PILOTING THE IMPLEMENTATION OF THE WASTE DISCHARGE CHARGE SYSTEM IN THE CROCODILE (EAST) CATCHMENT

Final Report

to the Water Research Commission

by

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EXECUTIVE SUMMARY

Background

A properly implemented and maintained water resource management system, such as is catered for in the National Water Act (NWA) (1998) (Act 36 of 1998) should encourage desirable activities from waste dischargers, namely abatement of pollution at source, recycling of waste streams and wastewater, reuse of water, water conservation and return of good quality water to resources so that Resource Quality Objectives (RQOs) are achieved, and only in the event when this has not been done and there is still excess load in the system, should Waste Discharge Charge System (WDCS) mitigation charge come into play.

The WDCS is aimed at promoting waste reduction and water conservation in support of an integrated approach to managing the resource quality problems within specific catchments (reduction at source or in the resource). The Polluter Pays Principle is a well-recognized and globally celebrated environmental law principle, and the overall objective of the WDCS is to address the problem of water pollution. In attaining this objective, several other objectives would be achieved, including efficient resource utilisation (incentive objective), cost recovery for activities related to pollution abatement and damage reparations (financial objective), discouragement of excessive pollution (deterrent objective), and promotion of sustainable water use (social objective). The WDCS mitigation charge is therefore proposed as an economic incentive mechanism where the primary impact is associated with the cumulative impacts from several dischargers in a catchment, rather than localised impacts from a single discharger.

Initially, the WDCS was developed to be implemented as two distinct water use charges, either or both of which may be applied in a specific catchment, *i.e.*,

- **Waste Mitigation Charge,** which covers the charging for discharge of water containing waste into a water resource or onto land, *i.e.*, charges to cover the quantifiable costs of administratively implemented measures for the mitigation of waste discharge-related impacts, and
- **Waste Discharge Levy, also referred to as the incentive charge**, charges that provide a disincentive or deterrent to the discharge of waste, based on the use of the resource as a means of disposing of waste.

According to the NWA (Section 1 (1)(iv)), a charge includes a fee, price, or tariff imposed under the Act. It is not a tax, levy or duty (Section 57 (5)). It is therefore a direct payment for a service, namely, to use the assimilative capacity of the water resource, as well as cost recovery of expenses incurred by another party, such as water resource management costs, losses incurred through abstracting water of poor quality, and costs of downstream infrastructure to deal with the waste.

In terms of the updated revised version of the National Draft Pricing Strategy for Raw Water Use Charges (Version 3: 2023), the Waste Discharge Levy has been excluded as the NWA does not currently make provision for a tax or levy. Thus, only the waste mitigation charge of the WDCS is to be implemented.

The WDCS mitigation charge is differentiated from the Water Resource Management Charge (WRMC) for waste, also now included in the National Pricing Strategy, which is a payment for the day-to-day management of water quality and the authorisation of waste discharge activities. The WRMC is based on the volume of waste discharge and is applied on a Water Management Area (WMA) basis. Whereas the WDCS mitigation charge aims to finance strategic interventions to address specific targeted water quality interventions in threatened areas on a localised catchment basis.

The differential rates for waste discharges may be set depending on the geographical area, characteristics and amount of waste discharged, and the nature and extent of the impact on a water resource and its users (Section

56(5) of the Act). The determination of the waste mitigation charge must account for the water resource class and resource quality, *i.e.*, the RQOs of the water resource in question. The approach to the mitigation charge development requires that the various sub-catchments warrant their own charge rate due to the nature of the water uses and identified impacts (water quality threat posed).

About the project

The key objective of this project was to pilot the implementation of the *mitigation charge component* of the WDCS in the Crocodile (East) catchment based on the waste related water uses (Section 21 (e), (f) (g) and (h)), captured on the water use authorisation and registration management system (WARMS) and determination of the waste discharge charge rates.

The project piloting exercise was framed by the following key fundamentals:

- The mitigation charge is catchment-based for a targeted pollutant.
- The premise for the mitigation charge is that the RQO is exceeded or threatened. The most downstream RQO is adopted (at the outlet). For catchments with no RQOs, the water quality planning limits (WQPLs) determined are to be used as a surrogate.
- The excess load in the system, causing the water quality threat, cannot be removed or improved by compliance and enforcement.
- The contribution per user is based on the load added to the catchment – discharge/disposal higher than intake water (change in load). This is the basis for the charge apportionment.
- For non-point sources, a desktop estimation of load entering the resource will need to be made or the non-point source (NPS) calculator will need to be applied; however, it is noted that the load calculators used in the WARMS system were developed for the incentive charge and not the mitigation charge, and are linked to a point source
- All Section 21 (e), (f) (g) and (h) uses are registered on the WARMS database (verified and validated) and duly authorised by a water use authorisation.
- Adequate and reliable flow and water quality monitoring databases are available for the water resources in the catchment area.
- All water users are equitably and fairly ‘captured’ by the WDCS.

Project methodology and outcomes

The objective of this project was to pilot the WDCS mitigation charge in the Crocodile River (East) catchment from its source up to the confluence with the Komati River (the X2 secondary catchment). The piloting exercise comprised two phases: Phase 1 focused on the determination of the mitigation charge rates that included a situational assessment of the Crocodile (East) catchment to identify key water users and water quality threats in the catchment, and the state of water use authorisations related to the NWA (Act 36 of 1998) Section 21 (e), (f), (g) and (h) water uses; the determination of load for sub-catchment areas for the identified variables of concern and assessment of compliance to the gazetted RQOs; the determination and assessment of mitigation options that would best remove the excess load; and the undertaking of a costing analysis of the proposed options to determine the waste mitigation charge rate per targeted constituent per catchment. Phase 2 focused on the business case, addressing funding models and the implementation. Stakeholder components were limited to an introductory awareness session of the system and the proposed project, as well as workshops with the Inkomati-Usuthu Catchment Management Agency (IUCMA) officials and various directorates within the Department of Water and Sanitation (DWS).

The outcome of the project has indicated that the WDCS mitigation charge methodology is sound; however, its implementation within the current water resources management environment in the IUCMA and throughout the country does not support it in the short to medium term.

Based on the analysis and outcomes of this project, the following conclusions and recommendations are made:

Premise	***National considerations/ recommendations***
The premise for the implementation of a mitigation option and charge is that all water users are compliant with their water use authorisation conditions. This is a fundamental prerequisite to system implementation. **The system is based on the removal of excess load** above the RQO, which implies that all users are compliant, and the excess load removal will remain constant over a period for which a mitigation can be implemented and costed accurately. The compliance and enforcement function of the regulator is a key enabling component. At present, this function is ineffective and not achieving compliance by the enforcement of water use discharge/disposal conditions.	Assess the Compliance and Enforcement (C&E) functions and responsibilities and look at how this can be better managed; extend resourcing and capacity at the catchment level; improve regulation and legal effectiveness of source management. Only once compliance is achieved in a catchment should the WDCS mitigation charge be considered.
The water quality parameters included as part of the WDCS methodology (DWS, 2021), which fed into the pricing strategy, are not all applicable for the load determination approach of the WDCS mitigation charge. Examples are Electrical Conductivity (EC) and Chemical Oxygen Demand (COD), which do not lend themselves to load calculations.	Reassess the suite of water quality parameters to be applied as part of the strategy. A proposal would be to specify Total Dissolved Salts (TDS) and nitrate and orthophosphate, as overall national parameters, as they are good indicators of the salinity and nutrient status of water resources, and then situational water quality assessments must be conducted to identify the main water quality constituents of concern in areas where the WDCS mitigation charge is to be applied. This would make the mitigation options more relevant and address the local issue at hand.
The Water Use Authorisation and Registration Management System (WARMS) is the registration system for the water use and water user information; it is also the administration and billing system for the mitigation charge, and cannot be open to inaccuracies, inconsistencies and maladministration. Many uses are unverified, and the data on registered users and uses are outdated (specifically S21(e), (f), (g) and (h)). It also seems that once data is added, it cannot easily be amended. The system at this point is only linked to the water quality parameters and discharge volumes of water users (single use load), thus a load is determined for the point discharge i.e., the section 21 (e), (f) and (h) water uses, and in some cases using the in-built non-point source calculator for the Section 21 (g) water uses. This relates to the incentive charge that has now been removed from the WDCS. The system is unable to calculate catchment water resource loads to identify RQO	Validation and verification of all water uses (section 21 of the NWA), must be completed for all WMAs and fed into an update of the WARMS to ensure accuracy. An update to the WARMS system with an interface that links registered users to a catchment load model and the SAP billing system is required. The development and maintenance of a water resources catchment load model will be required for implementation.

exceedances and apportion back to the water users. A linkage from a catchment load model that will have apportioned excess load back to the users and to the billing system (SAP) is not available to charge the mitigation charge.	
The WDCS mitigation charge does not include non-point sources such as run-off/return flows from irrigated lands, and stormwater from urban and industrial areas.	These uses, such as run-off from irrigated lands, and stormwater from urban and industrial areas, need to be brought into the suite of waste-related uses/users if the system is to be considered fair and equitable, and the apportionment of load is to be accurate.
Premise	***Water Management Area Considerations/Recommendations***
Monitoring is the central enabler to the successful implementation of the WDCS and for the water quality situational assessment. Implementation of the WDCS requires a well-structured, operated and managed surface water and groundwater monitoring network that extends into tributary catchments. This also requires a data management system linked to WARMs. This information must be defensible against any contestations. It's the basis for the load assessment to identify the excess load, for the quantification of the load, for the assessment of the mitigation options and for apportionment of the load. The monitoring programme and database system must be sound, with little opportunity for errors, and account for upstream and downstream water quality compliance data from users.	Assess the extent, applicability and efficacy of the current monitoring systems across all WMAs and update accordingly. Consider possible options that would allow external water users to upload their compliance data.
The water quality component of the RQOs, as the basis for the WDCS, is technically sound. The RQO determination process is gazetted, and a step-by-step process is followed underpinned by considerable stakeholder engagement. The water quality component of the RQOs should highlight those areas where water quality is a concern, and which parameters are the main constituents of concern. This process is almost complete for all the WMAs in South Africa, and with the amendments to the NWA (Act No. 36, 1998), there will be opportunities to amend the RQOs, if necessary. There are, however, several WMAs where the RQOs have been set on a very broad scale, with few RQOs gazetted, which will make it difficult to only apply the water quality component of the RQOs for effective assessment of load in a sub-catchment. In addition, the RQOs set is not always set for the WDCS	Reassess RQOs distribution and water quality stringency within a catchment, and extend where necessary, especially for water quality priority hotspot areas.

parameters specified as part of the system, and in some cases, appear very lenient (or possibly incorrect) to maintain or protect the water resource class that has been set.	
The use of Water Quality Planning Limits (WQPLs) is a way in which the lack of water quality RQOs in a catchment can be filled; however, these would need to be determined through the development of an Integrated Water Quality Management Plan (IWQMP) for the WMA, which falls under the ambit of the Water Resource Management Charge (WRMC). The limits are also not gazetted and would need to be incorporated into the Catchment Management Strategy (CMS) that is gazetted for a WMA, after adequate stakeholder consultation.	Each WMA must have an IWQMP as part of the CMS that should specify WQPLs, at a finer scale as opposed to RQOs, which are most often at a coarser scale. The WQPLs determined should undergo stakeholder consultation. This will address the concerns of tributary catchments.
To be a defensible, equitable, and fair system, all water use authorisations must be valid, verified and issued for all water uses in the catchment, with appropriate conditions. These conditions should include, amongst other aspects, water quality limit values for a discharge as well as best practice aspects. The current situation indicates that many users are not authorised, or the authorisation conditions are not aligned to meet the assimilative capacity of the resource. The availability of a usable catchment load model and correct configuration to support load analysis, load balance and distribution is necessary for accurate and effective implementation of the mitigation charge. It is required to apportion the load transparently and consistently.	The CMA must develop and maintain a catchment load balance for each constituent of concern per sub-catchment, and once this is done, the water use authorisation limits or practices may need to be amended once assimilative capacity and the load balance is understood. Assess available models; an operational load balance model per WMA/ sub-catchment would be a very useful tool to allow a continuous assessment and understand where the hotspots are, which could then be easily dealt with.
A set of legal, institutional and governance arrangements will need to be implemented to ensure full and accurate and effective implementation of the mitigation charge, such as the funding models for the mitigation options that would require significant controls and measures to secure the investment and associated returns.	The CMA should have the necessary institutional and governance arrangements to secure investments and show credibility.
Stakeholder and water user buy-in is key to successful implementation and to ensure voluntary payment for the mitigation charge, should it be implemented.	Establish and maintain good relationships with all water users in the catchment and with robust ongoing stakeholder engagement to get buy-in.

Achievement of the Terms of Reference

Overall, the project objectives were achieved. The removal of the incentive charge component from the National Pricing Strategy (DWS, 2023) meant that those aspects related to that charge, including an assessment of the non-point calculator in the WARMS system, were not assessed. The following tasks were completed:

- Assessment of all waste-related water uses on the WARMS and a catchment assessment, *viz*:
    - Situational assessment of the Crocodile (East) catchment to understand and determine the water quality problems present and the key users in the catchment.
    - Assessment and identification of water quality threats and exceedances of RQOs.
- Identification of all authorised and registered users specifically related to the Section 21(e), (f), (g) and (h) water uses and to ensure all waste-related water uses were captured on the WARMS. However, there were shortcomings noted in respect of the incomplete water use registrations and limited number of water use authorisations on the system. This is related to the lack of institutional alignment between DWS and IUCMA, pre- and post-CMA establishment.
- Determination of the waste discharge rates:
    - Determination of the load discharge for sub-catchment areas for the identified variables of concern, assessment of compliance with the RQOs and identification of the mitigation options required. There were also several shortcomings related to the following:
        - Transfer of functions and information from DWS to the CMA, specifically related to water use regulation functions;
        - RQO inadequacies;
        - Water user data inadequacies;
        - Catchment-related shortcomings, such as flow and, to a lesser extent, water quality data
        - Land use gaps, specifically for irrigation with raw water, and
        - Limited information on the accounting services
- Assessment of options and costing analysis of selected pollution abatement/mitigation options and determination of the Waste Mitigation Charge Rates.
- Stakeholder Consultation included:
    - A 2-day internal workshop with the IUCMA (3rd and 4th of May 2023),
    - Presentation at the Crocodile Catchment Management Forum (CMF) on 11 August 2023,
    - A DWS, WRC and IUCMA workshop on the 25th of August 2024, and
    - It was agreed that, because of the limitations and uncertainties identified in the WDCS mitigation charge implementation, additional broader stakeholder participation was not warranted at this point.
- Development of funding model options for WDCS mitigation charge implementation in the Crocodile (East) catchment.
- Development of policy briefs on:
    - WDCS Strategy, and
    - National Non-point Source Strategy based on the outcomes of the piloting exercise, which has not been completed.

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ACRONYMS AND ABBREVIATIONS

DWS	Department of Water and Sanitation
CMA	Catchment Management Agency
CMS	Catchment Management Strategy
DCF	Discounted Cash Flow Analysis
EBITDA	Earnings Before Interest, Tax, Depreciation and Amortisation
GVA	Gross Value Added
IRR	Investment Rate of Return
IUCMA	Inkomati-Usuthu Catchment Management Agency
IWQMP	Integrated Water Quality Management Plan
NWA	National Water Act
O&M	Operation and Maintenance
PPP	Public-Private Partnership
RQOs	Resource Quality Objectives
URV	Unit Reference Value
WARMS	Water Use Authorisation and Registration Management System
WDCS	Waste Discharge Charge System
WfW	Working for Wetlands
WMA	Water Management Area
WMS	Water Management System
WQPLs	Water Quality Planning Limits
WRMC	Water Resource Management Charge
WSA	Water Services Authority
WWTW	Wastewater Treatment Works

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GLOSSARY

Ecological Infrastructure: Ecological infrastructure refers to naturally functioning ecosystems that deliver valuable services to people, such as fresh water, climate regulation, soil formation and disaster risk reduction. It is the nature-based equivalent of built or hard infrastructure and is just as important for providing services and underpinning socio-economic development. Ecological infrastructure includes, for instance, healthy mountain catchments, rivers, wetlands, coastal dunes, and nodes and corridors of natural habitat, which together form a network of interconnected structural elements in the landscape.

Discounted Cash Flow Model: a valuation method used to estimate the value of an investment based on its expected future cash flows.

Downstream users: water users downstream of any activity that may impact the water resource.

Investment Rate of Return: the annual rate of return that an investment or project achieves. The IRR can be compared to the cost of capital to determine whether an investment is desirable.

Non-point source (diffuse source): a source of pollution that emanates from widely distributed or pervasive environmental elements, such as run-off from irrigated agriculture, or seepage from a Tailings Storage Facility

Point source: a localised, and most often, stationary source of pollution, such as discharge from a municipal wastewater treatment works.

Public Private Partnership (PPP): a long-term cooperative agreement between a private company and the national or local government

Resource Quality Objectives (RQO): the means to ensure a desired level of protection. The purpose of RQOs is to provide limits or boundaries for biological, physical and chemical attributes which should be met in the receiving water resource in order to ensure protection (serves as a management goal). For the purposes of the WDCS, the water quality RQO applies.

Waste Discharge Charge System: a “polluter pays” system established in accordance with Section 56 (5) of the National Water Act (NWA) under the Pricing Strategy. The Waste Discharge Charge System aims to collect revenue to finance mitigation interventions and strategies.

Waste Mitigation Charge: Charges to cover the quantifiable costs of administratively implemented measures for the mitigation of waste discharge-related impacts on a catchment scale. The mitigation charge aims to finance strategic interventions to address specific targeted pollutants in threatened areas.

Waste Discharge Levy: Charges that provide a disincentive or deterrent to the discharge of waste, based on the use of the resource as a means of disposing waste (currently not included in the WDCS)

Water Quality Planning Limits. Water quality numerical limits which are set at a finer scale within the catchment, and these may be specific for pollutants expected within a catchment, which will enable the RQOs to be met at the downstream points.

Water Resource Development Charge: for funding water resource development and the use of waterworks.

Water Resources Management Charge: for funding the water resource management activities related to the protection, allocation, conservation, management, and control of all the nation’s water resources (payment for the day-to-day management of water quality). It comprises two components: the abstraction water use charge, and the waste discharge-related water use charge.

CHAPTER 1: BACKGROUND

1. INTRODUCTION

The Waste Discharge Charge System (WDCS) provides an economic instrument to support the management of water quality in the country. It was established in terms of Section 56 (1) of the National Water Act (NWA), 1998, (Act 36 of 1998) in respect of the Section 21 waste-related water uses. It is a component of the Department of Water and Sanitation's (DWS) Raw Water Pricing Strategy and is to be implemented on a catchment basis as part of a water resources management planning process that includes regulatory, economic and other instruments. The WDCS is aimed at promoting waste reduction and water conservation. By so doing, the waste discharge charge is one element of an integrated approach to managing the resource quality problems within specific catchments.

The Pricing Strategy for Water Use Charges, recently revised as part of a Water Research Commission (WRC) project C2021-2022001042 (WRC, 2022), provides a framework for implementing the charge system for water use. The Pricing Strategy for raw water use addresses the following two charges allowed for in the NWA:

- The ***Water Resource Development Charge*** for funding of water resource development and use of waterworks.

- The ***Water Resource Management Charge (WRMC)*** for funding of water resource management activities in each of the Water Management Areas (WMA). These activities relate to the protection, allocation, conservation, management and control of all of the nation's water resources. There are two components to WRMC:
  1. Abstraction water use charge, and
  2. Waste discharge related water use charge that relates to the following Section 21 water uses of the NWA (Act No. 36 of 1998):
     - 21(e) Engaging in a controlled activity (where the controlled activity relates to waste discharge activities), and in this case relates to Section 37(1) (a) irrigation of any land with waste or water containing waste generated through any industrial activity or by a waterwork
     - 21(f) Discharging waste or water containing waste into a water resource
     - 21(g) Disposing of waste in a manner that may detrimentally impact a water resource
     - 21(h) Disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process
     - 21(c) Altering the bed, banks, course or characteristics of a watercourse where such activities have impacts on the water quality of the water course, and
     - 21(i) altering the bed, banks. course or characteristics of a watercourse

The WRMC is aimed at providing financial support to eleven (11) identified water resource management functions or activities (WRC, 2022), summarised below and for which the waste discharge-related activities are highlighted:

1. Catchment management strategy and water resources planning
   a. Resource studies, investigations and integrated strategy development
   b. Water quality management plan
2. Resource Directed Measures (RDM)
   a. Implement programmes to monitor Resource Quality Objectives (RQOs)
   b. Implement source-directed controls to achieve RQOs
   c. Report against the achievement of the Class and RQOs

   d. Report on the water balance per catchment (*i.e.* water available for allocation after consideration of ecological requirements)
3. Water use authorisation
   a. Registration of water use
   b. Waste discharge activities authorisation
4. Control and Enforcement (C&E) of water use
   a. Control monitoring and enforcement of water use (compliance)
   b. Waste discharge control
5. Disaster Management
   a. Pollution incident planning and response (management)
6. Water resources management programmes
   a. Integrated water resources programmes
   b. Implementing water management strategies (e.g., cleaner technology, dense settlements, waste discharge strategies)
7. Water-related institutional development (Stakeholder management empowerment)
   a. Stakeholder participation, empowerment, institutional development & coordination of activities
   b. Establishment and regulation of water management institutions
   c. Stakeholder consultations
   d. Capacity and empowerment of stakeholders
8. Water weed control
   a. Aquatic weeds control
9. Maintenance and restoration of ecosystems to improve water resources
   a. Planning and implementation of ecosystem maintenance and rehabilitation programs required for water resource protection, e.g., sediment control, nutrient trapping, riparian rehabilitation
   b. Control of invasive alien plants with acknowledged negative impacts on water resources, e.g., riparian zones, mountain catchment areas, wetlands and in areas where there could be an impact on aquifers
10. Geohydrology and hydrology
   a. Groundwater and surface water monitoring
   b. Compilation of maps and yield information
   c. Extension and maintenance of the hydrological database and compilation of information
11. Administration and overheads
   a. Administrative, institutional and overheads for the regional office or Catchment Management Agency (CMA)

These charges focus mainly on water use in terms of volumes abstracted or discharged (volume only) and not on the impact caused by the associated discharge or the waste conveyed in the discharge. The WDCS is meant to address the waste discharge quality charge by introducing financial and economic instruments, designed to internalise costs associated with waste and to encourage the reduction in waste and the minimisation of detrimental impacts on water resources. The Pricing Strategy, as part of the charge system for water use, includes the WDCS, which will be implemented through the ***Waste Mitigation Charge.***

The implementation of the WDCS is aimed at achieving:

- Promotion of the sustainable development and efficient use of water resources
- The internalisation of environmental costs by impactors
- Recovery of costs for managing water quality, and
- Creation of financial incentives for dischargers to reduce waste and use water resources in an optimal manner.

The WDCS is an instrument that will be used to support existing water quality management initiatives and legislative requirements.

The development of the WDCS over the past two decades has involved a 4-phased approach:

- Phase 1: Formulation of a Framework Document
- Phase 2: Development of a draft WDCS strategy
- Phase 3: Establishment of the final strategy and implementable system, and
- Phase 4: Implementation of WDCS in pilot areas.

Phases 1, 2 and 3 have been completed. However, due to challenges experienced by the DWS in implementation aspects, the WDCS was still to be piloted within a catchment. Part of Phase 4 has been finalised through WRC Project C2021-2022-01042 with respect to the testing of assumptions and principles and the mitigation charge formula. The final component of Phase 4 focused on the piloting of the WDCS in identified catchments to ensure the approach and calculation methodology are clear, robust and sound before full-scale implementation can proceed nationally.

With the IUCMA having an established Catchment Management Strategy (CMS), and the implementation of the WDCS a key objective of its Financial Strategy (Chapter 10, CMS, 2010), the expectation was that the piloting exercise would support the development of the mitigation charges, business models and systems for the WDCS to be implemented to address resource quality initiatives in the WMA and fund generation to address the annual costs related to water resource management (such as pollution abatement). The IUCMA also conducts regular monitoring of the water resources within the WMA, which provides a sound basis for piloting the charge calculation.

The IUCMA is the responsible water resource management authority within the jurisdiction of the Inkomati-Usuthu Water Management Area (WMA), amongst others, including the coordination of water use activities, development of the CMS, investigation and provision of advice on protection, use, development, conservation, management and control of water resources and promotion of stakeholder participation and involvement in water resource management.

With the water resources in several catchments in South Africa currently classified and associated RQOs having been set according to a gazetted process, a legally sound framework now exists to pilot the WDCS, i.e., the waste mitigation charge. It was noted that the IUCMA, one of two established CMAs in the country, was ideally suited to pilot the WDCS, having the necessary institutional management and water resources management activities in place.

This project was therefore commissioned by the Water Research Commission (WRC) in March 2022 and focused on the testing of the implementation of the WDCS within the catchment and in respect of its Section 21 water uses. This system has been in development for over a decade, and implementation is critical to realising success and improvement in the quality of the country's water resources.

2. PROJECT OBJECTIVES AND ACHIEVEMENTS

The objective of this project was to pilot the implementation of the WDCS through the capture of all waste-related water uses that were registered on the water use authorisation and registration management system (WARMS) and the determination of the waste discharge rates related to the water quality issues in the catchment. Table 1 outlines the tasks that were undertaken to meet the project objectives and highlights the core elements of the WDCS methodology addressed as part of the process. The study area comprised the Crocodile (East) River catchment of the Inkomati-Usuthu WMA from its source up to the confluence with the Komati River (the X2 secondary catchment).

Table 1-1: Project Tasks of the Piloting Exercise

Task	Core Element of Piloting	Note/ Limitations
Assess all waste-related water uses on the water use authorisation and registration management system (WARMS) (and catchment assessment)	Situational assessment of the Crocodile (East) catchment to understand and determine the water quality problems present and the key users in the catchment. Assessment and identification of water quality threats and exceedances.	Completed as Deliverable 2
	Identification of all authorised and registered users specifically related to the Section 21 water uses and to ensure all waste-related water uses are captured on the WARMS.	Included in Deliverable 2, however, there were shortcomings noted in respect of the incomplete water use registrations and the limited number of water use authorisations on the system. The central location (database) of all water use licences (WULs) was also a challenge.
Determination of the waste discharge rates	Determination of the load discharge for sub-catchment areas for the identified variables of concern, assessment of compliance to the RQOs and identification of the mitigation options required.	Completed as Deliverable 3. There were also several shortcomings related to the following: • Transfer of regulatory functions and information from DWS to CMA. • RQO inadequacies. • Water user data inadequacies. • Catchment-related shortcomings, such as flow and, to a lesser extent, water quality data. • Land use gaps, specifically for irrigation with raw water. • Limited information around the IUCMA accounting system.
	Options and costing analysis of pollution abatement/mitigation options and determination of the Waste Mitigation Charge Rates.	Completed in Deliverables 4 and 5
	Stakeholder Consultation	The following stakeholder consultants took place: • 2-day internal workshop with the IUCMA (3rd and 4th of May 2023). • Presentation at the Crocodile Catchment Management Forum (CMF) on 11 August 2023. • DWS, WRC and IUCMA workshop on the 25th of August 2024. • It was agreed that, because of the limitations and uncertainties identified, additional broader stakeholder participation was not

Task	Core Element of Piloting	Note/ Limitations
		warranted at this stage, as many aspects of the system were still not clarified or supported.
Pilot the implementation of the WDCS in the Crocodile (East) catchment	Development of the business model for WDCS implementation in the Crocodile (East) catchment.	Included as Deliverables 4 and 5
	Development of policy briefs on the WDCS Strategy and National Non-point Source Strategy based on the outcomes of the piloting exercise.	Included as part of Deliverable 6

These elements comprised the building blocks of the WDCS mitigation options and associated charges. Once the charge rate was developed, it was then fundamental to define and assess the business case to implement the system. This is considered equally important to the success of the WDCS mitigation charge and its intended objective to improve water quality at a catchment level. The business case component of the piloting exercise focused on the proposed funding models for the mitigation options, implementation aspects and the prerequisites for an operational framework for the WDCS. The business case analysis was aimed at assessing whether the mitigation charge rate is accurate, affordable, acceptable and whether the WDCS makes economic sense to be implemented.

While stakeholder engagement and consultation are imperative to the process and a key success factor to the implementation of the WDCS mitigation charge within a catchment, and was a task of the project, it was determined through the piloting exercise that the outcomes were not at a level to withstand broader stakeholder scrutiny, as there are many loopholes and uncertainties that still exist. It also requires that the IUCMA is fully functional and adequately resourced in its water resource management activities before engaging stakeholders on the WDCS. This is something that will need to be thoroughly undertaken at every stage when implementing the WDCS. An information awareness session of the proposed process and the introduction of the WDCS was, however, undertaken during the project, as well as an internal workshop with the IUCMA personnel and a workshop with WRC, DWS and IUCMA.

The project has achieved the objective of piloting the system in the Crocodile East Catchment. While the project outcome proved that the methodology is sound, the practical application and feasibility of the WDCS implementation is premature in terms of water resource management in South Africa. The systems and functions of the IUCMA and DWS are still not optimally functional or in place. It will also require a sound legal framework and supporting regulations to be developed for the system to be fair, equitable and just for all users.

This report presents the outcome of the project and provides recommendations for the implementation actions required.

CHAPTER 2: STUDY AREA

The Inkomati-Usuthu WMA is in the eastern part of the country and falls within the Mpumalanga Province. It borders Mozambique in the east and eSwatini in the south-east. The WMA includes four secondary catchment areas: the Sabie-Sand, Crocodile (East), Komati and Usuthu. The Crocodile (East) catchment of the Inkomati-Usuthu WMA is the focus of the pilot exercise (Figure 2-1).

The Crocodile (East) River catchment forms part of the larger Inkomati basin, which is shared by Mozambique, South Africa and Swaziland. The Crocodile (East) River, originating near the town of Dullstroom, flows eastwards through Mbombela, confluencing with the Komati River at the Lebombo Border gate below Komatipoort as it enters Mozambique. The major tributaries of the Crocodile (East) River are the Elands and Kaap Rivers in the upper Crocodile and the Nels and White Rivers in the middle catchment. The flow of the Crocodile River is regulated by the Kwena Dam in the upper catchment. Other smaller dams in the catchment include the Ngodwana Dam on the tributary of the Elands River, Witklip Dam at the confluence of the Kruisfonteinspruit and Sand rivers, and Klipkoppie, Longmere and Primkop dams on the Wit River. The upper Crocodile River catchment has intensive afforestation and agriculture of sub-tropical fruits, sugarcane and nuts. Mbombela is the largest urban centre in the catchment area and within the Inkomati-Usuthu WMA. Scattered rural villages with a high population density are characteristic of the area. An important aspect is the international commitment to Mozambique that must be met in the lower catchment.

Important urban centres are Mbombela, White River, Barberton and Kanyamazane with associated wastewater treatment works (WWTW). The catchment is dominated largely by agricultural use, with extensive irrigation and domestic demands, and is under stress from a water supply point of view, and while the water quality in the catchment is generally good, there are some hotspots, and salinisation of water resources and microbiological pollution due to untreated or partially treated sewage is a growing concern.

There are at least sixteen municipal WWTWs in the study area, located in the Emakhazeni Local Municipality within the Nkangala District Municipality, and the Thaba Chweu, Mbombela/ Umjindi, and Nkomazi Local Municipalities in the Ehlanzeni District Council. The 2021/2022 Green Drop scores indicate major areas of concern at many of the WWTWs. These WWTWs will need to be upgraded and/ or maintained to optimise their use to achieve the effluent quality specified by the type of treatment option in place. The main parameters of concern will be organics, nutrients, ammonium and faecal coliforms.

The major mining activity occurs within the Barberton and Mbombela areas, in the Kaap River catchment, where increased salinity is noticed. The mineral deposits in this region include gold, asbestos, iron, nickel, copper and manganese and a significant number of coal reserves. Gold and other minerals were widely mined but have been reduced to mainly small-scale operations, although there are three significant gold mines in the Kaap catchment with tailings facilities, a retreatment facility and pollution control dams which are contributing to increased salinity and metals concentrations.

The Sappi Ngodwana Mill is in Quaternary Catchments X21 J and K, potentially contributing to increased salinity**.** There are extensive areas of irrigation (an estimated 433 km2) and afforestation (an estimated 1 927 km2) in the Crocodile (East) catchment, with the highest concentration of irrigation taking place in quaternary catchments X22C, H and J and X24D and H (WRC, 2022).

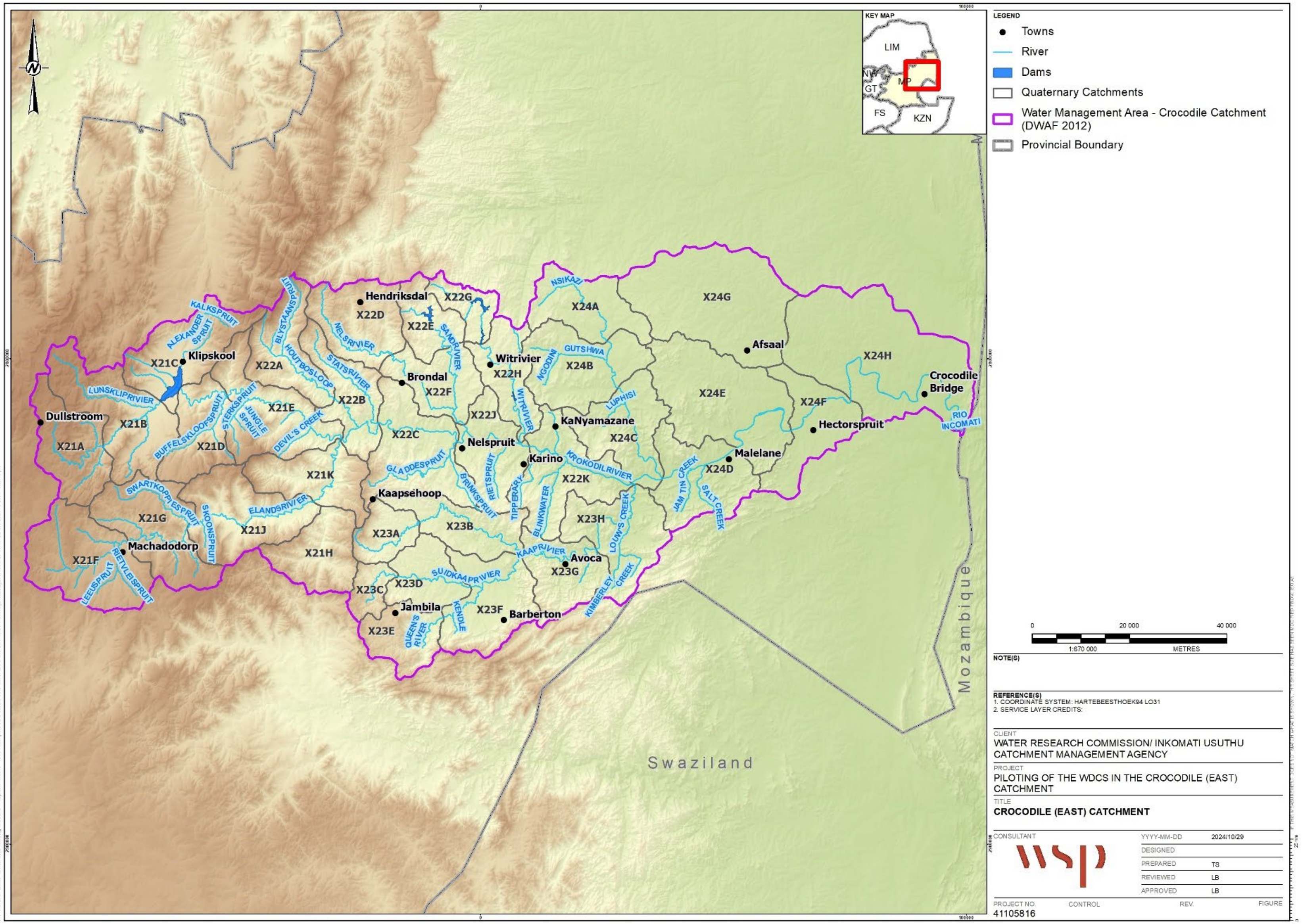

Figure 2-1: Crocodile (East) Catchment Area

CHAPTER 3: PHILOSOPHY AND OBJECTIVES

3.1 INTRODUCTION

The WDCS is a “polluter pays” system established in accordance with Section 56 (5) of the National Water Act (NWA) under the Pricing Strategy. The WDCS aims to collect revenue to finance mitigation interventions and strategies.

The Pricing Strategy may set charges on water use that may provide for a differential rate for waste dischargers, considering:

- The characteristics of the waste discharged;
- The amount and quality of the waste discharged; the nature and extent of the impact on a water resource caused by the waste discharged;
- The extent of permitted deviation from the prescribed waste standards or management practices; and
- The required extent and nature of monitoring of the water use.

The WDCS, as an economic incentive mechanism, is therefore the most appropriate for water quality problems for which the primary impact is associated with the cumulative impacts from a number of dischargers in a catchment, rather than localised impacts from a single discharger. In terms of the revised Pricing Strategy for Raw Water (2022), the WDCS is to be implemented as two distinct water use charges, either or both of which may be applied in a specific catchment:

- Charges to cover the quantifiable costs of administratively implemented measures for the mitigation of waste discharge-related impacts *(*i.e., the Waste Mitigation Charge, which covers the charging for the discharge of water containing waste into a water resource or onto land).

- Charges that provide a disincentive or deterrent to the discharge of waste, based on the use of the resource as a means of disposing of waste (i.e., Waste Discharge Levy).

According to the NWA (Section 1 (1)(iv)), a charge includes a fee, price, or tariff imposed under the Act. It is not a tax, levy or duty (Section 57 (5)). It is therefore a direct payment for a service, namely, to use the assimilative capacity of the water resource, as well as cost recovery of expenses incurred by another party, such as water resource management costs, losses incurred through abstracting water of poor quality, and costs of downstream infrastructure to deal with the waste.

The WDCS and its charges should be differentiated from the Water Resource Management Charge (WRMC), which is a payment for the day-to-day management of water quality, such as penalties for pollution incidents and the authorisation of waste discharge activities. Whereas the WDCS aims to finance strategic interventions to address specific targets in threatened areas.

The differential rates for waste discharges may be set depending on the geographical area, characteristics and amount of waste discharged, and the nature and extent of the impact on a water resource and its users (Section 56(5) of the Act). The latter should take cognisance of the class and resource quality of the water resource in question. The benefit of a specific water use and the economic circumstances, as well as the monitoring requirements associated with the waste discharge, should also be considered. It was envisaged at the project outset that the various sub-catchments with the Crocodile (East) pilot area would warrant their own charge rate due to the nature of the water uses, associated impacts and threats.

In setting water use charges, incentives, and disincentives to promote the efficient and beneficial use of water, to reduce the detrimental impacts on water resources and to prevent the waste of water (Section 56(6) of the Act) may be introduced. A properly implemented and managed WDCS would encourage desirable activities from waste dischargers, namely abatement of pollution at source, recycling of waste streams and wastewater, re-use of water, water conservation and return of water to source.

The WDCS is to be managed at two levels. At the national level, the DWS is responsible for the system *viz*. policy, strategy and regulation formulation, and management system. The Catchment Management Agencies (CMAs) will be responsible for setting, collecting and disbursing Waste Mitigation charges in terms of the catchment/WMA WDCS business plan developed in consultation with stakeholders.

3.1.1 Principles of the Waste Discharge Charge System

The following principles apply to the implementation of the Waste Mitigation Charge in terms of the WDCS.

- The WDCS will be applied at a catchment scale (for all catchments – threatened or not). The catchment area will be defined as those areas that have a significant impact on water quality or are impacted by the specific problem.
- Resource Quality Objectives (RQOs) (water quality) are the basis for the calculation of the mitigation charge.
- The WDCS will be based on the load discharged. This approach (1) avoids dilution of effluent to achieve cost reduction, (2) is more equitable, as it does not disproportionately penalise small dischargers with relatively higher effluent concentrations and (3) it is simple to implement.
- A constant charge rate will be applied to the waste discharge load and will not vary with concentration.
- The WDCS applies to both surface and groundwater resources, where water quality planning limits (WQPLs) may be defined for the resource. A single approach applies to the calculation of the WDCS in both surface and groundwater.
- Only registered waste discharge-related water use in terms of Sections 21 (e), (f), (g), and (h) of the NWA will be liable for waste mitigation charges. This is applicable to point and non-point sources.
- For non-point (diffuse) sources (NPS) associated with Section 21 (e), (g), and (h) the charge will be calculated as per point sources – based on the load discharged to the water resource. A desktop estimation of loads entering the resource will need to be made where adequate monitoring data is not available.
- For point sources, these are easily measurable, and charges will be based on the monitored loads discharged.
- Government will be responsible for the costs associated with load that cannot be charged to registered water users.
- The water quality load or concentration associated with water supplied to the discharger must be deducted from the load of water quality constituents that are discharged to get an accurate assessment of the contribution of the discharge to the water quality load, and then the calculation of the waste discharge charge.
- The WDCS may be applied to all discharges contributing to the load in an upstream catchment where downstream resource quality objectives are threatened or exceeded, even where incremental upstream resource quality objectives are met.
- The mitigation measures and thus the associated waste discharge charges may be phased in to enable planning by dischargers and to allow adaptive setting of charges as conditions change.
- Minimum load thresholds for charging may be specified based on administrative cost considerations. The charges below the threshold will be waived and are intended to cater for small dischargers that may, for example, be generally authorised. These users are not excluded but are charged a zero charge in the system.
- Water uses registered under Section 21 (i) of the NWA are also allocated a zero charge under the current WDCS, as this water use activity is rarely associated with significant contamination of the water resource.
- NPS that are not registered in terms of Section 21 water use under the NWA are currently not included.

