water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AND SANITATION
CHIEF DIRECTORATE: WATER ECOSYSTEMS

THE DETERMINATION OF WATER RESOURCE CLASSES AND ASSOCIATED RESOURCE QUALITY OBJECTIVES IN THE INKOMATI WATER MANAGEMENT AREA









OPERATIONAL SCENARIOS AND RECOMMENDED WATER RESOURCE CLASSES

Report Number: RDM/WMA05/00/CON/CLA/0214

SEPTEMBER 2014

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OPERATIONAL SCENARIOS AND RECOMMENDED WATER RESOURCE CLASSES

Report Number: RDM/WMA5/00/CON/CLA/0214

Approved for IWR Water Resources by:

……………………………………..	***25 June 2015***
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Project Manager	

DEPARTMENT OF WATER AND SANITATION (DWS)

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EXECUTIVE SUMMARY

INTRODUCTION

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study during 2013 for the provision of professional services to undertake the determination of Water Resource Classes and associated Resource Quality Objectives (RQOs) in the Inkomati Water Management Area (WMA).

This task is associated with steps 4 and 5 of the Water Resource Classification System. In summary, this task forms ***part*** of Step 4 within the integrated approach adopted for this study, i.e. the identification and evaluation of scenarios within the Integrated Water Resource Management Process. The purpose of this report is to recommended operational scenarios and draft Water Resource Classes for stakeholder evaluation.

INTEGRATED CONSEQUENCES EVALUATION APPROACH

Considering that the core purpose of the Classification process is to select the Water Resource Class (DWA, 2007) for a water resource, the scenario evaluation process provides the information needed to assist in arriving at a recommendation that will be consideration by the Minister of the Department of Water and Sanitation 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 scenario evaluation process therefore estimates the consequences of a set of plausible scenarios will have on these elements by quantifying selected metrics to compare the scenarios on relative bases with one another. The scenarios were ranked, first, for the individual variables and secondly an overall integrated ranking was derived based on multi-criteria analysis methods.

The results of the initial set of scenarios were interpreted to identify alternative release rules to improve the integrated scores with the objective to find and recommend an optimised scenario.

Thirty three scenarios were finally (after stakeholder input) identified for determination of consequences.

SCENARIO DESCRIPTION

The Tables below summarise the scenario definition in the form of a matrix, where each row represents a scenario and the columns indicate each of the variables applicable to each scenario. The scenarios are grouped into four sub-catchments, the Komati, the Crocodile, the Sabie and the Sand River. The reason that the Sand River was separated from the Sabie is that it was found that the most of the scenarios were applicable to either the Sabie (X31) or the Sand catchment, but not both.

Summary of the Komati (X1) scenarios

Scenario	Scenario variables					
	Update water demands	Domestic growth and increase irrigation (plus restrictions so system does not fail)	IIMA[1] Flows	DARDLA[2]	Silingane Dam (DS[3] Maguga)	EWR[4]
K1	Yes	No	No	No	No	No
K2	Yes	No	No	No	No	Yes
K31	Yes	Yes	Yes	No	No	Yes
K32	Yes	Yes	Yes	No	No	No
K41	Yes	Yes	Yes	Yes	No	Yes
K42	Yes	Yes	Yes	Yes	No	No
K43	Yes	No	Yes	Yes	No	No
K5	Water quality scenario (not for ecological assessment), includes mining aspects)					
K6	Yes	Yes	Yes	Yes	Yes	Yes

1 Interim IncoMaputo Agreement
2 Department of Agriculture, Rural Development and Land Administration
3 Downstream
4 Ecological Water Requirement

Summary of the Crocodile (X2) scenarios

Scenario	Scenario Variables						
	Update water demands with revised PES[1] EWR	Updated water demands	Domestic growth	IIMA Flows	Mountain View Dam (Kaap)	Boschjeskop Dam (Nels)	EWR
C1	Yes	No	No	No	No	No	No
C2	No	Yes	No	No	No	No	REC[2]
C3	No	Yes	Yes	Yes	No	No	PES
C4	No	Yes	Yes	Yes	No	No	REC
C5	No	Yes	Yes	Yes	Yes	No	No
C61	No	Yes	Yes	Yes	Yes	No	REC
C62	No	Yes	Yes	Yes	Yes	No	PES
C71	No	Yes	Yes	Yes	No	Yes	REC
C72	No	Yes	Yes	Yes	No	Yes	No
C81	No	Yes	Yes	Yes	Yes	Yes	REC
C82	No	Yes	Yes	Yes	Yes	Yes	PES

1 Present Ecological State
2 Recommended Ecological Category

Sabie River system scenarios

Scenario	Update water demands	Growth in water demands	EWR
S1	Yes	No	No
S2	Yes	No	Yes (REC)
S31	Yes	Yes	Yes (REC)
S32	Yes	Yes	No
S6	Yes	Minimised to meet REC	Yes (REC)

Sand River system scenarios

Scenario	Scenario Variables				
	Update water demands	Growth in water demands	Reinstate Sand Forestry	New Forest Dam (Mutlumuvi River)	EWR
S1	Yes	Yes, with no return flows	No	No	No
S4	Yes	Yes, with 50% return flows	Yes	No	No
S51	Yes	Yes, , with 50% return flows	Yes	Yes	Yes REC
S52	Yes	Yes, , with 50% return flows	Yes	Yes	No
S53	Yes	Yes, , with 50% return flows	Yes	Yes	Yes PES
S71	Yes	Yes, , with 25% return flows	Yes	Yes	Yes REC
S72	Yes	Yes, , with 25% return flows	Yes	Yes	No
S73	Yes	Yes, , with 25% return flows	Yes	Yes	Yes PES

ECONOMIC CONSEQUENCES

The economic evaluation of the impact of the different scenarios as evaluated is based on the broad assumption that the utilisation of any additional or current water allocation is utilised at maximum efficiency. Any economic evaluation takes place within the specific current situation, not an empty space, and it is necessary that the current situation be taken into consideration in the evaluation of any of the operational scenarios.

An economic baseline was established and the estimated deviation from the baseline was determined with water as the main driver. The economic impacts and impacts on employment for each scenario were calculated in the four river systems that make up the Inkomati Catchment.

Impact of the identified Scenarios on Gross Domestic Product

Komati River system

- Scenario K32, K41, K42, K43 and K6 will have a positive impact on the GDP due to the additional water to the domestic services sector.
- Scenario K2, K31, and K5 will have a negative impact on GDP due to the reduction of irrigation water to the irrigation sector.
- Scenario K42 will have the biggest economic impact while Sc K5 will have the most negative impact from a GDP perspective.

Crocodile River system

- Scenario C5 and C72 will have a positive economic impact on GDP mainly due to the increased allocation towards irrigation and the value added impact in the sugar manufacturing industry. There is also additional water available to the domestic service sector.
- Scenario C2, C3, C4, C61, C72 and C81 will have a significant negative impact on the GDP mainly due to the reduction of irrigation water in these scenarios which negatively impacts the GDP of the irrigation sector and to a certain extent the industry sector. There is additional water available to the domestic service sector but the negative impact on the irrigation sector outweighs the positive impact on the domestic service sector.
- Scenario C72 will have the biggest impact on GDP while on the other end of the scale; Sc C4 will have to most negative impact, with a severe decline in GDP.

Sabie River system

- Scenario S32 will have positive economic impact on the GDP due to the increased water allocation to the domestic services sector.

- Scenario S31 will have a negative impact on GDP as a result of a decrease in irrigation, while Sc S6 will have a slight negative impact due to the decrease in domestic water for this scenario.

Sand River system

- All the scenarios will have a positive impact on GDP, due to a significant increase in domestic water to the domestic services sector.

Impact of the identified Scenarios on Employment

Komati River system

- Scenario K32, K42, K43 and K6 will have a positive impact on employment due to the additional water to the domestic services sector.
- Scenario K2, K31, K41 and K5 will have a negative impact on employment due to the reduction of irrigation water to the irrigation sector.
- Scenario K6 will create the most employment opportunities while Sc K31 will have the most negative impact on employment.

Crocodile River system

- Scenario C5, C72 and C82 will have a positive impact on employment opportunities mainly due to the increased allocation towards irrigation and the value added impact in the sugar manufacturing industry.
- Scenario C2, C3, C4, C61, C72 and C81 will have a significant negative impact on employment and most job losses will be in the irrigation sector due to a reduction in the irrigation water allocation.
- Scenario C72 will have the biggest impact on employment while on the other end of the scale; Sc C4 will have to most negative impact, with a severe decline in jobs.

Sabie River system

- Scenario S32 will have positive impact on employment due to the increased water allocation to the domestic services sector.
- Scenario S31 will have a negative impact on employment as a result of a decrease in irrigation water for this scenario, while Sc S6 will have a slight negative impact due to the decrease in domestic water for this scenario.

Sand River system

- All the scenarios will have a positive impact on employment. This is due to a significant increase in domestic water to the domestic services sector.

ECOLOGICAL CONSEQUENCES

The scenarios were evaluated and, during a specialist meeting, the consequences were determined at each site by ranking the scenarios in terms of how successful they are in meeting the Recommended Ecological Category (REC). Based on the site weighting, a system ranking is determined. The results are summarised in the text and figure below.

Komati River system

The scenarios applicable to the Komati System are only relevant for EWR K3 (Komati River at Tonga Rapids) and EWR L1 (Lomati River downstream of Driekoppies Dam). There is no impact of the scenarios at K3. The Lomati River at EWR L1 is largely impacted on by the unseasonal releases for irrigation from Driekoppies Dam. The scenario results illustrate that Sc K2, K31 and K41 are similar to the present day flows (i.e. maintain the PES) whereas the other scenarios are in a worse state due to the impacts on riparian vegetation which in turn impacts on the instream components. This results in a change from a C to a C/D EcoStatus.

Crocodile River system

The scenarios only impact on EWR 3, 4, 5 and 6 in the Crocodile River and EWR 7 in the Kaap River. The worst case scenarios are Sc C72 and C5 which both includes new dam options but with no EWR releases. Scenario C1 which represents the current operating rule also has the potential to degrade the river although it will still maintain the EcoStatus of a C at EWR 6. The best options are those options that include the REC. It is however known that these have serious potential economic consequences. Scenario C3 (with no new dams) and Scenario C82 (that includes new dams) are potentially the best compromise options to explore further.

Sabie River system

The scenarios only impact on EWR 3 (Sabie River) and EWR 5 (Marite River). At all the other EWR sites, the status quo is therefore maintained. The results are summarised in the following Table.

Scenarios S31 and S6 are the best options as they are the closest to meeting the ecological objectives. If one however considers that the Sabie River has always been seen as the flagship river in the KNP as well as one of the few rivers left in South Africa in excellent condition, then the ranking order of the Sabie River should (from an ecological view point) override the integrated ranking. As Sc S6 is the only scenario that maintains the PES (and REC) in the Sabie River, this scenario is the ecological recommendation.

Sand River system

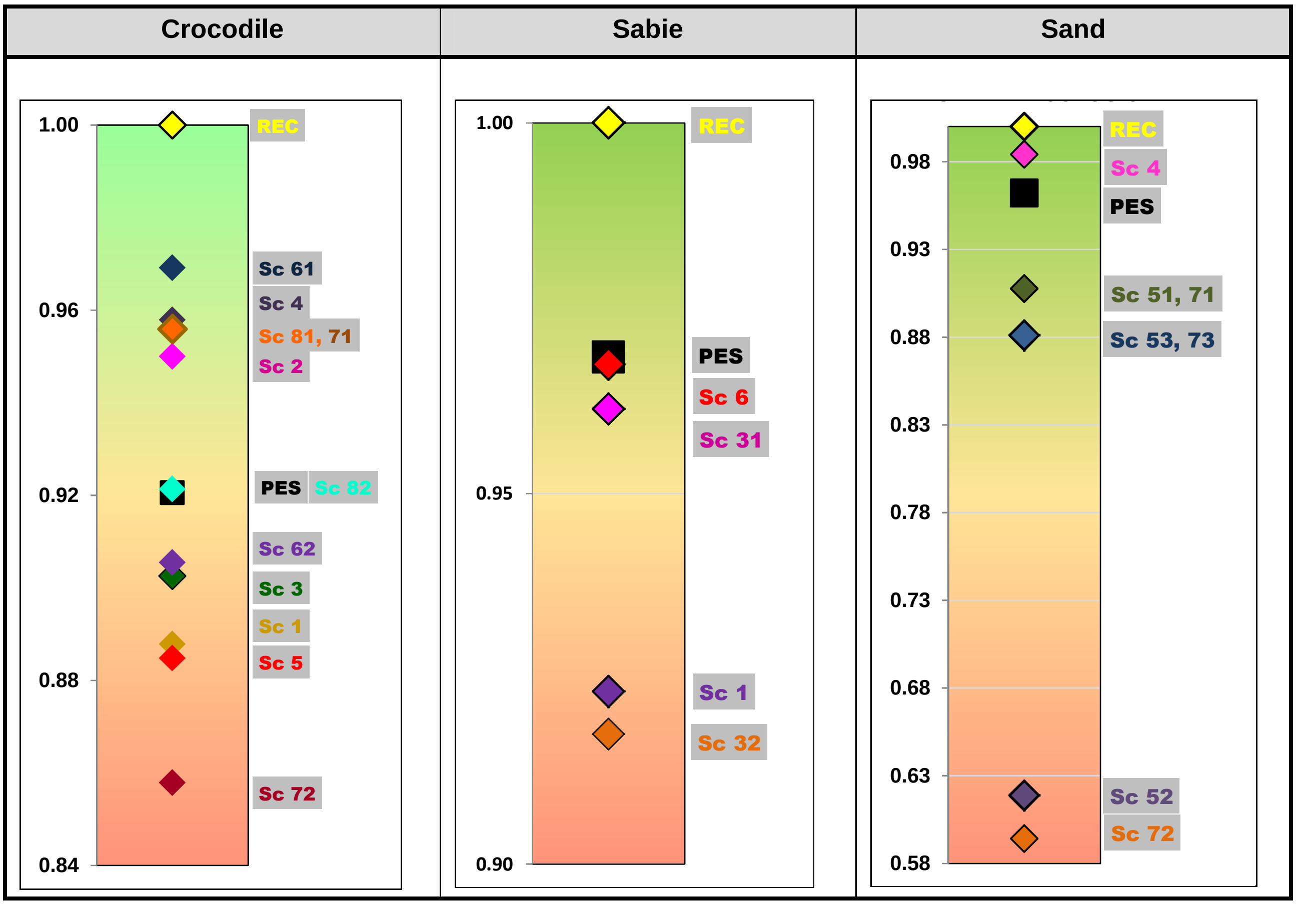
The scenarios largely impact on EWR 6 (Mutlumuvi River) and EWR 8 (Sand River). Due to the lower confidence at EWR 7 (Thulandziteka (Sand) River) and as it is situated upstream of the impact of the New Forest Dam, this site was not considered during the scenario evaluation. The results are summarised in the following Table.

The results at EWR 6 (Mutlumuvi River) illustrate that none of the scenarios meet the ecological objectives of the REC. Scenario S4 meets the ecological objectives of the PES and has the least impact of all the scenarios. Scenario S51 and S71 result in the PES EcoStatus although geomorphology and fish are impacted. Scenario S53 and S73 result in a deterioration in the PES while Sc S52 and S72 have serious impacts as the EWR site will receive zero flows except when the dam spills.

Although affected by the proposed New Forest Dam under Sc S51, S52 and S53, the impacts of these scenarios are ameliorated by the return flows from the lower catchment. Scenario S72 is marginally lower than the EWR during some months but does maintain the REC for all components and the EcoStatus.

Scenario S52 and S72 are not viable options as a section of the Mutlumuvi River will change to a seasonal system. Scenario S4, although the best option, was recognised not to be a realistic option as the return flows associated with this scenario are too high. Scenario S51 and S53 also include these return flows. The remaining scenarios are Sc S71 and S73. Scenario S71 includes a full EWR release which will have a major impact on the yield. To further optimise, it is recommended that Sc S73 be further investigated.

Integrated ecological ranging of the operational scenarios



ECOSYSTEM SERVICES

Natural habitats and ecosystems provide a range of environmental goods and services that contribute enormously – and are even essential – to human well-being. Protecting these areas is essential in order to achieve sustainable development. River systems and their associated use values are of particular importance.

An analysis of the EWR 3, 5, 6, 7 and 8 was undertaken for the Sabie and Sand River systems. Here Sc S1, S4, S51 and S53 were evaluated. Ecosystem Services associated with the sites, bearing in mind that they represent a wider area, were listed and where they were deemed to generate value they were evaluated against the scenarios applicable to the site. Each site was evaluated under the impact against a base value of 1, representing the status quo. Anticipated change was evaluated against the base value with a negative impact represented as a score lower than 1 and an overall positive score represented as greater than 1. The process to determine an integrated ranking of the different scenarios required determining the relative importance of the different EWR sites. Here the perceived vulnerability of households dependent on the provisioning aspect of Ecosystem Services played a major role. For the Sabie River system Sc S1 and S32 were deemed to be largely negative with respect to impact on Ecosystems Services. For the Sand River system all scenarios were either neutral in impact or marginally positive.

For the Crocodile River system EWR 3, 4, 5, 6 and 7 were examined. Here Sc C1, C2, C3, C4, C5, C61, C62, C71, C72, C81 and C82 were evaluated. Overall Sc C1, C5, and C72 were deemed to be marginally negative. The remaining scenarios were either neutral or marginally positive.

INTEGRATED MULTI-CRITERIA RESULTS

The scenario scores for the four variables, Ecology, Ecosystem Services, Economy and Employment were determined (Chapter 7). The rationale for the weights selected is to assess what the balance is between the ecological health and the socio-economic benefits (i.e. protection and use), therefore a weight of 0.5 (or 50%) is assigned to the ecology and the remaining 50% is divided among the other three variables; Ecosystem Services (5%), Economy (20%) and Employment (25%).

Komati River system

Scenarios K42 and K6 rank the highest among the scenarios with both having similar scores. Sc K6 has the highest employment score while Sc 42 the highest economic score. The selection of either scenario for the purpose of classification would result in the same Water Resource Class and set of Ecological Categories (ECs) for the biophysical nodes in the system. It can therefore be concluded that for the Komati River system the Water Resource Class and the set of ECs for the biophysical nodes is not sensitive to the range of scenarios that were evaluated and analysed.

Crocodile River system

The scenario scores indicated that there is a large advantage in the socio-economic variable scores for Sc C82 compared to Sc C61, while the ecology is maintained at a levels slightly above the Present Ecological State (PES) (as represented by Scenario 1). This implies Sc C82 is an improvement for both the ecology and socio-economics compared to current conditions (Sc C1) while Sc C61 only improves the ecology. A further aspect to consider is that the ecological score for Sc C61 is the highest for all the scenarios and as such represents an “extreme” option and not a balanced outcome.

Sabie Sand River system

The Sabie scenario scores indicated that Sc S31 and S32 represent the “extreme” cases where either the ecological protection or the socio-economic benefits is respectively the best or worst. Scenario S6 was therefore formulated as a “compromise” where the growth in water needs for rural/urban areas are supplied from the Sabie River system in order to improve the ecological conditions of Sc S32 towards achieving the REC. Scenario S6 therefore represents the case where a balance is achieved between the need to supply growing water requirements for socio-economic activities while still providing protection of the ecology.

Scenario S6 in the Sabie imply that additional water for growth in water use in the urban domestic sector need to be sourced and the proposed New Forest Dam (see description of Sc S71) in the Sand River system serve as a solution to make more water available.

The Sand scenario scores indicated opposing outcomes between ecological protection and socio economic benefits and a compromise would most likely result in the optimum solution – “the desired balance between protection and use. Considering the need for a possible New Forest Dam identified during the evaluation of the Sabie River system, and the ranking in the Sand, Sc 71 is recommended as the preferred scenario.

DRAFT WATER RESOURCE CLASSES: SUMMARY OF RECOMMENDATIONS AND IMPLICATIONS

Komati River system

- The scenario immediately applicable:
  - Maintain the current ecological state and operation of the Komati and Lomati Rivers.
  - Institute measures (non flow-related) to achieve the REC in tributaries of the main rivers (relevant for future scenarios as well).

Implications: No implications to users. The REC in the Lomati River is not achieved under the current situation and the ecological status quo is maintained.

- Long-term scenario / the scenario that may be applicable in future (Sc K42)
  - Maintain the current ecological state,
  - Provision of Interim IncoMaputo water use Agreement(IIMA)flows,
  - Providing water for domestic growth up to the year 2030,
  - Reinstatement of fallow irrigation as suggested by the Department of Rural Development and Land Affairs (DARDLA).

Implications: No negative economic implications as a whole but a reduction of the assurance of supply in irrigation downstream of Swaziland (other than the DARDLA irrigation).

The draft Water Resource Classes are provided in the table below. The catchment configuration is provided in the next table.

Komati River system draft Water Resource Classes

Green - immediately applicable
Blue - applicable in the medium to long term.

IUA (EWR site)	PES	REC	K42
X1-1	II	**II**	**II**
X1-2	II	**II**	**II**
X1-3 (K1)	II	**II**	**II**
X1-4 (G1)	III	**III**	**III**
X1-5 (K2)	II	**II**	**II**
X1-6 (T1)	II	**I**	**I**
X1-7	**II**	I	**II**
X1-8 (L1)	**III**	II	**III**
X1-9 (K3)	III	**III**	**III**
X1-10	XXX	**III**	**III**

Komati River system draft Water Resource Classes and Catchment Configuration

Note: The red blocks indicate SQs which require non flow-related improvements to achieve the REC
Note: The purple blocks indicate a change of the target EC once Sc K42 or similar is applicable.

IUA	Water Resource Class	Nodes	River	KM	Target EC for:	
					Immediate[1]	Sc K42[2]
X1-1	**II**	X11A-01300		12.3	**B**	**B**
		X11A-01354		25.6	**C**	**C**
		X11A-01358	Vaalwaterspruit	23.6	**C**	**C**
		X11A-01295	Vaalwaterspruit	12.0	**C**	**C**

IUA	Water Resource Class	Nodes	River	KM	Target EC for: Immediate[1]	Target EC for: Sc K42[2]
		X11A-01248	Vaalwaterspruit	30.2	C	C
		X11B-01370	Boesmanspruit	15.7	B	B
		X11B-01361		17.5	B/C	B/C
		X11B-01272	Boesmanspruit	29.1	C	C
X1-2	II	EWRK1	Komati	93	C	C
X1-3	II	X11C-01147	Witkloofspruit	33.5	C	C
		X11D-01129	Klein-Komati	39.6	C	C
		X11D-01137	Waarkraalloop	21.1	C	C
		X11E-01237	Swartspruit	29.3	B	B
		X11F-01133	Bankspruit	17.6	B	B
		X11G-01188	Ndubazi	22.3	B	B
		X11G-01143	Gemakstroom	14.9	C	C
X1-4	III	EWRG1	Mngubhudle	49.6	D	D
		X11K-01165	Poponyane	13.8	C	C
		X11K-01199		8.5	D	D
X1-5	II	EWRK2	Komati	80.8	C	C
X1-6	I	X12A-01305	Buffelspruit	33.6	B	B
		EWRT1	Teespruit	66.1	C	C
		X12B-01246	Hlatjiwe	22.8	C	C
		X12C-01242	Phophenyane	10.7	B	B
		X12C-01271	Buffelspruit	12.5	B	B
		X12D-01235	Seekoeispruit	26.7	C	C
		X12H-01338	Sandspruit	12.6	B	B
		X12H-01340		10.4	B	B
		X12H-01318	Sandspruit	8.3	C	C
		X12J-01202	Mtsoli	54.4	B	B
		X12K-01333	Mlondozi	23.8	B/C	B/C
		X12K-01332	Mhlangampepa	17.0	B	B
X1-7	II	X14A-01173	Lomati	47.7	B/C	B/C
		X14B-01166	Ugutugulo	24.8	C	C
		X14F-01085	Mhlambanyatsi	41.1	C	C
X1-8	III	EWRL1	Lomati	57.3	C	C/D
		X14G-01128	Lomati	23.5	D/E	D/E
X1-9	III	X13J-01214	Mgobode	24.2	C	C
		X13J-01205	Mbiteni	20.0	D	D
		X13J-01141	Mzinti	43.4	D	D
		EWRK3A	Komati	71.21	D	D
X1-10	III[3]	X13K-01114	Komati	5.2	D	D
		X13K-01136	Mambane	19.2	D	D
		X13K-01068	Nkwakwa	44.7	C/D	C/D

IUA	Water Resource Class	Nodes	River	KM	Target EC for:	
					Immediate[1]	Sc K42[2]
		X13K-01038	Komati	35.3	E	E
		X13L-01000	Ngweti	44.9	D	D
		X13L-01027	Komati	10.7	E	E
		X13L-00995	Komati	3.1	D	D

1 Immediately applicable until Sc 42 or a similar scenario is implemented.
2 Applicable in the medium to long term.
3 Due to the large sections of E EC river, this IUA does not comply with a Level III WRC. The Level III that has been allocated is applicable to the rest of the IUA which is in a D and C/D EC.

