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P RSA C000/00/2305/5

Development of an Integrated Water Quality Management Plan for the Vaal River System

Task 6

Evaluation of Water Quality Management Scenarios

September 2009

ZITHOLELE CONSULTING

Golder Associates

Development of an Integrated Water Quality Management Plan for the Vaal River System

TASK 6:

EVALUATION OF WATER QUALITY MANAGEMENT SCENARIOS

FINAL REPORT

Directorate National Water Resource Planning
Department of Water Affairs and Forestry

September 2009

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EXECUTIVE SUMMARY

Introduction

This task forms the core activity for the development of the IWQMP and has the objective of assessing the feasibility of possible management scenarios that could be implemented to cover the following three time horizons:

- Options, most likely operational in nature, to be implemented over the first five years.
- Medium term strategies that would require further investigations and have the objective of covering a ten year planning period. (Pre-feasibility assessment level of detail)
- Long term management measures to ensure the water quality in the system is maintained or even improved and considers the planning period up to the year 2025. (Reconnaissance assessment level of detail)

Management scenarios were developed for salinity and nutrients. The assessment of the salinity management scenarios were assessed in more detail than the nutrient management scenarios as the modelling and economic assessment tools are available for the assessment of the salinity management scenarios.

The report summarises the water quality status and the process followed in setting the RWQO. This serves as background to the development and assessment of the management Scenarios. The water quality in the Grootdraai Dam and the Vaal Dam catchments currently meets the water user requirements. The strategies were focussed on the middle reaches of the Vaal River from Vaal Barrage to Bloemhof Dam where the significant water quality issues are.

Approach to assessment of salinity management strategies

The achievement of an economically optimal solution involves determining the cost of a particular strategy and the dis-benefits in terms of the economic impact of the salinity supplied to the users. The approach adopted to evaluate the scenarios is summarised in **Figure 14** and the steps are described as follows:-

- Formulation of a scenario for analysis. The analysis period was from 2007 to 2025.
- Setting up the WRPM to represent the scenario. An initial run was undertaken using the WRPM to determine when the next augmentation scheme is required so that the reliability criteria for supply are met. Based on the results of the initial run, the WRPM was reconfigured in terms of the timing. The WRPM was run using a 100 stochastic sequences. The modelled 95 percentile TDS concentrations in the reaches of the main stem of the Vaal River and in the main tributaries were determined from the model results.

- The time series of capital expenditure (capex) and operational expenditure (opex) for the augmentation scheme were determined. The net present values (NPV) of the cash streams were determined for interest rates of 6%, 8% and 10%.

- The economic model on the impact of water quality on the users was applied to determine the time series of total dis-benefit costs to the industrial, domestic and agricultural users. The NPV of the water quality dis-benefit costs were determined

- The total NPV for a scenario was then determined.

- The process was repeated for each scenario and the total NPV costs could then be compared to determine the most economic scheme.

- During this process the percentiles of the TDS concentrations will be assessed and compared to the RWQO including the ecological Reserve water quality requirements. This assessment might require further refinement to a strategy or result in a particular strategy being favoured although it might not be the optimal strategy from an economic perspective.

Development of salinity management scenarios

The components of a salinity management scenario include the following:-

- A water requirement and return flow scenario. These scenarios were taken from the reconciliation strategy. The two scenarios used to analyse the salinity management scenarios using the Water Resource Planning Model (WRPM) were the base and high growth cases. Both these scenarios included Water Conservation and Demand Management reducing the water requirements by 15% over a 5 year period for the Rand Water water requirements.

- The future augmentation schemes considered were the Polihali Dam in Lesotho as well as the Jana and Mielietuin Dams in the Thukela River Catchment. The available capex and opex costs for these schemes were used to develop the cash flows needed to determine the NPV.

- The runs with the WRPM showed that with the growth in the return flows, an excess develops in the Vaal River system which is seen as an accumulation of water in Bloemhof Dam. In the analysis this excess water is used to support the water users in the lower Orange.

- The construction of the Polihali Dam will reduce the flow to the Orange River and necessitate the development of an augmentation scheme to supply the lower Orange. The Vioolsdrift Dam on the Orange River has been identified as the most economically attractive scheme. The excess water stored in Bloemhof Dam was used. If the excess was insufficient for a particular scenario then the Vioolsdrift Dam was included.

- The water quality management scenarios evaluated were:-

- The continuation of the current practise of diluting the Vaal Barrage outflow with releases of water from Vaal Dam. The dilution of the Vaal Barrage outflow to TDS concentrations of 600 mg/L and 450 mg/L were assessed.

- The treatment of the major mine and industrial discharges for direct re-use. The accepted technology of desalination using reverse osmosis was used for the treatment of the saline water to potable standards for supply to Rand Water.

- Two treatment cases were assessed viz the treatment of all the major industrial and mine discharges as case1 and the case 2 was the treatment of selected high load discharges which were the discharges from the Petrex and ERPM mines.

- The source of Rand Water supply plays a role in the use of the return flows. If Rand Water abstracts water from the Vaal Barrage then the return flows are being used in directly. The following two cases were considered:-

  - The blending of the Vaal Barrage water with Vaal Dam water to achieve a TDS concentration of 300 mg/L for the supply to Rand Water. This scheme will use more of the return flows as a form of indirect re-use but will still provide a reasonable quality of water.

  - A further option was assessed where Rand Water abstracted its full demand from the Vaal Barrage.

  - Abstracting water from the Vaal Barrage will require that the Rand Water water treatment plants be upgraded to treat eutrophic water. These costs were added into the cash flows for these scenarios.

  - A dilution canal will also have to be constructed to convey dilution releases from Vaal Dam to below the Rand Water pump stations on the Vaal Barrage so that the outflow from the Barrage can still be diluted to 600 mg/L. The cost of the dilution canal was also included in the cash flows for these scenarios.

The scenarios assessed are summarised in **Table E1.**

Table E1: Summary of planning scenarios

Planning Scenario No.	WRPM Run Reference	Water Use Scenario	Intervention Option Included	Water Quality Scenario	Purpose
1a	V07R1ABP	Base and High	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam)	No TDS treatment Rand Water supplied from Vaal Dam Dilution to 600 mg/l in Vaal Barrage	Assessment of: Current management practices Augmentation from Polihali Dam option Supply of excess water in Bloemhof Dam to ORS
1b	VT07R1B	Base	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam)	No TDS treatment Rand Water supplied from Vaal Dam Dilution to 450 mg/l in Vaal Barrage	Assessment of: alternative dilution rule
1c	VT07R1C	Base and High	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam) Re-use of mine and industrial discharges	Treatment of major mine and industrial discharges Rand Water supplied from Vaal Dam Dilution to 450 mg/l in Vaal Barrage	Evaluate impact of direct re-use of water and the removal of salinity.
1c1	VT07R1C1	Base and High	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam) Partial re-use of mine discharges	Treatment of selected mine discharges Rand Water supplied from Vaal Dam Dilution to 450 mg/l in Vaal Barrage	Evaluate direct partial re-use of water and the removal of salinity.
3	VT07R03	Base	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam)	No TDS treatment Rand Water supplied from Vaal Barrage Blend RW supply to 300 mg/l with water from Vaal Dam Dilution to 600 mg/l in Vaal Barrage	Assessment of alternative source of supply for Rand Water (Alternative to Scenario 1a).
8a	VT07R08	Base	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam)	No water quality management Rand Water supplied from Vaal Barrage	Alternative base scenario excluding the EWR.

Results of the assessment

The costs of the augmentation or intervention schemes are summarised in **Table E2** and the treatment and distribution costs in **Table E3.**

Table E2: Capex, Opex and implementation periods for intervention schemes

Element	Capex (million Rand)	Opex (million Rand/annum)	Implementation Period (years)
Polihali Dam (includes Polihali Dam Katse Dam tunnel)	5 118	21.8	7
Upgrade of Delivery Tunnel from Katse Dam to the Vaal River catchment	465	4.65	5
Vioolsdrift Dam (1160 million m^3 capacity)	368	1.99	6
Vioolsdrift Dam (1490 million m^3 capacity)	470	2.54	7
Vioolsdrift Dam (1770 million m^3 capacity)	557	3.00	7
Jana Dam	4 118	259.50	6
Mielietuin Dam	2 545	73.84	6

Table E3: Summary of plant capacity, implementation period as well as the capex and opex for the treatment options

Plant	Capacity (ML/d)	Capex (million Rand)	Opex (Rand/m^3)	Implementation period (years)
Mine discharges	275	3 480	6.78	6
Distribution system for treated mine effluent to Rand Water reservoirs	275	231	0.22	6
Sasol	35 ML/d for SCI and 6.5 ML/d for Midlands plant	457 (desal plant) 109 (Evap Crystalliser) Total 634	9.11 including desal, EC and disposal salt at Holfontein at R1500/tonne	6
Sappi Enstra	30	330 (desal plant) 90 (Evap Crystalliser) Total 420	9.11 including desal, EC and disposal of salt at Holfontein at R1500/tonne	6
Treatment of mine discharges from ERPM and Petrex	105	1 240	6.74	6
Distribution system for treated mine effluent from ERPM and Petrex	105	80	0.21	6

The total NPV of the augmentation/intervention cash flows and the water quality dis-benefits are given in **Table E4.**

Table E4: Total NPV for Scenarios

Scenario	NPV Interventions and Treatment (million Rand)			NVP Water Quality Dis-benefits (million Rand)			Total Costs (million Rand)		
	6%	8%	10%	6%	8%	10%	6%	8%	10%
1a (Base Demand)	3 585	2 998	2 536	4 087	3 597	3 194	7 627	6 595	5 730
1c (Base Demand)	19 271	14 475	11 468	3 759	3 303	2941	23 030	17 778	14 409
1c1 (Base Demand)	8 197	6 424	5 239	3 362	2 958	2 630	11 559	9 382	7 869
3 (Base Demand)	6 833	5 303	4 275	10 754	9 332	8 201	17 587	14 635	12 476
8a (Base Demand)	10 235	7 812	6 266	14 725	12 229	10 381	24 960	20 041	16 647
1a (High Demand)	11 954	9 240	7 433	4 087	3 597	3 194	16 041	12 837	10 627
1c (High Demand)	23 216	17 666	14 251	3 759	3 303	2 941	26 975	20 969	17 192
1c1 (High Demand)	10 590	7 913	6 248	3 362	2 958	2 630	13 952	10 871	8 878

The results for the base and high water demand scenarios differ. For the base water demand scenario, the total NPV clearly shows that Scenario 1a is the best from a purely economic perspective with Scenario 1c1 the next best. However for the high water demand scenario, Scenario 1c1 has the lowest total NPV. This is due to the implementation of all three augmentation schemes being required over the period 2019 to 2021 so that the high water demand and the dilution water requirements can be met.

The treatment of all mine and industrial effluent discharges to potable standard is expensive and does not result in a sufficient reduction in water quality dis-benefits and delay in the augmentation date for the next scheme to offset the treatment costs.

The overall conclusions based on the economic analysis work are as follows:

- The traditional approach of implementing Vaal River Augmentation Schemes to supply water and address water quality issues is still appropriate and economically attractive.
- The treatment and re-use of selected high concentration discharge streams is an attractive scenario. The economic analysis showed that Scenario 1c1 is economically the most attractive for the high water demand scenario while the total NPV for the base water demand scenario is not significantly more expensive than Scenario 1a.
- The treatment and reclamation of selected high salinity mine waters and industrial effluents are becoming increasingly more attractive. The treatment and reclamation of all the mine and industrial effluent discharges, irrespective of size, and salinity load is not economically defensible.
- Many other water resource management policy and management considerations over and above the economic aspects, drive the implementation of the saline mine/industrial effluent reclamation schemes. Some of these include:
    - best use of local water resources.
    - application of the “polluter pays” principle.
    - reduced reliance on transferred water.
    - use of good quality water to dilute pollution.

Compliance with RWQO

The simulated 95 percentile TDS concentrations in the different reaches of the Vaal River for the different scenarios are listed in **Table E5.** The current status and the RWQO set in October 2007 are also given in the Table.

Table E5: Summary of simulated 95 percentile TDS concentrations (mg/L) in Vaal River for Scenarios

	Scenario							
Reach	**1a**	**1b**	**1c**	**1c1**	**3**	**8a**	**Status**	**RWQO**
Douglas Barrage to Harts	883	828	772	858	958	934	961	600
Bloemhof Dam to Harts (Vaal Harts weir)	752	584	628	642	717	689	601	600
Bloemhof Dam	724	581	601	614	691	677	612	600
Sedibeng off take	763	558	621	623	1154	1444	742	450
Midvaal off take	612	507	482	484	640	833	670	450
Vaal Barrage	657	593	487	488	638	906	647	
Vaal Dam	116	116	116	116	116	116	189	180
Waterval to Vaal Dam	264	264	264	264	264	264	413	200
Grootdraai Dam	174	174	174	174	174	174	200	180

The WRPM results show that the RWQO set for the catchments upstream of Grootdraai Dam and Vaal Dam are met except for the reach from Waterval to Vaal Dam where the modelled TDS concentration of 264 mg/L exceeds the RWQO of 200 mg/L. The RWQO is governed by the preliminary determination of the ecological Reserve water quality requirements of 200 mg/L. The main water users in this reach are irrigation and domestic and the RWQO was relaxed to 250 mg/L which meets the TWQR for domestic and irrigation. This RWQO will be taken into the ecological Reserve process for possible re-assessment.

The WRPM model results show that the RWQO set on 12 October 2007 could not be met for any of the scenarios modelled for the reaches from Vaal Barrage to Douglas Barrage. The treatment of the saline discharges does significantly improve the TDS concentrations in the middle reaches of the Vaal River. Scenario 1a is the most economic scenario for the base water demand scenario and Scenario 1c1 for the high water demand scenario.

Nutrient Strategy

The proposed strategy for nutrient management is divided into the short and medium term actions. The results of the short term actions will largely dictate the medium term plans. The short term will cover the period up until 2010 and includes the following actions:-

- Flow manipulation which will generally occur in September when the potential for algal blooms is highest. A proposed release pattern to implement is :-
    - Base flow 15 m3/s – 28 days - 36.3 million m^3
    - 100 m^3/s for 48 hours – 17.3 million m^3
    - Total of 53.6 million m^3/a
- Through monitoring better understand the nutrient balance. This will include instream nutrient monitoring as well as at source monitoring.
- Audit the WTW and the sewerage systems of the local municipalities. The planned expansions of the WTW and the sewerage systems as presented in the water service development plans should also be reviewed.
- A study implemented to determine the impact of phosphorus free detergents and soaps on the influent and effluent qualities of the major WTW.
- A study to determine the feasibility of implementing additional phosphorus removal treatment at the WTW.

The medium term strategy will involve:-

- Nutrient reduction programs either through additional treatment at the WTW or the introduction of phosphorus free soaps and detergents or both.

- Modifications to the flow manipulation strategy based on lessons learnt from the implementation during the short term strategy period.

Conclusions and recommendations

The following conclusions can be made from the management scenario task -

- The economic analysis and comparison of simulated in-stream TDS concentrations shows that the dilution scenario 1a is the favoured water quality management scenario for implementation to manage the TDS concentration.

- The TDS management scenario was based on minimum growth of mine and industrial discharges. If increases in discharge volume or changes in water quality are predicted then the impact on the dilution rule will have to be assessed. Any further increases in TDS load to the system could impact on the public health and ecological Reserve aspects of the water quality as well as the timing of the next augmentation scheme. This will affect the economic valuation.

- The water users in the middle and lower reaches of the Vaal River are incurring dis-benefits due to poor water quality. A waste discharge charge should be imposed on the discharges in the upper Vaal WMA to compensate for the dis-benefits of the downstream users.

- The RWQO set as part of this study will have to be revised once the more detailed ecological Reserve information becomes available. The initial assessments provided by the water quality project team for the ecological Reserve has not raised any red flags.

- The flow manipulation as a nutrient management option in the short term should be assessed in practice to get an indication of its efficacy.

- The water quality input to the WRPM for the Grootdraai Dam catchment is represented as a seepage flow file in the WRPM. There are significant changes happening in the catchment with defunct mines filling, re-commissioning of the Camden Power Station and further mining planned. These planned activities are not included in the WRPM. The WRPM should be updated to include the mines as a mine module in the WRPM.

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Reports as part of this project:

Bold type indicates this report.

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5	P RSA C000/00/2305/4	Water Quality Economic Impact Modelling
6	**P RSA C000/00/2305/5**	**Evaluation of Water Quality Management Scenarios**
7	P RSA C000/00/2305/6	Monitoring Programme
8	P RSA C000/00/2305/7	Water Quality Management Strategy

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LIST OF ACCRONYMS AND ABBREVIATIONS

CMA	Catchment Management Agency
CMS	Catchment Management Strategy
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
ICM	Integrated Catchment Management
ISP	Internal Strategic Perspective
IWQMP	Integrated Water Quality Management Plan
IWRM	Integrated Water Resource Management
NWA	National Water Act
NWRS	National Water Resource Strategy
PES	Present Ecological State
RDM	Resource Directed Measures
RQOs	Resource Quality Objectives
RO	Regional Office
RWQO	Resource Water Quality Objectives
SAWQGs	South African Water Quality Guidelines
TDS	Total Dissolved Solids
TOR	Terms of Reference
TWQR	Target Water Quality Range
WMA	Water Management Area
WRPM	Water Resources Planning Model

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1 INTRODUCTION

1.1 Water Resource Management Studies in the Integrated Vaal River System

In terms of the National Water Act (NWA) (Act No. 36 of 1998) and in line with the Department of Water Affairs and Forestry's (the Department) obligation to ensure that the country's water resources are fit for use on an equitable and sustainable basis, it has adopted the approach of the progressive development and implementation of catchment management strategies (CMS) to fulfil this mandate. Each Catchment Management Agency (CMA) is responsible for the progressive development of a CMS for its respective Water Management Area (WMA) that is developed in consultation with stakeholders within the area. The Department's eventual aim is to hand over certain water resource management functions to these CMAs. Until such time as the CMAs are established and are fully operational, the Regional Offices of the Department will continue managing the water resources in their areas of jurisdiction with the support of the national office.