3.2 THE SYSTEM

The WDCS mitigation charge is to be applied at a catchment level, not necessarily at a WMA scale. The catchment area is to be defined as those areas that have a significant impact on or are impacted by the specific water quality problem. This may therefore be an entire catchment in which a widespread water quality problem exists or may be a sub-catchment within a larger basin, which is bounded by reservoirs and/or sub-catchments with insignificant contaminant loading. The WDCS may be implemented in catchments for which RQOs are either exceeded or threatened. In the absence of a class and associated RQOs, Water Quality Planning Limits (WQPLs) (previously referred to as Resource Water Quality Objectives) will need to be determined through the development of an Integrated Water Quality Management Plan (IWQMP) for the WMA, which falls under the ambit of the CMA. WQPLs are also not gazetted and would need to be incorporated into the Catchment Management Strategy (CMS) that is gazetted for a WMA, after adequate stakeholder consultation.

Application of the Waste Mitigation Charge is based on the identification and assessment of feasible mitigation measures to reduce the catchment load or its impacts. Mitigation measures need to be evaluated in terms of their unit cost of mitigation and only those measures with lower unit cost of mitigation than the cost of treating the same load at source should be considered (the other measures represent economically inefficient options). For feasible mitigation measures, the capital and operating costs of the mitigation measure must be calculated. The total load discharged into the resource must be estimated and the unit Waste Mitigation Charge rate per load discharged may be calculated. All point source discharge is included, and both registered and non-registered non-point source contributions must be estimated.

The mitigation cost is then distributed to the registered waste discharges according to the charge rate and individual discharge loads (discharge concentration multiplied by volume of discharge).

The WDCS may include, but not be restricted to, any of the following water quality variables:

- Nutrients: phosphate, nitrate and ammonium
- Salinity: Total Dissolved Solids/ Electrical Conductivity, chloride, sodium and sulphate
- Heavy Metals: arsenic, cadmium, chromium, copper, mercury, lead, nickel and zinc
- Organic material: Chemical Oxygen Demand.

Water quality indicator variables are selected based on a systemic water quality problem and its cumulative impact, identified in terms of exceedance of the RQOs or WQPLs and a catchment assessment. Isolated localised impacts, with limited cumulative impact, may be addressed through other regulatory tools. The selection and definition of a particular indicator water quality variable will consider the type of waste discharge sources in the catchment, the nature of the waste typically discharged, and the cost-effectiveness of monitoring different variables.

Marginal abatement cost is to be determined, which is an economic concept that measures the cost of reducing all water quality indicators to the required concentrations according to the RQOs. Distinctions should be made between different pollutants or groups of pollutants according to their toxicity and potential impact. The cost must be developed for the different options for the selection of the most optimal scenarios that will result in an improvement in in-stream water quality through pollution abatement. The costs associated with mitigating the impact will include capital costs, operation and maintenance (O&M) costs, and administrative costs. As a result, there will be a fixed charge (*i.e.*, to cover overheads) and a variable charge. The impact of the costs of the waste mitigation charge on the registered water users will go through a benefit analysis. This analysis will give an indication of the feasibility (*i.e.*, from the polluter's point of view and the benefits of having sustainable ecological infrastructure) of implementing the charge.

The WDCS is applied in order manage those residual aspects of pollution that remain even when all water users are authorised (Schedule I, Existing Lawful Use, General Authorisation or Water Use Licenses) and compliant with the relevant conditions associated with each of the authorisations, and where there is still an impact and/ or threat of excess load to the sustainability of the water resource. What needs to be assessed is:

1. Which activities are contributing to the excess load? All point sources are included, and both registered and non-registered non-point source contributions are to be estimated.
2. What is the cost to reduce that load (unit cost of mitigation and only those measures with lower unit cost of mitigation than the cost of treating the same load at source should be considered. Capital and operating costs of the mitigation measure are to be calculated), and
3. The distribution to the upstream registered waste discharges according to the charge rate and individual discharge loads (discharge concentration multiplied by volume of discharge). Abstraction and discharge concentrations of the variable is applied in the calculation. A dilution effect of a discharger will not attract a charge.

3.3 IMPLEMENTATION FRAMEWORK FOR PILOTING

The inception phase included clarification of concepts and the WDCS fundamentals, as well as the confirmation of the methodology to be applied in this piloting exercise. Consultation with the Reference Group members, engagement with the IUCMA and a meeting with the DWS: Directorate Resource Protection and Waste, as the WDCS champions, was also undertaken to confirm the approach. The following key aspects were confirmed during the inception phase that have had a bearing on this piloting exercise (DWS, 2021):

- The WRMC has been activated as part of the Pricing Strategy for waste-related activities, i.e., all users who engage in Section 21 (e), (f), (g) and (h) water uses. The WRMC is not based on load but on discharge volume. Hydropower users will not be liable for this charge. Differential charges may be levied within a WMA based on defined geographical areas or pertaining to specific water use categories. The WRMC is part of the funding charges for funding water resource management, which includes abstraction and discharge (only related to volume). It is still unclear if the WRMC will be capped, as it is done for abstraction and storage users. It is also important that there is no double accounting in terms of the mitigation charges.
- At this point in time, the waste discharge levy (charges that provide a disincentive or deterrent to the discharge of waste) as the second water use charge of the WDCS, has been excluded in the Pricing Strategy. Its implementation has been delayed until such time as there is the promulgation of the Money Bill that makes provision of the imposition of a tax, levy or duty. This does present a challenge in terms of the compliance and enforcement component to support mitigation charge implementation.
- The mitigation charge is to be implemented in three ways: when the water user exceeds the waste discharge standards; when the RQOs of the WMA (and catchments) are exceeded, and to address short and long-term pollution incidents in the WMA.
- For non-point (diffuse) sources, a desktop estimation of loads entering the resource will need to be made where adequate monitoring data is not available using the non-point source (NPS) calculator developed by the DWS.
- Water quality constituents in terms of the DWS 2021 implementation methodology are to include electrical conductivity, ortho-phosphate and chemical oxygen demand. However, for the purposes of this piloting project,

these were extended to include the constituents of concern identified in the Crocodile (East) catchment for which load data could be calculated, specifically nutrients and salinity.

CHAPTER 4: SETTING THE SCENE

The objective of this project was to pilot the WDCS in the Crocodile River (East) catchment from its source up to the confluence with the Komati River (the X2 secondary catchment). As the incentive charge component had been removed, this project therefore focused only on the mitigation charge. The piloting exercise comprised two phases. Phase 1 focused on the determination of the mitigation charge rates and the analyses and components leading up to this, and Phase 2 focused on the business case, addressing funding models and the implementation. Stakeholder components were limited to an introductory awareness session of the system and the proposed project.

The development of the mitigation charge rate included a situation assessment, load assessment and mitigation options assessment and the charge development, described in the sections to follow.

4.1 SITUATION ASSESSMENT

- A situation assessment of the Crocodile (East) catchment rivers to understand the water quality problems, identify the key water quality concerns, collate and assess water quality and flow data, assess the land uses, consider the economic profile and present the key users in the catchment.
- Collation and analysis of the water quality RQOs for the Crocodile (East) catchment rivers.
- The identification all authorised and registered users specifically related to the Section 21 water uses as captured on the WARMS and supplemented by water use authorisations that could be sourced from the IUCMA.

4.1.1 Land-use activities

Table 4-1 summarises the major land use activities per quaternary catchment, highlighting the type and capacity of the WWTWs and the 2021/2022 Green Drop Scores. The table includes the estimated areas under irrigation and the afforested areas from WR2012, also illustrated in Figure 4-2.

Table 4-1: Crocodile (East) quaternary catchments, main rivers and activities

Quaternary Catchment	Major river per quaternary catchment	Major activities identified	Wastewater Treatment Works				Irrigation Area (km²)[1]	Afforestation (km²)[2]
			Type of WWTW	Design Capacity (ML/d)	Discharges to	*GD score		
X21A	Crocodile River	• Town of Dullstroom with Dullstroom WWTW, however, the WWTW discharges to the Laersdriftspruit, which drains to the Steelpoort River (B41B) • Trout Dams					0.00	4.50
X21B	Crocodile River/ Lunsklip River/ Wilgekraalspruit	• Extensive agricultural activities • Recreational activities					4.18	19.70
X21C	Elandspruit/ Badfonteinloop/ Alexanderspruit	• Kwena Dam • Extensive agricultural activities • Forestry • Trout Farm					4.76	32.39
X21D	Crocodile River/ Buffelskloofspruit	• Forestry • Agricultural activities					3.46	39.87
X21E	Buffelskloofspruit/ Crocodile River	• Forestry					10.94	96.50
X21F	Elands River/ Leeuspruit/ Dawsonspruit	• Agriculture • eNtokozweni Town • eMthonjeni WWTW (WUL 24009877) • ARM Machadodorp Works (metal processing)	Activated sludge, mechanical aeration, aerobic digestion, ponds, sacrificial land disposal of sludge (do not appear to be formal drying beds)	1.5	Leeuspruit	45%	0.00	13.30
X21G	Elands River/ Swartkoppiespruit/ Joubertspruit/ Weltevredespruit	• Waterval Boven Town • Emgwenya WWTW (WUL: 05/X21G/FG/1421) • Agriculture • Forestry	Activated sludge, mechanical aeration, sacrificial land disposal of sludge (do not appear to be formal drying beds)	3	Elands River	48%	0.00	67.40
X21H	Ngodwana River	• Forestry					0.15	76.80
X21J	Elands River	• Forestry • Sappi Ngodwana Mill • Nature Reserve					14.96	108.20
X21K	Elands River/ Lupelule River	• Forestry • Sappi Ngodwana Mill • Agriculture • Nature Reserve					0.09	128.40

Quaternary Catchment	Major river per quaternary catchment	Major activities identified	Wastewater Treatment Works				Irrigation Area (km^2)[1]	Afforestation (km^2)[2]
			Type of WWTW	Design Capacity (ML/d)	Discharges to	*GD score		
X22A	Blystraanspruit/ Beestekraalspruit/ Houtbosloop	• Extensive forestry • Agriculture					0.10	155.70
X22B	Houtbosloop/ Crocodile River	• Extensive agriculture • Forestry					4.78	88.80
X22C	Crocodile River/ Gladdespruit/ Visspruit	• Extensive agriculture • Mbombela residential area (southwest of Mbombela Stadium) along an unnamed tributary					60.41	77.20
X22D	Nels River	• Extensive forestry • Extensive agriculture					0.00	238.20
X22E	Sand River/ Kruisfonteinspruit	• Extensive agriculture • Extensive forestry • Witklip Dam					0.00	110.40
X22F	Sand River/ Nels River	• Extensive agriculture • Extensive forestry • Rocky's Drift residential and industrial areas, White River • Rocky's Drift WTWW (WUL: 24009442)	Activated sludge, sludge drying beds	1.5	Sand River	52%	16.80	64.70
X22G	Wit River	• Klipkoppie Dam • Longmere Dam • Extensive agriculture • Forestry					0.00	90.60
X22H	Wit River	• White River Town • White River WWTW (WUL: 24089442) • Extensive agriculture	Activated Sludge, drying beds	6	White River	52%	41.09	65.50
X22J	Crocodile River	• Mbombela Town • Kingstonvale WWTW (WUL: 24010017) • Mbombela Industrial area • Extensive agriculture	Biofilters; Activated sludge; Anaerobic digestion, biofilters, anaerobic digestion, sludge drying beds	26	Crocodile River	84%	33.20	0.50
X22K	Blinkwater/ Mbuzulwane/ Crocodile River	• Kamyamazane residential areas • Kanyamazane WWTW (WUL: 24088363) • Entokozweni residential areas • Nsikazi WWTW (no data) • Nature Reserve	Activated sludge, sludge drying beds, maturation ponds	12	Crocodile River	84%	17.44	0.00

Quaternary Catchment	Major river per quaternary catchment	Major activities identified	Wastewater Treatment Works				Irrigation Area (km^2)[1]	Afforestation (km^2)[2]
			Type of WWTW	Design Capacity (ML/d)	Discharges to	*GD score		
X23A	Noordkaap River	• Extensive agriculture • Extensive forestry					1.30	95.20
X23B	Noordkaap River	• Extensive agriculture • Nature Reserve • Mine					11.66	35.00
X23C	Suidkaap River	• Extensive forestry					0.00	71.90
X23D	Suidkaap River	• Extensive agriculture • Extensive forestry • Glenthorpe Sawmill					7.91	87.00
X23E	Queen's River	• Extensive forestry • Nature Reserve					0.61	122.10
X23F	Queen's River/ Suidkaap River	• Sassenheim residential area • Barberton Town • Barberton WWTW (WUL: 24080806) • Dense informal residential areas • Extensive forestry • Extensive agriculture • Nature Reserve • Fairview Mine • Barberton Mines Tailings' retreatment facility	Activated sludge, Sacrificial land disposal of sludge	8	Tributary of the Suidkaap River	42%	11.10	15.50
X23G	Kaap River	• Sheba Mine • Natural areas					10.06	0.00
X23H	Kaap River	• Extensive agriculture • Nature Reserve					15.49	16.20
X24A	Nsikazi River	• Extensive villages • Kruger National Park					0.00	0
X24B	Gutshwa River/ Ngodini River/ Nsikazi River	• Extensive villages • Kabokweni WWTW • Subsistence agriculture • Kruger National Park	Activated sludge, sludge drying beds	3.6	Tributary of the Gutshwa which drains to Nsikazi River	48%	0.64	5.90
X24C	Luphisi River/ Nsikazi River/ Crocodile River	• Extensive villages • Matsulu WWTW (WUL: 24088372) • Subsistence agriculture • Mthethomusha Game Reserve • Kruger National Park	Activated sludge, sludge drying beds	6	Crocodile River	86%	10.08	0

Quaternary Catchment	Major river per quaternary catchment	Major activities identified	Wastewater Treatment Works				Irrigation Area (km²)[1]	Afforestation (km²)[2]
			Type of WWTW	Design Capacity (ML/d)	Discharges to	*GD score		
X24D	Crocodile River/ Salt Creek/ Jamtin Creek	• Kruger National Park • Extensive agriculture • Nature Reserve					53.70	0
X24E	Crocodile River	• Kruger National Park • Agriculture • Malelene VIlage and industrial area • Mhlatikop WWTW (GA) • Mhltiplaas/ Malelene WWTW (GA) • Nature Reserve	Activated sludge, Biological Nutrient Removal, anaerobic digestion; and Aerated lagoons/ oxidation ponds	1 and 0.75	Crocodile River	67% and 78%	20.78	0
X24F	Crocodile River	• Kruger National Park • Hectorspruit Village • Hectorspruit WWTW (GA) • Agriculture • Private Game Reserve	Aerated lagoons/ oxidation ponds	0.4	Crocodile River	75%	16.81	0
X24G	Mbyamiti River	• Kruger National Park					0.00	0
X24H	Crocodile River	• Kruger National Park • Komatipoort Village Crocodile River • Komatipoort WWTW (GA) • Agriculture	Aerated lagoons/ oxidation ponds	1.25	Crocodile River	78%	60.82	0

**2021/2022 Green Drop Score; 1 and 2 relate to WR2012 data*

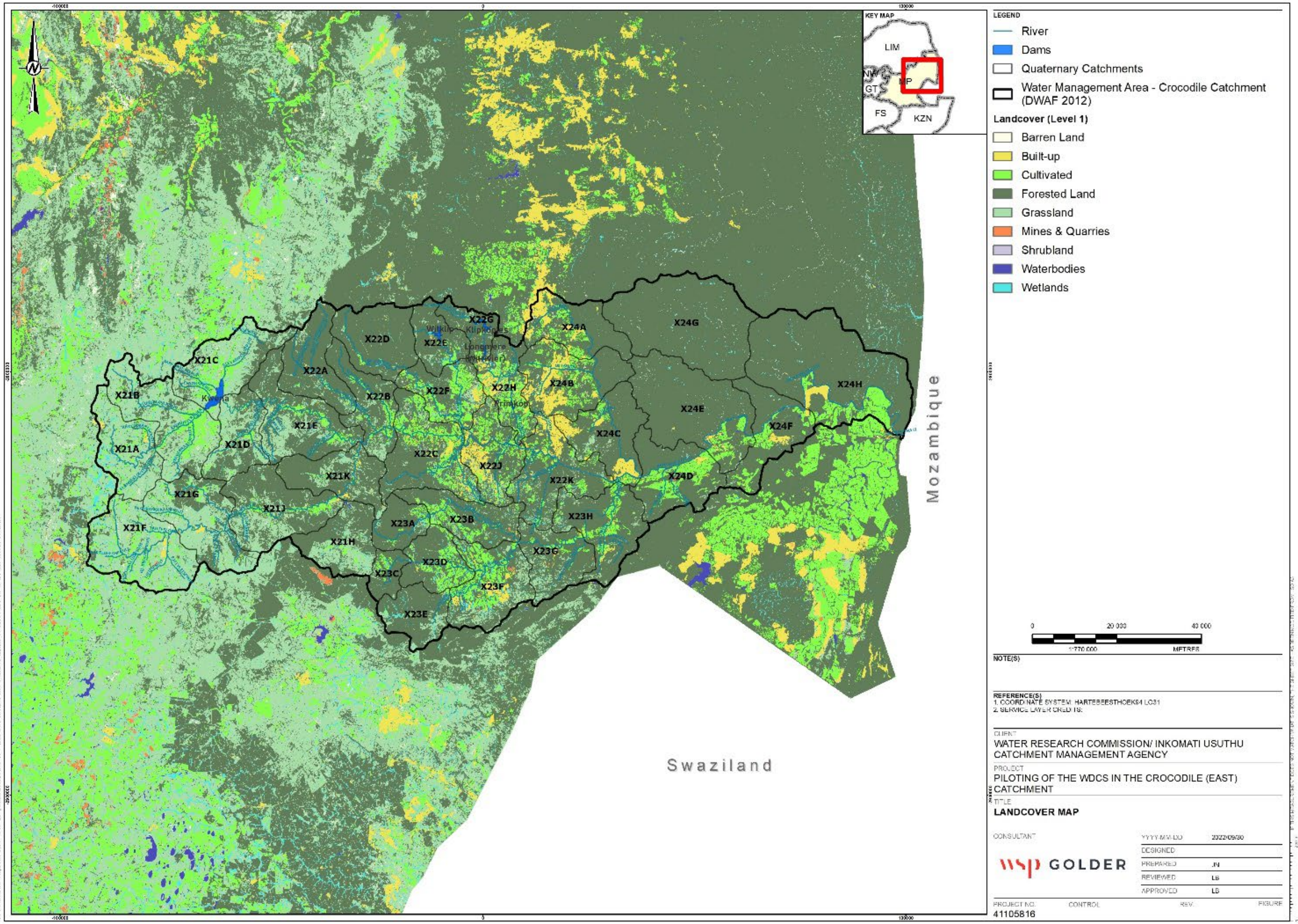

Figure 4-1: Land use for the study area

4.1.2 Resource Quality Objectives (RQO)

In line with the Resource Directed Measures (RDM) described in Chapter 3 of the NWA (Act No. 36 of 1998), water resource classes and RQOs have been set, and the preliminary Reserve has been determined and gazetted under:

- National Water Act (36/1998): Classes of Water Resources and Resource Quality Objectives for the Catchments of the Inkomati – Government Gazette Vol. 618, No. 40531, Notice 1616, 30 December 2016.

The RQOs determined and the applicable resource units that they relate to were compiled for each sub-catchment area within the Crocodile (East) catchment. It was noted that while RQOs were determined for 15 of the 31 resource units, only 13 of the 31 resource units were prioritised and gazetted. The water resources classes and RQOs for the 15 resource units are summarised in Appendix A.

4.1.3 Water Use Authorisation and Registration Management System (WARMS)

A key component of the WDCS piloting process is to understand the extent of water use in the Crocodile (East) catchment. Only registered waste discharge-related water use, in terms of Sections 21 (e), (f), (g), and (h) of the NWA, is liable for waste mitigation charges. This is applicable to point and non-point sources.

Data collection of all the registered water users available related to the Section 21 (e), (f), (g) and (h) water uses was undertaken for the Crocodile (East) catchment. The relevant Section 21 water uses of the NWA relevant to the application of the WDCS included:

- Section 21 (e) engaging in a controlled activity identified as such in section 37 (1) or declared under section 38 (1):
    - In terms of Section 37 (1), the following are controlled activities:
        (a) Irrigation of any land with waste or water containing waste generated through any industrial activity or by a waterwork;

    Section 38 (1) (b) and (c) would not be applicable to WDCS as these activities are not related to a waste or wastewater and are not associated with a waste load.

- Section 21 (f) discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;

- Section 21 (g) disposing of waste in a manner which may detrimentally impact a water resource; and

- Section 21 (h) disposing of water which contains waste from, or which has been heated in any industrial or power generation process.

Over the period of this study only ten (10) point source water uses, Section 21(f) were registered, and the other registered water uses related to non-point sources: eleven (11) Section 21 (e) irrigation with water containing waste and twenty (20) Section 21(g) water uses were registered, and no Section 21(h) water uses. This may have subsequently changed, as there was a registration drive to get water users to register. At the time, it was also noted that several of the registered water uses need to be verified and the validity of their authorisations needs to be confirmed.

Twenty-seven (27) water use licences were received, however only 10 of the 27 related to section 21(e), (f) and (g) water uses. There were no Section 21 (h) water uses.

4.1.4 Water quality and flow

The IUCMA has an extensive monitoring network that was assessed and used for the assessment of water quality and flow to inform the load assessments that were subsequently undertaken. The water quality data were statistically analysed (5, 50 and 95 percentiles determined) and trends were determined. The parameters assessed included those commonly monitored:

- Calcium (Ca)
- Chloride (Cl)
- Total Dissolved Solids (TDS)
- Electrical Conductivity (EC)
- Fluoride (F)
- Potassium (K)
- Total Kjedahl Nitrogen (TKN)
- Magnesium (Mg)
- Sodium (Na)
- Ammonium as N (NH_4)
- Nitrate/ nitrite as N (NO_3/ NO_2)
- Total Phosphate (TP)
- pH
- Orthophosphate as P (O-PO_4)
- Silica (Si)
- Sulphate (SO_4)
- Total Alkalinity (TAL)

The water quality and flow sites made available to the team and the parameters of concern identified per quaternary catchment in the Crocodile (East) catchment are listed in Table 4-2. The water quality statistics are included in Appendix B.

Table 4-2: Weirs and water quality sites and parameters of concern identified

Rivers	Water Quality site - WMS ID	Weir ID	Quaternary catchment	Description	Parameters of concern	
					Exceeds RQO	Increasing trends*
Main Stem Crocodile River	X21_102994	X2H070	X21D	Crocodile River at Kwena Dam downstream of the Dam Wall	Orthophosphate	Nitrate, ammonia
	X21_102958	X2H013	X21E	Crocodile River at Montrose	Orthophosphate	Electrical Conductivity
	X22_102953	X2H006	X22J	Crocodile River at Karino	Orthophosphate	Electrical Conductivity - chloride, sulphate and sodium
	X22 102975	X2H032	X22K	Crocodile River at Weltevrede	Orthophosphate	Electrical Conductivity, nitrate
	X24 102986	X2H046	X24E	Crocodile River at Riverside/ Kruger National Park	Orthophosphate	Electrical Conductivity, nitrate
	X24 102963	X2H016	X24H	At Ten Bosch Kruger National Park on Crocodile River	Orthophosphate; Electrical Conductivity	Nitrate, chloride, sodium, sulphate
	X24 102979	X2H036	X24H outlet to Mozambique	At Komatipoort Kruger National Park on Komati River	Orthophosphate; Electrical Conductivity	Nitrate, sulphate
Houtbos-loop-spruit	X22 102960	X2H014	X22A	Houtbosloopspruit at Sudwalaaskraal	-	Orthophosphate, Electrical Conductivity;
Elands River	X21 102961	X2H015	X21K	At Lindenau on Elands River	Electrical Conductivity Orthophosphate;	Nitrate, chloride, sodium, sulphate
Sand/ Wit/ Nels River	X22 102993	X2H068	X22E	Sand River at Witklip Forest Reserve	Orthophosphate	Nitrate
	X22 102952	X2H005	X22F	Nels River at Boschrand	Orthophosphate	-
Nsikazi River	X24 102995	X2H072	X24A	Nsikazi River at Madlabantu/ Kruger National Park	-	

Rivers	Water Quality site - WMS ID	Weir ID	Quaternary catchment	Description	Parameters of concern	
					Exceeds RQO	Increasing trends*
Queens/ Suidkaap/ Kaap Rivers	X23 102955	X2H010	X23A	North Kaap River at Bellevue	Orthophosphate	-
	X23 102954	X2H008	X23E	Queens River at Sassenheim	Orthophosphate	-
	X23 102974	X2H031	X23D	South Kaap River at Bornmans Drift	Orthophosphate	Nitrate
	X23 102965	X2H022	X23H	Kaap River at Dolton	-	Electrical Conductivity, chloride, sodium, sulphate, nitrate

4.1.5 Situation assessment summary outcomes

In summary, the assessment concluded the following:

- The RQOs have been determined and the applicable resource units that they relate to have been compiled for each sub-catchment area within the Crocodile (East) catchment. However, there were several concerns noted when reviewing the RQOs for the study area. These included:

  a. **Not all quaternary catchments have RQOs that have been gazetted**.

  b. In several cases, the RQOs that have been set are not feasible (too lenient or too stringent) for the water resource class that has been set and do not address the water quality concern or threat.

  To fill these gaps, the following was done:

  c. Where RQOs were not gazetted, but were determined as part of the study, these were used**.** WQPLs will need to be set where no RQOs exist and are needed. WQPLs will require stakeholder consultation and engagement and will have to be gazetted.

  d. Where the water quality objective of the RQOs set does not reflect the water resource class, a WQPL that is more relevant (stringent) was used.

  There were a few concerns noted in respect of the leniency of a few RQOs and the threat that this could pose over the long term for the Class II rivers. These should be re-evaluated by the DWS.

- In respect of land use, the agricultural sector dominates the economic scene and contributes significantly to employment, with 13% of jobs in eMakhazeni Local Municipality (LM), and 28% of jobs in the Thaba Chweu Municipality being supported by this sector. The agricultural sector is also the biggest water user in the catchment, as it is allocated 53% of the total water demand. The highest concentration of irrigation takes place in quaternary catchments X22C, H and J and X24D and H.

- Manufacturing also contributes significantly to the catchment economy, and this can also be attributed to the fact that Mbombela serves as an economic hub, with a sectoral contribution of R10.62 billion, making it possible for companies like Ambassador Foods (White River), Mpact Corrugated, and the Sappi Factory (Ngodwana) to operate from there.

- The mining industry makes up a smaller portion of the economy within the Barberton region, where gold was discovered more than a century ago. Lily and Scotia Talc mines are just a few of the mines that have either been shut down or abandoned; however there is active sand, gold, and manganese mining. The sector contributes an average of 5.5% to the GVA across all municipalities in the area.

- There are sixteen municipal WWTWs in the study area, located within the various local municipalities. Considering the 2021/2022 Green Drop Assessment, these WWTW are of concern and will need to be upgraded and/ or better maintained to optimise their use to achieve the effluent quality specified by the type of treatment option in place.

- Due to the numerous natural reserves within the area, including Kruger National Park, the tourism business is significant, with the trade sector contributing R20.35 billion to the GVA and 25% to the employment of the Mbombela Municipality.

- WARMS data was collected and summarised the registered water uses in the Crocodile (East) catchment in respect of Section 21 (e), (f) and (g) water uses. No registrations for Section 21 (h) water use have been recorded on the WARMS for this catchment area. The water uses include point and non-point sources, which were accounted for as best as possible in terms of the load assessment.

- Of the twenty-seven (27) water use licences received, only 10 were Section (e), (f) and (g) water uses. It was concerning that not all water use licences are registered on WARMS and not all are in the possession of the IUCMA.

- Several of the registered water uses need to be verified and the validity of their authorisations confirmed. This, however, was not within the scope of this project but will be a necessity prior to future full-scale implementation.

- Flow data was available for nineteen weirs in the catchment, which were described. The associated water quality data for the water resources was collated from the DWS Water Management Systems (WMS), as the latest data has not yet been incorporated. In addition, the DWS/ CMA monitoring IDs still need to be aligned. The flow and water quality monitoring sites were found to be inadequate to accurately calculate the load and contributions from catchments.

- The major areas of water quality concern based on the trend graphs and 95 percentile data assessment related to the impacts on the Crocodile River from the Kaap River and to a lesser extent from the Nsikazi River, and then elevated electrical conductivity, sodium, chloride and magnesium at the most downstream points which appears to be impacted by the extensive irrigation which occurs along the Crocodile River. Considering that the WDCS strategy relates only to registered waste discharge-related water use, in terms of Sections 21 (e), (f), (g), and (h) of the NWA, the non-point sources from irrigation of raw water may not be included. These and other unregistered users will still need to be accounted for in the catchment load balance assessment.

- In all cases along the Crocodile River, and for the tributaries, the 50^{th} percentile data indicate that the nutrient concentrations measured, orthophosphate and nitrates, are within the moderate to significant range for potential for algal growth and productivity and are expected to contribute to mesotrophic to eutrophic conditions.

- The modelling using WQSAM that is being undertaken for the catchments by the IUCMA was not available for this pilot exercise.

Leading on from the situation analysis, the following load assessment calculations were undertaken that informed the options analysis.

4.2 LOAD ASSESSMENT

- Determination of the load discharge for sub-catchment areas for the identified variables of concern, assessment of compliance with the RQOs and quantification of excess load.
- Identification and assessment of mitigation options for the load removal.

- Option analysis and determination of unit reference values for each intervention or technology option.
- Selection of the feasible mitigation options.
- Costing analysis of mitigation options and determination of the Waste Mitigation Charge rates.

Three pilot catchments were selected based on the assessment of the water quality variables of concern, excess load and identified threatened rivers. The catchments identified included:

- **Elands River,** which includes the tributary sub-catchments of the:
  - Leeuspruit
  - Swartkoppies;
  - Joubertspruit, Weltevredespruit;
  - Ngodwana and Lupelle Rivers.
- **Middle Crocodile River,** which includes the tributary sub-catchments of the:
  - Nels, Sands Rivers
  - White River
  - Gladdespruit, Blinkspruit, Rietspruit;
  - Blinkwater, Rietbokloop Rivers
- **Kaap River,** which includes the tributary sub-catchments of the:
  - Suidkaap River
  - Noordkaap River, and
  - Queens River.

The load assessment included the following:

- Data assessment:
  a. Water Quality
     i. Assessment of water quality data to determine the constituents of concern (COC) (approximately the last 20 years)
     ii. Calculation of average monthly data
     iii. Filling of gaps with average monthly data
  b. Water Quantity
     i. Assessment of the last 20 years of flow data
     ii. Calculation of average monthly data

- Calculation of monthly load for the data series using the following equation:
  c. COC load (kg/d) = average monthly flow (m^3/d) x average monthly concentration (mg/L) (A)
  d. RQO load (kg/d) = average monthly flow (m^3/d) x RQO (mg/L) (B)
  e. Load to be removed (kg/d) = (B) – (A), where
     i. a negative result indicates that there is still some assimilative capacity, and
     ii. a positive result indicates that load will need to be removed.

Based on the load, the following decision process was applied (illustrated in Figure 4-1):

Table 4-3: Decision process

Decision Step	Rationale	Next step (Refer to
1) Load (kg/month) of RQO vs current load	This is the measure for the application WDCS and indicates whether there is assimilative capacity in a selected catchment or not.	*Decision Step 2 or 3 applies*
2) Assimilative capacity is not available	In this scenario, the WDCS will apply, and mitigation interventions are required.	*Decision Step 7 applies*
3) Assimilative capacity is available	This scenario indicates that the current load in the river is less than what is calculated for the RQOs. The trends are, however, not known at this point.	*Decision Step 4*

Decision Step	Rationale	Next step (Refer to
4) Assess water quality and quantity (flow) trends at various points throughout the catchment.	This step is important to understand whether the water quality status is stable, and RQOs are being met. In addition, the flow is important in calculating load, highlighting seasonal changes, and potential aspects related to climate change that may have further implications for pollution in the catchment. The trends over time may indicate an increasing problem that should be dealt with before it becomes a major concern.	*Decision Step 5 or 6 applies*
5) -ve trends showing improvement over time/ stable	The trends over time show that the water quality is in an acceptable state*, i.e.,* it is compliant with the RQOs that have been set and the data indicate a decrease in contaminants of concern over time, or at least a stable trend over time.	*Monitoring and compliance and enforcement will apply.* Maintain the status quo. Ongoing monitoring at the various sites as for Step 1 to ensure that action can be taken timeously should it be needed, specifically if water quantity changes occur.
6) +ve trends showing deterioration over time with threats to the class/ RQOs	The trends show a deteriorating situation over time and even though the RQOs are being met there is a threat to the class and RQOs may be exceeded soon. This links back to the fact that loads will need to be removed. *Step 7 applies*	*Proceed to identification, assessment, analysis and selection of mitigation options.*
7) The load will need to be removed	In this scenario, there is no assimilative capacity, or the resource is in a threatened state and load will need to be removed to achieve the RQO. The current situation indicates a load that exceeds or will soon exceed (increasing trajectory) calculated for the RQOs. Assess what load (kg/month) will need to be removed for the contaminants of concern to achieve the RQO or reduce the increasing contaminants trend.	

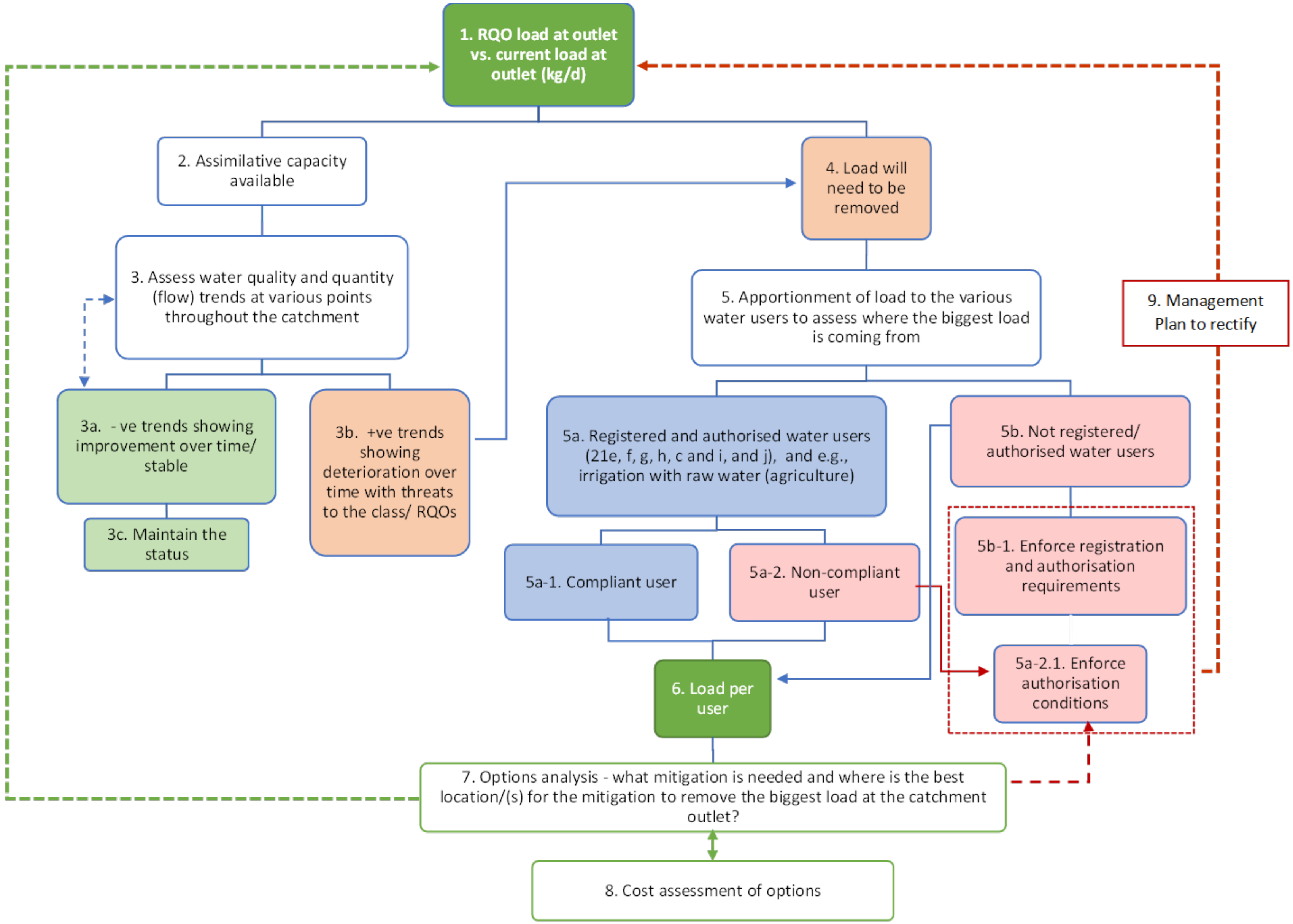

Figure 4-2: Summary of decision processes that need to be followed

The above decision analysis was applied in the three pilot catchments and loads to be removed were determined. A summary of the load assessment and its outcome in each of the three sub-catchments is included in Appendix C.

Based on the load assessment, total dissolved solids (TDS), sulphate and orthophosphate were identified as the key constituents of concern requiring load removal in the three pilot catchments. However, it should be noted that while these exceedances were identified, they present a localised situation within specified reaches, with the general catchment water quality of the Crocodile (East) currently being in a sustainable state if maintained.

This present status does not necessarily require the implementation of mitigation interventions, but would rather be achieved through source directed controls and achievement of compliance and enforcement. However, although the need for load removal was limited due to the general good state of water quality, to meet the objective of the piloting exercise and assessment of the WDCS the project tasks were taken through to completion.

The load assessment results indicated that the options that could be considered to reduce the contaminant load in the three pilot sub-catchments (Elands, Kaap and middle Crocodile rivers) related to the removal of:

- Orthophosphate, and
- Total dissolved solids and sulphate.

The load assessment also indicated a reduction in flow at downstream weirs, specifically in the Kaap River catchment, where the flow is an estimated 80% lower than the combined flow measured at the 3 upstream weirs. This indicates considerable abstraction is taking place, which would have a large impact on the assimilative capacity of the system, and while a physical load reduction option is considered for this pilot exercise, the following need to be undertaken prior to implementation of the water quality mitigation intervention:

- Assessment of the major abstractors
- Water Conservation/ Water Demand Management assessments for:
  - Mine operations (Fairview, Consort and Sheba Gold Mines)
  - Town of Barberton, and
  - Irrigation farmers.
- Potential for reuse/ recycle internally, and for example, between mines and irrigators.
- The development of the proposed Mountain View Dams in the catchment, and its impact on flow and future water quality load.

A sub-step that would need to be applied prior to mitigation option identification and analysis is the apportionment of the determined load to the various water users to assess where the load is coming from and from which sub-catchments. To know what and where the best mitigation option for load reduction would be, it is important to apportion the load to the various sources in the catchment. This requires that the load in the catchment be assessed in more detail to understand and identify the major sources (users and tributaries), which would then allow a fair charge allocation and catchment mitigation option location. It doesn't make sense to implement a solution at the outlet of a catchment when the largest contribution originates from one tributary because of a specific source. However, during the piloting exercise, this was not possible due to a lack of source load data, water user information and RQO limitations. In terms of the pilot catchment project, this sub-step (*i.e*. load apportionment to water users) was not carried out due to the following constraints:

- RQOs have only been set at the outlet of the catchment, and not all relevant RQOs have been set, e.g., there is no RQO for sulphate and this is a concern in the Kaap catchment. While the Pricing Strategy (DWS, 2023) proposes the use of WQPLs, these have not been set in the Crocodile East Catchment, and nor are there any gazetted.

- The flow and water quality monitoring points were few and far between to link to a specific source (*i.e*. an authorised water user). Assessment of local water quality and quantity data for completeness to enable local load quantification upstream and downstream of water users/sources was not possible.
- The water user monitoring, reporting and data linked to water use authorisations is not being captured or available to determine which water users contribute to the contaminant/(s) of concern and how much. It is unclear how and where the data that is meant to be submitted on the DW903 and DW904 forms is captured.
- A key gap is the lack of a suitable load assessment model that will fairly apportion the load to individual users. The WQSAM model currently being developed by the IUCMA would need further development to ensure that the loads determined per user are accurate and defensible.

Thus, the outlets of the pilot catchments where the RQOs are set and where water quality and flow monitoring data were available were selected as the “site” of implementation of the mitigation options for load removal for this pilot exercise. This, however, is not ideal and presents challenges in terms of the mitigation options that can be implemented and the effectiveness of achieving the desired load removal. No apportionment back to users could be undertaken.

It was apparent through this exercise that a sound methodology that is fair, equitable and technically sound is required to correctly apportion load to each user within a catchment before the charge is implemented.

4.3 MITIGATION OPTIONS ASSESSMENT

Based on the identification of water quality hotspots and related constituents of concern, and the quantification of load removal, mitigation options for load removal were assessed. Initially, these included chemical and mechanical options; however, the outcomes indicated that greener, softer options would be more relevant in some cases.

The load removal options identified for the removal of the elevated total dissolved solids, in particular sulphate, and nutrients, specifically orthophosphate, included water purification technologies, passive treatment, chemical options, and alternate measures such as river rehabilitation. A summary of the options is described and discussed in the following sections, and the analysis is presented. The viability of the options for implementation in terms of load removal, as well as in the context of meeting the objective of the piloting exercise, was considered in selecting the options of mitigation charge determination.

Water treatment technology selection is dependent on the following factors:

- Water quality and quantity aspects
- Site-specific conditions
- Treated water specifications
- Reuse application, and
- Dilution factor.

The treatment technologies may be required to remove or reduce pathogens, nutrients, trace metals and organics, total dissolved solids (TDS) and microconstituents. In this case, the objective is to remove/reduce TDS, sulphate and orthophosphate. The technology option was selected based on its applicability to meet the RQOs set out for the Kaap, Elands, and middle Crocodile (East) catchments. The above-mentioned factors were considered when selecting suitable treatment options. Appendix D includes the description of the technology options considered.

