Department of Water and Sanitation

Report No: P WMA 03/000/00/6923/2

WP11393

CROCODILE EAST WATER PROJECT (CEWP)

MODULE 1: TECHNICAL FEASIBILITY STUDY

Pre-Feasibility Study: Evaluation of Downstream Ecological Impacts of the Dam Options Report

June 2023

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DOCUMENT INDEX

This report forms part of the series of reports issued as part of the project Crocodile East Water Project (CEWP) Module 1: Technical Feasibility Study.

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LIST OF ACRONYMS

AR	Assessment Reach
CEWP	Crocodile East Water Project
DFFE	Department of Forestry, Fisheries and the Environment
D: NWRP	(DWS) Directorate: Integrated Water Resource Planning
D: NWRP	(DWS) Directorate: National Water Resource Planning
D: SWRP	(DWS) Directorate: Strategic Water Resource Planning
D: WRDP	(DWS) Directorate: Water Resource Development Planning
DM	District Municipality
DO	Dissolved Oxygen
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
Est	Estimated
EWR	Ecological Water Requirements
FS	Feasibility Study
FRAI	Fish Response Assessment Index
GAI	Geomorphology Driver Assessment Index
IHI	Instream Habitat Integrity
IUCMA	Inkomati-Usuthu Catchment Management Agency
IUA	Integrated Unit of Analysis
LM	Local municipality
MAR	Mean Annual Runoff
MIRAI	Macroinvertebrate Response Assessment Index

PAI	Physico-chemical driver Assessment Index
RQO	Resource Quality Objectives
RU	Resource Unit
SCC	Species of Conservation Concern
SQ	Sub Quaternary
TEC	Target Ecological Category
TTT	Technical Task Team
VEGRAI	Riparian Vegetation Response Assessment Index
WC/WDM	Water Conservation and Water Demand Management
WQ	Water Quality
Categories of the IUCN Red List	
NT	Near Threatened
VU	Vulnerable
CR	Critically Endangered

LIST OF UNITS AND SYMBOLS

km	Kilometre

GLOSSARY OF TERMS

Ecological Water Requirements (EWR)	The flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.
Integrated Unit of Analysis (IUA)	An IUA is a homogeneous area that can be managed as an entity. It is the basic unit of assessment for the Classification of water resources and is defined by areas that can be managed together in terms of water resource operations, quality, socio-economics and ecosystem services.
Resource Quality Objectives (RQOs)	RQOs are numeric or descriptive goals or objectives that can be monitored for compliance to the Water Resource Classification, for each part of each water resource. "The purpose of setting RQOs is to establish clear goals relating to the quality of the relevant water resources" (NWA, 1998).
Scenario	Scenarios, in the context of water resource management and planning, are plausible definitions (settings) of factors (variables) that influence the water balance and water quality in a catchment and the system as a whole. Each scenario represents an alternative future condition, generally reflecting a change to the present condition.
Sub-quaternary (SQ) reaches	A finer subdivision of the quaternary catchments (the catchment areas of tributaries of main stem rivers in quaternary catchments), to a sub-quaternary reach or quinary level.
Target Ecological Category (TEC)	This is the ecological category toward which a water resource will be managed once the Classification process has been completed and the Reserve has been finalised. The draft TECs are therefore related to the draft Classes and selected scenario.
Water Resource Class	The Water Resource Class (hereafter referred to as Class) is representative of those attributes that the DWS (as the custodian) and society require of different water resources. The decision-making toward a Class requires a wide range of trade-offs to be assessed and evaluated at a number of scales. Final outcome of the process is a set of desired characteristics for use and ecological condition of the water resources in a given catchment. The WRCS defines three management classes, Class I, II, and III, based on extent of use and alteration of ecological condition from the predevelopment condition.

1 INTRODUCTION

1.1 Background to Study

The water of the Crocodile (East) River Catchment in Mpumalanga has been fully allocated, yet the water requirements, especially domestic water requirements, continue to grow. The system is under stress, and it cannot fully meet the environmental water requirements as well as the reliability / assurance of supply for both the agricultural and municipal water uses.

The situation will worsen in the short term if water conservation and water demand management (WC/WDM) measures are not fully implemented. In the medium to long term, WC/WDM measures will not be sufficient to provide for the increase in domestic water requirement. The yield of the water resource will have to be increased by means of **additional storage**.

Both public and commercial sectors have requested development of **additional yield** through **storage** within the **Crocodile (East) River Catchment**. Due to the long lead-time required in developing new dams, the construction of an additional dam in the Crocodile River Catchment has to be investigated without delay.

Taking cognisance of the above-mentioned and based on previous studies and investigations carried out in the past, the following **four proposed dams** within the **Crocodile (East) River Catchment** were recommended for further study as part of this Study (WP11393: Module 1: Technical Feasibility Study):

- Mountain View Dam on the Kaap River.
- Montrose Dam on the Crocodile East River.
- Boschjeskop Dam on the Nels River.
- Strathmore Off-Channel Storage Dam, near the confluence of the Kaap and Crocodile rivers.

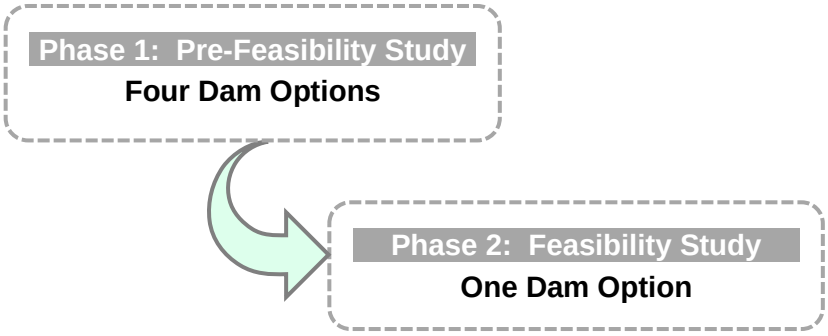
This Technical Feasibility Study will be undertaken in two separate phases, as follows:

Phase 1: Pre-Feasibility Study

The Pre-Feasibility Study (Phase 1) will be undertaken for the above-mentioned **four** proposed dams within the Crocodile (East) River Catchment.

Phase 2: Feasibility Study

Under the Phase 1: Pre-Feasibility Study, **one** of the possible four dam options will be selected and recommended for further study and development to a **feasibility level** of detail in the Phase 2: Feasibility Study.



1.2 Study Area

The Crocodile (East) River Catchment in Mpumalanga is located in the north-east of the country and forms part of the larger Inkomati River Basin. The water of the Inkomati River Basin is shared between Mozambique, South Africa and Eswatini. A map of the Study Area is included in **Figure 1-1**.

Engineering investigations and studies for the respective dams and associated infrastructure will **each** have their **specific focus** and **study area** and will also apply to dam access, advanced infrastructure for the dam and the possible relocation of services (roads, rail, etc).

However, with respect to the Water Resources task (water demands, yield analysis, future water balance, the development of short-term stochastic yield reliability curves, updating of the water resources planning model, etc.) of the Study, the study area will cover the **whole** of the **Crocodile (East) River Catchment** (see **Figure 1-1**).

The Crocodile (East) River Catchment comprises of the following four tertiary catchments as indicated in **Figure 1-2**:

- Upper Crocodile Catchment (X21)
- Middle Crocodile Catchment (X22)
- Lower Crocodile Catchment (X24)
- Kaap Catchment (X23)

Important tributaries of the Crocodile River include the following:

- Kaap River
- Elands River
- Nels River
- White River

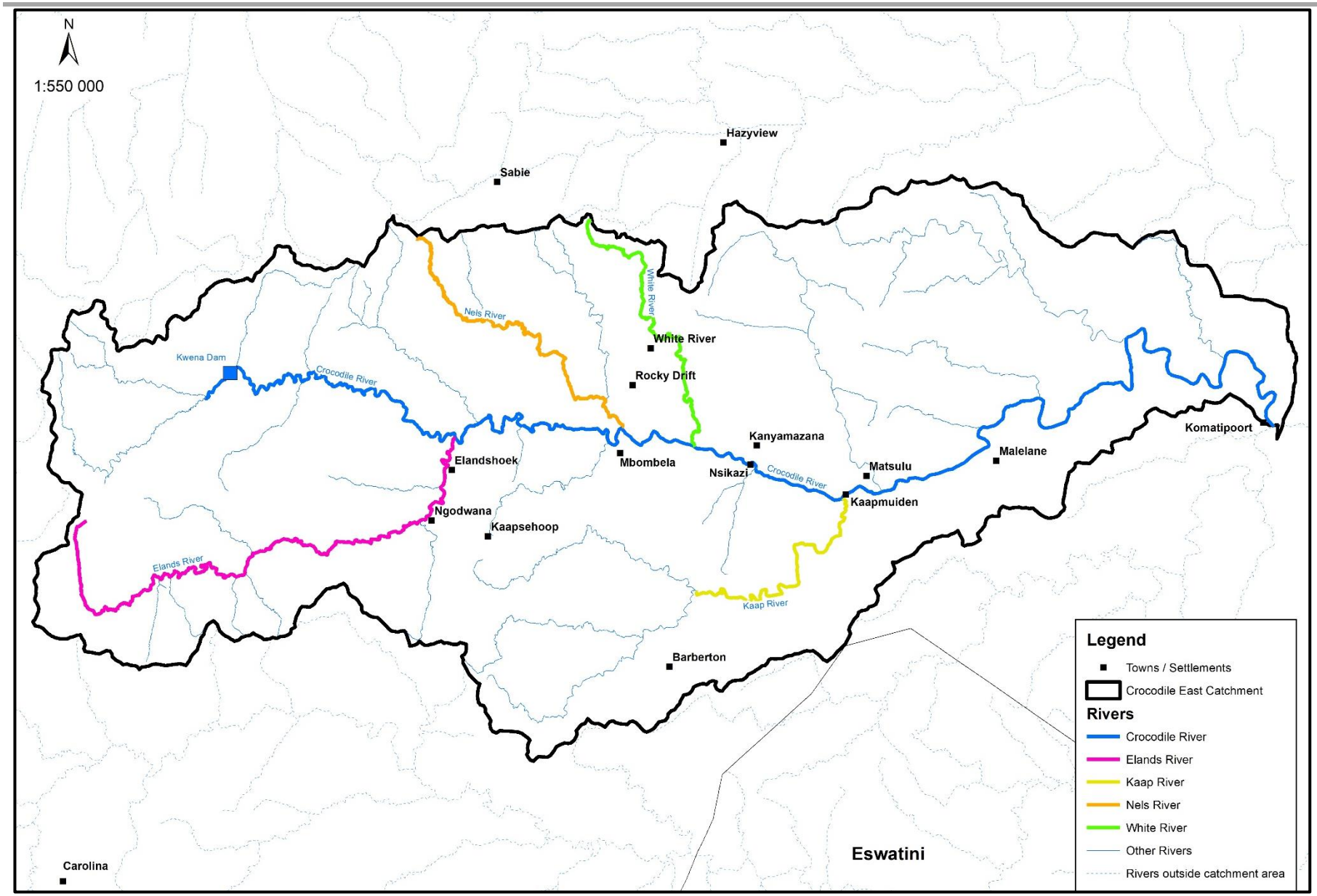


Figure 1-1: Crocodile River Catchment

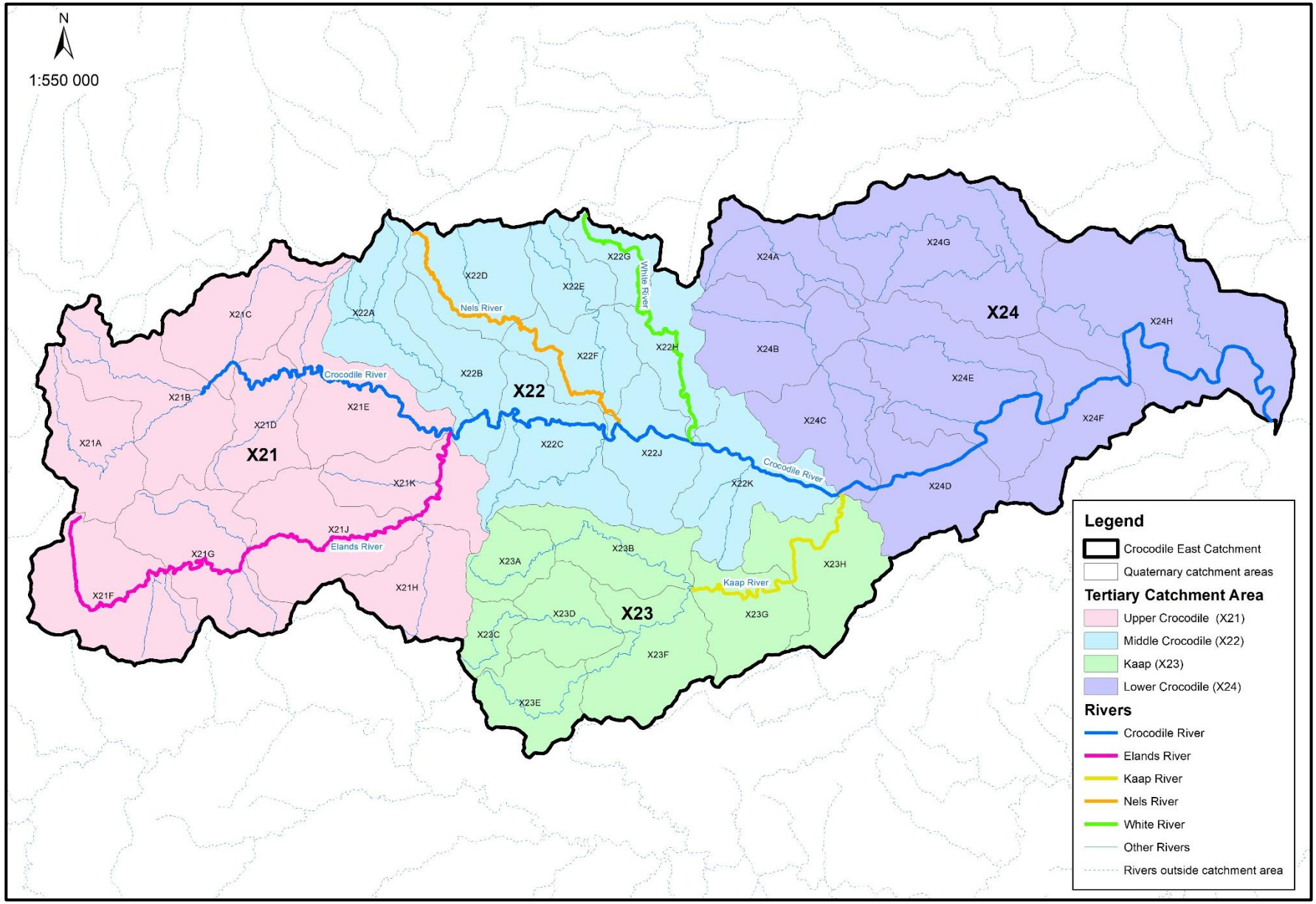


Figure 1-2: Crocodile East River: Tertiary Catchments

The following District and Local Municipalities fall within the Crocodile (East) River Catchment:

- Ehlanzeni District Municipality
  - Bushbuckridge Local Municipality
  - City of Mbombela Local Municipality
  - Nkomazi Local Municipality
  - Thaba Chweu Local Municipality
- Gert Sibande District Municipality
  - Chief Albert Luthuli Local Municipality
- Nkangala District Municipality
  - Emakhazeni Local Municipality

The Crocodile River Catchment is rural in nature, with agriculture being the main economic activity. The high rainfall escarpment catchments of the Upper and Middle Crocodile and Kaap catchments have significant areas of commercial forestry.

The Upper Crocodile Catchment is relatively undeveloped with small domestic and irrigation demands. The Middle Crocodile Catchment has large areas of controlled irrigation and urban demands in the Mbombela LM. The Kaap River Catchment is dominated in the lower eastern part by significant areas of controlled irrigation. Water is transferred into the Kaap River Catchment from the Lomati and Shiyalongubo dams for urban users (Umjindi Local Municipality which was disestablished and merged with Mbombela Local Municipality to establish the City of Mbombela Local Municipality) and agriculture (Louw's Creek Irrigation Board). The Lower Crocodile Catchment has large areas of controlled irrigation and smaller urban/domestic demands for the Nkomazi LM.

The only major dam in the catchment is the Kwena Dam in the Upper Crocodile River Catchment. The dam is approximately 60 km west of Mbombela on the main stem of the Crocodile East River or in the upper reaches of the Crocodile East Catchment. The dam is far from the water demand centers and therefore makes it difficult to regulate and manage water distribution to supply demands as required by the users.

1.3 Proposed Dams

Four proposed dams (listed below) will be investigated during the Pre-Feasibility Phase (Phase 1) of this Study. Only **one** will be selected and recommended for further study in the Feasibility Phase (Phase 2) of the Study. It is, however, possible that the second-best option could be taken forward at a later stage.

- Mountain View Dam on the Kaap River.
- Montrose Dam on the Crocodile East River.
- Boschjeskop Dam on the Nels River.
- Strathmore Off-Channel Storage Dam, near the confluence of the Kaap and Crocodile Rivers.

The regional orientation of the **four proposed dam sites** is indicated in **Figure 1-3**.

1.4 Purpose of Report

The purpose of this Report is to present the results of a screening exercise to determine the downstream ecological impacts of the proposed dam options in terms of meeting the Target Ecological Categories (TECs) gazetted for the system. Some linked upstream impacts are also taken cognisance of. The objective of the exercise is to rank the dam options and identify potential fatal flaws.

1.5 Structure of Report

The following is addressed in the relevant sections of this Report:

- **Section 1** provides a background of the Study, an overview of the Study Area, including the purpose and structure of this Report.
- **Section 2** describes the approach and methods used during this task.
- **Sections 3 to 6** describes the impacts of the proposed dams on the ecological status of the rivers.
- **Section 7** provides the ranking and fatal flaw identification.
- **Section 8** indicates the Study references.

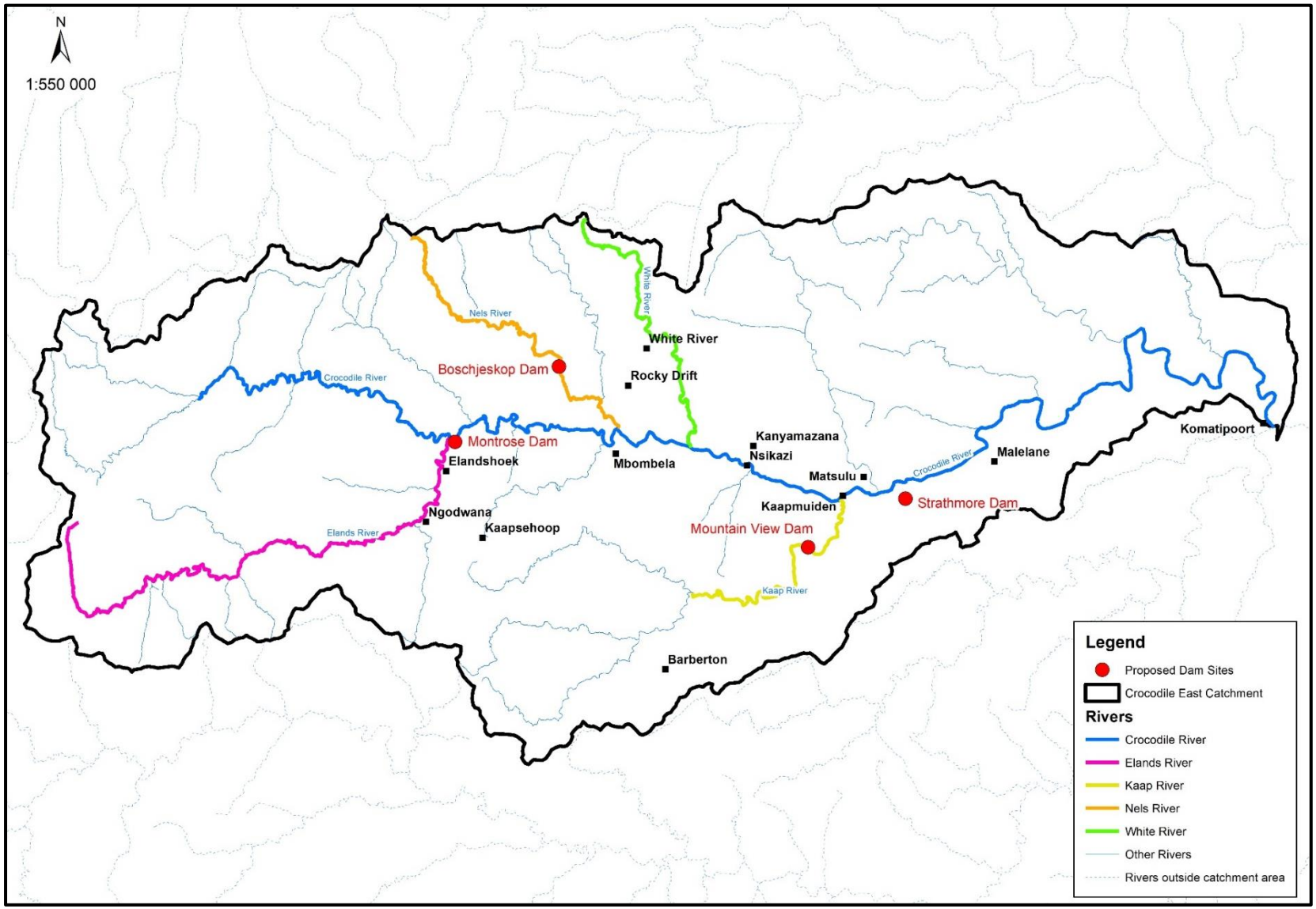


Figure 1-3: Regional Context of Four Proposed Dam Sites

1.6 Relevant Previous Studies

This section very briefly summarises the two most relevant studies undertaken in terms of environmental flows. These studies were:

- Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. Sabie and Crocodile Systems. (2008-2010).
- The determination of Water Resource Classes and associated Resource Quality Objectives in the Inkomati Water Management Area. (2013 – 2015).

Both the above studies were undertaken by Rivers for Africa and the key scientific consulting members forming part of the team for this 2023 study were involved in both previous studies. The Water Resources Classes (Classes) and Resource Quality Objectives (RQO) study used and expanded the results of the 2009 - 2010 Reserve study and the main outcomes are summarised in this section.

Considering that the core purpose of the Classification process is to select the Water Resource Class (DWAF, 2007) for a water resource, the scenario evaluation process provides the information needed to assist in arriving at a recommendation that will be considered by the Minister of the Department of Water Affairs or delegated authority to make the final decision.

The overarching aim of the scenario evaluation process is to find the appropriate balance between the level of environmental protection and the use of the water to sustain socio-economic activities. Once the preferred scenario has been selected the Water Resource Class is defined by the level of environmental protection embedded in that scenario.

There are three main elements (variables) to consider in this balance, namely the Ecology, Ecosystem Services and the Economic benefits obtained from the use of a portion of the water resource. The scenarios evaluation process therefore estimates the consequences that a plausible set of scenarios will have on these variables. The evaluation process uses the quantification of selected metrics to compare the scenarios on relative basis with one another. (DWS 2014b).

The water resources modelling and scenarios that were analysed is described in detail in Appendix A of DWS 2014b. The scenarios evaluated during the Classification study included Mountain View and Boschjeskop Dams. Other variables considered were updated water demands, domestic growth, IIMA Flows as well as EWRs (no EWRs, PES and REC).

It must be noted that evaluation of scenarios does NOT form part of this report and will only be undertaken as part of Feasibility report (see Section 7.4). The information provided above is to provide the context and background required. It must further be noted that any evaluation of scenarios during this 2023 study will include detailed technical information regarding the dams, outlets, locality etc which were not available during 2014 when the scenario evaluation as part of the Classification study was undertaken. The 2023 study will therefore not be repeating work done before.

The 2013 – 2015 Classification study provided recommendations for the Classes and Catchment configuration for the following terms:

- Immediate
- Near future (medium term)
- Far future (long term – included Mountain View implementation)
- Additional far future after both Mountain View and Boschjeskop were implemented.

The results were gazetted (No. 55, Government Gazette, 22 January 2016) and the Classes and Catchment Configuration are provided below. These results reflect the Immediate recommendation only.

IUA	Water Resource Class	Nodes	River	River Length (mm)	TEC
X2-2	**II**	EWR C3	Crocodile	58.3	**B/C**
X2-5	**I**	EWR E2	Elands	59	**B**
X2-8	**II**	X22F-00842	Nels	35.1	**C**
X2-9	**II**	X22F-00977	Nels	6.7	**C/D**
		EWR C4	Crocodile	41.3	**C**
X2-10	**II**	EWR K7	Kaap	11.2	**C**
X2-11	**II**	EWR C5	Crocodile	23	**C**
		EWR C6	Crocodile	99	**C**

2 APPROACH AND METHODOLOGY

2.1 General Approach

The Water Resource Classes (Class) and Resource Quality Objectives (RQOs) have been gazetted through the Water Resource Classification process for this system. Classes and the Catchment Configuration are therefore available for every Resource Unit. The Catchment Configuration is described as Ecological Categories and the Ecological Categories that have been gazetted are referred to as Target Ecological Categories (TEC). The gazetted RQOs are set for the gazetted TEC and are described for flows (Ecological Water Requirements (EWRs)), water quality, instream and riparian habitat and biota.

During the Pre-Feasibility phase, an assessment was made of the impacts of the proposed dams on the downstream environment, specifically the ecological categories. The main objective was to identify fatal flaws and to rank the options from the perspective of meeting the TECs and associated RQOs. During this Pre-Feasibility phase study, the assumption was made that the flow RQOs (representing the EWRs) will be met from the proposed dam options. Evaluation of flow scenarios and how to optimise yield while still ensuring that the flow RQOs are met, will be the main focus of the Feasibility Phase (see **Section 7.4**).

While the EWRs may be met (the assumption being made), there are other impacts resulting from dam development that may have an impact on the downstream environment, such as the barrier effect, change in water quality, scour, sedimentation, and provision of water for users combined with EWR releases (i.e., due to the operating system and manner of supply). The impacts will be described and then evaluated for water quality, geomorphology, riparian vegetation, fish and aquatic invertebrates. This will include the scale in terms of the longitudinal impact. EcoStatus models will be used to support predictions of the likelihood of changes in Ecological categories (A to F). These results will also be based on an impact rating to fit seamlessly into the environmental screening and Environmental Impact Assessment (EIA) process.

Detailed previous work was undertaken at relevant EWR sites downstream of the proposed dams during the Reserve (DWA, 2009), National Water Resource Classification (DWS, 2015) and Present Ecological State, Ecological Importance and Ecological Sensitivity (PESEIS - DWS, 2014a) studies. Some of these dams were also broadly evaluated during those studies. The available work includes a range of models which have been set up at EWR sites to describe the baseline (Present Ecological State (PES)). These models will form the starting point for evaluation during this study. The EcoStatus models (FRAI, MIRAI, PAI, GAI,

VEGRAI, IHI, EIS, EcoStatus) was sourced and all relevant information required obtained from the existing data basis.