In terms of meeting this obligation, the Department has initiated the development of management strategies for the various WMAs within South Africa in an attempt to provide the framework and constraints within which the water resources will be managed into the foreseeable future. These various strategies and plans that arose out of the Internal Strategic Perspective (ISP) development process which identified the relevant water resource management issues and concerns in each of the WMAs. The Vaal River System WMAs, which include the Upper, Middle and Lower Vaal and the Modder Riet catchment of the Upper Orange WMA, are four such catchments for which management strategies are currently being developed. At present three major studies are underway in the Vaal River System, which specifically aim to introduce overarching management measures to reconcile water requirements and availability, and to ensure the continued fitness-for-use of the water resources. These studies are the Development of Large Bulk Water Supply Reconciliation Strategies (LBWSRS), Water Conservation and Water Demand Management Potential Assessment and the Development of an Integrated Water Quality Management Plan (IWQMP). The immediate objectives of the individual studies are to:

- Develop strategies for meeting the growing water requirements of the industrial and urban sectors served by the Integrated Vaal River System (LBWSRS).
- Determine the potential for, and benefits of Water Conservation and Water Demand Management (WC/WDM) in the various water use sectors with the focus on the Upper and Middle Vaal WMAs.
- Develop water quality management measures to ensure continued fitness for use in the Vaal River System (IWQMP Study).

The management options identified through these studies aim to eventually feed into a reconciliation and water quality management strategy that will be determined for the Vaal River System (**Figure 1**). The strategy aims to support current and future water users and uses within the interdependent water resource systems of the Vaal WMAs and associated Modder Riet catchment.

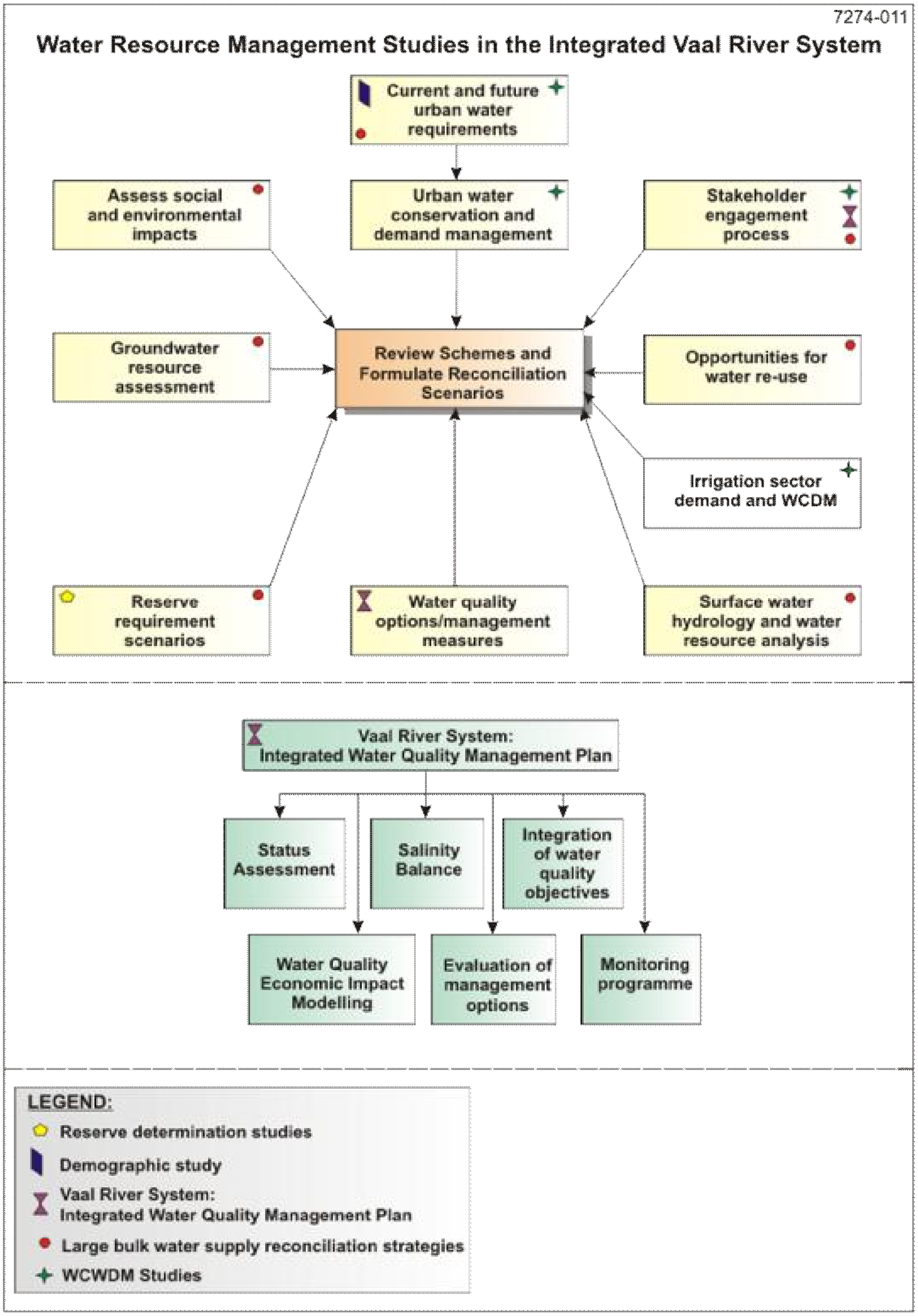

Figure 1: Water Resource Management Studies for the Integrated Vaal River System supporting the identification of reconciliation options (*adapted* DWAF, 2005a)

1.2 IWQMP Study description and context of the evaluation of the water quality management scenarios task

Having water of the right quality is just as important as having enough water. Integrated water resource management in the Vaal River System can only be achieved if water quality and quantity are managed together to meet the requirements of water users (including the aquatic ecosystem) and their needs in terms of use of the resource. The more the water resource is used and gets re-used, and as quantities get scarce and feedback loops within this highly exploited and utilised water resource system get even tighter, it is water quality that begins to take on a dominant role. The Department realises that just as planning and management are taking place to supplement and control water quantities, they also need to take place around water quality. In response to the need to meet the objectives of integrated water resource management (IWRM), the Department has initiated this process to address the management of the water quality in the Vaal River System. This need was identified through the ISP process that specifically highlighted the necessity for an integrated management plan to manage water quality within the Vaal River system. The purpose of this initiative is to eventually develop a management plan for the Vaal River System, which will serve as a coherent approach for water management institutions and stakeholders to manage the water resources in the interdependent Vaal WMAs. In essence the integrated management plan developed would serve as a holistic and comprehensive business-plan for water quality management in and among the WMAs of the Vaal River System. The plan will also feed into the NWRS as part of the national guiding framework.

The focus of this study is thus to develop an integrated water quality management plan (IWQMP) for the Vaal River System, which aims to identify management options that are technically, economically and socially feasible and which will support the continued fitness for use of the water resources for all users across the WMAs.

The approach followed for the development of the IWQMP involved:

- The assessment of the Vaal River System to obtain a perspective of water quality (variables of concern), pollution sources and key water users. This included the identification of existing Resource Water Quality Objectives (RWQOs) and their establishment where they are not available. It also included an understanding of the salinity balance of the system to determine where the major contributions are originating from.
- Establishing how the system complies with the RWQOs, which was determined through analysis of available data and undertaking modelling of possible future scenarios. Determining an integrated set of RWQOs that were achievable, aligned to the system behaviour and prevented further deterioration of water quality.
- Identifying and developing management measures to improve the non-compliance cases, address water quality stresses and priorities and allow utilisation of available allocatable water quality to the benefit of the water users in the system. The management measures were evaluated on the basis of their technical, environmental (range of aspects), social and economic feasibility. The scenarios identified were then formulated into a proposed strategy for implementation.

The IWQMP study comprises seven tasks which are depicted in **Figure 2.**

In order that the Department is able to effectively manage the water resources of the Vaal River System catchment, it is necessary that a range of management scenarios are assessed and strategies developed in order to maintain or improve the systems water quality. These have been investigated in parallel to the water quantity reconciliation strategies developed in the LBWSR study.

This task is therefore the core activity for the development of the IWQMP and has the objective of assessing the feasibility of possible management scenarios that could be implemented in the Vaal River System in the immediate, medium and long term. This report focuses on the evaluation of the scenarios and the strategies proposed for management of the system (Task 6 of the study). The output of this task essentially forms the basis of the IWQMP.

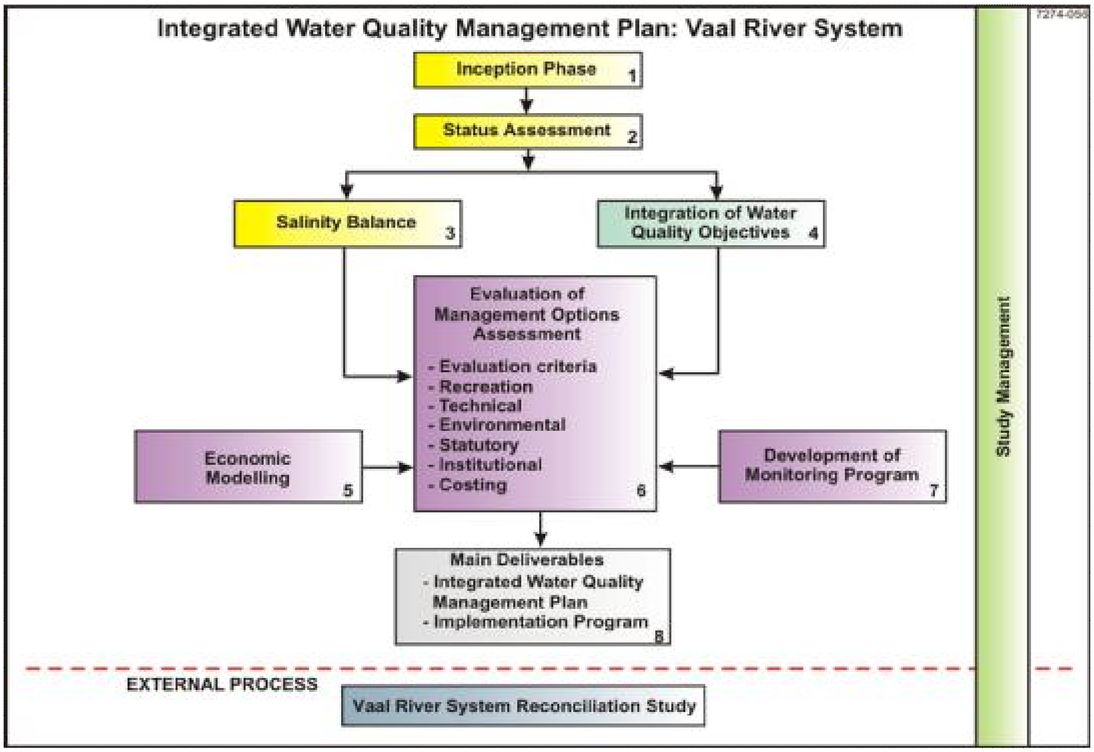

Figure 2: The study tasks comprising the development of the IWQMP for the Vaal River System (DWAF, 2005b)

1.3 Study Area

The study area for the IWQMP study includes the entire C drainage region within South Africa. This includes the Upper and Middle Vaal WMAs in their entirety, part of the Lower Vaal WMA (C31, C32, C33, C91 and C92 tertiary catchments), and part of the Upper Orange WMA (C51 and C52 tertiary catchments *i.e.* Modder Riet catchment) (**Figure 3**).

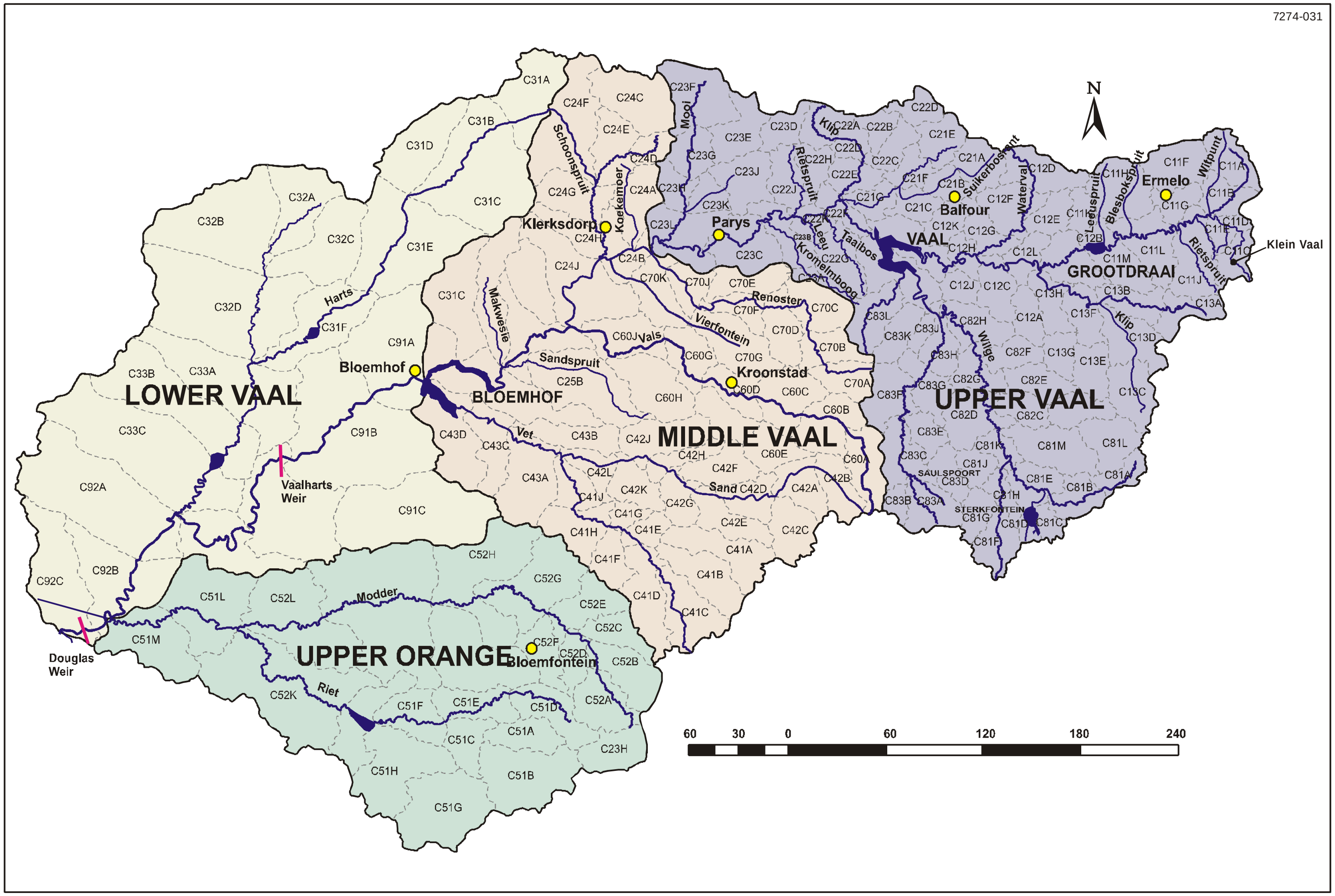

Figure 3: Study area of IWQMP study

The extent and approach of the study and this task is focussed on:

The main stem of the Vaal River as it flows from its origin in the Drakensberg escarpment to Douglas Barrage;

All the major tributaries to the Vaal River. The tributaries were considered just upstream of their confluences with the Vaal River. The strategies developed do not include the upper reaches of the tributary catchments.

Although the study considers the major tributaries of the Vaal River, the management options and identified strategies do not address specific issues in each of the tributary sub-catchments. Rather the management options identified for the Vaal River will feed into the respective catchment management strategies and water quality management plans as they are developed or revised per sub-catchment.

1.3.1 Strategic Monitoring Points

The extent of the study area and due to the high level nature of the analysis to be conducted necessitated the identification of monitoring points within the Vaal River System that would be strategically located and sufficiently widespread to provide an adequate indication of the prevailing water quality status.

Strategic monitoring points were identified at two levels:

- Level 1: Points on the Vaal River from its origin to Douglas Barrage; and
- Level 2: Points on the major tributaries of the Vaal River just upstream of their confluences.

Level 1 Points

The Level 1 strategic monitoring points refer to the monitoring points that are located on the Vaal River. Twenty Level 1 strategic points were identified and their locations are indicated on **Figure 4**.