4.3.1 Summary of Options

Table 4-4 summarises the chemical and mechanical technology options considered and a high-level basis that informed the decision-making process. This served as a preliminary assessment to select the most feasible options that were taken forward and assessed for the mitigation option implementation. Options that were rejected were not taken forward as they were considered to be fatally flawed.

Based on the water quality improvement and the load removal, the options taken forward included:

- The Kaap Catchment indicated elevated monovalents that can only be removed by (i) Reverse Osmosis and (ii) Ion Exchange, and
- The Elands Catchment (i) Reverse Osmosis, (ii) Ion Exchange and (iii) Nanofiltration

Refer to Appendix D for the details on the load estimates and costing analysis for the adopted options of reverse osmosis, ion exchange and nanofiltration.

4.3.1.1 Alternate Options to Remove Load from the Water Resource

After the chemical and mechanical options assessment and the exorbitant associated costs were determined, alternative options were considered. These included source reduction, river rehabilitation and constructed wetlands.

Source Reduction

Source reduction in the Kaap and Elands catchment would need to include, but is not limited to:

- Regional source treatment: Treatment through a centralised treatment facility whereby similar sources of the constituent of concern are treated and the final discharge results in the load removal. This will require a coordinated effort among the water users to implement.
- Point Source Pollution Control: Managing and regulating industrial and municipal discharges through effluent standards and wastewater treatment can significantly reduce pollution. Compliance and enforcement would be instrumental in achieving the reduction in pollutants.

In the Kaap catchment, the removal of the sulphate would need to target the mines through such a regional-based treatment plant, funded, operated and maintained by the mines. This will entail the treatment of all discharges at a central point prior to release to the water resource, or the treatment plant could be used to provide a more sustainable source of water to the mines, which currently abstract from the rivers, thereby resulting in the availability of additional flow and availability in the river. This could prove to be a more cost-effective option.

In the Elands, the orthophosphate removal could target the three wastewater treatment works in the upstream catchment. This would need to consider the upgrade of the plants to ensure compliance and efficient treatment of the nutrients. Non-compliance of wastewater discharges by municipalities is the fundamental issue that needs to be addressed by compliance and enforcement. This is a source management issue and does not necessarily warrant a mitigation intervention for the broader catchment.

In the Elands, a large part of the upstream area is dominated by agriculture. It is likely that orthophosphate load could also be originating from agricultural runoff water that would contain fertilisers and pesticides (essentially, it is now water containing waste that reports to the water resource). It is highly recommended that the return flows generated by run-off from irrigation use be brought into the net of Section 21 water uses so that they may also be authorised and accounted for in the load apportionment. In the Crocodile (East) catchment, a large component of the land use is irrigation with raw water and thus is outside of attracting any mitigation charge for the return flows added to the system.

Based on the current wastewater discharges from each of the sources, either the mines or wastewater treatment works a load can be quantified for "end of pipe". This could be used as an estimate to assess a source reduction option in each catchment. In both instances in the Kaap and Elands catchments, the confirmation of the load from each of the sources and apportionment to each water user was necessary to consider a source management measure that can be implemented to improve the discharge quality to achieve compliance and benefit to the catchment resource quality. This information was, however, not available.

Table 4-4: Summary of the Water Treatment Options and High-Level assessment

Option	Reverse Osmosis	Ion Exchange	Nanofiltration	Active Biological Nutrient Removal (BNR) – Biological Phosphate Removal (BPR)	Passive Biological Nutrient Removal (BNR) (e.g., constructed wetlands)	Passive treatment	Absorption	Adsorption	Chemical precipitation
Problem constituents that can be removed	Sodium; Calcium; Magnesium; Fluoride; Sulphate; Orthophosphate and TDS	Calcium; Magnesium; Fluoride; Sulphate and TDS	Sulphate and TDS	Orthophosphate	Nitrogen Phosphorus	Sulphate Monovalent ions	Dissolved contaminants	Orthophosphate	TDS; Calcium; Magnesium; Sulphate; Bicarbonate ions and Orthophosphate
% Non-compliance	**Elands River:** Ca: 13.4 %; Mg: 1.64%; PO_4: 15.77%; SO_4: 4.12%; F: 0.12% **Kaap River:** Na: 15.19%; SO_4: 15.08%; PO_4: 25.89%; F: 4.17%								
Advantages	• 95-99% of TDS are removed, producing a high-quality permeate (Sensorex, 2023). • Energy efficient • Removes most contaminants • Consistent results • Scalability • No chemical usage	• Low maintenance cost (Tripathi, 2017) • Produces a high flow rate of treated water (Tripathi, 2017) • Resin regeneration (NetSol Water, 2022)	• Lower retained concentrations for low-value salts when compared to RO (EMIS, 2020) • No chemical or salt requirements during operation (Agarwal, 2022) • pH after nanofiltration is non-aggressive (EMIS, 2020)	• Adaptability to wastewater composition, flow rates and treatment objectives • Environmentally sustainable • Cost-effective: Compared to chemical treatment methods, biological phosphate removal generally requires lower operational and chemical costs. • Biological nutrient removal: In addition to orthophosphate removal, biological phosphate removal is often part of a broader nutrient removal strategy that includes the removal of nitrogen compounds (nitrate, nitrite, and ammonia).	• Low energy requirements • Low operating and maintenance costs • Resilience to Power outages • Flexibility: Passive BNR systems can be designed and implemented in a variety of settings, including constructed wetlands, vegetated buffers, biofiltration systems, and decentralized treatment units.	• Do not require the input of external energy sources. • Low operational requirements - only intermittent maintenance and monitoring attention. • Retains the solid residues within the process units and allow gaseous residues to be vented to the atmosphere	• Physical removal • Many absorbent materials used in water treatment processes, such as activated carbon or ion exchange resins, can be regenerated and reused multiple times. • Absorption processes are relatively simple to operate	• Compatible with sustainable practices • Regeneration potential is good. Many adsorbent materials used for phosphate removal can be regenerated and reused multiple times. • Ease of operation	• Simple process • Cost effective • Reduced sludge volume
Disadvantages	• Membrane scaling/fouling • High capital and operating costs • Not self-sustaining	• High capital and operating costs • Reduced resin efficiency due to dissolved organic matter (Tripathi, 2017) • Fouling due to calcium reacting with regenerating sulphuric acid (Tripathi, 2017)	• High capital and operating costs however, lower than reverse osmosis technology • Rejection of monovalent ions is lower than in reverse osmosis. • Pre-treatment may be required for highly polluted water (Agarwal, 2022) • Limited salt and univalent ion retention	• Only suitable for orthophosphate removal • Limited applicability • High infrastructure requirements: Biological phosphate removal systems typically require dedicated infrastructure • Incomplete removal • Slow reaction rates: Biological phosphate removal processes may have slower reaction rates compared to	• Design and site constraints • Bioavailability and Microbial Activity: The bioavailability of sulphates, TDS, and orthophosphates in passive BNR systems may vary depending on factors such as water chemistry, microbial activity, and environmental conditions. • Inadequate residence time	• Limited trials in South Africa • Systems have not been proven to perform reliably over 0,5 ML/d (500 m^3/d). • Treated water may not meet the specifications required • Has limitations with regard to sulphate and TDS reduction and cannot remove the monovalent salts, such as sodium or chloride	• Saturation: • Competitive absorption • Physical constraints • Costs can be significant	• Mostly suitable for orthophosphate removal • Cost considerations: Adsorption processes can involve higher initial capital costs compared to some other treatment methods. • Adsorbent saturation: Over time, adsorbent materials can become saturated with phosphate	• High chemical usage • Formation of sludge • Secondary Impacts (water chemistry, salinity) • pH Sensitivity

Option	Reverse Osmosis	Ion Exchange	Nanofiltration	Active Biological Nutrient Removal (BNR) – Biological Phosphate Removal (BPR)	Passive Biological Nutrient Removal (BNR) (e.g., constructed wetlands)	Passive treatment	Absorption	Adsorption	Chemical precipitation
			• Fouling/scaling issues (Agarwal, 2022)	chemical treatment methods. Hydraulic retention time: Biological phosphate removal processes require sufficient hydraulic retention time for microbial uptake of orthophosphates to occur effectively.	• Limited to specific contaminants	• Capital cost of these units also tends to be higher than for active treatment options		ions, reducing their effectiveness • Orthophosphate ions may compete with other ions present in the water for adsorption sites on the adsorbent material	
Technical/ Operational Specifics	• Maximum water recovery of 75-85% • Robust design allows for treatment of higher flowrates	Resin regeneration effluent produced is high concentrated in pollutants. However, there is a smaller volume as compared to brine produced in membrane technology	• Rejects solutes in the size range of 1nm (Dupont, 2023) • Rejects molecules with molecular weight larger than 200-400 (Dupont, 2023) • Salts with monovalent ions have a rejection of 20-80% (Dupont, 2023) • Salts with divalent ions have rejections of 90-98% (Dupont, 2023)	• Optimal flow rates • Less complex wastewater composition • Establishment of microbial communities	• Active systems with mechanical components and controlled conditions • Requires contaminants to be bioavailable	• Treat up to 0,5 ML/d (500 m3/d) • Longer lead time to implementation • Feed material used must be installed upfront for a number of years.	• Physical process using absorbent material – bed of activated carbon		• Requires optimization of pH, dosage, and mixing conditions to ensure complete reaction and precipitation
Operating Costs	Medium to High	Medium to High	Medium to High	Medium	Medium	Medium	Medium	Medium	Medium to High
Capital Costs	High	High	High	Medium to High	Low to Medium	Low to Medium	Medium	Low to Medium	Medium to High
Waste Streams Produced	Brine	Concentrated regeneration waste	Brine	Sludge	Less than Active BNR	Minimal waste	Spent absorbent material	Desorbate from regeneration and adsorbent material	Sludge
Health and Safety Risks	Medium	Medium to High	Low to Medium	Low to medium	Low	Low to Medium	Low to Medium	Low to Medium	Medium
Complexity	Medium to High	Medium to High	Medium to High	Medium to High	Low to Medium	Low	Low to Medium	Low to Medium	Medium
Ergonomically Friendly	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Maintainability	High	High	Medium	Medium	Low to Medium	Medium to High	Medium	Medium	Medium to High
Accepted/ Rejected	Accepted	Accepted	Accepted	Rejected	Rejected	Rejected	Rejected	Rejected	Accepted
Reason	Standard water treatment option for the problem constituents Additional pre-treatment may be required.	Allows for selective removal. Additional chemical loading may be required.	Applicable as pre-treatment for removal of the problem constituents.	Limitations with regards to flow, mostly suitable for orthophosphates only, slow treatment process.	Inadequate residence time may lead to limited removal, and there are concerns related to site limitations and microbial activity.	Not been proven to perform reliably over 0,5 ML/d. No full-scale reference plants. May not be suitable for TDS and sulphate removal.	Limited by physical factors such as flow rate, contact time, or hydraulic conditions. High costs associated with this option and saturation can impact the effectiveness.	May reach saturation which impacts effectiveness. Challenges with competing ions. Mostly suitable for orthophosphate removal only.	High chemical usage and may have secondary impacts. May be suitable as a pre- treatment option.

4.3.1.2 River Rehabilitation and Maintenance

Other options identified that can improve overall river condition, contributing to a more sustainable water resource, include river rehabilitation measures that can be implemented as parallel measures. Investing in rehabilitating and maintaining ecosystems is a cost-effective means to augment engineering options, to address water quality and flow concerns, and ultimately improve the resource to achieve the RQOs. Natural infrastructure refurbishment and improvements of rivers should also be considered as supplementary mitigation measures that the IUCMA can implement.

Rehabilitation is defined as the promotion of the recovery of ecosystem functions and values of a degraded system to restore some of the value the system previously had to society (Water Research Commission, 2016). Rehabilitation essentially aims to improve aspects of the degraded state. Though rivers and wetlands have the assimilative ability to absorb and process nutrients, the enormous volumes introduced in concentrated form at point sources overwhelm the dilution capacity of the baseflow of the receiving stream and the assimilative capacity of the river ecosystem. Focused efforts at significant sources of pollution and effective catchment management (sediment and litter traps, vegetated swales and buffers) can aid in reducing the nutrient load in rivers and wetlands. Alternative natural-based solutions have been considered as part of the water quality management mitigation options for the Crocodile (East) Catchment. The focus was to provide options that utilize rehabilitation methods of wetlands and rivers to reduce the load within the Kaap River catchment, Elands River catchment and Middle Crocodile River catchment. From the data recorded for the three river catchments, load exceedances within the three river catchments are:

- Kaap river catchment: orthophosphate, TDS and Sulphates
- Elands River catchment: orthophosphate and Sulphates
- Middle Crocodile River Catchment: orthophosphate

For nutrients such as phosphorus, the focus on removal is at the source. Trapping sediments entering the river and establishing vegetated filter strips along seepage or runoff zones into the channel that enter the river can be used as rehabilitation approaches, as phosphorus often binds to inorganic sediments (e.g., fine sands and clays). Therefore, removing the sediments will remove the phosphorus. Periodic harvesting of plant material in wetlands or rivers to remove the nutrients (phosphorus) in plants may also be required in addition to rehabilitating wetlands and rivers to trap the phosphorus. The nutrients are usually trapped in the roots, soil (microbe zones), rather than stems and leaves; therefore, plant harvesting should be informed and coordinated by an aquatic or wetland biodiversity specialist.

Increased salinity through rehabilitation is difficult at a site scale, as this usually requires catchment-level interventions that require investigation of land use practices and salt sources, and how to reduce them first.

River rehabilitation options that could be considered are summarised in Table 4-5.

Table 4-5: River rehabilitation and maintenance options

Option	Description	Advantages	Disadvantages
Removal of weirs	Weirs and dams have a definite negative impact on the environment, specifically related to reduced flow, and sometimes the removal of these can be used as a rehabilitation method. Removing dams, weirs, or limiting water abstraction from rivers can restore free-flowing river conditions, reinstate migration routes for instream biota and restore more natural flows and sediment delivery to downstream reaches. Within the Kaap River catchment at Weir X2H022, high abstraction of water between monitoring points also leads to decrease in flow and a subsequent increase in concentration of nutrients, salts and TDS and a high impact on the assimilative capacity of the system. Though there are several potential benefits to the removal of weirs/dams, there may be negative consequences and therefore the option requires specialist input from environmental practitioners, engineers, and wetland specialists.	▪ Restores free-flowing river conditions ▪ Increases instream river flow volumes ▪ Reinstates migration routes for instream biota, and ▪ Restores more natural flows and sediment delivery to downstream reaches.	▪ Smothering of downstream habitats through the pulse released sediment loads as accumulated sediment from upstream of the removed weir is flushed downstream. ▪ Release of contaminated sediments to downstream areas (in a case where sediment is trapping pollutants such as mine tailings), *i.e.*, moving the problem from one site to another. ▪ Increased downstream flooding due to increased bed levels (alluviation from sediment), and ▪ Flushing of nutrients and anoxic conditions associated with the mobilisation of accumulated sediments in the impounded river upstream of the structure.

Option	Description	Advantages	Disadvantages
Revegetation	Where possible, the simple landscaping and revegetation of banks or eroded channels and encouraging the growth of reeds in channels to trap fine sediment is the most desirable form of bank rehabilitation, and the viability of this option should be considered as a first option (Water Research Commission, 2016). The need to stabilize the bank may come from flow velocities that are making the bank unstable.	▪ Landscaping and vegetating banks does not involve introducing foreign material to the river environment. ▪ Indigenous vegetation used for revegetating (if chosen appropriately) is adapted to thriving in the environment and will eventually spread down the river increasing the stability of the river, and ▪ Indigenous vegetation used for revegetating (if chosen appropriately) will support other life forms that belong in the habitat.	Difficulty in quantifying the engineering properties of the riverbank and vegetation to ensure a professionally reliable design, as the engineering properties of the vegetation are not constant. They depend on the age of the vegetation, presence of burrowing animals, status of the vegetation (rainfall, bush fires, etc.) and the presence of animals grazing and trampling the vegetation
Sediment traps	Sediment trapping in wetlands is an essential ecosystem service, with implications for the ecosystem downstream and water users. Sediment trapping refers to the process by which wetlands capture and retain sediments transported by water flows. Sediments are carried from upstream and can be harmful if they reach downstream ecosystems. Sediment traps can be created with excavation of a depression or pond in an active channel to slow down river flow or the widening of artificially narrowed channels to accommodate shallower flows to allow for sedimentation and trap fine sediments.	▪ Flood protection – by storing sediments, wetlands slow down the flow of water and thus reduce downstream flood peaks mitigating flood damage. ▪ Water quality improvement – when sediment is trapped in wetlands, the roots from the plants effectively filter out pollutants including nutrients, organic matter and metals. ▪ Erosion control – sediment deposits help prevent erosion by absorbing the energy of water flows, reducing the erosive force.	▪ Sediment accumulation – the continuous influx of sediment can lead to the filling of the wetland basins and reduce the storage capacity. This could potentially alter their natural functions. ▪ Wetland restoration and preservation – urbanization and industrial development often lead to degradation of the wetland or wetland loss. This reduces the area available for trapping sediment. ▪ Human activities – land practices such as construction and improper land management can increase sediment transport and overwhelm the wetlands' capacity to trap sediment.

Option	Description	Advantages	Disadvantages
	Wetlands can act as natural sediment filters that capture and store sediments before they enter rivers. When water flows into a wetland, the velocity decreases, which allows for the sediment to settle and be deposited. The vegetation and root systems within the wetland further enhance the sediment trapping by creating barriers that slow down and capture the sediments.		
Filter strips	The establishment of vegetation and the entrapment of sediment can result in phosphorous which is bound to the sediment remaining on the field landscape instead of entering sensitive water bodies. These vegetated conservation buffers improve infiltration and thus reduce runoff volume. The vegetation in conservation buffers recycles entrapped nutrients in any harvested material and provides permanent habitat for many types of fauna. This type of rehabilitation is useful in the following areas: ▪ Agricultural areas where both point and non-point source pollution occur, ▪ Areas with potential sediment erosion, ▪ Runoff from urban areas, and	▪ Flood damage prevention. ▪ Erosion control. ▪ Aesthetic value. ▪ Water quality improvement, and ▪ Soluble contaminant flow retardation.	▪ Includes cost of installation (grading slopes and vegetation establishment). ▪ Requires weed control. ▪ Maintenance costs, and ▪ Loss of acreage for pasture or crops.

Option	Description	Advantages	Disadvantages
	▪ Leachate and runoff from industrial areas. Filter strips can be used where land uses impact water resources, especially for non-point sources. Filter strips are most effective at slopes between 2 and 6 percent because of increased contact time between the runoff and the filter strip (Trimarco, 2023).		

4.3.1.3 Other Rehabilitation Activities

Rehabilitation and maintenance activities, in addition to rehabilitation and maintenance of wetlands, riparian zones and watersheds, could also include:

- Control of invasive alien plants, including initial clearing and subsequent ongoing maintenance activities, targeting species that have the largest impacts on water quantity and quality.
- Agricultural Best Practices: Promoting the use of conservation tillage, cover cropping, and nutrient management plans can minimize agricultural runoff and nutrient pollution.
- Livestock Exclusion: Fencing off water bodies from livestock access helps prevent contamination of water with faecal matter and nutrients.
- Land Use Planning: Implementing land use policies that encourage responsible development and limit urban sprawl can reduce impervious surfaces and improve water quality.
- Legislation and Regulation: Enforcing and strengthening water use legislation and regulations to deter pollution and ensure compliance with water quality standards.
- Collaborative Initiatives: Establishing partnerships between government agencies, local communities, NGOs, and industries to work together on catchment management and water quality improvement projects.
- Stormwater Management: Employing stormwater management techniques such as permeable pavements, green roofs, and retention basins can help control runoff and reduce the influx of pollutants into water bodies.

4.3.1.4 Constructed wetlands

Constructed wetlands are natural wastewater treatment systems that use natural geochemical and biological processes in a wetland ecosystem to treat contaminants. As for natural systems, the process is a complex interaction between water, plants, soil/gravel media, microorganisms, and the atmosphere, using the power of nature and energy from the sun.

Assessment of constructed wetlands has indicated that constructed wetlands can form an effective and adaptable treatment option with the potential to receive almost any contaminated water that is treatable by biological and physico-chemical means (Wood, 1999). There are many constructed wetland systems in operation in South Africa, the greater number of which have been constructed for domestic wastewater treatment in small community applications. Constructed wetlands are also being applied at several mining and industrial sites, as well as for stormwater and urban catchment management, riverine rehabilitation and protection, groundwater recharge and development of urban nature reserves and ecological sites (Wood, 1999).

Constructed wetlands can be used to treat run-off from sludge dewatering, landfill leachate, mine drainage, stormwater, industries, urban areas, and agricultural activities. As for natural wetlands, the common mechanisms include:

- Settlement of suspended matter.
- Filtration, chemical precipitation, and chemical transformation by bioremediation and denitrification processes of the water coming into contact with the substrate.
- Absorption and ion exchange on the surface of the vegetation, substrate, and sediment.

In this respect, the microorganisms and plants disrupt and transform the contaminants, and the microorganisms consume the nutrients, and the media acts as a filter, with concomitant predation and natural die-off of pathogens.

There are two basic concepts based primarily on whether the individual cells are operated as a surface flow or a subsurface flow system:

- Free Water Surface (FWS) systems that mimic natural systems in that water flows over the bed of the wetlands as a shallow water pond and is filtered through the dense stand of aquatic plants; and
- Subsurface Flow (SF) systems that promote water flow in a horizontal or vertical flow path through a shallow, permeable medium in which the plants are established. Treated effluent is collected in an underdrain for discharge.

Since each application is very site specific and largely dependent on land availability, and construction costs and treatment objectives, there is no consensus on the overall advantage of either of the two systems.

Free water surface systems generally have lower installation costs and potentially simpler hydraulics (Wood, 1999), as the provision of a suitably permeable medium tends to be the most expensive component of the sub-surface flow system, and the factor responsible for most treatment problems when permeability is not adequately catered for (Crites, 1992).

Advantages of the surface flow systems are minimisation of vector and odour problems, and possibly greater assimilation potential per unit area of land in terms of organics and nutrients.

It is important to note that the constructed wetland system itself is increasingly unlikely to be a single unit but rather an integration of units, which may include constructed wetlands, marshes, ponds, grasslands and even forest/shrub areas. The individual units making up the complete constructed wetland system may then operate as surface or subsurface filtration systems, as appropriate to optimise physico-chemical pollutant removal mechanisms and to balance aerobic and anaerobic biological degradation reactions, evapotranspiration and infiltration.

4.4 DEVELOPMENT OF THE MITIGATION CHARGE

Refer to **Appendix D** for the load estimates and the cost analysis of accepted load removal technology options used to establish Waste Mitigation Charge rates.

4.4.1 Approach to determining accurate mitigation charges

A Discounted Cash Flow (DCF) model was set up for each of the selected treatment mitigation options for the Elands and Kaap Rivers. DCF's are commonly used to plan capital and operational expenditure required to make infrastructure projects feasible during the life of the project. DCF's are especially powerful tools for estimating the prices needed to make the projects viable. There are multiple DCF models analysing each mitigation option, and the layout of each model is identical for each option. They consist of a so-called cash flow waterfall and a return-on-investment calculation.

4.4.1.1 Assumptions underlying the DCF models

The DCFs have been constructed based on several assumptions. These include:

- Assumptions made on discount rates
- Financing assumptions
- Capital expenditure assumptions
- Administration charge assumptions; and
- Personnel cost assumptions.

4.4.1.2 Discount rates

The DCF model has been set up to model nominal prices; thus, a key assumption includes the nominal risk-free rate. Risk-free rates are rates of return from investments that are considered risk-free. A common proxy used for risk-free rates is Government bond yields. This is because the financial markets assume that the Government won't default on its bond obligations. The nominal risk-free rate is based on the 10-year South African government bond yield. At the time of writing, this rate was 11.15%. Another assumption is the interest rate on any loans that may be required to finance capex requirements. One hypothetical way to finance the capital expenditure is through a conditional grant from National Treasury, and so this rate is provided as an alternative. The interest rate currently on these types of loans is 8%. It is to be noted that we have made this assumption merely to set up a capex financing module within the DCF. The CMAs will need to make complex financing arrangements to fund the capex requirements, the details of which are highlighted in section 5.2 of this report.

4.4.1.3 Capital expenditure assumptions

These assumptions set out when capital replacement will occur for each treatment option and the requirements of capital expenditure replacement. The Capital expenditure assumptions were derived from cost models for the priority treatment options.

4.4.1.4 Administration charge assumptions

The administrative charge refers to monitoring and enforcement activities.

There will be additional monitoring of downstream and upstream discharge points to measure the exact water quality constituents discharged. The cost is covered by an administration charge levied in addition to the waste mitigation charge, the WRMC (for waste discharges).

The typical monitoring and enforcement cost in a CMA was estimated. This amount is then divided by the volume discharged for each river system to get an estimate of the administration charge for each river.

The monitoring and enforcement costs were assumed to be based on a zero-budget approach. It takes the entire administration cost for the CMA and then allocates it on a proportional basis to the Elands River and the Kaap River systems. We note that a CMA needs to accrue reserves as part of its financial risk mitigation strategy.

4.4.1.5 Operation and Maintenance and Personnel costs

The operation and maintenance (O&M) and personnel expenditure assumptions were derived from cost models for the priority treatment options.

4.4.1.6 Financing

Financing will be required to ensure sufficient levels of capital for upfront capital expenditure and to cover working capital requirements over the life of the project. Financing assumptions, therefore, refer to how the capital expenditure and development of the plants will be paid for. The mitigation charge levied on the volume of load treated needs to be accurately calculated so that these capital and operational costs can be paid back within the financing model.

In its simplest form, three sources of capital exist: grant funding, commercial debt (through loans) or commercial equity (through equity investment). In the version of the model, we have assumed that the capital expenditure and replacements will be financed by debt, and/or grant and/or reimbursable grant. This assumption, therefore, builds into the mitigation charge the provision for interest on capital. The model has also been set up to allow for analysis of equity financing as a source of capital. It is important to note that the various sources of capital and respective returns on capital required would be determined by the specific business model to be implemented (e.g., a Public-Private-Partnership (PPP) model).

The tariffs are impacted by the financing of capital expenditure (including the capital replacement programme) and the covering of all relevant O&M and administrative expenses. Where debt financing (loans) or grants or reimbursable grants are used, the tariffs would need to cover the principal and interest payments on the debt or reimbursement of the grant. Where equity is employed, an agreed upon return on investment needs to be determined.

4.4.1.7 Cash Flow Waterfall and Return Calculation

The cash flow waterfall sets out cash flows in the order in which they occur. The cash flow waterfall was set up over a 20-year period, going from 2023 to 2043. This reflects a typical project life. The elements of the cash flow waterfall are described hereafter. It starts with the modelling of the physical parameters of the WDCS. This is the amount, in kilograms, of load to be removed each year between 2023 and 2043. The revenue needed to cover the cost of capital and operating expenses is calculated by taking the charge and multiplying it by the load removed each year. Thus, the discounted cash flows serve to solve for this charge.

After revenue comes operating expenses. They consist of plant operating expenses, personnel costs and other expenses. The personnel costs were assumed. Next in the cashflow waterfall comes Earnings Before Interest, Tax, Depreciation and Amortisation (EBITDA). EBITDA is calculated as the revenue received minus the operating expenses. After EBITDA comes net changes in working capital, which is zero for the purpose of this analysis.

After net changes in working capital comes capital expenditure. The capital expenditure for each option is the plant development cost for the specific option, shown as the initial cash outlay in 2023. The other capital expenditure could happen when a replacement occurs in the future. After capital expenditure comes cash available after investment. Cash available after investment is EBITDA less net changes in working capital, less the capital expenditure.

Next, the cash flow waterfall considers the type of financing. The debt drawdown is shown as a cash inflow. This is followed by the cash available after financing, which is the cash available after investment adjusted for any inflows and outflows from financing. The cash available for debt service is equal to the cash available after financing. After this comes the interest expense and principal payments (capital portion of loan repayments).

After deducting the tax paid, the cash left over is the cash available for dividend distribution if there are any equity investors. The dividend distributed is calculated as a percentage of the cash available for dividend distributions. Dividend tax is then calculated on the amount of dividends distributed. After this comes the cash and cash equivalents balance, which shows the opening cash balance from the prior year, the net cash flows for the year and then the closing cash balance available at the end of the year.

4.4.1.8 WDCS Return Calculation

The purpose of the return calculation is to calculate an Investment Rate of Return (IRR). IRR is the annual rate of return that an investment or project achieves. The IRR is based on the cash flows from the cash flow waterfall. It is based on the commonly used free cash flow to the firm method. The free cash flow to the firm refers to the cash generated from the operations of an entity, less the cash spent on capital expenditure. Thus, it is the cash that is available to the providers of funding, namely, debt and equity providers. The IRR can be compared to the cost of capital to determine whether an investment is desirable.

IRR (Investment Rate of Return): Investment Rate of Return: As we want the tariffs to only cover the operating costs and financed capital, once the goal seek function is performed the IRR will equal the interest rate on the loan i.e., the cost of capital. Thus, if investors would like to make a return that exceeds the cost of capital, a goal-seeking operation can be done that sets a tariff that achieves a higher IRR.

4.4.1.9 Solving for the charge

In order to solve for the charge, a goal seek function is performed. With the goal seek function, we can tell our model what we want the IRR to be. The model then solves for this IRR by changing the charge. This then sets the ultimate revenue that will be earned, that covers all the capital and operational costs and achieves the IRR we set. The purpose of this is to allow for different financing models and to accommodate different types of investors with different return profiles. This also ensures we set an accurate charge.

4.4.2 Results of the Discounted Cash Flow: The Mitigation Charge Rates

The results for the Elands River system are presented in Table 4-6 and incorporates the capital and operating costs of the different treatment options and solves for an IRR of 11.45%. This gives us the mitigation charge, which is shown in Table 4-6.

Table 4-6: Capital and operating costs of the different treatment options assessed for the Elands River

River system		Elands River		
Treatment option		Reverse Osmosis	Ion Exchange	Nanofiltration
Volume of water abstracted	MLD	17 - 5,400	17 - 5,400	17 - 5,400
Load removed	Kg/day	85 - 4,800	85 - 4,800	85 - 4,800
Capex required	R	663 million - 122 billion	190 million - 11 billion	265 million - 48 billion
Annual plant operating cost	R/a	211 million - 69 billion	350 million - 115 billion	181 million - 59 billion
Financing		100% Debt	100% Debt	100% Debt
Mitigation charge based on load removed	**R/Kg**	**2,100 - 739,000**	**2,900 - 1 million**	**1,600 - 586,500**

The results for the Kaap River system are presented in Table 4-7 and incorporates the capital and operating costs of the different treatment options and solves for an IRR of 11.45%:

Table 4-7: Capital and operating costs of the different treatment options assessed for the Kaap River

River system		Kaap River		
Treatment option		Reverse Osmosis	Ion Exchange	Nanofiltration
Volume of water abstracted	MLD	201 - 2,061	201 - 2,061	201 - 2,061
Load removed	Kg/day	2,000 - 676,000	2,000 - 676,000	2,000 - 676,000
Capex required	R	6 billion - 51 billion	1 billion - 6 billion	2 billion - 20 billion
Annual plant operating cost	R/a	2 billion - 26 billion	4 billion - 45 billion	2 billion - 22 billion
Financing		100% Debt	100% Debt	100% Debt
Mitigation charge based on load removed	**R/Kg**	**114 - 4,250**	**160 - 5,900**	**89 - 3,300**

The resultant excessively high mitigation charges are attributed to the high volumes of water ("river") that need to be treated for the load to be removed. The calculated abstracted volumes surpass the typical treatment capacity necessary for water treatment technology options assessed. The elevated costs also suggest a need for a larger treatment plant footprint and heightened environmental risk factors that demand attention. This option would need to be implemented at the outlet of the catchment (the most downstream point) and would also require water use authorisations for this activity.

Based on these high mitigation charge rates, it is evident that mitigation interventions and charges are non-viable for these catchments. It is therefore necessary to consider and test alternative load removal management strategies at the source of pollution to ensure compliance with the RQOs and to determine the most cost-effective and efficient approach to the water quality improvement in the Crocodile (East) catchment. This entails conducting a detailed load assessment in each of the upstream tributary catchments of the Kaap and Elands Rivers to address the specific pollutants and recommend treatment or management solutions to users that can be implemented directly at the source, prior to considering and implementing a catchment water treatment mitigation option. The approach could include regional on-site treatment, technology upgrades to existing plants and improved on-site control measures, or nature-based options. The alternative approaches can, however, be designed to ensure that the major costs are borne by the water users, but at the same time could potentially include catchment mitigation measures that attract a mitigation charge.

4.4.3 Costing for wetlands rehabilitation

To determine the cost of wetland rehabilitation, a Working for Wetlands (WfW) database was analysed. The data contains information on several rehabilitation projects completed by WfW and include the province where the project was implemented, the wetland area and the budget of the project.

The WfW data was sorted, organised and then analysed. The analysis is presented in the graph shown in Figure 4-3.
The Present Ecological State (PES) of the wetlands in the catchment should be assessed, particularly the floodplain wetlands which play a critical role in water purification, trapping excess nutrients like nitrogen and phosphorus, heavy metals, pathogenic microbiota, and synthetic organic pollutants such as pesticides (Collins, 2005), and those that are in poor condition, and that are no longer working optimally could be earmarked for rehabilitation and the analysis above can be used to determine total costs.

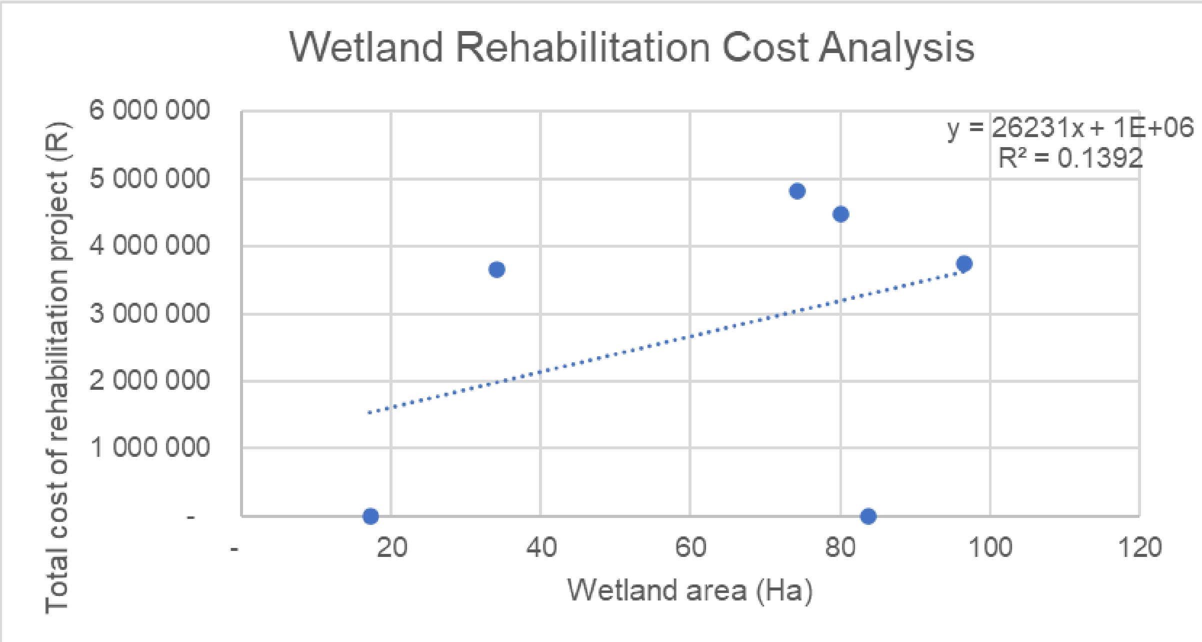

Figure 4-3: WfW data assessment

4.4.4 Costs related to constructed wetlands

It is difficult to give actual costs for constructed wetlands as it will be very site specific, and very dependent on the topography and type of soil, which will impact the berm formation and material that needs to be brought in, pipework required, and plants needed. It is likely that the biggest cost will be the infill aggregate material.

A high-level estimated cost for a surface flow wetland for a 1ML/d wetland is given in Table 4-8, and a sub-surface flow wetland is likely to be more expensive.

Table 4-8: Estimated high-level cost for a 1ML/d constructed wetland

Capital cost	R/First Year	R9 180 180
Wetland with Precipitation	R/Year	R1 802 808
Substrate Replacement	Assume once every 20 years	R13 942 060

CHAPTER 5: FUNDING MODELS FOR MITIGATION

As discussed in Chapter 4, the piloting exercise comprised two phases. This chapter addresses Phase 2, which focused on the business case that assessed proposed funding models and implementation aspects.

5.1 INTRODUCTION

It is evident that the chemical and mechanical treatment options require high capital investment for their construction. It is also apparent that the IUCMA does not have sufficient funds to cover the capital investment and so the funds required would need to come from external sources. This section describes the different sources of capital available for infrastructure mitigation projects and outlines the different funding models that could work in the context of the mitigation charge.

5.2 SOURCES OF CAPITAL

Sources of capital can be grouped into three categories: public sources, private sources, and blended sources of capital that employ a combination of private and public capital.

Table 5-1: Sources of capital

Categories of capital	Possible sources of capital
Public	• Fiscal transfers from DWS • Municipal Infrastructure Grant • DWS Grants • Development Bank of South Africa (DBSA) Infrastructure Fund
Private	• Commercial Banks • Equity Investors • Private Companies
Blended	• Donor Funders • Private Companies • Development Banks • Governments • Structured Funds

It is important to note that the different suppliers of capital have different risk profiles (the amount of risk the investors are willing to take), investment exposures (size of the investment), market incentives and return expectations. Grants providers typically have little to no expected financial return as grants are used to target specific impacts, such as biodiversity, climate change, or livelihoods. Other public providers of capital have concessional expected rates of return. Concessional means below market rates and are typically in the range of 1.4% and 5.0% depending on the industry (IFC, 2023). The private providers of capital have higher expected rates of return as they invest to achieve above-market rates of return. Their expected returns may be in the range of 12% - 18%. Blended finance uses the public and private suppliers of capital to lower risk and catalyse private investors to invest in markets they would not usually invest in. Expected returns from blended finance facilities are typically above concessional rates but below the rates expected from the private sector.

The funding models are described below:

- Model 1: Grant Funding
- Model 2a: Debt from a Commercial Bank
- Model 2b: Concessional Loan from a Development Agency
- Model 3: Public Private Partnership (PPP), and

- Model 4: Blended Finance Instruments

5.3 MODEL 1: GRANT FUNDING

5.3.1 Background

In this case, the funding required for the construction of the mitigation option is financed by grants provided to the IUCMA. These grants could come from the Department of Cooperative Governance via the Municipal Infrastructure Grants (MIG) programme, or from DWS through their grants, namely the Regional Bulk Infrastructure Grant (RBIG).

The MIG, managed by the Department of Cooperative Governance and is aimed at providing all South Africans with at least a basic level of service through the provision of grant finance to cover the capital cost of basic infrastructure. The MIG is a schedule 5(B) grant in terms of the Division of Revenue Act (DoRA) and is one of the largest conditional infrastructure grants in South Africa (Ndalasi, Luyaba & Vele, 2023).

The purpose of the RBIG is to assist in the development of new, and refurbish, upgrade, and replace, ageing water and sanitation infrastructure of regional significance which connects water resources to infrastructure, serving extensive areas across municipal boundaries, or large regional bulk infrastructure, and serving numerous communities over a large area within a municipality.

5.3.2 Explanation of the Model

The model and transaction flows, indicated by the arrows, are presented in Figure 5-1.

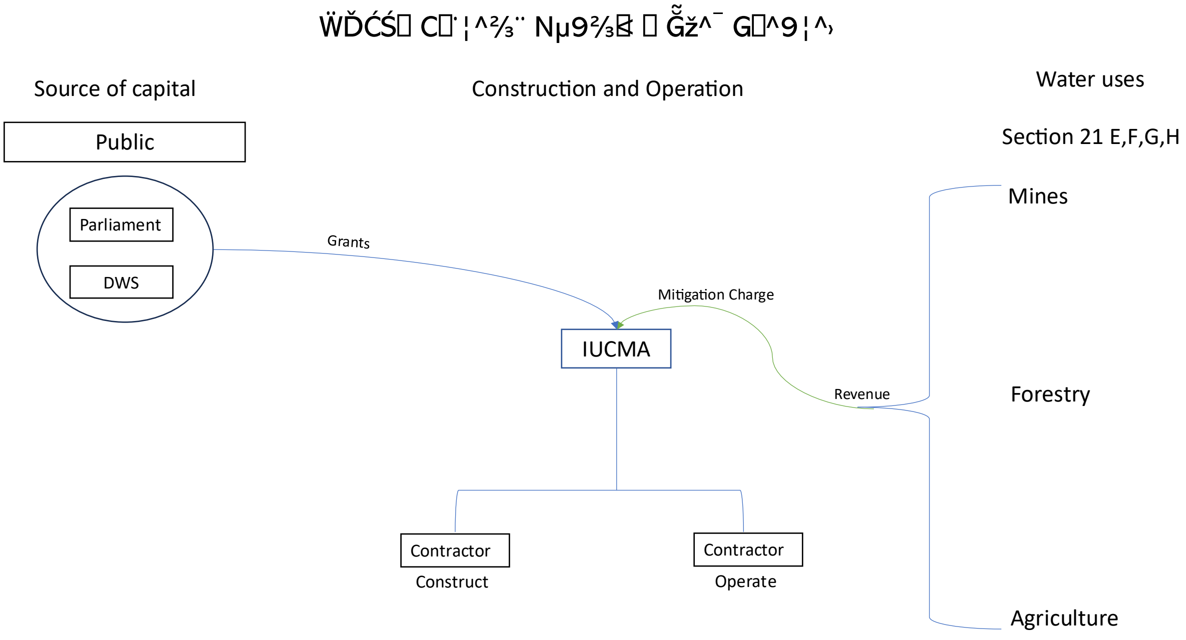

Figure 5-1: Graphic representation of Business Model 1 - Grant Funding

The IUCMA would contract a private party to construct the treatment plant as well as operate the plant. Construction and operation can be carried out by a single private entity or different private entities. The IUCMA uses the grant funding to pay the contractors for construction and operation. This is indicated by the blue line in the above figure, showing that the IUCMA receives the grant money and pays the contractors. The IUCMA then bills the different water uses accordingly and collects the revenue, as indicated by the green line in Figure 5-1.

