	B/C	5	3	3	4	✕	✕	✕	●	●	●	●	●	●	●	●	●
Msimbazi	B	A	B	5	3	1	2		✕	✕	●	●	●	●	●	●	●	●	●
Lovu	C/D	B	B/C	5	3	3	3	✕	✕	✕	●	●	●	●	●	●	●	●	●
Little aManzimtoti	E	D	E	1	2	1	2	✕	✕	✕	●	●	●	●	●	●	●	●	●
aManzimtoti	D/E	D	D	1	3	1	2	✕	✕	✕	●	●	●	●	●	●	●	●	●
Mbokodweni	E	D	E	1	3	1	3	✕	✕	✕	●	●	●	●	●	●	●	●	●
Sipingo	F	D	F	1	3	1	4	✕	✕	✕	●	●	●	●	●	●	●	●	●
Durban Bay	E	D	E	5	5	5	4	✕	✕	✕	●	●	●	●	●	●	●	●	●
uMngeni	E/D	D/E	D	5	4	3	4	✕	✕	✕	●	●	●	●	●	●	●	●	●
Mhlanga	D	B	B	5	4	3	4	✕	✕	✕	●	●	●	●	●	●	●	●	●
uMdloti	D	C	D	1	4	3	4	✕	✕	✕	●	●	●	●	●	●	●	●	●
uThongathi	D	C	D	1	4	1	4	✕	✕	✕	●	●	●	●	●	●	●	●	●
Mhlali	C/D	B/C	C	5	4	3	3	✕	✕	✕	●	●	●	●	●	●	●	●	●
Bob's Stream	B/C	B/C	B/C	1	1	1	3		✕	✕	●	●	●	●	●	●	●	●	●
Seteni	B/C	B/C	B/C	1	2	1	3		✕	✕	●	●	●	●	●	●	●	●	●
Mvoti	D	C	C/D	5	3	1	4	✕	✕	✕	●	●	●	●	●	●	●	●	●
Mdlotane	B	A/B	A/B	5	4	1	3		✕		●	●	●	●	●	●	●	●	●
Nonoti	C	C	C	1	3	1	2		✕	✕	●	●	●	●	●	●	●	●	●
Zinkwasi	B/C	A/B	B	5	4	3	3		✕	✕	●	●	●	●	●	●	●	●	●

6.2 HYDRODYNAMICS

Hydrology and hydrodynamics are monitored to determine if the primary physical processes that drive the conditions of the estuary are being .maintained or achieved. This type of data set can also serve as an early warning system that can highlight a decline in ecosystem condition before a decrease in the biologic health is observed.

Continuous flow recordings (gauging station) of river inflow at the head of estuaries and continuous water level recording at estuary mouths (and mouth observations) require longer-term data sets and it is therefore necessary to start such baseline monitoring programmes well in advance (at least 5 years) of any study that uses EWR results.

Recommended minimum requirements for hydrology and hydrodynamics are provided below and supported by the DWS National Estuary Monitoring Programme.

Table 6.2 Recommended minimum requirements for hydrology and hydrodynamics at high priority estuaries

Component	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
Hydrodynamics	Record water levels in the Estuary.	Continuous	At the mouth
	Measure freshwater inflow into the Estuary.	Continuous	Near head of estuary
	Aerial/Satellite photographs of Estuary.	Every year	Entire estuary

6.3 SEDIMENT DYNAMICS

The disturbance of the sediment erosion/deposition equilibrium in an estuary can lead either to siltation, resulting in the estuary becoming shallower, or it can lead to the erosion of important sediment habitats. Under natural conditions estuaries are generally in a state of long-term equilibrium of sedimentation and erosion. However, this equilibrium can be disturbed because of changes in run-off, especially if the occurrences and magnitudes of major floods are changed.

Floods and high seasonal flows influence the sediment erosion/deposition equilibrium in an estuary. Floods can alter important features within an estuary, such as the bathymetry (e.g. channel depth or the size of intertidal areas) and sediment composition (e.g. sand or mud) and may require additional ad hoc sampling to determine their influence.

Suitable sediment data records cannot be acquired in the short term. Therefore, if sediment processes in estuaries are to be better understood and quantified, long-term programmes will have to be implemented. In this regard it is recommended that the DWS implement such monitoring activities timeously in South African estuaries, particularly those on the receiving side of rivers earmarked for substantial water abstraction in future.

Table 6.3 Recommended minimum requirements for sediment dynamic monitoring at high priority estuaries

Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 200 - 500 m intervals, but in more detail in the mouth (every 100 m). The vertical accuracy should be about 5 cm.	Every 3 years	Entire estuary
Set sediment grab samples (at cross section profiles) for analysis of particle size distribution and origin (i.e. using microscopic observations)	Every 3 years (with invert sampling)	Entire estuary

6.4 WATER QUALITY

Estuaries receive water from two sources, i.e. the river and sea, each with distinctively different water quality characteristics, particularly in terms of system variables and nutrients. In turn, the water quality characteristics along the length of an estuary depends on the extent of the influences of each of these sources (governed by hydrodynamic processes), as well as biochemical processes (e.g. organic degradation, eutrophication) taking place at that point within the estuary. The influence of biochemical processes is particularly evident in parts of an estuary where residence time of water becomes longer, often observed along the middle reaches of an estuary during the low flow season. It is therefore also crucial that water are sampled in the two sources, i.e. river and sea.

The analytical techniques used in the processing of marine and estuarine water quality samples vary greatly form those used in the analysis of fresh water samples. It is therefore crucial that the analyses of water quality samples be conducted by an accredited marine analytical laboratory.

Just as the sediment sampling requirements, River water quality monitoring also requires longterm data sets and it is therefore necessary to start such baseline monitoring programmes at least 5 years in advance, to amongst others, detect trends (whether negative or positive) which will inform important pro- active management decisions. For example, monitoring points at the head of estuaries should be included in the water quality monitoring programme of the DWS.

At present water quality of near-shore waters is not measured on a routine basis along the SA coast, as is the case for some rivers. Because the seawater quality may show strong seasonal variability, particularly along the SA West coast, a short term monitoring survey may not necessarily be representative. In the short term, data on near-shore seawater quality therefore needs to be derived from available data sources, including the South African Water Quality Guidelines for Coastal Marine Waters. Volume 1: Natural Environment (DWAF, 1995), until such time as routine water quality monitoring programmes are implemented along the SA coast.