The points are:

- numbered from 1 to 20 from the most upstream point to the most downstream point in the Vaal catchment; and
- preceded by the letters ‘VS’ which implies ‘Vaal System’ (for example VS 10)

Level 2 Points

The Level 2 strategic monitoring points refer to the monitoring points that are located on the major tributaries of the Vaal River, just upstream of their confluences. Twenty six level 2 strategic points were identified and their locations are indicated on **Figure 5.**

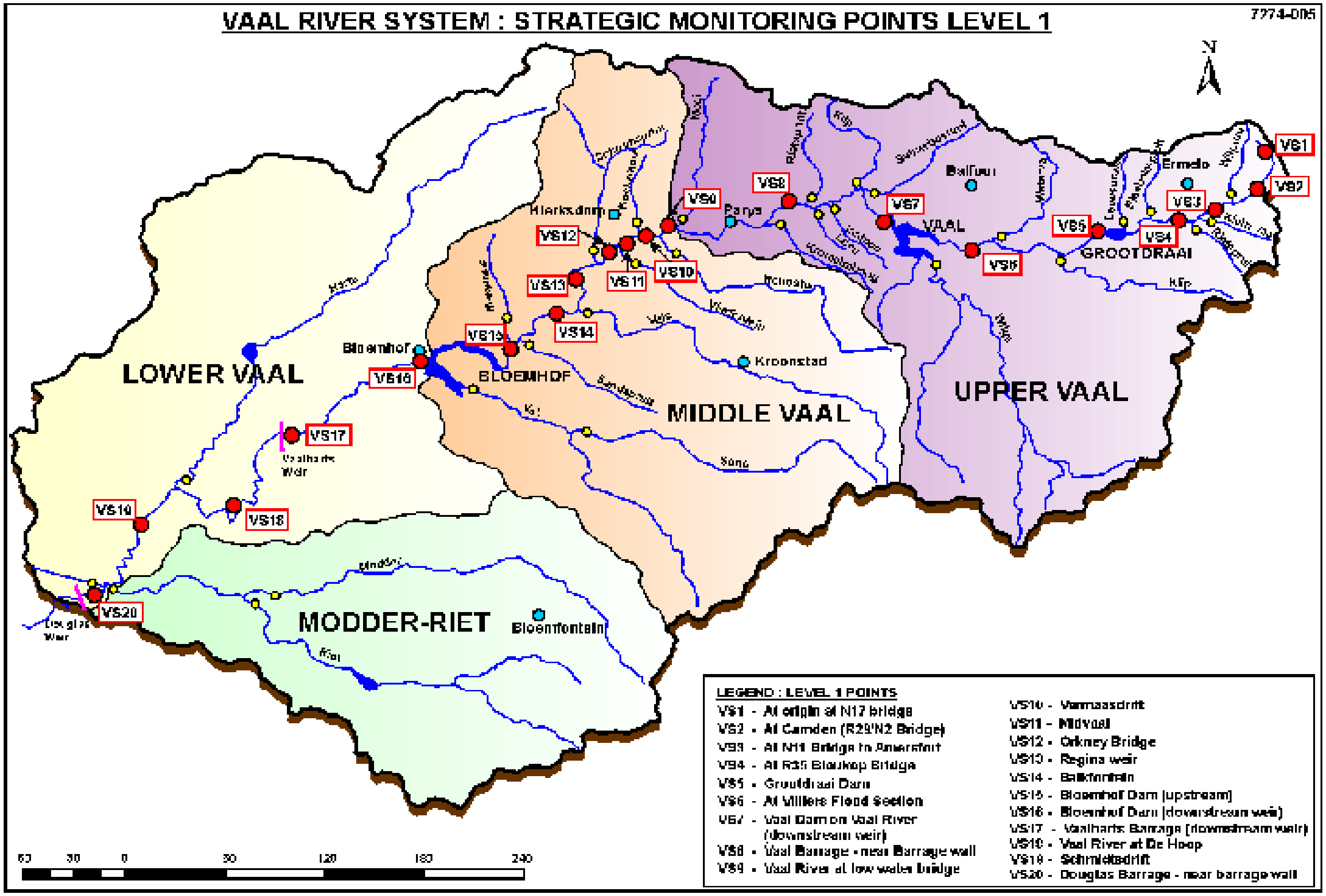

Figure 4: Location of Level 1 strategic monitoring points in Vaal River System

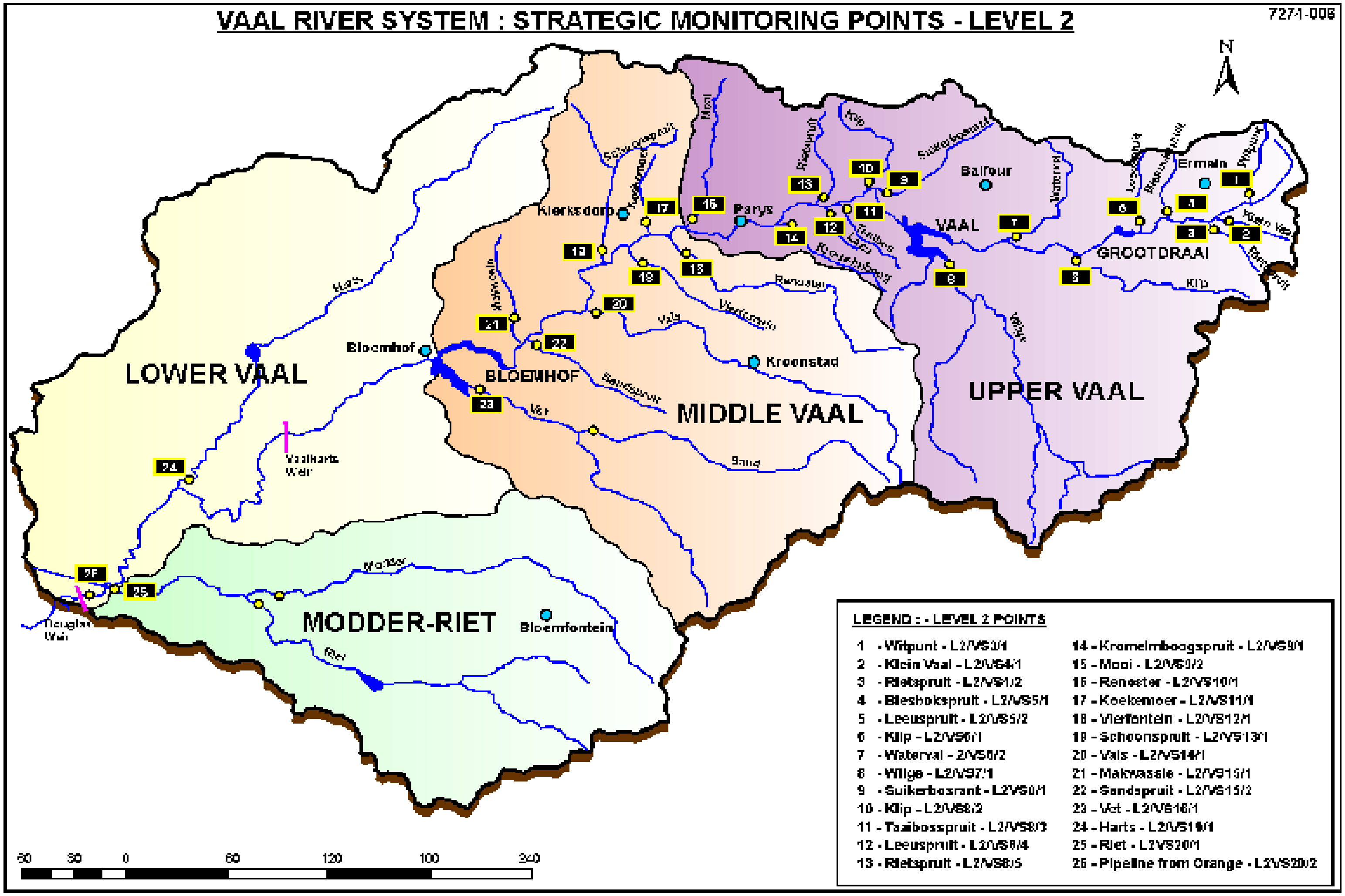

Figure 5: Location of Level 2 strategic monitoring points in Vaal River System

1.4 Objective of the evaluation of water quality management scenarios task

This task forms the core activity for the development of the IWQMP and has the objective of assessing the feasibility of possible management scenarios that could be implemented to cover the following three time horizons:

- Options, most likely operational in nature, to be implemented over the first five years.
- Medium term strategies that would require further investigations and have the objective of covering a ten year planning period. (Pre-feasibility assessment level of detail)
- Long term management measures to ensure the water quality in the system is maintained or even improved and considers the planning period up to the year 2025. (Reconnaissance assessment level of detail)

The key to the successful management of the water quality in the Vaal River System is the formulation of management measures that integrates all the relevant aspects that have a bearing on the water resources. This requires assessments of the physical, economical, social, institutional, statutory and ecological aspects in the system in order to understand the current situation and be in a position to find strategies (management options) that will be able to handle the existing as well as anticipated future challenges. Furthermore it has been identified that the growing economy, particularly in the Upper Vaal Water Management Area and upper area of the middle Vaal River, have and will continue to intensify the pressures on the water quality of the resource and it is therefore necessary to find innovative measures that offers economical and sustainable management solutions.

The objective of this task was therefore in consultation with relevant stakeholders, to identify and screen possible management measures with the aim to find the most feasible options for implementation. This was carried out through the execution of the sub-tasks as described in the following sections.

The evaluations of all the scenarios was undertaken at a reconnaissance level of detail and those earmarked for implementation over the medium term (ten year planning period) were assessed at a pre-feasibility level of detail. The identified sub-tasks and associated activities for this task are listed below and the approach described in more detail in the subsequent sections:

- Task 6a: Identification and preliminary screening of management scenarios.
- Task 6b: Definition of evaluation criteria.
- Task 6c: Screening of scenarios (involving economic assessment, technical viability, etc.).
- Task 6d: Development of an implementation programme.
- Task 6e: Reporting and deliverables (including the compilation of the IWQMP).

2 WATER QUALITY STATUS, SALINITY BALANCE AND THE RESOURCE WATER QUALITY OBJECTIVES

In order that the most suitable, cost-effective and appropriate water quality management measures are implemented for the Vaal River System, it is important that the current status of the system is understood and the focus in terms of the management objectives of the Vaal River is known.

Thus in identifying and developing management measures to improve and address water quality stresses and priorities and allow utilisation of available allocatable water quality to the benefit of the water users in the system, it was important that the system and its behaviour was understood. This required that three prior tasks be undertaken to serve as a basis for the development of the management options. The prior tasks included:

- The assessment of the Vaal River System to obtain a perspective of water quality (variables of concern), pollution sources and key water users. This included the identification of existing Resource Water Quality Objectives (RWQOs) and their establishment where they are not available.
- Understanding the salinity balance of the system (the major sources in a system context); and
- Establishing how the system complies with the RWQOs, which was determined through analysis of available data and undertaking modelling of possible future scenarios.

The following sub-sections of Section 2 provide a summary of the outcomes of the above tasks. Each task has a detailed report available which may be consulted for further information. What is presented here is a brief description of the results of each, to provide the background to the reader and put the management options analysis in context.

2.1 Status Assessment of the Water Quality of the Vaal River

2.1.1 Introduction

Task two of the study – the water quality status assessment task concentrated on the water quality of the Vaal River System in terms of chemical and biological quality. It did not deal with the microbiological status of the water resources as this monitoring information was not readily available yet. However a snapshot of some areas in terms of microbiological quality was given.

The status assessment task report (DWAF, 2006c) provides background to the study and the context of the task, and provides the framework for this study. It also deals with the characterisation of the study area, physical attributes, water resource systems, description of the current land use activities and development, and then goes on to provide an assessment of the results indicating the current water quality status of the Vaal River System. The task also dealt in essence with discussion of the findings of the assessment, formulating and prioritising the water quality issues, concerns, problems. The report also provides concluding remarks and recommendations regarding possible management options.

2.1.2 Methodology followed

The study area for the assessment comprised the C drainage area, which included the Upper Vaal WMA, Middle Vaal WMA, part of the Lower Vaal WMA (C secondary drainage regions), and part of the Upper Orange WMA *viz.* the Modder Riet Catchment (refer to **Figure 3**).

To simplify the assessment and to present the information in such a way that it would be useful for water quality management purposes, strategic monitoring points at two levels were identified for the system. Level 1 points were located on the main stem of the Vaal River (refer to **Figure 4**) and level 2 points on the major tributaries (refer to **Figure 5**), just upstream of their confluences with the Vaal River. Water quality was assessed on the basis of compliance to resource water quality objectives (RWQOs), and based on the fitness for use for different user groups in terms of the South African Water Quality Guidelines (SAWQGs).

The assessment was limited to historical data and a once-off sampling and field survey conducted during May and June 2006. A review of the literature including limnological and ecological studies and water quality data from the Department of Water Affairs and the three major water boards, *viz*. Rand Water, Midvaal Water and Sedibeng Water, served as the primary source of data for the analysis for the Level 1 and Level 2 strategic monitoring points. An average study period of 10 years was used for assessing water quality.

The data used for the analysis has different time scales, different sampling frequencies, variation in the water quality variables monitored and different laboratories and analytical methods used. The lack of an integrated holistic monitoring programme for the Vaal River System has made the identification of water quality trends difficult. Taking these limitations into account, the data obtained has been used to determine the downstream trends in the Vaal River and to correlate these with the contributions received from the tributary catchments and to the discharges being released into the Vaal River and its tributaries.

The results of the assessment were presented in a series of graphs.

2.1.3 Results and Conclusions in summary

From the water quality status assessment task, a spectrum of problems has been identified with regard to the current water quality in the Vaal River. Some issues are related to the whole length of the Vaal River while others are of a localised nature. This study has confirmed that increase in salinity (and related macro ions) has had the greatest impact on the usage of the water in the Vaal River (**Figure 6**). The increase in TDS and concomitant increase in constituents such as chloride and sulphate has major implications on domestic, industrial and agricultural water use.

The ratio of the median TDS concentrations at the level 1 points to the median concentration at VS1 listed in **Table 1** highlights the increasing trend observed. The trend is also shown by examining the average TDS concentrations along the length of the Vaal River. The reach of the Vaal River to Vaal Dam (VS1 to VS7) has an average TDS concentration of 155 mg/ℓ. There is a significant increase in the average TDS concentration to 455mg/ℓ between VS7 and VS14 *i.e.* the outflow from Vaal Dam to the Vals and Vaal River confluence. There is a slight drop in the average TDS concentration to 338mg/ℓ from the Vals and Vaal River confluence to the de Hoop weir. The average TDS concentration increases to 470mg/ℓ at points VS18 and VS20 below De Hoop weir.

Table 1: TDS increase as a ratio along length of Vaal River from origin

Monitoring site	*Ratio of increase in TDS along Vaal River from Background Concentration at origin
VS1 (Background concentration)	1.0
VS2	1.7
VS3	1.7
VS4	2.4
VS5	2.7
VS6	4.1
VS7 (Outflow Vaal Dam)	2.6
VS8 (Vaal Barrage)	7.3
VS9	8.3
VS10	7.8
VS11	7.7
VS12	8.9
VS13	8.0
VS14	8.0
VS16 (Outflow Bloemhof Dam)	5.6
VS17	5.5
VS18	5.4
VS19	8.0
VS20 (In flow Orange River Canal)	7.4

Note: *Ratio of increase in TDS was determined using the 50th percentile value at each point and dividing that value by the 50th percentile value at point VS 1 which was taken as 'background concentration'. This provides an indication of the increase).*

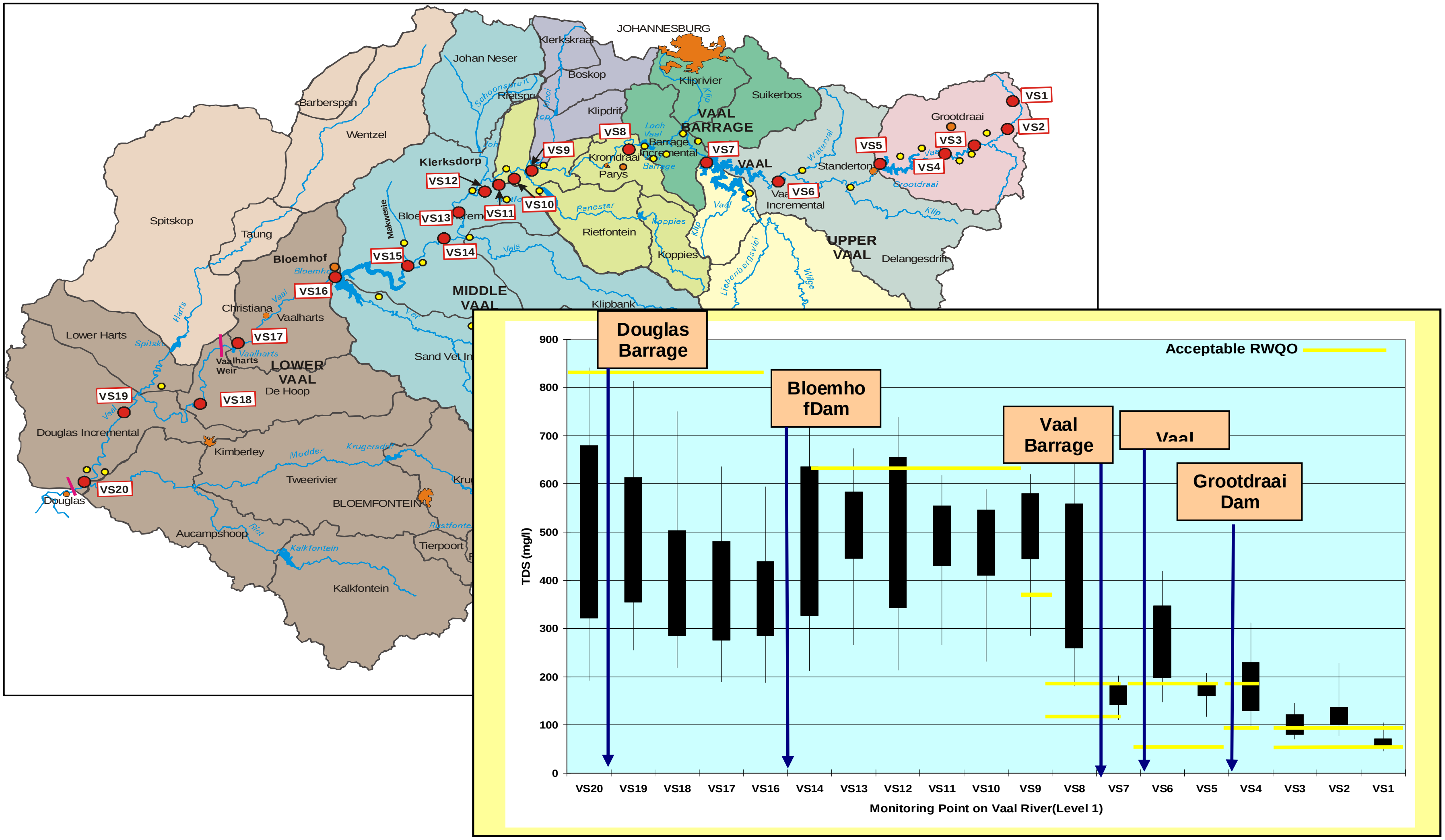

Figure 6: TDS trends along the Vaal River

The occurrence of microbiological pollutants as localised problems are also an emerging concern, as well elevated levels of certain metals. Eutrophication is the other key water quality problem in the Vaal River System. This problem has resulted in excessive algal blooms and growth of water hyacinth (**Figure 7, Figure 8** and **Figure 9**). Eutrophication impacts have resulted in economic implications for users (**Figure 10** and **Figure 11**) and large expenditure to control it. The effect of the extensive algal blooms and biomass upon water treatment processes and quality of potable may yet increase in significance.