5.3.3 Administration

In this model the IUCMA is responsible for administering the WDCS and ensuring that all the proper procedures and institutional arrangements are in place. The IUCMA would need to ensure accurate monitoring and compliance is taking place.

5.3.4 Billing system and revenue collection

Once again, in this model the IUCMA would be responsible for the billing and revenue collection process. The IUCMA would need to ensure that invoices are issued to the respective water users in a timely manner. Similarly, payments need to be processed without delay and accurate debt management needs to be in place to ensure any outstanding invoices are followed up and addressed.

5.4 MODEL 2A: DEBT FROM A COMMERCIAL BANK

5.4.1 Background

This business model uses debt as the source of funding for the construction of the mitigation option. This debt is in the form of a loan provided by a commercial bank. Due to the amount of funding required, the IUCMA may not be able to borrow the funds based on their balance sheet. Therefore, the loan could be provided to another entity and in doing so the debt lies with entities that could handle large loans. Possible entities identified at this stage include the Water Trading Entity established within the DWS. The Water Trading Entity was first established as a Water and Equipment Trading Account in 1983, but was later converted into a Water Trading Entity in terms of the Public Finance Management Act of 1999 in 2008. The primary role of the Water Trading Entity is to manage water infrastructure and resources, and the sale of raw water.

Another entity could be the South African National Water Resources Infrastructure Agency (SANWRIA) SOC Limited. SANWRIA was established as a juristic person under the ownership of the state. The purpose of SANWRIA is to acquire, dispose of, fund, provide, maintain, operate, manage and secure funding of national water resources infrastructure in an efficient and cost-effective manner.

5.4.2 Explanation of the Model

The model and transaction flows, indicated by the arrows, are presented in Figure 5-2.

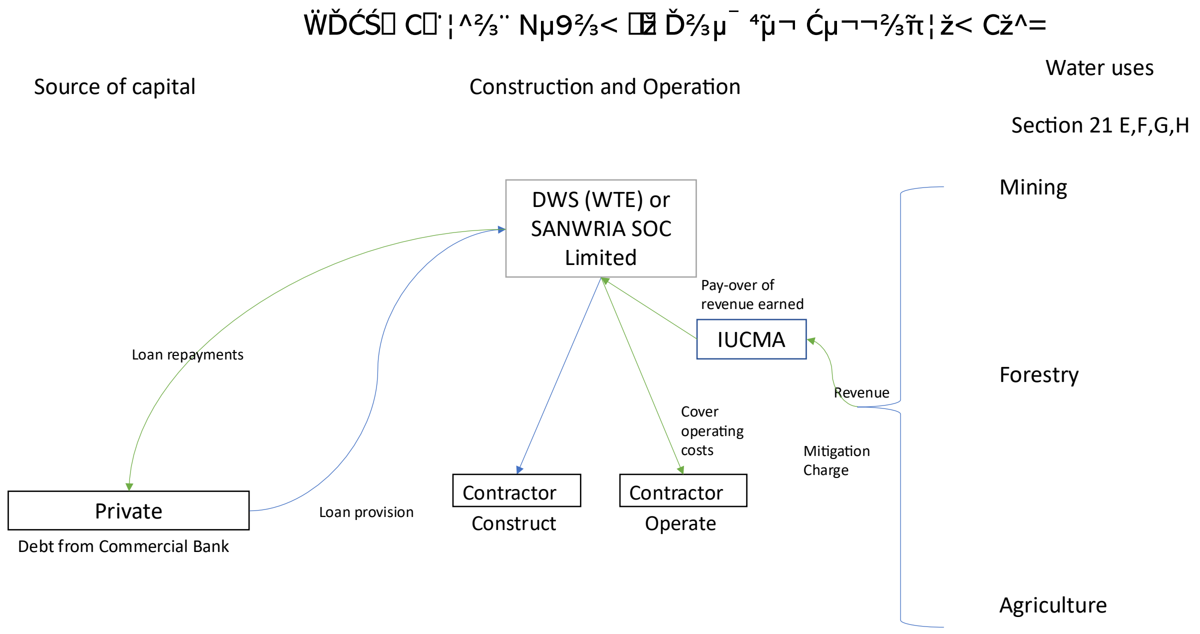

Figure 5-2: Graphic representation of business model 2a - Debt from a commercial bank

Under this model, a loan from a commercial bank is provided to the WTE or SANWRIA (could be another suitable entity if identified). This is indicated by the blue arrow going from the private funder, being the commercial bank, going to the WTE or SANWRIA. They would then contract a private party to construct the treatment plant as well as operate the plant. Construction and operation can be carried out by a single private entity or different private entities. The loan is used to pay the contractor for construction of the plant. This is indicated by the blue arrow going from WTE or SANWRIA to the contractor.

Once the plant is operational, a private party can be responsible for its operation. The IUCMA would bill the water users and collect the revenue (indicated by the green arrow called 'Revenue"). The IUCMA has the responsibility to pay over the revenue collected to the WTE or SANWRIA (indicated by the green line going from IUCMA to "DWS (WTE) or SANWRIA SOC Limited"). The WTE or SANWRIA then uses this money to pay the contractor for operating the plant and make principal and interest payments on the debt (indicated by the green arrows going from the "WTE or SANWRIA SOC Limited" to the "Contractor" and "Private" funder being the commercial bank).

The benefit of this model is that if the circumstances are right, then the full amount of funding required for the construction of the treatment plant could be borrowed. However, it would be crucial to ensure that revenue collection ties in with the debt service payments, so that the risk of late payments can be mitigated.

5.4.3 Administration

In this model, the IUCMA is responsible for administering the WDCS and ensuring that all the proper procedures and institutional arrangements are in place. The IUCMA would need to ensure accurate monitoring and compliance is taking place, as well as accurate calculation of the mitigation charge. However, the IUCMA needs to work closely with the WTE or SANWRIA to ensure that the revenue collected is ring-fenced and handed over to the WTE or SANWRIA in accordance with the arrangements.

5.4.4 Billing system and revenue collection

In this model, the IUCMA is the party responsible for the billing and revenue collection process. The IUCMA would need to ensure invoices are issued to the respective water users timeously and efficiently. Similarly, payments need to be processed without delay and ring-fenced for payment over to the WTE or SANWRIA. Once again, accurate debt management needs to be in place to ensure any outstanding invoices are followed up on and addressed.

5.5 MODEL 2B: CONCESSIONAL LOAN FROM A DEVELOPMENT AGENCY

5.5.1 Background

This model differs from Model 2a only in that the loan comes from the public sector, from development banks. These could be the African Development Bank, the Development Bank of Southern Africa or even the World Bank Group. These kinds of banks usually issue green or blue bonds, which are recent innovative loan mechanisms provided to support the achievement of the Sustainable Development Goals (SDGs) and improve the lives of society. These kinds of bonds work the same as a normal loan, except that the interest rates are much lower than market rates. This is because these mechanisms are more geared towards achieving impact rather than financial return.

5.5.2 Explanation of model

The model and transaction flows, indicated by the arrows, are presented in Figure 5-3.

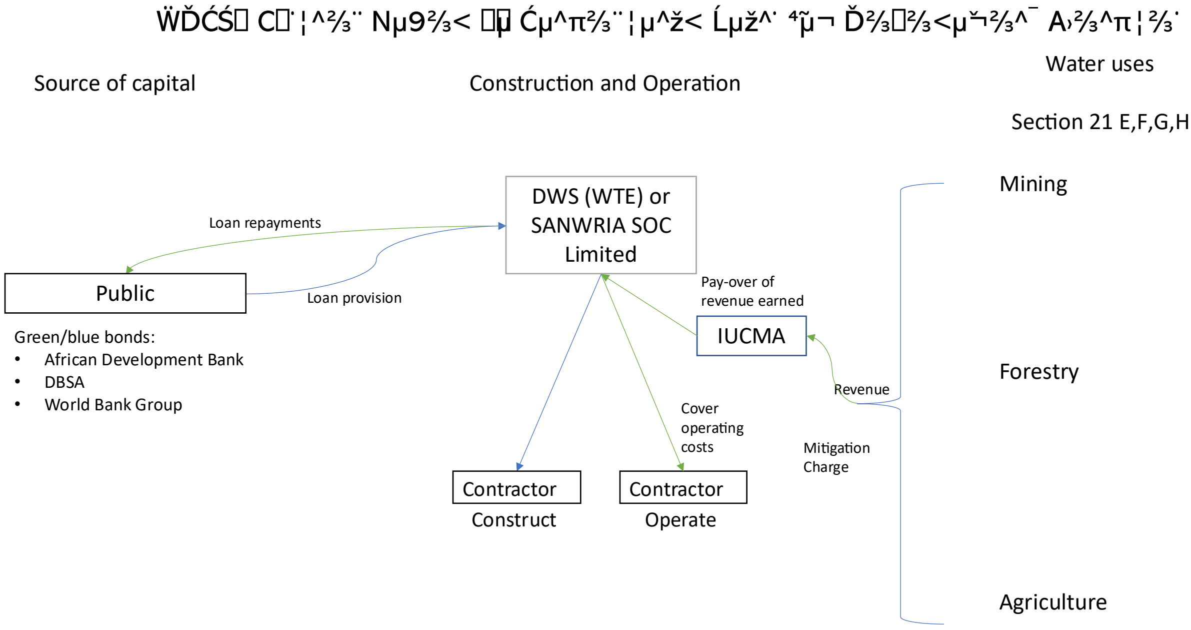

Figure 5-3: Graphis representation of Model 2b - Concessional loan from development agencies

The way this model works is the same as Model 2A above. A loan is provided to an entity able to borrow significant amounts of funds. The WTE and SANWRIA are two examples. This entity contracts private parties to construct and operate the treatment plants. The loan is used to pay the contractor for construction. Revenues are collected by the IUCMA, who pay the revenue over to the WTE or SANWRIA. They then use this money to pay the contractor for operating the plant and pay the debt service payments back to the public lenders.

This model has the advantage over Model 2a as the loan would be at concessional rates, meaning the debt payments would be less. Whether the full amount of the funding required for the construction of the treatment plant would be obtained is difficult to estimate, but this would only be apparent once the loan is agreed with the development bank. Once again, it would still be crucial to ensure that revenue collection ties in with the debt service payments, so that the risk of late payments can be mitigated. An important thing to note is that these kinds of bonds usually have a target impact in mind. Thus, the project might have regular and ongoing monitoring to ensure environmental, social or governance (ESG) targets are achieved.

5.5.3 Administration

As in Model 2a, the IUCMA is responsible for administering the WDCS and ensuring that all the proper procedures and institutional arrangements are in place. The IUCMA would need to ensure accurate monitoring and compliance is taking place as well as accurate calculation of the mitigation charge. However, the IUCMA needs to work closely with the WTE or SANWRIA to ensure that the revenue collected is ring-fenced and handed over to the WTE or SANWRIA in accordance with the arrangements. In addition, the WTE or SANWRIA may have to provide regular oversight and monitoring to ensure that any ESG targets the development bank may set is achieved.

5.5.4 Billing system and revenue collection

As with Model 2a, the IUCMA is the party responsible for the billing and revenue collection process. The IUCMA would need to ensure invoices are issued to the respective water users timeously and efficiently. Similarly, payments need to be processed without delay and ring-fenced for payment over to the WTE or SANWRIA. Once again, accurate debt management needs to be in place to ensure any outstanding invoices are followed up and addressed.

5.6 MODEL 3: PUBLIC-PRIVATE PARTNERSHIP (PPP)

5.6.1 Background

The PPP model has been quite extensively employed in the energy sector, specifically in South Africa's REIPP Programme. The model has been worked and tested and is thus a proven method of catalysing the private sector to invest in public infrastructure. Equity investment can play a crucial role in the WDCS operation and, if properly structured, can lead to an affordable mitigation charge.

5.6.2 Explanation of model

The model and transaction flows, indicated by the arrows, are presented in Figure 5-4.:

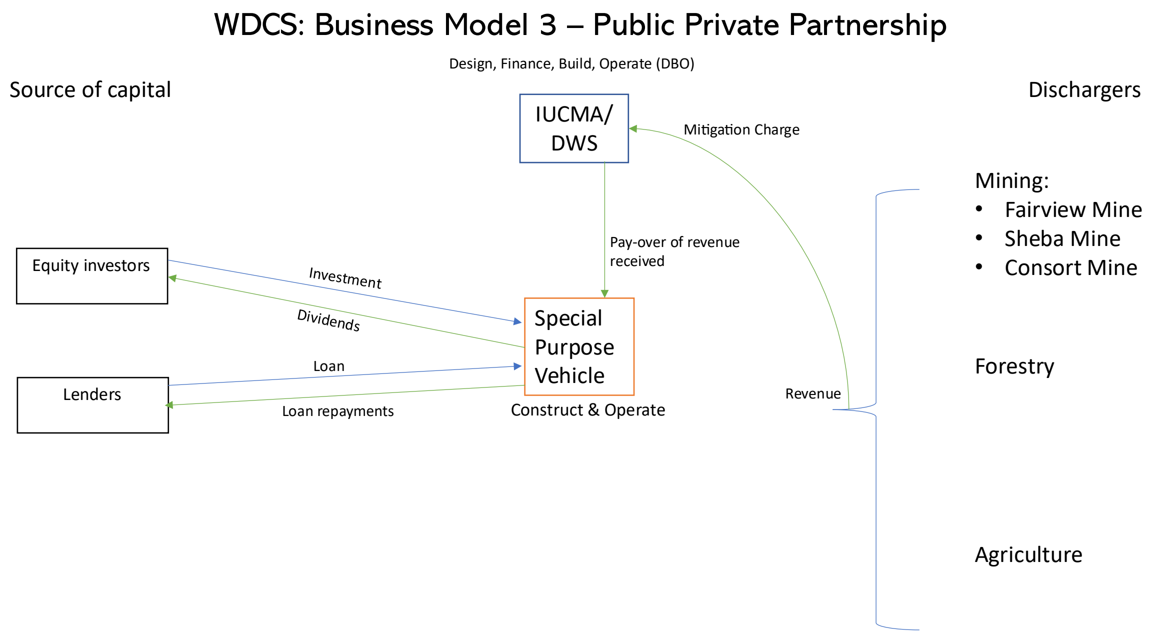

Figure 5-4: Graphic representation of Model 3 - Public Private Partnership

In this instance, the PPP arrangement will take the form of a "Design, Build, Finance, Operate (DBFO)" model. In this model, the private party to the agreement may set up a specific project company referred to as a special purpose vehicle (SPV). In this way, the financing sourced for the project is ring-fenced solely for the project. The SPV raises financing for the design and construction of the mitigation option. This is typically in the form of debt and equity.

Equity is provided by investors in the SPV, who set up the SPV and applied for the project. The SPV can raise debt from commercial banks or other financial institutions. The combination of debt and equity is aimed at lowering the cost of capital for the project. Additionally, the government could provide grants or subsidise the construction costs, which would then further lower the cost of financing. The lower the cost of financing the lower the mitigation charge will be.

The private party, via the SPV, would finance, design, build and operate the treatment plant for a certain period. The operating period would be negotiated with the DWS or IUCMA, but is usually for a period of 20 years or longer. During this period, the IUCMA will be responsible for implementing the mitigation charge and collecting revenue from the water users. The IUCMA then pays over this revenue to the SPV. The SPV uses the funds to pay the operating costs, service the debt and provide returns to the equity investors. At the end of the operating period, the assets may be transferred to the IUCMA or DWS, who would be responsible for operating the treatment plant. The IUCMA would then be responsible for charging the water users and collecting the revenue.

5.6.3 Administration

In this model, the IUCMA is responsible for administering the WDCS and ensuring that all the proper procedures and institutional arrangements are in place. The IUCMA would need to ensure accurate monitoring and compliance is taking place as well as accurate calculation of the mitigation charge. However, the IUCMA needs to work closely with the SPV to ensure that the revenue collected is ring-fenced and handed over to the SPV in accordance with the arrangements.

5.6.4 Billing system and revenue collection

For the PPP model to work, the billing system and revenue collection process need to be properly instituted and worked out. This is because revenues need to be secured in order to get the private sector interested in investment. The IUCMA would be responsible for the billing and revenue collection process. The IUCMA would need to ensure invoices are issued to the respective water users timeously and efficiently. Similarly, payments need to be processed without delay and ring-fenced for payment over to the SPV. Once again, accurate debt management needs to be in place to ensure any outstanding invoices are followed up on and addressed.

5.7 MODEL 4: BLENDED FINANCE INSTRUMENTS

5.7.1 Background

Blended finance instruments use development finance and donor funding to catalyse commercial capital, primarily from private sources, with the aim of achieving sustainability goals. One approach to blended finance is structured funds. Structured funds are funds that are capitalised by different tranches of capital (classes of investors with different risk-return profiles) with the aim of lowering the fund's risk profile, allowing commercial investors to invest in markets they would not usually invest in. Therefore, one method of financing the mitigation option is by setting up a structured fund.

5.7.2 Explanation of model

The model and transaction flows, indicated by the arrows, are presented in Figure 5-5.:

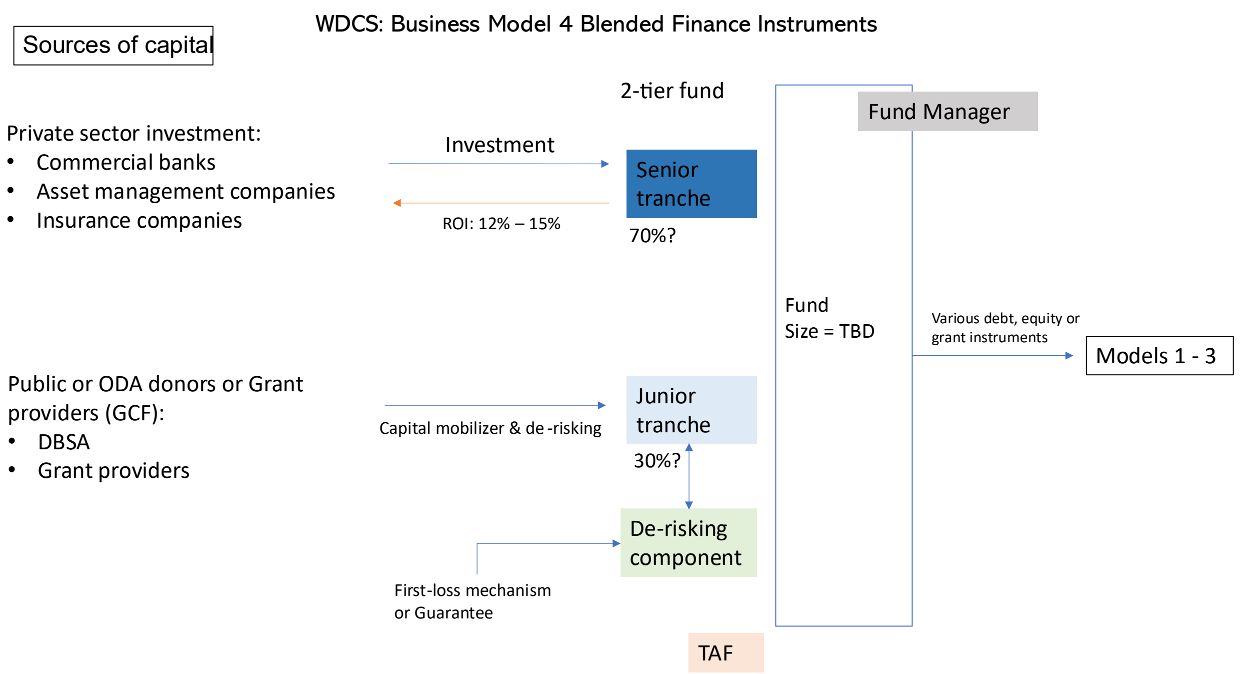

Figure 5-5: Graphic representation of a structured fund/blended finance instrument

In this model, the structured fund would need a fund manager. Any impact fund manager in South Africa could fulfil this role. The fund would be a two-tier fund with a junior and a senior tranche. The DBSA and other development agencies could invest in the junior tranche, with lower rates of return. Private commercial investors could invest in a senior tranche. The junior tranche lowers the risk profile of the fund, making it more attractive for the senior tranche investors.

The capital from the fund could be deployed for the IUCMA (Model 1), WTE, or SANWRIA (Models 2A&B) or for the establishment of a private company, which would construct and operate the treatment plant (much like Model 3). As with the other models, revenue is collected and used to provide returns to the fund.

5.7.3 Administration

In this instance, the fund manager would play an important role. Firstly, in sourcing the investors for the different tranches. Secondly, by working with the IUCMA to implement suitable institutional arrangements so that revenue sources are secure, and project risks are more easily identified and managed. The IUCMA would be responsible for calculating an appropriate mitigation charge, which would be informed by the fund manager and for making sure proper procedures are in place that make the WDCS work.

5.7.4 Billing system and revenue collection

It is most likely that the IUCMA would still be responsible for billing the water users and collecting the revenue. Thus, it is important that the billing system is accurate, and invoices are sent out timeously. Payment of the charge needs to be processed promptly and most likely should be ring-fenced, depending on the arrangements with the fund manager.

CHAPTER 6: MITIGATION CHARGE IMPLEMENTATION IN THE CROCODILE (EAST) CATCHMENT

6.1 OUTCOME OF THE PILOTING EXERCISE

The outcome of the piloting exercise for a mitigation charge in the Crocodile (East) catchment has shown that the most appropriate mitigation options result in **excessively high mitigation charges attributed to the high volumes of water ("river") that needs to be treated for the load to be removed.** The calculated abstracted volumes surpass the typical treatment capacity necessary for water treatment technology options assessed. The elevated costs also suggest a need for a larger treatment plant footprint and heightened environmental risk factors that demand attention. This option would need to be implemented at the outlet of the catchment (the most downstream point) and would also require water use authorisations for this activity. **Based on these high mitigation charge rates, it is evident that mitigation interventions and charges are non-viable.**

In terms of the WDCS, the determination of charges is to be based on the following principles (DWS, 2021):

- Economic efficiency: the charges should aim to create a situation where economic and environmental goals align in support of sustainable development, by providing an incentive for moving towards the efficient use and re-use of water.
- Affordability: the economic and social circumstances should be considered to ensure affordability of the system to both the regulatory infrastructure and waste dischargers.
- Equity and fairness: the system should not create inequitable impacts on different sectors of society and associated costs should therefore be equitably distributed.
- Simplicity: the charge structure and its estimation should be understandable both to the agency administering the system and dischargers, easy to implement, effective and limiting the cost of implementation.
- Transparency: should be ensured during the estimation and disbursement of the charges by means of extensive consultative processes and participation of affected parties.
- Consistency: the system must be consistent with national macro-economic goals and programmes as well as government initiatives that may impact on the system, including the raw water pricing strategy and environmental taxes.
- Stability: the system should be predictable and phased in so that dischargers can anticipate the expected final charge levels to create a stable costing environment.

In terms of this piloting exercise and analysis, it is evident that a business case does not yet exist to implement the mitigation charge. The high mitigation charge rates as determined for the Crocodile (East) catchment areas have indicated that the implementation of WDCS mitigation charge is not a viable option at this scale of improvement required. Because of the minor loads that need to be removed, the benefit to the water resource is not significant enough to warrant the high costs of the catchment mitigation.

The reasons for this are manifold and are set out in the roadmap action steps in Chapter 7.

The accuracy of the mitigation charge can only be determined once:

- Compliance and enforcement are in place, and as a result, the portion of the load to be removed has been accurately determined, apportioned to emitters and are accurately metered.
- All dischargers (point and non-point) are registered and compliant with their water use authorisations.
- Technically feasible mitigation options have been designed and costed.

- A technically sound catchment load model has been developed to apportion the excess load to each user, and
- A suitable funding model has been developed through which to raise the needed capital.

The affordability has to be tested against the expenses of the dischargers (water users). This has two components:
- The relative cost of the mitigation charge to the dischargers, and
- The cost to dischargers/water users of reducing their emission loads through internal measures.

Once all of the above conditions are met (accuracy, affordability and the other salient requirements discussed in the previous sections), the mitigation would be expected to be credible and implementable.

This outcome of the exercise has proven that insufficient information exists at this stage upon which to determine whether the mitigation charge is acceptable and affordable, and accurate.

6.2 WAY FORWARD FOR THE IUCMA

Based on the outcome, it is recommended that at this point the IUCMA focus on the following activities that will improve water quality management of the water resources and reduce the loads. The implementation of the WDCS mitigation charge is a long-term option that may only be implemented for specific catchments in South Africa, and at a stage when full compliance with waste discharge standards and water quality conditions by all users is attained. At this stage, the focus should be on source-directed controls, best practice and most appropriate technology, and achieving compliance.

This piloting exercise has highlighted that the implementation of the mitigation charge is not a viable option in the Crocodile (East) catchment and for most catchments in South Africa. To initiate the process that would possibly enable the implementation of the WDCS mitigation charge in the future in the Crocodile (East) catchment, the IUCMA should address the following aspects that are current functions and funded by the current water resource management charges (including the waste charge):

- Water Resource Monitoring (Load Assessment)
- Validation and Verification of Water Use
- Water Users and Water Use Authorizations
- Compliance and Enforcement
- Catchment Water Quality Management

A brief outline of the aspects for each function/activity is highlighted below.

Resource Monitoring for Load Assessment

1) Develop an IWQMP for each catchment and set WQPLs as identified. This plan will need to be incorporated into the CMS for the WMA that needs to be gazetted.
2) Identify water quality constituents of concern in each sub-catchment area.
3) Improve flow monitoring by reinstatement/construction of weirs.
4) Monitor gazetted RQOs and WQPLs that have been set.
5) Identify strategic monitoring sites for load assessment in each sub-catchment.
6) Undertake a catchment load balance for constituents of concern and determine available assimilative capacity for each constituent that can be allocated in each sub-catchment.

Validation and Verification of Water Use

1) Validate and verify all water use authorizations (WUAs) and facilitate transfer of all WULs from DWS to IUCMA to ensure that all water uses are accounted for and within the mandate of the IUCMA.
2) Update WARMS accordingly.

Water Users and Water Use Authorizations

1) For all WULs (new and existing), update as relevant to include applicable water quality parameters and limits, as well as discharge volumes to determine the assimilative capacity that exists in the water resource.
2) Authorize the water uses that are not currently registered or authorized.
3) Implement compulsory licensing if necessary.
4) Input all water quality parameters and limits, and volume data for each water user as per the water use authorizations into WARMS.
5) On a regular basis, input DW903 and DW904 data for each user into WARMS to track actual water quality and volumes (for users' load to be tracked as per registered parameters).

Compliance and Enforcement

1) Audit existing WULs and assess compliance.
2) Implement legal requirements and applicable regulatory instruments to address non-compliances e.g. Section 19, Section 20
3) Identify illegal water uses that need to be authorized.

Once all of the above is in place and full compliance by users is achieved in each catchment, and excess load is still present (in quantities that are severely impacting the sustainability of the water resource, exceeding or threatening the RQOs/WQPLs), the mitigation options in terms of the WDCS can be evaluated. Should this be viable the following will be required:

Mitigation Option

1) Confirm excess load (compare monitored load to RQO load)
2) Apportion the load to each sub-catchment and to each water user. This will require a standardised accepted methodology/approach to determine how much a water user is contributing to the excess load determined and will require evidence on behalf of the IUCMA to prove the contribution made by each water user. It is foreseen that the methodology of apportionment would need to be taken to stakeholders for consultation.

1) Undertake mitigation options analysis and select option(s) for implementation.
2) Determination of the charge rate per water quality constituent of concern per mitigation option(s).
3) Consult and engage the water users/stakeholders on the applicable charge rates.
4) Gazette the mitigation charge rates to be implemented.

Funding Model

1) Evaluation and selection of the funding model.
2) Setting up of the institutional, contractual, financing and business arrangements among the contracting parties.
3) Confirmation of the revenue collection mechanism and debt repayment.

WARMs Interface

1) Develop an interface that will allow input of a calculated load per user per catchment and the gazetted charge rate allocated to each water user per water quality constituent for the mitigation option selected.

SAP billing

1) Ensure that the linkages to the SAP billing process is in place and all water users’ data is current and accurate.

CHAPTER 7: THE WDCS IMPLEMENTATION ROADMAP

The outcomes of the piloting of the WDCS in the Crocodile (East) catchment have presented the mitigation charge rate and proposed business models for implementation. The process and approach can be considered technically sound and each aspect **in an ideal environment** can be determined and/or assessed to support charge development and mitigation implementation. In respect of this piloting exercise, the project proceeded with 'dummy' data where necessary and on **the assumption that all users are compliant with their waste discharge standards**, using as much current data as possible, and filling gaps as required, to determine waste mitigation charge rates.

However, based on the outcomes from the application of the approach in the piloting exercise, the process has highlighted that in order for the system to be implementable in catchments South Africa and achieve its objective of mitigating water quality deterioration in a catchment and making economic sense and being practically achievable, key elements need to be in place that are supported by necessary, legal, institutional, operational, regulatory and system enablers to achieve the desired outcome.

A properly implemented and managed WDCS would encourage desirable actions from waste dischargers, namely abatement of pollution at source, recycling of waste streams and wastewater, re-use of water, water conservation and return of water to source.

Implementation requires:

- All users are compliant with their waste discharge standards of their water use authorisations (in the absence of an incentive charge/ waste discharge levy);
- All water uses are authorised;
- Water Quality RQOs and/or WQPLs are gazetted for all catchment areas of concern (wider spatial extent into tributary catchments) within all integrated units of analysis in a WMA;
- Agricultural return flows and urban non-point source contributions are brought into the net of Section 21 water uses;
- All WARMS registrations are validated and verified, and the system is updated with all water quality constituents for each user with associated authorised loads;
- All water use authorisations are reviewed, verified and revised as necessary;
- All authorisation conditions are reasonable, relevant and being met.
- Users are submitting accurate and regular water quality monitoring data (loads).
- Adequate resources are available for compliance and enforcement;
- Adequate and reliable flow and water quality monitoring (surface and groundwater) networks are in place to support the load-based modelling and calculations (point and non-point).
- Sound and robust administrative and billing systems are in place.
- An interface between WARMS and SAP is developed to facilitate the billing (input of the apportioned load in a catchment and the determined mitigation charge rate).
- Activities are related to the mitigation charge versus the WRM waste discharge charge are ring-fenced and revenue is allocated to where it needs to be.

If the above mentioned aspects are not in place the responsible authority will first need to demonstrate that it has have followed the relevant legislative requirements under the NWA to achieve compliance, as trying to implement a mitigation charge without the above in place will certainly lead to court cases The fundamentals of adequate regulation, compliance, enforcement and monitoring need to be in place in order that users would be satisfied to pay a 'voluntary' mitigation charge. The mitigation charge can only be applied once all users are compliant and meet their discharge loads.

Currently, as it stands, the water resource management environment in South African, including in the Crocodile (East) catchment, does not appear to support the implementation of the WDCS mitigation charge at this point in time. This can be attributed to a lack of compliance and enforcement of WULs conditions, inadequate water quality and flow monitoring, incomplete water use authorization and registrations, non-compliant users, unauthorized users, a non-conducive environment to act against pollution and non-compliances, absence of integrated systems to manage these process, lack of resources (budget and manpower), lack of tools to accurately assess and apportion load, lack of integration of all the process that are meant to support it (e.g. RQOs, monitoring, regulation, compliance, WARMS, SAP), institutional misalignment between DWS functions and the IUCMA, non-corporation of water users and the various other factors that create mistrust between water users and the regulator. This system is based on the premise that water users will voluntarily pay for an intervention that they may not necessarily buy into or are not necessarily responsible for.

Based on the learnings from this piloting project a proposed road map to achieving successful implementation of the WDCS is outlined in Figure 7-1. The following aspects are seen as 'pre-requisites and non-negotiables':

- Legal Framework
- Institutional Competencies and Authority
- Resource Quality Objectives
- Water Use Authorization and Registration Management System
- Compliance and Enforcement
- Surface Water Monitoring Systems
- Incentive Charge (waste discharge levy),
- Apportionment of Load, and
- Stakeholder Buy-in and Partnerships

Chapter 2 of this report outlines the principles applicable to the implementation of the WDCS. Table 7-1 discusses the enablers and prerequisites necessary for implementation as they relate to principles and highlights the concerns that were noted during this piloting process that have a bearing on the successful implementation of the WDCS. These aspects were clarified and distilled, based on engagement with the responsible DWS Directorates and functions during a focused implementation workshop undertaken through the project. It was agreed that the WDCS and the mitigation charge are not at a point where they can currently be implemented in catchments in South Africa.

Based on the roadmap for implementation of the WDCS and the aspects identified for an enabling environment, Table 7-1 unpacks specific 'pre-requisites and non-negotiable enablers' that this study team has identified that must be met or be in place for the system to be considered robust, defensible, fair, equitable, viable and technically sound.

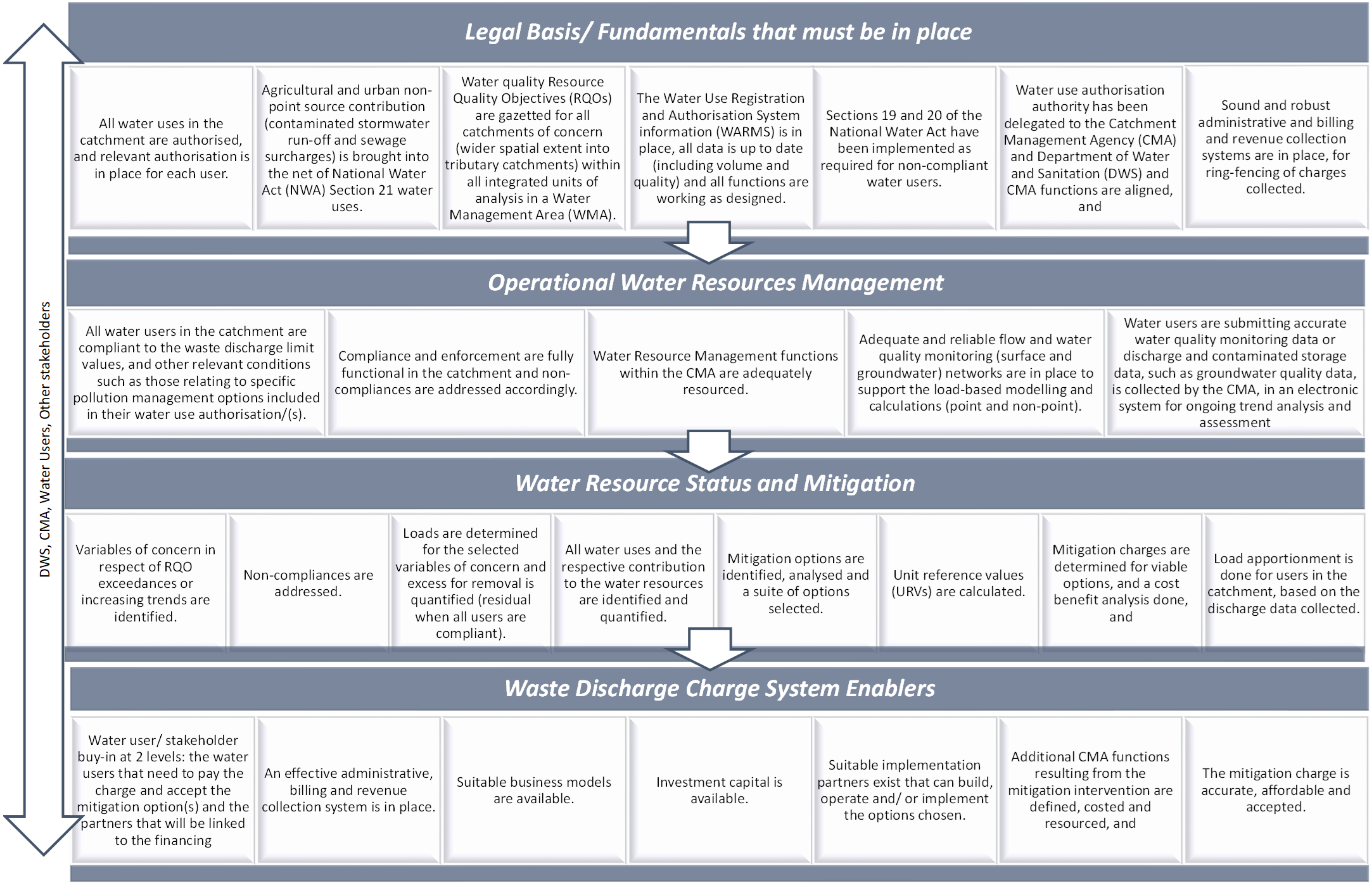

Figure 7-1: Roadmap to Implementation

Table 7-1: WDCS principles as related to enablers and implementation pre-requisites for the WDCS mitigation charge

Waste discharge system principle		***Enabling environment***	***Gaps related to the enabling environment for the mitigation charge***
1.	The mitigation charge is catchment based for a targeted pollutant	An adequate surface water and groundwater monitoring network must be in place to ensure accurate, up to date data at specific reaches within the rivers, and impacted aquifers, and must include quality and quantity monitoring.	Current water monitoring networks (surface and groundwater) are inadequate and do not necessarily cover the full extent of the catchment. For various reasons monitoring networks have been rationalised and discontinued, which does not support the WDCS implementation. Flow data is inadequate in that many weirs are no longer operational. In general, there has been steady decline of water quality monitoring in South Africa of recent years and until these systems are re-activated, extended, and updated, implementation of the WDCS will prove to very difficult. Use of modelled/ simulated flow will also need considerable calibration and verification before it will be acceptable, especially if there is court action. Water quality data may be supplemented if the water users' data is also captured, however this does not currently happen.
		All water users must be registered and authorised.	Water use registration is still incomplete as not all water users understand what is required, and not all water users are authorised.
		All water users must be compliant with their authorisation, and if not, it must be shown that all NWA Section 19 and Section 20 legal aspects have been implemented for all non-compliances. The National Water Act, 1998 (Act 36 of 1998) (NWA) has the tools to deal with non-compliance and pollution incidents. These sections of the NWA are supportive of the WDCS in the absence of the incentive charge/ waste discharge levy. Part 4 of the NWA deals with pollution prevention, and in particular the situation where pollution of a water resource occurs or might occur because of activities on land. This section must be applied before the WDCS is implemented. It needs to be used as a mechanism to ensure users are compliant and is a regulatory instrument that can be used to recover costs and support mitigation measures. Because it links to a specific user, the rest of the catchment does not have to bear the burden of the impacts.	The WDCS cannot be implemented until compliance is achieved, as there will be no legal basis to support the removal of excess load. It appears that the compliance and enforcement of water use conditions and waste discharge standards related to current authorised water uses is weak or lacking. It is not clear how many water users are compliant with the conditions of the water use authorisations issued, and what directives have been implemented and followed through in respect of Section 19 and Section 20 of the NWA. The WDCS cannot be implemented if non-compliance exists, as this would be considered unfair to those users that do comply.

Waste discharge system principle		*Enabling environment*	*Gaps related to the enabling environment for the mitigation charge*
		Part 5 of the NWA deals with pollution of water resources following an emergency incident, such as an accident involving the spilling of a harmful substance that finds or may find its way into a water resource. The responsibility for remedying the situation rests with the person responsible for the incident or the substance involved. If there is a failure to act, the relevant catchment management agency may take the necessary steps and recover the costs from every responsible person.	
		There will need to be proper ringfencing of WRM activities in a catchment/WMA as it relates to the WRMC for waste discharges and the mitigation charge.	It is important that the implementation model for the WRM charge for waste is well defined and that the CMAs have proper accounting systems in place so that double accounting does not occur with the two charges. Currently water resource management activities are split (DWS/ CMA) and it appears that they are not clearly defined and budgeted for. While the basis for charges is different, the WRM charge for waste being based on volume and the mitigation charge on a specific intervention related to a target constituent and water quality problem, how the revenue is distributed needs to be legally sound. For example, both would require monitoring activities.
		All users are compliant to their waste discharge standards (as per their WULs) and excess load is still present in the water resource.	This is the premise of the WDCS. Water users that are compliant cannot be expected to pay a mitigation charge if neighbouring water users in a catchment are non-compliant or unauthorized. The WDCS cannot be implemented until compliance is achieved, as there will be no legal basis to support the removal of excess load.
		For the mitigation options that remove more than one targeted pollutant sound, consistent methodologies are required to quantify the charge rate for removal of each individual pollutant in the catchment.	This piloting exercise has identified that it is quite difficult to quantify a single unit cost for one targeted pollutant when calculating the charge rate as most mitigation intervention options often result in the removal of more than one targeted pollutant (e.g. for salt removal). It is unclear that this point in time.

Waste discharge system principle		*Enabling environment*	*Gaps related to the enabling environment for the mitigation charge*
2.	Resource Quality Objectives (RQOs) (water quality) are the basis for calculation of the mitigation charge.	Water quality Resource Quality Objectives (RQOs) must be gazetted for all catchments of concern (wider spatial extent into tributary catchments) and for all constituents of concern, within all integrated units of analysis in a Water Management Area (WMA). Catchment load balances must be undertaken to determine the excess load in the system and sources areas of the load. This is required per constituent of concern.	For the study area the RQOs were gazetted in December 2017 (GN 1386). There will need to be some extrapolation to smaller tributaries where RQOs have not been set. The RQO determination process has been applied and completed in almost all WMAs, however it appears that due consideration of water quality impacts has not always been adequately done. Thus, in many instances the water quality RQOs set and gazetted for a WMA and related Integrated Unit of Analysis (IUA) are significantly inadequate and limited (only for a few water resources). In addition, RQOs have not been set for all water quality constituents of concern identified in a specific catchment, or as specified as part of the WDCS. The absence of water quality RQOs for the full spatial extent of the catchment specifically where a water quality concern exists is a gap, While currently not included, there will be an opportunity for revision of gazetted RQOs through the NWA amendment process which will allow for the update of the RQOs. There is also the option to use water quality planning limits (WQPLs), however it is important to note that e WQPLs are not gazetted, so are seen as guidelines. WQPLs will need stakeholder consultation and engagement through standardised processes before they can be adopted and applied. Water use authorisations have not been updated since the RQOs have been gazetted, and WUL conditions have not been set based on a catchment load balance and may therefore require amendments and there may be areas where compulsory licensing should be implemented.
3.	The WDCS will be based on load discharged. This approach (1) avoids dilution of effluent to achieve cost reduction, (2) is more equitable, as it does not disproportionately penalise small dischargers with	To apply load calculations flow measuring weirs need to be located at specific reaches in the rivers that will allow accurate load calculations and extrapolation upstream to the water users to enable load apportionment to individual users.	Inadequate flow measuring weirs as many have been taken out of operation. Water quality data may be adequate in this catchment; however, throughout South Africa water quality data is inadequate, especially related to apportionment of the charge.