It is proposed to gazette the WRCs and catchment configuration as in the table above for the immediate target ECs and RQOs will be set for the short term Ecological Categories.

Crocodile River system

- The scenario immediately applicable:
    - The current situation which includes the release of a portion of the ecological flow requirements that were determined to maintain the PES.
    - Institute measures (non flow-related) to achieve the REC in tributaries of the main rivers (Elands, Crocodile and Kaap Rivers)(relevant for future scenarios as well),

Implications: No implications to users as this scenario represent the current baseline. The REC in the downstream Crocodile River will not be met and the scenario will in the long term possibly degrade the Present Ecological State.

- The scenario that may be applicable in the near future (medium term) (Sc C3)
    - Allow for future domestic growth,
    - Give effect to the IIMA,
    - Supply the full flow requirements to maintain the PES.

Implications: Some negative impact on GDP and jobs. The REC in the downstream Crocodile River will not be met. The ecological state may improve from Sc C1 but will likely still not achieve the PES.

- The scenario that may be applicable in the far future (long term) (Sc C62)
    - Supply the full flow requirements to maintain the PES,
    - Allow for future domestic growth,
    - Give effect to the IIMA,
    - Mountain view Dam development in the Kaap River.

Implications: Job losses in the irrigation sector due to the provision of water for the domestic section (improvement from Sc C3). The ecological implications are the same as for Sc C3.

- The scenario that may be applicable in the far future (next phase after Sc C62 has been implemented) (Sc C82)
    - Dam developments in both the Kaap River (Mountain View) and the Nels(Boschjeskop) River,
    - Supply the full flow requirements to maintain the PES,
    - Allow for future domestic growth,
    - Give effect to the IIMA.

Implications: Jobs will increase from the baseline. The ecological implications are the same as for Sc C3.

Crocodile River system draft Water Resource Classes

Green - immediately applicable
Blue - applicable in the short term
Pink - applicable in the long term
Orange - applicable in the far long term.

IUA	Scenarios and Water Resource Class				
	PES	REC	C3	C62	C82
X2-1	II	II	II	II	II
X2-2	II	II	II	II	II
X2-3	I	I	I	I	I
X2-4	I	I	I	I	I
X2-5	I	I	I	I	I
X2-6	II	I	II	II	II
X2-7	II	I	I	I	I
X2-8	XXX	II	II	II	II
X2-9	II	I	II	II	II
X2-10	II	II	II	II	II
X2-11	II	I	II	II	II
X2-12	II	II	II	II	II
X2-13	I	I	I	I	I

Crocodile River system draft Water Resource Classes and Catchment Configuration

Note, the red blocks indicate SQs which require non flow-related improvements to achieve the REC and refers to Table 8.7.

Note: The purple blocks indicate SQs where the catchment configuration (in terms of the Target EC) is different between the current state and future scenario.

IUA	Water Resource Class	Nodes	River	KM	Target EC for:			
					Im-mediate	Sc C3	Sc C62	Sc C82
X2-1	II	X21B-00898	Lunsklip	11.0	C/D	C/D	C/D	C/D
		X21B-00929	Gemsbokspruit	8.8	C/D	C/D	C/D	C/D
		X21B-00925	Lunsklip	21.5	C	C	C	C
		EWRC1	Crocodile	30.8	A/B	A/B	A/B	A/B
		EWRC2	Crocodile	30.1	B	B	B	B
		X21C-00859	Alexanderspruit	36.9	C	C	C	C
X2-2	II	EWRC3	Crocodile	58.3	B/C	C	C	C
		X21D-00957	Buffelskloofspruit	27.1	B/C	B/C	B/C	B/C
		X21E-00897	Buffelskloofspruit	14.6	B	B	B	B
X2-3	I	X21F-01100	Leeuspruit	12.9	C	C	C	C
		X21F-01092	Leeuspruit	1.0	C/D	C/D	C/D	C/D
		X21F-01091	Rietvleispruit	13.2	C	C	C	C
		EWRE1	Elands	55.6	B	B	B	B
X2-4	I	X21G-01090	Weltevredespruit	13.8	C	C	C	C
		X21G-01016	Swartkoppiespruit	13.8	C	C	C	C
		X21H-01060	Ngodwana*	20	B	B	B	B

IUA	Water Resource Class	Nodes	River	KM	Target EC for: Im-mediate	Sc C3	Sc C62	Sc C82
		X21K-01007	Lupelule	20.0	B	B	B	B
X2-5	I	EWRE2	Elands	59	B	B	B	B
X2-6	II	X22B-00987	Crocodile	**Linked to EWR C4** The results at EWR C4 (IUA X2-9) is relevant for these SQs as they fall in the same Resource Unit as EWR C4				
		X22B-00888	Crocodile					
		X22C-00946	Crocodile					
		X22J-00993	Crocodile					
X2-7	I	X22A-00824	Blystaanspruit	19.4	B	B	B	B
		X22A-00887	Beestekraalspruit	7.4	B/C	B/C	B/C	B/C
		X22A-00875	Houtbosloop	10.4	B	B	B	B
		X22A-00919	Houtbosloop	0.7	B/C	B/C	B/C	B/C
		X22A-00920		4.5	B	B	B	B
		X22A-00917	Houtbosloop	2.7	C	C	C	C
		X22A-00913	Houtbosloop	28.3	B	B	B	B
		X22C-00990	Visspruit	10.0	B/C	B/C	B/C	B/C
X2-8	II	X22D-00843	Nels	24.9	C	C	C	C
		X22D-00846		16.7	C	C	C	C
		X22F-00842	Nels	35.1	C	C	C	C
		X22E-00849	Sand	12.7	C	C	C	C
		X22E-00833	Kruisfonteinspruit	9.8	C	C	C	C
		X22F-00886	Sand	29.7	C	C	C	C
		X22F-00977	Nels	6.7	C/D	C/D	C/D	C/D
		X22C-01004	Gladdespruit	36.7	B/C	B/C	B/C	B/C
		X22H-00836	Wit	59.2	D	D	D	D
X2-9	II	X22K-01042	Mbuzulwane	10.0	B	B	B	B
		X22K-01043	Blinkwater	16.3	B	B	B	B
		X22K-01029	Blinkwater	3.4	C	C	C	C
		EWRC4	Crocodile	41.3	C	C	B/C	C
X2-10	II	X23B-01052	Noordkaap	7.2	C	C	C	C
		X23C-01098	Suidkaap	22.9	B/C	B/C	B/C	B/C
		EWRK7	Kaap	11.2	C	C	C	C
		X23E-01154	Queens	31.0	B/C	B/C	B/C	B/C
		X23F-01120	Suidkaap	28.6	C	C	C	C
X2-11	II	EWRC5	Crocodile	23	C	C	C	B/C
		EWRC6	Crocodile	99	C	C	C	C
X2-12	II	X24A-00826	Nsikazi	27.8	C	C	C	C
		X24A-00860	Sithungwane	12.4	A	A	A	A
		X24A-00881	Nsikazi	10.3	B	B	B	B
		X24B-00903	Gutshwa	19.1	D	D	D	D
		X24B-00928	Nsikazi	11.9	A/B	A/B	A/B	A/B

IUA	Water Resource Class	Nodes	River	KM	Target EC for:			
					Im-mediate	Sc C3	Sc C62	Sc C82
		X24C-00969	Mnyeleni	12.4	A	A	A	A
		X24C-00978	Nsikazi	21.2	B	B	B	B
X2-13	I	X24E-00973	Matjulu	17.3	B	B	B	B
		X24E-00922	Mlambeni	39.2	A/B	A/B	A/B	A/B
		X24G-00902	Mitomeni	21.9	A	A	A	A
		X24G-00876	Komapiti	16.0	A	A	A	A
		X24G-00844	Mbyamiti	19.8	A	A	A	A
		X24G-00823	Muhlambamadubo	21.0	A	A	A	A
		X24G-00820	Mbyamiti	28.9	A	A	A	A
		X24G-00904	Mbyamiti	5.2	A	A	A	A
		X24H-00882	Vurhami	36.6	A	A	A	A
		X24H-00892	Mbyamiti	28.8	A	A	A	A

*Note, the B is relevant upstream of Godwana Dam. The dam and the short river distance downstream of the dam is in an E category, but the management of the rest of the river upstream of the dam (20 km) must be in a B.

It is proposed to gazette the WRCs and catchment configuration ECs as in the Immediate column and RQOs will be set for these.

Sabie-Sand River systems

- The scenario immediately applicable:
  - Maintain the current ecological state and operation of the system,
  - Institute measures (non flow-related) to achieve the REC in the Sabie River upstream of the KNP and various tributaries(relevant for future scenarios as well),
  - May include the reinstatement of forestry in the Sand catchment.

Implications: No implications to users as this scenario represent the current baseline. This scenario will not however cater for an increase in domestic use in the Sabie River in the future. The REC in the Mutlumuvi River is not achieved under the current situation and the ecological status quo is maintained in this river.

- Long-term scenario / the scenario that may be applicable in future (Sc S71)
  - New dam development in the Mutlumuvi River,
  - Supply of the environmental flows supporting the REC in the Mutlumuvi River and downstream Sand River,
  - Assumed increase in return flows of 25% resulting from improved water supply to the Sand catchment,
  - Decreased transfer from the Sabie.

Implications: Significant economic improvement in GDP and jobs in the Sand River. Water for increased domestic growth in the Sabie River will be available. The REC will be maintained in all rivers except for the Mutlumuvi River.

Sabie-Sand River systems draft Water Resource Classes

Green - immediately applicable

Blue - applicable in the medium to long-term

IUA	Catchment	Scenarios and Water Resource Class		
		PES	REC	S71
X3-1	Sabie	II	I	I
X3-2	Sabie	II	I	I
X3-3	Sabie	I	I	I
X3-4	Sabie	III	III	III
X3-5	Sabie	I	I	I
X3-6	Sabie	I	I	I
X3-7	Sand	III	II	II
X3-8	Sand	II	II	II
X3-9	Sand	I	I	I

Sabie-Sand River systems draft Water Resource Classes and Catchment Configuration

Note, the red blocks indicate SQs which require non flow-related improvements to achieve the REC and refers to Table 8.7.

Note: The purple blocks indicate SQs where the catchment configuration (in terms of the Target EC) is different between the current state and future scenario.

IUA	Water Resource Class	Nodes	River	KM	Immediate	Sc S71
X3-1	I	X31A-00741	Klein Sabie	14.6	B/C	B/C
		X31A-00783		5.4	C	C
		X31A-00786		5.2	B	B
		X31A-00794		1.1	B	B
		X31A-00796		1.0	B	B
		X31A-00803		0.6	B/C	B/C
X3-2	I	EWR S1	Sabie	**57**	B	B
		X31B-00792	Goudstroom	8.8	B/C	B/C
		EWR S4	Mac-Mac	46.8	B	B
		EWR S2	Sabie		B	B
		X31E-00647a	Marite (US of dam)	19.9	B	B
		X31F-00695	Motitsi	42.8	B	B
X3-3	I	EWR S5	Marite	8.0	B/C	B/C
		EWR S3	Sabie		A/B	A/B
X3-4	III	X31D-00773	Sabani	19.8	C/D	C/D
		X31H-00819	White Waters	32.6	C	C
		X31J-00774	Noord-Sand	16.9	D	D
		X31J-00835	Noord-Sand	13.4	D	D
		X31K-00713	Bejani	17.7	D	D
		X31L-00657	Matsavana	12.8	C	C
		X31M-00673	Musutlu	40.3	B/C	B/C
		X31L-00664	Saringwa	28.9	C	C

IUA	Water Resource Class	Nodes	River	KM	Immediate	Sc S71
		X31L-00678	Saringwa	16.6	B/C	B/C
X3-5	I	X33A-00731	Sabie		A/B	A/B
		X33A-00737	Sabie		A/B	A/B
		X33B-00784	Sabie		A/B	A/B
		X33B-00804	Sabie		A/B	A/B
		X33B-00829	Sabie		A/B	A/B
		X33D-00811	Sabie		A/B	A/B
		X33D-00861	Sabie		A/B	A/B
X3-6	I	X31K-00771	Phabeni	19.2	B	B
		X31M-00763	Nwaswitshaka	56.0	A	A
		X33A-00661	Nwatindlopfu	25.9	A	A
		X33A-00806	Nwatimhiri	35.5	A	A
		X33B-00694	Salitje	35.4	A	A
		X33B-00834	Lubyelubye	20.7	A	A
		X33C-00701	Mnondozi	46.9	A	A
		X33D-00864	Mosehla	19.9	A	A
		X33D-00894	Nhlowa	9.9	A	A
		X33D-00908	Shimangwana	8.3	A	A
		X33D-00911	Nhlowa	5.7	A	A
X3-7	II	X32E-00629	Nwarhele	18.0	C	C
		X32E-00639	Ndlobesuthu	6.8	D/E	D/E
		EWR S6	Mutlumuvi		C	C
		X32F-00628	Nwarhele	6.5	C/D	C/D
X3-8	II	X32B-00551	Motlamogatsana	27.1	C	C
		EWR S7	Tlulandziteka		C	C
		X32C-00558	Nwandlamuhari	15.1	C	C
		X32C-00564	Mphyanyana	11.9	C	C
		X32C-00606	Nwandlamuhari	1.2	C	C
		X32G-00549	Khokhovela	28.0	C	C
X3-9	I	X32H-00560	Phungwe	**30.9**	A	A
		EWR S8	Sand		B	B
		X32J-00651	Mutlumuvi	**24.8**	A	A

It is proposed to gazette the Water Resource Classes and catchment configuration as in the Immediate column above and RQOs will be set for the short term ECs these.

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ACRONYMS AND ABBREVIATIONS

AMD	Acid Mine Drainage
CD: RDM	Chief Directorate: Resource Directed Measures
Cs	Current State
DARDLA	Department of Agriculture, Rural Development and Land Administration
DWA	Department of Water Affairs (Change after 2008)
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water Affairs and Sanitation (Change after May 2014)
EC	Ecological Category
EI	Ecological Importance
EIS	Ecological Importance and Sensitivity
ER	Economic Region
ES	Ecological Sensitivity
EWR	Ecological Water Requirement
GDP	Gross Domestic Product
GIS	Geographic Information System
IFC	International Finance Corporation
IIMA	Interim IncoMaputo Agreement
IUA	Integrated Unit of Analysis
IUCMA	Inkomati-Usuthu Catchment Management Agency
IWAAS	Inkomati Water Availability Assessment Study
KNP	Kruger National Park
KOBWA	Komati Basin Water Authority
LM	Local Municipality
MRU	Management Resource Unit
PES	Present Ecological State
PSP	Professional Service Provider
REC	Recommended Ecological State
RQOs	Resource Quality Objectives
Sc	Scenario
SCI	Socio-Cultural Importance
SQ	Sub-quaternary (may also be termed a quinary)
TWQR	Target Water Quality Range
WIM	Water Impact Model
WMA	Water Management Area
WRCS	Water Resources Classification System
WReMP	Water Resources Modelling Platform

1 INTRODUCTION

1.1 BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study during 2013 for the provision of professional services to undertake the determination of Water Resource Classes and associated Resource Quality Objectives (RQOs) in the Inkomati Water Management Area (WMA). IWR Water Resources was appointed as the Professional Service Provider (PSP) to undertake this study.

1.2 STUDY AREA OVERVIEW

The study area comprises the Komati, Crocodile East and Sabie-Sand rivers.

1.3 INTEGRATED STEPS APPLIED IN THIS STUDY

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

Table 1.1 Integrated study steps

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

This task forms ***part*** of Step 4, i.e. the identification and evaluation of scenarios within the Integrated Water Resource Management Process. This step is closely linked to the next step where the scenarios are tested with stakeholders and the draft Water Resource Classes are determined. Using the results of the status quo assessment (DWA, 2013a) (Step 1), the next steps were initiated and the results of Step 4 is documented in this report.

1.4 TASK D4: IDENTIFICATION AND EVALUATION OF OPERATIONAL SCENARIOS TO IDENTIFY CONSEQUENCES

This task is associated with step 4 and 5 of the Water Resource Classification System (WRCS). In practice, these two steps function as one and are integrated as Task 4 (or step 4 within the integrated approach) (DWA, 2013b). The objective of this task was to describe and document the following:

- Identification of operating scenarios in accordance with the Reconciliation Strategy Study.
- River ecological consequences of the operational scenarios (Sc) at the key biophysical nodes (Ecological Water Requirements (EWR) sites) by evaluating and determining the impact on the Ecological Category (EC).
- Economic consequences of operational scenarios by determining the impact of any water allocation changes.

- Assessment of the impacts of the various scenarios on Ecosystem Services of operational scenarios to identify the direction of change (either positive or negative) and estimate the magnitude of the change in benefits and costs that may be experienced within the river system.
- Water quality consequences (other than water quality consequences associated with the ecological component).
- Integrate the consequences to provide preliminary Water Resource Class for stakeholder evaluation.

The process described above is illustrated in Figure 1.1 and Figure 1.2. Figure 1.1 illustrates the broad conceptual process from the determination of the Status Quo (Integrated Step 1) through to the determination of Water Resource Classes. Within these steps there are further sub-steps that pertain to integrated step 4 which are described in Figure 1.2. Please note that Water Resource Classes are commonly referred to as Management Classes (MC).

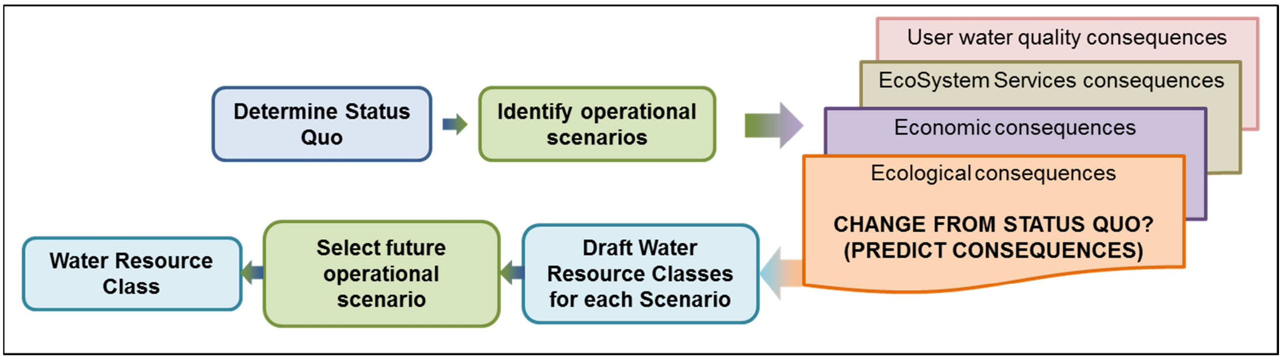


Figure 1.1 The process in Step 4 and 5: Identification of scenarios to the gazetted Water Resource Class

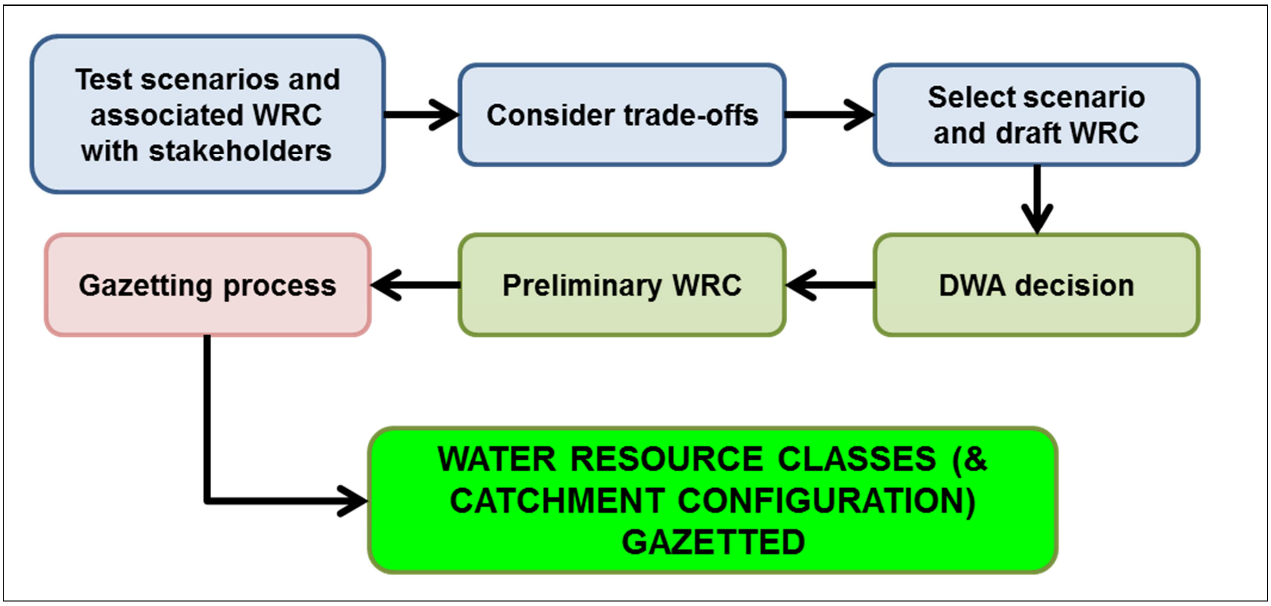


Figure 1.2 Step 5: Illustrates the steps from the testing of scenarios with stakeholders to a final gazetted Water Resource Class and catchment configuration

1.5 PURPOSE AND OUTLINE OF THIS REPORT

The purpose of this report is to recommend operational scenarios and preliminary Water Resource Classes for stakeholder evaluation.

The report outline is provided below.

Chapter 1: Introduction

This Chapter provides general background to the project Task.

Chapter 2: Integrated Consequences Evaluation Approach

This chapter provides an overview of the scenario evaluation process. Ecology, Ecosystem Services and the Economic benefits are compared when determining the degree of achieving the appropriate balance between ecological objectives and the socio-economic benefits. This chapter also provides an expanded description of how the metric for each of the three components were derived.

Chapter 3: Scenario Description

The scenarios considered for evaluation are discussed.

Chapter 4: Economic Consequences

The results of different scenarios and the consequences on the different economic sectors are presented in this Chapter.

Chapter 5: Ecological Consequences

The results of the ecological consequences of the various scenarios are presented in this Chapter.

Chapter 6: Ecosystem Services

The results of impact of the different scenarios on Ecosystem Services are presented in this Chapter.

Chapter 7: Integrated Multi-Criteria Results

The results of the rating, weighting and scoring for the three variables, Economy, Ecology and Ecosystem Services presented in Chapters 4 – 6 were integrated to obtain the overall ranking of the scenarios and described in this chapter.

Chapter 8: Water Resource Classes

The recommended Water Resource Classes among the scenarios are presented. Conclusions and recommendations are provided.

Chapter 9: References

Chapter 10: Appendix A: Water Resource Modelling

The Water Resources Modelling Platform (WReMP) configuration was obtained for the Komati, Crocodile and Sabie River systems from the following previous studies:

- Komati: Development of an Ecological Water Requirement Policy and Water Management Plan for the Komati River Basin (Nepid Consulting, 2009)
- Crocodile: Mbombela Reconciliation Strategy (DWA, 2013c)
- Sabie: Development of the Sabie/Sand Operating Rules (DWA, 2013d)

The Appendix provides further detail regarding model configuration and schematic network diagrams

Chapter 12: Appendix B: Example of Rating, Weighting and Scoring

Appendix B provides an example (extract) of the full scoring calculation carried out for the ecological component of the Integrated multi-criteria analysis model for the Sand River system.

The elements of the table are described in Section 7 in accordance with the respective column alphabetic labels

Chapter 13: Appendix C: User Water Quality Consequences to Operational Scenarios

This Appendix presents the approach undertaken to include non-ecological water quality into the consequences evaluation and the results of this assessment.

Chapter 14: Appendix D: Report Comments

2 INTEGRATED CONSEQUENCES EVALUATION APPROACH

2.1 OVERVIEW OF THE SCENARIOS EVALUATION PROCESS

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.

During the evaluation process stakeholders are engaged at various stages, initially by providing their respective visions for the catchments (Integrated Units of Analysis - IUA), then defining and selecting the scenarios for evaluation and finally to assess the consequences with the aim of making a recommendation of which Water Resource Class should be implemented.

The scenario evaluation process entails a sequence of activities followed during the Inkomati Catchment Classification Study and are illustrated schematically in Figure 2.1.