Figure 7: Cyanobacterial bloom (*Microcystis aeruginosa)* in Leeuspruit that enters Grootdraai Dam (29/5/2006)

Figure 8: Cyanobacterial bloom (*Microcystis aeruginosa)* in the Vaal Dam (March 2002) – photo with permission from Rand Water

Figure 9: Water hyacinths growth at the Vaal Barrage (30-05-2006)

Figure 10: Scum and foam layer of algae at Midvaal Water Company intake tower with close-up picture (2/6/2006) – visible symptoms of eutrophication

One of the major consequences of eutrophication is the algal related water purification and water quality problems associated with high algal concentrations in the raw water. Based on the high annual chlorophyll-***a*** concentrations at Balkfontein (mean, 45 µg/ℓ), the trophic status of the Vaal River in this point is classified as hypertrophic (**Figure 11**).

Figure 11: Thick foam scum in settling tanks of Sedibeng Water purification plant associated with a diatom (*Stephanodiscus* sp.) bloom in the Vaal River at Balkfontein (3/6/2006). The dark red-brown colour is partially attributed to the diatoms and the chemicals (ferrichloride) added to the water

While the upper part of the catchment has water of fairly good quality, the areas of concern include the Vaal Barrage, Middle Vaal River, and Lower Vaal River downstream of the Harts River confluence, where TDS levels are high. Of further concern is the impact of the high TDS concentrations on downstream water users below the Vaal Barrage and those abstracting from the Barrage.

Specific catchments are of concern as well in terms of their contributions to the deteriorating water quality of the Vaal River. These include the Waterval, Suikerbosrand, Rietspruit, Klip River (Gauteng), Mooi River, Koekemoerspruit, Schoonspruit, Vierfontein, Sand Vet and the Harts River Catchments. These catchments must ensure the development of water quality management strategies to manage the impacts originating from them, thereby alleviating the stress currently being placed on the Vaal River.

It is apparent that the status quo in terms of land based activities and water use practices cannot continue unabated as they have. Water users, major role players and the Department have to all start taking responsibility where required, to ensure the situation does not worsen, and to ensure sustainable use of the water resources. While it is accepted that socio-economic development is needed in South Africa, with the Vaal River System being a key area for this, it cannot occur at the expense of the water resource system. A range of management strategies and control measures are required to deal with the current situation.

The study has identified that while high salinity concentrations is currently a serious problem in the Vaal River System, the current trends indicate that the problem is not expected to increase substantially in the future. Thus the issue hand is how to handle the current situation in terms of management measures and reduction. Eutrophication on the other hand is a looming threat, and the system is considered to be a high risk from eutrophication.

2.2 Salinity Balance of the Vaal River System

2.2.1 Introduction

The WQT salinity model has been set up for the Vaal River system as part of the Vaal River System Analysis Update Study (VRSAU) (DWAF, 1998). The process of setting up the water quality model involved calibrating the WQT model and the calibrated WQT model input parameters being input into the WRPM. The WRPM is used for the strategy development, planning and operational management of the Vaal River System. The WRPM is the model that was used to evaluate the management options for the IWQMP and the Reconciliation Study. The process of calibration involved the collection of point source discharge volumes and Total Dissolved Solid (TDS) concentrations, land use information, instream flows and qualities at river and dam monitoring points for use in calibrating the model. The WQT model uses the monthly naturalised hydrology as input. The WQT and the hydrological models have been calibrated up until September 1995.

The hydrological model and WQT have not been calibrated since the VRSAU Study. The water quality situation in the Vaal River has changed since September 1995 with changes in the discharge volumes and qualities from gold mines such as Petrex (formerly Grootvlei mine) and the wastewater treatment works (WWTW). A recalibration of the water quality model will require a substantial amount of work including the calibration or extension of the hydrology. This additional work may be largely unnecessary for the broad level planning being undertaken in this study. A simpler approach has therefore been proposed to check if the water quality component of the WRPM is still valid. An annual salinity balance was developed for the hydrological years from October 1995 to September 2004. This is aimed at determining the relative contributions of pollution sources and identifying any significant divergence from the assumptions that drove the VRSAU study calibrations. Details of the salinity balance can be found in the salinity balance report for Task 3.

2.2.2 Approach to salinity balance

The steps involved in carrying out the salinity balance were :-

- Selection of key monitoring stations in the system. Monitoring stations located at the outlet of the major catchments were selected. The catchment areas used for the salinity balance are shown in **Figure 12** and the key monitoring stations listed in **Table 2**.

- The measured flow and TDS concentration information was collected patched and aggregated to calculate the salt loads leaving the catchment area for which the salt balance was being undertaken.

- The available point source discharge information which included the wastewater treatment plant, industrial, mine discharges and the volumes and qualities of water transferred from outside the catchment. This data was patched and represented inputs of salt into the catchment area being analysed.

- The data on the abstractions from the catchments was also collected. The abstraction data included irrigation, industrial and domestic water use. The abstractions represent the removal of load from the catchment.

- The start and end volumes stored in the major dams were collected from the Department's dam balance database. The TDS concentrations were collected from the Department's water quality databases. This gives the load in the major dams at the start and end of the calculation period.

- The total load out of the catchment less the total load into the catchment gave the TDS load contribution from the catchment. The WRPM model abstraction and effluent flow data was set to mimic the patched observed values. The beginning of October 1995 salt washoff, reservoir and irrigation module starting salt storages were set equal to those simulated in the VRSAU for the end of September 1995. The WRPM was then run for the period 1995 to 2004 to generate a series of salt concentration scenarios at key monitoring stations. The simulated WRPM results were compared with the calculated values at the key points in the system to determine if the observed scenario is within reasonable statistical limits.

Table 2: Key Stations used in the salinity balance

Salinity Balance sub-catchment	Key Station
Grootdraai Dam	C1R002 – dam balance for Grootdraai Dam C1H019 – Dam outflow quality and quantity
Frankfort	C8H001 – flow and water quality data
Vaal Dam incremental	CR001 – dam balance for Vaal Dam C2H122 – Anniesdrift weir measuring outflow quality and quantity released from Vaal Dam
Vaal Barrage	C2R008 – water quality data daily discharge information from Barrage obtained from Rand Water
Mooi	C2H085 – Flow and water quality data
Vaal Barrage to Bloemhof Dam	C9R002 – Bloemhof Dam balance C9H021 – Flow and water quality of Bloemhof Dam discharge
Harts at Spitskop Dam	C3R002 – Spitskop Dam balance and water quality data C9R001 – Vaal Harts weir abstraction data

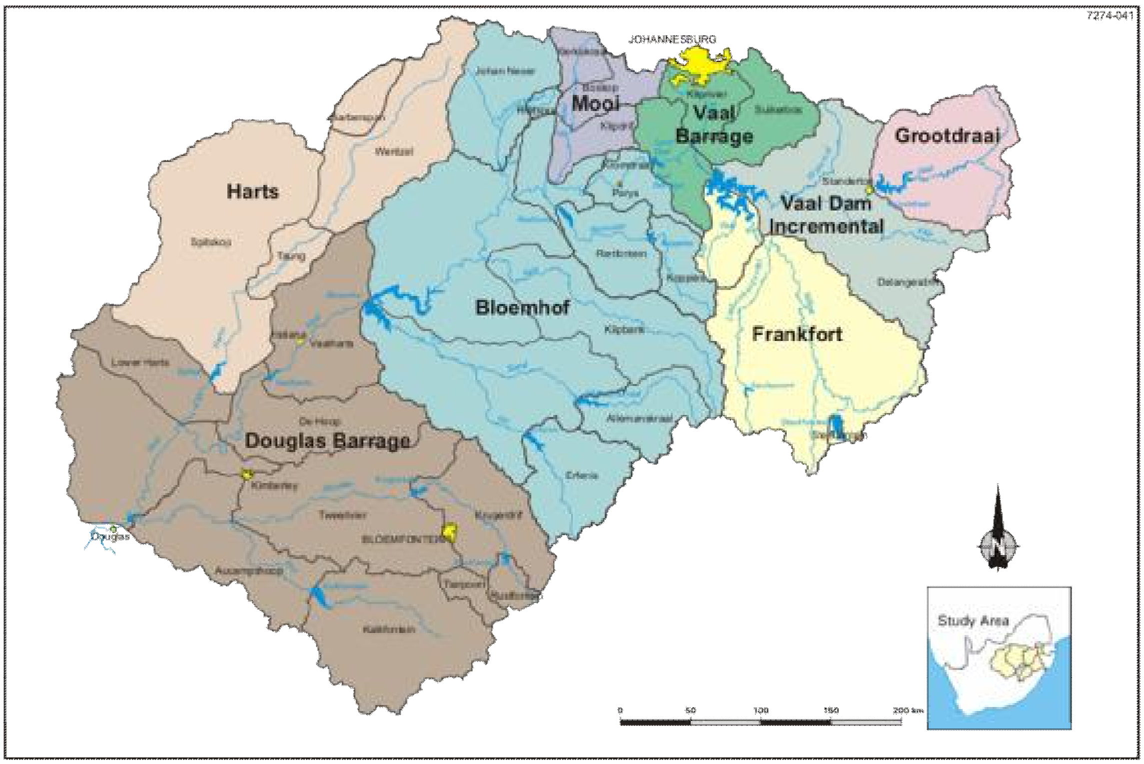

Figure 12 : Catchments used to develop the salinity balance

The results of the salinity balance showed that the simulated catchment loads and concentrations compared favourably to the salinity balance values and the calibration parameters in the WRPM were therefore adequate for the development of the IWQMP. A summary of the annual TDS loads, volumes and average TDS concentrations from the different sources for the catchment down to Bloemhof Dam are listed in **Table 3.** The summary shows that mine discharges contribute a significant salt load at a high concentration with the industrial and waste water treatment plant effluent having the next highest concentration. The transferred water, largely from Lesotho has a low TDS concentration and contributes to the maintenance of the TDS concentrations in Vaal Dam.

Table 3: Summary of volume (million m^3/a) and TDS load (tonne/a) from sources for catchment down to Bloemhof Dam

	Transferred	Effluent	Mines	Catchment
Volume (million m^3/a)	479	492	91	4235
Load (tonne/a)	37935	254691	161667	1039257
Ave TDS Conc (mg/l)	79	518	1777	245

In carrying out the salinity balance the following conclusions were also drawn:-

- The system network needs updating to reflect the latest layout.
- Irrigation modules need to be added for the Upper and Middle Vaal catchment areas to model the salt and water balances.
- The irrigation modules in the Lower Vaal and Rietspruit catchment need to be reviewed.
- The return flows from the Midvaal Water demand centre need to be reviewed.

2.3 Resource Water Quality Objectives (RWQOs) in Vaal River System

It is a given that it is impossible to meet the ideal water quality requirements in the Vaal River System as huge impacts from land developments, the extensive use of the resources and high regulation of the system already exists. Thus while RWQOs currently set are at levels which are achievable through sound management practices, in many instances the results of the status assessment task indicated that the RWQOs must be revised and integrated on a WMA and in a system context to enable the Vaal River to be managed sustainably and to cater for downstream users and uses. Thus while the emphasis is on improving water quality over time, the current situation has warranted on one hand that acceptable levels of impact are assimilated to maintain current water quality. However on the other hand improvement of water quality is the only option, but this comes at a cost which is interrogated further on in this report in section 4. Both situations have economic implications – maintenance of current status (relaxation of RWQOs in some cases), would mean the downstream user would bear the cost, and improvement of current status (stricter RWQOs) would mean the discharger /polluter would bear the cost. Thus the integrated RWQOs proposed have considered the balance between the needs of users and uses, and reflects the realities that exist in such a regulated and impacted system.

The integration of the RWQOs task (task 4) of the IWQMP study, details the process and approach followed in determining an integrated set of RWQOs for the Vaal River System (DWAF, 2007). The information collated and the results of the task are presented in the task 4 report and are thus not detailed here. However the outcome of the process and the RWQOs proposed are presented in the section below.

2.3.1 Process Followed

Based on the current water quality status of the system, the assessment of the situation with regard to the water users and various uses and the consideration of all variables, an attempt was made to integrate, align and revise the RWQOs of the Vaal River main stem and its tributaries.

The process followed to arrive at a proposed set of integrated RWQOs for the Vaal River System included the following:

Desk Top Assessment

As the first attempt, an assessment of all the existing RWQOs for the water resources in the catchment was undertaken by the study team. Based on their current understanding of the system and the results of the status assessment and salinity balance the study team at a desktop level identified proposed changes to the existing RWQOs. This exercise was aimed at identifying the key issues and focus areas that required attention. This analysis provided the basis for the iterations that followed. The results of this first order assessment are presented in Appendix B of the RWQOs report.

The proposed changes to RWQOs as they currently existed per sub-catchment for the Level 1 and 2 points in the Vaal River system and the reasoning behind these were indicated in the tables in Appendix B of the RWQOs report. The acceptable range RWQO was used as the “reference” as in most instances the acceptable level RWQO was used as the management target for the catchment. The suggested concentrations given in the tables were based on data available (past 10 years), field observations, professional expertise and knowledge, gut feeling, and literature. These recommended changes/proposals were presented to the Department for discussion.

Workshops

Following on from the draft discussion document, two workshops were held with key stakeholders in the Department to confirm a set of proposed RWQOs for the Vaal River System. The Department stakeholders that participated included representatives from the Department National Office (various Directorates) and Regional Offices (Gauteng, Free State and Northern Cape). The first integration of RWQOs workshop was held on 12 October 2007 in Pretoria, at which the approach was confirmed, and set of RWQOs were proposed. These RWQOs were then modelled using the WRPM to determine what was achievable and possible based on the current operation and restraints in the system. A second workshop was then held on 1 November 2007 to present the outcome of these modelling runs, and to confirm a proposed set of integrated RWQOs for the Vaal River and its tributaries.

2.3.2 Record of Decisions

The results/ record of decisions of the workshops regarding the approach and process followed and the integrated RWQOs proposed are discussed below.

Approach and process

The approach to the process followed was agreed upon by all stakeholders present. The key components of the approach were identified key drivers and reality check factors that were considered integral to the process. These components are listed below with the identified criteria for each:

Reality check factors:

The factors identified that the RWQOs were based on/tested against included:

- Bottom up approach
- Defined River Reaches
- Vision for the Vaal River
- Selected Water Quality Variables
- Single management objective
- Principles for setting the Level 2 RWQOs

Key Drivers:

The RWQOs in addition to being guided by the reality check factors were also dependent on key drivers for the river reaches of the system. These included**:**

- Water User requirements
- Protection level
- Status quo

The criteria (reality check factors), decisions taken and considerations regarding the approach and process followed are presented below in **Table 4.**

2.3.3 The integrated RWQOs proposed

Based on the criteria defined and considerations identified, as well as the key drivers, RWQOs for the selected water quality variables for the Vaal River were determined as part of task 4 of the study. A set of integrated RWQOs for total dissolved salts (TDS), phosphate, and *E.coli* (microbiological) were defined for the Vaal River (main stem) for each of the 14 river reaches identified (**Table 5** and **Figure 13**). The proposed RWQOs are presented in **Table 6, Table 7** and **Table 8**. Based on the model runs that were undertaken, RWQOs for TDS for the major tributaries of the Vaal River were also defined and these are presented in **Table 6** as well.

Table 6 also includes the eco-specifications outputs related to the ecological protection levels for TDS determined using the water quality based TEACHA programme of the Reserve process. This assessment was undertaken to ensure that the RWQOs proposed were aligned to and took into consideration the level of ecological protection required for the various reaches of the Vaal River. The ecology is a key component of the system and in almost all instances the RWQOs proposed are stricter than the requirements specified by TEACHA.