For toxic substances (e.g. trace metals and hydrocarbons) it is considered more appropriate to sample environmental components which tend to integrate or accumulate change over time, such as sediments. These surveys need, however, not be done in ALL estuaries, only in systems where river water quality or human activities along the banks of the estuary suggest possible contamination (e.g. waste water treatment works, industrial effluents or storm water run-off from large urban developments).

For long-term monitoring programmes, water and sediment quality data are particularly important for interpretation of specific biological responses and, therefore must be collected by the relevant biotic components as indicated during their sampling surveys.

Table 6.4 Recommended minimum requirements for water quality monitoring at high priority estuaries

Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
Water quality (e.g. system variables (i.e. pH, oxygen, turbidity), nutrients and toxic substances) measurements on river water entering at the head of the estuary.	Monthly continuous	Close proximity to head of estuary
Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: ▪ End of low flow season (i.e. period of maximum seawater intrusion). ▪ Peak of high flow season (i.e. period of maximum flushing by river water).	Seasonally every year	Entire estuary (3 - 10 stations)
Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples).	Seasonal surveys, every 3 years or when significant change in water inflows or quality expected	Entire estuary (3 - 10 stations)
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue.	Every 3 - 5 years	sheltered, depositional areas
Water quality (e.g. system variables, nutrients and toxic substances) measurements on near-shore seawater.	Use available literature need to give guidelines here	Seawater adjacent to estuary mouth at salinity 35

6.5 MICROALAGAE

Microalgae (Phytoplankton and Benthic microalgae) is used in long-term monitoring to indicate whether there is a functional river-estuarine interface. Microalgae is also used effectively in long term monitoring as an indicator of water quality problems.

Phytoplankton: To estimate phytoplankton biomass, collect duplicate samples for *chlorophyll-a* at the surface and at 0.5 m depth intervals. Use a spectrophotometer for sample analysis before and after acidification (add 0.1 ml HCl to sample). Do cell counts (at 400 X magnification) on dominant phytoplankton species to establish species distribution and composition, i.e. green algae, flagellates, dinoflagellates, diatoms and blue-green algae.

Benthic microalgae: Collect intertidal and subtidal benthic samples for *chlorophyll-a* (biomass) analysis. Collect five samples at each station. Collect and analyse samples using a recognised technique, e.g. High Precision Liquid Chromatography (HPLC). Record the relative abundance of dominant algal groups, i.e. green algae, dinoflagellates, diatoms and blue-green algae and identify the dominant species.

At each station also measure:

- Water salinity and inorganic nutrient.
- Sediment particle size distribution and organic content, and
- Light penetration (photosynthetic active radiation (PAR)) or Secchi disk depth.

For the most cost effective method related to time and money, combine water and sediment quality surveys on a particular estuary with the microalgal surveys. The temporal scale of the microalgal sampling needs to match that of the invertebrates (zooplankton) to link the response patterns of these biotic components as best as possible.

Table 6.5 Recommended minimum requirements for microalgae monitoring for high priority estuaries

Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
Phytoplankton: Conduct water column *chl-a* measurements and counts of dominant phytoplankton groups (incl. flagellates, diatoms, dinoflagellates, chlorophytes and cyanobacteria). Benthic microalgae: Conduct intertidal & subtidal benthic *chl-measurements*.	Summer and winter survey every 3 years	Entire estuary (3 - 10 stations)

6.6 MACROPHYTES

The following information needs to be captured from recent aerial photographs and ortho-photographs covering the entire estuary as defined by the geographical boundaries, including:

- The number of different habitats (plant community types).
- The area covered by each plant habitat.
- Any historical change in area covered by plant habitat, and
- The extent of anthropogenic impacts (agriculture, flood plain development).

Field data need to be collected for ground truthing of aerial photographs:

- The number of different plant habitats (plant community types).
- The area covered by each plant habitat.

- A species list for each plant habitat, and
- The extent of anthropogenic impacts such as grazing, trampling, alien vegetation, boating, bait digging etc.

Permanent transects (sampling stations) are needed to monitor changes in plant habitats. Along each transect (minimum of four) the following data need to be collected:

- Elevation profile and water level.
- Water column salinity and turbidity, and
- Sediment salinity, moisture content and sediment composition.

Table 6.6 Nine different habitat types recognised for estuaries

Habitat Type	Indicator Species
Open surface water area	Indicates available habitat for phytoplankton
Intertidal sand and mudflats	Indicates available habitat for intertidal benthic microalgae
Submerged macrophyte beds	*Zostera capensis (eelgrass), Ruppia cirrhosa, Potamogeton pectinatus*
Macroalgae	*Cladophora* spp*., Enteromorpha* spp*., Caulerpa filiformis*
Intertidal salt marsh	*Spartina maritima, Sarcocornia perennis, Triglochin* spp
Supratidal salt marsh	*Sarcocornia pillansii, Sporobolus virginicus*
Reeds and sedges	*Phragmites australis, Schoenoplectus littoralis*
Mangroves	*Avicennia marina, Rhizophora mucronata, Bruguiera gymnorrhiza*
Swamp forest	*Barringtonia racemosa, Hibiscus tiliaceus*

These include the microalgal habitats as the area covered by each habitat is used to calculate the overall botanical importance of an estuary.

Table 6.7 Recommended minimum requirements for monitoring macrophytes

Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
▪ Develop ground-truthed maps. ▪ Record number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit. ▪ Record percentage plant cover, salinity, water level, sediment moisture content and turbidity on a series of permanent transects along an elevation gradient. ▪ Take measurements of depth to water table and ground water salinity in supratidal marsh areas.	Summer survey every 3 years	Entire estuary

6.7 INVERTEBRATES

Because of the high variability in invertebrates in response to flow it is important to sample over two years to obtain the required confidence level (medium confidence for Intermediate level and high confidence for Comprehensive level).

Lack of information on invertebrates is the reason for the greater intensity (temporal scale) of sampling for this component to get the required confidence. There is also a rapid change in community composition and abundance over time (weeks to months). Sampling is even more intensive for zooplankton because of their rapid response over time. As far as possible, the

invertebrate and macrophyte sampling stations should be matched to be able to link habitats with invertebrate occurrence and characteristics.