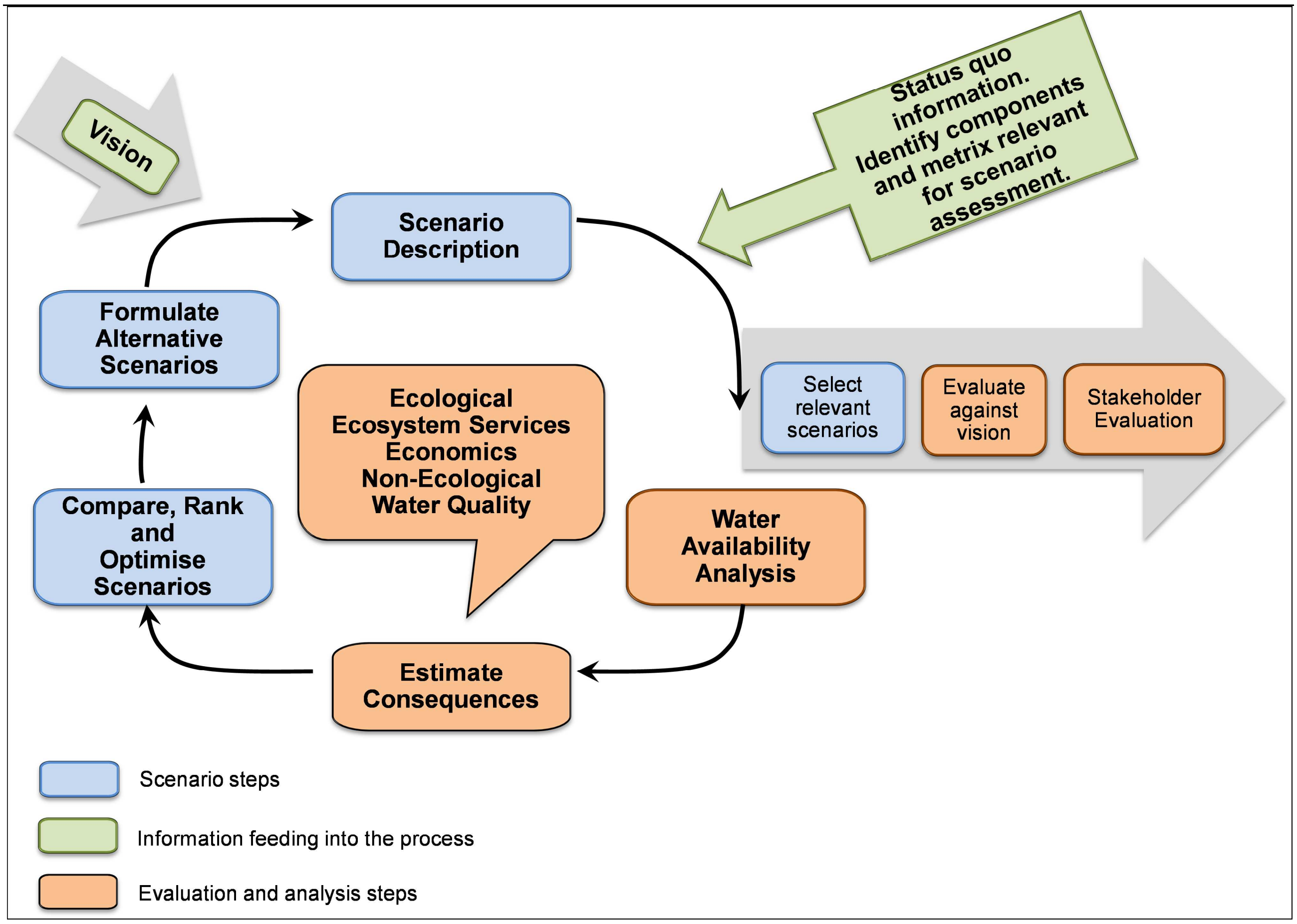


Figure 2.1 Schematic representation of the scenario evaluation process

Each activity presented in Figure 2.1 is briefly described in the following sections.

2.1.1 Vision

The visioning activity was carried out through interactive engagements with stakeholders where their respective views as to what the desired future state of the water resources should be were obtained. These visions were documented in the form of narrative descriptions and captured for the twelve delineated Integrated Units of Analysis (DWA, 2013a,e).

2.1.2 Scenario description

The definition and evaluation of scenarios were undertaken in context of the prevailing and proposed water resource management activities in the Inkomati System. A scenario, in context of water resource management and planning, are plausible definitions (settings) of all the factors (variables) that influence the water balance and water quality in a catchment and the system as a whole. While a workshop was held with stakeholders to identify scenarios, the development options were already well established as part of several previous studies (DWA, 2013c; TPTC, 2012; Chunnet Fourie and Partners, 1990). This preliminary list was presented to stakeholders for their consideration after which a final list was compiled for evaluation (see Section 3.2 for a description of the scenarios that were evaluated).

2.1.3 Assign attributes to EWR nodes

Applying the Status Quo information (DWA, 2013a) all the relevant properties (attributes) were defined for the biophysical nodes with respect to the Ecology, Ecosystem Services as well as the economic characteristics (in context of the IUA). A key aspect of this activity was to incorporate these nodes into the water resource simulation model to enable the generation of monthly time series of flow data for the scenarios where appropriate. At selected nodes (key biophysical nodes or EWR sites) the flows required to achieve a particular ecological state were also defined, along with rules to make releases from upstream weirs and dams.

2.1.4 Water availability analysis

This activity applied the water resource simulation model to determine the volume of water that is available for abstraction from the water resource for economic use, given that the flow regime in the river is maintained to achieve a certain ecological state. The ecological state is defined by the particular EC specified for the scenario under consideration, which could be the Recommended Ecological Category (REC), Present Ecological State (PES) or any other appropriate EC.

2.1.5 Estimate consequences

The simulated flow regimes at the nodes and the water available for abstraction form the basis for evaluating and estimating the consequences of each scenario. The text box in the centre of Figure 2.1 indicates the aspects that were evaluated. Table 2.1 lists these aspects and provides a brief description of the evaluation method and purpose as well as references to where further detail information is provided.

Table 2.1 Variables considered in the scenario comparison and evaluation process

Variable	Evaluation purpose and method	Reference to further detail information
Ecological	Determine the EC and indicate the degree in which the scenario achieves the REC.	Report 4.2; Chapter 5
Ecosystem Services	Determine the extent that each scenario changes the Ecosystem Services relative to the PES conditions.	Chapter 6
Economy	Determine the economic benefit of utilising the available water (abstractions) in terms of Gross Domestic Product (GDP) and Employment (Jobs).	Chapter 4
Non-ecological Water Quality	Consider the consequences of having to achieve elevated water quality standards for users other than the ecology (fitness for use or UserSpecs). This may involve determining the economic implications of such elevated standards.	

2.1.6 Compare, rank and optimise

The consequences from the abovementioned activity are expressed numerically for the scenarios and compared separately for each variable and then the results are combined for all variables to derive overall scores which give effect to the ranking of scenarios. The methodology employed for this is based on Multi Criteria Analysis approach where weighting factors are applied, firstly to give effect that certain nodes are more important than others and secondly that the variables listed in Table 2.1 may differ in their relative importance (see Section 2.2) for further details on the Multi Criteria Analysis methodology).

When the results of the first set of scenarios were evaluated it was identified that there were possible alternative EWR release methods that may achieve a more optimised overall solution. All the scenarios are described in Chapter 3.

2.1.7 Formulate alternative scenarios

This activity involves the formulation of alternative scenarios, usually consisting of adjustment to the initial list (rather than completely different scenarios) for further consideration. The other steps are then repeated.

2.1.8 Select scenario subset for stakeholder evaluation

The technical study team assessed several scenarios of which the results defined the boundaries of the variable settings and point to the aspects that are important to consider in the Inkomati System. A relevant subset of the full list of scenarios was selected for discussion with stakeholders.

2.2 MULTI CRITERIA ANALYSIS FOR SCENARIO EVALUATION AND COMPARISON

2.2.1 Evaluation variables

As explained in Section 2.1 there are three main aspects that are compared when determining the degree of achieving the appropriate balance between the ecological objectives on the one hand and the socio-economic benefits on the other.

The ecological state (or health) rating is expressed relative to how the scenario achieves the REC. This is quantified as a numerical ratio ranging usually between 1 and 0, where a score of 1 indicates the scenario achieves the REC and zero when the scenario is typically in an F Ecological Category.

The rating of the Ecosystem Services for a scenario is expressed numerically and relative to the baseline Ecosystem Services available under current conditions (2013). A score of 1 indicates the scenario will provide the same services as under present conditions where a score of 1.2 imply there is 20% more utility in terms of Ecosystem Services. A score of 0.8 indicates a reduction of 20% in the services provided by the scenario.

In terms of the socio-economic component, two aspects are evaluated, namely the GDP and employment (the number of jobs) that will be supported by the volume of water that can be abstracted from the system for the scenario. The GDP is expressed in monetary terms (Rand) and employment in the number of jobs supported.

The following sections provide an expanded description of how the metric for each of the three components presented above were derived.

2.2.2 Ecological Metric

Deriving a single metric (one number) that reflects the ecological health relative to the REC for the system, requires several steps, sub-steps and the application of various tools. Broadly, the rationale to achieve this single rating is based on the following.

- Scenarios at each EWR site are ranked on the basis of the degree to which the scenarios meet the REC.
- Comparing the impact of the scenarios at the different EWR sites to determine a ranking from a system context depends both on the degree to which the scenario meets the REC, as well as the relative ecological importance of the sites.

To further explain this, if a scenario is ranked highest at a site of low importance, but lower at a site of high importance, this scenario will not carry the same weight as the scenario that scored the highest at the sites of high importance.

The steps and sub-steps to derive a single number are illustrated in Figure 2.2 and Figure 2.3 and described in the bulleted list below:

- Step 1: Rank scenarios at each EWR site (Figure 2.2 and Figure 2.3)
  - Apply the EcoClassification (Kleynhans and Louw, 2007) process at each EWR site where the scenario influences the flow or water quality to determine the EC for each component[1].
  - Provide the associated percentage that represents the category.
  - Calculate the degree to which the scenario meets the ecological objectives which is represented by the REC. I.e., if the REC for a component is 62% and the scenario results in this component being at 62%, then the resulting score would be a 1 (or a 100% successful in meeting the REC). If a scenario's rating for the component is 48%, then the score would be 0.77 (or 77% successful in meeting the REC).
  - Average the score at each component to obtain a score for the scenario at the site.
  - Each site's score is then normalised to obtain a rating that is 1 if the REC is achieved, above one if the REC is exceeded (i.e. 1.1) or between 1 and zero if the score (EC) is below the REC.
  - Rank the scenarios in terms of a numerical scale with values zero and one (typically, where one (1) indicates the scenario achieves the REC and a zero (0) represents the situation where the scenario results in a "F").

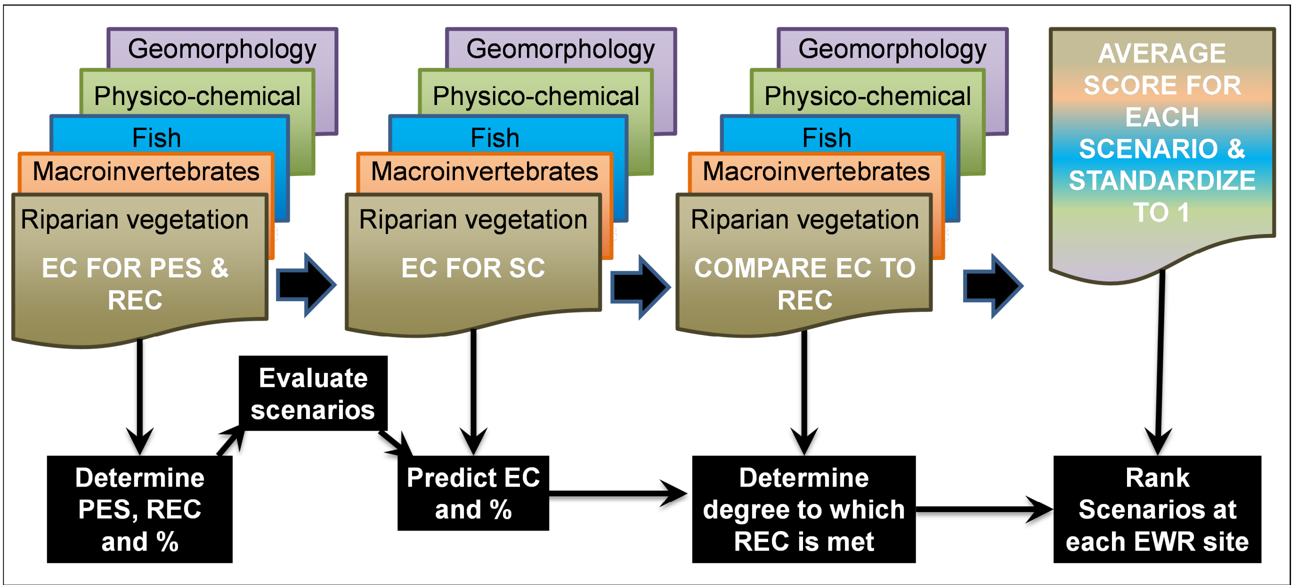


Figure 2.2 Process to rank scenarios at each EWR site

- Step2: Determine the relative importance of EWR sites to each other (Figure 2.3)

The following aspects are considered when determining the relative importance of the EWR sites to each other:

- PES: The higher the PES the more important the EWR site. The PES percentage is used in this calculation.
- Ecological Importance and Sensitivity (EIS): The higher the EIS rating, the more important the EWR site. The EIS score is used in this calculation.
- Conservation importance: The locality of the site within a declared conservation area is highlighted. A site within a Transfrontier park or a Wilderness Area will be more important than a National Park which in turn will be more important than a provincial nature reserve.

The above metrics are averaged and the score is then normalised out of one.

1Component: Habitat drivers (geomorphology and water quality (hydrology is a given)); Biological responses (fish, macroinvertebrates, riparian vegetation).

- Step 3: Rank the scenarios in a system context (Figure 2.3)

All the scores from the EWR sites are then combined into a single score by accounting for the above site importance ranking. This is achieved by assigning different weights (factors) to each site to reflect the importance relative to the others.

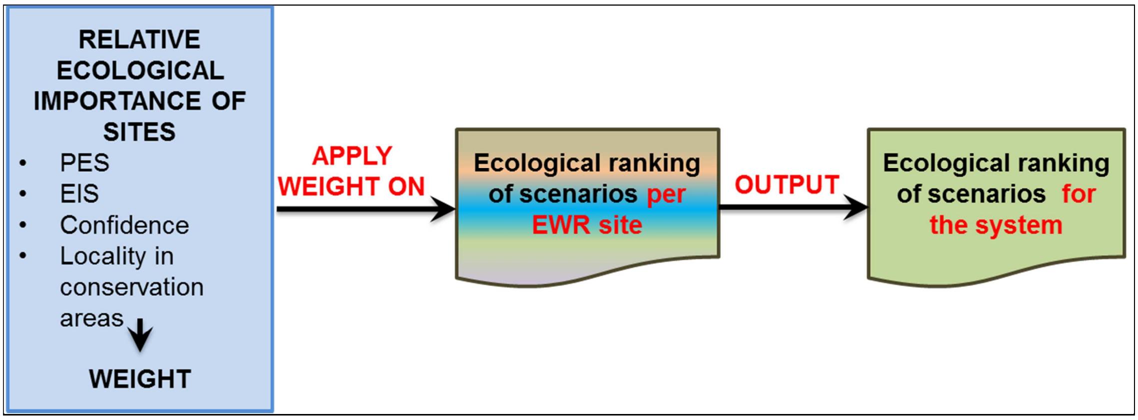


Figure 2.3 Process to achieve the ecological ranking of all scenarios on the river systems

The output of the application of these processes result in an ecological ranking of each scenario for the Komati, Crocodile, and Sabie-Sand River systems. The individual ranking and consequences at each EWR site have therefore been integrated into one ranking and consequences applicable to the specific river system.

2.2.3 Ecosystem Services metric

An approach to Ecosystem Services, following “The Millennium Assessment” has been adopted. The Millennium Assessment primarily focuses on the interaction between dependence on ecosystems, and how changes in ecosystem services have affected human well-being and will continue to impact people. The concept is developed around notions of dealing with vulnerability and poverty and promoting sustainability in the face of development challenges. The approach adopted for the Inkomati is informed by both the Millennium assessment as well as International Finance Corporation (IFC) Performance Standard 6 that give guidance on management of ecosystem services. As such the approach is a risk based rather than quantitative approach that seeks to:

- Provide a clear picture of the current state of ecosystems in the area.
- Provide an understanding of the relationship and linkages between ecosystems and human well-being, including economic, social and cultural aspirations in the Inkomati area.
- Acknowledge the potential of ecosystems to contribute to poverty reduction and enhanced well-being.
- Assess scenarios with respect to vulnerability and poverty impacts.

Natural habitats and ecosystems provide a range of environmental goods and services that contribute enormously – and are even essential – to human well-being. Protecting these areas is essential in order to achieve sustainable development. River systems and their associated use values are of particular importance.

For operational purposes this study follows the approach defined in the 2005 Millennium Ecosystem Assessment and classifies ecosystem services along functional lines using categories of provisioning, regulating, cultural, and supporting services.

Provisioning services are the products obtained from ecosystems, including food and fibre. This includes the fish found in the river as well as materials such as wood and fibres for timber and fuel as well as for items of utilitarian or craft value. Provisioning services also includes natural medicines, and pharmaceuticals. Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.

Regulating services are the benefits obtained from the regulation of ecosystem processes and include:

- Water regulation: The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.
- Erosion control: Vegetative cover plays an important role in soil retention and the prevention of landslides.
- Water purification and waste treatment: Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes.
- Regulation of human diseases: Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.

Cultural Services includes the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including spiritual and religious values. Many religions attach spiritual and religious values to ecosystems or their components. Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, “scenic drives,” and the selection of housing locations. Many people value the “sense of place” that is associated with recognized features of their environment, including aspects of the ecosystem. People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are either indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. Some examples of supporting services are primary production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitats.

In the first part of the approach the Sub Quaternary (SQ) catchments were analysed and evaluated against each other. In this regard the most important step was to provide an integrated assessment of the current population of the study area. Analysis was undertaken using four primary tools. These were:

- The 2011 census as adjusted.
- Geographic Information System (GIS) overlays of quaternary catchments and the census “sub place name” data. “Sub place name” data fields are the most detailed subsets of data released by Statistic South Africa. This allows for the population for each quaternary to be calculated and a profile of the population for each unit to be analysed. Data was analysed to select areas in which populations likely to be dependent on riverine goods and services were possibly or probably present.
- Cross check of the GIS data sets with available mapping to determine likely livelihood styles and profiles.

- Site visits to likely “hot spots”.
- The DWA/Anchor Environmental (2010) entitled “The nature, distribution and value of aquatic ecosystem services of the Olifants, Inkomati and Usutu to Mhlathuze Water Management Areas, Contract Report by Anchor Environmental Consultants for Department of Water Affairs.

A second level of analysis based on the typology of settlements in the area and their likely associated dependence on ecosystem services for livelihoods was undertaken for this report (DWA, 2013a). This was sourced from information available from Statistics South Africa and cross referenced with an examination of aerial photography, largely that provided by Google Earth. This allowed for an analysis of land use types associated with the settlement typology.

Based on the Status Quo analysis (DWA, 2013a) the catchment has been divided into zones that reflect the ecosystem services attributes as a direct dependent of land use attributed. For the purposes of this catchment five different land use forms that reflect types of ecosystem services that might be associated with the usage have been identified. It should be noted that as the building block for the analysis is the SQ, a judgment call has to be made as to which land form dominates in the section under consideration. In some instances there are multiple land uses that apply to the SQ. The land use based zones are:

- Commercial Agriculture and Plantation: This is largely given over to zones dominated by commercial farming entities. Utilisation of ecosystem services tends to be low and restricted often to farm workers or incidental recreational aspects.
- Subsistence agriculture: These areas are dominated by subsistence agriculture but in areas where population densities are relatively low. Utilisation of ecosystem services tends to be higher here and the populations that make use are often poor and marginal.
- Rural Closer Settlement - Subsistence: These are the former homeland areas that have generally higher population densities than the purely subsistence areas. In some instances densities are high enough to be categorised as closer settlement/informal urban. Utilisation of ecosystem services tends to be higher here and the populations that make use are often poor and marginal. However, the population densities are such that resources tend to be under pressure.
- High Density Formal Urban: These are the SQs heavily influenced by the town of Tzaneen. The utilisation of ecosystem services tends to be low as the populations tend to be urbanised and alienated from direct use of the resources.
- Recreational/Dams/Game Farms: These are areas given over to game farms (notably the Kruger National Park (KNP)) as well as SQs dominated by dams. Recreational usage tends to dominate ecosystem services attributes.

Further, each quaternary catchment of the Inkomati system has been examined in detail and scored. The score was based on an earlier analysis of Socio Cultural Importance (SCI) and was determined from (a) a site visit that covered points along the river, (b) extrapolation to sites not visited by reference to available literature as well as to existing mapping. Given the size of the budget and the geographical scope of the work most of the information used to influence the score was derived from direct observation and consideration of the literature available. A limited number of direct interviews were held with people who were resident proximate to the river. The provisioning, regulating, cultural, and supporting services were considered in turn and rated per SQ from 1 (no importance wither in terms of magnitude or significance) to 5 (extreme importance in both magnitude and significance). The ratings were given weights to generate an overall score as follows

- Provisioning services: Given a weight of 0.5 or half the overall Ecosystem Services score. This is done so as to ensure that where there are vulnerable communities dependent on the direct consumption of goods for livelihoods due cognisance is given to this requirement. The Inkomati catchment is relatively highly populated and includes a number of vulnerable communities.

- Cultural services: Given a weight of 0.25. These services include recreational aspects and again are of relatively high importance in the Inkomati catchment.
- Supporting and regulating services: Given a weight of 0.125 each. While not to downplay these services they are given lesser importance in the overall Inkomati catchment given the nature of the overall socio-political makeup that contains a number of vulnerable communities for whom provisioning services are critical.

This analysis generates a weighted ranking of the overall importance of the SQs when compared to each other.

A further round of analysis was undertaken in a specialist workshop and this is these results that are reflected in this report. It should be noted that the objective in describing and valuing the use of aquatic ecosystems is to determine the way in which aquatic ecosystems are currently being used in each socio-economic zone (represented by an EWR site), and to estimate the value generated by that use. This provides the baseline against which the socio-economic and ecological implications of different catchment configuration scenarios can be compared. It is important to point out that while Ecosystem Services were identified and described in qualitative terms, a baseline value can often only be described for some of these, as the information required is not available without investing in a costly survey.

A list of the relevant ecosystem services that were found in the various reaches examined, and deemed to be significant, was generated as a table. These were cross checked with the biophysical experts that formed part of the project team at a specialist workshop held in June 2014.

The biophysical specialists then identified the potential change that each of the key ecosystem services may undergo in each of the scenario clusters. The potential change will be noted as a factor and used in later calculations. For example, no change = 1, a 50% increase = 1.5, and a 20% decrease = 0.8.

The scenario impact on various ecosystem services (including botanical or fish species) were then amalgamated into overall categorisation of provisioning, regulating, cultural, and supporting services. The scenarios are also weighted with respect to the importance of the services at each EWR site. As such the score given to each of the services when the SQs are evaluated is examined against the nature of the particular EWR site and associated area. In an instance where regulating services, for example are deemed to be important, then these services are given a higher weight. The same goes for the other services.

2.2.4 GDP and employment metric

The economic evaluation of the impact of the different scenarios as evaluated is based on the broad assumption that the utilisation of any additional or current water allocation is utilised at maximum efficiency.

Any economic evaluation takes place within the specific current situation, not an empty undeveloped or river catchment, and it is necessary that the current situation be taken into consideration in the evaluation of any of the operational scenarios.

Currently the following main water users are identified in a catchment or WMA, or are dependent on the water in the river. The main users are:

- Irrigation.
- Commercial forestry.
- Mining.
- Heavy Industry.
- Urban and Domestic Household Use.
- Light Industry; and
- Tourism.

The tourist activity depends on the availability and quality of the water in the river or estuary and the overall condition of the environment.

As the main aim of the classification process is to stabilise the river or estuary class, the possibility that the water in the river will be reduced is not always an acceptable option. Therefore, the tourist activities can only be positively impacted on, the worst case option is that the sector will remain as it is at present.

The commercial forestry sector is regulated by a permit system, and we could not find any evidence that any reduction in the commercial plantation area is considered. For this reason it was accepted that on the medium term the forestry sector will not be impacted on by any operational scenario.

The irrigation, mining and industry sectors will only be impacted by scenarios which result in available volumes increasing or decreasing.

Measuring Parameters

It was decided to use, in both the baseline as well as the different scenarios, two macro-economic indicators, namely GDP and employment. Although the use of the GDP created is generally accepted as an economic growth indicator, it sometimes does not present the full picture. In the case of irrigation agriculture irrigated sugarcane provides a very large GDP contribution. If the area is highly rural and impoverished then job creation is perhaps more important than GDP creation.

A second factor to consider is the value added process in the production area, as an example, sugarcane mills create a service point in the primary area of production. Many social services start to concentrate around sugarcane mills, such as health clinics, pension pay points and police stations.

On the opposite side is, possibly, citrus production which creates a large number of jobs in the primary production activity, but very little value added takes place in the primary production area as most of the fruit is exported. This is not always the complete picture as juice facilities and other value added processes can be added. However, it has a positive impact on the Balance of Payments.