During the hybrid (virtual and meeting) specialist session of 13 to 16 February 2023, the following stepwise process was followed to assess the proposed dam impacts on the downstream reaches (referred to as Assessment Reaches (AR); see **Section 2.2**).

To measure whether the Target Ecological Category will be met for the various reaches and if not, how severe the impact or change of TEC is, the following process was undertaken:

- Identify the reaches downstream of the dam which must be assessed.
- Obtain the TEC for each reach.
- Identify the detailed impacts each specialist must rate for the relevant component (fish, invertebrates, geomorphology, riparian vegetation, water quality).
- Identify the metrics for the relevant component which will be evaluated.
- Rate each of the metrics with a scoring system to be designed by each specialist for their component.
- Supply ONE rating (-5 - 0 - +5) for the component for the relevant reach. The rating definitions are as follows:
  - 5: Extreme/critical improvement from PES (>80% change).
  - 4: Serious improvement from PES (60 - 80% change).
  - 3: Large improvement from PES (40 - 60 change%).
  - 2: Moderate improvement from PES (20 - 40 change%).
  - 1: Slight improvement from PES (<20 change%).
  - 0: No change (PES maintained).
  - -1: Slight deterioration from PES (0 - 20% change).
  - -2: Moderate deterioration from PES (20 - 40% change).
  - -3: Large deterioration from PES (40 - 60% change).
  - -4: Serious deterioration from PES (60 - 80 change%).
  - -5: Extreme/critical deterioration from PES (>80% change).
- Link the rating to the expected change in Ecological Category from the TEC.

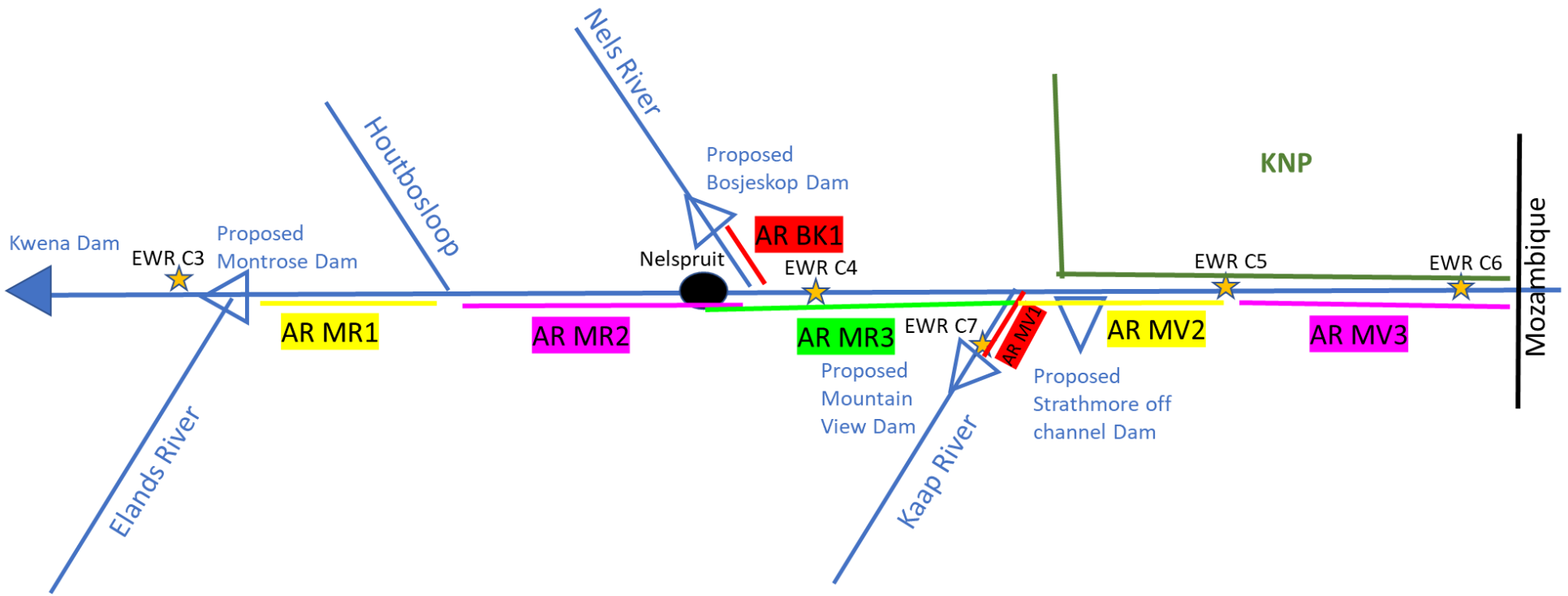
The main driver (geomorphology) is assessed first and the results provided to the rest of the team. The secondary drivers (water quality and riparian vegetation (also a response

component)) then assess the impact and provide it to the instream specialists. The responses in changes in habitat are then assessed by the instream specialists.

2.2 Delineation

The study area was delineated into sub-quaternary (SQ) reaches during the PESEIS assessment (DWS, 2014a). These SQ reaches were then grouped into Resource Units (RU) (DWS, 2015) and RQOs set for each RU. The RU is represented by a gazetted Target Ecological Category or TEC (DWS, 2015; 2016a). The RU and SQ delineation were used to delineate the river reach downstream of the proposed dam into Assessment Reaches (AR), for the sake of this study. The AR immediately downstream of the proposed dams is referred to as the high Impact or sacrificial reach. These reaches are subject to direct impacts associated with releases even when releasing EWRs as mitigation measures.

The delineation is shown as a diagrammatic map (**Figure 2-1**).



Montrose		Bosjeskop		Mountain View		Strathmore Dam	
		AR BK1	Nels downstream of dam.				
AR MR1	Dam wall to Houtbosloop						
AR MR2	Houtbosloop to Nels						
AR MR3	Nels to Kaap	AR BK2	Nels to Kaap				
				AR MV1	Kaap downstream of dam		
AR MR4	Kaap to EWR C5 to Mozambique	AR BK3	Kaap to EWR C5 to Mozambique	AR MV2 AR MV3	Kaap to EWR C5 EWR C5 to Mozambique	AR SM1 AR SM2	Kaap to EWR C5 EWR C5 to Mozambique

Figure 2-1: Delineated Assessment Reaches of Study

2.3 Geomorphological Approach

The following steps were followed to rate the impacts of the 4 proposed dams:

- Data from previous geomorphological assessments, i.e., the Geomorphology Driver Assessment Index (GAI) used for the 2010 Inkomati Reserve study and Inkomati Classification study for the Crocodile system were collected.
- Metrics were selected to describe the main impacts that are expected downstream of dams. The metrics and rationale for each metric are presented below.
    - Channel incision and bed armouring - Large dams and reservoirs have large trapping efficiencies, removing all bedload and a large component of the suspended load, effectively only releasing the fine suspended load and dissolved load to downstream reaches (Brune, 1953). Some of the trapped sediment can be released through sediment release strategies, but South African reservoir basins are often not ideal (often shallow, wide and long) for sediment management procedures. This results in sediment starvation downstream of dams. During high flow, spillage or releases will erode sediment from the downstream channel bed and bank toe to recover and balance the sediment load in the river. This results in the lowering of the bed and the removal of finer sediment (dependent on the stream reaching a critical flow), selectively removing the finer particles and leaving a coarser immobile layer behind to form an armour layer along the bed.
    - Bank erosion - River banks are sensitive to gradient and pore water pressure (and vegetation). With bed armouring and channel incision, the benches and bars are removed, exposing and steepening the banks. This can lead to direct bank erosion through fluvial action or bank collapse under gravitational forces. Further, frequent changes in water level during flow releases for downstream abstraction could increase the water level in the banks, leading to high pore water pressure during low flows. This will effectively weaken bank cohesion through increased pore water pressure and enhance bank collapse.
    - Sedimentation - Sedimentation occurs when the sediment load exceeds the transport energy available. When reservoirs reduce flow rates or energy, but the lateral sediment input remains the same, sedimentation is likely. This is often evident at and downstream of tributary junctions where high flows are reduced due to dams upstream.

- Sub-quaternary reach description - Each sub-quaternary reach was described in terms of valley confinement, the presence of bedrock and weirs, the extent of alluvial features in the channel and along the banks, and signs of sedimentation. Google Earth was used for this component as the historical images were readily available to ensure images with relatively low and clear flows could be used for the descriptions.

- Ground-based photos available on Google Earth were used to improve the understanding of the geomorphic character.

- Qualitative assessment of changes to sediment loading - The volume of each reservoir was compared relative to its catchment Mean Annual Runoff (MAR). If the ratio is large, as it is for most of the in-channel dams, then the trapping efficiency is high, thus removing all bedload and most of the suspended load (Brune, 1953). This reduction in sediment load was compared to the relative size of the incremental catchment downstream and the likely sediment input from the incremental catchment based on the sediment yield classes presented by Msadala *et al.* (2010). This resulted in a relative change to the sediment load and yield for the sub-quaternary reaches. This was used to rate the likely channel incision and/or bed armouring.

- Bank erosion was rated based on the channel incision and/or bed armouring and the effect of frequent changes to flow on the water table within the banks (see the explanation for metric ‘bank erosion’).

- Sedimentation was rated based on reductions in high flows relative to lateral sediment input (see the explanation for metric ‘sedimentation’).

- The metrics were rated for each SQ, using a rating system from 1 to 5 for improvements to the TEC, and -1 to -5 for deterioration from the TEC (see Section 2.6 for full list). The scores for the SQs were combined for the AR score.

- The AR score was used to predict the likely change in the geomorphological category per EWR site under the dam development scenario.

2.4 Water Quality Approach

The following steps were undertaken as preparation for the screening assessment for the physico-chemistry component, hereafter referred to as water quality.

- Access documentation as follows:
  - EWR, Ecological Consequences and RQO reports from the Inkomati Classification study, completed in 2015.
  - Gazette for the Inkomati Classification Study, dated December 2016 (DWS, 2016a).
- The associated Physico-chemical driver Assessment Index (PAI) models used for the 2010 Inkomati Reserve study and Inkomati Classification Study for the Crocodile system, including those related to the ecological consequences phase of the Classification study.
- Results of the water quality Technical Task Team (TTT) meeting as undertaken during the Inkomati Classification Study.
- *EcoStatus of the Crocodile River Catchments, Inkomati River System*; report prepared for the Inkomati-Usuthu Catchment Management Agency (IUCMA) in 2017 (IUCMA, 2018).

From the documentation, list the following:

- TEC, PES and associated water quality category for each impacted EWR site.
- Identified water quality priority areas (output from the Classification study).
- Driving variables associated with water quality state at EWR sites and water quality (WQ) priority areas.
- Identify the metrics to be used in the Crocodile East dams assessment, for the ARs and associated SQs identified by the team leader. Identified water quality metrics were as follows:
  - Nutrients.
  - Temperature.
  - Dissolved Oxygen (DO).

- Salts.
- Turbidity/clarity; results provided by the geomorphologist for the Sedimentation metric were used.
- Water quality assimilation service provision (from the Inkomati Classification Goods and Services assessment).
- Water quality dilution service provision (from the Inkomati Classification Goods and Services assessment).
- Note assimilation and dilution service provision were considered but not generally used as part of the calculation for the integrated water quality impact.

- Evaluate the impact of the dam development on the identified metrics, using the agreed upon rating system, from 1 - 5 for improvements beyond/above those of the TEC, and -1 to -5 for deterioration away from the TEC (see Section 2.1 and 2.6 for full list). No change from the TEC is indicated by 0.
- Provide an *integrated water quality change rating* for each AR, by averaging the results of the metrics.
- Provide an *integrated water quality category* expected per EWR site under the dam development and implementation scenario.

2.5 Riparian Vegetation Approach

The following steps were undertaken for the screening assessment for riparian vegetation:

- Collection of previous data and reports pertaining to the study area including photographs, raw data and VEGRAI assessments (models used for the 2010 Inkomati Reserve study and Inkomati Classification study for the Crocodile system).
- Identify the metrics to be used in the Crocodile East dams assessment, for the ARs and associated SQs. Riparian vegetation metrics used for the assessment included:
  - Algae – the prevalence of algae in the system has already been identified as a potential problem and its ongoing presence will be affected by water quality (notably nutrients), water depth and velocity, all of which have the potential to be altered by dams.
  - Change in marginal zone habitat – dams have the potential to alter downstream sediment loads which may result in elevated scour or channel erosion leading to

a loss in marginal zone habitats. Conversely, additional sedimentation may occur, and can elevate, expand or alter marginal zone vegetation in both spatial distribution and species composition.

- Altered seasonality – usually the distribution of flood events in time and duration is altered, but this is mainly due to dry season releases for downstream irrigation purposes. Altered seasonality could also be complexly affected by hydro power schemes.
- Woody species abundance - usually dams result in some regulation of flow regimes and reduced peaks during flooding and this frequently promotes the establishment and or dominance of woody species, both riparian and terrestrial. This metric has been evaluated for different zones within the riparian zone:
  - Woody: non-woody ratio - marginal zone.
  - Woody: non-woody ratio - flood features.
  - Woody: non-woody ratio - river banks.
- Terrestrialisation – the process whereby terrestrial species encroach into the riparian zone and become established or dominant. This process can be promoted by altered flooding regimes, especially downstream of dams.
- Alien woody species – similar to terrestrialisation but by alien species which may be favoured by altered flooding regimes.