Zooplankton: Collect quantitative samples after dark, preferably during neap tides (mid to high tide), because currents are less strong and zooplankton will be more active in the water column. Sampling should be done at mid-water level, i.e. not at the surface. Two net trawls (WP 2 – 200 micron mesh) representing two replicate samples should be taken at each station. The net should be pulled for three minutes per station (10.0 -12.0 m^3 of water) at 0.15 knots diagonally across the estuary at each site. Record the abundance (density per volume) of each species in each trawl and average the results over the two replicates for each station. At each station phytoplankton samples (i.e. water column sample) and benthic microalgae samples need to be collected for *chlorophyll-a* analyses.

Benthic invertebrates: Collect (subtidal) samples using a Zabalocki-type Eckman grab sampler with six to nine randomly placed grabs (replicates) at each station. Collect intertidal samples at spring low tide using a core sampler with a minimum diameter of 150 mm and depth of 250 mm, with six to nine replicates at each site along the transect. Grab/core sample should then be placed in a 500-micron sieve bag and the contents gently sifted so as to remove fine particles. Animals and any other relatively coarse material are then stored in formalin for identification in the laboratory. At least six replicates are required per station. For intertidal benthic invertebrates that are not well quantified by core sampling (e.g. mud prawns, sand prawns, some crabs), count overall density for each species in 0.25m^2 minimum quadrat areas, with five replicates at each station.

The following must be completed at each site:

- Identify fauna to the lowest taxon possible.
- Record animal density and species abundance (animals per m^2), and
- Record the presence of *Zostera* (beds) or other macrophytes at the site.

At each station, sediment samples need to be collected for particle size analysis (250 ml) and organic content (250 ml) using standard techniques. Other parameters that must be measured at each site are temperature, salinity, oxygen, conductivity, turbidity, chlorophyll-a and pH. Measurements should be taken at the surface, 0.5 m, 1.0 m from the surface and thereafter at 1.0 m depth intervals.

Macrocrustaceans: Quantitative sampling for macrocrustaceans should be conducted during neap tides (mid to high tide), at the same stations used for zooplankton. Use a benthic sled (80 cm x 80 cm, with a 500 micron mesh) attached to a flow meter to collect the sample; tow for 30 metres diagonally across the estuary. Take two samples at each station. Set two prawn/crab traps per station overnight (more applicable to sub-tropical areas).

Identify fauna to the lowest taxon possible. Record the number of species and determine densities for each species. A sampling station is defined as a specific location in the estuary (at a specific 'distance from the mouth') from where a number of replicates are collected.

For invertebrate surveys, seven sediment grain size categories should be used, ranging from mud to very coarse sand. Each category relates to a particular size diameter in the following manner:

- 1 - 2 mm and > 2 mm: very coarse sand.
- 1 - 0.5 mm: coarse sand.

- 0.5 - 0.25 mm: medium sand.
- 0.25 - 0.125 mm: fine sand.
- 0.125 - 0.0625 mm: very fine sand.
- < 0.0625 mm: mud (silt and clay).

The percentage organic content of sediments can roughly be classified as:

- <0.5%: Very low.
- 0.5 - 2%: Low.
- 1 - 2%: Moderately low.
- 2 - 4%: Medium.
- > 4%: High.

Water (salinity, temperature, pH, dissolved oxygen and turbidity) and sediment quality (sediment grain size and organic content) measurements also need to be collected during the invertebrate surveys. Combining water and sediment quality surveys on a particular estuary with the invertebrate surveys are more cost-effective and it will give a better indication of the relationship of the various indictors with each other due to changes in an estuary.

Table 6.8 Recommended minimum requirements for monitoring for invertebrates

Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
▪ Record species and abundance of zooplankton, based on samples collected across the estuary at each of a series of stations along the estuary; ▪ Record benthic invertebrate species and abundance, based on subtidal and intertidal grab samples at a series of stations up the estuary, and counts of hole densities; and ▪ Measure sediment characteristics at each station.	Summer and winter survey every 3 years	Entire estuary (3 - 10 stations)

6.8 FISH

The primary goal of fish sampling is to obtain species and size composition of the fish present in the system. Fish surveys should be conducted using seine nets and gill nets as primary gear, but non-destructive sampling should be practiced where possible. The survival rate of larger fish is much greater if they are removed from a gill net by cutting the mesh (easily repaired afterwards) whereas most seined fish can be measured and released alive. If there are abundant fish in a sample, 100 individuals of a species should be measured, the rest counted and released. However this is not always possible, as it must be accepted that some fish, especially clupeids, die very easily.

Seine nets: 30 m x 2 m x 15 mm multifilament bar mesh in the wings and a 5 mm bar mesh in the purse. Seine-nets should be 30 m long by 2 m depth. The cod end (bag, purse) and the wings 5 m either side of it should be a 5 mm bar whereas the remaining 15 m of each wing can be 15 mm bar mesh. This is required to adequately sample estuarine and 'faster moving' marine species. The net should be weighted such that it sinks below the surface when set in water deeper than 2 m (i.e. the distance between the lead and cork lines). A light net makes it more difficult to obtain a representative sample from weed and sandy areas, e.g. flatfish species tend to burrow in the sand and escape under a light seine.

Gillnets: Monofilament gill nets should comprise at least 3 different mesh sizes within the range 40 - 150 mm stretch mesh. Monofilament gill nets should comprise at least 4 nets (or panels) of which

one net comprises 44, 48, 51 and 54 mm mesh, plus 3 more nets in the 75 - 150 mm stretched mesh range (e.g. 75, 100 and 145 mm stretched mesh). Gill nets are extremely valuable in determining the seasonal changes in the along-stream distribution of the adults of large fish species. Non-destructive sampling should be practiced where possible.