In the final instance it is necessary to take into consideration the current situation, a certain economic sector is in operation while some of the others are based on assumptions and projections. There is always the risk that the projected benefits will not materialise because of a number of reasons, e.g. government policy, economic circumstances or lack of entrepreneurial skills.

Economic Modelling

The model, as is currently constructed, is in the form of a dynamic computerised water entitlement model which can be used to identify and quantify the following indicators:

- Economic benefits.
- Maximum possible water reduction.

The first step is to calculate the macro-economy of each of the Economic Regions (ERs) in the project area and to identify and establish the detailed water users in terms of volume used. In the case of irrigation and commercial forestry the detailed areas in production are determined together with the different crops produced.

A Water Impact Model (WIM) was constructed for the catchment which included the identified ERs. The model is water driven and gives the direct and indirect/induced results for the following sectors: irrigation agriculture, commercial forestry, heavy and light industries, mining, urban and household use and eco-tourism. Regarding agriculture the model can accommodate up to 20 different products and for forestry it makes provision for pine, and gum sub-species.

The following impacts are estimated by the WIM:

- GDP.
- Employment Creation.

A group of economic multipliers was then developed for comparing different water use activities in terms of GDP (Rand million/m^3) and employment creation (number/million m^3). As the economy entails a number of mechanisms and linkages between sectors, definitions of the economic impacts used in the economic results are described below in terms of the direct, indirect and induced effects explained by means of the agricultural sector:

- **Direct effects:** Refers to effects occurring directly in the agriculture sector such as the hectares cultivated impacts.
- **Indirect effects:** Refers to those effects occurring in the different economic sectors that link backward to agriculture due to the supply of intermediate inputs, i.e. fertiliser, seed, etc.
- **Induced effects:** Refers to the chain reaction triggered by the salaries and profits (less retained earnings) that are ploughed back into the economy in the form of private consumption expenditure.

Project area specific considerations

In the evaluation of the different users it was identified that the following sectors in the project area could be affected by a change in the water allocation:

- Irrigation.
- Urban and Domestic Household Use.
- Light Industry.

An additional urban allocation as proposed by a number of scenarios will impact positively on the household sector.

An economic baseline was established and the estimated deviation from the baseline was determined with water as the main driver. Three economic activities are used in the evaluation process, namely:

- Irrigation.
- Light Industry; and

- Domestic Household Use.

Approach

In the formulation process of the different scenarios the projected available volume of water was calculated for each of the economic zones in the four catchments. The economic zones are as follows:

a. Komati Catchment

- Zone 1: Komati-West.
- Zone 2: Komati (Nkomati).
- Zone 3: Lomati (RSA).
- Zone 4: Lower Komati.

b. Crocodile Catchment

- Zone 1: Upper Crocodile.
- Zone 2: Lower Kwena.
- Zone 3: Elands.
- Zone 4: White.
- Zone 5: Middle Crocodile.
- Zone 6: Kaap River.
- Zone 7: Lower Crocodile.

c. Sabie Catchment

- Zone 1: Sabie River.
- Zone 2: Maritsane/Inyaka.

d. Sabie Catchment

- Zone: Sand River.

In the following sections the assumptions used in the different sectors are discussed.

Irrigation Agriculture

Currently irrigation is the major user of water and also the large economic enterprise in the Inkomati catchment. In analysing the possible impact of a specific operational scenario the following assumptions were made.

1. It was assumed that the current irrigation development is based on this long term water volume provision and that the management practises of the irrigators have been adapted to this reality.
2. Modern irrigation equipment is used in all crops.
3. The long term crop yields were adapted to be in line with the average long term water supply and not the irrigation demand assuring a 100% crop yield.
4. Komati Catchment - In the case of Scenario 4.3 and 6, where increases in water provision were expected, the average crop yields where adapted upwards.
5. Komati Catchment - In the case of Scenario 2, 3.1, 3.2, 4.1 and 4.2, where available irrigation water was reduced significantly, the hectares in production were reduced to be in line with the expected water supply, the crop yields retained, calculated for the average long term water provision.
6. Crocodile Catchment - In the case of Scenario 5 and 7.2, where increases in water provision were expected, the average crop yields where adapted upwards.

7. Crocodile Catchment - In the case of Scenario 2, 3, 4, 6.1, 6.2, 7.1, 8.1 and 8.2, where available irrigation water was reduced significantly, the hectares in production were reduced to be in line with the expected water supply, the crop yields retained, calculated for the average long term water provision.
8. Sabie Catchment - In the case of Scenario 3.2 and 4, where increases in water provision were expected, the average crop yields where adapted upwards.
9. Sabie Catchment - In the case of Scenario 3.1, where available irrigation water was reduced significantly, the hectares in production were reduced to be in line with the expected water supply, the crop yields retained, calculated for the average long term water provision.
10. Sand Catchment – The scenarios for the Sand catchment will not influence the irrigation sector of the Sand catchment and all values for irrigation in the Sand is expected to stay static.

Light Industry Sector

The light industry sector is relatively small and includes:

- Saw Mills.
- Sugar Mills.

It was accepted that the forestry sector will not expand; therefore the production from the saw mills will be static, with no growth at all. It was assumed that the irrigation based product light industry sector can expand, but no specific products were investigated as the baseline and specific multipliers were already determined in the previous phases of the study. It was also assumed that additional light industrial development can take place not based on the irrigation based products, but in the irrigation service sector. In line with this it was accepted that an expanding local urban population will also add to a growing informal economic sector.

Agriculture and forestry related light industrial activities are taking place in all four of the catchments that make up the Inkomati Catchment. In this analysis no difference was made between light industrial activities and informal activities, as they very often support one another in a small urban area. The macro-economic multipliers used are representative of the light industry sector as drawn from the Mpumalanga Social Accounting Matrix and applied in the calculation of the GDP, labour and household income.

As the current WIM model is set up for light industry and heavy industry only, the informal sector was incorporated into the light industry sector multipliers.

Domestic Sector

The third activity identified and analysed is the Household Sector and its contribution to economic growth. Should more water be allocated to households and the living standards start improving, the household as such contributes to economic growth by using more water, paying larger accounts and using the service sector increasingly.

Multipliers were developed for domestic water usage that estimates the value of domestic water for GDP and employment opportunities. The multipliers developed were updated to 2013 prices, incorporated into the WIM and applied to estimate the additional GDP and employment opportunities created by the additional water.

Although this sector was not originally incorporated into the baseline it became necessary to incorporate it in order to estimate a value for the sector in terms of GDP and employment, when the additional water is allocated.

Tourism Sector

In analysing the sector the following groups were identified:

- The KNP where animals concentrate around the rivers.
- The Badplaas resort, which is situated in the Komati Catchment.
- The tourists on their way to the KNP or from the KNP and private reserves who overnight in the many facilities along the KNP in the Crocodile, Sabie and Sand Catchments.
- The tourists just visiting the Lowveld region of the Inkomati catchment because of the beautiful scenery; and
- The business tourists.

As discussed the tourism sector consists of a number of economic sectors. In the case of the KNP all the proposed scenarios will improve the instream water flow in the river part that is in the National Park. Secondly the current unit occupation rate of all the Kruger camps during the 2012/2013 was 78%, with a peak during the winter months.

The question, whether there is actually scope for increased occupancy of tourist facilities should the volume of the water in the rivers increase, then arises. Our deduction was that the "experience" of the visitors will improve but not necessarily the number of visitors. We came to the same conclusion for the other tourist facilities in the catchment and therefore did not estimate the possible impact on tourism for any of the facilities.

2.2.5 Overall Ranking Metric

The first aspect to consider in deriving the overall ranking for each scenario is the method employed to normalise each variable's results. This is necessary to remove the effect of the different dimensions (Rand for the economy, number of jobs for employment and the different rating scales for the ecology and Ecosystem Services) and make the scores of each variable comparable. The second aspect is to make provision to vary the importance each variable has in the overall ranking. Both these are described further below.

Relative Importance

The relative importance (among the variables) is defined by assigning relative weights to each of the four variables. Examples of how different weights would result in a preselected bias are presented in Table 2.2 for illustration purposes. The actual weight scheme applied in the study is discussed in Chapter 7.

Table 2.2 Explanation of the application of variable weights

Pre-selected Importance Bias	Weights assigned (Sum of weights for the four variables must add up to one)			
	Ecological Protection	Ecosystem Services	Economic Indicator (GDP)	Employment Indicator (Jobs)
Neutral[1]	0.5	0.1666	0.1666	0.1666
Preference for ecology	0.7	0.1	0.1	0.1
Preference for socio-economy	0.3	0.2333	0.2333	0.2333
Preference for socio-economy with emphasis on employment	0.3	0.2	0.2	0.3
Preference for socio-economy with emphasis on economy	0.3	0.2	0.3	0.2

1 This weight scheme is neutral because all the socio-economic variables together carry the same weight as the ecology variable.

Normalising methods

The **first method** normalise the score to a scale between 0 and 1, where the scenario with the best score is 1 and lowest score is 0. This is carried out for each variable respectively. The **second method** applies the rank order (1 for the one with the lowest score and 6 for the one with the highest score) of the scores of each variable. Both these methods were applied in the analysis and the results are described in Chapter 7**Error! Reference source not found.**

The overall rank for a scenario is therefore determined by the sum of the products of each variable's metric multiplied with importance weight of the variable.

2.3 WATER RESOURCE CLASS DETERMINATION

In accordance with the WRCS Guidelines (DWAF, 2007), the Water Resource Class for an IUA is defined by the distribution of the selected ECs for the biophysical nodes in an IUA. In general, if the nodes are in "A" or "B" ECs the IUA is in a Class I, a Class II will be assigned if most nodes are in a C EC and if the nodes mostly falls into a D EC the IUA is in a Class III.

The guidelines recommend the scheme presented in Table 2.3 as the criteria to determine the Water Resource Class. The "units" applied in the table is the percentage of river length (associated with a biophysical node) falling into each of the indicated ECs.

The following is an example interpretation to illustrate the application of the guideline scheme.

An IUA is in Water Resource Class I if the following applies:

- 40% of the units are greater than or equal to an A/B Ecological Category.
- 60% of the units are greater or equal to and B Ecological Category.
- 80% of the units are greater or equal to and C Ecological Category.
- 99% of the units are greater or equal to and D Ecological Category.
- Less than 1% of the units can be in an E EC.

Table 2.3 Preliminary guidelines for the calculation of the IUA Class for a scenario (DWAF, 2007)

		% EC representation at units represented by biophysical nodes in an IUA				
		≥ A/B	≥ B	≥C	≥ D	< D
Class I		40	60	80	99	-
Class II			40	70	95	-
Class III	**Either**			30	80	-
	Or				100	-

The results presented in Chapter 8 list the IUA Water Resource Classes for the indicated scenarios. The specific scheme (adjusted from the guideline scheme presented here) is also presented and discussed in Chapter 8.

3 SCENARIO DESCRIPTION

3.1 INTRODUCTION

The Inkomati Water Management Area, consisting of the Komati, Crocodile and Sabie Rivers, is highly a stressed system with water use equal to or exceeding the available resource in most areas. The system is institutionally well developed in that there is a catchment management agency (referred to as the Inkomati-Usuthu Catchment Management Agency or IUCMA), several well managed irrigation boards as well as the Komati Basin Water Authority (KOBWA). The Department of Water and Sanitation also has a regional office located in Nelspruit.

3.2 WATER MANAGEMENT SCENARIOS

In term of physical infrastructure the Inkomati WMA is not fully developed and there is scope for several new dams in this WMA. The scenarios considered as part of this study therefore include several infrastructure development options. While a workshop was held with stakeholders to identify scenarios, the development options were already well established as part of several previous studies, as listed below.

- Mbombela Reconciliation Strategy (DWA, 2013c).
- Progressive Realisation of the IncMaputo Water Use Agreement (TPTC, 2012).
- Sabie Feasibility Study (Chunnet Fourie and Partners, 1990).

These scenarios derived from these previous studies broadly consist of options to reduce the water requirements and options to increase the water supply. The water conservation and demand management options are incorporated into the water demand growth scenarios:

- **Komati River system**
  - Water Conservation & Water Demand Management.
  - Construction of the Silingane.
- **Crocodile River system**
  - Water Conservation & Water Demand Management.
  - Construction of the Mountain View Dam.
  - Construction of the Boschjeskop Dam.
- **Sabie River system**
  - Water Conservation & Water Demand Management.
  - Construction of the New Forest Dam.

A complicating factor in the Inkomati WMA is the fact that all the major rivers within the WMA form part of the larger Incomati River Basin which is shared with Swaziland and Mozambique. Two international agreements have relevance to the cross border flow into Mozambique. These are the Piggs Peak Agreement (TPTC 1990) and the IncoMaputo Water Use Agreement (TPTC, 2002). The Piggs Peak agreement specifies a minimum flow in from the Crocodile and Komati rivers into Mozambique of 2m^3/s. The arrangement within South Africa is that the Crocodile River will contribute 0.9 m^3/s while the Komati River contributes 1.1 m^3/s.

While the Piggs Peak agreement has been superseded by the IncoMaputo Water Agreement (TPTC, 2002), this agreement has yet to be implemented in practice, at least in terms of the cross border flow which have been increased from the Piggs Peak agreement from 2 m^3/s to 2.6 m^3/s.

3.3 ECOLOGICAL WATER REQUIREMENT OPTIONS

With respect to the EWR, the following three options were considered in each major river system (Komati, Crocodile and Sabie):

- No EWR.
- PES.
- REC.

In the Crocodile River system a further scenario referred to as the 'Present Day EWR' was also considered. This scenario stems from the Ecological Reserve study (DWA, 2010a;b) in which the recommendation was to maintain the present day flow.

3.4 CONSOLIDATED DEFINITION OF THE SCENARIOS

Table 3.1 - 3.4 summarise the scenario definition in the form of a matrix, where each row represents a scenario and the columns indicate each of the variables applicable to each scenario. The scenarios are grouped into four sub-catchments, the Komati, the Crocodile, the Sabie and the Sand River. The reason that the Sand River was separated from the Sabie is that it was found that the many of the scenarios were applicable to either the Sabie (X31) or the Sand catchment, but not both.

Details of the modelling assumptions for each scenario analysed are presented in Appendix A (Chapter 10), along with the description of the network configuration and the data applied in the model for the simulations.

The consequences (resulting effect) of the scenarios on the Economy, Ecology and Ecosystem Services are described respectively in Chapters 4, 5 and 6.

3.4.1 Komati River system

The proposed scenarios for the Komati River system are summarised in Table 3.1 and the associated variables associates with the scenarios are described below.

Table 3.1 Summary of the Komati (X1) scenarios

Scenario	Scenario variables					
	Update water demands	Domestic growth and increase irrigation (plus restrictions so system does not fail)	IIMA[1] Flows	DARDLA[2]	Silingane Dam (DS[3] Maguga)	EWR
K1	Yes	No	No	No	No	No
K2	Yes	No	No	No	No	Yes
K31	Yes	Yes	Yes	No	No	Yes
K32	Yes	Yes	Yes	No	No	No
K41	Yes	Yes	Yes	Yes	No	Yes
K42	Yes	Yes	Yes	Yes	No	No
K43	Yes	No	Yes	Yes	No	No
K5	Water quality scenario (not for ecological assessment), includes mining aspects)					
K6	Yes	Yes	Yes	Yes	Yes	Yes

1 Interim IncoMaputo Agreement 2 Department of Rural Development and Land Affairs
3 Downstream

Update water demands

The existing yield model, which was set up as part of the Inkomati Water Availability Assessment Study (IWAAS) (DWA, 2009a), was updated with more recent water use information. In the Komati River system this included improved estimates of water use obtained from the All Towns Reconciliation Strategies (DWA, 2011).

Growth in domestic and irrigation water requirements

The All Towns Reconciliation Strategies (DWA, 2011) were used as a data source of information on likely growth in domestic water requirements up to and including 2030. While no growth in irrigation is anticipated in the South African part of the catchment, Swaziland has yet taken up their full allocation. This scenario assumed that Swaziland would take up their full irrigation allocation.

Increased cross-border flows as stipulated in the Interim IncoMaputo Agreement

The current operating rule allows for the Komati River to contribute 1.1 m^3/s to the 2.0 m^3/s minimum flow into Mozambique as stipulated in the Piggs Peak agreement (TPTC, 1990). The more recent Interim IncoMaputo Agreement (IIMA) (TPTC, 2002) allows for a minimum cross border flow of 2.6 m^3/s of which 1.43 m^3/s will be provided from the Komati River.

Uptake of unutilised irrigation allocations through the intervention of the DARDLA

There is an estimated 14.6 million m^3/annum of water allocated to irrigators in the Upper Komati that is not being used. The DARDLA plan to reinstate 6.6 million m^3/annum of this irrigation at the original location and apply to DWS to transfer the remaining 8.8 million m^3/annum to downstream of Swaziland. Since the operating rule of the Vygeboom Dam includes the release of 0.6 m^3/s for these irrigators, the inclusion of this irrigation requirement does not impact on the transfers to Eskom since no additional release is required.

Impact of mining operations on the water quality in the upper Komati

The coal mines in the upper reaches of the Komati catchment pose a serious risk to the water quality in the Nooitgedacht and Vygeboom dams as well as the rivers feeding into these dams. There have already been incidences of spills which had dire consequences to the water supply to the town of Carolina. This scenario considered the impact of uncontrolled mining development with eventual acid mine drainage. This was modelled with and without transfers of water from the Usuthu catchment. This scenario has no ecological consequences, only a cost implication. The cost of treating Acid Mine Drainage (AMD) must be subtracted from the economic benefit of the mining.

Inclusion of the Silingane Dam on the Komati River

The study referred to as the Progressive Realisation of the IncoMaputo Agreement (TPTC, 2012) identified the Silingane Dam on the Komati River in Swaziland (at the downstream end of the X13D catchment) as a potential development option to increase the utilisable water within the Komati Basin. Although this development is probably a long way off, it was considered as a scenario and evaluated. The assumed parameters for this dam are as follows:

- Full supply capacity: 590 million m^3
- Full supply area: 17.4 km^2
- Dead storage: 5.0 million m^3

The assumed operating rule is that water will first be drawn from Silingane Dam and water released from Maguga Dam to Silingane Dam when the storage in the Silingane Dam drops below 10% of its full supply capacity.

Ecological Water Requirements

The EWR in the Komati River system was determined in 2005 (AfriDev, 2005). The management class of the PES and REC is the same at all EWR sites hence it was not necessary to distinguish between PES and REC in the scenarios. An important point to note with regard to the EWR in the Komati River system is that there is no EWR requirement downstream of the confluence of the Komati and Lomati Rivers. The reason for this is the numerous weirs constructed on this stretch of river in the late 80's which effectively transformed this reach of river into a reservoir and not deemed appropriate for Reserve assessments.

3.4.2 Crocodile River system

The proposed scenarios for the Crocodile River system are summarised in Table 3.2. The variables associated with the scenarios are described below.

Table 3.2 Summary of the Crocodile (X2) scenarios

Scenario	Scenario Variables						
	Update water demands with revised PES EWR	Updated water demands	Domestic growth	IIMA Flows	Mountain View Dam (Kaap)	Boschjeskop Dam (Nels)	EWR
C1	Yes	No	No	No	No	No	No
C2	No	Yes	No	No	No	No	REC
C3	No	Yes	Yes	Yes	No	No	PES
C4	No	Yes	Yes	Yes	No	No	REC
C5	No	Yes	Yes	Yes	Yes	No	No
C61	No	Yes	Yes	Yes	Yes	No	REC
C62	No	Yes	Yes	Yes	Yes	No	PES
C71	No	Yes	Yes	Yes	No	Yes	REC
C72	No	Yes	Yes	Yes	No	Yes	No
C81	No	Yes	Yes	Yes	Yes	Yes	REC
C82	No	Yes	Yes	Yes	Yes	Yes	PES

Updated water demands

The yield model used as part of the Ecological Reserve Study (DWA, 2010a) was based on the validation study carried out in 2006. New information on water use is now available from various sources, such as the Mbombela Reconciliation Strategy (DWA, 2013c), the All Towns Strategies (DWA, 2011) and the Validation and Verification study being undertaken by the Inkomati-Usuthu Catchment Management Agency (ICMA, in progress).

Revised PES EWR

The de-facto EWR, as implemented by the IUCMA through their Crocodile Operations Committee is included in this scenario. This EWR was based on the minimum of the 'Present Day' flow and a EWR related to a C Ecological Category at EWR 6. See example from the month of October in Figure 3.1 below.

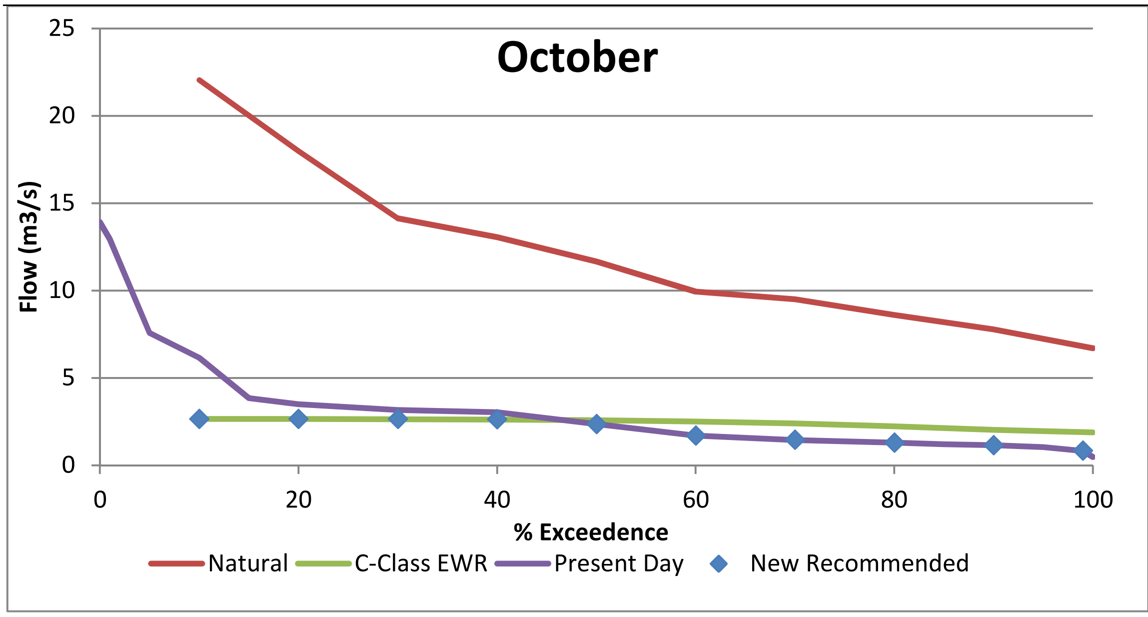


Figure3.1 Derivation of the EWR as implemented by the IUCMA

Growth in Domestic water requirements

The Mbombela Reconciliation Strategy (DWA, 2013c) and the All Towns Reconciliation Strategies (DWA, 2011) were used as a data source of information on likely growth in domestic water requirements up to and including 2030. No growth in irrigation is anticipated in Crocodile River system without the development of new dams.

Increased cross-border flows as stipulated in the Interim IncoMaputo Agreement

The current operating rule allows for the Crocodile River to contribute 0.9 m^3/s to the 2.0 m^3/s minimum flow into Mozambique as stipulated in the Piggs Peak agreement (TPTC, 1990). The more recent Interim IncoMaputo Agreement (IIMA) (TPTC, 2002) allows for a minimum cross border flow of 2.6 m^3/s of which 1.17 m^3/s will be provided from the Crocodile River.

Mountain View Dam

One of the infrastructure interventions considered during the Mbombela Reconciliation Strategy study (DWA, 2013c) was the construction of a dam on the Kaap River near the confluence with the Crocodile Dam at a site referred to as Mountain View. The construction of this dam could meet the growing domestic requirements or contribute to the EWR (PES or REC). The parameters for this dam used in the scenario analyses are as follows:

- Full supply capacity: 75 million m^3.
- Full supply area: 3.6 km^2.
- Dead storage: 2.0 million m^3.

Boschjeskop Dam

Another possible infrastructure intervention considered during the Mbombela Reconciliation Strategy study (DWA, 2013c) was the construction of a dam on the Nels River at the farm Boschjeskop. As with the Mountain View Dam, this dam could meet the growing domestic requirements of Mbombela or contribute to the EWR (PES or REC). The parameters for this dam used in the scenario analyses are as follows:

- Full supply capacity: 120 million m^3.
- Full supply area: 6.0 km^2.
- Dead storage: 2.0 million m^3.

Ecological Water Requirements

Four scenarios were considered with regard to the EWR. These are:

- The *de facto* EWR as applied by the IUCMA (see Section 3.3.2); secondly
- No EWR.
- PES.
- REC.