- Evaluate the impact of the dam development on the above metrics in each downstream SQ, using a rating system from 1 - 5 for improvements to the TEC, and -1 to -5 for deterioration from the TEC (see Section 2.6 for full list). No change from the TEC is indicated by 0.
- Indicate generalised reasons for the expected changes / response to impacts.
- Provide an *integrated riparian vegetation change rating* for each AR.
- Provide an expected *integrated riparian vegetation category* for each applicable EWR site.

2.6 Instream Approach

Impacts on the instream biota that can in general be expected to occur as a result of a dam in a river system, were identified and listed. Various metrics were then identified for fish and

macroinvertebrates that would provide an indication of the potential change or impact of the proposed dams on the river systems of concern. The following metrics were assessed:

- **Water Quality:** This assessment was primarily based on the input from the water quality specialist and considered the impact expected on all instream biota, with emphasis on fish species and macroinvertebrate taxa with a requirement for unmodified water quality.

- **Migration:** The potential impact of the dam wall as a migration barrier was considered on especially catadromous species (such as eels and *Macrobrachium* prawns) that requires catchment scale migration to complete their life-cycle as well as potadromous fish species that requires movement between reaches. For the fish assessment upstream refuge areas were also considered.

- **Refugia** (only macroinvertebrates)**:** The potential impact of the dams on refugia for macroinvertebrates was assessed (such as loss of backwaters due to altered geomorphology, etc.).

- **Seasonality:** Altered seasonality as a result of altered flow releases (to cater for specific water users such as irrigation of sugarcane) was considered. The assessment of the vegetation specialist was especially considered to align the instream specialist opinion of this impact.

- **Species Diversity and Abundance (fish):** The potential impact of the dam on the overall fish species diversity and their relative abundance was considered.

- **Species of Conservation Concern (SCC) (fish):** The potential impact of the dam on fish species with high conservation concern (based on IUCN criteria) was considered.

- **Substrate:** The potential impact of the dam on fish species and macroinvertebrate taxa with a high preference for substrate as cover (boulders, cobbles etc.) was considered. The assessment of the geomorphologist, and especially the sedimentation component, was considered in the assessment of this metric.

- **Vegetative Cover:** The potential impact of the dam on vegetation as cover/habitat for fish and macroinvertebrates were assessed. The impact from the vegetation specialist, especially the “change in marginal zone vegetation “as well as the geomorphologists “bank erosion” assessment were considered together with the generally expected impact.

- **Food Source /Trophic Structure (fish):** The potential impact of the dam on the food source of fish was considered, with special emphasis on the expected change in macroinvertebrates as a food source guiding the scoring of tis metric.

- **Alien Fish:** The potential of the dam to increase the presence, abundance and distribution of alien fish species within, upstream, and downstream of the dam was considered.

The above metrics were rated for each AR relevant for each proposed dam. Although the emphasis was on the potential impact on the reaches downstream of the dam, the dam itself and upstream reaches were also broadly considered for fish (especially for migration, species diversity and species of conservation concern and alien fish impacts). Each of the above mentioned metrics were scored according to the following scale (considering a change from the present ecological state expected in the reach):

- 5: Extreme/critical improvement from PES (>80% change).
- 4: Serious improvement from PES (60 - 80% change).
- 3: Large improvement from PES (40 - 60 change%).
- 2: Moderate improvement from PES (20 - 40 change%).
- 1: Slight improvement from PES (<20 change%).
- 0: No change (PES maintained).
- -1: Slight deterioration from PES (0 - 20% change).
- -2: Moderate deterioration from PES (20 - 40% change).
- -3: Large deterioration from PES (40 - 60% change).
- -4: Serious deterioration from PES (60 - 80 change%).
- -5: Extreme/critical deterioration from PES (>80% change).

A single rating was then calculated for fish and invertebrates for each assessment reach (average of all ratings). The Fish Response Assesses Index (FRAI) and Macroinvertebrate Response Assessment Index (MIRAI) was changed proportionally based on the overall (average) rating for each AR that included an EWR site or previous assessment that included the application of these indices. Where no FRAI or MIRAI index scores (percentages) were available, the TEC was used as a baseline. The change in FRAI and MIRAI scores was then used for each AR to estimate the expected change in ecological category from the PES/TEC.

3 PROPOSED MONTROSE DAM

The reaches assessed downstream of Montrose Dam were the following:

AR MR1	Dam Wall to Houtbosloop Tributary
AR MR2	Houtbosloop Tributary to Nels Tributary
AR MR3	Nels Tributary to Kaap Tributary
AR MR4	Kaap Tributary to EWR C5 to Mozambique

The impact assessment is based on the assumption that the EWRs can be supplied from the dam, including the floods. Cognisance must be taken of the fact that due to the attenuation factor over large distances, the success of managing floods at EWR C6 will be very limited.

The assumptions made regarding operation of the dam is that it will be managed in the same way that Kwena Dam is currently being managed.

As a reminder, the impact rating follows the following scoring approach:

- 5: Extreme/critical improvement from PES (>80% change).
- 4: Serious improvement from PES (60 - 80% change).
- 3: Large improvement from PES (40 - 60 change%).
- 2: Moderate improvement from PES (20 - 40 change%).
- 1: Slight improvement from PES (<20 change%).
- 0: No change (PES maintained).
- -1: Slight deterioration from PES (0 - 20% change).
- -2: Moderate deterioration from PES (20 - 40% change).
- -3: Large deterioration from PES (40 - 60% change).
- -4: Serious deterioration from PES (60 - 80 change%).
- -5: Extreme/critical deterioration from PES (>80% change).

3.1 Geomorphological Impacts

Table 3-1: Geomorphological Impact Ratings

Assessment Reach	MR1	MR2	MR3	MR4
PES=TEC	-	-	B/C	C/D
Expected post-dam EC	-	-	B/C	C/D
AR Impact Rating (-5 to 5)	-2.5	-2.00	-0.50	-0.80
Geomorphological Metrics				
Channel incision and/or bed armouring	-3	-2	-0.5	0
Bank erosion	-2	-1	-0.3	0
Sedimentation	0	-1	-0.4	-1
Comments	Confined valley, bedrock controlled, small flood features, long pools, limited signs of sediment deposition. **Impacts:** Sediment starved, no significant lateral sediment inputs. Channel incision resisted by bedrock, but bed armouring likely. Bank toe is likely to be eroded, exposing the banks to fluvial erosion and collapse. Flow level fluctuations during releases can accelerate bank erosion. Sedimentation unlikely due to sediment starvation and limited lateral sediment input.	Partly confined valley, bedrock controlled, several weirs, small flood features, long pools, limited signs of sediment deposition. **Impacts:** Incision resisted by bedrock and weirs, bed armouring reduced due to lateral sediment contributions. Bank erosion is possible but reduced as sediment load recovers and releases are somewhat attenuated. Localised sedimentation downstream of significant lateral sediment contributions.	Confined, small flood features, bedrock controlled, limited sediment deposition. **Impacts:** Incision resisted by bedrock, bed armouring reduced due to incremental recovery of bedload. Bank erosion reduced as sediment balance recovers. Localised sedimentation downstream of lateral sediment inputs as high flows are reduced.	Bedrock controlled, small flood features. Several weirs. Significant sediment/sand input from X24E-00922 and X24H-00892. Sandbars and benches widespread. **Impacts:** Incision resisted by bedrock base level control, armouring negated by lateral sediment input. Bank erosion unlikely due to high sediment loading. Possible increased sedimentation due to reduced high flows through flood harvesting.

3.2 Water Quality Impacts

Table 3-2: Water Quality Impact Ratings

AR	Nutrients	Temperature	Turbidity/ Clarity	DO	WQ Assimilation	WQ Dilution Impact Score	Integrated Change	Post Dam EC	Comments
MR1	-1.5	-1	0	-2	-1	-2	-1.5		The dam will 'reduce' the natural flow patterns brought into the Crocodile from the Elands, and impact on the good water quality state from the Elands River. Should water quality (WQ) issues develop from the upper Crocodile or Elands, the dam could improve assimilative capacity in the long term through appropriate and effective management.
MR2	-0.5	-1	-1	-1	-0.5	-0.5	-1		The assimilative capacity of the system expected to be mostly maintained throughout this reach. Water quality state will drop at the end of the reach, from the water quality hotspot at Mbombela. Reduced high flows, so an expected turbidity impact.
MR3	0	0	-0.5	0	0	0	0	**C**	Wit River (WQ hotspot) comes in at end of X22J-00958, with hotspots upstream and downstream. Unlikely to pick up any impacts / ameliorating affect from MR Dam in AR MR3, particularly with water quality inputs from the Wit River and other impacting activities along length of mainstem.
MR4	0	0	-1	0	0	0	0	**C**	Unlikely to pick up any impacts/ameliorating affect from MR Dam in AR MR4.

3.3 Riparian Vegetation Impacts

Table 3-3: Riparian Vegetation Impact Ratings

Assessment Reach	MR1	MR2	MR3	MR4
PES=TEC	C	C	C	C
Expected post dam EC	C/D	C/D	C	C
AR Impact Rating (-5 to 5)	-2	-2.17	-1.33	-0.42
Vegetation Metrics				
Algae	-1.5	-0.5	0	0
Change in marginal zone habitat	-2	-2.5	-1	-0.5
Altered seasonality	-2	-2	-1	-0.5
Woody : non-woody ratio - marginal zone	-1	-2	-1	-0.5
Woody : non-woody ratio - flood features	-1	-1	0	0
Woody : non-woody ratio - river banks	0	0	0	0
Terrestrialisation	-1	-1	0	0
Alien woody species	0	-1	0	0

Assessment Reach	MR1	MR2	MR3	MR4
Comments	The reach is steep sloped, bedrock controlled with a dominance of rocky habitats and woody vegetation, mostly tall trees. Any channel incision or scouring will likely remove non-woody vegetation, while woody vegetation should remain unchanged as the bed is already at bedrock.	Mostly bedrock controlled with tall dense woody vegetation. Long pools likely to support aquatic vegetation. Some alluvial flood features in places supports predominantly non-woody vegetation. Channel incision and scour likely to reduce / remove sediment-dependent vegetation such as reeds, grasses and sedges.	This reach is mostly bedrock controlled and dominated by dense tall woody vegetation, but with more of a mixed nature where pockets of non-woody vegetation are associated with alluvial features. Some woodiness will be promoted and some scour of marginal zone vegetation.	The SQ has elevated sediment levels from a tributary compared to the last SQ, the reach is characterised by lateral alluvial bars that support predominantly non-woody vegetation and the banks have a distinct tree line comprising riparian woody species. It is unlikely that this dam scenario will affect this SQ.

3.4 Fish Impacts

Table 3-4: Fish Impact Ratings

Assessment Reach		MR1	MR2	MR3	MR4
WQ	Description	Small to moderate change in WQ expected (WQ specialist).	Small change in WQ expected (WQ specialist).	Impact negated.	Impact negated.
	Score	-1.5	-1	0	0
Migration (incl. refugia)	Description	Although current natural migration barrier at Montrose falls (preventing fish migration us into croc), this dam may in fact flood the waterfall and hence create pathway from fish to migrate upstream in terms of the Crocodile River, resulting in species change from natural and present. Migration into Elands (catadromous and potadromous) will also be impacted (esp. eels).	Impact on various spp. (esp. eels and yellowfish) due to u/s barrier effect (also chemical barrier due to WQ).	Impact negated due to distance.	Impact negated due to distance.
	Score	-5	-2	0	0
Seasonality	Description	Potential slight increase in dry season due to irrigation releases.	As above.	Slight impact (due to distance).	Negated due to distance from dam.
	Score	-3	-2	-0.5	0
	Fish spp.	13	20	20	35

Assessment Reach		MR1	MR2	MR3	MR4
Species diversity & abundance	Description	Potential change in species due to high impact zone (WQ, flow).	Slight change (WQ, flow) will especially impact abundance of intolerant species.	Negated due to distance from dam.	Impact negated.
	Score	-2	-0.5	0	0
SCC (spp. of conservation concern)	Description	*Anguilla mossambica* (Not threatened - NT) and *Oreochromis mossambicus* (Vulnerable -VU) in reach potentially negatively impact. (Upstream - *Chiloglanis emarginatus* (Critically endangered (CR)) may also be impacted if Montrose falls breached by other species.	*Anguilla mossambica* and *Oreochromis mossambicus* potentially impacted.	Negated due to distance from dam.	Impact negated.
	Score	-3	-0.5	0	0
Substrate	Description	No notable change (geomorphology).	Slight change (lateral input with reduced floods) (geomorphology).	Very slight change (lateral input with reduced floods) (geomorphology).	Impact negated.
	Score	0	-0.8	-0.3	0
Vegetative cover	Description	Moderate change in marginal vegetation expected (vegetation assessment). Moderate bank erosion (geomorphology).	Moderate change in marginal vegetation expected (vegetation assessment). Slight bank erosion (geomorphology).	Slight change in marginal vegetation expected (vegetation assessment).	No change expected.
	Score	-2	-2.2	-0.75	0
	Description	Moderate impact on esp. invertebrates as food.	Slight impact, especially on invertebrates as food source.		No impact.