In temporarily open/closed estuaries not all pre-selected sites may be assessable with the same gear during the various sampling trips. This would especially be the case for sites selected on habitat variability, e.g. protective backwater areas. This is an acceptable practice, as long as representative sites are monitored in the same salinity regime to allow for extrapolation.
The advantages of using fish as indicators include (Whitfield and Elliot, 2002):

- Fish are present in all aquatic systems.
- Life-history and environmental response information is available for most species.
- Relatively easy to identify and samples can be processed in the field, with the fish being returned to the water (non-destructive sampling).
- Communities usually include a range of species that represent a variety of trophic levels.
- Fish are relatively long-lived and therefore provide an integrative record of environmental stress.
- Fish contain many life forms and functional guilds and are likely to cover a number of components of aquatic ecosystems (habitat types) affected by change.
- Both sedentary and mobile and thus will reflect localized stressors as well as provide a broader assessment of effects.
- Acute toxicity and stress effects can be evaluated in the laboratory;
- High public awareness value, i.e. general public relates more to information on fish than on invertebrates or plants.
- Societal costs of environmental degradation (e.g. cost-benefit analyses) are more readily determined in terms of the economic, aesthetic and conservation values attached to fish.

Table 6.9 Recommended minimum requirements for long-term monitoring for fish

Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
Record species and abundance of fish, based on seine net and gill net sampling.	Summer and winter survey every 3 years	Entire estuary (3 - 10 stations)

Water quality measurement (salinity, temperature and other physico-chemical properties) need to be collected during the fish surveys at all fish sites. Because there is a direct correlation between the water quality, habitat type and fish occurrence/abundance, it is strongly recommended to always combine the fish sampling with the water quality, and flow surveys to allow for measuring the correlation between the different constituencies and due to the fact that it is most cost-effective (money and labour wise).

6.9 BIRDS

Undertake full bird counts of all water-associated birds. First, divide the estuary into counting sections on the basis of habitat type, and taking into account the area that can be covered per counter during a low tide period. For each counting session capture the following information:

- A species list.
- The number of birds of each species (at low tide).
- The state of the habitat at the time of observation (take a photo of site).
- The levels of human disturbance at time of counting (photos of disturbance will be very valuable to do comparison with later monitoring).

- Take note of key areas for feeding, roosting and breeding on the estuary and adjacent floodplain.
- Take note of and count high tide aggregations of feeding or roosting birds as far as possible;
- Take note of breeding areas and count breeding aggregations as far as possible.
- The state of the mouth must be recorded at each count.

The upper boundary of the study area is the same as that for the overall study, i.e. the upper geographical boundary of the estuary. The seaward boundary, which is regularly crossed by seabird species such as cormorants, gulls and terns, is more difficult to define. As a guideline, it should include the full tidal delta area and sand bars up to the back line of breakers outside the estuary mouth.

Bird numbers fluctuate cyclically, in fact often with a 3-year periodicity. If counting is done every two years complete loss of the pattern will occur, which will make interpretation of trends very difficult. Therefore, in the long-term, birds should preferably be monitored annually.

Ideally, the summer count should be in a consistent month, with the same month being used for the monitoring programme. Thus, unless there is a problem with mouth closure, the summer count should always be in February or March, and never after the end of March. Numbers of birds in an estuary change markedly throughout the year, with summer numbers often continuing to increase from spring right up until the end of March, after which there is a dramatic drop in early April following the departure of long-distance Palearctic migrants. Counting birds earlier than February would not only potentially lead to an underestimate of maximum bird numbers, but would be compromised in quality by presence of summer holiday-makers. Human disturbance on estuaries is known to have a significant impact on the number of birds counted on estuaries.

The Coordinated Waterbird Counts (CWAC) monitors South Africa's waterbird populations and the conditions of the wetlands which are important for waterbirds. This is being done by means of a programme of regular mid-summer and mid-winter censuses at a large number of South African wetlands and estuaries, at regular six-monthly intervals. CWAC currently monitors over 350 wetlands around the country. It is recommended that the Department of Water and Sanitation in collaboration with South African National Biodiversity Institute (SANBI) provide CWAC with a list of priority estuaries, and in this way those estuaries could be considered for inclusion in their monitoring network.

Although the selection of components in long-term monitoring programmes will be selected on a site specific level, birds are likely to be important indicators for indicating

- Large permanently open estuaries.
- Estuarine lakes and bays.
- If there are a number of rare and/or endangered species (diversity and/or density.
- Estuaries that are known to be utilized during migration.

Table 6.10 Recommended minimum requirements for long-term monitoring birds

Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)
Full count of all water associated birds, covering as much of the estuarine area as possible, from a boat and on foot.	Annual winter (Jul/Aug) and summer (Jan/Feb) surveys	Entire estuary

7 REFERENCES

CEMAGREF. 1982. Etude des methodes biologiques quantitatives d'appreciation de la qualite des eaux. Rapport Division Qualité des Eaux Lyon - Agence Financiere de Bassin Rhône-Méditerranée- Corse. Pierre-Benite.

Cormier, S.M. and Suter, G.W. 2008. A framework for fully integrating environmental assessment. Environmental Management 42:543–556.

Dallas H.F. and Day J.A. 2004. The Effect of Water Quality Variables on Aquatic Ecosystems: A Review. WRC Report No TT224/04. Water Research Commission, Pretoria.

Department of Water Affairs and Forestry (DWAF). 1995. South African Water Quality Guidelines for Coastal Marine Waters. Volume 1: Natural Environment. Pretoria.

Department of Water Affairs and Forestry (DWAF), South Africa. 1996. South African water quality guidelines. Volume 3: Industrial Use.

Department of Water Affairs and Forestry (DWAF), South Africa. 2004. Internal Strategic Perspective: Umvoti to Mzimkulu Water Management Area: Prepared by Tlou & Matji (Pty) Ltd, WRP (Pty) Ltd, and DMM cc on behalf of the Directorate: National Water Resource Planning (East). DWAF Report No. P WMA 11/000/00/0304.

Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the water quality component of the Ecological Reserve. Report prepared for Department of Water Affairs and Forestry, Pretoria, South Africa by P-A Scherman of Scherman Consulting.

Department of Water Affairs (DWA), South Africa. 2009a. Operationalise the Reserve: Pilot Studies (Letaba, Luvuvhu, Kat, Upper Komati Rivers) Report. Prepared by Water for Africa. Authored by S Mallory. Report no. RDM/NAT/05/CON/0607.

Department of Water Affairs (DWA), South Africa. 2010. Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. Sabie and Crocodile Systems: EcoSpecs Report. Prepared by Water for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/012.