It was identified during the Inkomati Reserve study (DWA, 2010a,b) that EWR6 (at the downstream end of the Crocodile River) is the so-called driver station in that if the EWR at this point is met then the EWR is met at all the other six EWR sites. The possible exception to this is the EWR on the Kaap River (EWR7) which is located just upstream of the site of the proposed Mountain View Dam. Hence the construction of the Mountain View Dam will not be able to contribute to the EWR of the Kaap River.

3.4.3 Sabie and Sand River system

While the yield model of the Sabie catchment (of which the Sand River is a major tributary) considers the Sabie and Sand as one system, the scenarios relate to either the Sabie River system (X31) or the Sand River system (X32). For clarity, the scenarios have therefore been presented in two tables. The scenarios for the Sabie sub-catchment are summarised in Table 3.3 (Sabie) and Table 3 4 (Sand).

Table 3.3 Sabie River system scenarios

Scenario	Update water demands	Growth in water demands	EWR
S1	Yes	No	No
S2	Yes	No	Yes (REC)
S31	Yes	Yes	Yes (REC)
S32	Yes	Yes	No
S6	Yes	Minimised to meet REC	Yes (REC)

Table 3.4 Sand River system scenarios

Scenario	Scenario Variables				
	Update water demands	Growth in water demands	Reinstate Sand Forestry	New Forest Dam (Mutlumuvi River)	EWR
S1	Yes	Yes, with no return flows	No	No	No
S4	Yes	Yes, with 50% return flows	Yes	No	No
S51	Yes	Yes, , with 50% return flows	Yes	Yes	Yes REC
S52	Yes	Yes, , with 50% return flows	Yes	Yes	No
S53	Yes	Yes, , with 50% return flows	Yes	Yes	Yes PES
S71	Yes	Yes, , with 25% return flows	Yes	Yes	Yes REC
S72	Yes	Yes, , with 25% return flows	Yes	Yes	No
S73	Yes	Yes, , with 25% return flows	Yes	Yes	Yes PES

Updated present day

The water demand applied within the water resources model (as used during the Ecological Reserve study – DWA, 2010a,b) were based on the validation study carried out in 2006. New information on water use is now available from various sources and the model was updated to provide a more accurate representation of present day (ICMA, in progress) water use in the Sabie River system.

Specific updates include:

- Improved estimates of irrigation areas through a validation process.
- Improved understanding of the operation of the Sabie Irrigation Board.
- Reduced irrigation in the Sand River due to the collapse of several irrigation schemes.
- Increased abstraction from the Sabie River at Hoxani.

Growth in Water Demands

The growth in domestic water demands was sourced from the All Towns Strategies and Mbombela Reconciliation Strategy (DWA, 2011; DWA, 2013c). There are plans to expand the irrigation activities upstream of the Inyaka Dam to leverage on recent successful land claims. The exact details of this expansion are not known but an increased abstraction of 10 million m^3/annum was assumed.

Reinstate forestry in the Sand River

Early in the millennium most of the forestry was removed from the Sand River in order to preserve the riverine ecology. The intention was that job lost from the forestry industry would be taken up through increased eco-tourism. However, this did not happen. The Department of Agriculture and Forestry have announced their intention to reinstate some of the forestry. Exact details of their intentions could not be obtained but based on areas previously removed the area to be reinstated was assumed to be 3 000 ha.

New Forest Dam

A dam site was identified on the Mutlumuvi River, a tributary of the Sand River (Chunnet, Fourie and Partners, 1990), approximately at EWR6. This dam is a likely source of water to meet the rapidly increasing domestic requirements which will soon exceed the yield available from the Inyaka Dam. The parameters of this dam are as follows:

- Full supply capacity: 50 million m^3.
- Full supply area: 5.0 km^2.
- Dead storage: 0.0 million m^3.

Return flows

Currently, approximately 18 million m^3/annum is transferred into the Sand River system from the Inyaka Dam. However, there is very limited waste water treatment capacity in the catchment. As a result, return flows are negligible. As a general rule of thumb, return flow of about 50% of the domestic use can be expected and this is allowed for in most water resources analyses. Initially the assumption was made that by 2030 (the future water use scenario), there will be full treatment of all domestic effluent resulting in 50% return flow. As an alternative scenario, return flow was reduced to 25% of domestic use. The reasoning behind this is that it could take a lot longer to fully develop waste water treatment capacity in the Sand River than the 15 years initially assumed.

Ecological Water requirements

Three scenarios were considered with regard to the EWR. These are:

- No EWR.
- PES.
- REC.

4 ECONOMIC CONSEQUENCES

The results of different scenarios of each catchment as it impacted on the different economic sectors are presented in this Chapter. The impact on GDP and then on labour is provided to produce a final integrated in the final result.

4.1 KOMATI RIVER SYSTEM: GDP RESULTS

In Table 4.1 the GDP results of the different scenarios of the Komati River system are presented.

Table 4.1 Komati River system: GDP created per Scenario and percentage change if compared with the Baseline (2013 prices)

Scenario	GDP (Rand Million)	Percentage change from baseline	Ranking
Baseline	R 3 592		
K42	R 3 678	2,3%	1
K43	R 3 642	1,4%	2
K32	R 3 628	1,0%	3
K 6	R 3 612	0,6%	4
K41	R 3 593	0,0%	5
K2	R 3 575	-0,5%	6
K31	R 3 562	-0,8%	7
K5	R 3 531	-1,7%	8

Table 4.1 indicates that Sc K2, K31 and K5 have a negative impact on GDP of which Sc K5 has the largest negative impact when compared to the baseline. Figure 4.1 and Figure 4.2 highlight the results.

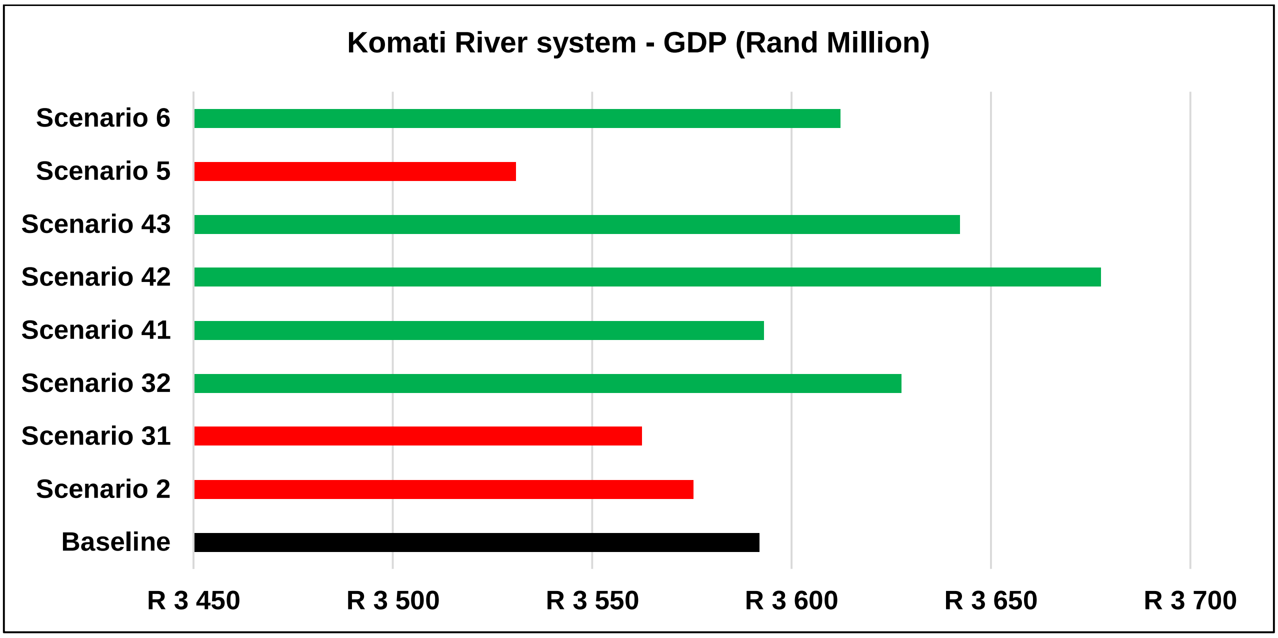


Figure 4.1 Komati River system: The GDP created by each Scenario

The comparative change of the impact of each of the scenarios when compared with the baseline is presented in Figure 4.2.

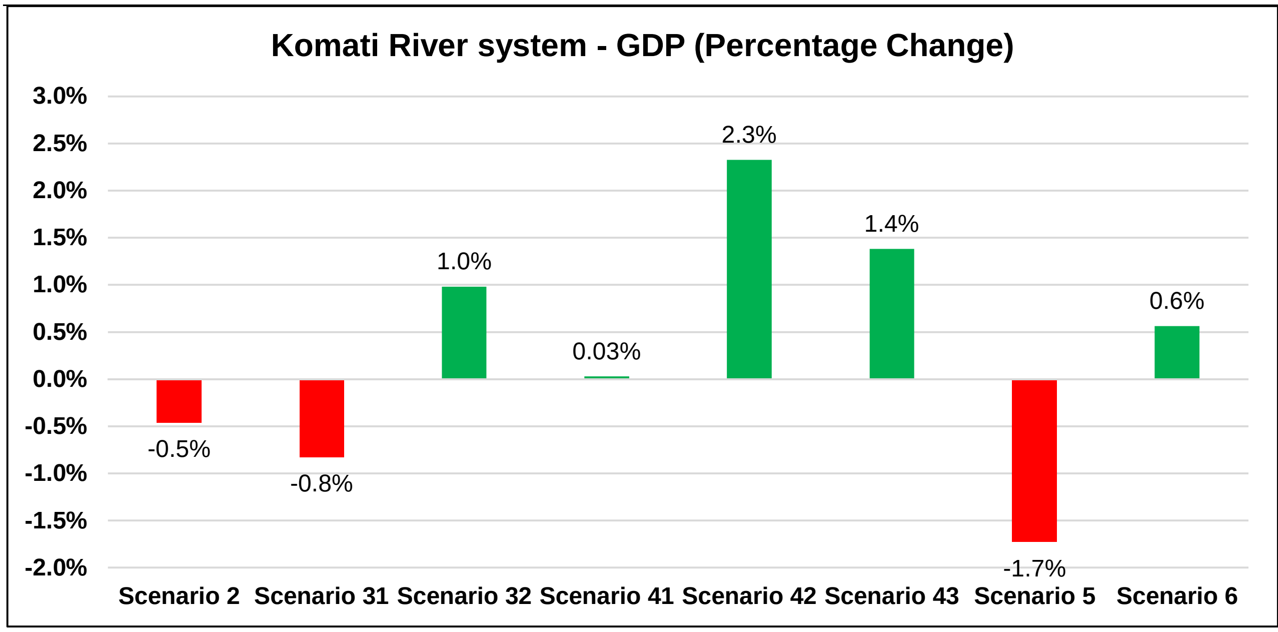


Figure 4.2 Komati River system: Comparative percentage of the impact of each scenario with the Baseline

Figure 4.1 and Figure 4.2 show that Sc K5 will have the severest negative impact followed by Sc K31 and K2. Scenario K32, K41, K42, K43 and K6 will increase the GDP of the Komati River system.

4.2 CROCODILE RIVER SYSTEM: GDP RESULTS

Table 4.2 provides the GDP results of the different scenarios of the Crocodile River system.

Table 4.2 Crocodile River system: GDP created per Scenario and percentage change if compared with the Baseline (2013 prices)

Scenario	GDP (Rand Million)	Percentage change from baseline	Ranking
Baseline	R 4 522		
C72	R 5 041	10,3%	1
C5	R 4 626	2,2%	2
C82	R 4 513	-0,2%	3
C62	R 4 384	-3,1%	4
C3	R 4 235	-6,8%	5
C81	R 4 069	-11,2%	6
C61	R 3 988	-13,4%	7
C71	R 3 729	-21,3%	8
C2	R 3 699	-22,3%	9
C4	R 3 656	-23,7%	10

Table 4.2 indicates that all the scenarios except Sc C7.2 and C5 have a negative impact on GDP with Sc C4 having the largest negative impact when compared to the baseline. Figure 4.3 and Figure 4.4 highlight the results.

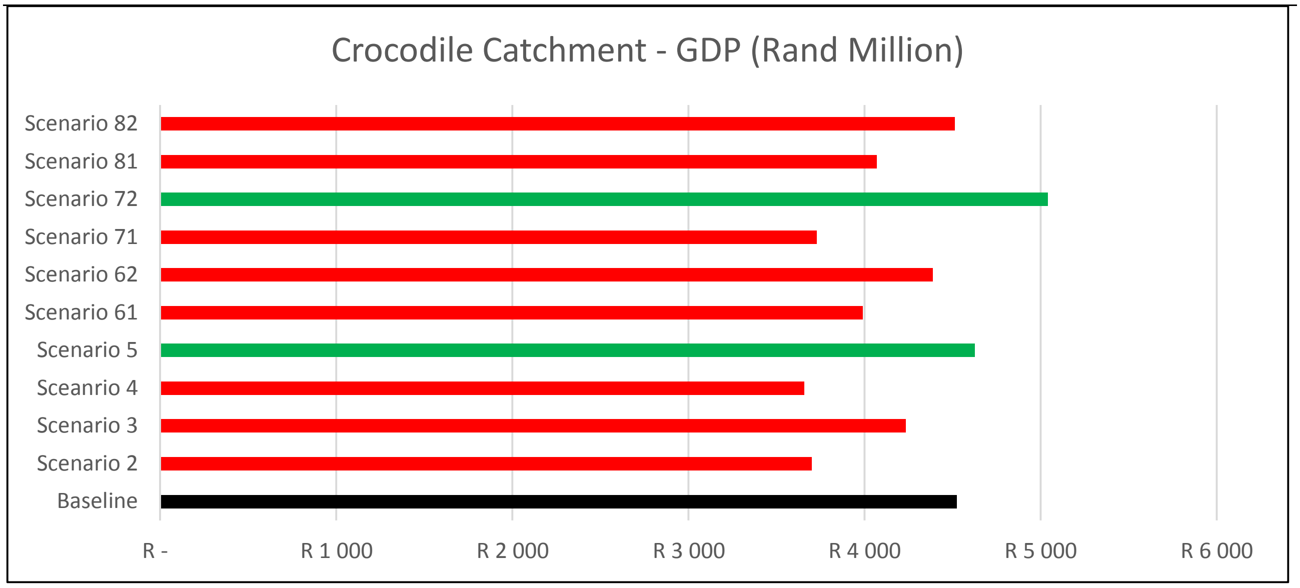


Figure 4.3 Crocodile River system: The GDP created by each Scenario

The comparative change of the impact of each of the scenarios when compared with the baseline is presented in Figure 4.4.

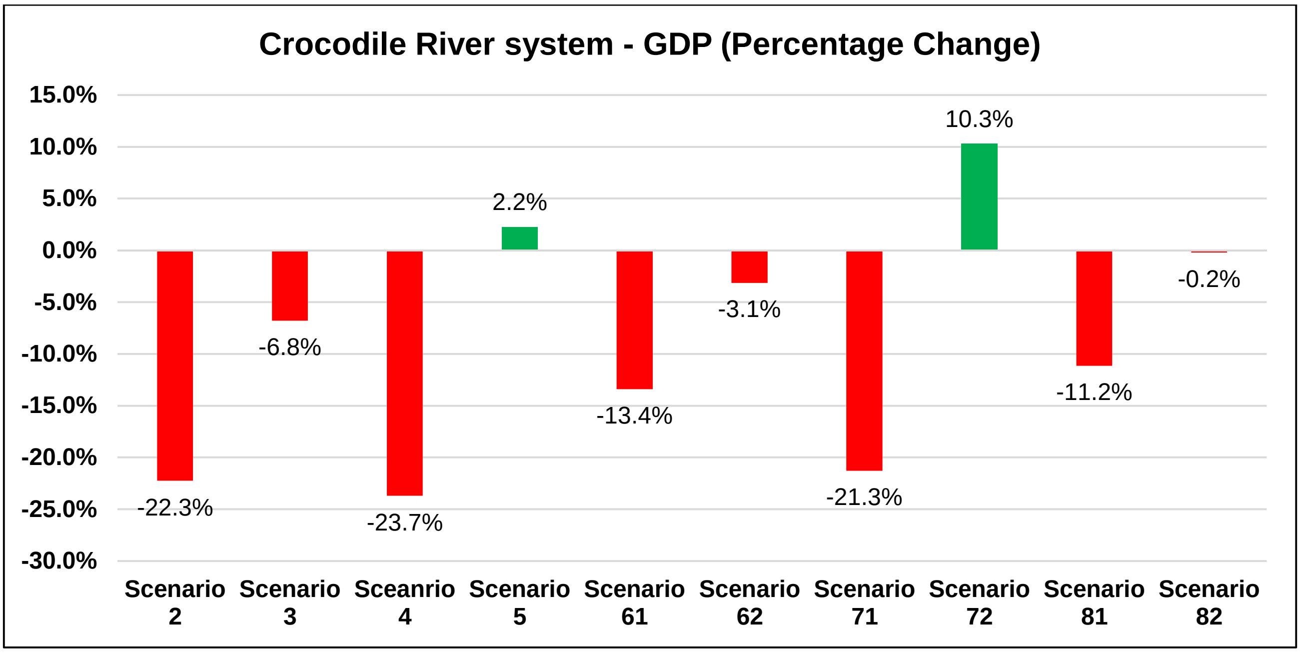


Figure 4.4 Crocodile River system: Comparative percentage of the impact of each scenario with the baseline

Figure 4.3 and Figure 4.4 show that Sc C4 will have the severest negative impact followed by Sc C2, C71 and C61. Scenario C5 and C71 will increase the GDP of the Crocodile River system.

4.3 SABIE RIVER SYSTEM: GDP RESULTS

In Table 4.3 the GDP results of the different scenarios of the Sabie River system are presented.

Table 4.3 Sabie River system: GDP created per Scenario and percentage change if compared with the baseline (2013 prices)

Scenario	GDP (Rand Million)	Percentage change from baseline	Ranking
Baseline	R 1 314		
S32	R 12976	1,9%	1
S6	R 12650	-0,9%	2
S2	R 12600	-1,29%	3
S31	R 12250	-4,2%	4

Table 4.3 indicates that Sc S2, S31 and S6 have a negative impact on GDP with Sc S31 having the largest negative impact when compared to the baseline. Figure 4.5 and Figure 4.6 highlight the results.

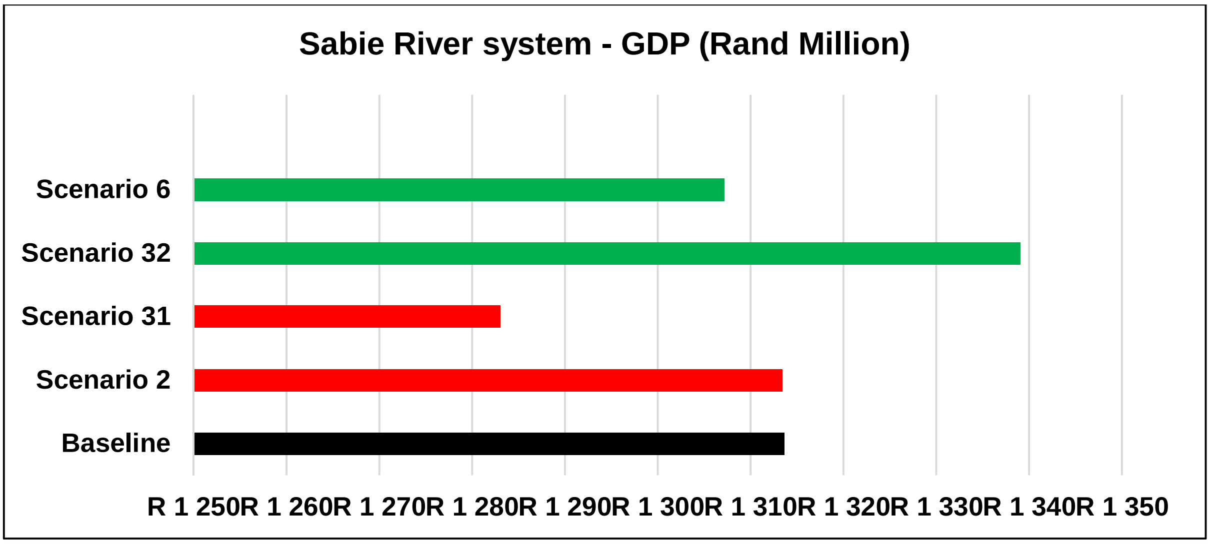


Figure 4.5 Sabie River system: The GDP created by each Scenario

The comparative change of the impact of each of the scenarios when compared with the baseline is presented in Figure 4.6.

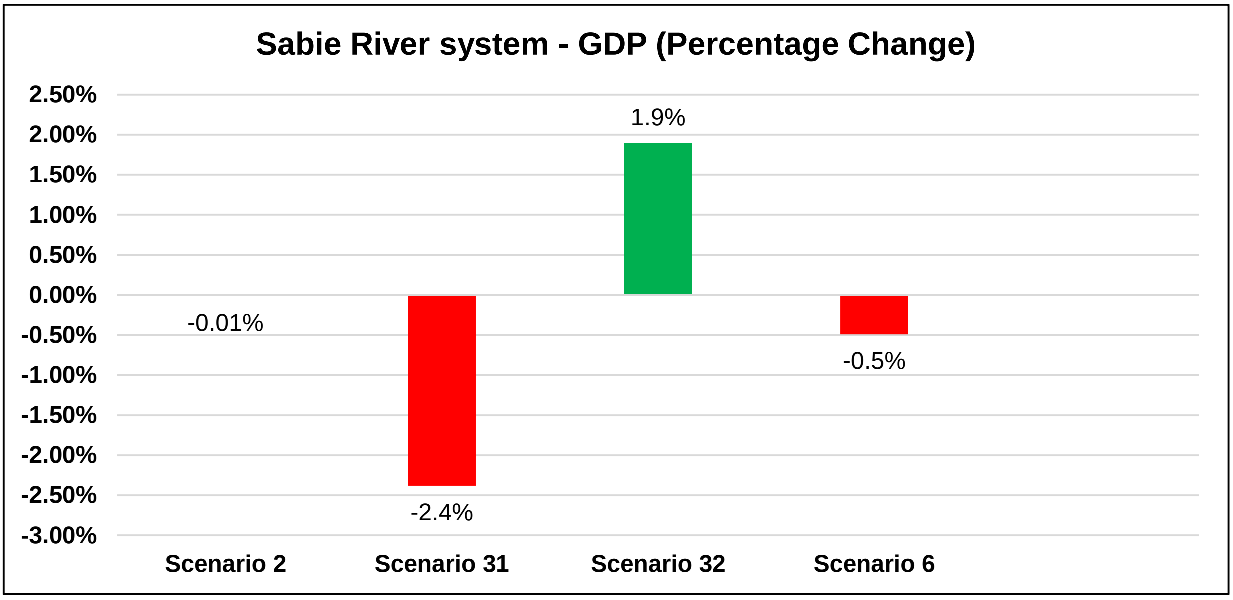


Figure 4.6 Sabie River system: Comparative percentage of the impact of each scenario with the Baseline

Figure 4.5 and Figure 4.6 show that Sc Sc31 will have the severest negative impact followed by Sc S6. Scenario S32 will increase the GDP of the Sabie River system.

4.4 SAND RIVER SYSTEM: GDP RESULTS

Table 4.4presents the GDP results of the different scenarios of the Sand River system.

Table 4.4 Sand River system: GDP created per Scenario and percentage change if compared with the Baseline (2013 prices)

Scenario	GDP (Rand Million)	Percentage change from baseline	Ranking
Baseline	R 194		
S52	R 244	20,4%	1
S53	R 238	18,6%	2
S51	R 238	18,5%	3
S72	R 235	17,3%	4
S71	R 223	13,0%	5
S73	R 220	11,9%	6
S80	R 208	6,8%	7

Table 4.4 indicates that all scenarios will have a positive impact on GDP with Sc S52 having the largest positive impact when compared to the baseline. Figure 4.7 and Figure 4.8 highlight the results.