Waste discharge system principle		*Enabling environment*	*Gaps related to the enabling environment for the mitigation charge*
	relatively higher effluent concentrations and (3) it is simple to implement.	Even should flow modelling be available, adequate calibration will be needed, based on accurate data. Using instream flow and quality for the identified parameters of concern, load is calculated per parameter to determine the catchment load at the downstream point. This catchment load then needs to be compared against the RQO load limits to determine whether there is assimilative capacity or whether load needs to be removed, and then load needs to be apportioned to users within the catchment. A catchment load model is required as well as a standardised approach/mechanism to fairly and equitably apportion the excess load.	A load-based model will need to be set up to apportion the load to individual users and has not been done in this catchment. The IUCMA is evaluating the use of the Water Quality Systems Assessment Model (WQSAM) (Slaughter et al., 2011) for load assessment. It was developed as a model linked to the SPATSIM (Spatial and Time Series Information Modelling) framework. It was designed to integrate water quality components with an existing quantity model. WQSAM directly inputs the water quantity output (storage, abstraction, return flows, incremental and cumulative flows) from a water resources system model (the Water Resources Yield Model). WQSAM is being considered to support the WDCS implementation in the Crocodile (East) catchment and is being applied to the catchment for the IUCMA. The model however does not cater for the load distribution, is complex and data intensive. Its suitability is still to be determined.
4.	A constant charge rate will be applied to the waste discharge load and will not vary against concentration.	Emphasises the need for adequate water quality monitoring and flow measurements to ensure a fair charge.	It has proven difficult to apportion the estimated load with the current gaps. While a charge was calculated, it was not possible to distribute the loads to individual users on a sound legal basis due to the lack of a defensible load model, and thus billing will not be possible. It is evident that this will prove to be a key challenge to the implementation of the WDCS. Determination of an appropriate distribution model that quantifies the load contribution back to the individual water user is fundamental (given that all other requirements are in place). The gaps described under point 1 in respect of monitoring are relevant.
5.	The WDCS applies to both surface and groundwater resources, where water quality planning limits (WQPLs) may be defined for the resource. A single approach applies to the calculation of the WDCS in both surface and groundwater.	Adequate water quality and quantity monitoring is in place. An Integrated Wate Quality Management Plan (IWQMP) must be developed for the WMA as a whole and the sub-catchments and would need to be incorporated into the Catchment management Strategy that will be gazetted.	Need clarity on how the groundwater apportionment will be implemented - this could not be done for the mitigation charge, possibly only for the incentive charge (waste discharge levy) which is no longer part of the WDCS. The use of water Quality Planning Limits (WQPL) has been mentioned in the WDCS strategy; however, these would need to be determined through the development of an Integrated Water Quality Management Plan (IWQMP) for the WMA, which falls under the ambit of the Water Resource Management Charge (WRMC).

	Waste discharge system principle	*Enabling environment*	*Gaps related to the enabling environment for the mitigation charge*
			No IWQMP has been developed for this WMA or it's sub-catchments, and there are very few WMAs for which this has been done. Very few Catchment Management Strategies have been developed or gazetted.
6.	Only registered waste discharge related water use, in terms of Sections 21 (e), (f), (g), and (h) of the NWA, will be liable for waste mitigation charges. This is applicable to point and non-point sources (NPS).	All water users in these categories will need to be registered. A NPS calculator has been developed by DWS and is part of the WARMS system. NPS are those pollutants that emanate from a site, facility or land and are transported into water resources because of rainfall infiltration, stormwater runoff or groundwater flow. The NPS load discharges into the water resource through diffuse pathways, which is a key distinguishing factor between point and NPS of pollution. It is often difficult to manage as it is not attributable to a single source. The NPS calculator is to be applied as part of WDCS process, with the aim of developing a methodology for measuring the load of diffuse pollutants into water resources. The calculator has been developed for registered water uses in accordance with Section 21 of the NWA, and treats registered NPS as point sources, whereby it seeks to calculate the load discharged into the resource to determine the potential impact of such a load.	Water use registration is still not adequately done. Return flows from irrigation with raw water, and contaminated run-off from urban areas which includes contaminated stormwater during rain events and surcharging sewers at all times, are not included in the registered Section 21 water uses (21 e, f, g and h) and therefore according to the current WDCS, no mitigation charge can be applied to these non-point sources even though these sources are often the largest contributors to poor water quality. This is relevant to many catchments in South Africa. The DWS should consider a regulatory measure to capture these uses under the net of the WDCS. This situation will make it difficult to apportion load back to the registered and compliant water uses. Alternatively, it may place a large burden on government to cover the mitigation costs linked to these sources.
		Alignment between institutional competencies and regulatory authorities *i.e*. DWS and the CMAs is required.	Where CMAs are established, not all functions and information in respect of the water uses in question, Section 21 e, f, g and h, have been adequately transferred. This is specifically related to the water use authorisations and the compliance and enforcement function. This was apparent through this piloting exercise, where water use authorisation information was split between DWS and the IUCMA. Records were absent or disjointed and knowledge of all water uses and users could not be confirmed. It is not possible to implement the WDCS if all the information does not reside with one authority.

Waste discharge system principle		***Enabling environment***	***Gaps related to the enabling environment for the mitigation charge***
		As the administrative system for identifying registered water users, the applicable Section 21 water uses, registered uses and the tool to serve as the interface to the SAP billing system for the mitigation charge, the WARMS information has to be accurate, up to date and valid. All water uses must be verified.	The Water Use Authorisation and Management System (WARMS) was found to be significantly outdated with major data gaps with respect to registered Section 21 water users. WARMS is not setup to cater for the calculation of the changes in water resource load as it is currently only linked to licensed use of each user. It includes a current load of a licenced user that must input on a monthly basis (linked to compliance) but not the change in load from upstream to downstream. In addition, there is no methodology on how to apportion the excess load to be removed to each licensee. The WARMS database will need to be developed further to include an interface that accounts for this load apportionment in the water resource. This interface would then cater for an input of the charge rate per water quality constituent being removed by the mitigation option.
7.	For non-point (diffuse) sources (NPS) associated with Section 21 (e), (g) and (h) the charge will be calculated as per point sources – based on the load discharged to the water resource. A desktop estimation of loads entering the resource will need to be made where adequate monitoring data is not available.	Desktop load estimation for non-point sources will need to be proven before it can be implemented which means that adequate up and downstream monitoring for all users will be needed. The NPS calculator has been developed for registered water uses in accordance with Section 21 of the NWA, and treats registered NPS as point sources, whereby it seeks to calculate the load discharged into the resource to determine the potential impact of such a load. The objective of the NPS calculator is to estimate the load entering the resource for: • Section 21 (e): engaging in a controlled activity, and • Section 21 (g): disposing of waste in a manner which may detrimentally impact a water resource. The data required for the calculator are: • Waste volume and quality variables and concentrations to calculate load. • Management Practices being implemented: o Best available technology leading to zero impact (BATZI) o Standard requirements (standard practices) o Poor management practices.	Section 21(h) is related to point sources, with an associated 21(g), so clarity is needed on what is meant here. The current situation is that there is inadequate up and downstream monitoring in many cases and where users are monitoring, there is no database to which it can be uploaded. Registration of these sources to include water quality parameters is necessary. Currently, in many instances, only volumes or tonnages are specified. The availability of the data to support the application of the calculator and the accuracy of the calculator outputs is not clear. This calculator also requires testing and validation to be accepted. Correct information must be available and monitoring data must be applied. Results can be easily contested.

Waste discharge system principle		***Enabling environment***	***Gaps related to the enabling environment for the mitigation charge***
8.	For point sources, these are easily measurable, and charges will be based on the monitored loads discharged.	Adequate up and downstream monitoring for each water user discharger must be in place.	Inadequate monitoring in many instances, and currently very little is known about the contribution from individual sources
9.	Government will be responsible for the costs associated with load that cannot be charged to registered water users.	Relates to Principle 6: *Only registered waste discharge-related water use, in terms of Sections 21 (e), (f), (g), and (h) of the NWA, will be liable for waste mitigation charges.*	This seems to indicate that government will pay for those water users that are not registered, which means that government is paying for non-compliance, and in addition government will be paying or poor land use, for example, run-off from irrigated and urban areas.
10.	The water quality load or concentration associated with water supplied to the discharger must be deducted from the load of water quality constituents that is discharged to get an accurate assessment of the contribution of the discharge to the water quality load, and then the calculation of the waste discharge charge.	Requires adequate water resource monitoring, upstream monitoring and downstream of a water use discharge. This functionality must be built in WARMS to determine the difference in load and an assessment mechanism to trigger if a charge is warranted.	Still, there is inadequate monitoring in many instances and where users are monitoring there is no database to which it can be uploaded. If the user is discharging better quality water than is abstracted, are these users exempted from the mitigation charge as there is no contribution in terms of load?
11.	The WDCS may be applied to all discharges contributing to the load in an upstream catchment where downstream resource quality objectives are threatened or exceeded, even where incremental upstream RQOs are met.	A surface water monitoring network will need to be in place to ensure accurate up to date data (quality and quantity) at specific reaches within the rivers. A catchment load-based model is required.	Current monitoring networks are inadequate and do not necessarily cover the full extent of the catchment.
12.	The mitigation measures and thus the associated waste discharge charges may be phased in to enable planning by dischargers and to allow adaptive setting of charges as conditions change.	Adequate scenario analysis and cost-benefit analysis must be done, especially around the removal of load and to what extent it is impacting the ecology and other users. Compliance and enforcement are required.	This is an important aspect as mitigation may be the construction of a facility and it is important to remember that once a facility is in place, the capital needs to be paid, and the facility needs to be operated and maintained. Once the load has been removed, it may no longer be required, so a detailed understanding and planning is essential, and source control and softer, greener options within the catchment are a far better option.

Waste discharge system principle		***Enabling environment***	***Gaps related to the enabling environment for the mitigation charge***
			A similar situation would arise should a new dam be constructed in the catchment, such as the Mountain View Dam on the Kaap River, Montrose Dam on the Crocodile East River, Boschjeskop Dam on the Nels River, and Strathmore Off-Channel Storage Dam, near the confluence of the Kaap and Crocodile Rivers, that are being considered (pre-feasibility phase). These would impact the load.
		All water users are compliant.	It is not clear what mechanism would be applied to get the users to voluntarily pay a mitigation charge, especially in cases where it can be shown that other water users in the catchment are illegal or non-compliant or are exempt from the mitigation charges (e.g., agricultural non-point run-off), and the regulator has not done the work to get all water users to be legally/compliant or undertake enforcement to prevent pollution. The legal basis for payment of the mitigation charge will need to be clarified. If it's not equitable or fair it will be difficult to enforce.
		Water user/ stakeholder buy-in is required. This applies at two levels, the water users that need to pay the charge and accept the mitigation option(s) and the partners that linked to the financing, operation and maintenance. Stakeholder buy-in can only be achieved if the system is robust, fair, equitable and defensible. As this a "voluntary" charge stakeholder trust is paramount.	At this point, the piloting exercise has indicated that there many gaps that exist in the process, and as such stakeholder support will be difficult to achieve. Stakeholders will be reluctant to support a mitigation option or pay a charge with so many unknowns and significant gaps in water monitoring, load assessment and apportionment, unregistered and non-compliant users, lack of compliance and enforcement, applicable RQOs in catchments of concern and accurate and up to date administration and billing systems.
13.	Minimum load thresholds for charging may be specified based on administrative cost considerations. The charges below the threshold will be waived and are intended to cater for small dischargers that may, for example, be generally authorised. These users are not excluded but	All water users need to be registered, and water use details validated and verified. All water users must be appropriately authorised. Loads will need to be accurately calculated and apportioned.	This is currently not the case as many users are unregistered and unauthorised. Information is also outdated. The WARMs system currently cannot be relied upon due to many inaccuracies in water user and use information. Accurate load calculation is important as a so-called small user may be thought to be polluting more than a big user, so accurate load calculations and apportionment are critical.

Waste discharge system principle		*Enabling environment*	*Gaps related to the enabling environment for the mitigation charge*
	are charged a zero charge in the system.		
14.	Non-point sources that are not registered in terms of the Section 21 water use under the NWA are currently not included.	These uses need to be brought in if the system is to be considered fair and equitable.	This excludes a very large portion of the pollution in many South African catchments that contribute considerably to the catchment load, and in many cases is likely to be > 80% of the load. There cannot be fair assessment and apportionment of load if users are not registered. In addition, a user cannot be charged a mitigation charge if they are not registered. All water users will need to be equitably and fairly ‘captured’ by the WDCS which is only possible through registration.

7.1 VOLUNTARILY PAYMENT OF CHARGE

It is not clear what mechanism would be applied to get the users to voluntarily pay a charge, especially in cases where it can be shown that other water users in the catchment are illegal or non-compliant or are exempt from the mitigation charges (e.g., agricultural non-point run-off), and the regulator has not done the work to get all water users to be legally/compliant or undertake enforcement to prevent pollution. This is viewed as being unfair and inequitable, which is contrary to the principles of the NWA and WDCS.

The legal basis for payment of the mitigation charge will need to be clarified. If it's not equitable or fair it will be difficult to enforce.

7.2 WATER RESOURCE MANAGEMENT CHARGE FOR WASTE DISCHARGES

It is important that the implementation model for the WRMC for waste is well defined and that the CMAs have proper accounting systems in place so that double accounting does not occur with the two charges. Currently, water resource management activities are split (DWS/ CMA) and it appears that they are not clearly defined and budgeted for. There will need to be proper ringfencing of WRM activities as they relate to each charge.

While the basis for charges is different, the WRM charge for waste is based on volume and the mitigation charge on a specific intervention related to a target constituent and water quality problem, how the revenue is distributed needs to be legally sound. For example, both would require monitoring activities.

7.3 WATER USE AUTHORISATION AND MANAGEMENT SYSTEM

The WARMS was found to be significantly outdated with major data gaps. As the administrative system for identifying water users, the applicable water uses, registered uses and the tool to serve as the key linkage to the billing system, the information must be accurate, up to date and valid. Currently, this is not the case. The WDCS cannot be implemented if this system is not in order. It can be easily contested by water users and rendered invalid in a court of law if all users are not captured with accurate, validated and verified information.

The system should be updated to include the functionality for users to upload water quality data, and potentially also volume data. This is specifically relevant for the load quantification and the billing component of the system.

Assessment of the WARMS system at a meeting with the DWS, the following has become apparent:

- DW903 and DW904 forms are meant to be submitted to the DWS by each authorised user. These include measured data for Section 21 (f) and (h) and 21 (e) and (g) water uses, respectively and include information that must be recorded in respect of:
    - Intake and output volumes for DW903 and waste volume onto land for DW904
    - Water quality variables (includes 44 variables which can also be added to) for both DW903 and DW904; and
    - Management classification details should be provided if there have been any changes over the monitoring period for the Section 21(e) and (g) water uses.
- This collected data from DW903 allows the WARMS system to calculate loads for the discharge under Section 21 (f) and (h); and the non-point source calculator is used to calculate loads from the DW904 data submitted for the Section 21(e) and (g) water uses.
- In this respect, WARMS data, and the loads calculated give only the load that would be discharged by a user, and not the loads up and downstream of the discharge, which would be required to determine the load contribution and the mitigation charges apportioned to the user, and
- These loads from WARMS would be relevant to the 'incentive' charge should it ever be implemented.

- Further calculation would be required to calculate the load in the water resource and to allocate it to a user. There is no platform for this to be submitted at the moment, although users should be submitting it in a water quality report, at intervals specified in the authorisation.

In this respect, the WARMS database will need to be developed further to include an interface that accounts for this load apportionment in the water resource. This interface would then cater for an input of the charge rate per water quality constituent being removed by the mitigation option.

CHAPTER 8: FUNDAMENTAL PREMISE

The Waste Mitigation Charge is based on the removal of excess load that will remain constant over a period and is determined on the selection of the most feasible and technically suited mitigation option to reduce this excess catchment load. The water quality load of the targeted constituent that exceeds the RQO or presents a threat to it is quantified.

Using instream flow and quality concentration for the identified targeted pollutants of concern, load is calculated per pollutant to determine the catchment load at the downstream weir/point. This load then needs to be compared against the RQO load determined at the compliance point to see whether there is assimilative capacity or whether the load needs to be removed. This excess load will ultimately need to be allocated to users in the catchment using a catchment-based load model.

The mitigation measure is evaluated in terms of its unit cost of mitigation. For feasible mitigation, the capital and operating costs of the mitigation option for load removal are calculated. The total load discharged for the targeted pollutant into the resource, which includes all point and non-point sources, is estimated and the unit Waste Mitigation Charge rate per load (kg) to be removed is calculated.

Through the piloting exercise, through the interrogation of the approach and the testing of how the WDCS would be implemented in a catchment, it has become evident that the mitigation charge can only be applied once all users are compliant and meet their discharge loads, and excess load still exists in a catchment. It is important to note that the mitigation intervention implemented is based on a historic load condition at a point in time and assumes that the excess load to be removed will remain constant and there is certainty that the intervention will operate as planned over the funding period to achieve the desired water quality. The mitigation charge rate is also determined based on this “certainty”; thus, any change in load, positive or negative, will defeat the objective of the mitigation and will not be considered fair and equitable to the user being charged.

This means that the excess load of the targeted pollutant is determined once, at a point in time at which the mitigation charge is determined. This implies that the volume of load to be removed per targeted pollutant has been determined and fixed and accepted with the charge rate. If it increases beyond the volume of the mitigation option feasibility assessment, it will potentially render the option inefficient, inadequate and exceed the design parameters; if the load drops below the volume of the mitigation option feasibility assessment, it will also render the option inefficient and unviable. This will have a significant impact on the financing, debt repayment of the option and revenue collection.

Coupled to compliance by all dischargers and fixed catchment load, for a user to be accurately billed, an apportionment of the excess load to their water use would have to be quantified prior to the issuing of an invoice. The user must be aware of their contribution and the estimated cost of charges that apply to his/her water use. This apportionment methodology is still absent, and if users are compliant, it is unclear how the apportionment of the load is to be done, as the mitigation charge is essentially around the historic load that needs addressing.

It is important to note that the load calculators currently included in the WARMS system for point and non-point sources are only relevant for load determined for individual point source dischargers, for example effluent from a WWTW, and estimated for non-point sources per water user, for example, pollution to a water resource from a pollution control dam or tailings facility, and are not relevant to use in the catchment-based load for allocation of load to users.

Thus, based on this premise, the viability and effectiveness of implementing the waste mitigation charge as a part of the WDCS is still not currently acceptable.

It is to be noted that the waste discharge levy (incentive charge) (charges that provide a disincentive or deterrent to the discharge of waste), as the second water use charge of the WDCS, has been excluded. The incentive charge is water user-specific, linked to a specific source of load and water pollution. The incentive charge is a mechanism that was meant to address the non-compliances, which would have served as a complementary instrument to the mitigation charge in the same catchment. Through the incentive charge, the non-compliances and sources of pollution could be addressed once all other NWA processes had been undertaken. This would instill some degree of fairness among users, ensuring that everyone is included in the net of charges. With its exclusion, it becomes difficult for the waste mitigation charge to be a defensible instrument for the removal of the load.

The mitigation charge relates to options that are considered for the management/ control of residual pollution that is still in place when all users are compliant. Thus, no incentive charge limits the regulators' ability to enforce the polluter pays principle to ensure compliance. It should be noted, however, that this is possible in terms of Sections 19 and 20 of the National Water Act, 1998.

The dual charge of the mitigation and incentive charges may provide the business case for the compliant user to be willing to pay a voluntary mitigation charge.

CHAPTER 9: CONCLUSIONS

Based on the analysis and outcomes of this project, the following conclusions and recommendations are made.

National considerations/ recommendations

- The premise for the implementation of a mitigation option and charge is that all water users are compliant with their water use authorisation conditions. This is a fundamental prerequisite to system implementation. **The system is based on the removal of excess load** above the RQO, which implies that all users are compliant, and the excess load removal will remain constant over a period for which a mitigation can be implemented and costed accurately. The compliance and enforcement function of the regulator is a key enabling component. At present, this function is ineffective and not achieving compliance by the enforcement of water use discharge/disposal conditions.

Recommendation: Assess the Compliance and Enforcement (C&E) functions and responsibilities and look at how this can be better managed; extend resourcing and capacity at the catchment level; Improve regulation and legal effectiveness of source management. Only once compliance is achieved in a catchment should the WDCS mitigation charge be considered.

- The water quality parameters included as part of the WDCS methodology (DWS, 2021), which fed into the pricing strategy, are not all applicable for the load determination approach of the WDCS mitigation charge. Examples are Electrical Conductivity (EC) and Chemical Oxygen Demand (COD), which do not lend themselves to load calculations.

Recommendation: Reassess the suite of water quality parameters to be applied as part of the strategy. A proposal would be to specify TDS and nitrate and orthophosphate, as overall national parameters, as they are good indicators of the salinity and nutrient status of water resources, and then situational water quality assessments must be conducted to identify the main water quality constituents of concern in areas where the WDCS mitigation charge is to be applied. This would make the mitigation options more relevant and address the local issue at hand.

- WARMS is the registration system for the water use and water user information, it is also the administration and billing system for the mitigation charge, and cannot be open to inaccuracies, inconsistencies and maladministration. Many uses are unverified, and the data on registered users and uses are outdated. It also seems that once data is added, it cannot easily be amended. The system at this point is only linked to the water quality parameters and discharge volumes of water users (single use load), thus a load is determined for the point discharge i.e., the section 21 (e), (f) and (h) water uses, and in some cases using the in-built non-point source calculator for the Section 21 (g) water uses. This relates to the incentive charge (waste discharge levy) that has now been removed from the WDCS. The system is unable to calculate catchment water resource loads to identify RQO exceedances and apportion back to the water users. A linkage from a catchment load model that will have apportioned excess load back to the users and to the SAP billing system is not available to charge the mitigation charge.

Recommendation: Validation and verification of all water uses (section 21 of the NWA) must be completed for all WMAs and fed into an update of the WARMS to ensure accuracy. An update to the WARMS system with an interface that links registered users to a catchment load model and the SAPs billing system is required. The development and maintenance of a water resources catchment load model will be required for implementation.

- The WDCS mitigation charge does not include non-point sources such as run-off/return flows from irrigated lands, and stormwater from urban and industrial areas.

Recommendation: These uses, such as run-off from irrigated lands and stormwater from urban and industrial areas, need to be brought into the suite of waste-related uses for the system to be considered fair and equitable, and the apportionment of load is to be accurate.

Water Management Area Considerations/Recommendations

- Monitoring is the central enabler to the successful implementation of the WDCS and for the water quality situational assessment. Implementation of the WDCS requires a well-structured, operated and managed surface water and groundwater monitoring network that extends into tributary catchments. This also requires a data management system linked to WARMs. This information must be defensible against any contestations. It's the basis for the load assessment to identify the excess load, for the quantification of the load, for the assessment of the mitigation options and for apportionment of the load. The monitoring programme and database system must be sound, with little opportunity for errors, and account for upstream and downstream water quality compliance data from users.

Recommendation: Assess the extent, applicability and efficacy of the current monitoring systems across all WMAs and update accordingly. Consider possible options that would allow external water users to upload their compliance data.

- The water quality component of the RQO process, as the basis for the WDCS, is technically sound. The RQO determination process is gazetted, and a step-by-step process is followed underpinned by considerable stakeholder engagement. The water quality component of the RQOs should highlight those areas where water quality is a concern, and which parameters are the main constituents of concern. This process is almost complete for all the WMA in South Africa, and with the amendments to the NWA (Act No. 36 of 1998), there will be opportunities to amend the RQOs, if necessary. There are, however, several WMAs where the RQOs have been set on a very broad scale, with few RQOs gazetted, which will make it difficult to apply only the water quality component of the RQOs for effective assessment of load in a sub-catchment. In addition, the RQOs set is not always set for the WDCS parameters specified as part of the system, and in some cases, appear very lenient (or possibly incorrect) to maintain or protect the water resource class that has been set.

Recommendation: Reassess RQOs distribution and water quality stringency within a catchment, and extend where necessary, especially for water quality priority hotspot areas.

- The use of WQPLs is a way in which the lack of water quality RQOs can be filled; however, these would need to be determined through the development of an IWQMP for the WMA, which falls under the ambit of the WRMC. The limits are also not gazetted and would need to be incorporated into the CMS that is gazetted for a WMA, after adequate stakeholder consultation.

Recommendation: Each WMA must have an IWQMP as part of the CMS that should specify WQPLs, at a finer scale as opposed to RQOs, which are most often at a coarser scale. The WQPLs determined should undergo stakeholder consultation. This will address the concerns of tributary catchments.

- To be a defensible, equitable and fair system, all water use authorisations must be valid, verified and issued for all water uses in the catchment, with appropriate conditions. These conditions should include, amongst other aspects, water quality limit values for a discharge as well as best practice aspects. The current situation indicates that many users are not authorised, or the authorisation conditions are not aligned to meet the assimilative capacity of the resource. The availability of a usable catchment load model and correct configuration to support load analysis, load balance and distribution is necessary for accurate and effective implementation of the mitigation charge. It is required to apportion the load transparently and consistently.

Recommendation: The CMA must develop and maintain a catchment load balance for each constituent of concern per sub-catchment, and once this is done, the water use authorisation limits or practices may need to be amended once assimilative capacity and the load balance are understood. Assess available models; an operational load balance model per WMA/ sub-catchment would be a very useful tool to allow a continuous assessment and understand where the hotspots are, which could then be easily dealt with. It is understood that the DWS has started using the SWAT model and that there is a database for the whole country that is being set up. It is also understood that the SWAT model has been set up for the Kaap catchment, so this could be a positive way forward, i.e., extension of the model to see whether it would be suitable for catchment load assessment from both point and non-point sources in the catchment, and it would be possible to allocate the load back to the user in the catchment. It may be possible that the streamflow prediction 'model' could be incorporated.

- A set of legal, institutional and governance arrangements will need to be implemented to ensure full and accurate and effective implementation of the mitigation charge, such as the funding models for the mitigation options that would require significant controls and measures to secure the investment and associated returns.

Recommendation: The CMA should have the necessary institutional and governance arrangements to secure investments and show credibility.

- Stakeholder and water user buy-in is key to successful implementation and to ensure voluntary payment for the mitigation charge, should it be implemented.

Recommendation: Establish and maintain good relationships with all water users in the catchment and with robust ongoing stakeholder engagement to get buy-in.

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APPENDIX A: Class per Integrated Unit of Analysis, and prioritised Resource Units and associated RQOs

IUA	Class	Resource Unit	Sub-component	Narrative RQO	Numerical RQO
X2-1	**II**	**MRU Croc A** X21A-00930 (EWR-C1)	Nutrients (Phosphate)	Acceptable	50th percentile of data must be less than 0.015 mg/l PO_4-P (aquatic ecosystems: driver)
			Electrical conductivity (salts)	Ideal	95th percentile of data must be less than or equal to 30 mS/m (aquatic ecosystems: driver)
			Faecal coliforms and *E. coli*	Recreation (intermediate use)	Meet the target water quality range of 0-120 counts per 100 ml.
		MRU Croc A X21B-00962 (EWR-C2)	Nutrients (Phosphate)	Acceptable	50th percentile of data must be less than 0.025 mg/l PO_4-P (aquatic ecosystems: driver)
			Electrical conductivity (salts)	Ideal	95th percentile of data must be less than or equal to 30 mS/m (aquatic ecosystems: driver)
			Faecal coliforms and *E. coli*	Recreation (intermediate use)	Meet the target water quality range of 0-130 counts per 100 ml.
		RU C1* X21B-00929 X21B-00898 X21B-00925	Nutrients (Phosphate)	Acceptable	50th percentile of data must be less than 0.025 mg/l PO_4-P (aquatic ecosystems: driver)
			Faecal coliforms	Recreation (intermediate use)	Meet the target water quality range of 0-1000 counts per 100 ml.
X2-2	**II**	**MRU Croc B** X21E-00943 (EWR-C3) X21D-00938 X21E-00947	Nutrients (Phosphate)	Acceptable	50th percentile of data must be less than 0.015 mg/l PO_4-P (aquatic ecosystems: driver)
			Electrical conductivity (salts)	Ideal	95th percentile of data must be less than or equal to 30 mS/m (aquatic ecosystems: driver)
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
X2-3	**I**	**MRU Elan A** (X21F-01046 X21F-1081 X21G01037 EWR-ER1)	Nutrients (Phosphate)	Acceptable	50th percentile of data must be less than 0.025 mg/l PO_4-P (aquatic ecosystems: driver)
			Electrical conductivity (salts)	Ideal	95th percentile of data must be less than or equal to 30 mS/m (aquatic ecosystems: driver)
			Faecal coliforms and *E. coli*	Recreation (full contact)	Meet the target water quality range of 0-130 counts per 100 ml.
			pH	Ideal	5th and 95th percentile of 6.5 and 8 (aquatic ecosystems: driver)
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
			Hexavalent Chromium	Ideal	95th percentile of the data must be less than 0.014 mg/l Cr (VI) (aquatic ecosystems: driver)
			Manganese	Ideal	95th percentile of the data must be within the target water quality range of 0.180 mg/l Mn

IUA	Class	Resource Unit	Sub-component	Narrative RQO	Numerical RQO
		RU C7 X21F-01100	Nutrients (Phosphate)	Acceptable	50th percentile of data must be less than 0.025 mg/l PO_4-P (aquatic ecosystems: driver)
			Electrical conductivity (salts)	Ideal	95th percentile of data must be less than or equal to 30 mS/m (aquatic ecosystems: driver)
			Faecal coliforms and *E. coli*	Recreation (full contact)	Meet the target water quality range of 0-130 counts per 100 ml.
			pH	Ideal	5th and 95th percentile of 6.5 and 8 (aquatic ecosystems: driver)
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
			Hexavalent Chromium	Ideal	95th percentile of the data must be less than 0.014 mg/l Cr (VI) (aquatic ecosystems: driver)
			Manganese	Ideal	95th percentile of the data must be within the target water quality range of 0.180 mg/l Mn
X2-4	**I**	**RU C8*** X21G-01090 X21G-01016	Nutrients	Acceptable	50th percentile of data must be less than 0.025 mg/l PO_4-P (aquatic ecosystems: driver)
			Faecal coliforms	Recreation (intermediate use)	Meet the target water quality range of 0-1000 counts per 100 ml.
		MRU Elan B X21G-01073 X21J-01013	Electrical conductivity (salts)	Acceptable	95th percentile of data must be less than or equal to 55 mS/m (aquatic ecosystems: driver)
			Nutrients	Acceptable	50th percentile of data must be less than 0.025 mg/l PO_4-P (aquatic ecosystems: driver)
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
			Turbidity	Acceptable	Not available (aquatic ecosystems: driver)
X2-5	**I**	**MRU Eland B** X21K-01035 (EWR-ER2) X21K-00997	Electrical conductivity (salts)	Acceptable	95th percentile of data must be less than or equal to 55 mS/m (aquatic ecosystems: driver)
			Nutrients (Phosphate)	Acceptable	50th percentile of data must be less than 0.025 mg/l PO_4-P (aquatic ecosystems: driver)
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
			Turbidity	Acceptable	Not available (aquatic ecosystems: driver)
X2-6 and	**II**	**MRU Croc C**	Nutrients (Phosphate)	Acceptable	50th percentile of data must be less than 0.025 mg/l PO_4-P (aquatic ecosystems: driver

IUA	Class	Resource Unit	Sub-component	Narrative RQO	Numerical RQO
part of X2-9		X22B-00987 X22B-00888 X22C-00946 X22J-00993 X22J-00958 X22K-00981	Electrical conductivity (salts)	Acceptable	95th percentile of data must be less than or equal to 55 mS/m (aquatic ecosystems: driver)
			Faecal coliforms and *E. coli*	Recreation (full contact)	Meet the target water quality range of 0-130 counts per 100 ml.
			Turbidity	Acceptable	Not available (aquatic ecosystems: driver)
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
			Manganese	Ideal	95th percentile of the data must be within the target water quality range of 0.180 mg/l Mn
X2-7	**I**	**RU C6*** X22A-00913	Turbidity	Acceptable	A moderate change from present with temporary high sediment loads and turbidity
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
			Arsenic	Ideal	95th percentile of the data must be less than 0.020 mg/l Arsenic (aquatic ecosystems: driver)
			Cyanide (free)	Ideal	95th percentile of the data must be less than 0.004 mg/l Cyanide (aquatic ecosystems: driver)
X2-8	**II**	**RU C12** X22C-01004	Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
			Manganese	Ideal	95th percentile of the data must be within the target water quality range of 0.180 mg/l Mn
			Turbidity	Acceptable	Not available (aquatic ecosystems: driver)
		RU C13* X22D-00843 X22D- 00846 X22E-00849 X22E-00833 X22F-00842 X22F-00886 X22F-00977	Nutrients (Phosphate)	Acceptable	50th percentile of data must be less than 0.025 mg/l PO_4-P (aquatic ecosystems: driver
			Electrical conductivity (salts)	Ideal	95th percentile of data must be less than or equal to 30 mS/m (aquatic ecosystems: driver)
		RU C14 X22H-00836	Electrical conductivity (salts)	Acceptable	95th percentile of data must be less than or equal to 55 mS/m (aquatic ecosystems: driver)

IUA	Class	Resource Unit	Sub-component	Narrative RQO	Numerical RQO
			Nutrients (Phosphate)	Tolerable	50th percentile of data must be less than 0.125 mg/l PO_4-P (aquatic ecosystems: driver)
			Faecal coliforms and *E. coli*	Recreation (full contact)	Meet the target water quality range of 0-130 counts per 100 ml.
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
X2-9	**II**	**MRU CROC D** X22K-01018 C4	Electrical conductivity (salts)	Acceptable	95th percentile of data must be less than or equal to 70 mS/m (aquatic ecosystems: driver)
			Nutrients (Phosphate)	Tolerable	50th percentile of data must be less than 0.125 mg/l PO_4-P (aquatic ecosystems: driver)
			Faecal coliforms and *E. coli*	Recreation (full contact)	Meet the target water quality range of 0-130 counts per 100 ml.
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
X2-10	**II**	**RU C16*** X23B-01052	Nutrients (Phosphate)	Acceptable	50th percentile of data must be less than 0.025 mg/l PO_4-P (aquatic ecosystems: driver)
			Electrical conductivity (salts)	Ideal	95th percentile of data must be less than or equal to 30 mS/m (aquatic ecosystems: driver)
			Turbidity	Acceptable	Not available (aquatic ecosystems: driver)
		RU C17* X23C-01098 X23E-01154 X23F-01120	Nutrients (Phosphate)	Tolerable	50th percentile of data must be less than 0.075 mg/l PO_4-P (aquatic ecosystems: driver)
			Faecal coliforms and *E. coli*	Recreation (full contact)	Meet the target water quality range of 0-130 counts per 100 ml.
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
			Arsenic	Ideal	95th percentile of the data must be less than 0.020 mg/l Arsenic (aquatic ecosystems: driver)
			Cyanide (free)	Ideal	95th percentile of the data must be less than 0.004 mg/l Cyanide (aquatic ecosystems: driver)
		MRU Kaap A X23G-01057 (EWR-C7)	Nutrients (phosphate and total inorganic nitrogen)	Tolerable	50th percentile of data must be less than 0.125 mg/l PO_4-P (aquatic ecosystems: driver).
					The 50th percentile of the data must be ≤ 4.0 mg/L TIN-N (aquatic ecosystems: driver).

IUA	Class	Resource Unit	Sub-component	Narrative RQO	Numerical RQO
			Electrical conductivity (salts)	Acceptable	95th percentile of data must be less than or equal to 200 mS/m (aquatic ecosystems: driver). Note this is a naturally salinised system.
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
			Toxics: Arsenic	Ideal	95th percentile of the data must be less than 0.020 mg/l Arsenic (aquatic ecosystems: driver)
			Toxics Cyanide (free)	Ideal	95th percentile of the data must be less than 0.004 mg/l Cyanide (aquatic ecosystems: driver)
X2-11	**II**	**MRU CROC D** X24C-01033	Nutrients	Tolerable	50th percentile of data must be less than 0.125 mg/l PO_4-P (aquatic ecosystems: driver)
			Electrical conductivity (salts)	Acceptable	95th percentile of data must be less than or equal to 70 mS/m (aquatic ecosystems: driver).
			Faecal coliforms and *E. coli*	Recreation (full contact)	Meet the target water quality range of 0-130 counts per 100 ml.
			Turbidity	Acceptable	A moderate change from present with temporary high sediment loads and turbidity
		MRU Croc E X24D-0094 (EWR-C5) X24H-00934 (EWR-C6) X24H-00880 X24E-00982 X24F-00953	Nutrients	Tolerable	50th percentile of data must be less than 0.075 mg/l PO_4-P (aquatic ecosystems: driver)
			Electrical conductivity (salts)	Acceptable	95th percentile of data must be less than or equal to 70 mS/m (aquatic ecosystems: driver).
			Temperature	Acceptable	A moderate change to instream temperature should occur infrequently, *i.e.*, vary by no more than 2°C. (aquatic ecosystems: driver).
			Faecal coliforms and *E. coli*	Recreation (full contact)	Meet the target water quality range of 0-130 counts per 100 ml.
			Toxics	Acceptable	95th percentile of the data must be within the chronic effect value range for toxics (DWAF, 1996a) or the B category in DWAF (2008) (aquatic ecosystems driver: C6)
X2-12	**II**	**RU C18*** X24A-00826	Nutrients (Phosphate)	Tolerable	50th percentile of data must be less than 0.125 mg/l PO_4-P (aquatic ecosystems: driver)
			Electrical conductivity (salts)	Acceptable	95th percentile of data must be less than or equal to 55 mS/m (aquatic ecosystems: driver)
			Faecal coliforms and *E. coli*	Recreation (full contact)	Meet the target water quality range of 0-130 counts per 100 ml.