Department of Water Affairs (DWA), South Africa. 2011. Classification of Significant Water Resources in the Mvoti to Umzimkulu Water Management Area (WMA 11): Scoping Report. Report No: RDM/WMA11/00/INT/CLA/0112. September 2011.

Department of Water Affairs (DWA), South Africa. 2014a. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Volume 2: EcoClassification and EWR assessment on the Mtamvuna, Lovu, uMngeni, Karkloof and uMnsunduze Rivers. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. May 2014. DWA Report Number: RDM/WMA11/00/CON/CLA/0214.

Department of Water Affairs (DWA), South Africa. 2014b. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Volume 3: EcoClassification and EWR assessment on the

uMkhomazi, uMngeni, and Mvoti Rivers. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. July 2014. DWA Report Number: RDM/WMA11/00/CON/CLA/0314.

Department of Water and Sanitation (DWS), South Africa, 2014a. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Volume 7a: Recommended Water Resource Classes for the uMkhomazi (U1) and Mvoti (U4) River systems. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. September 2014. DWS Report Number: RDM/WMA11/00/CON/CLA/0414.

Department of Water and Sanitation (DWS), South Africa. 2014b. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Secondary: T4 – T5, U1 – U8. Compiled by RQIS-RDM: http://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx.

Department of Water and Sanitation (DWS), South Africa. 2014c. The determination of water resource classes and associated resource quality objectives in the Inkomati Water Management Area. Operational Scenarios and recommended Water Resource Classes. Authored by Huggins G, Louw MD, Mallory S, Van Jaarsveld P and Van Rooyen P. DWS Report, RDM/WMA05/00/CON/CLA/1114. September 2014.

Dickens, C.W.S., and Graham, P.M. 2002. The South African Scoring System (SASS) Version 5 Rapid Bioassessment Method for Rivers. African Journal of Aquatic Science 27:1-10.

Elzinga, C.L., Salzer, D.W., and Willoughby, J.W. 1998. Measuring and monitoring plant populations. BLM Technical Reference 1730-1, BLM/RS/ST-98/005+1730.

GroundTruth Consultants. 2006. eThekwini Municipality - State of Rivers Report.

Kelly M.G. and Whitton B.A. 1995. The Trophic Diatom Index: a new index for monitoring eutrophication in rivers, Journal of Applied Phycology 7, 433- 444.

Kershner, J.L., Bischoff, C.M., Horan, D.L. 1997. Population, habitat, and genetic characteristics of Colorado River cutthroat trout in wilderness and non-wilderness stream sections in the Uinta Mountains of Utah and Wyoming. North American Journal of Fisheries Management 17, 1134-1143.

Kleynhans, C.J. 2007. Module D: Fish Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 330/08.

Kleynhans, C.J., Mackenzie, J and Louw, M.D. 2007. Module F: Riparian Vegetation Response Index. In River EcoClassification: Manual for EcoStatus Determination (version 2) Water Research Commission Report No. TT 333/08. Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

Kleynhans, C.J., Louw, M.D., Birkhead, A.L., Thirion, C., Deacon, A., Angliss, M., Maseti, P., Rodgers, S and Weston, B. 2009. On the way to implementation: Ecological reserve Monitoring. International Conference on Implementing Environmental Water Allocations (IEWA), Port Elizabeth – South Africa 23-26 February 2009.

Lecointe, C., Coste, M. and Prygiel, J. 1993. “Omnidia”: Software for taxonomy, calculation of diatom indices and inventories management. Hydrobiologia 269/270: 509-513.

Luís, A.T., Teixeira, P., Almeida, S.F.P., Ector, L., Matos, J.X. and Ferreira da Silva, A. 2008. Impact of Acid Mine Drainage (AMD) on Water Quality, Stream Sediments and Periphytic Diatom Communities in the Surrounding Streams of Aljustrel Mining Area (Portugal). Water Air Soil Pollution. DOI 10.1007/s11270-008-9900-z.

ORASECOM, 2013. EFR Monitoring Programme. Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth. UNDP-GEF: Orange-Senqu Strategic Action Programme (Atlas Project ID 71598). Orange Senqu River Commission Report No. TR35. Prepared by Rivers for Africa, e-Flows Consulting (PTY) LTD.

Rogers, K.H. and Bestbier, R. 1997. Development of a protocol for the definition of the desired state of riverine systems in South Africa. Department of Environmental Affairs and Tourism, Pretoria.

Taylor, J.C., Harding, W.R. and Archibald, C.G.M. 2007b. An illustrated guide to some common diatom species from South Africa. Water Research Commission Report TT282/07. Water Research Commission. Pretoria.

Taylor, J.C., Harding, W.R. and Archibald, C.G.M. 2007a. A methods manual for the collection, preparation and analysis of diatom samples. Water Research Commission Report TT281/07. Water Research Commission. Pretoria.

Thirion, C. 2007. Module E: Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08.

Van Dam, Mertens, A., and Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology 28(1): 177-133.

Whitfield, A.K. and Elliott, M. 2002. Fishes as indicators of environmental and ecological changes within estuaries: a review of progress and some suggestions for the future. Journal of Fish Biology 61, 229-250.