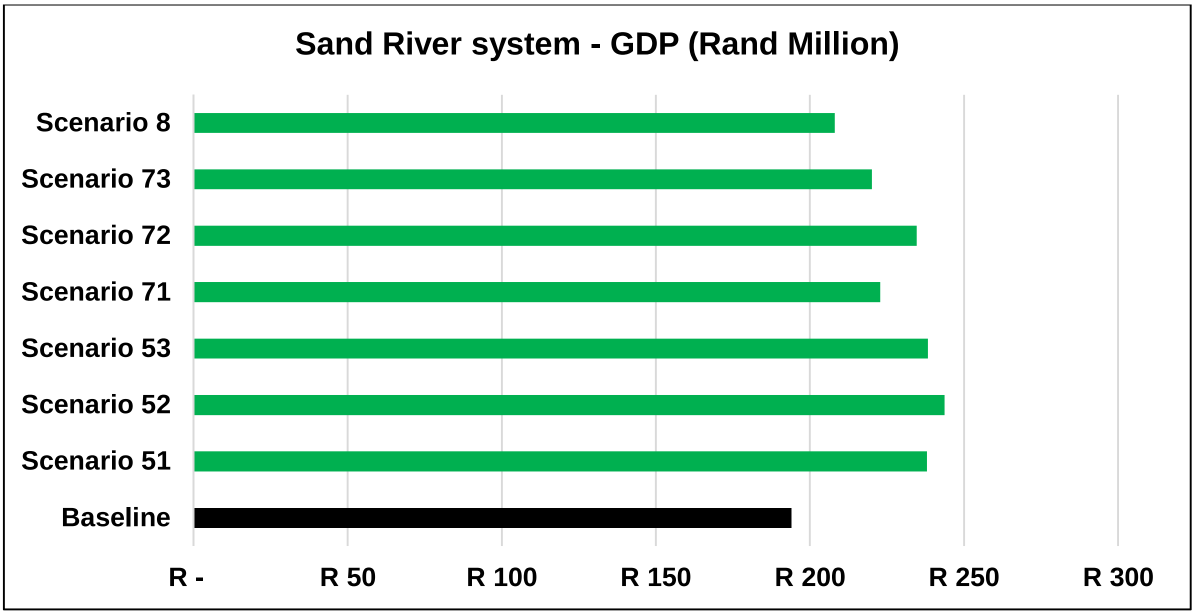


Figure 4.7 Sand River system: The GDP created by each Scenario

The comparative change of the impact of each of the scenarios when compared with the baseline is presented in Figure 4.8.

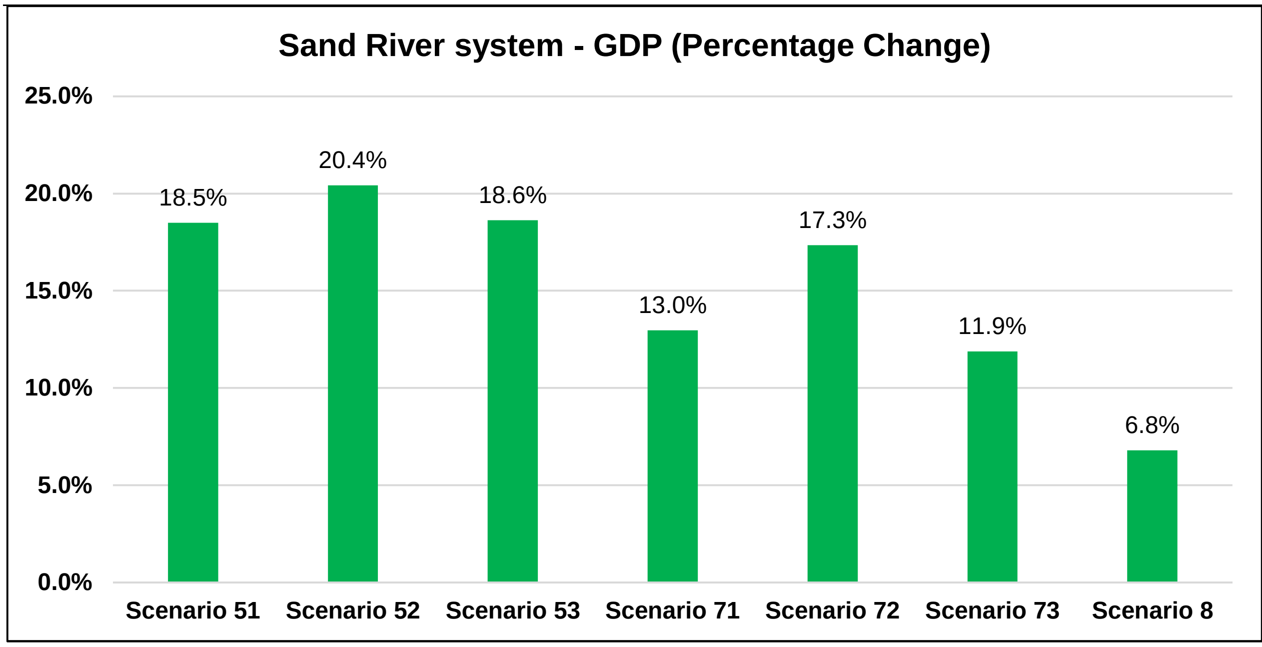


Figure 4.8 Comparative percentage of the impact of each scenario with the Baseline

Figure 4.7 and Figure 4.8 show that Sc S52 will have the largest economic impact in the Sand River system followed by Sc S53.

4.5 EMPLOYMENT

4.5.1 Komati River system: Employment Results

In Table 4.5 the impact on employment for the different scenarios in the Komati River system are compared with the baseline.

Table 4.5 Komati River system: Employment and projected job gains or losses per Scenario

Scenario	Employment	Job Creation/Losses	Deviation from Baseline	Ranking
Baseline	19 318			
K6	20690	1372	6,6%	1
K42	19642	324	1,6%	2
K43	19531	213	1,1%	3
K32	19402	84	0,4%	4
K5	19269	-49	-0,3%	5
K2	19155	-164	-0,9%	6
K41	18 945	-373	-2,0%	7
K31	18 860	-458	-2,4%	8

Table 4.5 shows that Sc K43, K6, K42, and K32 will be beneficial for employment creation while K41 and K31 will potentially have the largest negative impact.

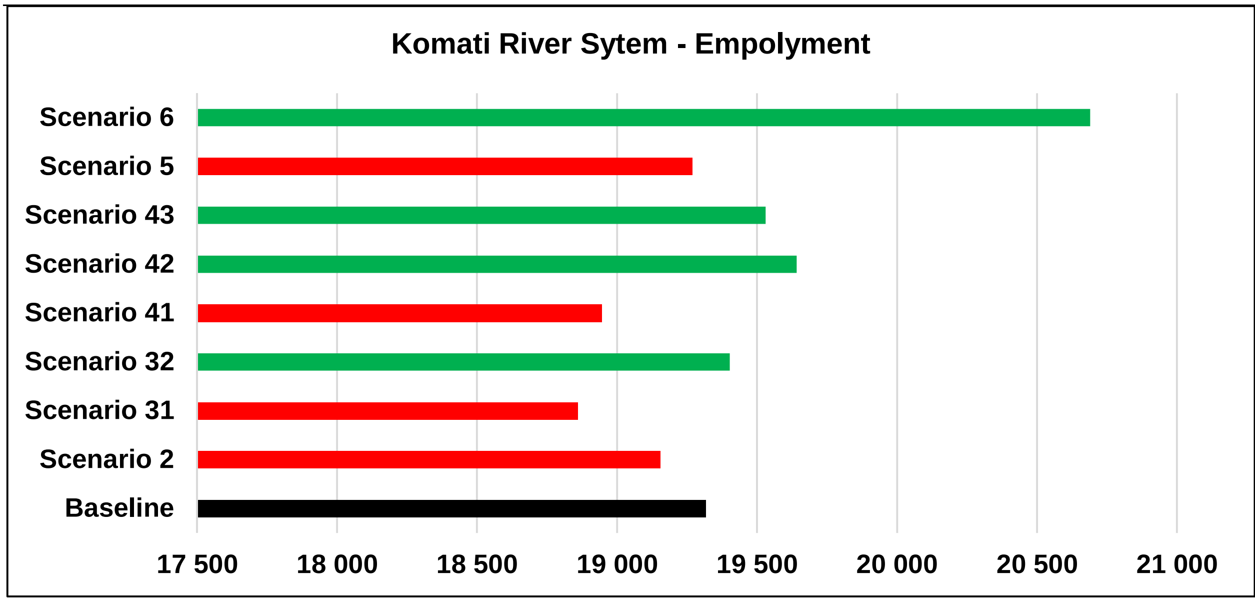


Figure 4.9 Komati River system: Employment deviation from Baseline as percentage

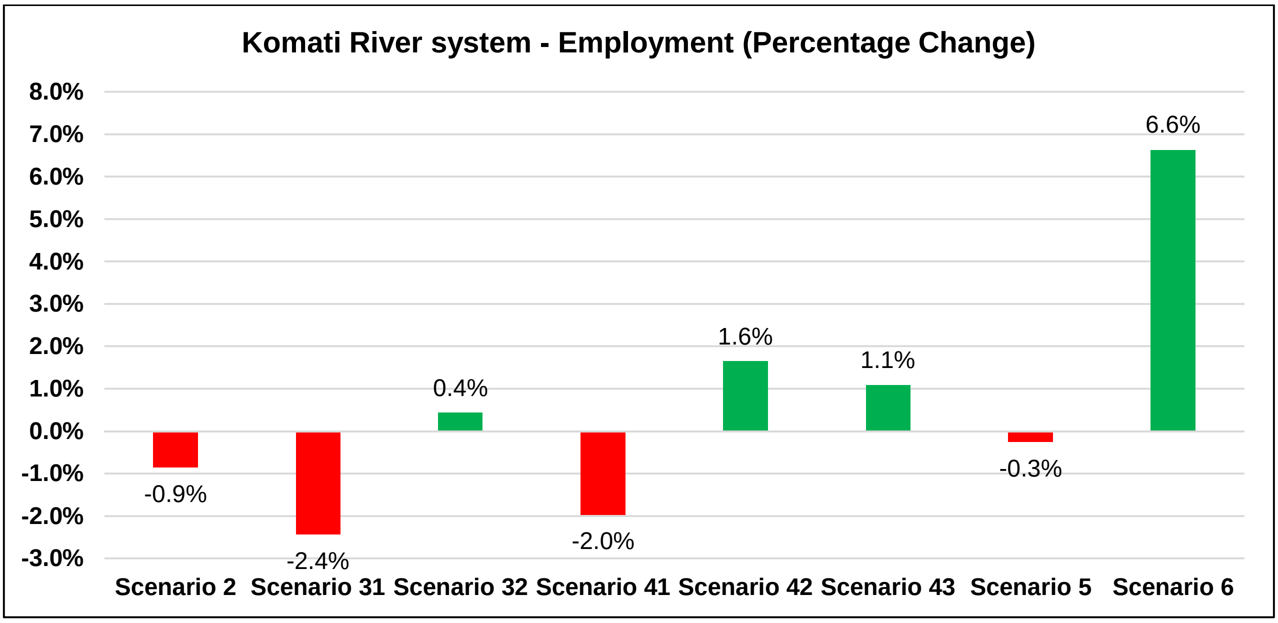


Figure 4.10 Komati River system: Employment deviation from Baseline as percentage

Figure 4.10 illustrates the deviation from the baseline in terms of percentage and very clearly shows that Sc K2, K31 and K41 can have a negative impact on employment in the Komati River system.

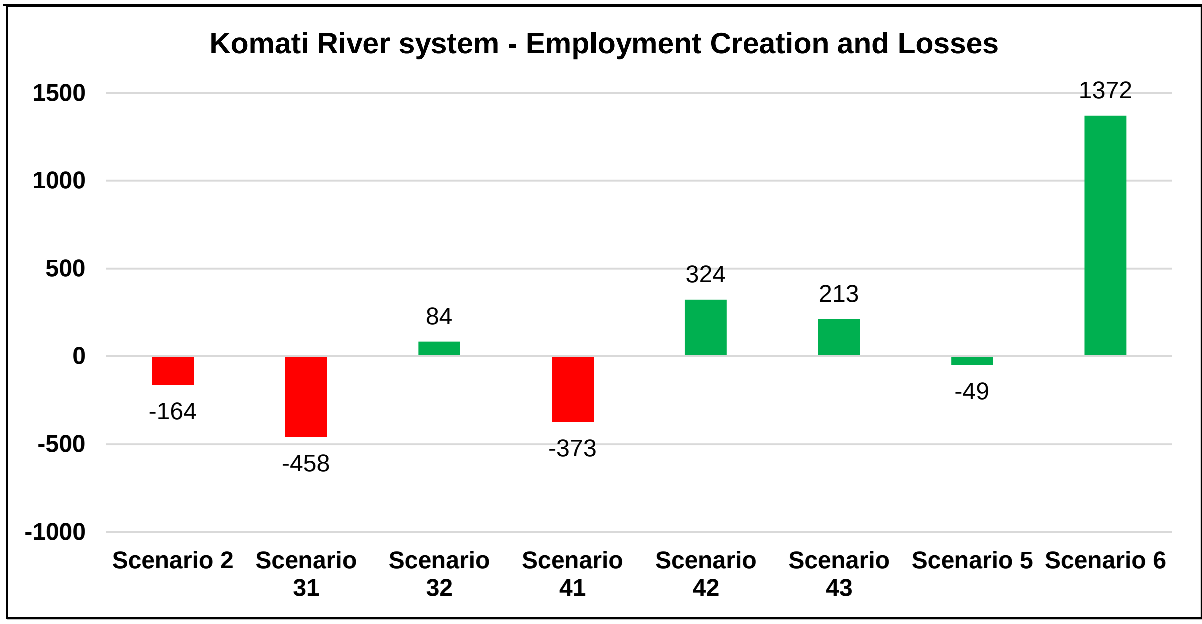


Figure 4.11 Komati River system: Employment creation and job losses numbers

Figure 4.11 illustrates the number of job losses and job created by each of the scenarios in the Komati River system. Scenario K6 will create the most jobs while Sc K31 will result in the most job losses.

4.5.2 Crocodile River system: Employment Results

Table 4.6 presents the impact on employment for the different scenarios in the Crocodile River system compared with the baseline.

Table 4.6 Crocodile River system: Employment and projected job gains or losses per Scenario

Scenario	Employment	Job Creation/Losses	Deviation from Baseline	Ranking
Baseline	35 197			
C72	38167	2970	7,8%	1
C82	36475	1278	3,5%	2
C5	36377	1180	3,2%	3
C62	34653	-544	-1,6%	4
C3	33167	-2031	-6,1%	5
C81	33294	-1903	-5,7%	6
C61	31888	-3309	-10,4%	7
C71	30772	-4425	-14,4%	8
C2	29473	-5724	-19,4%	9
C4	29206	-5991	-20,5%	10

Table 4.6 shows that Sc C72, C82 and C5 will be beneficial for employment creation while Sc C2 and C4 potentially having the largest negative impact.

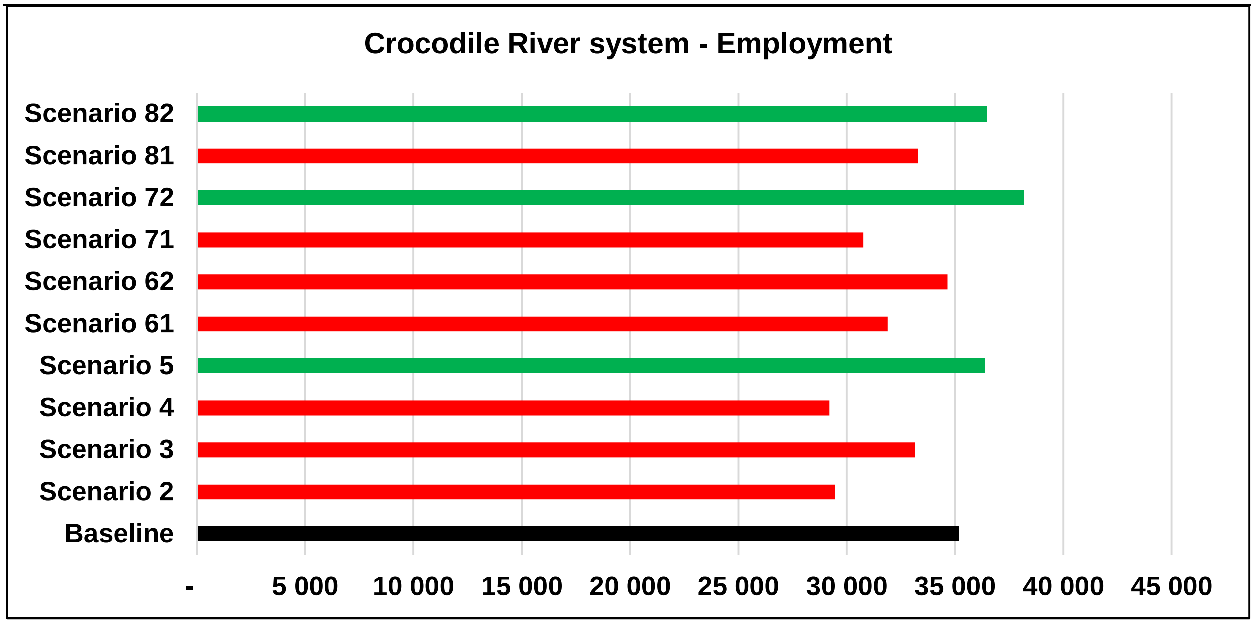


Figure 4.12 Crocodile River system: Employment deviation from Baseline as percentage

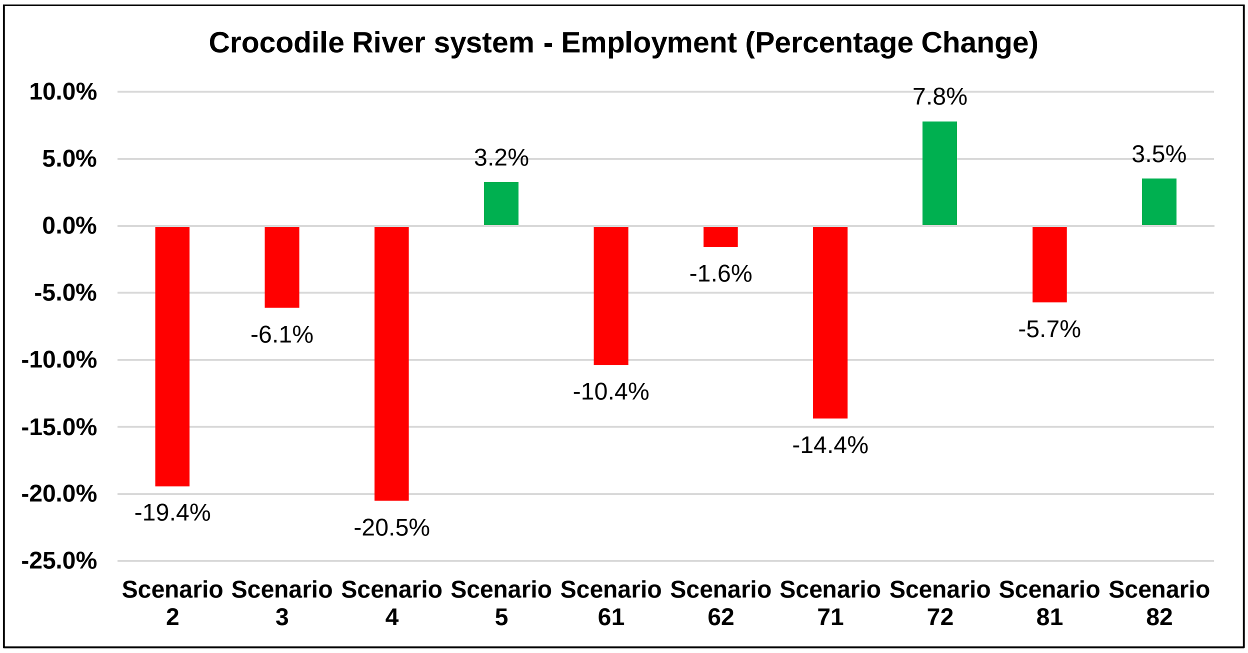


Figure 4.13 Crocodile River system: Employment deviation from Baseline as percentage

Figure 14.13 illustrates the deviation from the baseline in terms of percentage and very clearly shows that Sc C2, C3, C4, C61, C71 and C81 can have a very negative impact on employment in the Crocodile River system.

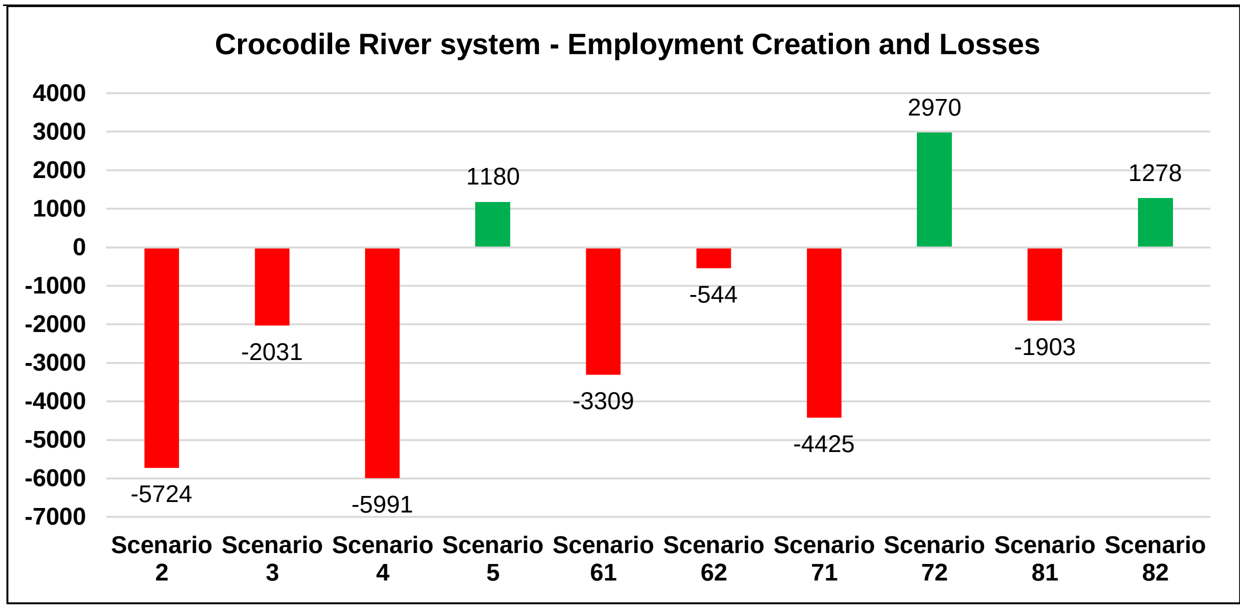


Figure 4.14 Crocodile River system: Employment creation and job losses numbers

Figure 4.14 illustrates the number of job losses and job created by each of the scenarios in the Crocodile River system. Scenario C72 will create the most jobs while Sc C4 will result in the most job losses.

4.5.3 Sabie River system: Employment Results

In Table 4.7 the impact on employment for the different scenarios in the Sabie River system are compared with the baseline.

Table 4.7 Sabie River system: Employment created and projected job gains or losses per Scenario

Scenario	Employment	Job Creation/Losses	Deviation from Baseline	Ranking
Baseline	12762			
S32	12976	215	1,7%	1
S6	12650	-112	-0,9%	2
S2	12600	-162	-1,29%	3
S31	12250	-511	-4,2%	4

Table 4.7 shows that Sc S32 will be beneficial for employment creation while Sc S2 and S31 potentially having the largest negative impact.