Assessment Reach		MR1	MR2	MR3	MR4
Food sources/trophic structure	Score	-1.5	-0.8	-0.1	0
Alien fish	Description	Presence of dam creates favourable habitat for some alien spp. (e.g. *Cyprinus carpio* and *Micropterus salmoides*), that may be also then spread us and ds. Dams also often stocked by anglers.	Dispersal of aliens from dam (increased abundance due to dam habitat created).		No impact.
	Score	-2	-1	-0.5	0
OVERALL FISH Rating (average)		**-2.1**	**-1.3**	**-0.3**	**0.0**
PES FRAI (%)		84.7	84.7	84.2	66.1
PES = TEC FRAI (EC[1])		**B**	**B**	**B**	**C**
Post Dam FRAI (%)		48.7	62.9	79.7	66.1
Post Dam FRAI (EC)		**D**	**C**	**B/C**	**C**
Change in PES/TEC		Notable deterioration expected with decrease of two categories towards a D. Not maintaining TEC.	Moderate deterioration expected with decrease by one category to C. Not maintaining TEC (if considered to be a B EC).	Slight deterioration expected with decrease by half a category expected (B/C). Just below TEC.	No change expected (maintains TEC).
Confidence rating		2	2	3	3

1 Ecological Category

3.5 Aquatic Macroinvertebrate Impacts

Table 3-5: Aquatic Macroinvertebrate Ratings

Assessment Reach		MR1	MR2	MR3	MR4
WQ	Description	The reach close to the dam will experience reduced dilution and assimilation, resulting in additional high nutrient input will impact on WQ sensitive macro-invertebrate taxa.	The assimilative capacity of the system expected to be mostly maintained throughout this reach.	Unlikely to pick up any impacts affect from dam, particularly with water quality inputs from the White River.	Unlikely to pick up any impacts affect from dam.
	Score (-5 to 5)	-1.5	-0.5	0	0
Migration	Description	The dam will be a complete migration barrier to all aquatic macro-invertebrates that need to move between reaches.	Unlikely to impact on this downstream reach.	Unlikely to impact on this downstream reach.	Unlikely to impact on this downstream reach.
	Score (-5 to 5)	-1	0	0	0
Refugia	Description	Any channel incision or scouring will likely remove marginal overhanging vegetation habitat as a refuge for vegetation dwellers.	Channel incision and scour likely to reduce sediment-dependent vegetation such as reeds, grasses and sedges which serves as a refuge for vegetation dwellers.	Lateral alluvial bars support predominantly non-woody vegetation as a refuge for vegetation dwellers.	Pockets of non-woody vegetation are associated with alluvial features and will serve as a refuge for vegetation dwellers.
	Score (-5 to 5)	-2	-1	0	0

Assessment Reach		MR1	MR2	MR3	MR4
Seasonality	Description	Damming and dam releases will alter seasonality of flows significantly and consequently influence the thermal and flow cues of breeding and migration invertebrates.	Dam releases will alter seasonality further downstream significantly and consequently influence the thermal and flow cues of breeding and migration invertebrates.	Dam releases will alter seasonality of downstream reaches to some degree.	Fluxes in flow less evident.
	Score (-5 to 5)	-2	-1.5	-0.5	0
Species diversity	Description	Large fluxes in macro-invertebrate population dynamics as habitat undergoes significant changes; even so, taxa are unlikely to disappear.	Moderate fluxes in macro-invertebrate population dynamics as habitat undergoes changes; even so, taxa are unlikely to disappear.	Impact of dam release fluxes on habitat declines and macro-invertebrate population changes less likely.	Impact of dam release fluxes on habitat declines and macro-invertebrate population changes disappears.
	Score (-5 to 5)	-1.5	-0.5	-0.5	0
Substrate	Description	This reach is sediment-starved; thus, no sediment inputs will impact on the gravel, sand and mud dwellers which are dependent on these biotopes.	Sediment input from tributaries increasingly mitigates for sediment starved water.	Sediment input from tributaries mitigate for sediment starved water.	Sediment input from tributaries mitigate for sediment starved water.
	Score (-5 to 5)	-2	-0.5	0	0
Vegetative cover	Description	Any channel incision or scouring will likely remove non-woody vegetation. Bank toe erosion driving bank erosion, frequent flow variation.	Channel incision and scour likely to reduce / remove sediment-dependent vegetation such as reeds, grasses and sedges. These actions are likely to reduce non-woody, marginal zone aquatic habitats which will impact on vegetation dwellers.	A small increase in deposition is likely to favour non-woody increase.	It is unlikely that this dam scenario will affect this SQ.
	Score (-5 to 5)	-2	-2	0	0

Assessment Reach		MR1	MR2	MR3	MR4
Alien inverts	Description	None expected.	No impact even as alien crayfish is present.	No impact even as alien crayfish is present.	No impact even as alien crayfish is present.
	Score (-5 to 5)	0	0	0	0
OVERALL INVERTS Rating		-1.3	-1.5	-0.8	-0.1
MIRAI PES = TEC (EC)		**B**	**C**	**C**	**C**
MIRAI (%)		83.5	74.4	74.4	75.9
Post Dam MIRAI (EC)		**C/D**	**D**	**C/D**	**C**
Post Dam MIRAI (%)		61.6	52.1	63.2	74.0
Change in PES/TEC		Expect to decrease from PES C to C/D.	Expect to decrease from PES C to D.	Expect to decrease from PES C to C/D.	Very small change thus remains in a category C.
Confidence rating		3	3	3	3

4 PROPOSED BOSCHJESKOP DAM

The reaches assessed downstream of Boschjeskop Dam are the following:

AR BK1	Nels Tributary downstream from Dam Wall
AR BK2	Nels Tributary to Kaap Tributary
AR BK3	Kaap Tributary to EWR C5 to Mozambique

The impact assessment is based on the assumption that the EWRs can be supplied from the dam, including the floods. Cognisance must be taken of the fact that due to the attenuation factor over large distances, the success of managing floods at EWR C6 will be very limited. Additional factors to be considered is that this will be a smaller dam than Montrose Dam with possibly less available yield.

The assumptions made regarding operation of the dam is that it will be managed in the same way that Kwena Dam is currently being managed.

4.1 Geomorphological Impacts

Table 4-1: Geomorphological Impact Ratings

Assessment Reach	BK1	BK2	BK3
PES=TEC	-	B/C	C/D
Expected post-dam EC	-	B/C	C/D
AR Impact Rating (-5 to 5)	-2.5	-0.5	-0.2
Geomorphological Metrics			
Channel incision and/or bed armouring	-2.5	-0.5	0
Bank erosion	-2.5	0	0
Sedimentation	-2	0	-0.2
Comments	Confined valley, small river channel, small flood features, bedrock controlled, several weirs, and limited sediment deposition. **Impacts:** sediment starved, but will resist incision due to bedrock nature. Armouring likely and erosion along channel margins, driving bank erosion. Bank erosion possibly exacerbated by variations in flow level and large increases in high flows during releases. Sedimentation likely during periods of low flow with significant lateral sediment input.	Confined, small flood features, bedrock controlled, limited sediment deposition. **Impacts:** reduced sediment load, but bedrock nature will resist incision. Localised bed armouring possible. Bank erosion and sedimentation unlikely.	Bedrock controlled, small flood features. Several weirs. Significant sediment/sand input from X24E-00922 and X24H-00892. Sandbars and benches widespread. **Impacts:** Incision resisted by bedrock base level control, armouring negated by lateral sediment input. Bank erosion unlikely due to high sediment loading. Possible increased sedimentation due to reduced high flows through flood harvesting, but effect should be small due to small volume of Boschjeskop.

4.2 Water Quality Impacts

Table 4-2: Water Quality Impact Ratings

AR	Nutrients	Temperature	Turbidity/ Clarity	DO	WQ Assimilation	WQ Dilution Impact Score	Integrated Change	Post Dam EC	Comments
BK1	-2	-1	-1.5	-1	-1	-2	-1.5		Dam located in this SQ. Elevated nutrients a priority. Moderate Priority Water Quality (WQ) reach; drivers are elevated nutrients and salts.
BK2	-1	0	0	0	-1	0	-0.5	**C**	WQ hotspots in upstream and EWR C4 reach. Turbidity due to reduction in longitudinal input; loss of habitat diversity.
BK3	0	0	0	0	0	0	0	**C**	Unlikely to pick up any impacts/ameliorating affect from BK Dam in AR BK3.

4.3 Riparian Vegetation Impacts

Table 4-3: Riparian Vegetation Impact Ratings

Assessment Reach	BK1	BK2	BK3
PES=TEC	**C**	**C**	**C**
Expected post dam EC	**C**	**C**	**C**
AR Impact Rating (-5 to 5)	-2	-1	-0
Vegetation Metrics			
Algae	-2	-1	0
Change in marginal zone habitat	-1	0	0
Altered seasonality	-2	-1	0
Woody : non-woody ratio -marginal zone	-1	0	0
Woody : non-woody ratio - flood features	0	0	0
Woody : non-woody ratio - river banks	0	0	0
Terrestrialisation	0	0	0
Alien woody species	0	0	0

Assessment Reach	BK1	BK2	BK3
Comments	This reach is mostly bedrock controlled and dominated by dense tall woody vegetation, many of which are riparian, with scattered pockets of non-woody vegetation but less common. Channel incision and scouring; together with reduced flood peaks will further promote woody vegetation cover and abundance, which is already high.	This reach is mostly bedrock controlled and dominated by dense tall woody vegetation, many of which are riparian, with scattered pockets of non-woody vegetation associated with a few alluvial deposition portions. A small amount of channel incision and scouring, together with reduced flood peaks will further promote woody vegetation cover and abundance.	The reach is characterised by lateral alluvial bars that support predominantly non-woody vegetation and the banks have a distinct tree line comprising riparian woody species. It is unlikely that this dam scenario will affect this reach.

4.4 Fish Impacts

Table 4-4: Fish Impact Ratings

Assessment Reach		BK1	BK2	BK3
WQ	Description	Small change in WQ expected.	Very small change in WQ expected.	Impact negated.
	Score	-1.5	-0.5	0
Migration (incl. refugia)	Description	Catadromous *Anguilla mossambica* migration as well as some potadromous spp. (esp. *Labeobarbus marequensis*) to upper reaches of Nels River impacted by dam, however relatively small catchment upstream of dam.	No impact.	Impact negated.
	Score	-1.5	0	0
Seasonality	Description	Moderate change due to increased release in dry season esp. (also change noted by vegetation specialist).	Slight change due to increased release in dry season esp. (also change noted by vegetation specialist).	Impact negated.
	Score	-2	-0.8	0
Species diversity & abundance	Fish spp.	8 & 14	20	35
	Description	Potential slight change (esp. eels, and for intolerant fish spp. downstream of dam).	No change expected.	No change expected.
	Score	-1	0	0
SCC	Description	*Anguilla mossambica* (NT) entire reach and *Oreochromis mossambicus* (VU) in lower SQ. Potential slight change in *Anguilla mossambica* due to migration impact of dam.	Same species applicable but no notable change expected.	Same species applicable but no notable change expected.
	Score	-1	0	0

Assessment Reach		BK1	BK2	BK3
Substrate	Description	Sedimentation: Reduction in longitudinal input, loss of habitat diversity (geomorphology).	No impact (geomorphology).	No impact (geomorphology).
	Score	-1.5	0	0
Vegetative cover	Description	Increased localised bank erosion (geomorphology). Small change in marginal zone vegetation.	Very slight impact on marginal vegetation (in SQ at inflow of Nels River).	No impact (geomorphology).
	Score	-1.25	-0.3	0
Food sources/trophic structure	Description	Slight decrease expected (esp. inverts).		Impact negated.
	Score	-0.8	-0.1	0
Alien fish	Description	Presence of dam creates favourable habitat for some alien spp. (e.g., *Cyprinus carpio* and *Micropterus salmoides*), that may be also then spread us and ds. Dams also often stocked by anglers.	Dispersal of aliens from dam (increased abundance due to dam habitat created upstream).	No impact expected.
	Score	-2	-0.2	0
OVERALL FISH Rating (average)		**-1.4**	**-0.2**	**0.0**
PES FRAI (%)			84.2	67.3
PESEIS (EC)			**B**	**C**
Post Dam FRAI (%)		0.0	80.2	67.3
Post Dam FRAI (EC)		**D**	**B/C**	**C**
TEC (Fish)		**C (PESEIS)**	**B**	**C**
Change in PES/TEC		Deterioration of at least one category expected (D EC).	Potential slight deterioration of half category towards B/C.	No change (remain in C EC).

Assessment Reach	BK1	BK2	BK3
Confidence rating	2	3	3

4.5 Aquatic Macroinvertebrate Impacts

Table 4-5: Aquatic Macroinvertebrate Ratings

Assessment Reach		BK1	BK2	BK3
WQ	Description	Elevated nutrients and salts. Turbidity due to erosion and scouring.	The increase in nutrient levels will adversely influence the WQ sensitive macro-invertebrate taxa.	Any further impact from dam unlikely.
	Score (-5 to 5)	-1	-0.5	0
Migration	Description	No impact expected.	No impact expected.	No impact expected.
	Score (-5 to 5)	0	0	0
Refugia	Description	Localised bank erosion along alluvial sections, loss of habitat diversity.	Very localised bank erosion will influence areas, but will not be significant to impact on macro-invertebrate diversity.	No impact expected.
	Score (-5 to 5)	-0.5	0	0
Seasonality	Description	Damming and dam releases will alter seasonality of flows and consequently influence the thermal and flow cues of breeding and migration invertebrates.	Very little impact further downstream.	No impact further downstream.
	Score (-5 to 5)	-1.5	0	0
Species diversity	Description	Reduction of sediments will impact on the gravel, sand and mud dwellers which is dependent on these biotopes.	Very little impact on these biotopes.	No impact expected.
	Score (-5 to 5)	-1	0	0
Substrate	Description	Large reduction in bedload driving armouring, thus remove gravel, sand and mud biotopes and the macro-invertebrate communities dependant on these biotopes will be impacted adversely.	Small reduction in finer bedload will have a lower impact on macro-invertebrate communities dependant on these biotopes.	Small reduction in finer bedload.
	Score (-5 to 5)	-1.5	-0.5	0

Assessment Reach		BK1	BK2	BK3
Vegetative cover	Description	Lower marginal vegetation due to scouring and channel incision. These actions are likely to reduce non-woody, marginal zone aquatic habitats which will impact on vegetation dwellers.	It is unlikely that this dam scenario will affect this SQ.	It is unlikely that this dam scenario will affect this SQ.
	Score (-5 to 5)	-1	0	0
Alien inverts	Description	No Impact.	No Impact.	No Impact.
	Score (-5 to 5)	0	0	0
OVERALL INVERTS Rating		-0.8	-0.1	0.0
MIRAI PEC and TEC		**C**	**C**	**C**
MIRAI (%)			75.9	74.8
Post Dam MIRAI (EC)		**C/D**	**C**	**C**
Post Dam MIRAI (%)		0.0	74.0	74.8
Confidence rating		2	2	2

5 PROPOSED MOUNTAIN VIEW DAM

The reaches assessed downstream of Mountain View Dam are the following:

AR MV1	Kaap Tributary downstream from Dam Wall
AR BK2	Kaap Tributary to EWR C5 (Malelane)
AR BK3	EWR C5 to Mozambique

The impact assessment is based on the assumption that the EWRs can be supplied from the dam.