Table 4: Approach followed in integration/setting of RWQOs for the Vaal River

Criteria	Decision	Consideration
Bottom up	Bottom up approach - Start at Douglas Barrage and move up the system	Need to test impact – "sea" – bottom up on Orange River Top-down and Bottom up - both have some implications for drivers and users
River reaches	14 River Reaches were agreed upon for setting of RWQOs (see **Figure 13**)	Reserve needs to be taken account of Need to consider management approach Criteria to apply: - Water user profiles - Ecoregions - Hydrodynamics – tributaries entering - Discontinuity e.g. discharges Middle Vaal - 1 reach for Schoon / Koekemoerspruit area is sufficient. Management will dictate / direct outcomes. Lethabo weir – accepted as end of Vaal Dam Reach
Vision	Three catchment areas defined: • Upstream Grootdraai Dam • Downstream Grootdraai Dam to Vaal Dam • Below Vaal Dam to Douglas Barrage Visions (Main Stem) **Upstream Grootdraai** Good state – keep as is – ecologically functioning Not highly modified **Downstream Grootdraai Dam to Vaal Dam** Highly modified area Maintain at a C category ecologically Preserve Wilge River Consider trade offs if deterioration observed Moderately impacted river **Below Vaal Dam to Douglas Barrage** Workhorse catchment - overworked Have to improve current state	Two definitions to agree on vision: • Uses – Heavily used catchment areas • State of catchment: Background WQ • Need to consider economics and social issues and impacts • Reality check must be done with Reserve process and links must be made with ecological water requirements • Ecological scenarios should also consider water quality needs and issues that prevail in the catchment • Collective for visions need to be derived • Qualitative statement for protection required

Criteria	Decision	Consideration
	Need to ensure an acceptable state that is sustainable	
Objective (RWQOs)	Set at level that should not be exceeded 95th% tile management objective set Set maximum limit Range / or single number may be set	
Water quality variables	TDS TP TN *E. coli* (Microbiological)	TDS: Indicator of issue Salinity management is required Sulphate (most and problematic). Causes: Corrosion Diarrhoea (health impact) Sulphate salts – impact on the aquatic ecosystem (some are toxic) Ask sulphate question along each reach – to determine if RWQO is needed NUTRIENTS TP – as PO_4 TN – as N/NO_3 Immediate objective for Phosphate can be set Long term management option for total phosphorus and total nitrogen must be available. MICROBIOLOGICAL Indicator organism selected – *E.coli* Current problem being faced relates to analysis – issues related to accuracy of analysis

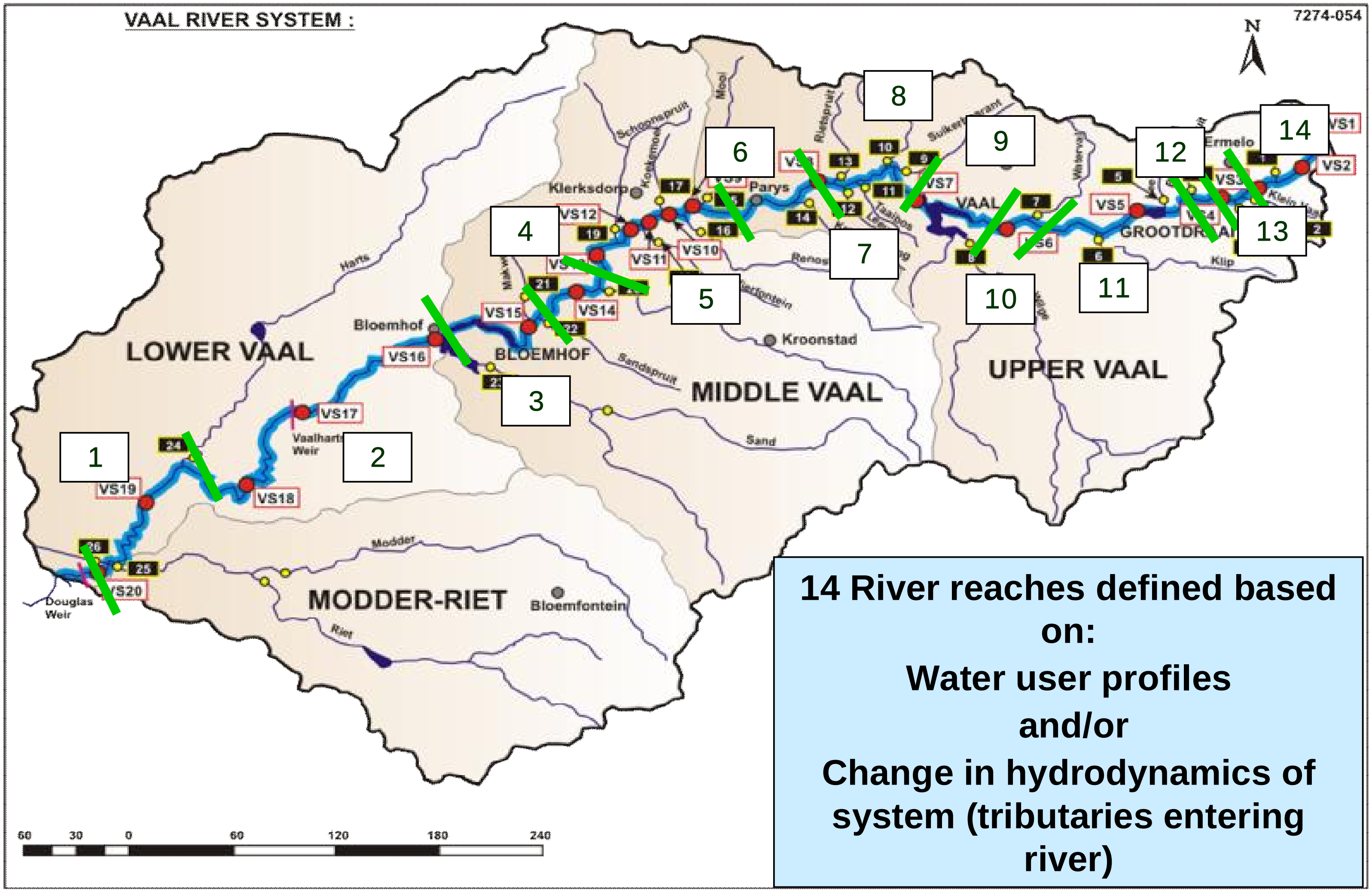

Figure 13: River reaches defined for the Vaal River main stem

Table 5: River reaches identified for the Vaal River main stem

Reach no (map)	Reach (Bottom up)
1	Vaal River downstream Harts River confluence to Douglas Barrage
2	Vaal river d/s Bloemhof Dam and u/s Harts confluence
3	Makwassiespruit to Bloemhof Dam
4	Vaal River d/s Vals confluence to Sandspruit confluence
5	Vaal River d/s Mooi confluence to Vals River confluence
6	Vaal River d/s Vaal Barrage u/s Mooi confluence
7	Vaal River d/s Lethabo weir to Vaal Barrage
8	Vaal Dam to Lethabo weir
9	Vaal River Downstream Waterval Confluence to inflow Vaal Dam
10	D/S Grootdraai Dam to u/s Waterval confluence
11	Vaal River d/s Blesbokspruit to Grootdraai Dam
12	Vaal River d/s Rietspruit u/s Blesbokspruit
13	Vaal River u/s and d/s of Rietspruit
14	Vaal River u/s Klein Vaal to origin of Vaal River

Table 6: Proposed RWQOs for TDS for the Vaal River main for each river reach defined and for the major tributaries

VAAL RIVER SYSTEM: LEVEL 1 POINTS: RWQOS FOR TDS												
NO	REACH	WATER USERS	SOUTH AFRICAN WATER QUALITY GUIDELINES				PROTECTION (TEACHA OUTPUT - Preliminary Ion EcoSpecs)	CURRENT STATUS (95th %tile value)	RWQO SET (12th October 2007)	RWQO (1 November 2007) based on model runs	RESULTS OF MODEL RE-RUNS (December 2007)	TDS RWQO: Tributaries (1 November 2007) based on model runs
			TWQR (*1)	A (*2)	T (*3)	U (*4)						
1	Vaal River downstream Harts River confluence to Douglas Barrage	Irrigation#	260	585	1755	3510	1198 mg/l (average VS19 to VS20)	961 mg/l	600 mg/l	600 mg/l	800 mg/l	1500 mg/l
		Domestic	450	1000	2400	3400						
		Recreation	No guideline prescribed									
2	Vaal river d/s Bloemhof Dam and u/s Harts confluence	Irrigation#	260	585	1755	3510	574 mg/l (average VS16, VS17 & VS18)	601 mg/l (average)	600mg/l	600mg/l	700 mg/l	no tributary
		Domestic	450	1000	2400	3400						
		Recreation	No guideline prescribed									
3	Makwassiespruit to Bloemhof Dam	Irrigation#	260	585	1755	3510	1167 mg/l	807 mg/l	600 mg/l	600 mg/l	700 mg/l	Vet River: 660 mg/l
		Recreation	No guideline prescribed									
4	Vaal River d/s Vals confluence to Sandspruit confluence	Irrigation#	260	585	1755	3510	1167 mg/l	807 mg/l	450 mg/l	600 mg/l	750 mg/l	Vals River: 700 mg/l
		Domestic	450	1000	2400	3400						
		Recreation	No guideline prescribed									
5	Vaal River d/s Mooi confluence to Vals River confluence	Irrigation#	260	585	1755	3510	1526 mg/l (average VS 9, VS10, VS12)	673 mg/l	450mg/l	600mg/l	600 mg/l	Schoonspruit: 800mg/l Koekemoerspruit: 800mg/l Renoster: 200mg/l ; Mooi: 450mg/l
		Domestic	450	1000	2400	3400						
		Recreation	No guideline prescribed									
		Industry (*category)	100	200	450	1600						
6	Vaal River d/s Vaal Barrage u/s Mooi confluence	Irrigation#	260	585	1755	3510	845 mg/l	647 mg/l	600mg/l	To be determined (Need to model to reach 600mg/l in Middle Vaal River)	600 mg/l	no tributary
		Domestic	450	1000	2400	3400						
		Recreation	No guideline prescribed									
7	Vaal River d/s Lethabo weir to Vaal Barrage	Irrigation	260	585	1755	3510	845 mg/l	647 mg/l	To be determined (Driven by blending option to 300mg/)	To be determined (Need to model to reach 600mg/l in Middle Vaal River)	600 mg/l	Klip: 600 mg/l, Suikerbos: 650mg/l; Leeu: 455mg/l; Taai: 390 mg/l; Rietspruit: 550 mg/l; Kromelmboog: 195 mg/l
		Domestic	450	1000	2400	3400						
		Recreation	No guideline prescribed									
		Industry (*category)	100	200	450	1600						
8	Vaal Dam to Lethabo weir	Irrigation#	260	585	1755	3510	245 mg/l	198 mg/l	180mg/l (Sulphate 30mg/l)	125mg/l (Sulphate 30mg/l)	125 mg/l	Wilge River: 110 mg/l
		Domestic	450	1000	2400	3400						
		Recreation	No guideline prescribed									
		Industry (*category)	100	200	450	1600						
		Power Generation	175									
9	Vaal River Downstream Waterval Confluence to inflow Vaal Dam	Irrigation#	260	585	1755	3510	200 mg/l	413 mg/l	200mg/l	200mg/l	250 mg/l	450 mg/l
		Domestic	450	1000	2400	3400						
		Recreation	No guideline prescribed									
10	D/S Grootdraai Dam to u/s Waterval confluence	Irrigation#	260	585	1755	3510	264 mg/l	200 mg/l	200mg/l	195 mg/l	200 mg/l	Klip River: 195 mg/l
		Domestic	450	1000	2400	3400						
		Recreation	No guideline prescribed									
11	Vaal River d/s Blesbokspruit to Grootdraai Dam	Irrigation#	260	585	1755	3510	264 mg/l	256 mg/l	180mg/l (Sulphate 30mg/l)	180mg/l (Sulphate 30mg/l)	180 mg/l	Leeuspruit: 400 mg/l Blesbokspruit: 400 mg/l
		Domestic	450	1000	2400	3400						
		Recreation	No guideline prescribed									
		Industry (*category)	100	200	450	1600						
12	Vaal River d/s Rietspruit u/s Blesbokspruit	Irrigation#	260	585	1755	3510	too little data (< 60)	313 mg/l	150mg/l (Sulphate 30mg/l)	150mg/l (Sulphate 30mg/l)	150 mg/l	no tributary
		Recreation	No guideline prescribed									
13	Vaal River u/s and d/s of Rietspruit	Irrigation#	260				too little data (< 60)	144 mg/l	150mg/l (Sulphate 30mg/l)	150mg/l (Sulphate 30mg/l)	150 mg/l	Rietspruit: 100 mg/l
		Recreation	No guideline prescribed									
14	Vaal River u/s Klein Vaal to origin of Vaal River	Irrigation#	260	585	1755	3510	too little data (< 60)	159 mg/l (average)	150mg/l (Sulphate 30mg/l)	100mg/l (Sulphate 30mg/l)	100 mg/l	Klein Vaal: 100 mg/l Witpuntspruit: 100 mg/l
		Domestic (informal)	450	1000	2400	3400						
		Recreation	No guideline prescribed									

u/s = upstream **d/s = downstream** **Irrigation# - TDS values fo crop yield**

Table 7: Proposed RWQOs for phosphate for the identified reaches in the Vaal River main stem

Vaal river system RWQO for phosphate (Po_4-P)							
No	**Reach**	**Water users**	**Guidelines for trophic status of vaal river waters (ug/l)**				**RWQO set**
			Oligotrophic	**Mesotrophic**	**Eutrophic**	**Hypertrophic**	
1 - 3	**Vaal River, Bloemhof Dam to Douglas Barrage**	Irrigation, domestic, recreation, industry, aquatic ecosystem	< 10	10 - 50	50 -150	> 150	**30 ug/l**
4 - 5	**Vaal River d/s Mooi confluence to Sandspruit confluence**						**100 ug/l**
6 - 7	**Vaal River d/s Lethabo weir to u/s Mooi confluence**	Irrigation, domestic, recreation, industry, aquatic ecosystem	< 10	10 - 50	50 -150	> 150	**150 ug/l**
8 -14	**Vaal River, Vaal Dam to headwaters**						**50 ug/l**

Table 8: Proposed RWQOs for *E.coli* for all reaches in the Vaal River (main stem)

Vaal River System RWQO for *Escherichia coli* (Microbiological)							
No	**Reach**	**Water users**	**South african water quality guidelines**				**RWQO set**
			TWQR	**A**	**T**	**U**	
1 - 14	**All reaches in Vaal River System**	Recreation - Full contact (counts per 100ml)	0 - 130	130 - 200	200 - 400	> 400	**< 300 (counts/100ml)**

These RWQOs above represent a set of integrated/revised RWQOs being presented as part of task 4 of this study. The revised set of RWQOs proposed, while aimed at maintaining and/or improving water quality is dependent on what is achievable and can be cost-effectively implemented. The RWQOs are also dependant on the flow requirements and related operating rules of the Vaal River System and thus are inter-dependant on the water quality management options and the reconciliation options in terms of what is achievable in terms of a system perspective. The scenarios outlined in section 4 confirm what RWQOs are achievable per river reach for the Vaal River and its major tributaries. The economic assessment related to the final management options is also a key determinant in the RWQOs that are adopted.

3 APPROACH TO EVALUATION OF MANAGEMENT SCENARIOS

3.1 Introduction

The water quality status assessment of the Vaal River described in Section 2 of this report identified salinity, eutrophication and microbiology as the priority water quality issues in the catchment that need management. The salinity related issues have been modelled since the 1980s and the WRPM has the ability to model the TDS concentrations in the Vaal River System. The majority of the sources are known and the salinity balance is reasonably well understood. The salinity in the system has been managed by releasing dilution water from Vaal Dam to maintain the TDS concentration in the Barrage at a maximum concentration of 600 mg/L. Water use licencing, IWWMP and the EMPR/EIA processes are used to manage the mines and industries through operation to closure and beyond. The nutrient and related eutrophication issues are not as well understood as salinity. The modelling of nutrients is more difficult than salinity as they are non-conservative pollutants. The understanding of the nutrient balance is not well developed in the Vaal River System. The Department is in the process of applying models to the middle reaches of the Vaal River to better understand the nutrient balance and the behaviour of the system.

As far as the salinity issues are concerned, the Grootdraai Dam water quality is at present acceptable and further increases in the TDS concentration will have significant economic impacts on Sasol and Eskom. The major salinity issues relate to the reach of the Vaal River from the Barrage to Bloemhof Dam and then the lower reach of the Vaal River from the Harts confluence to the Orange River. The sources of the salinity in the Grootdraai Dam catchment are largely related to mining activities. The major source has been assigned to seepage from mine workings and waste storage facilities and decants from defunct mines. The major sources of salinity in the reach of the Vaal River from the Vaal Barrage to the Bloemhof Dam are mine and industrial discharges. The return flows from the wastewater treatment works and irrigation areas also add salinity to the system. The salinity in the lower reaches of the Vaal River is related to the high TDS discharges from the Harts and the Riet Rivers. These are related to the saline return flows from the extensive irrigation taking place in these catchments.

The major eutrophication issues are in the middle reaches of the Vaal River from the Barrage to the Sedibeng Water offtake. The sources of nutrients are related to the discharges from the wastewater treatment works, irrigation return flows, industrial effluents, urban stormwater runoff and the lack of management and maintenance of sewerage systems. Some of the wastewater treatment works are performing to meet their design and licence criteria. There are however others which are not performing to their specifications due to overloading and poor maintenance. The lack of modelling tools and understanding of the nutrient balances of the Vaal River System makes the development of a nutrient management strategy difficult as the cause and affect relationships of management actions are not well understood.