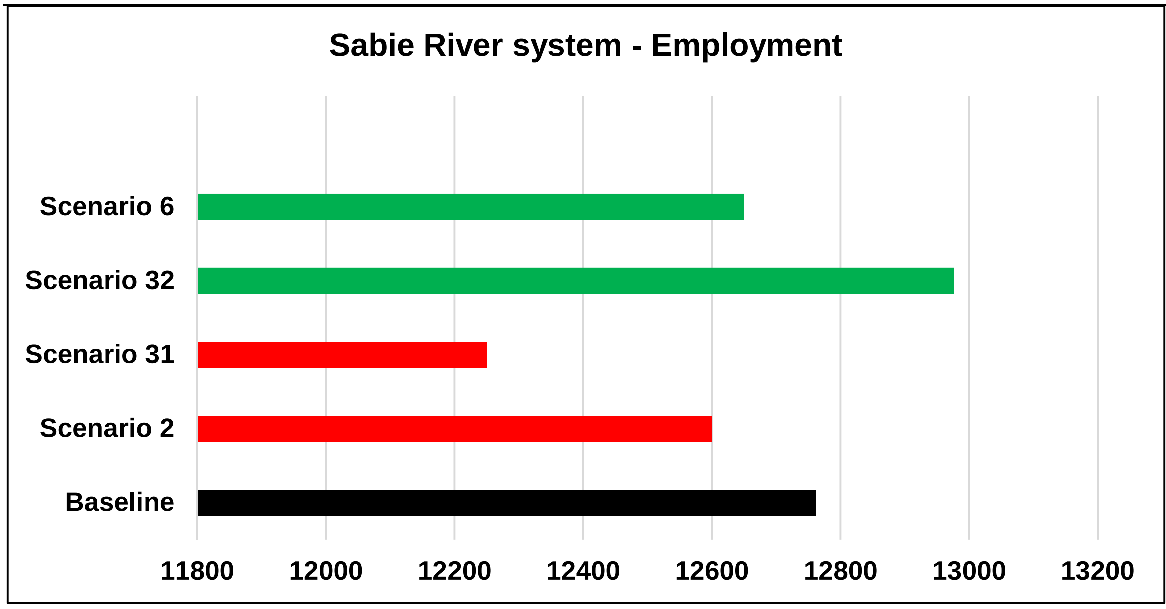


Figure 4.15 Sabie River system: Employment deviation from Baseline as percentage

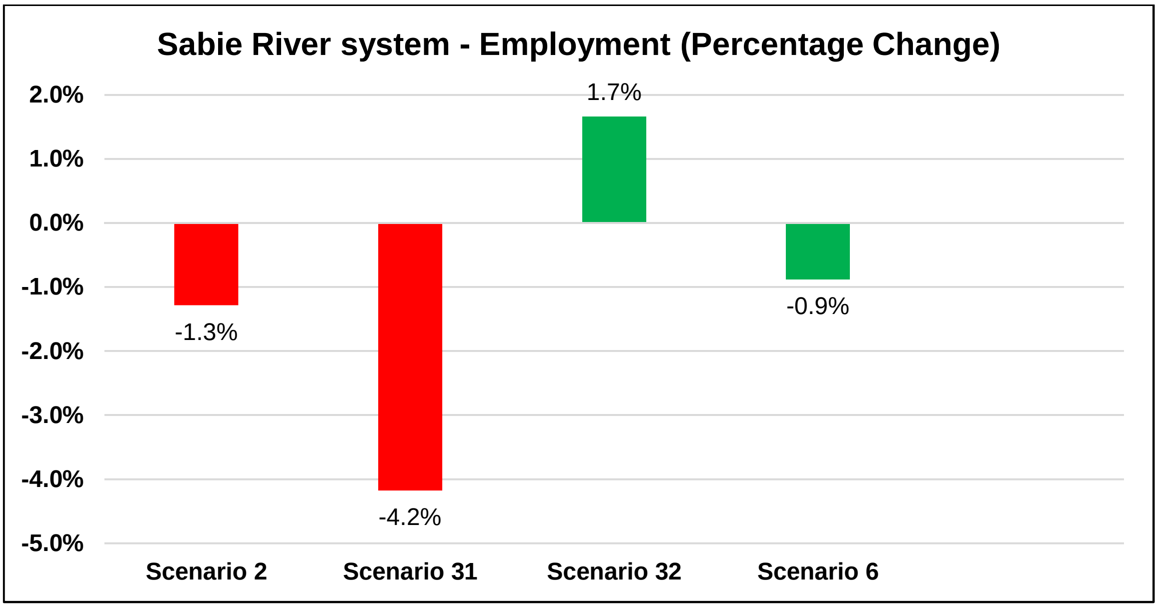


Figure 4.16 Sabie River system: Employment deviation from Baseline as percentage

Figure 4.16 illustrates the deviation from the baseline in terms of percentage and very clearly shows that Sc S2, S31 and S6 can have a negative impact on employment in the Sabie River system.

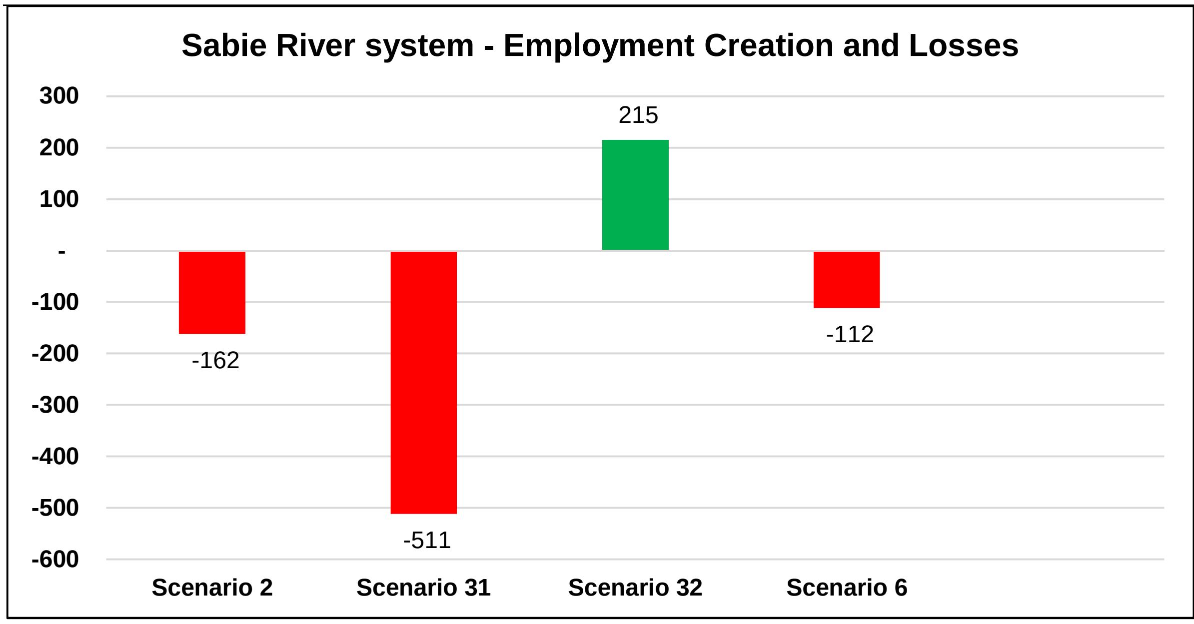


Figure 4.17 Sabie River system: Employment creation and job losses

Figure 4.17 illustrates the number of job losses and job created by each of the scenarios in the Sabie catchment. Scenario S32 will create the most jobs while Sc S31 will result in the most job losses.

4.5.4 Sand River system: Employment Results

In Table 4.8 the impact on employment for the different scenarios in the Sand Catchment are compared with the baseline.

Table 4.8 Sand River system: Employment and projected job gains per Scenario

Scenario	Employment	Job Creation	Deviation from Baseline	Ranking
Baseline	1 789			
Scenario 52	2598	809	31,1%	1
Scenario 53	2548	759	29,8%	2
Scenario 51	2545	756	29,7%	3
Scenario 72	2514	725	28,9%	4
Scenario 71	2405	617	25,6%	5
Scenario 73	2380	591	24,8%	6
Scenario 80	1919	130	6,8%	7

Table 4.8 shows that all the scenarios will be beneficial for employment creation in the Sand River system.

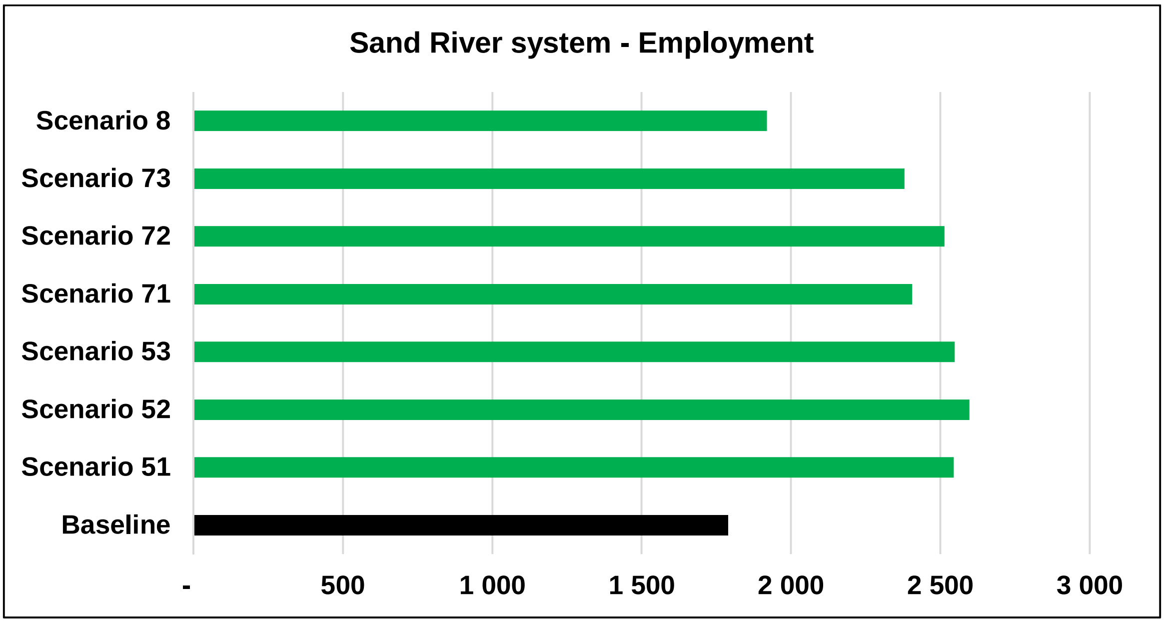


Figure 4.18 Sand River system: Employment deviation from Baseline as percentage

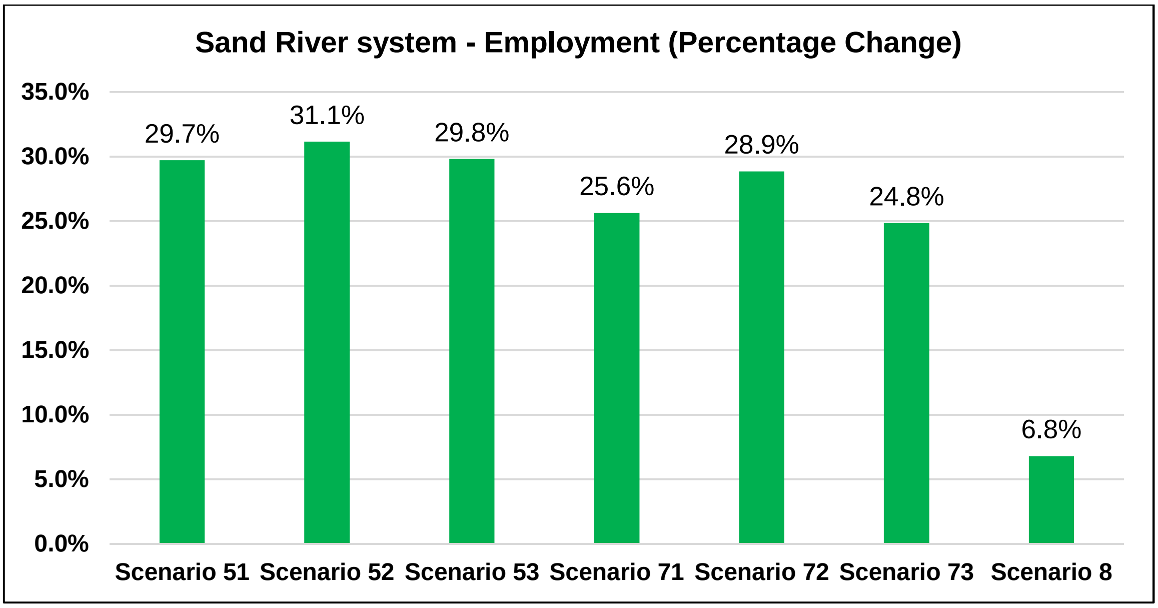


Figure 4.19 Sand River system: Employment deviation from Baseline as percentage

Figure 4.19 illustrates the deviation from the baseline in terms of percentage and very clearly shows that all the scenarios will have a positive impact on employment in the Sand River system.

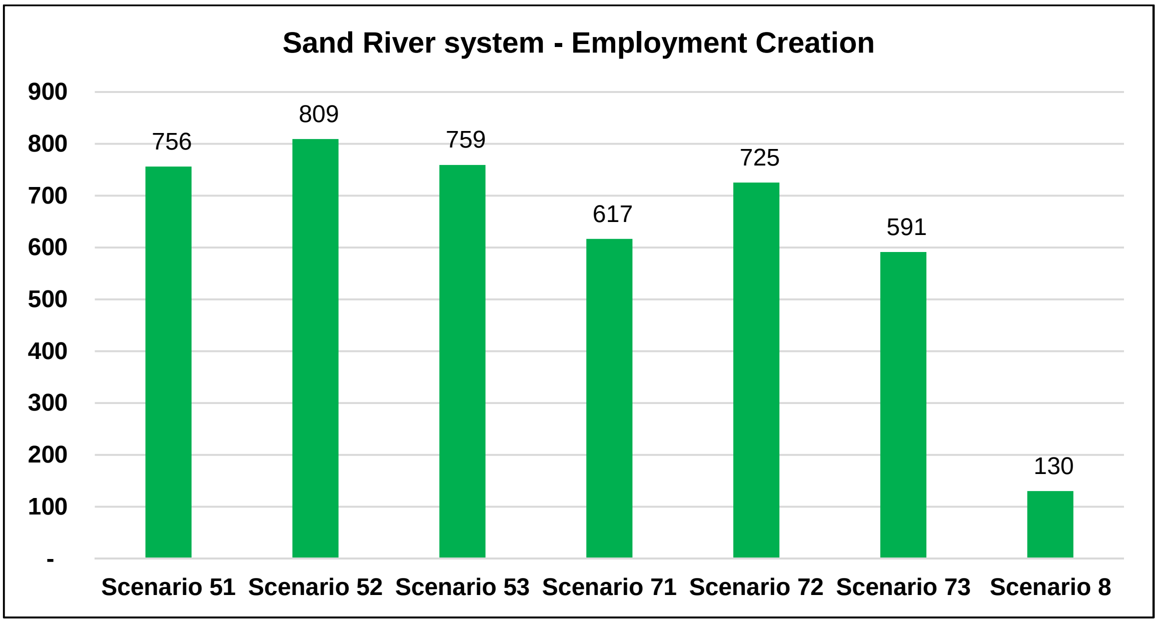


Figure 4.20 Sand River system: Employment creation numbers

Figure 4.20 illustrates the number of jobs created by each of the scenarios in the Sand River system, Sc S52 will create the most jobs.

5 ECOLOGICAL CONSEQUENCES

This Chapter focuses on the results of the evaluation of the various scenarios. The integration into a single ecological ranking for the Komati, Crocodile, Sabie, and Sand River systems are provided in Section 5.1 – 5.4 respectively. Detailed consequences are provided in the supporting document, Report 4.2 (DWS, 2014a).

5.1 KOMATI RIVER SYSTEM: ECOLOGICAL CONSEQUENCES OF SCENARIOS AT THE EWR SITES

The scenarios are described in Table 3.1. The scenarios applicable to the Komati System only impact on EWR K3 (Komati River at Tonga Rapids) and EWR L1 (Lomati River downstream of Driekoppies Dam).

Recent changes in the lower Komati operating rule from Maguga Dam have resulted in improvement in the system since the 2004 EWR study. The results illustrate that all the scenarios meet the ecological objectives at EWR K3.

The Lomati River at EWR L1 is largely impacted on by the unseasonal releases for irrigation from Driekoppies Dam. The scenario results illustrate that Sc K2, K31 and K41 are similar to the present day flows (i.e. maintain the PES) whereas the other scenarios are in a worse state due to the impacts on riparian vegetation which in turn impacts on the instream components. This results in a change from a C to a C/D EcoStatus.

5.2 CROCODILE RIVER SYSTEM ECOLOGICAL CONSEQUENCES OF SCENARIOS

5.2.1 Crocodile River system: Ecological consequences of scenarios at the EWR sites

The scenarios are described in Table 3.2. The ecological consequences are summarised in Table 5.1. The first column provides the ECs for each component at the EWR site. The second column provides the ranking of the scenarios. The third column includes a short explanation of the consequences and ranking.

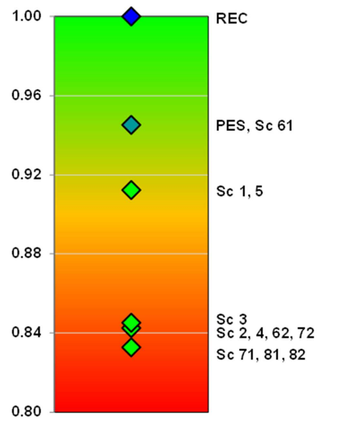
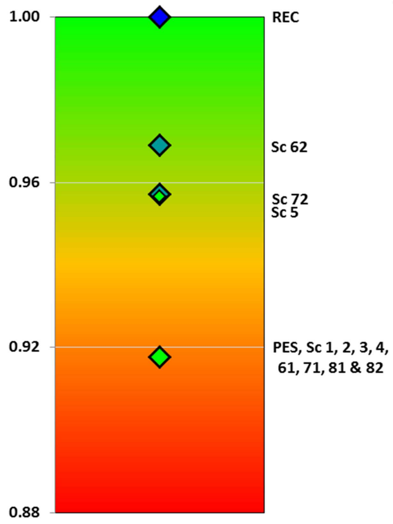
The scenarios only impact on EWR 3, 4, 5 and 6 in the Crocodile River and EWR 7 in the Kaap River.

EWR 3: The results illustrate that none of the scenarios meet the ecological objectives of the REC. Only Sc C61 maintains the EcoStatus PES although there is deterioration in geomorphology. The major issue is that EWR 3 is downstream of Kwena Dam and that current and scenario releases are unseasonal resulting in too high flows in winter and too little flows in summer.

EWR 4: The results illustrate that all the scenarios meet the ecological objectives of the PES and of these scenarios Sc C62 and C72 result in an improvement in the PES, although the REC requirements are not met. This site is upstream of the major off-takes into canals for irrigation further downstream and the problems (current and with scenarios) are the constraints on the operation for irrigation resulting in an unseasonal distribution of flows.

EWR 5: The results illustrate that all the scenarios meet the ecological objectives of the PES and of these scenarios Sc C2, C4. C61, C71, C81 and C82 result in an improvement in the PES, although the REC requirements are not met.

Table 5.1 Crocodile River system: Summary of ecological consequences at the EWR sites

Ecological consequences as ECs	Ecological consequences	Ranked scenarios	Ranking rationale
EWR C3 (CROCODILE RIVER)			
(see EC table for EWR C3 below)	Reduced flood peaks and reduced summer season baseflows all result in smaller, less frequent floods. This reduces scour of the bed, pools and lower banks and also promotes vegetation encroachment and channel width reduction (narrowing). These impacts and the increased high flows early in the dry season, may result in flushing juvenile fish downstream.		The results illustrate that none of the scenarios meet the ecological objectives of the REC. Only Sc C61 maintains the EcoStatus PES although there is deterioration in geomorphology. The major issue is that EWR C3 is downstream of Kwena Dam and that current and scenario releases are unseasonal resulting in too high flows in winter and too little flows in summer.
EWR C4 (CROCODILE RIVER)			
(see EC table for EWR C4 below)	As there are no large dams which can inhibit the provision of flood flows this far down the catchment (the impact of altered spills from the upstream Kwena Dam will not have a measureable impact on geomorphology at this site due to amelioration from numerous tributary inputs), moderate and large floods necessary for channel maintenance will still occur. Instream biota remains in the PES or improves due to improved low flow conditions.		The results illustrate that all the scenarios meet the ecological objectives of the PES and of these scenarios, Sc C62 and C72 result in an improvement in the PES, although the REC requirements are not met. This site is upstream of the major off-takes into canals for irrigation further downstream and the problems (current and with scenarios) are the constraints on the operation for irrigation resulting in an unseasonal distribution of flows.

EWR C3 – Ecological consequences as ECs

Component	PES	REC	Sc 1	Sc 2, 3, 4, 62, 72	Sc 5	Sc 61	Sc 71, 81, 82
Physico chemical	C	B/C	B	B	B	B	B
Geomorphology	C	C	C/D	C/D	C/D	C/D	C/D
Fish	B	B	B	C	B	B	C/D
Invertebrates	C	B	C	C	C	C	C
Riparian vegetation	C	B	C	C	C	C	C
EcoStatus	B/C	B	C	C	C	B/C	C

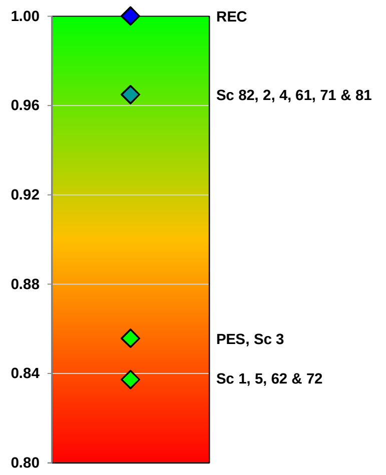
EWR C4 – Ecological consequences as ECs

Component	PES	REC	Sc 1,2.3,4, 61, 71, 81, 82	Sc 5	Sc 62, 72
Physico chemical	C	B	C	B	B
Geomorphology	B/C	B	B/C	B/C	B/C
Fish	B	B	B	A/B	A
Invertebrates	C	B	C	B	A/B
Riparian vegetation	C	B	C	C	C
EcoStatus	C	B	C	C	B/C

EWR C5 (CROCODILE RIVER)

Component	PES	REC	Sc 3	Sc 1, 5 62, 72	Sc 2, 4, 61, 71, 81, 82
Physico chemical	C	B	C	C	B/C
Geomorphology	C/D	C	C/D	C/D	C/D
Fish	C	B	C	C	B/C
Invertebrates	C	B	C	C	B
Riparian vegetation	C	B	C	C	B/C
EcoStatus	C	B	C	C	B/C

As there are no large dams which can supply floods this far down the catchment, the scenario will not have a measureable impact on geomorphology at this site due to amelioration from numerous tributary inputs. Instream biota remains in the PES or improves due to improved wet season volumes for downstream irrigation.

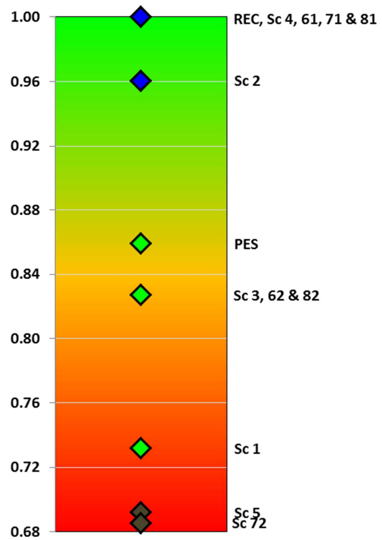


Most of the scenarios meet the ecological objectives of the PES and of these scenarios, Sc C2, C4. C61, C71, C81 and 82 result in an improvement in the PES, although the REC requirements are not met. Scenario C1, C5, C62 and C72 result in the PES EcoStatus although low flows is lower than the PES requirement.

EWR C6 (CROCODILE RIVER)

Component	PES	REC	Sc 1	Sc 2	Sc 3, 62, 82	Sc 4	Sc 5	Sc 61, 71	Sc 72	Sc 81
Physico chemical	C	B	C	B	C	B	C/D	B	C/D	B
Geom	C	C	C	C	C	C	C/D	C	D	C
Fish	C	B	D	C	C/D	B	D	B	D	B
Invert	C	B	D	B/C	C	B	D	B	B	B
Riparian vegetation	C	B	B/C	B	B	B	C	B	C	B
EcoStatus	C	B	C	B	C	B	C/D	B	C/D	B

Scenario C5 and C72 impacts on the water quality and geomorphology due to reduced wet season flows below the PES. Fish will respond with possible impacts on fish functions such as spawning, breeding, nursery and migration. Although the situation is improved under Sc C62 and C82, the PES is still not achieved for all components although the EcoStatus is a C.

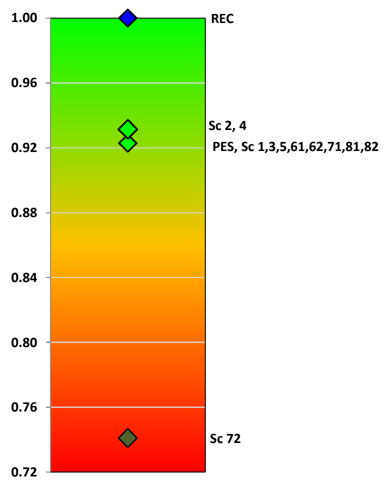


This site is the key site in the system, both from an operational and ecological importance viewpoint. The results illustrate that Sc S5 and Sc S72 do not meet the ecological objectives of the PES or the REC and are the worst case scenarios. Scenario S4, S61, S71 and Sc S81 meet the REC requirements. Scenario 2 also meets the REC requirements although the ecological objectives for invertebrates are not fully met. Scenario C1, S3, S62 and S82 meet the PES requirements however the instream biota are impacted to a greater extent under these scenarios and ecological objectives are not fully met for fish and invertebrates.

EWR K7 (KAAP RIVER)

Component	PES	REC	Sc72,	Sc 2, 4	Sc 1,3,5, 61,62,71, 81,82
Physico chemical	B	B	C	B	B
Geomorphology	B	B	B	B	B
Fish	C	B	D	B	C
Invertebrates	B	B	C/D	B/C	B
Riparian vegetation	C/D	B/C	C/D	C/D	C/D
EcoStatus	C	B	C/D	C	C

The evaluation against EWR was made based on the assumption that the EWR should not be higher than PD flows during the dry season. All scenarios meet the PES or marginally improve the PES (Sc S2 and S4) except for Sc S72 results in a drop in most categories and results in a C/D EcoStatus. The reason for the lower category is due to lower flows than the EWR and the PD during the dry months which impacts on the water quality and instream biota.



ScenarioS72 does not meet the ecological objectives of the PES or the REC. The rest of the scenarios meet the PES EcoStatus requirements although and all component requirements. Of these scenarios, Sc S2 and S4 are the best scenarios as the fish improves a category..