The assumptions made regarding operation of the dam is that it will be managed in the same way that Kwena Dam is currently being managed. The Crocodile River downstream of the dam will be managed from the Kaap River and Kwena Dam will only operate the section upstream of the Kaap River except during times when the Mountain View Dam may have insufficient yield, such as during drought times.

5.1 Geomorphological Impacts

Table 5-1: Geomorphological Impact Ratings

Assessment Reach	MV1	MV2	MV3
PES=TEC	**B**	**C/D**	**C**
Expected post-dam EC	**C**	**D**	**C**
AR Impact Rating (-5 to 5)	-2	-1	-0.5
Geomorphological Metrics			
Channel incision and/or bed armouring	-2	-1	0
Bank erosion	-2	-1	0
Sedimentation	-1	-0.5	-1
Comments	Largely bedrock with no/limited floodplain. Many weirs and no clear sedimentation along the channel. **Impacts:** large reduction in longitudinal sediment supply, with riverbed relatively stable due to bedrock nature and many weirs. Bed armouring likely. Significant scour of bank toe and water level fluctuations with flow releases likely to drive bank erosion along alluvial sections. Localised sedimentation associated with lateral sediment inputs and reduced high flows.	Bedrock controlled, incised channel with narrow flood features. Significant sediment/sand input from northern tributaries. Sandbars and benches widespread. **Impacts:** Bedrock will resist incision, possible bed armouring upstream of confluence with X24C-00978 (significant sediment source). Increased sedimentation likely where lateral sediment inputs are high due to reduced high flows moving sediment downstream.	Bedrock controlled, small flood features. Several weirs. Significant sediment/sand input from X24E-00922 and X24H-00892. Sandbars and benches widespread. **Impacts:** Incision resisted by bedrock base level control, armouring negated by lateral sediment input. Bank erosion unlikely due to high sediment loading. Possible increased sedimentation due to reduced high flows through flood harvesting.

5.2 Water Quality Impacts

Table 5-2: Water Quality Impact Ratings

AR	Nutrients	Temperature	Turbidity/ Clarity	DO	WQ Assimilation	WQ Dilution Impact Score	Integrated Change	Post Dam EC	Comments
MV1	-2	-1.5	-1	-1	-2.5	-3.5	-2	**C**	WQ PES EWR 7: B, 82.6%. Assumes multi-level release structures. Drops to a C EC with dam in place, as reduced dilution and assimilation capacity. Unknowns: (1) are there still large flushing floods which may still come over dam wall; (2) volume of water from Kaap vs mainstem Croc; (3) height of dam wall; (4) dam operation.
MV2	-1	0	-1	0	-1	-1	-0.5	**C**	WQ PES EWR 5: C, 67.8%. A negative impact on the Crocodile River as the positive impact of water from the Kaap River (dilution effect, B category) is reduced with the dam in place. Less dilution effect; unlikely to pick up temp and DO impacts as integrate across the AR. No impact by EWR C5.
MV3	0	0	-1	0	0	0	0	**C**	

5.3 Riparian Vegetation Impacts

Table 5-3: Riparian Vegetation Impact Ratings

Assessment Reach	MV1	MV2	MV3
PES=TEC	**C/D**	**C**	**C**
Expected post dam EC	**D**	**C**	**C**
AR Impact Rating (-5 to 5)	-2	-1	-0.75
Vegetation Metrics			
Algae	-2	-1	0
Change in marginal zone habitat	-2	-1	0
Altered seasonality	-1	-1	0
Woody : non-woody ratio -marginal zone	-2	-1	0
Woody : non-woody ratio - flood features	-2	-1	0
Woody : non-woody ratio - river banks	-1	0	0
Terrestrialisation	-1	0	0
Alien woody species	-1	0	0
Comments	The reach is characterised by a narrow marginal zone, rocky habitats and a high degree of woody cover. Altered flooding (reduced peak flows) is likely to promote woody species establishment in the marginal zone and	The reach has elevated sediment levels from a tributary compared to the last SQ, the reach is characterised by lateral alluvial bars that support predominantly non-woody vegetation and the banks have a distinct tree line	The reach is characterised by lateral alluvial bars and flood benches. Vegetation is predominantly non-woody along the marginal zone macro channel bed (grasses and reeds, extensive in places), with mainly taller woody tree

Assessment Reach	MV1	MV2	MV3
	along flood features, while increased scour is likely to reduce non-woody marginal zone habitats, particularly those that are dependent on alluvial deposits that are already scattered and which may be reduced.	comprising riparian woody species. Some deposition may increase marginal zone cover in places while altered flooding (reduced peak flows) is likely to promote woody species establishment in the marginal zone and along flood features.	species aligned along the top of the banks that form a distinct riparian tree line. Altered flooding (reduced peak flows) is less likely to promote woody species establishment this far downstream in the reach.

5.4 Fish Impacts

Table 5-4: Fish Impact Ratings

Assessment Reach		MV1	MV2	MV3
WQ	Description	Close to dam (high impact zone).	Diluted impact after confluence.	Too far from dam to be impacted.
	Score	-1.5	-0.5	0
Migration (incl. refugia)	Description	Eels (U/S), potadromous spp.	Unlikely to impact.	Impact negated.
	Score	-2	0	0
Seasonality	Description	Potential slight increase in dry season due to irrigation releases (esp. dry season).	Slight impact (due to distance from release).	Impact negated.
	Score	-1.5	-0.5	0
Species diversity & abundance	Fish spp.	17	35	35
	Description	Potential decrease in eels.	No notable impact.	Impact negated.
	Score	-1	0	0
SCC	Description	*Anguilla mossambica* (NT) present and potentially negatively impacted due to migration barrier (esp. us of dam)	*Anguilla mossambica* (NT) and *Oreochromis mossambicus* (VU) present, no notable impact expected.	Impact negated.
	Score	-2	0	0
Substrate	Description	Based on sediment change (geomorphology) impact on substrate quality/composition.	Slight change expected (based on geomorphology sedimentation assessment).	Slight change expected (based on geomorphology sedimentation assessment).
	Score	-1.3	-0.5	-0.3

Assessment Reach		MV1	MV2	MV3
Vegetative cover	Description	Vegetation assessment (decrease in marginal zone habitat).	Vegetation assessment (slight decrease in marginal zone habitat).	Vegetation assessment very slight decrease in marginal zone habitat).
	Score	-2	-1	-0.5
Food sources/trophic structure	Description	Slight decrease in food sources (based on invertebrate assessment).	Impact negated.	Impact negated.
	Score	-0.5	0	0
Alien fish	Description	Presence of dam creates favourable habitat for some alien spp. (e.g., *Cyprinus carpio* and *Micropterus salmoides*), that may be also then spread us and ds. Dams also often stocked by anglers.	Dispersal of aliens from dam (increased abundance due to dam habitat created).	Very slight impact due to distance from dam.
	Score	-2	-1	-0.5
OVERALL FISH Rating (average)		**-1.5**	**-0.4**	**-0.2**
PES FRAI (%)		76.8	66.1	67.3
PES (TEC) FRAI (EC)		**C**	**C**	**C**
Post Dam FRAI (%)		54.1	60.3	65.1
Post Dam FRAI (EC)		**D**	**C/D**	**C**
Change in PES/TEC		Potential drop by one category (D EC), not meeting TEC.	Potential drop by half a category (C/D EC), not meeting TEC.	Slight decrease, but remains in same EC (C category), maintaining TEC.
Confidence rating		3	3	3

5.5 Aquatic Macroinvertebrate Impacts

Table 5-5: Aquatic Macroinvertebrate Ratings

Assessment Reach		MV1	MV2	MV3
WQ	Description	This reach is close to dam wall, changes in the water quality of the released water will be most evident here. Furthermore, reduced dilution and assimilation will occur here and also further downstream.	Lowered WQ from Kaap River does not have the same positive influence on this reach as in the past.	Too far from dam to be impacted. Unlikely to pick up any impact from Mountain View Dam.
	Score (-5 to 5)	-1.5	-0.5	0
Migration	Description	The presence of the migratory *Macrobranchium* prawns from coastal breeding sites to the upstream area will be detrimental to the distribution of this crustacean.	*Macrobranchium* prawns still have free movement in this reach.	*Macrobranchium* prawns still have free movement in this reach.
	Score (-5 to 5)	-1.5	0	0
Refugia	Description	Sedimentation of backwater pools – reduce depth of pools and marginal habitats, including marginal vegetation overhang and undercut banks. Bank erosion along lower alluvial sections due to sediment trapping by reservoir, will also compromise marginal habitat integrity.	Reduced sediment yield, bench formation and fluctuating flow levels.	Too far from dam to be impacted.
	Score (-5 to 5)	-1.5	0	0
Seasonality	Description	Flows released from the Mountain View Dam to supply water to the Crocodile River in the dry season will create unnatural high flows in the low-flow periods. This will impact on the breeding and migrating ques of many aquatic macro-invertebrates.	Flows from the Mountain View Dam will supply additional flows to the Crocodile River, which will maintain the low flows, or have a slightly higher flow rate to supply downstream users.	Flow changes will not manifest in a significant way in this reach.
	Score (-5 to 5)	-2	-1	0

Assessment Reach		MV1	MV2	MV3
Species diversity	Description	The dam creates a migration obstruction to *Macrobranchium* prawns and this will be detrimental to the distribution of this crustacean in the upstream catchment of the Kaap River.	*Macrobranchium* prawns still have free movement in this reach.	*Macrobranchium* prawns still have free movement in this reach.
	Score (-5 to 5)	-0.5	0	0
Substrate	Description	Some scouring of sediments directly downstream of dam, remove sand, gravel and mud habitats in this reach.	Some sedimentation of SIC habitats downstream of Crocodile-Kaap River confluence.	Little influence from dam.
	Score (-5 to 5)	-1	-1	0
Vegetative cover	Description	Bank erosion; increased scour is likely to reduce non-woody marginal zone habitats.	Some bank erosion may reduce marginal zone cover.	Some deposition may increase marginal zone cover.
	Score (-5 to 5)	-2	-1	1
Alien inverts	Description	Alien crayfish has the potential to increase in the extended dam marginal zones and the larvae will spill over in inflated numbers to the downstream reaches where it will settle and start tunnelling into mud embankments, compromising the marginal habitats of fish and other invertebrates.	Alien crayfish: increase in dam and spill over into downstream areas. Can migrate further downstream.	Alien crayfish: increase in dam and spill over into downstream areas. Can migrate further downstream.
	Score (-5 to 5)	-0.5	-0.3	0
OVERALL INVERTS Rating		-1.3	-0.5	0.1
MIRAI PES / TEC		**B**	**C**	**C**
MIRAI (%)		83.5	76.9	74.8
Post Dam MIRAI (EC)		**C/D**	**C**	**C**
Post Dam MIRAI (%)		61.6	69.6	76.7

Assessment Reach	MV1	MV2	MV3
TEC (Inverts)	**B**	**C**	**C**
Change in PES/TEC	Expect to decrease from PES C to C/D.	Slight decrease thus remains in a category C.	Very small change thus remains in a category C.
Confidence rating	3	3	3

6 PROPOSED STRATHMORE OFF-CHANNEL DAM

The reaches assessed downstream of Strathmore Dam are the following:

AR SM1	Outlet of Jam Tin Creek to EWR C5 (Malelane) on the Crocodile River
AR SM2	EWR C5 to Mozambique

The impact assessment is based on the assumption that the Strathmore Dam inlet will be close to the dam, i.e., upstream of Jam Tin Creek. The proposed outlet from the dam will be in Jam Tin Creek which is a drainage line not digitized or assessed as part of the PESEIS project. The implication is then that Jam Tim Creek is not a significant resource, as defined in the National Water Act of 1998. The Act further states that all significant resources must have a Reserve (including ecological requirements) determined and must form part of Classification. This evaluation has therefore not considered the short stretch of drainage line making up Jam Tin Creek.

The assumption has also been made that the offtake will be limited to low flows and possibly Class I floods. Information related to the intake for Strathmore Dam from the Crocodile River is not available and it has been assumed that it will not consist of any major weir structure. It is further assumed that EWR flows largely be supplied from Kwena Dam rather from the off channel storage. This will be due to the potential impact of scour and erosion downstream of the dam. The assumptions made regarding the operation of the dam is that it will provide for the lower Crocodile River users in a similar manner as that which is proposed from the Kaap River.