The development of a water quality management strategy involves the evaluation of water management options such as further treatment to reduce loads discharged to the river system, land use changes, use of releases of clean water to dilute pollution sources to achieve an acceptable instream water quality. The implementation of a management strategy incurs costs to the water users and the country. Similarly the deterioration of water quality has an economic impact on the users. Poor water quality impacts on the costs to the water users due to additional treatment costs, loss in agricultural production or deterioration of water supply infrastructure. There are also health and ecological impacts of a poorer water quality that will have to be considered in developing an appropriate water quality management strategy. A water quality strategy can also impact on the water reconciliation status of the Vaal River System. The water quality considerations are normally captured in the RWQO set to protect the users and the ecology. However in setting the RWQO, a balance between the cost of achieving the RWQO and the impact of the water quality on the user economics must also be considered. The RWQO at this stage have been set using only preliminary water quality analysis results from the ecological Reserve studies and the Department’s water quality guidelines. The economic analysis has not been considered. The aim of this evaluation is to include the economic aspects into developing the strategy. At this stage the economic assessment has only been applied to salinity as the economics and the understanding of nutrient balance does not allow for the same level of evaluation as for salinity.

3.2 General description of approach

The approach to the evaluation of the scenarios described in this report relates to the economic evaluation of the management scenarios for salinity to meet the water supply criteria and the basis of the technical analysis of the scenarios will be based on meeting the following criteria :-

- Meet the water requirements at an adequate assurance of supply and curtailment level
- Economically optimal strategy for water quality (salinity)

The basic assumption for the analysis is that all the strategies assessed will have to meet the reliability of supply and curtailment criteria. This implies that the scheme implementation dates and the size of the augmentation schemes must be able to supply the demand scenario at the required reliability of supply for all the strategies considered.

The achievement of an economically optimal solution involves determining the cost of a particular strategy and the dis-benefits in terms of the economic impact of the salinity supplied to the users. The approach adopted to evaluate the scenarios is summarised in **Figure 14** and the steps are described as follows:-

- Formulation of a scenario for analysis. The analysis period was from 2007 to 2025.
- Setting up the WRPM to represent the scenario. An initial run was undertaken using the WRPM to determine when the next augmentation scheme is required so that the reliability criteria for supply are met. Based on the results of the initial run, the WRPM was reconfigured in terms of the timing. The WRPM was run using a 100 stochastic sequences. The modelled 95 percentile TDS concentrations in the reaches of the main stem of the Vaal River and in the main tributaries were determined from the model results.

- The time series of capital expenditure (capex) and operational expenditure (opex) for the augmentation scheme were determined. The net present values (NPV) of the cash streams were determined for interest rates of 6%, 8% and 10%.

- The economic model on the impact of water quality on the users was applied to determine the time series of total dis-benefit costs to the industrial, domestic and agricultural users. The NPV of the water quality dis-benefit costs were determined

- The total NPV for a scenario was then determined.

- The process was repeated for each scenario and the total NPV costs could then be compared to determine the most economic scheme.

- During this process the percentiles of the TDS concentrations will be assessed and compared to the RWQO including the ecological Reserve water quality requirements. This assessment might require further refinement to a strategy or result in a particular strategy being favoured although it might not be the optimal strategy from an economic perspective.

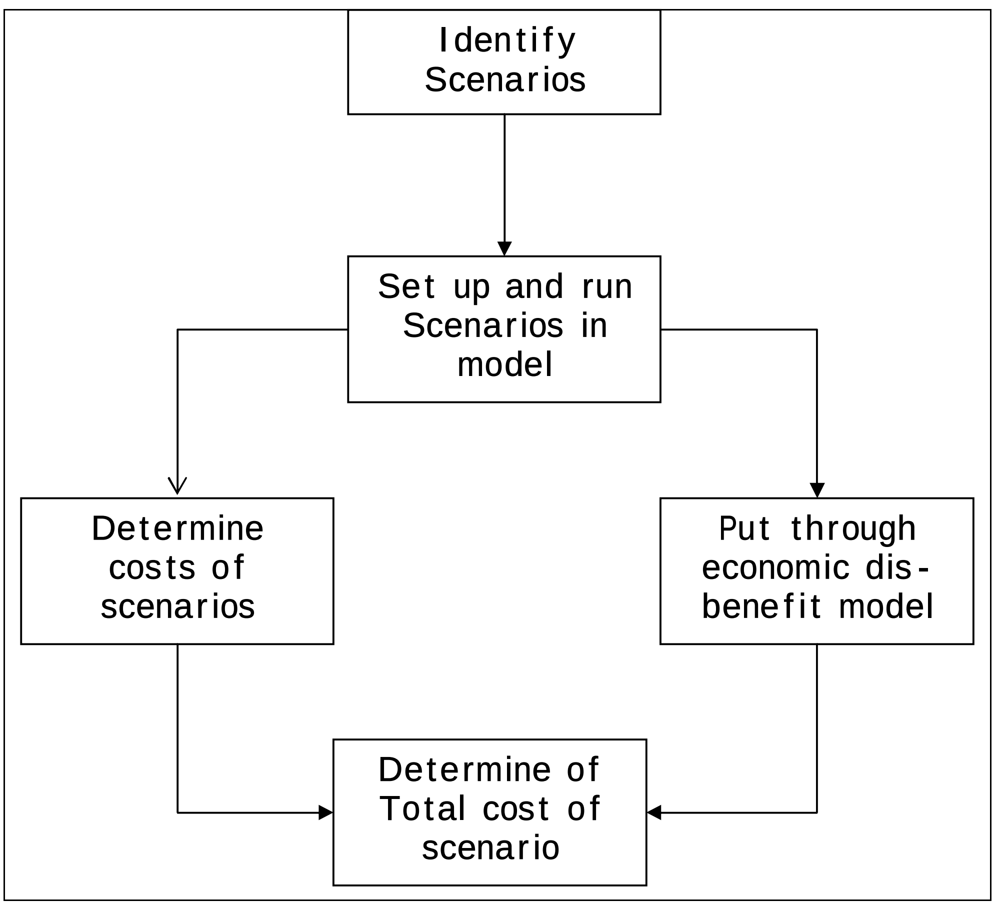

Figure 14 : Graphic showing the management option evaluation process

The economic assessment described above is based on salinity and not nutrients which are also water quality variables of concern. Nutrients are not modelled in the WRPM. Mixing flows have been recommended as a short term strategy to limit the excessive algal concentrations currently experienced at the Midvaal and Sedibeng Water off takes from the Vaal River.

3.3 Background to analysis approach development

There were a number of factors that affected the scenario evaluation approach originally envisaged for the LBWSRS and IWQMP studies. The factors were:-

- In the management scenario evaluation and strategy development phases of the Vaal River IWQMP and the LBWSRS studies, it become apparent that the water quality and reconciliation scenarios for the Vaal River could not be assessed in isolation. Due to this, an integrated approach was adopted for the two studies as far as modelling and strategy formulation was concerned.

- One of the future augmentation schemes is the development of further phases of the Lesotho Highlands Water Project. Water taken from Lesotho for supply to Vaal Dam reduces the flow in the Orange River reporting to the Gariep and van der Kloof Dams. This will affect the yield of these dams and hence the reliability of meeting the demands in the Orange River. This impact needs to be included in the analysis as the yield reduction caused by the transfer of water from Lesotho to Vaal Dam needs to be compensated for by the development of augmentation schemes in the Orange River. Possible augmentation schemes have been investigated in the LORMS Study. The yield and costs of the various augmentation schemes are available from this study.

- The first round analysis highlighted the accumulation of water in Bloemhof Dam over time. The accumulation is due to the increasing return flows from the wastewater treatment works in the Vaal Barrage catchment and dilution releases made to maintain the TDS concentrations in the Vaal Barrage at the required concentration. The return flow volumes increase with the increasing water use in the Rand Water supply network. The accumulated water in Bloemhof Dam can be released along the lower reaches of the Vaal River to meet the water demands in the lower Orange River. This water will therefore impact on the timing and size and hence cost of the scheme needed to support the water requirements in the lower reaches of the Orange River.

The approach was therefore changed to address these factors by including the following :-

- The management scenarios formulated addressed both the reconciliation and water quality strategy requirements. This was achieved by developing scenarios which included the following elements :-
    - the water requirement and return flow projection scenario;

  - the future intervention /augmentation scheme
  - the water quality management option
  - Source of water supply for Rand Water

- The area analysed was extended to include the entire Orange River System ie the costs to mitigate the impacts on the Orange River of transfers from Lesotho to Vaal Dam were included in the analysis of the scenarios.

- The use of the excess return flow water stored in Bloemhof Dam to support the water requirements in the Lower Orange was included in the analysis. This required an initial exploratory run of the system to determine the excess volume and the release that can be made from Bloemhof Dam to the lower reaches of the Orange River.

3.4 Description of scenario components

3.4.1 Water requirement and return flow component

Water requirement projections were prepared for the study area. The water requirement projections included the irrigation, industrial, power generation, water boards and the smaller towns. The following were included in the water requirement projections for the different sectors:-

- In developing the irrigation requirement projections, it was found that a substantial volume of water is being used for irrigation unlawfully. The projection of the irrigation requirement allows for the eradication of the unlawful use. No growth in the irrigation water requirements has been allowed for.
- The water requirements for power generation and the major industries were developed in consultation with the water users.
- Different scenarios were developed for the water requirement projections for Rand Water. The scenarios were a combination of high, base and low population growth scenarios coupled with a WCWDM intervention. The three water conservation and water demand interventions were:-
  - **Scenario C**: 5 Year water loss programme where water wastages are reduced through measures such as leak detection and repair. The loss management measures are maintained after the five year period. This scenario also include measures to improve the efficiency of water use and the assumption was made that a 1% saving can be gained per annum from the year 2015 onwards for the entire planning period (1% of selected large urban users that were assessed in detail).
  - **Scenario D**: Reduction in wastage over 5 years. No efficiency improvement measures were included in this scenario.
  - **Scenario E**: Reduction in wastage over 10 years, allowing for a slower implementation period of the proposed measures.
- The water requirements projections supplied by Midvaal and Sedibeng Water were used in the projection scenarios.

The water requirement projection scenarios that were used in this study for Rand Water were the high and base population growths with a 15% saving in water use due to WCWDM over 5 years (Scenario D). The irrigation projection used assumed that the majority of the unlawful irrigation will be eradicated.

3.4.2 Future augmentation schemes

Future major augmentation schemes have been identified in the Thukela catchment and in Lesotho. Two possible schemes have been identified in the Thukela River catchment viz the Jana and Mielietuin Dams. These schemes have not been optimised in terms of phasing in the schemes to meet the projected growth in water demands. A study to optimise the Lesotho schemes is underway and preliminary results from the study in terms of yield and costs are currently available. In the economic analysis, for the reconciliation and IWQMP studies, the Lesotho option of Polihali Dam has been considered as the next major source of additional water thereafter the Jana and Mieleituin Dams in the Thukela River catchment are considered.

The Vaal and Orange Rivers have to be considered as a system. The Vioolsdrift Dam was found in the LORMS Study to be the most economically attractive option. Cost and yield curves for different sizes of the Vioolsdrift Dam are available. The costs of incorporating the various sizes of this dam to make up for the loss in yield in the Orange River due to the transfer of water from Lesotho to the Vaal Dam were therefore included in the cost analysis.

The volume that can be abstracted from the Bloemhof Dam to support the lower Orange River demands will be determined and included in the analysis. The volume that can be supplied will be included in the WRPM as a release into the Vaal River from Bloemhof Dam as such a release will affect the water quality in the lower Vaal River.

3.4.3 Water quality management scenario

The water quality management scenario considered in the analysis were :-

- The release of low salinity water from Vaal Dam to maintain the TDS concentration in the Vaal Barrage at a level which ensures an acceptable water quality in the middle reaches of the Vaal River. This management option is currently being applied with a 600 mg/L TDS concentration target in the Vaal Barrage. Lower target TDS concentrations in the barrage can also be considered. This will require the release of more water from Vaal Dam and will bring the date of the next augmentation scheme forward.

- The treatment of the major discharges from the mines and industries. This involved the conceptual level design and costing of desalination plants to treat the water to a potable standard for re-use in the Rand Water supply network. In developing the conceptual designs accepted reverse osmosis treatment technology was used for the desalination plants.

3.4.4 Source of water for Rand Water

Rand Water can draw water directly from the Vaal Dam or from the Vaal Barrage. One of the scenario considered previously was to blend the water from the barrage with the lower TDS concentration Vaal Dam water to achieve a TDS concentration of 300 mg/L which is considered to be adequate for the Rand Water users in terms of salinity economic impacts. This has implications in terms of the treatment technology used at the Rand Water water treatment plant. Rand Water is currently not drawing water from the barrage as the Rand Water water treatment plant cannot deal with the microbiological and eutrophic conditions of the barrage water. If blending is to be considered as an option then the Rand Water water treatment plant has to be upgraded to deal with these conditions.

4 DESCRIPTION AND EVALUATION OF PLANNING SCENARIOS FOR SALINITY MANAGEMENT

4.1 Description of planning scenarios

Although twenty planning scenarios were formulated for analysis and/or evaluation, only six were analysed with the WRPM. The six scenarios selected for analysis covered a range of possible future conditions and interventions as described in the following sections. The initial 6 scenarios were investigated using the base demand scenario. The best three from the initial assessment were further analysed using the high demand scenario.

4.1.1 Scenario 1a (V07R1ABP): Base and High Demand Scenario and current management practice

The purpose of this scenario was to assess the current management practices within the Vaal River System and included the following assumptions:

- **Urban water requirements and return flows**: The Base and High $_2$ demand and return flow projections were adopted for this planning scenario. This scenario includes the irrigation water requirement scenario curtailing the unlawful irrigation water use.
- **Intervention option**: The recommended Polihali Dam and conveyance infrastructure option was included in the WRPM configuration used for this scenario.
- **Water quality management scenario:** No treatment of mine and industrial effluent discharges was considered. The management option adopted was the dilution by releasing water from Vaal Dam to maintain the Vaal Barrage at a maximum TDS concentration of 600 mg/L.
- **Rand Water's source of supply:** It was assumed that Rand Water is supplied directly from Vaal Dam.

Based on the dilution option mentioned above, it was expected that an increasing trend in the projected storage volumes would occur within Bloemhof Dam. It was assumed that the excess water available in Bloemhof Dam could be used to augment the water supply to the lower Orange River.

The following stepwise approach was adopted for the assessment of the impact of different assumptions of **Scenario 1a:**

- Analyse the Vaal River System by using the WRPM configuration that excludes the Polihali Dam option. The results from this initial analysis would then indicate the date at which the recommended LHFP option would be required.

- Determine the excess water that can be supplied from Bloemhof Dam to the Lower Orange River System.

- Assess the impact on the Vaal River System when incorporating the Polihali Dam option and supplying the Bloemhof Dam's excess water to the lower Orange River.

4.1.2 Scenario 1b (VT07R1B): Alternative dilution option (450 mg/l)

The purpose of this scenario was to assess the impact of maintaining a maximum TDS concentration of 450 mg/l downstream of Vaal Barrage. The other assumptions that were adopted for **Scenario 1b** are identical to that of **Scenario 1a** except that the scenario was only assessed for the base demand scenario. Similar to **Scenario 1a** Bloemhof Dam's excess water supply to the Lower Orange River was also determined for this scenario.

4.1.3 Scenario 1c (VT07R1C): Treatment of mine and industrial discharges

The purpose of **Scenario 1c** was to evaluate the impact of direct re-use of mine and industrial discharges and the subsequent removal of salinity in the relevant catchments. The basic assumptions adopted for **Scenario 1c** are similar to that of **Scenario 1a** with the following exception:

- **TDS treatment scenario:** The treatment of mine and industrial effluent discharges as indicated in **Table 9** was included in the WRPM configuration.

Scenario 1c was assessed for both the base and high demand scenarios.

Table 9: Summary of treated mine and industrial discharges

Description of source	WRPM File name	WRPM Channel No	Catchment	Recipient of treated effluent
Mines in Western Basin	Westm.Q/TDS	890	Klip	Rand Water
Mines in Central Basin	Centm.Q/TDS	848	Klip	Rand Water
Mines in Eastern Basin	Eastm1.Q/TDS	832	Suikerbosrand	Rand Water
Mines in Eastern Basin	Eastm2.Q/TDS	1028	Suikerbosrand	Rand Water
Mines in Far-Western Basin	Fwestm.Q/TDS	850	Upper Riet	Rand Water
Mines in Wonderfonteinspruit	Bosmdw.Q/TDS	786	Mooi	Rand Water
Mines in Middle Vaal	Minew.Q/TDS	167	Middle Vaal	Rand Water
Sasol Secunda	Sasol.Q/TDS-	1357	Waterval	Sasol Secunda Complex
Sasol Sasolburg	-	77	Vaal Barrage	Sasol Sasolburg Complex
Seepage in Waterval catchment	Seepwa.Q/TDS		Waterval	Seepage was set to zero

The mine discharges volumes selected for treatment totaled 100 million m^3/annum in 2007. The possible growth in the mine discharges in the future were not allowed for in the modelling. This is based on the assumption that no further releases of mine water with TDS concentrations in excess of the RWQO for the Vaal River and the local receiving water bodies will be allowed in the future. Sasol at Secunda has already started the process of treating their blow down effluent discharges for re-use. The removal of these discharges from the Waterval catchment was included in the model runs but the costs were not as these are already being incurred by Sasol. The abstraction and industrial effluent of the Sasol Sasolburg Complex is modeled by means of a Demand Centre Module. The resulting treated effluent considered for re-use by Sasol Sasolburg was in the order of 15.1 million m^3/annum in 2007 and increasing to about 21.9 million m^3/annum in 2018 after which it was assumed to remain constant. The Sappi Enstra discharge of 11 million m^3/annum was also treated and assumed to be re-used in the Sappi plant as for Sasol. A TDS concentration 200 mg/l was used for all the treated effluent.

4.1.4 Scenario 1c1 (VT07R1C1): Treatment of selected mine discharges

The purpose of **Scenario 1c1** is to evaluate the impact of the re-use of selected mine discharges. To this end, **Scenario 1c1** was based on **Scenario 1c**, but only the discharges of selected mines were treated for re-use. The mines selected were ERPM located in the central basin and Petrex located in the Eastern Basin. These discharges were selected as they have the highest TDS concentrations and the highest discharge volume. Treatment would therefore result in the greatest removal of load. The WRPM filenames and channels listed in **Table 10** were treated and re-used by Rand Water. This scenario was assessed for the base and the high demand scenarios.