IUA	Class	Resource Unit	Sub-component	Narrative RQO	Numerical RQO
		RU C19* X24B-00903	Nutrients (Phosphate)	Tolerable	50th percentile of data must be less than 0.125 mg/l PO_4-P (aquatic ecosystems: driver)
			Electrical conductivity (salts)	Acceptable	95th percentile of data must be less than or equal to 55 mS/m (aquatic ecosystems: driver)
			Faecal coliforms and *E. coli*	Recreation (full contact)	Meet the target water quality range of 0-130 counts per 100 ml.
			Toxics	Ideal	95th percentile of the data must be within the target water quality range for toxics (DWAF, 1996a) or the upper limit of the A category in DWAF (2008).
			Turbidity	Acceptable	A moderate change from present with temporary high sediment loads and turbidity

*Note: *RQOs and numerical limits developed but not included in the suite of key resource units RQOs that were gazetted. These RQOs will however form part of the analysis.*

APPENDIX B: Water Quality Statistics

Table B-1: Statistics for surface water quality monitoring sites in tertiary catchment - X21

Variables	Unit	X21 102958			X21 102961			X21 177758			X21 102994 (X2H070)		
		1966 - 2019			1972 - 2018			2015 - 2018			1983 - 2018		
		5	50	95	5	50	95	5	50	95	5	50	95
Calcium (Ca)	mg/L	5.5	9.1	13.0	7.3	18.2	39.2	6.3	10.7	15.0	6.8	8.7	11.4
Chloride (Cl)	mg/L	1.5	4.7	7.6	1.5	21.4	73.0	2.9	4.5	6.0	2.5	5.0	9.3
Total Dissolved Solids (TDS)	mg/L	60.9	101.0	126.0	75.0	178.3	391.5	139.4	139.4	139.4	82.4	101.4	123.8
Electrical Conductivity (EC)	mS/m	8.6	13.0	16.4	10.2	18.4	58.7	10.1	11.6	16.3	11.1	14.1	17.0
Fluoride (F)	mg/L	0.05	0.13	0.31	0.05	0.13	0.27	0.04	0.13	0.17	0.05	0.15	0.28
Potassium (K)	mg/L	0.34	0.87	2.11	0.15	0.71	1.91	1.26	1.38	1.49	0.74	1.11	2.48
Total Kjedahl Nitrogen (TKN)	mg/L	0.13	0.43	1.28	0.40	0.43	0.45	0.66	0.66	0.66	0.31	0.61	0.90
Magnesium (Mg)	mg/L	4.2	7.7	9.9	5.2	12.6	25.1	5.8	7.2	8.5	6.1	8.0	10.1
Sodium (Na)	mg/L	2.0	4.0	6.1	3.9	11.3	45.4	6.2	7.1	8.1	1.5	3.9	6.4
Ammonium as N (NH_4)	mg/L	0.02	0.03	0.15	0.02	0.02	0.11	0.05	0.05	0.13	0.02	0.03	0.12
Nitrate/ nitrite as N (NO_3/ NO_2)	mg/L	0.02	0.10	0.29	0.02	0.13	0.37	0.05	0.05	0.21	0.03	0.15	0.35
Total Phosphate (TP)	mg/L	0.03	0.04	0.13	0.01	0.01	0.01	0.05	0.05	0.05	0.01	0.06	0.19
pH		6.8	7.8	8.2	6.8	8.0	8.4	8.0	8.1	8.3	7.4	7.9	8.2
Orthophosphate as P (O-PO_4)	mg/L	0.003	0.02	0.10	0.00	0.02	0.06	0.01	0.01	0.02	0.01	0.01	0.04
Silica (Si)	mg/L	4.3	6.6	9.1	5.5	7.5	9.3	8.5	9.2	9.9	4.6	6.4	8.3
Sulphate (SO_4)	mg/L	2.0	4.7	10.1	2.0	17.8	76.7	1.5	2.0	2.4	2.0	5.1	9.5
Total Alkalinity (TAL)	mg/L	31.5	56.2	70.7	38.1	75.1	121.7	40.3	45.9	76.5	42.6	55.2	69.6

nd: no data

Table B-2: Statistics for surface water quality monitoring sites in tertiary catchment - X22

Variables	Unit	X22 102952			X22 102953			X22 102960			X22 102975			X22 88419 (= X22 102967)	X22 102993		
		1962 - 2017			1962 - 2018			1966 - 2017			1972 - 2018			2014 (1968 – 1992))	1977 - 2018		
		5	50	95	5	50	95	5	50	95	5	50	95	1 sample only	5	50	95
Calcium (Ca)	mg/L	3.9	7.5	11.9	6.6	12.4	20.0	3.5	7.9	13.8	7.8	13.4	20.4	9.4	0.5	1.9	9.2
Chloride (Cl)	mg/L	1.5	5.0	9.2	1.5	11.3	23.6	1.5	3.1	6.1	3.9	11.1	24.0	8.7	1.5	4.4	6.1
Total Dissolved Solids (TDS)	mg/L	46.0	76.3	112.2	69.2	123.8	196.1	37.0	71.0	120.0	80.0	135.0	205.0	nd	17.9	27.9	70.9
Electrical Conductivity (EC)	mS/m	6.0	10.1	15.3	10.0	17.5	29.7	5.0	9.5	14.5	11.0	17.0	30.2	14.9	3.2	4.3	9.3
Fluoride (F)	mg/L	0.05	0.12	0.27	0.05	0.14	0.26	0.05	0.05	0.27	0.05	0.15	0.33	0.15	0.04	0.10	0.20
Potassium (K)	mg/L	0.38	0.73	2.30	0.49	1.10	2.22	0.15	0.37	1.25	0.63	1.20	2.74		0.40	0.71	1.84
Total Kjedahl Nitrogen (TKN)	mg/L	0.15	0.15	0.15	0.47	0.47	0.47	0.39	0.39	0.39	0.68	0.68	0.68	nd	nd		
Magnesium (Mg)	mg/L	2.2	4.4	6.8	4.7	8.6	12.6	2.2	4.9	8.1	5.3	8.8	13.1	7.0	0.5	0.8	1.8
Sodium (Na)	mg/L	2.8	4.7	7.4	3.8	7.8	16.2	1.0	2.4	4.1	4.7	8.8	18.7		1.5	3.6	5.4
Ammonium as N (NH_4)	mg/L	0.02	0.02	0.10	0.02	0.05	0.24	0.02	0.02	0.08	0.02	0.04	0.12	0.05	0.02	0.05	0.35
Nitrate/ nitrite as N (NO_3/ NO_2)	mg/L	0.02	0.15	0.36	0.04	0.56	1.35	0.02	0.08	0.23	0.02	0.58	1.78	0.05	0.02	0.04	0.21
Total Phosphate (TP)	mg/L	0.02	0.05	0.11	0.07	0.07	0.07	0.01	0.01	0.01	0.08	0.08	0.08	nd	nd		
pH		6.4	7.6	8.0	6.6	7.7	8.2	6.4	7.5	8.1	6.7	7.7	8.2	7.9	6.4	7.3	7.8
Orthophosphate as P (O-PO_4)	mg/L	0.003	0.01	0.05	0.003	0.03	0.12	0.003	0.01	0.03	0.006	0.04	0.17	0.01	0.01	0.01	0.05
Silica (Si)	mg/L	5.6	6.6	7.8	5.5	7.2	8.8	5.3	6.7	7.7	5.0	7.3	9.5	6.2	3.8	4.7	5.9

Sulphate (SO_4)	mg/L	1.5	4.2	11.8	2.0	14.5	33.1	2.0	2.0	9.3	4.2	15.2	30.9	12.2	0.6	2.0	8.1
Total Alkalinity (TAL)	mg/L	21.7	39.3	60.9	30.6	54.0	75.8	17.1	38.9	67.7	34.6	58.6	82.6	42.2	4.0	11.6	36.3

nd: no data

Table B-3: Statistics for surface water quality monitoring sites in tertiary catchment - X23

Variables	Unit	X23 102954			X23 102955			X23 102965			X23 102968			X23 102974		
		1969 - 2018			1963 - 2018			1962 - 2017			1972 - 1996			1966 - 2018		
		5	50	95	5	50	95	5	50	95	5	50	95	5	50	95
Calcium (Ca)	mg/L	6.9	10.7	14.6	4.8	6.7	10.5	16.1	28.8	43.5	2.7	4.4	8.0	6.2	9.9	14.2
Chloride (Cl)	mg/L	1.5	5.0	8.9	1.5	5.0	7.9	10.3	20.2	40.7	1.5	1.5	4.0	1.5	5.8	9.9
Total Dissolved Solids (TDS)	mg/L	82.6	129.7	164.3	54.0	80.0	107.2	202.7	402.5	719.6	43.5	55.0	78.0	76.0	114.2	153.6
Electrical Conductivity (EC)	mS/m	11.2	16.9	22.2	7.2	10.1	14.1	27.2	50.6	83.3	5.5	7.1	10.7	9.6	14.4	21.0
Fluoride (F)	mg/L	0.05	0.13	0.27	0.05	0.12	0.30	0.17	0.33	0.73	0.05	0.05	0.17	0.05	0.17	0.32
Potassium (K)	mg/L	0.15	0.50	1.58	0.15	0.54	1.70	0.47	1.09	2.80	0.15	0.41	0.98	0.15	0.69	2.17
Total Kjedahl Nitrogen (TKN)	mg/L	0.28	0.28	0.28	0.54	0.54	0.54		nd		0.54	0.54	0.54	0.58	0.58	0.58
Magnesium (Mg)	mg/L	5.4	10.4	13.2	2.8	3.8	5.4	14.4	29.1	54.2	0.8	2.3	3.3	3.8	6.0	9.0
Sodium (Na)	mg/L	3.8	7.1	11.4	4.1	7.8	10.1	16.1	36.3	85.3	5.2	6.6	7.9	6.1	10.7	14.5
Ammonium as N (NH_4)	mg/L	0.02	0.03	0.10	0.02	0.02	0.08	0.02	0.05	0.13	0.02	0.02	0.11	0.02	0.03	0.09
Nitrate/ nitrite as N (NO_3/ NO_2)	mg/L	0.02	0.06	0.25	0.02	0.04	0.13	0.02	0.50	1.22	0.02	0.02	0.17	0.02	0.11	0.33
Total Phosphate (TP)	mg/L	0.00	0.00	0.01	0.03	0.05	0.22		nd		0.02	0.02	0.02	0.03	0.03	0.03
pH		6.7	7.7	8.2	6.4	7.6	8.1	7.3	8.2	8.6	6.1	7.0	7.5	6.6	7.7	8.2
Orthophosphate as P (O-PO_4)	mg/L	0.003	0.01	0.06	0.003	0.02	0.07	0.01	0.02	0.07	0.003	0.01	0.08	0.003	0.02	0.06
Silica (Si)	mg/L	7.6	11.7	15.1	7.1	12.6	14.4	10.7	13.4	19.6	11.4	13.6	14.9	7.5	12.7	14.5
Sulphate (SO_4)	mg/L	2.0	6.6	12.8	1.5	2.0	9.9	17.4	44.7	103.4	2.0	2.0	9.5	2.0	4.9	11.8
Total Alkalinity (TAL)	mg/L	41.5	71.2	91.4	27.8	43.0	58.5	92.2	185.7	340.2	21.2	31.3	43.4	38.2	61.1	83.2

nd: no data

Table B-4: Statistics for surface water quality monitoring sites in tertiary catchment - X24

Variables	Unit	X24 102963			X24 102979			X24 102986			X24 102995		
		1970 - 2018			1982 - 2018			1986 - 2018			1990 - 2018		
		5	50	95	5	50	95	5	50	95	5	50	95
Calcium (Ca)	mg/L	11.2	22.0	41.3	10.6	23.1	38.9	10.3	18.8	25.9	7.8	12.6	16.6
Chloride (Cl)	mg/L	11.0	26.5	64.3	14.3	37.1	99.4	8.7	18.8	32.9	16.6	24.7	43.1
Total Dissolved Solids (TDS)	mg/L	140.5	319.0	589.0	138.9	330.0	596.1	122.8	256.0	384.1	135.0	200.0	289.2
Electrical Conductivity (EC)	mS/m	19.8	42.7	75.2	19.9	46.0	80.8	17.5	35.8	51.7	19.3	27.7	37.2
Fluoride (F)	mg/L	0.14	0.28	0.55	0.15	0.28	0.47	0.13	0.22	0.36	0.24	0.34	0.57
Potassium (K)	mg/L	0.63	1.38	3.39	0.82	1.47	3.38	0.84	1.32	3.42	1.14	2.23	6.84
Total Kjedahl Nitrogen (TKN)	mg/L	0.24	0.59	1.44	0.29	0.56	1.50		nd			nd	
Magnesium (Mg)	mg/L	9.2	20.4	35.4	8.3	20.8	36.8	7.3	17.60	27.09	5.3	8.5	11.4
Sodium (Na)	mg/L	13.8	35.6	74.0	13.1	38.6	79.8	8.9	23.8	41.1	19.0	28.5	48.0
Ammonium as N (NH_4)	mg/L	0.02	0.05	0.12	0.02	0.05	0.14	0.02	0.0	0.1	0.02	0.04	0.09
Nitrate/ nitrite as N (NO_3/ NO_2)	mg/L	0.02	0.44	1.13	0.02	0.35	0.87	0.02	0.56	1.09	0.02	0.07	1.16
Total Phosphate (TP)	mg/L	0.02	0.06	0.15	0.02	0.04	0.16		nd			nd	
pH		7.3	8.2	8.6	7.4	8.2	8.7	7.3	8.07	8.46	7.6	8.1	8.5

Variables	Unit	X24 102963			X24 102979			X24 102986			X24 102995		
		1970 - 2018			1982 - 2018			1986 - 2018			1990 - 2018		
		5	50	95	5	50	95	5	50	95	5	50	95
Orthophosphate as P (O-PO_4)	mg/L	0.003	0.02	0.05	0.01	0.02	0.06	0.007	0.03	0.075	0.01	0.02	0.07
Silica (Si)	mg/L	7.8	11.1	18.2	7.3	10.7	16.0	6.7	9.33	11.49	3.8	8.4	12.7
Sulphate (SO_4)	mg/L	7.9	24.5	43.5	7.3	22.2	40.2	10.8	24.7	42.9	4.4	9.3	21.8
Total Alkalinity (TAL)	mg/L	65.9	152.9	279.6	61.3	149.4	254.7	55.4	119.3	182.2	51.4	91.7	128.7

APPENDIX C: Load Determination

Kaap River Catchment

Figure C-1 shows the Kaap sub-catchment illustrating the land uses and monitoring sites where load has been determined and that contributes to the load at the outlet of the Kaap River catchment. This also illustrated schematically in Figure C-2.

Aspects of the catchment are summarised in Table C-1, including water quality and quantity sites (weirs) at which quality and quantity have been assessed to determine the load at the outlet of this catchment, highlighting those areas of concern determined during the status assessment.

Table C-1: Kaap quaternary catchments description

Quaternary catchment	River	Water Quality site - WMS ID	Weir ID	Description of monitoring weir	Water users
X23A	Noordkaap River	X23 102955	X2H010	North Kaap River at Bellevue	• Extensive agriculture • Extensive forestry
X23B	Noordkaap River	No sites			• Extensive agriculture • Nature Reserve • Consort Mine
X23C	Suidkaap River	No sites			• Extensive forestry
X23D	Suidkaap River	X23 102974	X2H031	South Kaap River at Bornmans Drift	• Extensive agriculture • Extensive forestry • Glenthorpe Sawmill
X23E	Queen's River	X23 102954	X2H008	Queens River at Sassenheim	• Extensive forestry • Nature Reserve
X23F	Queen's River/ Suidkaap River	No sites			• Sassenheim residential area • Barberton Town • Barberton WWTW draining to Suidkaap River • Densely populated formal/ informal residential areas • Extensive forestry • Extensive agriculture • Nature Reserve • Fairview Mine • Barberton Mines Tailings' retreatment facility
X23G	Kaap River	No sites			• Sheba Mine • Natural areas
X23H	Kaap River	X23 102965	X2H022	Kaap River at Dolton; outlet of Kaap River catchment	• Extensive agriculture • Nature Reserve

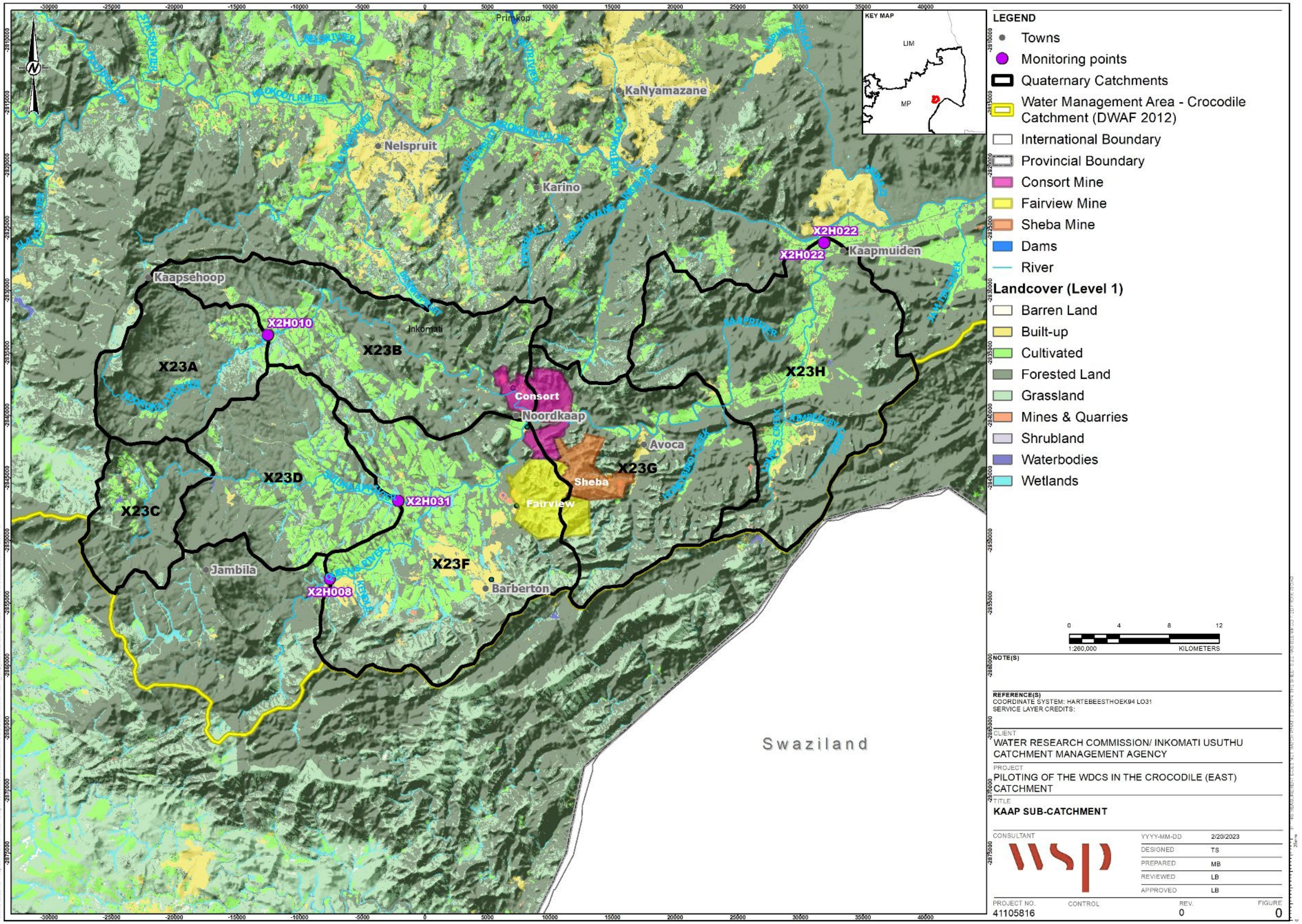

Figure C-1: Kaap River sub-catchment

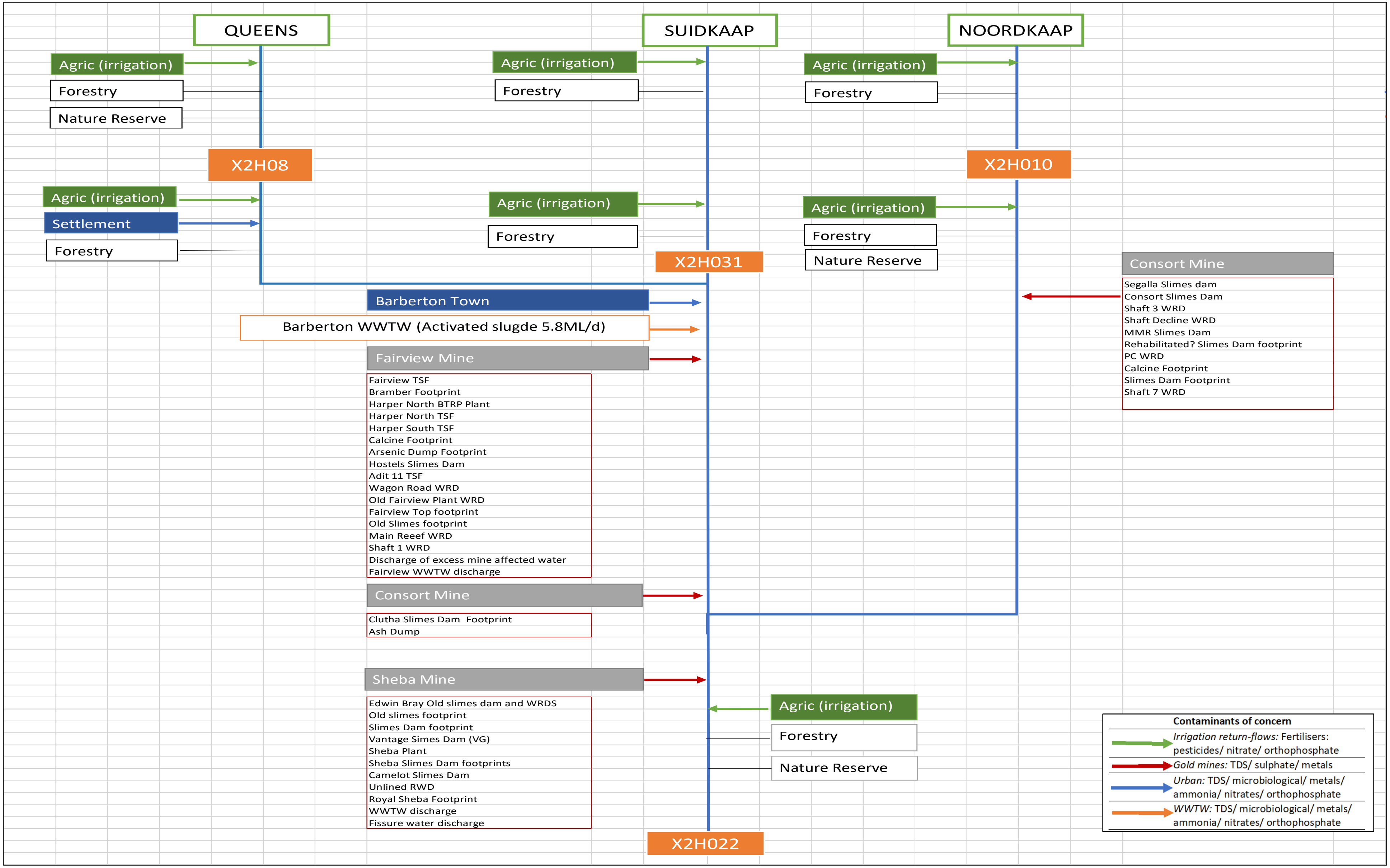

Figure C-2: Kaap River catchment schematic

Water quality and quantity data

Monthly average water quality data from January 2003 to the date on which flow was available were assessed and gaps filled with the monthly averages (Table C-3). Water quantity data was assessed for the 20-year period starting in January 2003 (Figure C-3). The flow rate graph indicates a higher flow rate at X2H31 on the Suid Kaap River, just upstream of the confluence with the Queens River at the outlet of quaternary catchment X23D. The change is indicative of the abstractions taking place in the downstream catchments of the Suid Kaap River in the area of the Town of Barberton and the Kaap River downstream.

Table 4-3 summarises the average monthly flow rates at the four weirs and the percentage that reaches the outlet of the Kaap catchment at X2H022, illustrating that the annual average percentage that reaches the outlet is only 18.67%. This is important as it reduces the catchments assimilative capacity.

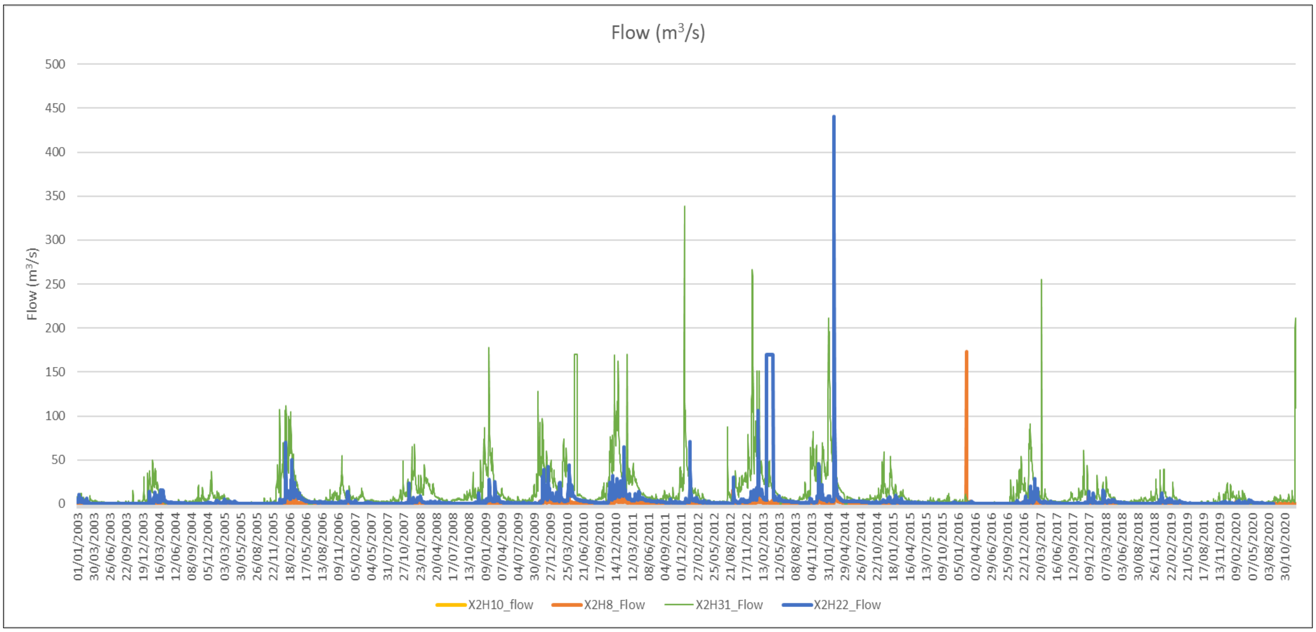

Figure C-3: Flow rate at the four weirs (Jan 2003 to Oct 2020)

Table C-2: Percentage flow reaching downstream weir (X2H022)

Month	X2H008	X2H031	X2H010	X2H022	Percentage of Total
January	128,787.72	2,191,363.82	84,996.39	474,230.25	19.72%
February	153,436.79	2,189,079.10	1,594,652.10	391,526.36	9.94%
March	126,462.97	1,501,603.66	522,351.95	1,160,557.47	53.97%
April	67,749.44	701,393.28	59,237.60	582,020.96	70.26%
May	37,860.08	655,118.86	433,706.01	173,343.33	15.39%
June	26,378.08	228,094.94	791,033.44	116,257.60	11.12%
July	21,232.57	214,917.21	26,943.95	91,080.15	34.62%
August	18,670.92	290,517.83	21,983.69	69,624.46	21.02%
September	24,217.58	432,809.28	21,165.63	64,368.51	13.46%
October	24,808.60	783,185.01	411,560.74	64,394.72	5.28%
November	55,359.87	1,503,393.20	891,317.14	185,755.43	7.58%
December	102,364.16	2,467,593.67	1,063,330.21	336,297.98	9.26%
Average annual flow	65,610.73	1,096,589.16	493,523.24	309,121.44	18.67%

Table C-3: Monthly average water quality

Month	X2H008				X2H031				X2H010				X2H022			
	TDS	Nitrate	Ortho-P	Sulphate	TDS	Nitrate	OP	Sulphate	TDS	Nitrate	Orthophos phate	Sulphate	TDS	Nitrate/ nitrite	OP as P	Sulphate
Jan	101.67	0.09	0.02	6.94	104.80	0.12	0.02	4.55	79.66	0.06	0.02	3.21	325.00	0.37	0.02	44.40
Feb	117.43	0.07	0.02	9.36	110.26	0.09	0.03	6.54	78.12	0.08	0.02	3.11	346.00	0.42	0.03	50.26
Mar	123.13	0.08	0.02	8.61	109.75	0.15	0.02	4.54	77.95	0.06	0.02	3.55	363.00	0.40	0.03	49.19
Apr	152.27	0.11	0.02	12.36	135.24	0.14	0.02	8.57	89.04	0.10	0.04	4.05	409.00	0.57	0.04	51.42
May	122.99	0.10	0.03	6.85	116.52	0.16	0.02	5.25	86.57	0.06	0.02	2.48	443.00	0.66	0.02	54.78
Jun	126.57	0.17	0.01	6.97	120.24	0.20	0.03	4.90	92.23	0.04	0.02	2.88	512.00	1.06	0.02	65.13
Jul	146.72	0.07	0.02	11.49	129.21	0.15	0.03	5.75	89.28	0.05	0.01	3.25	577.00	0.82	0.02	74.57
Aug	138.27	0.08	0.01	9.57	127.40	0.14	0.01	5.25	96.66	0.07	0.02	2.19	662.00	0.76	0.03	83.77
Sep	147.22	0.07	0.02	8.61	133.63	0.07	0.85	4.64	100.66	0.05	0.03	3.99	559.00	0.60	0.03	71.42
Oct	136.47	0.08	0.04	8.24	146.44	0.17	0.02	9.37	98.26	0.05	0.01	3.32	652.00	0.49	0.02	82.57
Nov	124.07	0.22	0.03	9.30	131.72	0.11	0.02	5.34	96.33	0.05	0.01	5.19	538.00	0.45	0.03	71.91
Dec	107.08	0.09	0.02	8.44	118.75	0.09	0.04	5.15	87.90	0.05	0.02	2.10	405.00	0.26	0.03	66.01

Load determination

Table C-4 sets out the average monthly load at the four sites, highlighting in red (-ve) where the average monthly calculated load (based on measured/ average data) is greater than the RQO load. Figures C5, C6 and C7 illustrate the measured load at the site vs the RQO load.

Table C-4: Average monthly loads to be removed

Catchment	Monitoring weir	Notes/ concerns	Month	Average monthly load to be removed (kg/d) - where measured load >RQO load (-ve)			
				Total Dissolved Solids	Sulphate	Nitrate	Ortho-phosphate
Queens River	X2H008 – upstream monitoring site	• This weir is located ~12km upstream of the confluence with the Suid Kaap River. • The contributions to the load at this site would come from the extensive forested area of quaternary catchment X23E, and excludes the Town of Barberton and it's WWTW, cultivated areas and Fairview Mine. • The calculated load assessment based on measured or average data vs the RQO load highlighted the following:	**Jan**	13,682.61	10,054.94	54.04	13.70
			Feb	10,962.83	11,829.13	66.26	16.39
			Mar	9,151.34	9,672.46	43.42	13.98
			Apr	4,138.79	4,984.95	26.92	7.26
			May	2,747.46	2,935.57	15.29	3.84

Catchment	Monitoring weir	Notes/ concerns	Month	Average monthly load to be removed (kg/d) - where measured load >RQO load (-ve)			
				Total Dissolved Solids	Sulphate	Nitrate	Ortho-phosphate
		○ The average monthly measured TDS load is still within the RQO load, however, is approaching the RQO of 195 mg/L. ○ Considering the land use in this catchment it appears that afforestation is the predominant contributor that is likely to be reducing the flow in the river and therefore reducing any assimilative capacity. ○ The water users are not included in the WDCS. ○ There is no downstream weir in QC X23F at a point just upstream of the confluence with the Noorkaap River, so any load in this area is not well understood. ○ A weir at this proposed site would indicate the load from the extensive cultivated areas in the QC, that is currently not accounted for.	Jun	2,059.01	2,058.24	8.90	2.97
			Jul	1,124.21	1,561.62	9.13	2.19
			Aug	1,167.31	1,415.23	7.99	2.11
			Sep	1,214.61	1,851.74	10.28	2.52
			Oct	1,935.29	1,894.14	10.81	2.31
			Nov	4,209.96	4,187.45	16.06	5.04
			Dec	8,742.60	7,877.09	41.97	11.39
Suid Kaap River	X2H031	• This weir is located ~2.5km upstream of the confluence with the Queens River at the outlet of X23D. • The flow at this point appears to be the highest in the Kaap catchment. The calculated load assessment based on measured or average data vs the RQO load highlighting the following: ○ There is limited non-compliance for orthophosphate. ○ The TDS load, while below the RQO load, is approaching that of the RQO of 195 mg/L. ○ The contributions to the load at this site would come from the extensive cultivation and afforestation in quaternary catchments X23C and X23D. ○ These water users are not included in the WDCS.	Jan	203,157.49	176,311.10	871.71	223.60
			Feb	184,383.89	170,271.62	851.67	194.63
			Mar	128,659.57	121,324.63	498.20	153.94
			Apr	43,321.70	54,246.36	235.70	76.00
			May	51,333.08	52,245.70	220.57	67.73
			Jun	18,023.97	18,395.09	64.68	24.01
			Jul	14,506.97	17,097.60	75.93	20.09
			Aug	20,824.30	23,233.42	108.18	33.16
			Sep	27,836.65	34,847.24	183.08	-399.75
			Oct	37,679.12	60,210.81	260.75	87.17
			Nov	98,809.61	120,136.96	586.36	164.18
			Dec	187,628.78	197,508.23	966.18	179.16
Noord Kaap River	X2H010	• This weir is on the Noord Kaap River at the outlet of X23A.	Jan	9,924.42	6,941.97	37.04	9.01
			Feb	179,897.87	131,256.00	681.66	171.54

Catchment	Monitoring weir	Notes/ concerns	Month	Average monthly load to be removed (kg/d) - where measured load >RQO load (-ve)			
				Total Dissolved Solids	Sulphate	Nitrate	Ortho-phosphate
		• Figure 4-6 illustrates the calculated load assessment based on measured or average data vs the RQO load highlighting the following: ○ The contributions to the load at this site would come from the extensive forested area of quaternary catchment X23A and cultivated areas downstream of the forestry. ○ There is no downstream site that would indicate the load from the cultivated areas, afforestation and Consort Mine in QC X23B.	Mar	61,175.06	42,555.02	228.84	54.65
			Apr	6,770.68	4,809.11	23.87	5.34
			May	47,061.55	35,794.31	192.48	46.26
			Jun	76,634.26	66,010.83	375.28	94.49
			Jul	2,856.40	2,202.88	12.03	3.02
			Aug	2,176.41	1,821.95	9.36	2.43
			Sep	2,010.91	1,707.84	9.59	2.13
			Oct	39,831.15	33,617.60	183.66	46.81
			Nov	87,959.82	71,137.24	400.82	98.58
			Dec	111,818.63	88,267.12	482.86	110.12
Kaap	X2H022	• This point is at the outlet of the quaternary catchment, X23H, the outlet of the Kaap sub-catchment. • This load includes the cumulative load of the tertiary catchment and would include the Town of Barberton, Barberton WWTW and the activities of Consort, Fairview and Sheba mines, however the load from theses sources is not known. • The flow at this point is, on average an estimated 80% lower than the combined flow at X2H008, X2H031 and X2H010, indicating considerable abstraction taking place. • It is unclear where the biggest abstraction is taking place, although considering the land-use (Figure 4-1) it is likely that it is in X23F, with lower abstractions in X23G and X23B. • The calculated load assessment based on measured or average data vs the RQO load highlighting the following: ○ TDS and sulphate both exceed the water quality component of the RQO on a number of occasions. ○ Orthophosphate is also a concern in that in many cases the measured orthophosphate load is close to that of the RQO load. ○ Water users that need to be further assessed in terms of their load apportionment to the catchment are: ▪ Consort, Fairview and Sheba Mines, and	Jan	42,518.63	19,138.76	1,716.27	49.16
			Feb	20,254.96	11,667.25	1,379.93	36.42
			Mar	35,312.11	37,497.20	4,193.08	108.06
			Apr	-4,658.68	17,612.70	2,006.79	47.31
			May	-971.17	5,522.67	588.08	17.30
			Jun	-10,807.63	2,295.73	341.34	12.33
			Jul	-16,158.19	798.27	288.57	9.33
			Aug	-17,345.37	-122.07	227.05	7.03
			Sep	-7,773.03	880.81	221.21	6.43
			Oct	-16,600.66	-83.76	225.92	6.55
			Nov	-27,109.89	2,683.89	659.47	18.25
			Dec	-4,478.71	5,074.31	1,255.80	33.55

Catchment	Monitoring weir	Notes/ concerns	Month	Average monthly load to be removed (kg/d) - where measured load >RQO load (-ve)			
				Total Dissolved Solids	Sulphate	Nitrate	Ortho-phosphate
		▪ Barberton Town and it's WWTW, ○ The cultivated and forested areas are not included in the WDCS. ○ There is no upstream site in X23G downstream of the mines to understand what load is being added by the mines, as well as what load may being added by the downstream activities in X23G and X23H.					