8 APPENDIX A: REPORT COMMENTS

Page &/ or section	Report statement	Comments	Changes made?	Author comment
R Pillay, DWS Durban – 13 November 2015				
		Targets for faecal coliforms and E. coli cannot be achieved in some of the more urbanised areas without adopting a phased approach toward achieving reduction. It would have been better if the guideline relates to an incremental reduction in coliform counts over a specified period (e.g. achieve a 25% reduction from present state within a 5 year period). This will allow for progressive movement towards achieving the target.	No	This comment was made in response to reviewing the gazette and is addressed in the RQO report. It is no longer relevant as RQOs not immediately applicable will not be gazetted, but the reply given in the RQO report is repeated here for the sake of completeness. The RQO Report does state that a phased approach to reaching objectives would be required in some instances. The exact detail of how reaching objectives would be phased, and over what time period, has to be assessed on a site-by-site basis as part of planning and water use licensing, for example. Note that RQOs for faecal coliforms and *E. coli* have been rewritten in terms of assessing health risk rather than achieving absolute values.
		What I would like to see is a list of all the monitoring sites, including co-ordinates and the list of monitoring requirements for each of those sites. A tabular format would be great. The Region will need to determine the actual costs associated with monitoring.	No	DWS has indicated that we must remove the river programme as all monitoring must be undertaken as part of the existing REMP.
S Jooste, DWS: RQIS – 11 November 2015				
		The water quality RQOs are under-specified. Although the use of percentiles is acceptable, one needs to recognize the data implications. When you test compliance to a percentile (in fact to any number) one needs to know something about the expected statistical confidence that was intended, because that determines whether the data you have is sufficient. And that in turn speaks to the frequency. The time window of observation should also be specified (1 year, 5 years, 10 years etc). Data quality should therefore have been discussed in the RQO study.	Yes	Addressed in both the RQO Methods section and Implementation Report.
		Monitoring implementability: The report recognized that there are often insufficient data to generate a realistic RQO at a point and that monitoring is necessary. But where that is the case, it would be senseless setting any form of RQO. It should rather be specified what sort and quality of data should be produced in order to generate RQOs. Generally, compliance monitoring programs are much more data intensive than national programs and the implications	Yes	The text in the RQO Report has been enhanced and clarified to explain the difference between RQOs that have been based on suitable monitoring data and are immediately applicable (and will be gazetted), vs. those that are only provisional indications of RQOs. The latter can only be evaluated and confirmed once adequate monitoring data are available. The type of data to be collected depends on the driving variables identified per RU and are documented in this report. These factors are also mentioned in the RQO Methods section and Implementation Report. The

Page &/ or section	Report statement	Comments	Changes made?	Author comment
		of this has significant impact on the spatial and temporal requirements of RQO compliance monitoring and its cost and practicality.		removal of provisional RQOs from this report was considered, but finally left in the document so as to provide the DWS with some indications as to the expected range a RQO for a particular variable in a particular area, may fall into. All provisional RQOs must however be verified by appropriate monitoring data before they become applicable.
Consolidated comments from PMC members from M Thwala: 6 November				
		Link the Implementation Plan to the State of Water Report and the Catchment Management Strategy (providing information to the Catchment Management on how they can operationalize the Reserve/RQOs/Class).	Yes	Added text on Page iii and Page 2-3 regarding the CMFs. The System Operating Forum (SOF) produces reports such as the "Status of Water Resources" and therefore referencing the SOF rather than the report (see Page ii) is appropriate.
		Provide the limitations and assumptions of the report.	Yes	Added text in Section 1.4 presenting the context of the report.
		Is it a DWS plan or a Sector plan? DWS cannot carry it all out on its own, specify which institutions need to do what.	Yes	Added text in Section 1.4 describing that the applicable institutional structures can only be defined through engagement of DWS with the all the relevant institutions. It is therefore premature to specify such arrangements in this report. This was an instruction from DWS regarding implementation.
		RQOs as a new science, how is it going to incorporate other existing programmes which are doing related tasks? Link it to all related National Programmes.	No	The form of the document and the plan is based on the premises that RQOs are new and thet it need to be integrated with prevailing water resource management activities. This document therefore provides a beginning point for implementation and a framework for starting the process. Internalising the plan in the form of detail business planning will be premature at this stage.
		Align to existing structures (Catchment Management Forums etc.).	Yes	Added text on Page iii and Page 2-3 regarding the CMFs.
		Where there was no baseline information, mention which areas these were and provide a review section indicating what the review requirement is and over what period of time (e.g. the next 5 yrs or 10 yrs etc.).	Yes	This query is comprehensively dealt with in the Water Quality Approach section of the RQO Report. The areas where RQOs are immediately applicable, and therefore part of current monitoring programmes, is listed. All other sites need to be assessed for monitoring activities, and an adequate set of data collected before compliance to RQOs can be undertaken. Data quality and the length of data records are also addressed.
		The implementation plan is too generic, it is not site specific. Provide what needs to be done for each system to meet the set RQOs.	No	The intention of the plan is to list and describe the type of activities needed for implementation and since these are documented for the first time and is based on new thinking they are generic and need to be further unpacked when detail business planning is carried out by the relevant directorate. The constraints of budget and human resources will also play a role in selecting the priorities for progressive implementation.

Page &/ or section	Report statement	Comments	Changes made?	Author comment
				Ii will therefore be premature to define prescriptive actions in this report.
		The implementation plan doesn't talk about training of Provincial Officers on how to effectively implement RQOs.	No	Note that any training requirements will have to be met through directed and specialized courses to ensure that monitoring personnel are appropriately trained.
		The report doesn't clearly talk about where monitored results will be stored (Information database) and how it will be used to improve water resource condition.	No	DWS has substantial databases both in the region and at national level. These will form a source of data to be used in the implementation. It may well be that one of other of these existing data repositories will have to house the information (data), however, that need must be given as another requirement to be factored into the Department's overarching information management strategy. It will be premature to define those in this report.
		Did you consider aspects that came out of the 1st operationalization project that can assist with this report?	No	This plan has been structured and is in form the same as the already approved implementation plans for the Letaba and Inkomati Systems. All the requirements and comments received during the compilation of those plans were incorporated in the formulation of this document.
Executive summary	This coordination may be formalised in an appropriate structure similar to a System Operating Forum (SOF) (as set up by DWS in various catchments across the country).	The coordination should be aligned to the already existing Catchment Management Forums (CMFs).	Yes	Added text on Page iii and Page 2-3 regarding the CMFs.
Exec Sum: Activities milestones and related processes table.		Activities 1 and 2 are already in place, hence irrelevant on this table, remove.	Yes	The activities 1 and 2 are required to provide the context of the remaining activities. Note added to the activity table.
	It is recommended that an Implementation Plan Management Committee (IPMC) be formulated to oversee the roll out of the actions of the plan.	Need to work within existing structures.	No	The option remains to expand the functions of an existing forum(s) or to establish a dedicated committee as indicated in the paragraph following this sentence.
Exec Summ:	The DWS has eight functional estuary water level recorders on the online HYDSTRA database for the study area.	Refer to the table that Specifies the sites where those 8 exist.	Yes	(see Table 4.2).