Table 10: Summary of mine discharges selected for partial re-use scenario 1c1

Description of source	WRPM File name	WRPM Channel No	Catchment	Recipient of treated effluent
Mines in Central Basin	Centm.Q/TDS	848	Klip	Rand Water
Mines in Eastern Basin	Eastm1.Q/TDS	832	Suikerbosrand	Rand Water
Mines in Eastern Basin	Eastm2.Q/TDS	1028	Suikerbosrand	Rand Water

The treated mine discharges ranged from 23.8 million m^3/annum in 2007 to about 37.2 million m^3/annum from the year 2014 onwards (i.e. a re-use of almost 69% less compared to **Scenario 1c**). A TDS concentration of 200 mg/l was used for all the treated effluent. The surplus water available in Bloemhof Dam to support the water requirements of the Lower Orange System was also assessed for this scenario

4.1.5 Scenario 3 (VT07R03): Rand Water supplied from Vaal Barrage (Blending Option)

Scenario 3 is an alternative to **Scenario 1a** with the purpose of assessing the impact of supplying Rand Water from the Vaal Barrage and to allow for blending with water from Vaal Dam to maintain a TDS concentration of 300 mg/l. The water management scenario remained dilution to a TDS concentration of 600 mg/L. Sasol and Eskom remain on Vaal Dam (Lethabo weir) water. This scenario was only assessed for the base demand scenario.

This scenario requires that a canal be constructed to convey the dilution water from Vaal Dam to beyond the Rand Water pump stations on the Vaal Barrage otherwise the pumps will draw in the dilution water and it will not be available to dilute the water leaving the Barrage to the required 600 mg/L set as part of this scenario.

4.1.6 Scenario 8a (VT07R08): No water quality management

This scenario was based on **Scenario 3**. In essence, the no water quality management option adopted for **Scenario 8a** incorporated the following changes in terms of the WRPM configuration:

- **Rand Water's source of supply:** It was assumed that Rand Water is supplied from Vaal Barrage and no blending is made with releases from Vaal Dam (i.e. the TDS concentration of the water that was supplied to Rand Water was not controlled). Sasol draws as much water as possible from the Vaal Barrage and Lethabo Power Station stays on Vaal Dam water.

- **Dilution option:** No releases were made from Vaal Dam to maintain a specified TDS concentration downstream of the Vaal Barrage.

Scenario 8a assumptions allow for the maximum utilization of mine and urban discharges in the Vaal Barrage catchment. This scenario requires that Sasol Sasolburg, Sappi Enstra and the Rand Water treatment plant get upgraded to handle the poor quality water drawn from the Vaal Barrage. This scenario was only assessed for the base demand scenario.

4.1.7 Summary of planning scenarios

The planning scenarios are summarised in **Table 11**.

Table 11: Summary of planning scenarios

Planning Scenario No	WRPM Run Reference	Water Use Scenario	Intervention Option Included	Water Quality Scenario	Purpose
1a	V07R1ABP	Base and High	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam)	No TDS treatment Rand Water supplied from Vaal Dam Dilution to 600 mg/l in Vaal Barrage	Assessment of: Current management practices Augmentation from Polihali Dam option Supply of excess water in Bloemhof Dam to ORS
1b	VT07R1B	Base	LHFP (Polihali Dam), Thukela	No TDS treatment Rand Water supplied	Assessment of: alternative dilution

Planning Scenario No	WRPM Run Reference	Water Use Scenario	Intervention Option Included	Water Quality Scenario	Purpose
			(Jana and Mielietuin Dams) Orange (Vioolsdrift Dam)	from Vaal Dam Dilution to 450 mg/l in Vaal Barrage	rule
1c	VT07R1C	Base and High	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam) Re-use of mine and industrial discharges	Treatment of major mine and industrial discharges Rand Water supplied from Vaal Dam Dilution to 450 mg/l in Vaal Barrage	Evaluate impact of direct re-use of water and the removal of salinity.
1c1	VT07R1C1	Base and High	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam) Partial re-use of mine discharges	Treatment of selected mine discharges Rand Water supplied from Vaal Dam Dilution to 450 mg/l in Vaal Barrage	Evaluate direct partial re-use of water and the removal of salinity.
3	VT07R03	Base	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam)	No TDS treatment Rand Water supplied from Vaal Barrage Blend RW supply to 300 mg/l with water from Vaal Dam Dilution to 600 mg/l in Vaal Barrage	Assessment of alternative source of supply for Rand Water (Alternative to Scenario 1a).
8a	VT07R08	Base	LHFP (Polihali Dam), Thukela (Jana and Mielietuin Dams) Orange (Vioolsdrift Dam)	No water quality management Rand Water supplied from Vaal Barrage	Alternative base scenario excluding the EWR.

4.1.8 Infrastructure associated with Scenarios

The capital (Capex) and operating (Opex) costs associated with the infrastructure needed for the scenarios was determined. The costs for the interventions were taken from the feasibility study on the further phases of the Lesotho Highlands Water Project for the Polihali Dam and its associated infrastructure. The costs for the Vioolsdrift Dam augmentation of the Orange River System were taken from the Lower Orange River Management Study (LORMS). The costs were adjusted to 2006 Rands.

The further phases of the Lesotho Highlands Water Project include the Polihali Dam and a delivery tunnel to Katse Dam. The current delivery tunnel from Katse Dam to the Vaal River catchment was originally sized to cater for growth and will only need expansion about 5 years after completion of the

Polihali Dam and the Polihali to Katse Dam delivery tunnel. The capex and opex for the Polihali development is given in **Table 12**.

There are three possible sizes of Vioolsdrift Dam that can be constructed depending on the extent that the water requirements of the lower Orange River need to be augmented. The capex and opex for the three dam sizes are given in **Table 12**.

Table 12: Capex, Opex and implementation periods for intervention schemes

Element	Capex (million Rand)	Opex (million Rand/annum)	Implementation Period (Years)
Polihali Dam (includes Polihali Dam Katse Dam tunnel)	5 118	21.8	7
Upgrade of Delivery Tunnel from Katse Dam to the Vaal River catchment	465	4.65	5
Vioolsdrift Dam (1160 million m^3 capacity)	368	1.99	6
Vioolsdrift Dam (1490 million m^3 capacity)	470	2.54	7
Vioolsdrift Dam (1770 million m^3 capacity)	557	3.00	7
Jana Dam	4 118	259.50	6
Mielietuin Dam	2 545	73.84	6

The cost of the water treatment scenario for the mine and industrial discharges are based on treatment to 200 mg/L TDS concentration. The costs have been developed at the pre-feasibility level and the supply routes to discharge the treated water into the Rand Water reservoirs have not been optimised. The capex for the plants treating the mine water discharges includes sludge and brine disposal facilities for 15 years. The capex for the plants at Sasol Sasolburg and at Sappi Enstra includes the cost of an evaporator crystalliser (EC) to deal with the brine. The salt load from the EC is disposed of off site at the Holfontein waste site. The opex for the desalination plants include a 5 yearly replacement of membranes at 5% of capex, opex of R4.36/m^3 and maintenance of the plant in terms of replacement calculated at 7% of the capex. The opex for the distribution pipelines include electricity costs at R0.17/Kwh at a 90% duty and maintenance at 7% of the capex. The same assumptions were made for all the plants except the distribution system for the Sappi and Sasol plants were not included. The implementation period allows for the feasibility, detailed design, construction and EIA processes needed to implement the plants. The summary of the costs and capacities of the plants are given in **Table 13**.

Table 13: Summary of plant capacity, implementation period as well as the capex and opex

Plant	Capacity (ML/d)	Capex (million Rand)	Opex (Rand/m^3)	Implementation period (years)
Mine discharges	275	3 480	6.78	6
Distribution system for treated mine effluent to Rand Water reservoirs	275	231	0.22	6
Sasol	35 ML/d for SCI and 6.5 ML/d for Midlands plant	457 (desal plant) 109 (Evap Crystalliser) Total 634	9.11 including desal, EC and disposal salt at Holfontein at R1500/tonne	6
Sappi Enstra	30	330 (desal plant) 90 (Evap Crystalliser) Total 420	9.11 including desal, EC and disposal of salt at Holfontein at R1500/tonne	6
Treatment of mine discharges from ERPM and Petrex	105	1 240	6.74	6
Distribution system for treated mine effluent from ERPM and Petrex	105	80	0.21	6

Scenario 3 requires the construction of a canal from Lethabo weir to below the Klip River (Gauteng) confluence with the Vaal River. The canal is required to convey 5 m^3/s and will cost R250 million to construct with an annual maintenance cost of R2.5 million/annum. The canal will take 5 years to implement.

Scenario 8a results in poor water quality having to be used by Sasol Sasolburg and Sappi Enstra. The poor water quality received by Sappi Enstra will be via the Rand Water network. Sasol provided costs to desalinate a side stream of the incoming water to the Sasolburg plant to achieve the baseline or design water quality for the plant. Golder determined costs for the Sappi Enstra plant. The costs for the two desalination plants are listed in **Table 14**.

Table 14: Costs for desalination at Sasol Sasolburg and Sappi Enstra for Scenario 8a

Scheme	Capex (million Rand)	Opex (Rand/m^3)	Implementation time years
Sappi Enstra	429	9.70	5
Sasol Sasolburg	409	9.70	5

Scenarios 3 and 8a require that the Rand Water treatment plant be upgraded to be able to treat Vaal Barrage water. The addition of activated carbon and ultrafiltration technologies to the treatment trains were costed at the conceptual level. The capex is R1 150 million and the opex is R197 million/annum.

4.1.9 Summary of infrastructure included in scenarios

For each scenario an initial run was undertaken to determine the timing of the supply intervention, the volume of water that can be released from Bloemhof Dam to support the water requirements in the lower Orange River and the size of the Vioolsdrift Dam needed to meet the lower Orange River water requirements at the required assurance of supply.

The elements included in the scenarios and the implementation date that it is required are summarised in **Table 15**. The dates given in **Table 15** and the costs described above are used to put together the cash flows for the scenarios over the simulation period. Scenario 1b was dropped from the analysis as the implementation data for Polihali Dam of 2010 cannot be achieved. The earliest Polihali Dam can be constructed by is 2019.

4.2 Determination of NPV for intervention and water treatment scenarios

A spreadsheet model of the cash flow streams for each scenario was developed. The NPV determined for each scenario for the interest rates of 6%, 8%, and 10% are given in **Table 16**. The most expensive scenario is 1c because of the high cost of desalination and disposal of brines and sludges. Scenarios 1c1, 3 and 8a are similar in cost while Scenario 1a has the lowest NPV for all three interest rates. The NPV value for Scenario 1a is significantly lower than the other scenarios as it does not involve expensive desalination treatment and relies on dilution to manage the TDS concentrations.

Table 15: Summary of elements and implementation dates included in the Scenarios

Base Demand Scenario						
Scenario	**Augmentation Scheme**	**Delivery tunnel upgrade**	**Vioolsdrift Dam**	**Dilution canal**	**Additional water from Bloemhof Dam to Orange**	**Treatment options**
1a	Polihali Dam, 2019	2024	Not needed planning horizon	Not required	140 million m^3 by 2014 growing to 300 million m^3 by 2040	none
1b	Polihali Dam 2010	2015	Not needed in planning horizon	Not required	-	none
1c	Polihali Dam 2024	2040	1490 million m^3 needed in 2015	Not required	None	Treatment of major discharges by 2014
1c1	Polihali Dam 2019	2024	Not needed in planning horizon	Not required	140 million m^3 by 2014 growing to 300 million m^3 by 2040	Treatment of ERPM and Petrex discharges by 2014
3	Polihali Dam 2023	2039	1770 million m^3 needed in 2015	2014	None	Upgrade Rand Water works to take Vaal Barrage water by 2014
8a	Polihali Dam 2028	2041	1770 million m^3 needed in 2015	Not required	None	Upgrade Rand Water works by 2014 Sasol Sasolburg and Sappi Enstra require desalination plants by 2014
High Demand Scenario						
Scenario	**Polihali Dam**	**Delivery tunnel upgrade**	**Vioolsdrift Dam**	**Dilution canal**	**Additional water from Bloemhof Dam to Orange**	**Treatment options**
1a	Polihali Dam 2019 Jana Dam 2020 Mielietuin Dam 2021	2024	Not needed planning horizon	Not required	Not calculated	None
1c	Polihali Dam 2019 Jana Dam 2038	2024	1 490 million m^3 Storage needed in 2015	Not required	Not calculated	Treatment of major mining / industrial discharges by 2014
1c1	Polihali Dam 2019 Jana Dam 2034	2024	Not needed planning horizon	Not required	Not calculated	Treatment of selected ERPM and Petrex discharges by 2014

Table 16: Summary of NPV (million Rand) for interventions and treatment cashflow streams

Base Demand Scenario			
Scenario	**Interest Rate**		
	6%	**8%**	**10%**
1a	3 585	2 998	2 536
1c	19 271	14 475	11 468
1c1	8 197	6 424	5 239
3	6 833	5 303	4 275
8a	10 235	7 812	6 266
High Demand Scenario			
Scenario	**Interest Rate**		
	6%	**8%**	**10%**
1a	11 954	9 240	7 433
1c	23 216	17 666	14 251
1c1	10 590	7 913	6 248

4.3 Determination of water quality dis-benefits

The method of calculating the economic dis-benefit due to water quality for the domestic, agriculture, Eskom and Sasol water users is described in the impact modelling report resulting from task 5. The methodology developed in task 5 was applied to the domestic water abstractions by Rand Water, Midvaal Water, Sedibeng Water and Kimberley. The time series of TDS concentrations as modelled in the WRPM supplying the domestic centres were abstracted from the WRPM for the 100 stochastic sequences run. The resulting time series were put through the economic model for domestic use and the NPV for the different interest rates was calculated for the different scenarios.

Similarly for the agriculture, the time series of volumes and TDS concentrations of the abstractions from the middle and lower reaches of the Vaal River to the irrigation blocks were taken from the WRPM results. The time series were run through the economic model to give the dis-benefits for agriculture. No allowance was made in the economic assessment for significant changes in crop types over time. The current crop area distribution was used in the analysis. The crops types and areas are detailed in the economic model report.

The results of the analysis are given in **Table 17**. The agricultural dis-benefit is small compared to the domestic users. The reason for this is that the TDS concentration at which crop yield is impacted for the crops irrigated with water abstracted from the Vaal River is about 600 mg/L. The 95 percentile of the modelled TDS concentrations at the Vaal Harts weir range from 580 mg/L to 750 mg/L (see **Table 19**). The water quality is such that the crop yield is not impacted significantly by the water quality.

The water treatment scenarios 1c and 1c1 resulted in an increase in the dis-benefit costs for Rand Water users when compared to Scenario 1a. The average TDS concentration supplied from the Vaal Dam for Scenario 1a is 110 mg/L. For Scenario 1c and 1c1, treated mine water with a TDS concentration of 200 mg/L is discharged back into the Rand Water supply system resulting in higher TDS concentrations than for Scenario 1a. Hence the higher dis-benefits for Scenario 1c and

1c1 for Rand Water users. However for the downstream users the water quality dis-benefits are less due to the lower TDS concentrations resulting from the treatment and dilution of Vaal Barrage to a maximum TDS concentration of 450 mg/l.

The analysis of the high water demand scenarios was not carried out in full in terms of water quality and in the economic analysis of the water quality dis-benefit costs were assumed to be the same as the base water demand scenario options. This is considered to be a reasonable assumption as the water quality in the middle reaches of the Vaal River is unlikely to change significantly between the base and high water demand scenarios for a particular option as the Vaal Barrage dilution concentration is kept the same for the water demand scenarios.

Table 17: NPV (million Rand) of water quality dis-benefits

Scenario 1a		**Interest Rate**		
		6%	**8%**	**10%**
Domestic	Rand Water	1 317	1 198	1 086
	Sedibeng Water	1 375	1 196	1 056
	Midvaal Water	859	744	652
	Kimberley	467	401	351
Agriculture		69	58	49
	Total	**4 087**	**3 597**	**3 194**
Scenario 1c		**Interest Rate**		
		6%	**8%**	**10%**
Domestic	Rand Water	1 854	1 649	1 486
	Sedibeng Water	953	828	728
	Midvaal Water	610	528	464
	Kimberley	341	296	262
Agriculture		1.7	1.4	1.2
	Total	**3 759**	**3 303**	**2941**
Scenario 1c1		**Interest Rate**		
		6%	**8%**	**10%**
Domestic	Rand Water	1 335	1 198	1 082
	Sedibeng Water	1 003	871	766
	Midvaal Water	648	561	493
	Kimberley	374	326	286
Agriculture		2.9	2.4	2.0
	Total	**3 362**	**2 958**	**2 630**
Scenario 3		**Interest Rate**		
		6%	**8%**	**10%**
Domestic	Rand Water	7 965	6 907	6 065
	Sedibeng Water	1 547	1 355	1 200
	Midvaal Water	813	705	618
	Kimberley	414	353	309
Agriculture		15	13	11
	Total	**10 754**	**9 332**	**8 201**
Scenario 8a		**Interest Rate**		
		6%	**8%**	**10%**
Domestic	Rand Water	11 030	9 138	7 742
	Sedibeng Water	2 150	1 804	1 542
	Midvaal Water	1 085	902	767
	Kimberley	438	369	316
Agriculture		22	17	14
	Total	**14 725**	**12 229**	**10 381**

4.4 Total costs and in-stream TDS concentrations for scenarios

To allow for a comparison of the scenarios, the total NPV associated with each scenario was calculated as the sum of the NPV for the intervention and treatment and the NPV of the water quality dis-benefit. The total NPV for each scenario are given in **Table 18**.