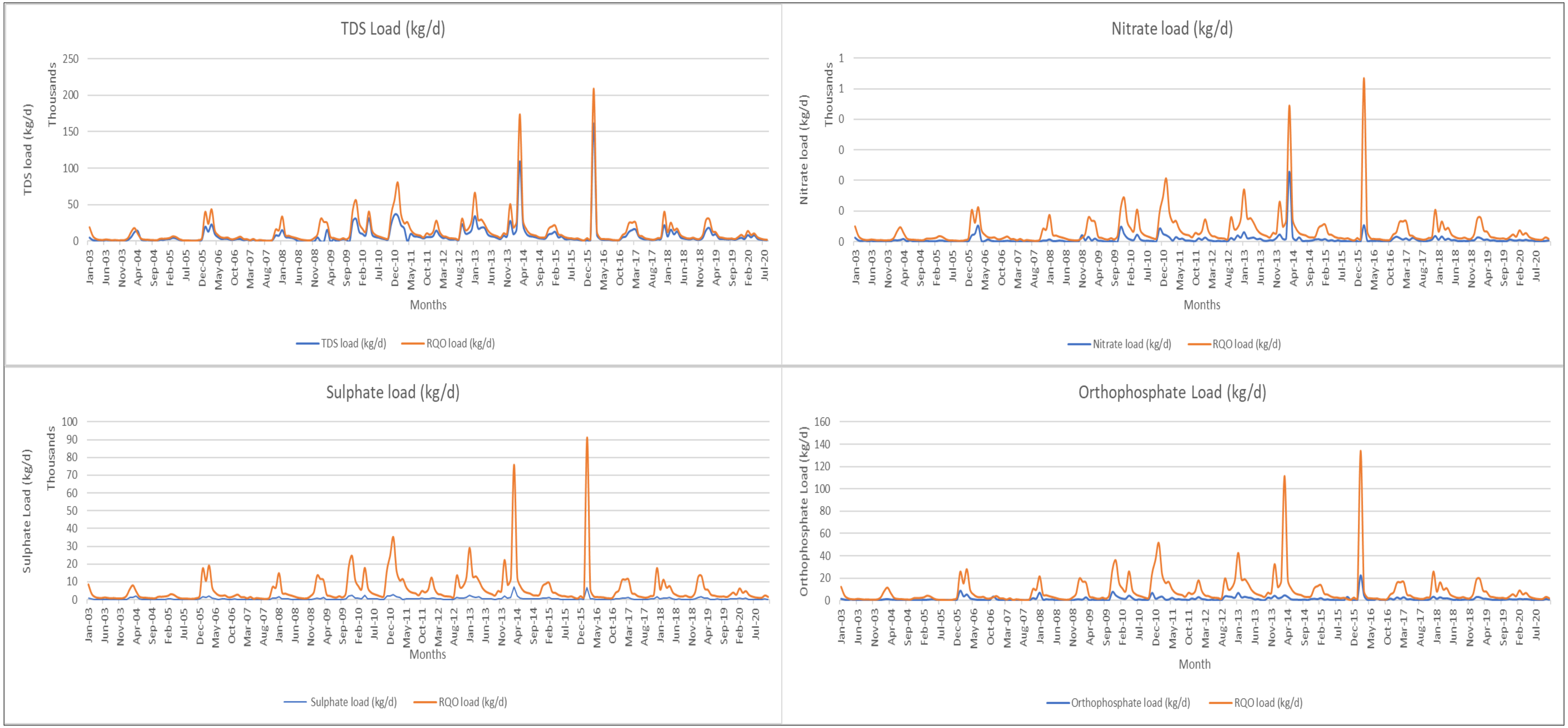

Figure C-4: X2H008 – measured load at the site vs the RQO load

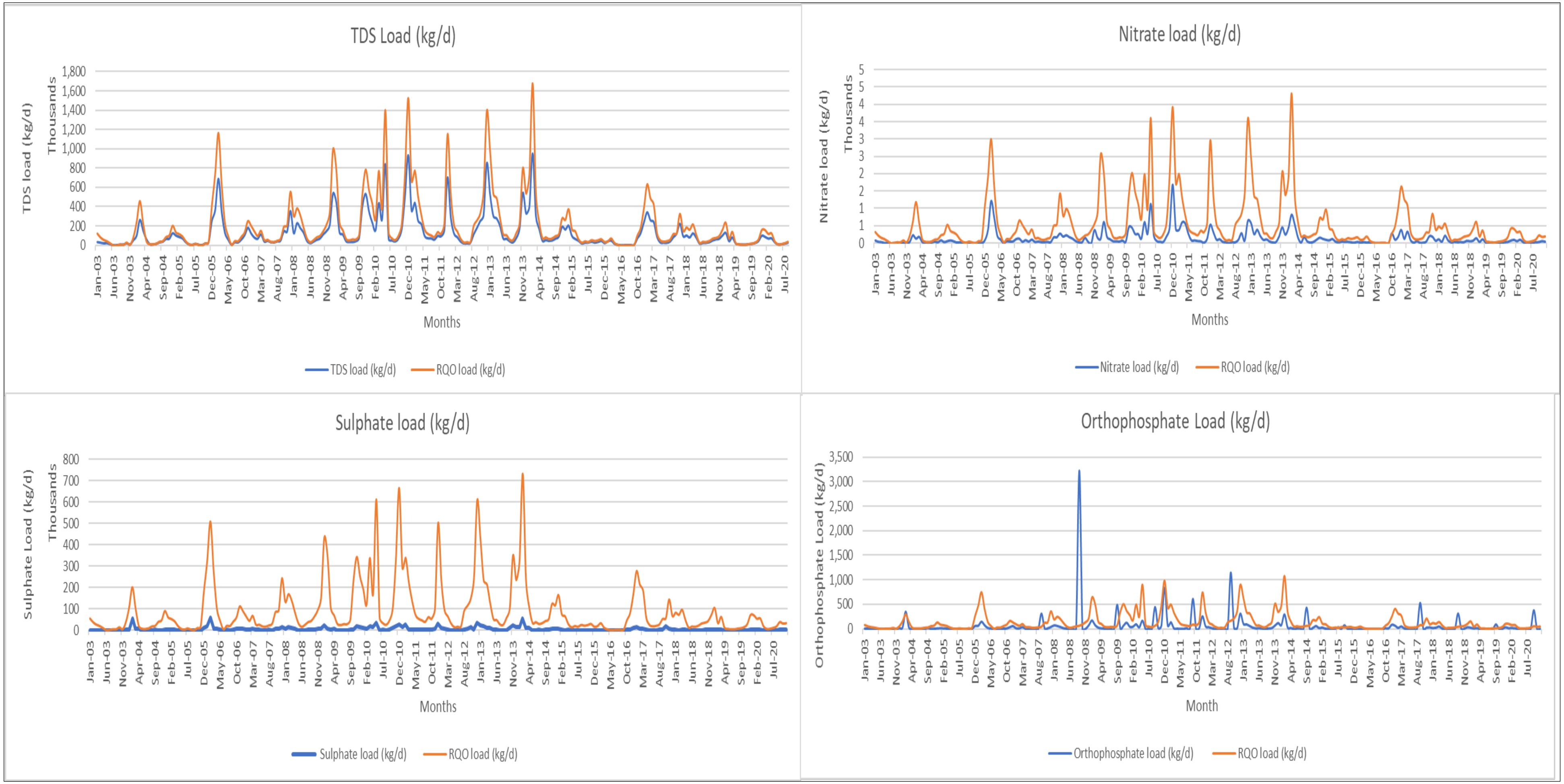

Figure C-5: X2H031 – measured load at the site vs the RQO load

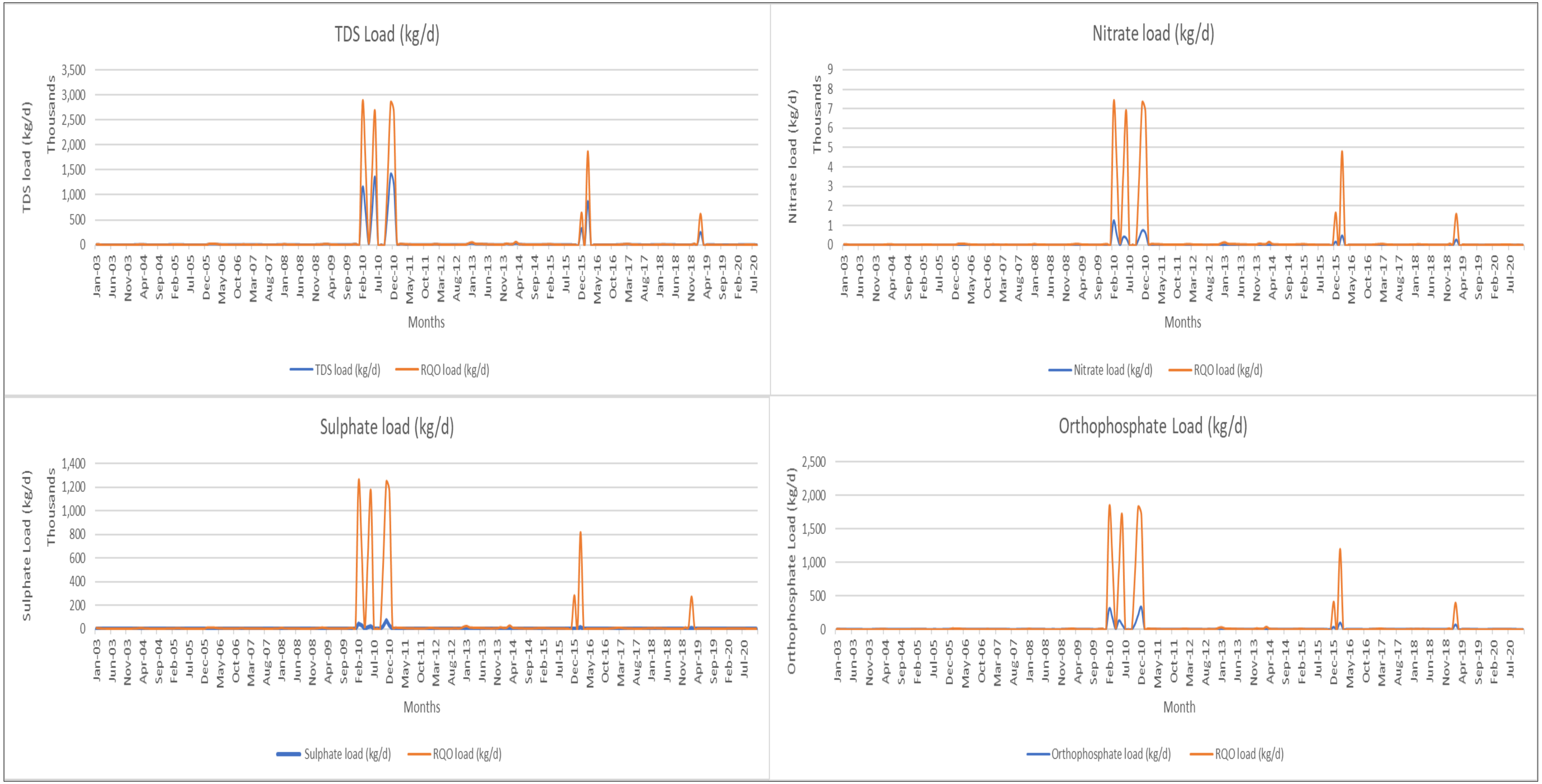

Figure C-6: X2H010 – measured load at the site vs the RQO load

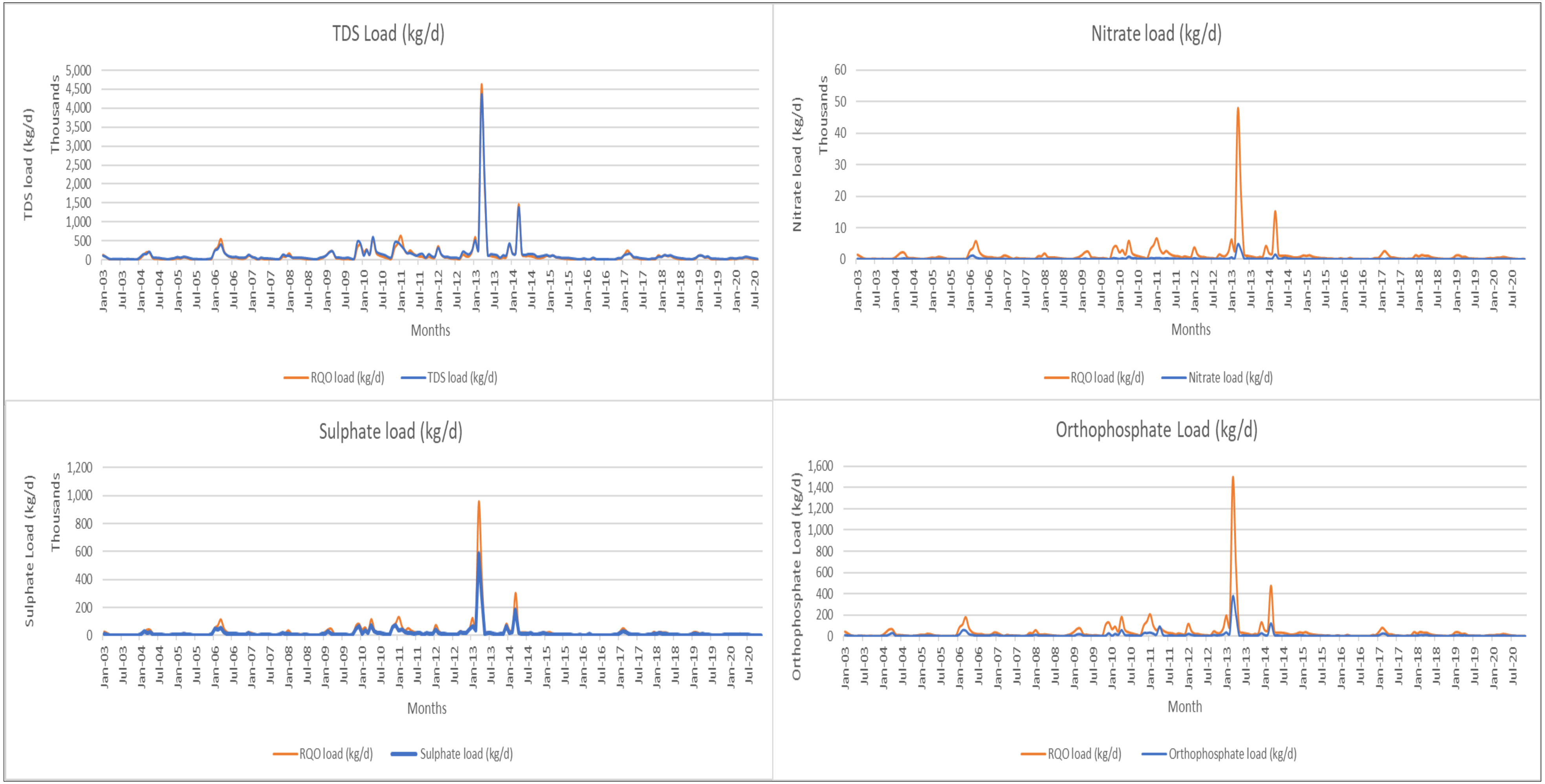

Figure C-7: X2H022 - measured load at the site vs the RQO load

The Elands River Catchment

Figure C-8 shows the Elands River sub-catchment illustrating the land uses and monitoring sites where load has been determined and that contributes to the load at the outlet of the Elands River catchment. This is also illustrated schematically in Figure C-9.

Aspects of the catchment are summarised in Table C-4, including water quality and quantity sites (weirs) at which quality and quantity have been assessed to determine the load at the outlet of this catchment, highlighting those areas of concern determined during the status assessment.

Table C-4: Elands River quaternary catchments' summary

<table>
<tr><th>Quaternary catchment</th><th>River</th><th>Water Quality site - WMS ID</th><th>Weir ID</th><th>Description of monitoring weir</th><th>Water users</th></tr>
<tr><td rowspan="2">X21F</td><td rowspan="2">Elands River/ Leeuspruit/ Dawsonspruit</td><td>X21 102957</td><td>X2H012</td><td>Dawsonspruit/ Leeuspruit approximately 1km upstream of the Elands confluence</td><td rowspan="2">• Agriculture
• eNtokozweni Town
• eMthonjeni WWTW discharging to the Leeuspruit
• ARM Machadodorp Works (metal processing)</td></tr>
<tr><td>X21 102956 (no data after 2009)</td><td>X2H011</td><td>On the Elands River at the outlet of the quaternary catchment</td></tr>
<tr><td>X21G</td><td>Elands River/ Swartkoppiespruit/ Joubertspruit/ Weltevredespruit</td><td>X21 177758 (3 data sets)</td><td>X2H047</td><td>At the outlet on Swartkoppies-spruit at Kindergoed.</td><td>• Waterval Boven Town
• Emgwenya (Waterval Boven) WWTW discharges to Elands River
• Agriculture
• Forestry</td></tr>
<tr><td>X21H</td><td>Ngodwana River</td><td colspan="3">No data after 1995 when it was measured upstream of the Ngodwana Dam</td><td>• Forestry</td></tr>
<tr><td>X21J</td><td>Elands River</td><td colspan="3">No sites</td><td>• Forestry
• Sappi Ngodwana
• Nature Reserve</td></tr>
<tr><td>X21K</td><td>Elands River/ Lupelule River</td><td>X21 102961/ 102962</td><td>X2H015</td><td>At Lidenau on the Elands River approximately 4 km upstream of the Crocodile confluence</td><td>• Forestry
• Sappi Ngodwana
• Agriculture
• Nature Reserve</td></tr>
</table>

There is a concern in this catchment in that there are only two weirs with adequate flow and quality data, X2H012, and X2H015. X2H012, is far upstream on a small stream (Leeuspruit/ Dawsonspruit) that would only include load from portions of the Town of Ntokozweni and is therefore not very relevant to the load determination in the Elands River. X2H015 is the most downstream point and is relevant in that it includes the Ngodwana Mill.

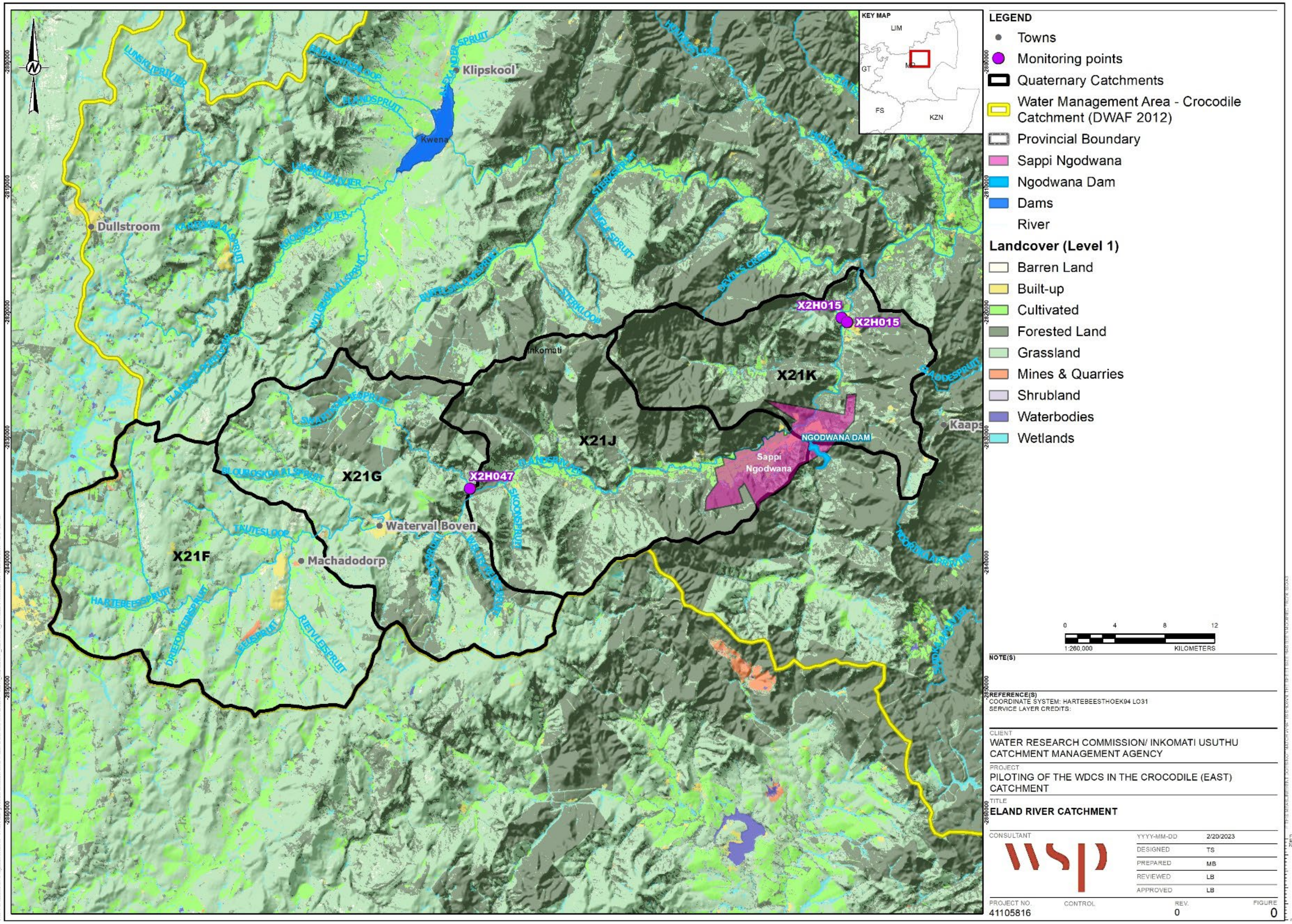

Table C-7: Eland River sub-catchment

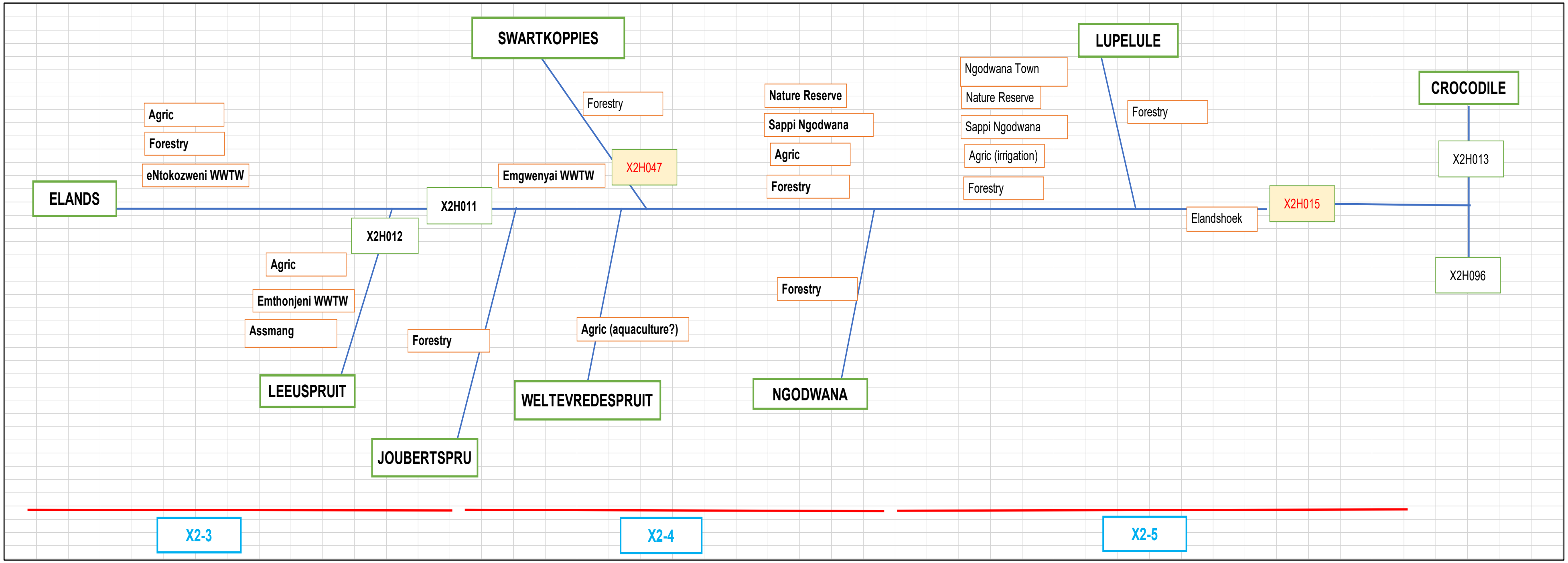

Figure C-8: Elands River catchment schematic

Water quality and quantity data

Monthly average water quality data from January 2003 was assessed and gaps filled with the monthly averages (Table C-5). Water quantity data was assessed for the 20-year period starting in January 2003 (Figure C-9). The graph illustrates the flow at the downstream point X2H015, and the weir located on the Dawsonspruit/ Leeuspruit approximately 1km upstream of the Elands confluence, that would only include load from portions of the Town of Ntokozweni and is therefore not very relevant to the load determination in the Elands River.

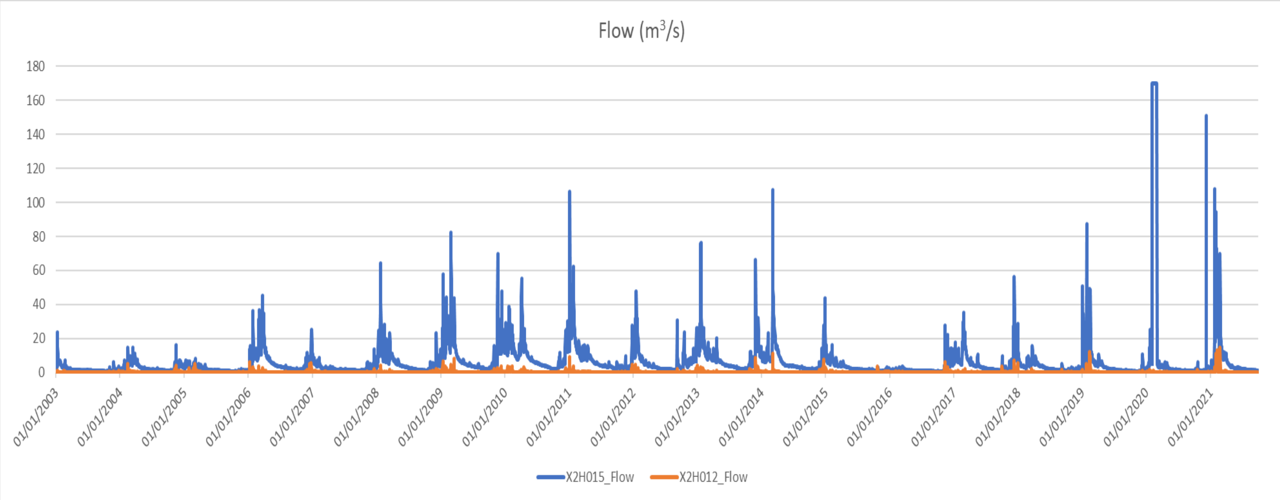

Figure C-9: Flow rate at weir X2H012 and X2H015 (Jan 2003 to Oct 2021)

The monthly average for the water quality parameters of concern at X2H015 (Monitoring site 102961) is set out in Table C-5.

Table C-5: Average monthly water quality at weir X2H015 (Monitoring site 102961)

Month	TDS	EC	Nitrate-Nitrite	OP as P	Sulphate
Jan	121.98	17.60	0.11	0.020	11.80
Feb	129.70	19.70	0.10	0.017	16.40
Mar	148.80	20.90	0.18	0.018	18.40
Apr	173.10	23.80	0.14	0.017	23.30
May	175.20	27.20	0.13	0.016	24.00
Jun	214.80	31.20	0.15	0.020	31.20
Jul	195.40	29.30	0.15	0.017	23.50
Aug	225.20	35.40	0.16	0.020	36.60
Sep	257.90	37.30	0.15	0.024	38.10
Oct	220.10	33.69	0.16	0.020	33.20
Nov	170.12	26.60	0.20	0.025	21.50
Dec	146.60	21.50	0.22	0.036	18.80

Load determination

Table C-6 sets out the average monthly load at the downstream site, highlighting in red (-ve) where the average monthly calculated load (based on measured/ average data) is greater than the RQO load. The measured load at the site vs the RQO load is illustrated in Figure C-10.

Table C-6: Average monthly loads to be removed at outlet of the Elands River catchment

Catchment	Monitoring weir	Notes	Month	Average monthly load to be removed (kg/d) - where measured load >RQO load (-ve)			
				Total Dissolved Solids	Sulphate	Nitrate	Ortho-phosphate
X21K	X2H015 (X21 102961)	• Weir X2H015 is located at Lidenau on the Elands River approximately 4 km upstream of the Crocodile confluence, and the most downstream point in quaternary catchment X21K. • The load measured would include all the upstream users of forestry and agriculture, as well as Sappi Ngodwana timber Mill. • The data in the adjacent table and illustrated in Figure 5-4 indicates that sulphate and orthophosphate are concerns when compared against the Class I (as gazetted) limits of 30mg/L and 0,015 mg/L. There is still assimilative capacity for total dissolved solids and nitrate. • The problem is that there are no upstream sites that can assess where the main sources are, however, Sappi Ngodwana should have upstream and downstream data that they could share, to at least give an indication of what is upstream of Ngodwana.	**Jan**	229,432.71	12,069.25	621.92	-8.75
			Feb	176,366.12	6,539.92	506.88	-6.16
			Mar	164,343.78	4,758.13	473.87	-6.19
			Apr	95,561.10	-1,216.26	353.00	-1.82
			May	52,504.35	-3,502.08	212.02	-0.07
			Jun	27,076.85	-4,702.06	144.37	-0.96
			Jul	25,325.12	-1,995.56	119.81	-0.77
			Aug	15,233.73	-5,446.82	101.39	-1.24
			Sep	6,158.99	-4,463.81	92.52	-1.70
			Oct	18,221.56	-4,342.68	105.23	-1.04
			Nov	54,441.57	-1,006.13	140.10	-6.77
			Dec	144,787.33	3,156.39	248.54	-45.73

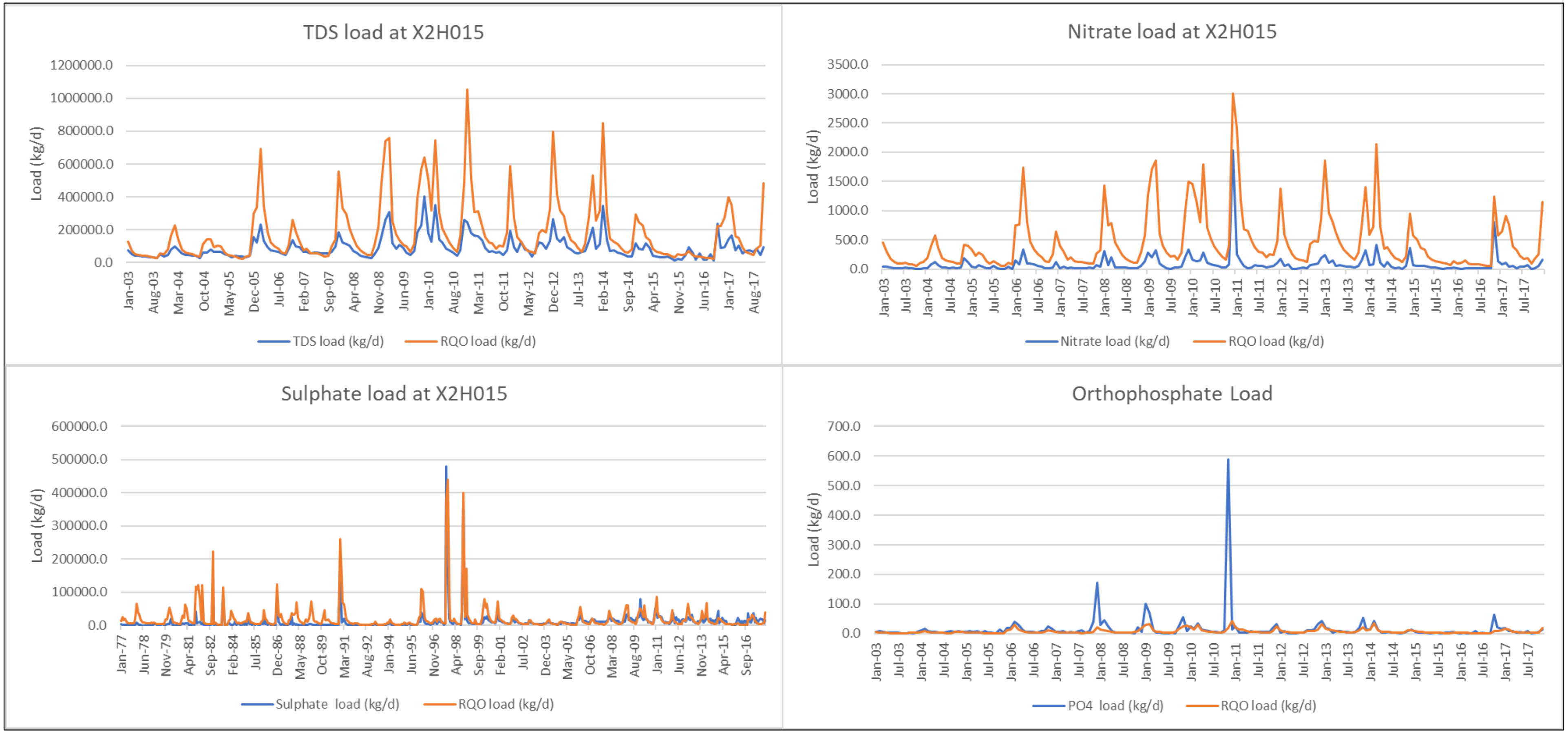

Figure C-10: X2H015 – measured load at the site vs the RQO load

Middle Crocodile (East) River Catchment

Figure 6-1 shows the Middle Crocodile (East) sub-catchment illustrating the land uses and monitoring sites where load has been determined and that contributes to the load at the outlet of the Middle Crocodile (East) River catchment. This also illustrated in more detail in a schematic, Figure 6-2.

Aspects of the catchment are summarised in Table 6-1, including water quality and quantity sites (weirs) at which quality and quantity have been assessed to determine the load at the outlet of this catchment, highlighting those areas of concern determined during the status assessment. The major contaminants of concern in the central areas of the Crocodile River catchment relate to elevated electrical conductivity, which relates to total dissolved solids and orthophosphate.

Table C-7: Water users in the Elands quaternary catchments

Quaternary catchment	River (s) in the quaternary catchment	Water Quality site - WMS ID	Weir ID	Description of monitoring weir	Water users/ uses
X22C	Crocodile River/ Gladdespruit/ Visspruit	No site			• Extensive agriculture • Mbombela residential area (southwest of Mbombela Stadium) along an unnamed tributary
X22D	Nels River	No site			• Extensive forestry • Extensive agriculture
X22E	Sand River/ Kruisfonteinspruit	X2 102993	X2H068	Sand River at Witklip Forest Reserve	• Extensive agriculture • Extensive forestry • Witklip Dam
X22F	Sand River/ Nels River	X2 102952	X2H005	Nels River at Boschrand	• Extensive agriculture • Extensive forestry • Rocky's Drift residential and industrial areas, White River • Rocky's Drift WTWW discharging to Sand River
X22G	Wit River	No site			• Klipkoppie Dam • Longmere Dam • Extensive agriculture • Forestry
X22H	Wit River	X22 88419 (only 1 data set)	X2H059	Goedhoop 128 on White River	• White River Town • White River WWTW draining to the White River • Extensive agriculture
X22J	Crocodile River	X2 102953	X2H006	At Karino on Crocodile River	• Mbombela Town • Kingstonvale WWTW discharging to Crocodile River • Mbombela Industrial area • Extensive agriculture
X22K	Blinkwater/ Mbuzulwane/ Crocodile River	X2 102975	X2H032	Crocodile River at Weltevrede	• Kamyamazane residential areas • Kanyamazane WWTW draining to Crocodile River • Entokozweni residential areas • Nature Reserve

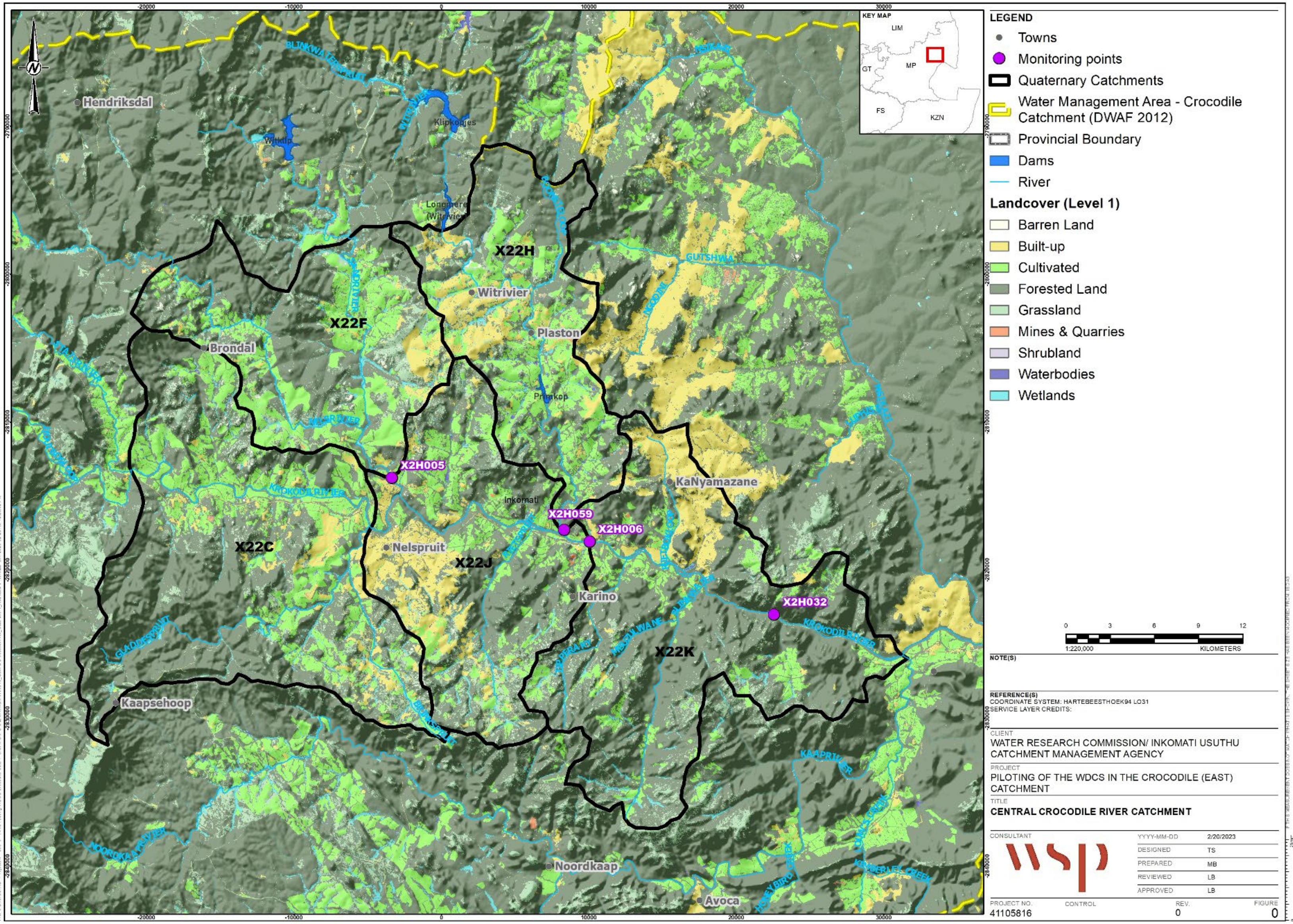

Figure C-11: Middle Crocodile River sub-catchment

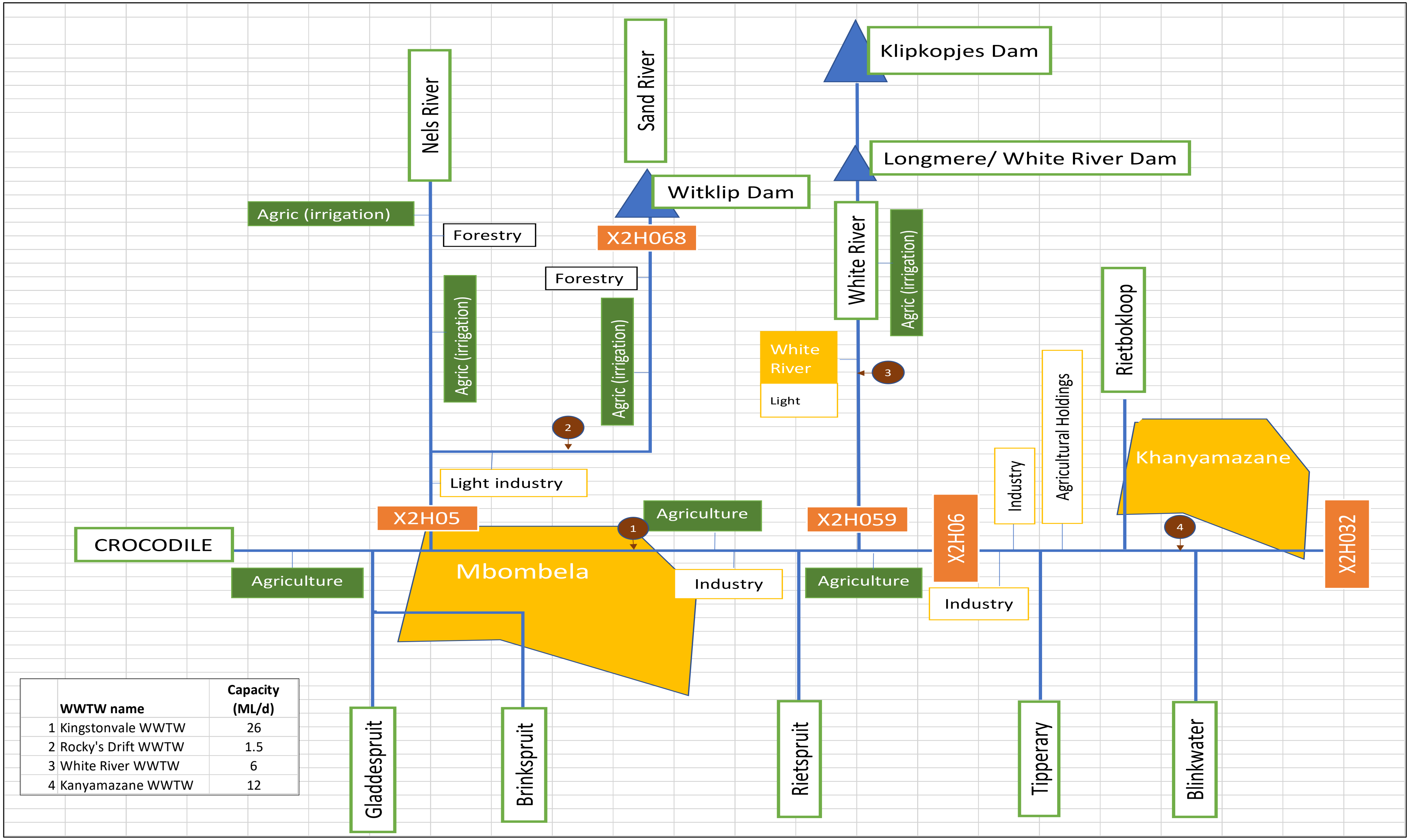

Figure C-12: Middle Crocodile River catchment schematic

Water quality and quantity data

Monthly average water quality data from January 2003 was assessed and gaps filled with the monthly averages. Water quantity data was assessed for the 20-year period starting in January 2003 (Figure 6-3). The flow data indicate lower flows at X2H005 (Nels River) compared against those in the Crocodile River at X2H006 and X2H032. The data for weir X2H059 was unreliable with extended periods without flow measurements and is not included.

Table 6-2 summarises the average monthly flows at weir X2H005 close to the outlet of quaternary catchment X22F, where the Nels River joins the Crocodile River. The monthly average flow at weir X2H032 ranged from 25% to 108% of the flow upstream at X2H006, with an average 80%.

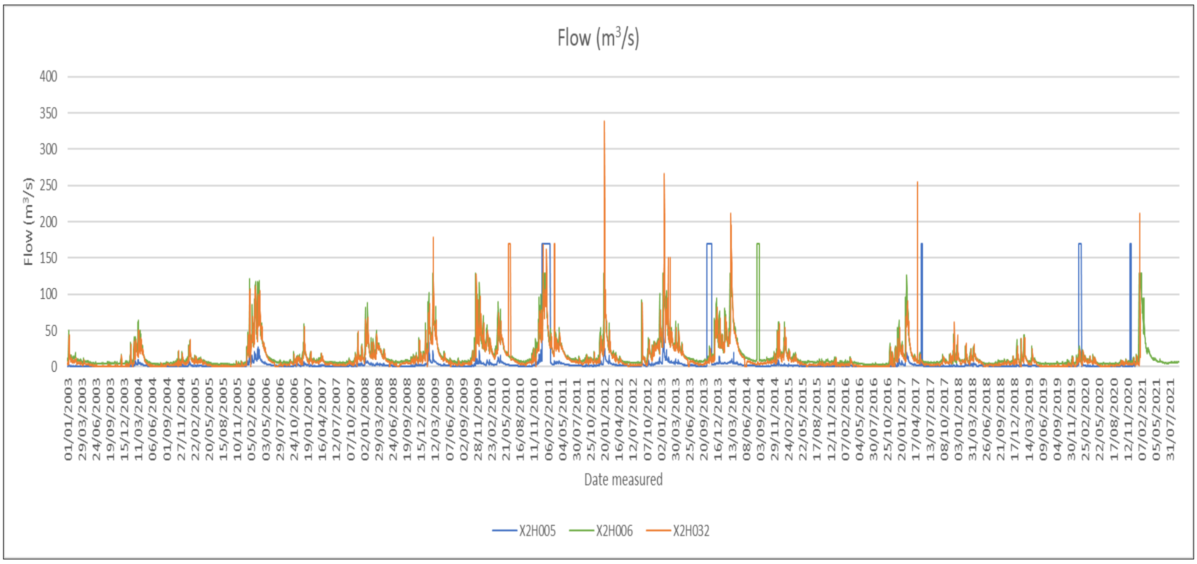

Figure C-13: Flow rate at Middle Crocodile weirs (Jan 2003 to Sept 2021)

Table C-8: Average monthly flow

Month	Monthly average (m^3/d)			% X2H032 vs flow at X2H006
	X2 H005	X2H006	X2H032	
January	1,613,414.09	2,782,786.37	2,385,660.70	85.73%
February	934,178.25	2,463,551.81	2,149,843.74	87.27%
March	320,977.39	2,335,168.41	2,226,556.34	95.35%
April	251,404.48	1,642,015.04	1,519,425.60	92.53%
May	347,922.12	905,674.37	709,959.48	78.39%
June	90,598.72	620,930.08	668,020.96	107.58%
July	71,323.51	522,305.34	229,644.70	43.97%
August	46,775.38	873,849.14	214,917.21	24.59%
September	47,020.40	599,132.67	294,478.22	49.15%
October	642,202.67	711,626.63	429,265.37	60.32%
November	417,665.56	1,078,583.04	766,594.67	71.07%
December	297,235.67	1,789,257.93	1,496,215.85	83.62%
Average annual flow	423,393.19	1,360,406.74	1,090,881.90	80.19%

Table C-9: Monthly water quality

Month	X2H005		X2H006		X2H032	
	TDS	Ortho-phosphate as P	TDS	Ortho-phosphate as P	TDS	Ortho-phosphate as P
Jan	76.11	0.02	147.64	0.04	169.44	0.08
Feb	85.12	0.02	134.40	0.03	171.52	0.04
Mar	77.59	0.01	134.05	0.06	151.16	0.07
Apr	80.18	0.03	137.13	0.03	158.60	0.06
May	72.66	0.02	161.81	0.04	212.96	0.06
Jun	76.50	0.01	179.04	0.06	184.33	0.08
Jul	86.19	0.02	189.05	0.09	235.95	0.07
Aug	106.43	0.02	201.39	0.08	226.65	0.17
Sep	102.71	0.02	180.65	0.08	218.65	0.10
Oct	97.7576	0.012556	182.73	0.06	194.55	0.13
Nov	97.23	0.01	164.49	0.04	169.56	0.09
Dec	88.12	0.02	155.06	0.05	159.58	0.10

Load determination

Table 6-3 sets out the average monthly load at the three sites, highlighting in red (-ve) where the average monthly calculated load (based on measured/ average data) is greater than the RQO load.