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Exec Summ:	This is only the case for about four of the systems at present	Specify which ones.	Yes	(Mvoti, uMkhomazi, Tongati and Mdloti (Table 4.1)).
	The relevant elements of this environment are: Water resource management functions performed by DWS and other institutions.	Somewhere in the text mention the responsibilities that are to be carried out by the other institutions, i.e. DEA, eThekwini municipality.	No	The responsibilities to be assigned to other institutions need to determine through engagement and negotiations. It is premature to specify these in detail in this document.
2.10	Groundwater levels: The water levels at any one point may not reflect stresses in another point of the aquifer if outside the radius of influence of an abstraction zones.	This is broad, those areas that were referred to still need to be mentioned.	No	In stressed catchments, the stress is localised and due to specific wellfields, and no quaternary has a very high stress index. Hence monitoring can occur at a local level to monitor specific wellfields, but such monitoring does not reflect conditions in the rest of the catchment. Boreholes located outside the radius of influence of the wellfield would not detect stresses from over abstraction.
	Abstraction: Although a critical variable to compare volumes abstracted against recharge, abstraction is rarely monitored and needs to be monitored at every abstraction point, hence its monitoring is problematical. Generally it is estimated via secondary measures such as hectares irrigated, number of people supplied and level of service, pumping hours, size of reservoirs etc.	Same applies as the above, groundwater is not abstracted everywhere so actual areas need to be mentioned. These comments need to be considered particularly because of the drought conditions in KZN.	No	Monitoring of abstraction is necessary where large volumes are abstracted.
2.10.3	Baseflow monitoring	It is crucial to identify/mention specific sites. The previously done preliminary Reserve determination should serve as a baseline for this purpose. DWS Regional Office should have been consulted if there were budget constraints in this regard. My concern arises when the findings of this study are used for monitoring purposes in those stressed catchments, stream flow reduction activities where the groundwater part of baseflow is impacted upon	No	The section of the report deals with the principals of monitoring and therefor describes the conceptual aspects that need to be considered rather than specifics. The analyses that were carried out in the study did consider all known land use and the time series simulation approach provided numerical results that made it possible to categorise the degree of baseflow reduction in the study area. This comment will have to be confirmed by K Sami.

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		thereby impacting on the flow to EWR sites.		
2.10.4	Water quality monitoring	Where WQ issues were observed, which actual variables were of concern in these identified sites? In making recommendations to Water Use License Applications, it is important to refer to specific sites so that water quality can be improved upon so that BHN quality is not compromised. RQOs need to be set at specific sites so as to strengthen the implementation plan on both the quantity and quality side.		Sami.
3.1	**When** should the activities take place? i.e. the frequency of work of activity; and	Include the timeframes in terms of the period over which these activities must be undertaken.	Yes	For water quality (rivers) it is assumed that this comment may refer to the frequency of sampling. This point is addressed in both the RQO and Implementation reports.
3.3	It is recommended that an Implementation Plan Management Committee (IPMC) be formulated to oversee the roll out of the actions of the plan.	Use existing structures.	No	The option remains to expand the functions of an existing forum(s) or to establish a dedicated committee. It will be premature to provide prescriptive recommendations in this report.
4.1.2.1	Minimum release of 0.9 m^3/s defined as a compensation release for downstream uses.	How often? Apply comment to all.	No	A release specified as per second is continuous.
4.1.2.1	Releases in accordance with the system operating rules, supporting the abstractions from Nagle Dam.	Provide in annexures	Yes	The rereleases are dictated by the water use which increases every year in accordance with the supply requirements. It is part of the analyses carried out in support of the System Operations Forum. The scenarios analysed showed that these variations in releases (currently and in future) will achieve the TEC under all possible operational regimes. Changes have been made in the text rather than in annexures.
4.1.2.2	The release requirements from the proposed Smithfield Dam will be in accordance with the recommended scenario (DWS, 2014a) which will achieve the TECs of C, B and C for the three primary EWR sites; Mk_I_EWR1, Mk_I_EWR2 and Mk_I_EWR 3 respectively.	It is inconvenient for one to have to dig through another report to find the info. Specify what the scenario is and what it entails/means for the Dam release. You can then refer to the report for the full details about the scenario.	Yes	Added text defining the scenarios and provided recommendations on the processes to be considered for implementation.

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	Mvoti River System (Proposed Isithundu Dam or alternative). The release requirements from a proposed dam on the Mvoti River (such as the proposed Isithundu Dam) will be in accordance with the recommended scenario (DWS, 2014a) which will achieve the TEC of C at the EWR site; Mv_I_EWR1.	See above.		See above.
Table 4.3	Groundwater monitoring plan	Refer monitoring actions to the GRUs. In other words, mention what needs to be done at each site within the Quat. It currently appears generalised for the entire Quat.	No	The complexity of defining monitoring at sites would require much higher resolution primary information (data) than what was available for use in the study. It would be prudent to specify the need to define such high resolution monitoring as part future hydro census studies. This comment will have to be confirmed by Karim. Sami.
5	Water Quality Monitoring	For the Rivers and Estuaries: provide per site what needs to be done for all the components (WQ, habitat & biota etc.). It is currently generalized and one cannot establish what needs to be done at which sites. Following the text, add a similar table as Table 4.3.	No	The RQO (rivers) Report outlines what variables should be monitored at which sites. Monitoring frequency and data quality is addressed in that and the Implementation Report.
Barbara Weston:6 November				
2.2	A RQO implementation plan must function within the existing environment of water resource management as well as existing monitoring programmes. While the regulation and control of the required RQOs are the responsibility of DWS's CD: WE, certain aspects that could cause violations of the required RQOs may relate to legislation managed and	No the CD;WE is responsible for developing the RQO but the Regulation Branch will be responsible for actual regulation through monitoring compliance and directives where required. The SDC line functions need to ensure that the required protection measures i.e. conditions are worked into for instance WULA etc.	No	The description provided in the document was approved by the study manager of Letaba and Inkomati Classifications Studies.