Table 18: Total NPV for Scenarios

Scenario	NPV Interventions and Treatment (million Rand)			NVP Water Quality Dis-benefits (million Rand)			Total Costs (million Rand)		
	6%	8%	10%	6%	8%	10%	6%	8%	10%
1a (Base Demand)	3 585	2 998	2 536	4 087	3 597	3 194	7 627	6 595	5 730
1c (Base Demand)	19 271	14 475	11 468	3 759	3 303	2941	23 030	17 778	14 409
1c1 (Base Demand)	8 197	6 424	5 239	3 362	2 958	2 630	11 559	9 382	7 869
3 (Base Demand)	6 833	5 303	4 275	10 754	9 332	8 201	17 587	14 635	12 476
8a (Base Demand)	10 235	7 812	6 266	14 725	12 229	10 381	24 960	20 041	16 647
1a (High Demand)	11 954	9 240	7 433	4 087	3 597	3 194	16 041	12 837	10 627
1c (High Demand)	23 216	17 666	14 251	3 759	3 303	2 941	26 975	20 969	17 192
1c1 (High Demand)	10 590	7 913	6 248	3 362	2 958	2 630	13 952	10 871	8 878

The results for the base and high water demand scenarios differ. For the base water demand scenario, the total NPV clearly shows that Scenario 1a is the best from a purely economic perspective with Scenario 1c1 the next best. However for the high water demand scenario, Scenario 1c1 has the lowest total NPV. This is due to the implementation of all three augmentation schemes being required over the period 2019 to 2021 so that the high water demand and the dilution water requirements can be met.

The treatment of all mine and industrial effluent discharges to potable standard is expensive and does not result in a sufficient reduction in water quality dis-benefits and delay in the augmentation date for the next scheme to offset the treatment costs.

The overall conclusions based on the economic analysis work are as follows:

- The traditional approach of implementing Vaal River Augmentation Schemes to supply water and address water quality issues is still appropriate and economically attractive.
- The treatment and re-use of selected high concentration discharge streams is an attractive scenario. The economic analysis showed that Scenario 1c1 is economically the most attractive for the high water demand scenario while the total NPV for the base water demand scenario is not significantly more expensive than Scenario 1a.
- The treatment and reclamation of selected high salinity mine waters and industrial effluents are becoming increasingly more attractive. The treatment and reclamation of all the mine and industrial effluent discharges, irrespective of size, and salinity load is not economically defensible.
- Many other water resource management policy and management considerations over and above the economic aspects, drive the implementation of the saline mine/industrial effluent reclamation schemes. Some of these include:
    - best use of local water resources.
    - application of the “polluter pays” principle.
    - reduced reliance on transferred water.
    - use of good quality water to dilute pollution.

Although Scenario 1a is the best from an economic view point for the base demand scenario, the resulting instream TDS concentrations need to be compared to the RWQO set for the Vaal main stem. The 95 percentile TDS concentrations were taken from the WRPM results. The values are listed in **Table 19** together with the current status and the RWQO as set on 12 October 2007. The RWQO at that stage of the study was based on water user requirements. The results of the model runs were not included in the RWQO deliberations at that stage.

The WRPM results show that the RWQO set for the catchments upstream of Grootdraai Dam and Vaal Dam are met except for the reach from Waterval to Vaal Dam where the modelled TDS concentration of 264 mg/L exceeds the RWQO of 200 mg/L. The RWQO is governed by the preliminary determination of the ecological Reserve water quality requirements of 200 mg/L. The main water users in this reach are irrigation and domestic and the RWQO was relaxed to 250 mg/L which meets the TWQR for domestic and irrigation. This RWQO will be taken into the ecological Reserve process for possible re-assessment.

The WRPM model results show that the RWQO set on 12 October 2007 could not be met for any of the scenarios modelled for the reaches from Vaal Barrage to Douglas Barrage. Scenario 1a is the most economic scenario for the base water demand scenario and Scenario 1c1 for the high water demand scenario. However before the Scenarios can be proposed as management strategies, the public health and ecological Reserve should be considered by comparing the in stream TDS concentration to the water user requirements.

The TWQR for domestic use for TDS concentration is <450 mg/L and the acceptable range is from 450 mg/L to 1000 mg/L. The 95 percentile TDS concentration along the middle and lower reaches of the Vaal River falls in the acceptable range for domestic use. The 95 percentile means that 95 percent of the TDS concentrations are lower than the 95 percentile value. The risk to public health can be considered to be low if Scenario 1a or Scenario 1c1 is implemented and the Vaal main stem is managed to meet the 95 percentile concentrations given in **Table 19**.

The ecological Reserve for the Vaal River is currently being determined by the Department. Part of the ecological Reserve determination includes setting the water quality component of the ecological Reserve. The final results from this study were not available at the time of writing this report. However a provisional set of TDS concentrations were provided by applying the Teacha model to the measured TDS concentration data along the Vaal main stem. The results of the application of the model are summarised in **Table 6**. For the middle and lower reaches of the Vaal main stem, the initial assessment of the TDS requirements of the ecological Reserve range from 845 mg/L to 1198 mg/L except for reach 2 from Bloemhof Dam to the Harts River confluence. For this reach Teacha calculated an ecological Reserve requirement of 574 mg/L. The simulated TDS concentrations meet the ecological Reserve requirements at the 95 percentile level except for reach 2. Here the 95 percentile concentration is 752 mg/L as compared to the 574 mg/L suggested by Teacha. Once the specialist input becomes available for the ecological Reserve study the impact of exceeding the 574 mg/L Teacha requirement can be better evaluated. At this stage the preliminary results on the water quality requirements of the ecology indicate that Scenario 1a or Scenario 1c1will meet these requirements.

Table 19: Summary of simulated 95 percentile TDS concentrations (mg/L) in Vaal River for Scenarios

	Scenario							
Reach	**1a**	**1b**	**1c**	**1c1**	**3**	**8a**	**Status**	**RWQO**
Douglas Barrage to Harts	883	828	772	858	958	934	961	600
Bloemhof Dam to Harts (Vaal Harts weir)	752	584	628	642	717	689	601	600
Bloemhof Dam	724	581	601	614	691	677	612	600
Sedibeng off take	763	558	621	623	1154	1444	742	450
Midvaal off take	612	507	482	484	640	833	670	450
Vaal Barrage	657	593	487	488	638	906	647	
Vaal Dam	116	116	116	116	116	116	189	180
Waterval to Vaal Dam	264	264	264	264	264	264	413	200
Grootdraai Dam	174	174	174	174	174	174	200	180

5 EVALUATION OF NUTRIENT MANAGEMENT SCENARIOS

5.1 Introduction

As previously discussed, the nutrient balance is not as well understood as the salinity balance. Without the modelling tools to assess the cause and affect of management scenarios such as improved phosphorus standards for wastewater treatment plant discharges, the assessment of nutrient management scenarios is difficult. Some of the causes of the eutrophic conditions in the Vaal River main stem were identified in the water quality status assessment undertaken as part of Task 2. The causes were poor quality wastewater treatment plant discharges, poorly managed and maintained sewerage systems, agriculture, irrigation return flows and runoff from urban areas. The change in flow regime due to regulation with long periods of low flow was also cited as a cause of algal blooms. Flow manipulation during bloom periods was put forward as a management option. The relative contributions of nutrients from the identified sources is not well known nor is the fate of nutrients once entering the river system as they travel from the source to the Vaal River.

The two aspects relating to the management of nutrients from the wastewater treatment works that must be considered are:-

- If the works are functioning correctly and producing effluent with a quality at a concentration in line with the treatment technology employed. If the works are producing effluent out of specification then the management action is to get the works operating correctly.

- If the treatment technology is adequate ie is a more stringent discharge standard for phosphorus required for the wastewater treatment works than is currently being applied. This would require additional treatment technology being added to the works.

5.2 Analysis of performance of wastewater treatment works

The most readily available nutrient data is on the water quality of the effluent discharges from the wastewater treatment works in the major tributaries entering the Vaal Barrage. The orthophosphate concentration data was analysed and the average, 5 percentile and 95 percentile values were determined for the plants in the Suikerboschrand, Riespruit and Klip River catchments. The results are presented in **Table 20**, **Table 21** and **Table 22**.

The majority of the WTW have biological nutrient removal treatment processes as part of their treatment train. These works can typically achieve a 1 mg/L phosphorus concentration in the effluent. The results show that the average orthophosphate concentration meets the biological nutrient plant removal processes limits on average for the WTW in the Suikerboschrand and Klip River catchments. There are periods as shown by the 95 percentile concentration where the 1 mg/L standard is not achieved. The water quality data available for the works in the Rietspruit catchment was limited and only the range of orthophosphate in the effluent is given in **Table 22**. The range indicates higher orthophosphate concentrations than the 1 mg/L concentration achieved in the other WTW. There have also been management issues associated with the works that are managed by Metsi-a-Lokoa. This has recently been addressed with the appointment of consultant teams to refurbish the works and to upgrade those that are overloaded. The sewerage reticulation system is also been investigated in this area.

Table 20 : Analysis of treated effluent ortho-phosphate concentrations from WTW in the Suikerboschrand catchment

WTW	Average month Volume (million m^3)	PO_4 as P (mg/L)		
		Average	5%	95%
Daveyton	0.53	0.72	0.05	3.2
Jan Smuts	0.27	0.78	0.05	1.4
Benoni	0.30	0.48	0.05	1.9
Rynfield	0.28	0.82	0.05	3.1
JP Marais	0.61	0.68	0.05	3.2
McComb	0.39			
Ancor	0.88	0.44	0.05	1.3
Tsakane	0.34	1.26	0.05	3.8
Grundling	0.08	0.65	0.05	1.93
Welgedacht	0.35	0.94	0.05	2.38
H Bickely	0.24	0.53	0.05	2.77
Ratanda	0.04	0.17	0.05	0.70
Heideberg	0.2			

Table 21: Analysis of treated effluent ortho-phosphate concentrations from WWTW in the Klip River catchment

WTW	Average month Volume (million m^3)	PO_4 as P (mg/L)		
		Average	5%	95%
Bushkoppies	5.53	0.75	0.30	2.46
Olifantsvlei	4.66	0.35	0.09	0.60
Goudkoppies	3.45	0.38	0.05	0.60
Waterval	3.15	0.90	0.20	1.70
Dekema	0.78	0.88	0.20	2.17
Rondebult	0.52	0.62	0.05	1.90
Vlakplaats	2.84	1.01	0.05	2.58

Table 22 : Analysis of treated effluent ortho-phosphate concentrations from WWTW in the Rietspruit River catchment

WTW	Average month Volume (million m^3)	Range PO_4 as P (mg/L)
Sebokeng	1.63	1.8 - 6.8
Leeuwkuil	0.40	0.6 - 7.6
Ennerdale	0.10	0.2 – 0.95
Rietspruit	0.90	1.5 – 4.8

The orthophosphate concentration measured in the three rivers is shown plotted in **Figure 15**. The orthophosphate measured in the Rietspruit has the highest concentration with the Klip and Suikerboschrand Rivers below a concentration of 1 mg/L most of the time. The high orthophosphate concentration in the Rietspruit could be directly attributable to the WTW discharge qualities.

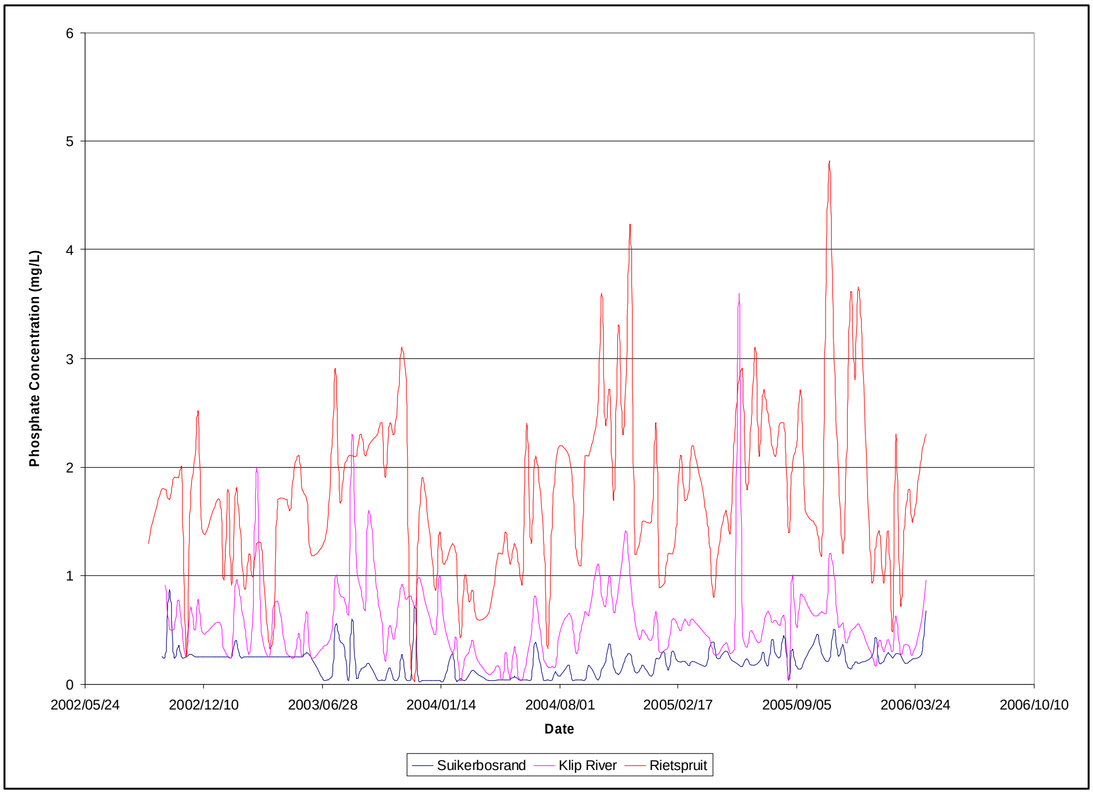

Figure 15 : Plot of orthophosphate concentrations measured in the Suikerboschrand, Rietspruit and Klip Rivers

The RWQO for orthophosphate set for the Vaal Barrage is 0.15 mg/L. The average orthophosphate concentration in the water released from Vaal Dam is 0.04 mg/L which meets the RWQO set for the Vaal Barrage. To achieve the RWQO set for the Vaal Barrage, the orthophosphate concentrations of the major inflow streams need to be significantly reduced. The most likely option for this would be a higher orthophosphate standard on the WTW. This would involve the inclusion of chemical phosphorus removal at the plants. An initial capital cost estimate of R350 million to implement the additional technology at the major WTW to reduce the orthophosphate concentration in the effluent to 0.3 mg/L. There is also the possibility of implementing a program of phasing in the use of phosphorus free soaps and detergents. These actions involve substantial investment and the effects of the investment on the orthophosphate concentration reaching the Vaal Barrage and the downstream impact cannot readily be determined until the nutrient balance is better understood.

5.3 Proposed nutrient management strategy

The proposed strategy for nutrient management is divided into the short and medium term actions. The results of the short term actions will largely dictate the medium term plans. The short term will cover the period up until 2010 and includes the following actions:-

- Flow manipulation which will generally occur in September when the potential for algal blooms is highest. A proposed release pattern to implement is :-
    - Base flow 15 m3/s – 28 days - 36.3 million m^3
    - 100 m^3/s for 48 hours – 17.3 million m^3
    - Total of 53.6 million m^3/a
- Through monitoring better understand the nutrient balance. This will include instream nutrient monitoring as well as at source monitoring.
- Audit the WTW and the sewerage systems of the local municipalities. The planned expansions of the WTW and the sewerage systems as presented in the water service development plans should also be reviewed.
- A study implemented to determine the impact of phosphorus free detergents and soaps on the influent and effluent qualities of the major WTW.
- A study to determine the feasibility of implementing additional phosphorus removal treatment at the WTW.

The medium term strategy will involve:-

- Nutrient reduction programs either through additional treatment at the WTW or the introduction of phosphorus free soaps and detergents or both.
- Modifications to the flow manipulation strategy based on lessons learnt from the implementation during the short term strategy period.

6 RECOMMENDATIONS AND CONCLUSIONS

The following conclusions can be made from the management scenario task -

- The economic analysis and comparison of simulated in-stream TDS concentrations shows that the dilution scenario 1a is the favoured water quality management scenario for implementation to manage the TDS concentration.

- The TDS management scenario was based on minimum growth of mine and industrial discharges. If increases in discharge volume or changes in water quality are predicted then the impact on the dilution rule will have to be assessed. Any further increases in TDS load to the system could impact on the public health and ecological Reserve aspects of the water quality as well as the timing of the next augmentation scheme. This will affect the economic valuation.

- The water users in the middle and lower reaches of the Vaal River are incurring dis-benefits due to poor water quality. A waste discharge charge should be imposed on the discharges in the upper Vaal WMA to compensate for the dis-benefits of the downstream users.

- The RWQO set as part of this study will have to be revised once the more detailed ecological Reserve information becomes available. The initial assessments provided by the water quality project team for the ecological Reserve has not raised any red flags.

- The flow manipulation as a nutrient management option in the short term should be assessed in practice to get an indication of its efficacy.

- The water quality input to the WRPM for the Grootdraai Dam catchment is represented as a seepage flow file in the WRPM. There are significant changes happening in the catchment with defunct mines filling, re-commissioning of the Camden Power Station and further mining planned. These planned activities are not included in the WRPM. The WRPM should be updated to include the mines as a mine module in the WRPM.

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