6.1 Geomorphological Impacts

Table 6-1: Geomorphological Impact Ratings

Assessment Reach	SM1	SM2
PES=TEC	**C/D**	**C**
Expected post-dam EC	**C/D**	**C**
AR Impact Rating (-5 to 5)	-1	-0.2
Geomorphological Metrics		
Channel incision and/or bed armouring	0	0
Bank erosion	0	0
Sedimentation	-1.5	-0.5
Comments	Bedrock controlled, incised channel with narrow flood features. Significant sediment/sand input from northern tributaries. Sandbars and benches widespread. **Impacts:** Significant erosion along receiving stream likely for first 5 to 10 years. Bedrock will resist incision, bed armouring unlikely due to high sediment load. Increased sedimentation likely during erosional phase of receiving stream and where lateral sediment inputs are high due to reduced high flows moving sediment downstream (assumption: water abstracted from Crocodile River during high flows to fill Strathmore).	Bedrock controlled, small flood features. Several weirs. Significant sediment/sand input from X24E-00922 and X24H-00892. Sandbars and benches widespread. **Impacts:** Incision resisted by bedrock base level control, armouring negated by lateral sediment input. Bank erosion unlikely due to high sediment loading. Possible increased sedimentation due to reduced high flows through flood harvesting.

6.2 Water Quality Impacts

Table 6-2: Water Quality Impact Ratings

AR	Nutrients	Temperature	Turbidity/ Clarity	DO	WQ Assimilation	WQ Dilution Impact Score	Integrated Change	Assessment of EC Change	Comments
SM1	0	0	-1.5	0	0	0	-0.5	**C**	Small impact shown is at EWR C5. No impact if the whole AR is considered.
SM2	0	0	-0.5	0	0	0	0	**C**	Unlikely to pick up any impacts/ameliorating affect from SM Dam in AR SM2.

6.3 Riparian Vegetation Impacts

Table 6-3: Riparian Vegetation impact ratings

Assessment Reach	SM1	SM2
PES	**C**	**C**
Expected PES	**C**	**C**
AR Impact Rating (-5 to 5)	-1	-0.25
Vegetation Impacts		
Algae	0	0
Change in marginal zone habitat	-1	0
Altered seasonality	-1	0
Woody : non-woody ratio -marginal zone	-1	0
Woody : non-woody ratio - flood features	-1	0
Woody : non-woody ratio - river banks	0	0
Terrestrialisation	0	0
Alien woody species	0	0
Comments	The reach is characterised by lateral alluvial bars that support predominantly non-woody vegetation and the banks have a distinct tree line comprising riparian woody species. Some deposition may increase marginal zone cover in places while altered flooding (reduced peak flows) is likely to promote woody species establishment in the marginal zone and along flood features.	The reach is characterised by lateral alluvial bars and flood benches. Vegetation is predominantly non-woody along the marginal zone macro channel bed (grasses and reeds, extensive in places), with mainly taller woody tree species aligned along the top of the banks that form a distinct riparian tree line. It is unlikely that this dam scenario will affect this reach.

6.4 Fish Impacts

Table 6-4: Fish Impact Ratings

Assessment Reach		SM1	SM2
WQ	Description	Very slight WQ impact mostly close to inflow.	Impact negated due to distance.
	Score	-0.5	0
Migration (incl. refugia)	Description	No impact on migration (off-channel migration barrier).	No impact on migration (off-channel migration barrier).
	Score	0	0
Seasonality	Description	Potential slight increase in dry season due to irrigation releases.	Mostly negated due to distance.
	Score	-0.4	-0.2
Species diversity & abundance	Fish spp.	35	35
	Description	No change expected.	No change expected.
	Score	0	0
SCC	Description	*Anguilla mossambica* (NT) and *Oreochromis mossambicus* (VU) present, no notable impact expected.	*Anguilla mossambica* (NT) and *Oreochromis mossambicus* (VU) present, no notable impact expected.
	Score	0	0
Substrate	Description	Sediment/erosion from receiving stream flowing into reach, decreased impact with distance from impact.	Mostly negated due to distance from impact.
	Score	-0.6	-0.1

Assessment Reach		SM1	SM2
Vegetative cover	Description	Slight change in marginal vegetation (vegetation specialist).	Slight change in marginal vegetation (vegetation specialist).
	Score	-0.6	-0.25
Food sources/trophic structure	Description	Very slight decrease in food source expected (invertebrates).	Negated due to distance.
	Score	-0.1	0
Alien fish	Description	Dispersal of aliens from dam (increased abundance due to dam habitat created).	Negated due to distance.
	Score	-0.2	0
OVERALL FISH Rating (average)		**-0.3**	**-0.1**
PES FRAI (%)		66.1	67.3
PES (TEC) FRAI (EC)		**C**	**C**
Post Dam FRAI (%)		62.1	66.4
Post Dam FRAI (EC)		**C**	**C**
TEC (Fish)		**C**	**C**
Change in PES/TEC		Very slight overall impact expected (-0.3) with PES remaining in C (achieving TEC).	Very slight overall impact expected (-0.4) with PES remaining in C (achieving TEC).
Confidence rating		3	3

6.5 Aquatic Macroinvertebrate Impacts

Table 6-5: Aquatic Macroinvertebrate Ratings

Assessment Reach		SM1	SM2
WQ	Description	Some return flows from irrigation below the dam wall impact on WQ and will influence the WQ sensitive macro-invertebrate taxa.	No impact.
	Score (-5 to 5)	-0.5	0
Migration	Description	No impact expected.	No impact expected.
	Score (-5 to 5)	0	0
Refugia	Description	No impact expected.	No impact expected.
	Score (-5 to 5)	0	0
Seasonality	Description	A slightly higher flow rate released into the Crocodile River to supply downstream users (especially dry season) will influence macro-invertebrate abundance.	No further impact downstream.
	Score (-5 to 5)	-0.5	0
Species diversity	Description	No impact expected.	No impact expected.
	Score (-5 to 5)	0	0
Substrate	Description	Erosion along receiving stream supplying extra sediment to Crocodile River.	Some sediment transported downstream.
	Score (-5 to 5)	-0.5	-0.2

Assessment Reach		SM1	SM2
Vegetative cover	Description	Reduced peak flows are likely to promote woody species establishment in the marginal zone to replace some overhanging non-woody species, which will impact on the vegetation dwellers which is dependent on these biotopes.	It is unlikely that this dam scenario will affect this SQ.
	Score (-5 to 5)	-0.5	0
Alien inverts	Description	No Impact.	No Impact.
	Score (-5 to 5)	0	0
OVERALL INVERTS Rating		-0.3	0.0
MIRAI PES = TEC (EC)		**C**	**C**
MIRAI (%)		76.9	74.8
Post Dam MIRAI (EC)		**C**	**C**
Post Dam MIRAI (%)		73.1	74.4
Change in PES/TEC		Very small change thus remains in a category C.	No notable change.
Confidence rating		2	2

7 RANKING AND FATAL FLAW IDENTIFICATION

Once a single rating had been produced for each AR for each component, the following process was undertaken.

- A Multi Criteria Decision Analysis and Classes determination tool (DWS, 2016b) was used to come up with an integrated AR impact rating.
- The AR rating was weighted according to the following parameters: TEC, Ecological Importance and Sensitivity (EIS), Confidence (of the EWR/PES assessment 2014) and Conservation Importance of the reach (DWS, 2016b).
- The weighting was used to obtain an impact rating for each dam; this is in terms of the likelihood of meeting the TEC.
- Expected changes in Ecological Category were also provided so that an estimate can be made of the likelihood of the TEC being maintained.
- Modifying factors that may influence the rating were then considered in the final ranking and to identify fatal flaws.

7.1 Ranking based on Severity of Impacts of the Proposed Dam Options

The TECs, which in this case are all the same as the PES scores, were given a value of 1. The impact ratings for the different ARs (out of 5) were normalised to 1. An impact rating smaller than 1 indicates that it may not meet the TEC, whereas any rating higher than 1 may improve the EC.

A summary of the normalised impact ratings out of 1 is provided in **Table 7-1**.

Table 7-1: Summary of the Normalised Impact Rating for each AR per Proposed Dam

Proposed Dams	Montrose				Boschjeskop			Mountain View			Strathmore	
Component	MR1	MR2	MR3	MR4	BK1	BK2	BK3	MV1	MV2	MV3	SM1	SM2
Physico chemical	0.7	0.8	1.0	1.0	0.7	0.9	1.0	0.6	0.9	1.0	0.9	1.0
Geomorphology	0.5	0.6	0.9	0.9	0.5	0.9	1.0	0.6	0.8	0.9	0.8	1.0
Fish	0.6	0.7	0.9	1.0	0.7	1.0	1.0	0.7	0.9	1.0	0.9	1.0
Invertebrates	0.7	0.8	1.0	1.0	0.8	1.0	1.0	0.6	0.9	1.0	0.9	1.0
Riparian vegetation	0.6	0.6	0.7	0.9	0.6	0.8	1.0	0.6	0.8	0.9	0.8	1.0
AR Integrated Impact Rating	**0.6**	**0.7**	**0.9**	**1.0**	**0.7**	**0.9**	**1.0**	**0.6**	**0.9**	**1.0**	**0.9**	**1.0**
Proposed Dam Impact Rating	**0.84**				**0.90**			**0.84**			**0.94**	

7.2 Ranking Considering Modifying Factors

The impact ratings illustrate only one aspect of the factors to be considered in the ranking of the dam options. Other modifying factors that must be considered as they could result in the gazetted TEC not being met, are the following:

7.2.1 Potential of Failing to meet the Target Ecological Category

TECs are gazetted for each Resource Unit (RU) nested within IUAs, which are broader delineation units of Classification. The combination of TECs for an IUA are called the Catchment Configuration and define the ensuing Water Resource Class (or Class) assigned. Classes are defined as Class I (minimal use and good ecological state) through to Class III (high use and dominated by poorer ecological state). The TEC (and subsequently Classes) for each RU is gazetted and must be met. What must also be considered is that for RUs containing EWR sites, the TEC for each component, and not just for the integrated EcoStatus, must also be met. This implies that any potential deviation from a category will result in non-compliance with the gazetted conditions (Government Gazette, 30 December 2016, No. 40531).

A number of factors must be considered during this evaluation:

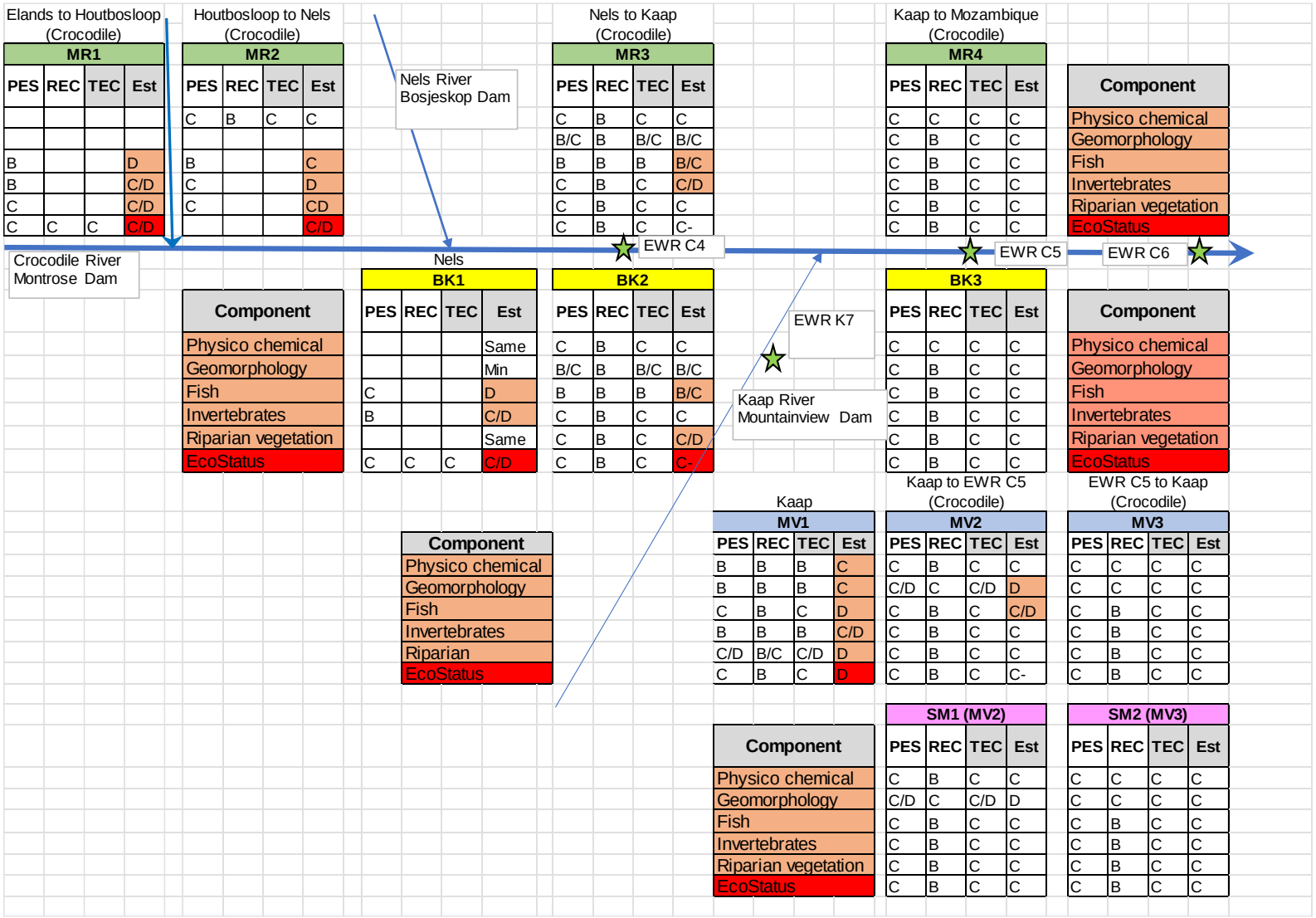
Firstly, a realistic evaluation of dam-building impacts must consider that a dam can never meet the TEC immediately below the dam wall. These sections must be seen as sacrificial zones.