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	implemented by other Directorates within DWS, or even other government departments.			
2.2	The plan should therefore allow for the linkages that will initiate the appropriate actions to enforce compliance in accordance with procedures already in place. In the light of this and the important link between Classification and RQO implementation for the water resources in this CMA, background and detail are provided regarding Estuarine Management Plans.	Why are you just referring to the estuaries should the EMP not be used as an example what about the other water resources?	Yes	A note has been made in the report that no such plan exist for rivers.
2.2.1	An estuary must be maintained in its ecological category as determined in the 2011 National Biodiversity Assessment and subsequent updates in order to meet biodiversity targets, and to take into account the recommended extent of protection and recommended ecological health category.	Won't use that as a reference since a number of the estuaries did not have validated data only based on desktop and specialist input I am not so worried if we over estimated the PES but if we under then its not good thus lets rather base it on EWR studies and hence classification and RQO as the final values to be taken. (once available)	No	This comment cannot be deleted as it refers to a Gazetted requirement of the National Estuarine Management Protocol under the ICM Act. There is no conflict if the TEC is higher, but there is conflict if the TEC is lower.
2.5	Should the model results indicate substantial deviations from the target flows, recommendations for additional ecological monitoring can be made to ascertain if adaptive measures are required?	What about flow recorders at the head of estuaries to measure flow and mouth conditions?	No	Water level gauges are recommended at all priority systems. This statement refers to the fact in future the measured flows may not match the required flows and that additional monitoring may be required to decide on a way forward if the measured data do not match the modelled curve.

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2.6	However for estuaries, water quality RQOs can include both flow and non-flow related activities. For example, salinity penetration in estuaries are strongly influenced by flow, while nutrient enrichment is typically associated with non-flow related activities such as WWTW effluent, agricultural return flow or contaminated urban stormwater runoff.	But this is relevant to rivers as well isn't it??	Yes	This point was made specifically in relation to salinity penetration to estuaries. The rivers section states that this section of the report is discussing issues not dependent on flow. An explanatory sentence has been added to the rivers statement at the beginning of Section 2.6.
2.6	If a site has been identified as a High Priority RU from a water quality perspective (a 3WQ site), e.g. Mbokodweni (U60E-Patsy04792), Amanzimtoti and the Little Amanzimtoti (U70F-04845 and U70F-04893), (all three sites characterised by high water quality impacts) with measurable water quality RQOs specified but no current instream monitoring taking place, the RQOs set for this RU would be separated into a first phase vs. second and third phase monitoring activities if the site is prioritized for monitoring.	What does this mean does the 3 refer to the importance of the site ito measuring the WQ pls clarify and provide explanation. Break this paragraph down into more understandable shorter chunks.	Yes	A 3WQ site is a High Priority water quality site that is not an EWR site. An explanatory statement has been included in the Implementation Report that distinguishes between immediately applicable RQOs, where monitoring is currently taking place, vs. provisional RQOs where monitoring has to take place before RQOs can be measured against. The priority level of a provisional RQO site that does not have a current monitoring database, will determine when monitoring would be set up. First phase (short-term) activities would include setting up a monitoring programme for specified RQOs (as outlined in the monitoring programme), with data collection stretching into the medium-phase, and measurement against the RQOs being the long-term phase.
	The following types of non-flow related interventions were identified as important requirements in meeting	Why are you focussing only on estuaries? The title of this report is based on water resources. Other wise one must refer to estuaries as an example – what about wetlands I have seen no reference to wetlands anywhere in this report?	Yes	The section above describes the same issues for rivers. Wetlands have not specifically been mentioned as the non-flow related aspects are well covered in other legislation. I will include a sentence to this effect.

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	the objectives of the estuary classification process and are all relevant for this study area: Water quality interventions include the management of stormwater and agricultural return flow and improving or reducing the quality and quantity of WWTW discharges (see Chapter 2);			
	For toxic substances (e.g. trace metals and hydrocarbons) it is considered more appropriate to sample environmental components which tend to integrate or accumulate change over time, such as sediments. These surveys need, however, not be done in ALL estuaries, only in systems where river water quality or human activities along the banks of the estuary suggest possible contamination (e.g. industrial effluents or storm water run-off from large urban developments).	What about WWTW discharges - very high Nutrient constant loads could lead to Cyanobacterial; blooms which could be toxic or high nutrient loads could cause anaerobic conditions that could lead to fish kills and proliferation of alien weeds etc.??	No	This section is specifically written with relevance to toxic substances in terms of trace metals and hydrocarbons.
2.9.3		Look at the sentence structure with the word Increase a the end doesn't make sense.	No	This is a referenced quote and cannot be changed.
7.7	Because of the high variability in invertebrates in response to flow it is important to sample	What does medium and high refer to the number of visits or samples ?????	Yes	Changed text to: (medium confidence for Intermediate level and high confidence for Comprehensive level).

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	over two years to obtain the required confidence level (medium for Intermediate level and high for Comprehensive level).			
Comments from CJ Kleynhans presented at 16 November meeting and agreed on proposed action.				
		Reference to monitoring levels inappropriate as there could be more levels than mentioned in the report.	Yes	All reference to monitoring levels removed apart from the generic section.
		Rivers habitat and biota monitoring programme to be removed as it is covered with the REMP procedures.	Yes	Dr Kleynhans provided a generic description of the REMP and appropriate tools which have also been included in the document.
		An attempt to be made to make similar changes to estuaries.	Yes	Estuary programme was not removed as the existing programme from DWS (NEMP) does not cover all the detail required. Reference has however been made to the NEMP and required linkages identified.
		Reference to diatom monitoring to be removed.	Yes	The diatom monitoring was not removed as the water quality specialist requires this in areas where nutrients are a problem. Changes have been made to indicate this.
Pillay Renelle: Received 18 January2016				
Page 1-1		Background – first sentence should be changed to read. 'There is an urgency to ensure that water resources in the Mvoti to Umzimkulu Water Management area (WMA) which is one of three WMA's that form part of the Pongola to Umzimkulu Proto Catchment Management Agency ……' Page 4-1: Catchment and river characteristics – first sentence makes refer to the Inkomati study area and must be amended.	Yes	
Page 4-3		Table 4.1 the column for comments refers to observations being recorded. What does observation entail? What will be required in this instance?	Yes	
		There are still a few spelling and grammatical errors in the document and it is advised that it be reviewed in this light. e.g. Page 2-3: Sentence no. 3 'In the case of the estuaries, coordinated management instead of managed. Sentence 5 'Alignment with the activities of the Catchment Management waste water Forums also need to be (incomplete sentence).	Yes	