Table C-10: Average monthly loads to be removed

Catchment	Monitoring weir	Notes	Month	Average monthly load to be removed (kg/d) - where measured load >RQO load (-ve)	
				Total Dissolved Solids	Ortho-phosphate
Nels River	X2H005	• This weir is located on the Nels River just upstream of where it joins the Crocodile • Includes the load from extensive small agricultural areas and forestry in X22D, X22E and X22F. • Figure 6-4 and the adjacent average monthly load data illustrates the calculated load assessment based on measured or average data vs the RQO load highlighting the following: o The average monthly measured TDS load is still within the RQO load, however, is approaching the RQO of 385 mg/L. o The average monthly orthophosphate load is still within the RQO of 0.125 mg/L but approaches the RQO during the drier winter months. o Considering the land use in this catchment it appears that the agriculture and upstream forestry are the predominant contributors.	**Jan**	499,373.27	178.52
			Feb	283,411.85	99.39
			Mar	102,914.82	35.51
			Apr	82,073.28	24.52
			May	107,733.30	39.35
			Jun	28,439.00	10.32
			Jul	22,004.25	7.42
			Aug	13,410.96	5.19
			Sep	13,373.90	5.05

<table>
<tr><th rowspan="2">Catchment</th><th rowspan="2">Monitoring weir</th><th rowspan="2">Notes</th><th rowspan="2">Month</th><th colspan="2">Average monthly load to be removed (kg/d) - where measured load >RQO load (-ve)</th></tr>
<tr><th>Total Dissolved Solids</th><th>Ortho-phosphate</th></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3">o The water users are not included in the WDCS.</td><td>Oct</td><td>185,024.75</td><td>72.23</td></tr>
<tr><td>Nov</td><td>120,904.10</td><td>46.13</td></tr>
<tr><td>Dec</td><td>88,487.61</td><td>31.46</td></tr>
<tr><td rowspan="12">Crocodile (East) River</td><td rowspan="12">X2H006</td><td rowspan="12">• The weir is located on the Crocodile River downstream of the City of Mbombela at the outlet of X22J
• The loads would therefore include runoff from the city, the discharge from the Kingstonvale WWTW (26ML/d), Rocky’s Drift WWTW (1.5ML/d) and White River WWTW (6 ML/d), as well as industrial run-off (and discharges)
• Figure 6-5 and the adjacent average monthly loads data illustrates the calculated load assessment based on measured or average data vs the RQO load highlighting the following:
o The TDS is within the RQO of 385 mg/L and does not appear to be deteriorating.
o Orthophosphate loads are also within the RQO of 0.125 mg/L and appear to be quite stable.</td><td>Jan</td><td>665,589.20</td><td>232.75</td></tr>
<tr><td>Feb</td><td>649,363.40</td><td>247.85</td></tr>
<tr><td>Mar</td><td>621,559.37</td><td>184.14</td></tr>
<tr><td>Apr</td><td>418,330.77</td><td>151.45</td></tr>
<tr><td>May</td><td>217,984.91</td><td>76.56</td></tr>
<tr><td>Jun</td><td>131,138.20</td><td>42.97</td></tr>
<tr><td>Jul</td><td>101,993.61</td><td>21.26</td></tr>
<tr><td>Aug</td><td>165,198.64</td><td>66.97</td></tr>
<tr><td>Sep</td><td>124,603.60</td><td>29.59</td></tr>
<tr><td>Oct</td><td>156,566.89</td><td>53.54</td></tr>
<tr><td>Nov</td><td>238,759.64</td><td>86.99</td></tr>
<tr><td>Dec</td><td>416,421.27</td><td>142.97</td></tr>
<tr><td rowspan="8">Crocodile (East) River</td><td rowspan="8">X2H032</td><td rowspan="8">• The weir is located on the Crocodile River downstream of Kanyamazane at the outlet of X22K
• The loads would therefore include runoff from the Kanyamazane development, the discharge from the Kanyamazane WWTW (12ML/d), as well as industrial run-off (and discharges)
• Figure 6-6 and the adjacent average monthly loads data illustrates the calculated load assessment based on measured or average data vs the RQO load highlighting the following:
o The TDS is within the RQO of 385 mg/L and</td><td>Jan</td><td>547,284.82</td><td>125.22</td></tr>
<tr><td>Feb</td><td>478,015.70</td><td>189.63</td></tr>
<tr><td>Mar</td><td>550,440.43</td><td>164.48</td></tr>
<tr><td>Apr</td><td>358,026.06</td><td>118.29</td></tr>
<tr><td>May</td><td>150,374.02</td><td>55.18</td></tr>
<tr><td>Jun</td><td>138,872.15</td><td>35.40</td></tr>
<tr><td>Jul</td><td>35,903.74</td><td>15.86</td></tr>
<tr><td>Aug</td><td>35,540.45</td><td>-19.24</td></tr>
</table>

Catchment	Monitoring weir	Notes	Month	Average monthly load to be removed (kg/d) - where measured load >RQO load (-ve)	
				Total Dissolved Solids	Ortho-phosphate
		does not appear to be deteriorating. ○ Orthophosphate loads are predominantly within the RQO of 0.125 mg/L with limited exceedances.	Sep	51,536.69	11.00
			Oct	82,576.41	-0.43
			Nov	170,325.82	36.08
			Dec	343,812.45	53.59

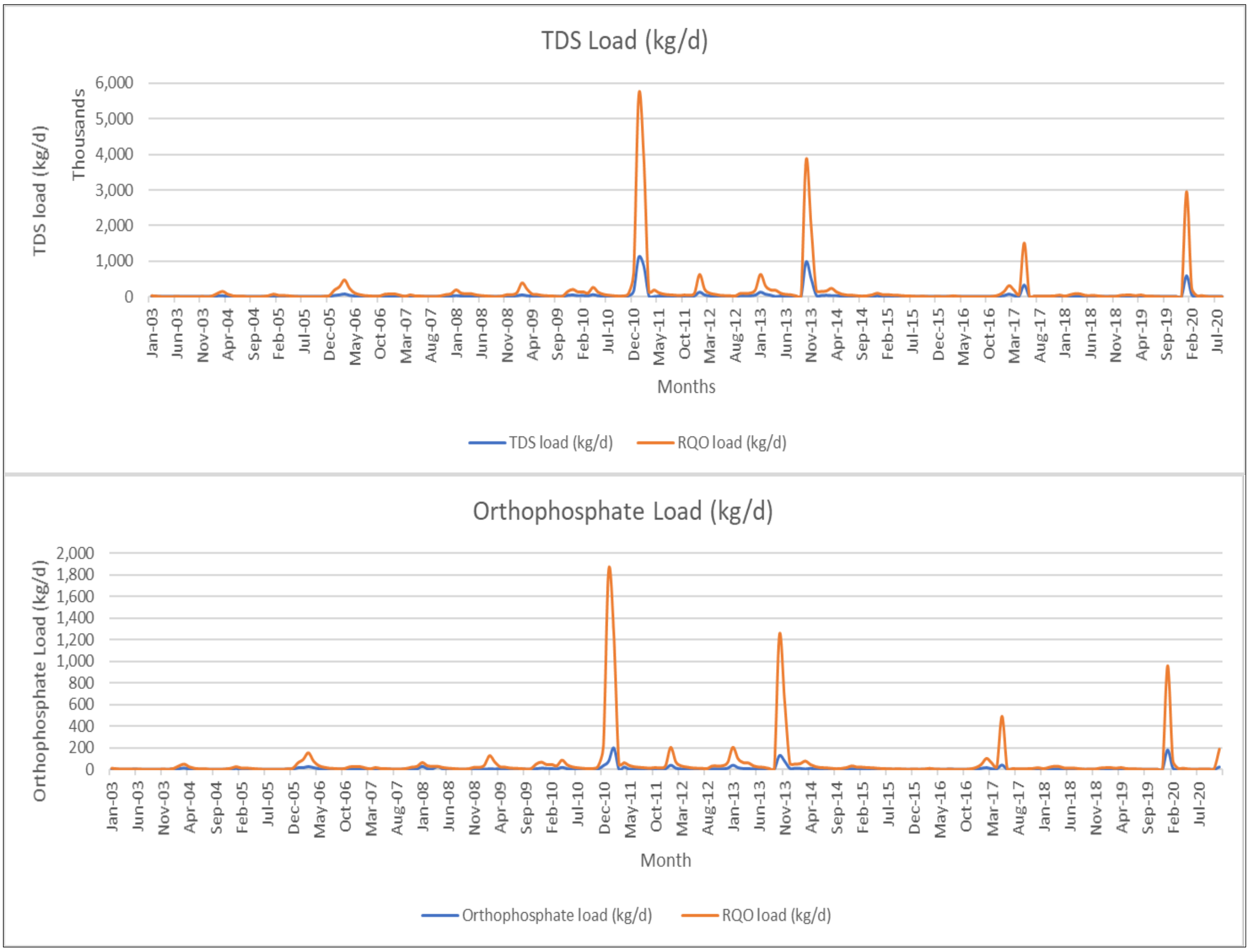

Figure C-14: X2H005 – measured load at the site vs the RQO load

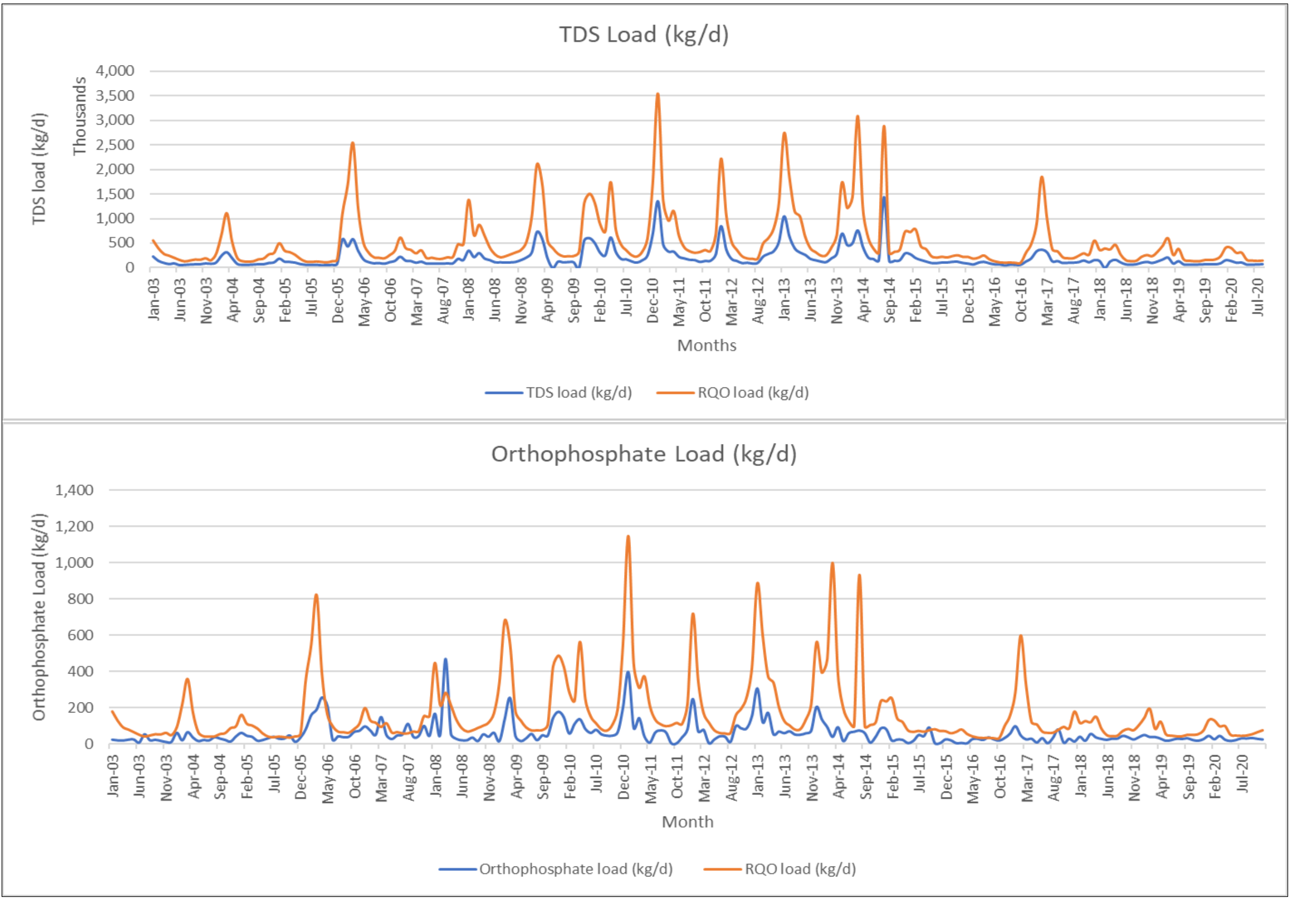

Figure C-15: X2H006 – measured load at the site vs the RQO load

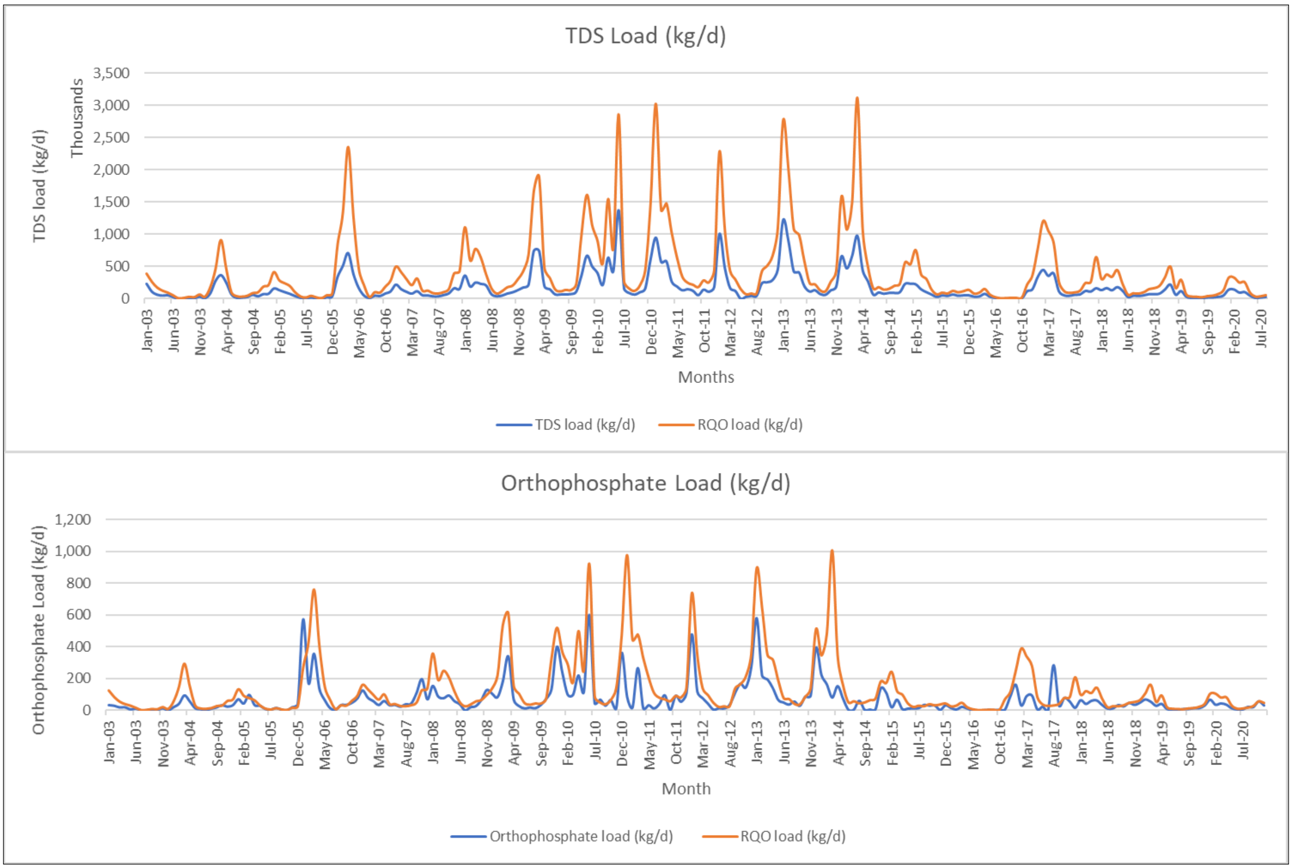

Figure C-16: X2H032 – measured load at the site vs the RQO load

APPENDIX D: Cost Analysis of Load Removal Technology Options

Once the load excess for targeted constituents of concern were determined in each of the pilot catchments a cost analysis of load removal technology options was undertaken as a basis to establish Waste Mitigation Charge rates.

The following methodology was employed to determine treatment considerations and associated costs:

- Analysis of water quality data spanning from 1997 to 2011 for the Elands and Kaap catchments. This period was selected as it presented a good range of water quality and flow data to estimate load. The period provided a snapshot of the representative situation.
- Identification of the specific pollutant loads that must be removed, aligning with the Resource Quality Objectives (RQOs) and were excess load was noted.
- Further evaluation of non-compliant parameters to identify treatment technologies most suitable for achieving compliance with the RQOs for these parameters.
- Calculation of the abstracted volume, a crucial component in determining the treatment costs required to meet the RQOs.
- Determination of cost rates based on current supplier inputs, reflective of a Class 5 AAECI level estimate.
- This methodological approach was applied to assess treatment considerations and calculate associated costs.

WATER QUALITY

The feed water quality, depicted in Table D-1, was estimated based on water quality data gathered from 1997 to 2011. The 95th percentile of the water quality was utilized to determine the worst-case scenario. This calculation was performed for both wet and dry seasons in order to estimate costs accounting for seasonal variation.

Table D-1: Seasonal variation for TDS, Sulphate, Nitrate and Orthophosphate

Kaap Catchment Water Quality				
Month	Total Dissolved Solids (mg/L)	Sulphate (mg/L)	Nitrate (mg/L)	Orthophosphate (mg/L)
Wet Season	**713.13**	**93.138**	**0.703**	**0.067**
Dry Season	**750.455**	**90.1**	**1.3**	**0.0675**
Elands Catchment Water Quality				
Month	Total Dissolved Solids (mg/L)	Sulphate (mg/L)	Nitrate (mg/L)	Orthophosphate (mg/L)
Wet Season	**389**	**87**	**0.45**	**0.08**
Dry Season	**374**	**116**	**0.31**	**0.06**

WATER QUANTITY (FLOWS)

Based on flow measured data from the 1997 to 2011. The 95th percentile of the wet and dry seasons were used to estimate the flow that requires treatment as shown in Table D-2.

Table D-2: Seasonal Water Quantity

Season	Elands Catchment (MLD)	Kaap (MLD)
Wet Season	4071	4125
Dry Season	940	1628

MLD: megalitres/day

ABSTRACTED VOLUME: METHODOLOGY

The following section discusses the methodology used to attain the abstracted volumes, that require treatment in order to meet the downstream RQO's. Figure A1 depicts a high-level concept block flow diagram that was used to estimate the volume of water that requires abstraction. Ideally the flowrate upstream (Qus) is diverted through a weir (QABS) which feeds the water treatment plant. The treated water from the plant (QRET) is diverted back into the river to allow for effective dilution and to ensure that the RQO's are met with regards to the specific catchments. The abstracted volume and selected treatment options are the main drivers that would incur the costs for the treatment plant.

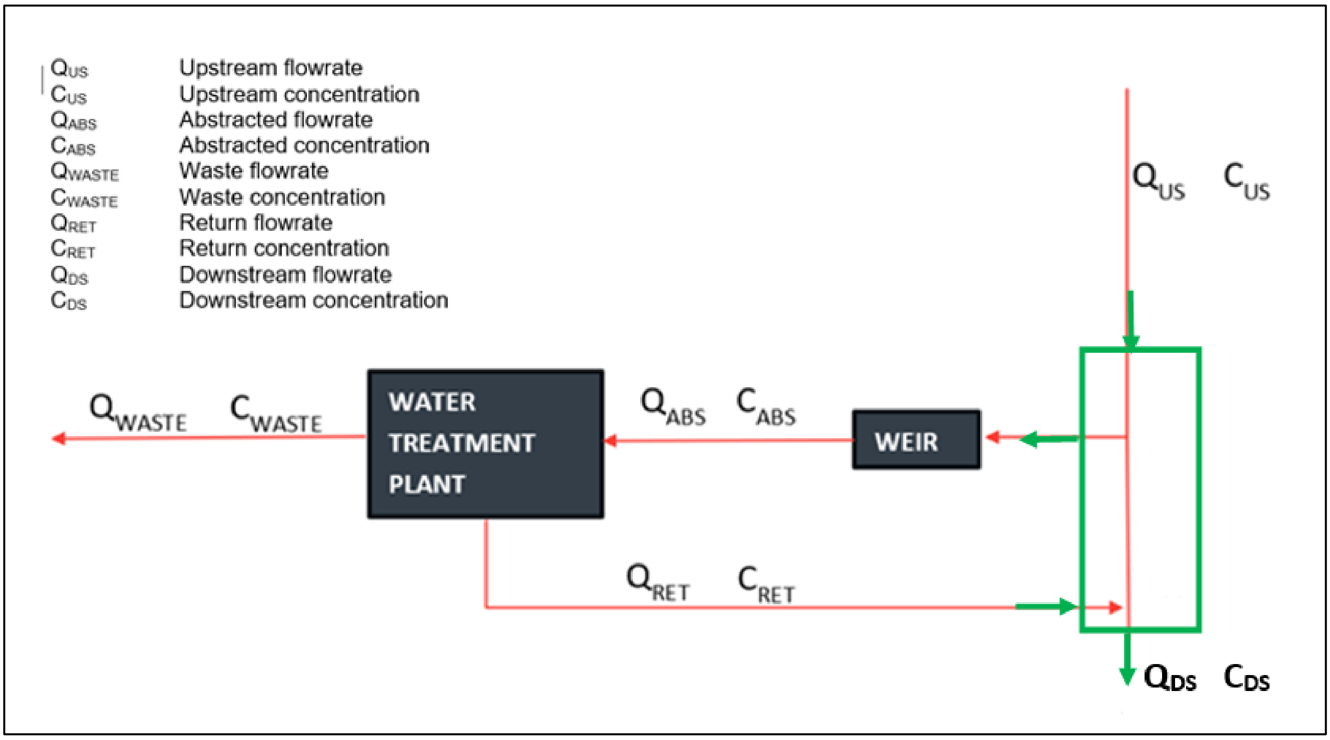

Figure D-1: Proposed Block flow diagram

The volume abstracted is calculated as follows:

It was assumed that the system is in steady state which results in the rate of change term $\left(\frac{\partial V}{\partial t}\right)$ equating to zero in equation 1.

$$\frac{\partial V}{\partial t} = Volume_{OUT} - Volume_{IN} \qquad (1)$$

This results in the volume in equivalent to volume out *i.e.* equation (2).

$$Volume_{IN} = Volume_{OUT} \qquad (2)$$

The upstream volumetric flow(Q_{US}) and the return volumetric flow (Q_{RET}) are inflow into the systems as shown in the green outline in Figure A1. The abstracted volumetric flow (Q_{ABS}) and downstream volumetric flow (Q_{DS}) are outflows based on Figure A1. Applying the above system description to (2) results in (3).

$$Q_{US} + Q_{RET} = Q_{ABS} + Q_{DS} \qquad (3)$$

Similarly, mass or loads are conserved as shown in (4).

$$Mass_{IN} = Mass_{OUT} \qquad (4)$$

$$M_{US} + M_{RET} = M_{ABS} + M_{DS} \qquad (5)$$

The mass/load is a function of concentration and volumetric flow. Equation 5 can be expanded to equation (6).

Where Q_{ABS} , C_{DS} and Q_{DS} are unkown.

$$C_{US}Q_{US} + C_{RET}Q_{RET} = C_{ABS}Q_{ABS} + C_{DS}Q_{DS} \qquad \textit{(6)}$$

Rearranging (6) to solve for Q_{ABS}.

$$Q_{ABS} = \frac{Q_{US}C_{US} - Q_{DS}C_{DS} + Q_{RET}C_{RET}}{C_{ABS}} \qquad \textit{(7)}$$

Rearranging (3) to solve for Q_{DS} and substituting (8) in (7).

$$Q_{DS} = Q_{US} + Q_{RET} - Q_{ABS} \qquad \textit{(8)}$$

The concentration for the discharge stream (C_{DS})nis the only unknown in equation (9). It was assumed that the (C_{DS}) will be compliant to the Resource quality objectives (RQO's) set for the catchments. The abstracted volume was calculated using equation (9).

$$Q_{ABS} = \frac{Q_{US}C_{US} - Q_{US}C_{DS} - Q_{RET}C_{DS} + Q_{RET}C_{RET}}{C_{ABS} - C_{DS}} \qquad \textit{(9)}$$

The water treatment plant's configuration, including the technology type and product specifications, has been assumed. The choice of water treatment plant depends on several factors:

- Volume of Water: The amount of water that needs treatment.
- Target Water Specifications: The required treated water quality standards.
- Feed Water Quality: Identifying contaminants/pathogens for removal and assessing whether the selected technology can achieve this.
- Land Availability and Social Implications.

For this study, three active water treatment configurations were assessed. These include reverse osmosis, ion exchange, and nanofiltration. These technologies were chosen due to their robustness, capacity to treat high water volumes, and established commercial viability. While passive options were also considered, they are most effective with low flow rates (<1MLD).

The above mentioned technology will be able to achieve the RQO limit as shown in Table D-3.

Table D-3: Resource quality objectives

Parameter	RQO downstream (CDS) for the Elands catchment (mg/l)	RQO downstream (CDS) for the Kaap catchment (mg/l)
Total dissolved solids	369	385
Nitrates	0.75	4
Orthophosphate	0.025	0.13
Sulphate	80	80

ABSTRACTION VOLUMES

The abstraction volumes were based on the load removal required to achieve the RQO's. A summary of the abstraction volumes is shown in Table A4.

In terms of the abstaction volume, a large quantity of water is required for treatment in order to meet the RQO. The treatment costs is associated with the volume, higher volumes result in higher treatment costs as shown in Table A5. The abstraction volumes required for the removal of nitrate is not applicable as the nitrate concentration based on the water quality analysis is below the RQOs and thus no load removal is necessary at this stage Similarily the phosphate concentration is below the RQOs for the Kaap catchment.

Table A4: Abstraction volumes calculated

Load Removal	Elands		Kaap	
	Wet Season (MLD)	Dry Season (MLD)	Wet Season (MLD)	Dry Season (MLD)
TDS	239	17	2061	857
Sulphate	343	310	638	201
Nitrate	n/a	n/a	n/a	n/a
Phosphate	5462	1803	n/a	n/a

Table D-5: Costs associated with water treatment

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Kaap								
		Option 1 Reverse Osmosis		**Option 2 Ion Exchange**			**Option 3 Nanofiltration**	
		CAPEX	OPEX (R/year)	CAPEX	CAPEX (RESIN)	OPEX (R/year)	CAPEX	OPEX (R/year)
Wet Season	TDS Load Removal (MLD)	R50,937,200,000	R26,335,300,000	R5,570,500,000	R557,100,000	R43,538,300,000	R20,374,900,000	R22,573,100,000
	Sulphate Removal (MLD)	R17,724,600,000	R8,149,700,000	R2,450,900,000	R245,100,000	R13,473,200,000	R7,089,900,000	R6,985,400,000
Dry Season	TDS Load Removal (MLD)	R23,126,700,000	R10,952,600,000	R3,014,300,000	R301,500,000	R18,107,000,000	R9,250,700,000	R9,387,900,000
	Sulphate Removal (MLD)	R6,260,600,000	R2,564,300,000	R1,091,000,000	R109,100,000	R4,239,300,000	R2,504,300,000	R2,198,000,000
Elands								
Wet Season	TDS Load Removal (MLD)	R7,338,300,000	R3,059,200,000	R1,234,400,000	R123,500,000	R5,057,500,000	R2,935,400,000	R2,622,200,000
	Sulphate Removal (MLD)	R10,143,200,000	R4,383,400,000	R1,587,800,000	R158,800,000	R7,246,700,000	R4,057,300,000	R3,757,200,000
	Phosphate Removal (MLD)	R122,420,200,000	R69,770,000,000	R11,017,600,000	R1,101,800,000	R115,345,800,000	R48,968,100,000	R59,802,900,000
Dry Season	TDS Load Removal (MLD)	R663,000,000	R211,600,000	R190,300,000	R19,100,000	R349,900,000	R265,200,000	R181,400,000

ASSUMPTIONS

The following assumptions were used:

1) The 95th percentile of the water quality was used to estimate the “worst case” of the water quality for the water treatment design parameters.
2) The 5th percentile data was used to estimate the “worst case” pH.
3) The system is in steady state i.e. mass is conserved
4) The technology specified will meet the require RQO’s.
5) Latest supplier-based rates were used to determine the treatment costs.

APPENDIX E: Wetland locations in the three sub-catchments that may be relevant for wetland rehabilitation

The viability to rehabilitate wetlands or introduce enhanced natural based solutions for reducing the load in the Kaap, Elands, and Middle Crocodile River catchments will require wetlands and water resources in proximity or upstream of the monitoring points that recorded increased concentrations for ortho-phosphates, sulphates and TDS. The monitoring points that recorded increased concentrations and where the load was higher than the RQO load, and wetlands within proximity to these points are provided in Table 4-6. Water quality and flow data recorded since 2003 to 2020 was used to determine the monthly loads and exceedances of RQOs for ortho-phosphates, sulphates and TDS.

Two (2) wetlands were identified near the monitoring point (X2H022) in the Kaap River catchment. The wetland identified as per the National Wetland Map 5 layer (NWM5) are described in Table E-1 and illustrated in Figures D-1, D-2 and D-3.. There were no wetlands identified in the immediate area surrounding X2H015 in the Elands River catchment. Several wetlands were identified to the west side of X2H032.

Table E-1: Wetlands identified in proximity to the river catchments

Kaap River Catchment	
Weirs: X2H031 X2H022 X2H008, and X2H010	Wetland_ID 137431 downstream of X2H008 and X2H31 (confluence of Queens River and Suidkaap River) (Along R38, just after X2H31) Wetland_ID 137440 downstream of X2H008 and X2H31 (confluence of Queens River and Suidkaap River) (Across R38 just before X2H83 in the Suidkaap River. Wetland is next to Barberton Mines Tailings Retreatment Plant and Downstream of Fairview Mine) Wetland ID 160938 (downstream of the confluence of the Noordkaap River and the Suidkaap River). River rehabilitation and widening, and Sediment Trapping. Confluence close to the Consort Mine. Wetland ID_125435 (Kaap River before X2H022) After the confluence of the Kaap River and Louw's Creek
Elands River Catchment	
Weir: X2H015	No wetlands in immediate proximity Wetland ID 165 in the Elands River. Downstream of Sappi Ngodwana. River rehabilitation and widening, and Sediment Trapping.
Middle Crocodile River Catchment	
Weir: X2H032	Wetland ID 87042 within Crocodile River (After Mbombela with nutrients from the town and neighbouring townships. Wetland ID 87032 within Crocodile River (after Mbombela with nutrients from the town and neighbouring townships (Nsikazi)). Wetland ID 86975 (upstream of monitoring point X2H032 and next to N4) Wetland ID 86969 (downstream of monitoring point X2H032 and next to N4) Wetland ID 137933 (in Gladdespuit River upstream of confluence with the Crocodile River). Several wetlands near Mbombela that can be used based on access, flow, current state, etc. Wetland ID 137888 (in Brinkspruit River upstream of confluence with the Crocodile River). Across the R40. Several wetlands near Mbombela that can be used based on access, flow, current state, etc.

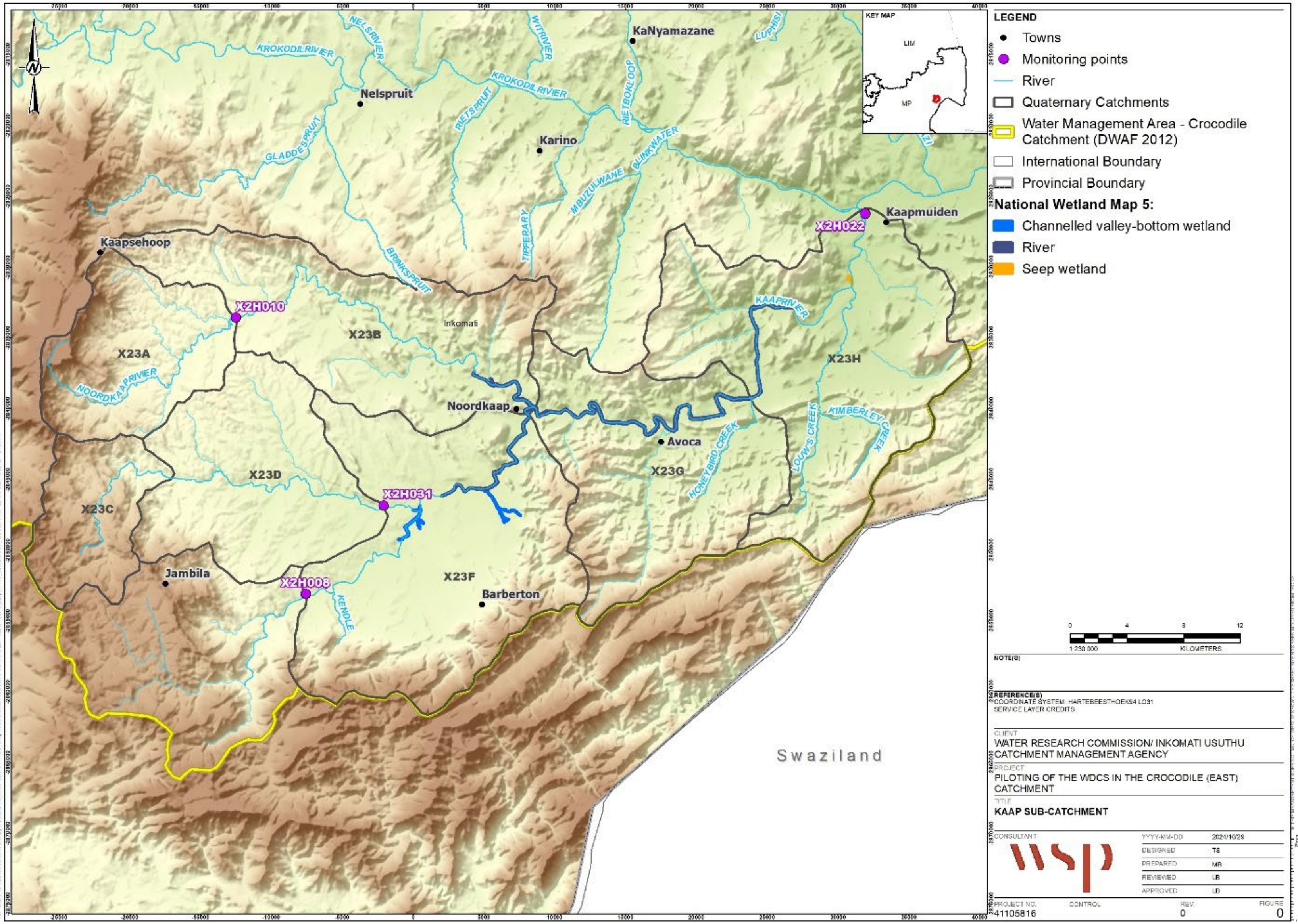

Figure E-1: Wetlands in the Kaap River catchment (NWM5)

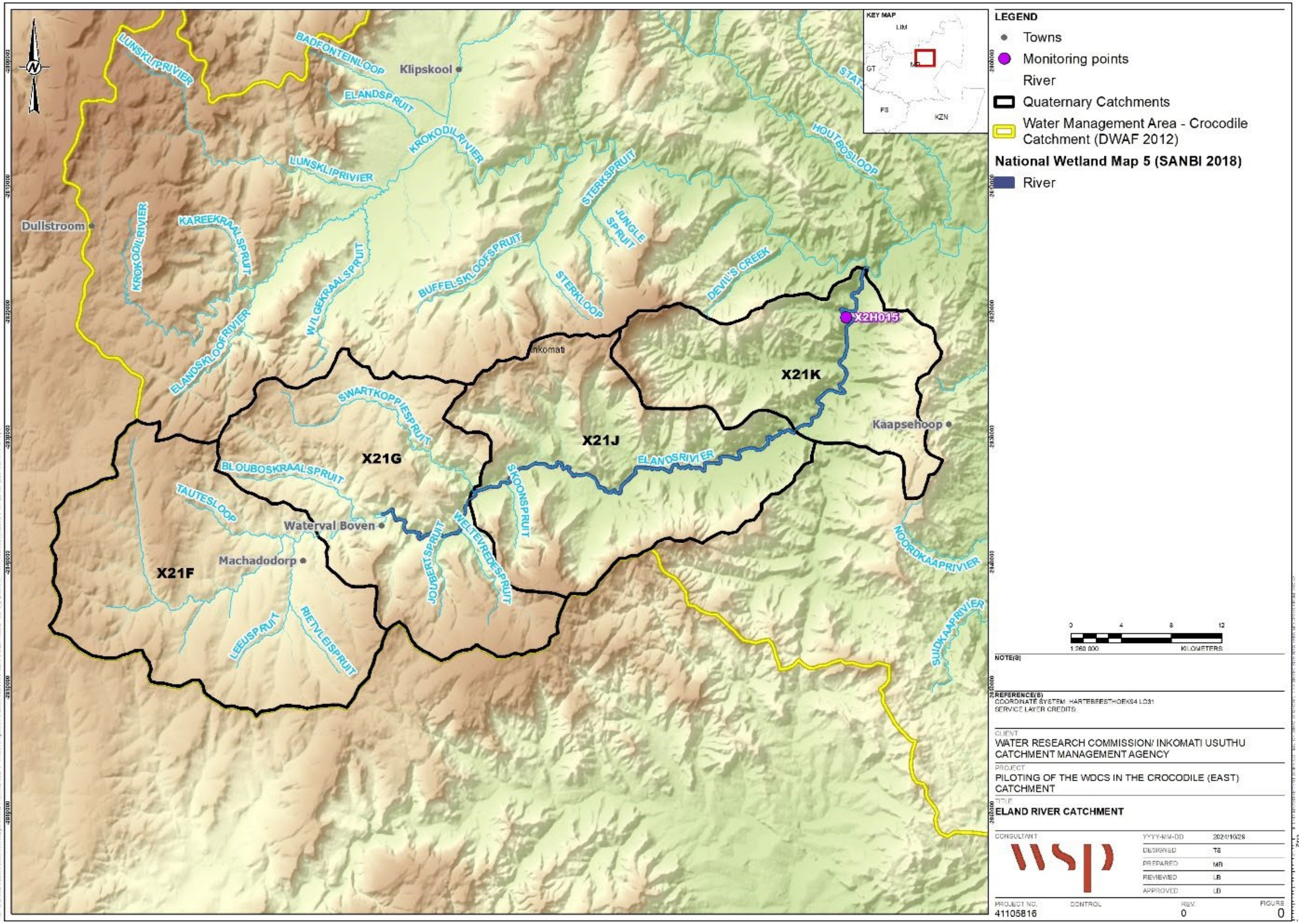

Figure E-2: Elands River catchment showing river related wetland areas (NWM5)

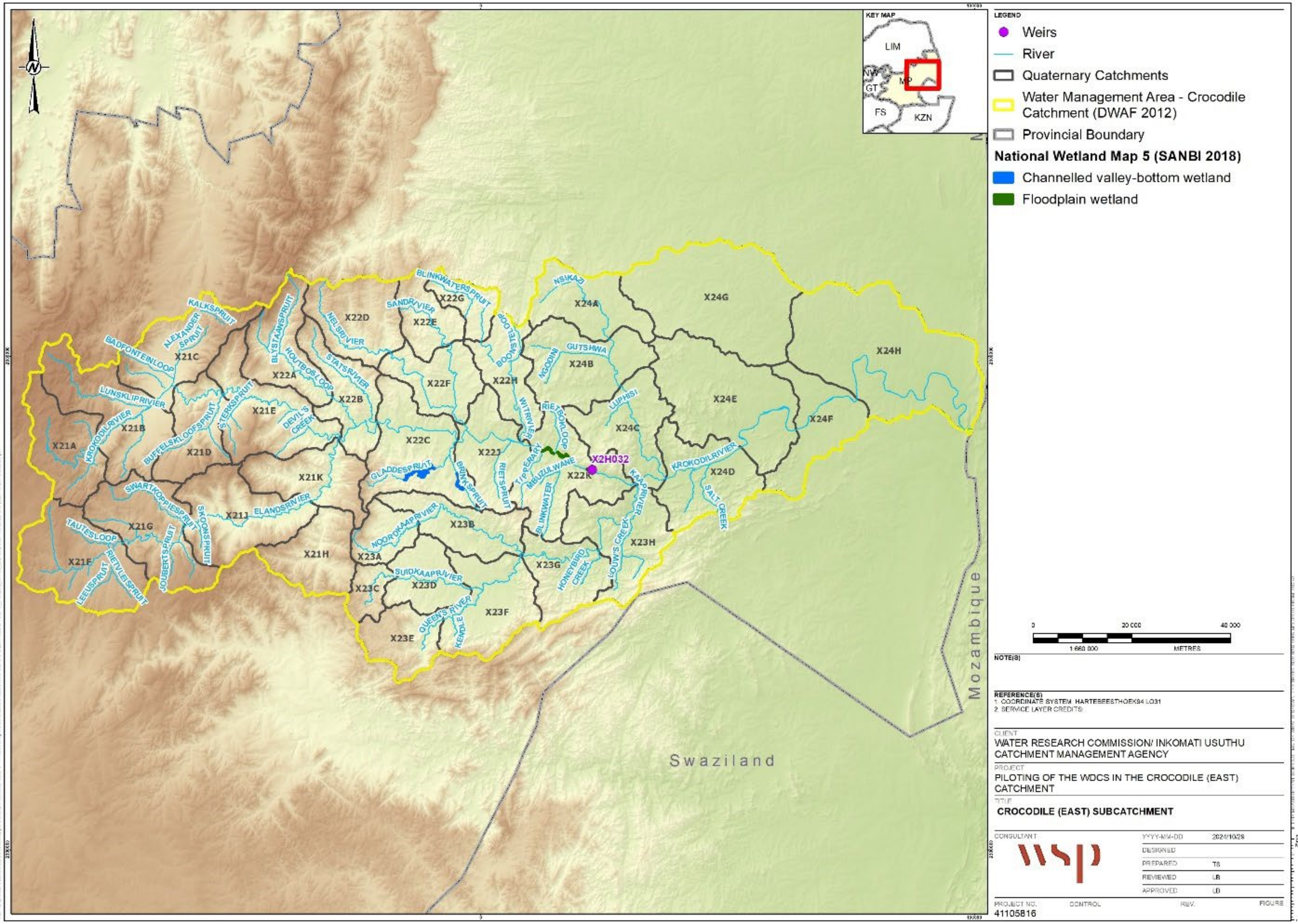

Figure E-3: Wetlands in the middle Crocodile (East) River catchment