Secondly, the potential change in EC at this screening level will inherently be of low confidence. Subsequently the individual changes in component are of lower importance as compared to the change in EcoStatus. The predicted change in EcoStatus may reflect a significant drop in a single response component or a drop in more than one of the three response components (fish, invertebrates and riparian vegetation). **Table 7-2** illustrates the change in EC from the TECs per component for the different ARs. Dam ARs are staggered from upstream to downstream illustrating the ARs which are the same for different dam options. Orange shading of the Estimated EC (Est) for the components shows a predicted change in EC from the TEC. Red shading of the Est shows a potential change in EcoStatus.

Both the proposed Boschjeskop and Montrose dams show a drop in EcoStatus for both the ARs downstream of the dam and the next AR. The two applicable reaches downstream of Montrose Dam fall in the Crocodile River, which has a higher ecological importance than the AR downstream of the Boschjeskop Dam in the Nels River. This would imply that the impact of not meeting the TEC is likely to be a fatal flaw for both options, but of greater significance in the case of the Montrose Dam.

As expected, the AR directly below Mountain View Dam also shows a drop in EcoStatus.

Table 7-2: Estimated Component and EcoStatus Ecological Categories comparing the TEC to the Post-Dam Condition



MR1

PES	REC	TEC	Est
B			D
B			C/D
C			C/D
C	C	C	C/D

MR2

PES	REC	TEC	Est
C	B	C	C
B			C
C			D
C			CD
			C/D

MR3

PES	REC	TEC	Est
C	B	C	C
B/C	B	B/C	B/C
B	B	B	B/C
C	B	C	C/D
C	B	C	C
C	B	C	C-

MR4

PES	REC	TEC	Est
C	C	C	C
C	B	C	C
C	B	C	C
C	B	C	C
C	B	C	C
C	B	C	C

Component
Physico chemical
Geomorphology
Fish
Invertebrates
Riparian vegetation
EcoStatus

Component
Physico chemical
Geomorphology
Fish
Invertebrates
Riparian vegetation
EcoStatus

BK1

PES	REC	TEC	Est
			Same
			Min
C			D
B			C/D
			Same
C	C	C	C/D

BK2

PES	REC	TEC	Est
C	B	C	C
B/C	B	B/C	B/C
B	B	B	B/C
C	B	C	C
C	B	C	C/D
C	B	C	C-

BK3

PES	REC	TEC	Est
C	C	C	C
C	B	C	C
C	B	C	C
C	B	C	C
C	B	C	C
C	B	C	C

Component
Physico chemical
Geomorphology
Fish
Invertebrates
Riparian vegetation
EcoStatus

Component
Physico chemical
Geomorphology
Fish
Invertebrates
Riparian
EcoStatus

MV1

PES	REC	TEC	Est
B	B	B	C
B	B	B	C
C	B	C	D
B	B	B	C/D
C/D	B/C	C/D	D
C	B	C	D

MV2

PES	REC	TEC	Est
C	B	C	C
C/D	C	C/D	D
C	B	C	C/D
C	B	C	C
C	B	C	C
C	B	C	C
C	B	C	C-

MV3

PES	REC	TEC	Est
C	C	C	C
C	C	C	C
C	B	C	C
C	B	C	C
C	B	C	C
C	B	C	C

Component
Physico chemical
Geomorphology
Fish
Invertebrates
Riparian vegetation
EcoStatus

SM1 (MV2)

PES	REC	TEC	Est
C	B	C	C
C/D	C	C/D	D
C	B	C	C
C	B	C	C
C	B	C	C
C	B	C	C

SM2 (MV3)

PES	REC	TEC	Est
C	C	C	C
C	C	C	C
C	B	C	C
C	B	C	C
C	B	C	C
C	B	C	C

7.2.2 Environmental Fatal Flaws

The proposed Montrose Dam may result in the flooding of the existing Montrose Falls in the Crocodile River, which would be located in the dam basin. This waterfall is currently a natural migration (distribution) barrier in the system preventing some fish species from colonising the upper reaches of the Crocodile River. At present seven indigenous fish species are expected to occur directly upstream of the Montrose Falls, while at least 13 species may be present downstream of the Falls. Should the dam result in the flooding (drowning out) of the waterfall it would create an unnatural pathway for both indigenous and alien fish species not currently present in the upper Crocodile River, to colonise this reach. This will result in a change in the natural fish assemblage of the Crocodile River upstream and potentially also downstream of the Montrose Falls, through competition for food and habitat as well as potential hybridization and genetic mixing of species that would have previously been isolated or separated. This impact will be of concern for all species present, but especially for a fish species of high conservation concern namely the Critically Endangered *Chiloglanis bifurcus* (IUCN, 2022). This should be seen as an environmental fatal flaw when considering the Montrose Dam as a potential dam option for the Crocodile River catchment, as it may result in the eradication of this fish species. It must be noted that barriers could be constructed (as was done for Springfield Dam in Kwazulu-Natal) to prevent alien or predatory fish from moving upstream of the dam. This was not considered at this stage as these type of barriers have their own set of environmental impacts, are costly, and not necessarily effective. The potential fatal flaw must therefore be seen as based on an evaluation without considering any mitigation measures.

7.2.3 Operation of EWRs for AR MR4, BK3, MV3 and SM2

These ARs are the most downstream ARs which form the southern border of the Kruger National Park. EWR C6 (nKongoma) is the key and most important EWR site in the Crocodile River system downstream of Kwena Dam. Its ecological importance is based on the assumption that if you meet the RQOs and TECs at EWR C6, the upstream sections will also be catered for.

Even though the assumption was made that the EWRs will be met through operation of the dams, it should be considered whether released flows will meet all criteria or aspects of ecological flow requirements. Releasing floods and even low (base) flows from a dam will result in attenuation of these flows as it moves downstream. The required peaks and velocities needed for ecological purposes may not be met and attempting to meet these can result in a significant decrease in yield to combat the attenuation factor. The further the dam is from the most downstream AR (e.g., Montrose and Boschjeskop dams), the less likely it is that impacts on the downstream river can be successfully mitigated by EWR releases. An additional factor

is that as the proposed Boschjeskop Dam is in a tributary which is significantly smaller than the Crocodile River, with a resulting smaller channel capacity, it will be less likely to achieve mitigation than Montrose Dam. It has a smaller reservoir capacity which will result in a lower yield and lower capacity for large or sustained releases, and significant scour in the small river channel from EWR flood releases.

Another aspect to consider is the impact of dams on the frequency of large floods. Ecological requirements set include floods (1:1, 1:2, 1:5, 1:10, etc.) that can possibly be met from a dam. It is assumed that the larger infrequent floods will occur as spills and these are subsequently excluded from estimated EWRs. The larger the dam or higher the dam wall, or the greater number of dams in the mainstem, the greater the potential cumulative impact on the large infrequent floods reaching EWR sites. Decreasing the number of these low frequency large floods would impact on habitat quality and biotic cues, which could result in the TECs not being met.

7.3 Rating and Fatal Flaws

Each of the following metrics were normalised and ranked (**Table 7-3** and **Figure 7-1**):

- Impact rating (severity of impacts described in **Section 7.1**).
- Meeting the TEC with specific reference to the EcoStatus (See **Section 7.2.1**).
- Environmental considerations other than the above which may result in a fatal flaw (See **Section 7.2.2**).
- Success of mitigating dam impacts on flow by releasing the EWRs (See **Section 7.2.3**).

Table 7-3: Ranking Metrics and Normalised Rating Ratings

Ranking Metrics	Montrose	Boschjeskop	Mountain View	Strathmore
Severity of Impacts	0.84	0.90	0.84	0.94
Change in EC (not meeting TEC)	0*	0.2	0.4	1
Environmental Fatal Flaws	0	1	1	1
Success to operate EWRs in Lower Crocodile River	0.2	0	0.6	0

* Red cells (value of 0) illustrate potential fatal flaws

In the ranking order the number 1 represents the no impact situation. Ranking of 0 represents a potential extreme impact and potential fatal flaw. The ranking for each of the four metrics is illustrated in a traffic diagram (**Figure 7-1**).

A normalisation approach (DWS, 2014b) was followed to integrate the metrics (right hand traffic diagram in **Figure 7-1**). The metrics were weighted according to the weights supplied below each traffic diagram. It must be noted that the weights did not influence the ranking order but provided more resolution. The final ranking of the options are therefore as follows:

- Strathmore (least impact)
- Mountain View
- Boschjeskop
- Montrose (most impact)

Potential fatal flaws are associated with the degree to which the TECs can be met as well as the impact on critically endangered fish species. Considering the results in **Table 7-3**, the specialist team reached consensus that there are potential fatal flaws associated with both the Montrose and the Boschjeskop Dam options. Emphasis must be on the fact that these are POTENTIAL fatal flaws and are used in the ranking process. It is noted that potential fatal flaws can in some cases be mitigated, but that would require a different scenario to be evaluated in the ranking process.

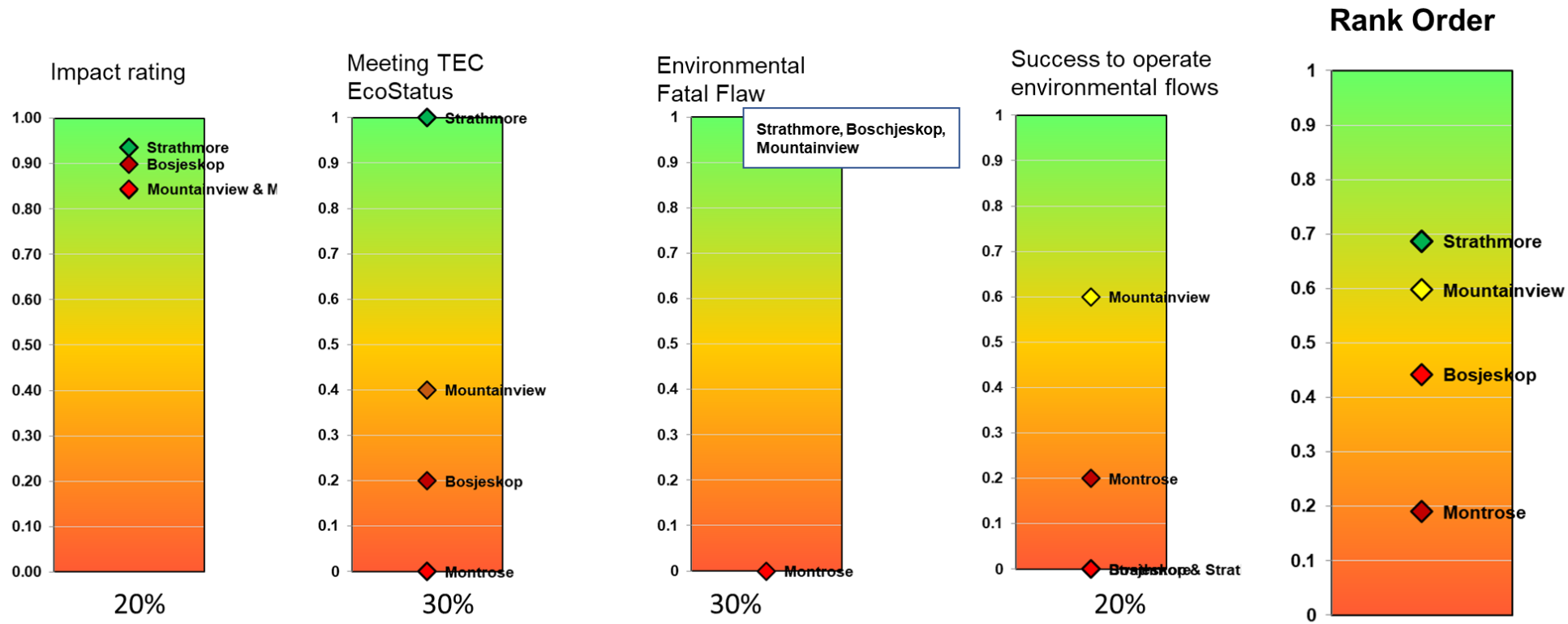


Figure 7-1: Ranking based on a Normalisation Approach

7.4 Way Forward

The Feasibility Phase will focus on one selected dam site. From the Ecological Reserve, Classification and RQO perspective, the focus will be on evaluating a maximum of six operating scenarios to ensure the optimisation of the yield while still meeting the gazetted TECs (Gazette No. 55, 2016). Developing the final six scenarios for evaluation will be an iterative process.

The same EcoStatus models will be used to assess the impacts of each operating scenario in a similar approach than for the Pre-feasibility study. Input can also be provided in terms of the flood releases. However, it must be noted that floods operating rules and the assessment of the size of floods that must be released to achieve a certain peak and velocity at the EWR as well as the attenuation affect will not be undertaken by the Reserve specialists. Input and recommendations only can be provided.

Input and liaison of the Flood Reserve Specialists with the relevant engineers on the team will also take place as part of the design of flood releases and output.

This component of the work will feed into all environmental impact assessment work as it is an important component of the outcome of these studies. Timing of the input and output of this task is vital as it is depending on water resource modelling and other studies such as preliminary design and impact assessments are dependent on the outcomes.

Funding for this task is still outstanding and there currently processes in motion for obtaining approval.

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