EWR C6: This site is the key site in the system, both from an operational and ecological importance viewpoint. The results illustrate that Sc C5 and Sc C72 do not meet the ecological objectives of the PES or the REC and are the worst case scenarios. ScenarioC4, C61, C71 and Sc C81 meet the REC requirements. ScenarioC2 also meets the REC requirements although the ecological objectives for macro-invertebrates are not fully met. Scenario C1, C3, C62 and Sc C82 meet the PES requirements however the instream biota are impacted to a greater extent under these scenarios and ecological objectives are not fully met for fish and macro-invertebrates. Scenario C1 is the worst scenario in this group for the fish, macro-invertebrate and riparian vegetation components. This will mean that if Sc C1 is implemented, there is a high risk that the EcoStatus will drop to a lower category.

EWR 7: The results illustrate that Sc C72 does not meet the ecological objectives of the PES or the REC. The rest of the scenarios meet the PES EcoStatus requirements although there is deterioration in macro-invertebrates. Of these scenarios, Sc C2 and C4 are the best scenarios as there is a small improvement in the PES.

The individual site rankings are illustrated in Figure 5.1.

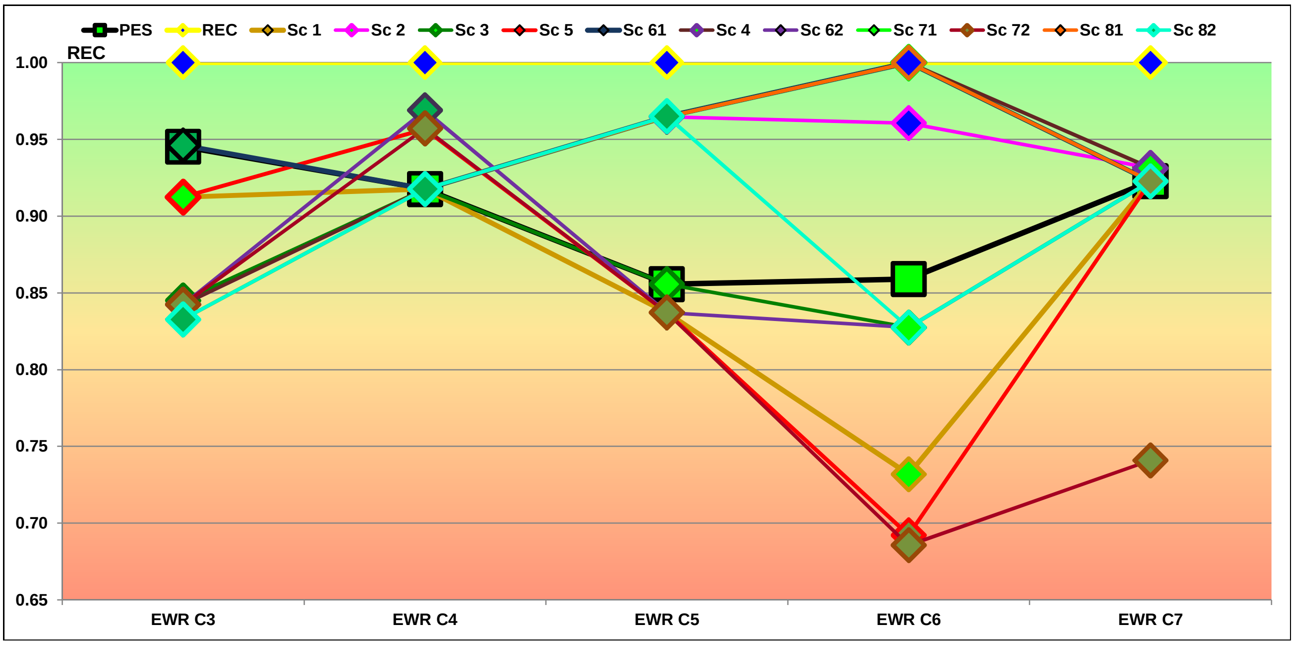


Figure 5.1 Crocodile River system: Ranking of scenarios

5.2.2 Crocodile River system: Integrated ecological consequences

The process to determine an integrated ranking of the different scenarios is described below. The first step was to determine the relative importance of the different EWR sites. The site weight (Table 5.2) indicates that EWR C6 carries the highest weight due to its high ecological importance and as it represents the KNP. Furthermore it is situated at the most downstream reach of the Crocodile River system and therefore plays an important role in the operation of the system.

The weights are provided in the Table 5.2. The weight is based on the conversion of the PES and EIS to numerical values to determine the normalised weight.

Table 5.2 Crocodile River system: Weights allocated to EWR sites relative to each other

EWR site	PES	EIS	Locality in protected areas (0 - 5)	Confidence	Normalised Weight
EWR C1	A/B	Moderate	1	3.75	0.14
EWR C2	B	High	1	3.5	0.14
EWR C3	B/C	High	1	2.5	0.12
EWR C4	C	High	2	2.5	0.13
EWR C5	C	Very High	5	3.4	0.18
EWR C6	C	Very High	5	4	0.20
EWR C7	C	High	1	1	0.10

The weight is applied to the ranking value for each scenario at each EWR site and this provides an integrated score and ranking for the operational scenarios of the Crocodile River system. The ranking of '1' refers to the REC and the rest of the ranking illustrate the degree to which the scenarios meet the REC. The results are provided in Table 5.3 after the weights have been taken into account.

Table 5.3 Crocodile River system: Ranking value for each scenario resulting in an integrated score and ranking

EWR site	PES	REC	Sc C1	Sc C2	Sc C3	Sc C4	Sc C5	Sc C61	Sc C62	Sc C71	Sc C72	Sc C81	Sc C82
EWR C1	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
EWR C2	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
EWR C3	0.11	0.12	0.11	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10
EWR C4	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
EWR C5	0.16	0.18	0.15	0.18	0.16	0.18	0.15	0.18	0.15	0.18	0.15	0.18	0.18
EWR C6	0.17	0.20	0.15	0.19	0.17	0.20	0.14	0.20	0.17	0.20	0.14	0.20	0.17
EWR C7	0.09	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.07	0.09	0.09
Score	**0.92**	**1**	**0.89**	**0.95**	**0.903**	**0.96**	**0.89**	**0.97**	**0.91**	**0.96**	**0.86**	**0.96**	**0.92**

The above results are plotted on a traffic diagram (Figure 5.2) to illustrate the integrated ecological ranking.

5.2.3 Crocodile River system: Conclusions

The integrated ecological ranking for the Crocodile River system that will be taken forward in the decision-making process on scenarios and Water Resource Class determination is summarised in **Error! Reference source not found.**.

The worst case scenarios are Sc C72 and C5 which both include new dam options but with no EWR releases. Scenario C1 which represents the current operating rule also has the potential to degrade the river although it will still maintain the EcoStatus of a C at EWR C6. The best options are those options that include the REC. It is however known that these have serious potential economic consequences. Scenario C3 (with no new dams) and Scenario C82 (that includes new dams) are potentially the best compromise options to explore further.

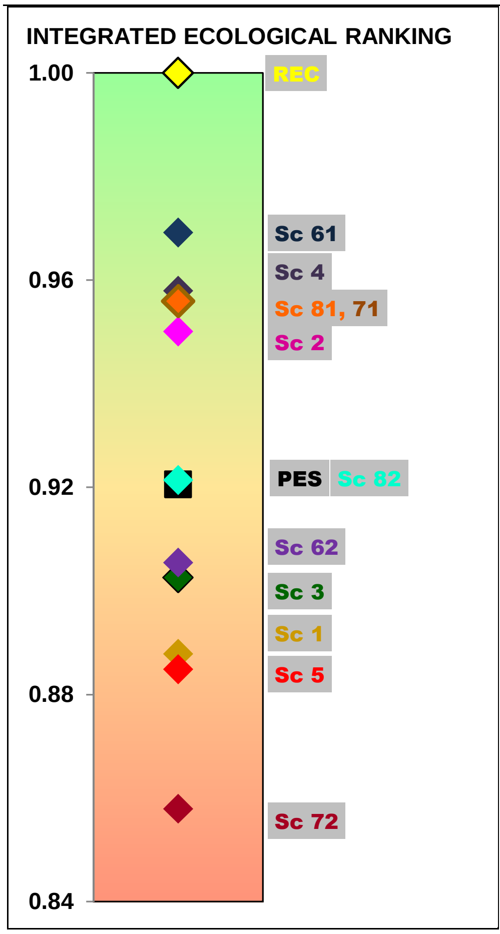


Figure 5.2 Crocodile River system: Integrated ecological ranking of the scenarios

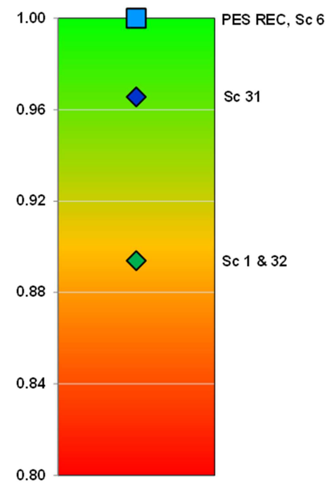
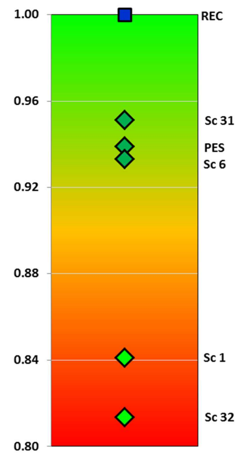
5.3 SABIE RIVER SYSTEM: ECOLOGICAL CONSEQUENCES OF SCENARIOS

5.3.1 Sabie River system: Ecological consequences of scenarios at the EWR sites

The scenarios are described in Table 3.3. The ecological consequences are summarised in Table 5.4. The first column provides the ECs for each component at the EWR site. The second column provides the ranking of the scenarios. The third column includes a short explanation of the consequences and ranking.

The scenarios only impact on EWR S3 (Sabie River) and EWR S5 (Marite River). At all the other EWR sites, the status quo is therefore maintained.

Table 5.4 Sabie River system: Summary of ecological consequences at the EWR sites

<table>
<tr><th>Ecological consequences as ECs</th><th>Ecological consequences</th><th>Ranked scenarios</th><th>Ranking rationale</th></tr>
<tr><th colspan="4">EWR S3 (SABIE RIVER)</th></tr>
<tr><td>
<table>
<tr><th>Component</th><th>PES & REC</th><th>Sc 1</th><th>Sc 31</th><th>Sc 32</th><th>Sc 6</th></tr>
<tr><td>Physico chemical</td><td>B</td><td>C</td><td>B</td><td>C</td><td>B</td></tr>
<tr><td>Geomorphology</td><td>B</td><td>B</td><td>B</td><td>B</td><td>B</td></tr>
<tr><td>Fish</td><td>B</td><td>C</td><td>B/C</td><td>C</td><td>B</td></tr>
<tr><td>Invertebrates</td><td>B</td><td>C</td><td>B</td><td>C</td><td>B</td></tr>
<tr><td>Riparian vegetation</td><td>A/B</td><td>B</td><td>B</td><td>B</td><td>A/B</td></tr>
<tr><td>EcoStatus</td><td>A/B</td><td>B/C</td><td>B</td><td>B/C</td><td>A/B</td></tr>
</table>
</td><td>Increased stress during the dry season results in water quality and instream biota degradation. Reduced base flows also impact on the marginal vegetation zone.</td><td>
</td><td>Sc S1 and S32 do not meet the ecological objectives of the PES and REC and degrade the EcoStatus to a B/C from the current A/B EC. Scenario S31 is an improvement of these scenarios but the fish and riparian vegetation REC are not met. Scenario S6 maintains the REC and is ecologically the most acceptable scenario for EWR S3 and the KNP.</td></tr>
<tr><th colspan="4">EWR S5 (MARITE RIVER)</th></tr>
<tr><td>
<table>
<tr><th>Component</th><th>PES</th><th>REC</th><th>Sc 1</th><th>Sc 31</th><th>Sc 32</th><th>Sc 6</th></tr>
<tr><td>Physico chemical</td><td>B</td><td>B</td><td>C</td><td>A/B</td><td>C</td><td>A/B</td></tr>
<tr><td>Geomorphology</td><td>C</td><td>C</td><td>C</td><td>C/D</td><td>C/D</td><td>C/D</td></tr>
<tr><td>Fish</td><td>B/C</td><td>B</td><td>C</td><td>B/C</td><td>C</td><td>B/C</td></tr>
<tr><td>Invertebrates</td><td>B/C</td><td>B</td><td>C</td><td>B</td><td>C</td><td>B/C</td></tr>
<tr><td>Riparian vegetation</td><td>B/C</td><td>B</td><td>B/C</td><td>B/C</td><td>B/C</td><td>B/C</td></tr>
<tr><td>EcoStatus</td><td>B/C</td><td>B</td><td>C</td><td>B/C</td><td>C</td><td>B/C</td></tr>
</table>
</td><td>Geomorphological impacts (Sc S6, S31 and S32) are small and largely related to the dam and the changes in sediment regime. These changes, as well as the water quality changes, result in a decrease in the fish status under Sc S1, and S32 due to the unseasonal high flows released from Inyaka Dam. Scenario S31 is however an improvement from Sc S6 as flows is generally lower. Scenario S32 flows are lower than the EWR requirement which results in increased stress.</td><td>
</td><td>Inyaka Dam is situated in the Marite River upstream of EWR S5. Operation of the Sabie River is dependent on releases from Inyaka Dam, whether it is for the EWR and/or the users. As is currently the case, the impacts of this operating rule on the Marite River result in releases that do not mimic the natural seasonal distribution and often results in too much flows (i.e. flows higher than natural). None of the scenarios therefore achieve the REC. Scenario S31 is marginally better than the PES whereas Sc S1 and S32 result in in an EcoStatus below the PES.</td></tr>
</table>

The ranking of the scenarios at each site in terms of how successful the scenarios are in meeting the REC is provided in Figure 5.3. The ranking order is quite different between EWR S3 and EWR S5 due to the operation of the system. Inyaka Dam is situated in the Marite River upstream of EWR S5. Operation of the Sabie River is dependent on releases from Inyaka Dam, whether it is for the EWR and/or the users. In essence, as is currently the case, the impacts of this operating rule on the Marite River result in releases that do not mimic the natural seasonal distribution and often results in too much flows (i.e. flows higher than natural). None of the scenarios therefore achieve the REC in the Marite River which would require smaller releases at times. Scenario S31 is marginally better than the PES whereas Sc S1 and S32 result in an EcoStatus below the PES. The ranking shows that Sc SS1 and S32 are the lowest in the ranking and significantly lower than the other scenarios.

The ranking in the Sabie River follows a similar order to the Marite River except for Sc S6 which is at opposite ends of the ranking. Scenario S6 was designed as an optimised scenario to ensure that the EWR is met in the Sabie River. To meet the EWR, additional releases from Inyaka Dam is required and that is why Sc S6 results in ecological degradation in the Marite River. Scenario S32 is the worst scenario in the Sabie River as well as in the Marite River.

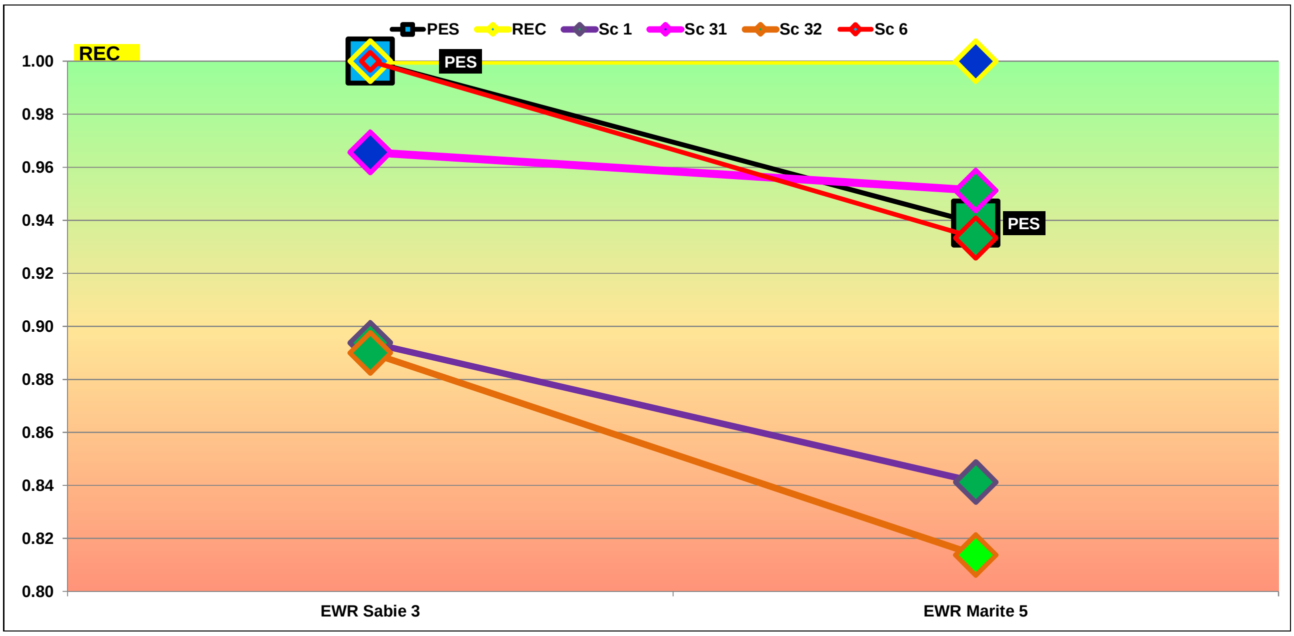


Figure 5.3 Sabie River system: Ranking of scenarios at EWR 3 and EWR 5

5.3.2 Sabie River system: Integrated ecological consequences

The process to determine an integrated ranking of the different scenarios is described below. The first step was to determine the relative importance of the different EWR sites. The site weight (Table 5.5) indicates that EWR S3 carries the highest weight due to its high ecological importance and as it represents the KNP.

The weights are provided in the Table 5.5. The weight is based on the conversion of the PES and EIS to numerical values to determine the normalised weight.

Table 5.5 Sabie River system: Weights allocated to EWR sites relative to each other

EWR site	PES	EIS	Locality in protected areas (0 - 5)	Confidence	Normalised Weight
EWR S1	B/C	High	1	3.25	0.17
EWR S2	C	High	2	3.25	0.19
EWR S3	A/B	Very High	5	3.75	0.26
EWR S4	B	High	3	3.15	0.21
EWR S5	B/C	High	1	3.25	0.17

The weight is applied to the ranking value for each scenario at each EWR site and this provides an integrated score and ranking for the operational scenarios of the Sabie River system. The ranking of '1' refers to the REC and the rest of the ranking illustrate the degree to which the scenarios meet the REC. The results are provided in Table 5.6 after the weights have been taken into account. Values for EWR S3 and S5 only have been provided as the scenarios do not impact on the other EWR sites.

Table 5.6 Sabie River system: Ranking value for each scenario resulting in an integrated score and ranking

EWR Site	PES	REC	Sc S1	Sc S31	Sc S32	Sc S6
EWR S3	0.26	0.26	0.24	0.26	0.24	0.26
EWR S5	0.16	0.17	0.15	0.17	0.14	0.15
Score	**0.97**	**1**	**0.92**	**0.96**	**0.92**	**0.95**

The above results are plotted on a traffic diagram (Figure 5.4) to illustrate the integrated ecological ranking.

5.3.3 Sabie River system: Conclusions

Scenario S31 and S6 are the best options as they are the closest to meeting the ecological objectives. If one however considers that the Sabie River has always been seen as the flagship river in the KNP as well as one of the few rivers left in South Africa in excellent condition, then the ranking order of the Sabie River should (from an ecological view point) override the integrated ranking. As Sc S6 is the only scenario that maintains the PES (and REC) in the Sabie River, this scenario is the ecological recommendation.

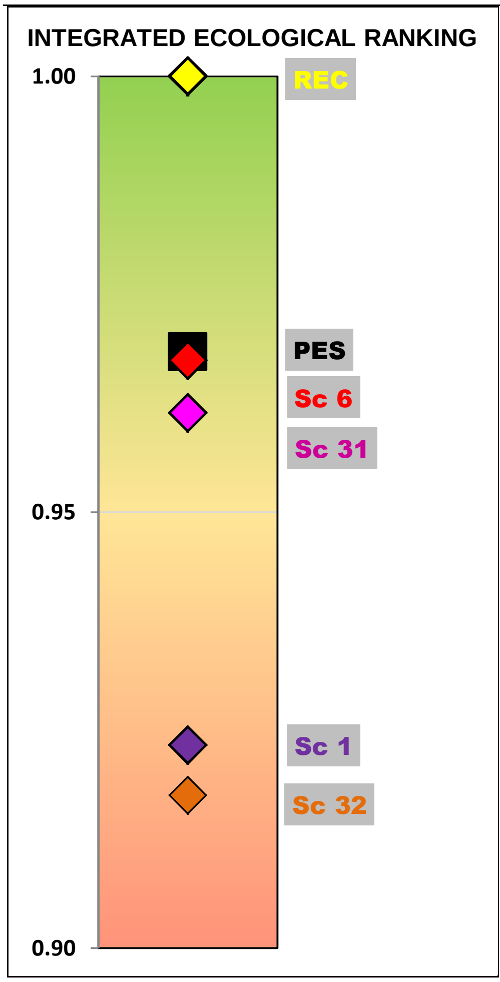


Figure 5.4 Sabie River system: Integrated ecological ranking of the scenarios

5.4 SAND RIVER SYSTEM: ECOLOGICAL CONSEQUENCES OF SCENARIOS

5.4.1 Sand River system: Ecological consequences of scenarios at the EWR sites

The scenarios are described in Table 3.4. The ecological consequences are summarised in Table 5.7. The first column provides the ECs for each component at the EWR site. The second column provides the ranking of the scenarios. The third column includes a short explanation of the consequences and ranking.

The scenarios largely impact on EWR 6S (Mutlumuvi River) and EWR S8 (Sand River). Due to the lower confidence at EWR S7 (Thulandziteka (Sand) River) and as it is situated upstream of the impact of the New Forest Dam, this site was not considered during the scenario evaluation.

The results at EWR S6 (Mutlumuvi River) illustrate that none of the scenarios meet the ecological objectives of the REC. Scenario S4 meets the ecological objectives of the PES and has the least impact of all the scenarios. Scenario S51 and S71 result in the PES EcoStatus although geomorphology and fish are impacted. Scenario S53 and S73 result in a deterioration in the PES while Sc S52 and S72 have serious impacts as the EWR site will receive zero flows except when the dam spills.

Although affected by the proposed New Forest Dam under Sc S51, S52 and S53, the impacts of these scenarios are ameliorated by the return flows from the lower catchment. Scenario S72 is marginally lower than the EWR during some months but does maintain the REC for all components and the EcoStatus.

Table 5.7 Sand River system: Summary of ecological consequences at the EWR sites

Ecological consequences as ECs	Ecological consequences	Ranked scenarios	Ranking rationale

EWR S6 (MUTLUMUVI RIVER)

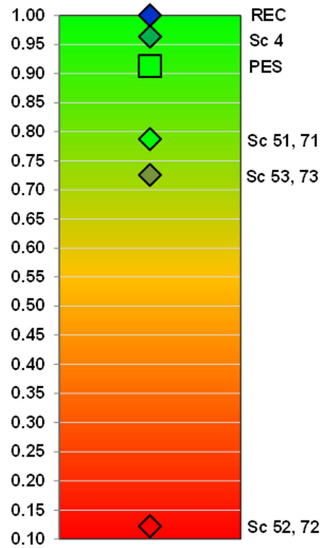
Ecological consequences as ECs

Component	PES	REC	Sc 4	Sc 51, 71	Sc 52, 72	Sc 53, 73
Physico chemical	B/C	B/C	B/C	C	F	C
Geomorphology	C	C	C	D	F	D
Fish	C	B	B/C	C/D	F	D
Invertebrates	B/C	B	B	C	F	C/D
Riparian vegetation	C	B	B/C	C	F	C/D
EcoStatus	C	B	B/C	C	F	C/D

Ecological consequences

Scenario S52 and S72 are the worst case scenario as the river will barely ever flow and the EC of all components will decrease significantly. Low flows and floods also decrease under Sc S51, S53, S71 and S73 with the resulting degradation of most of the components linked to the geomorphological and water quality deterioration. Scenario S4 is the best option (as it does not include a dam) and improves the PES although not achieving the REC.

Ranked scenarios



Ranking rationale

None of the scenarios meet the ecological objectives of the REC. Scenario S4 meets the ecological objectives of the PES and has the least impact of all the scenarios. Scenario S51 and S71 result in the PES EcoStatus although geomorphology and fish are impacted. Scenario S53 and S73 result in a deterioration in the PES while Sc S52 and S72 have serious impacts as the EWR site will receive zero flows except when the dam spills.

EWR 8 (SAND RIVER)

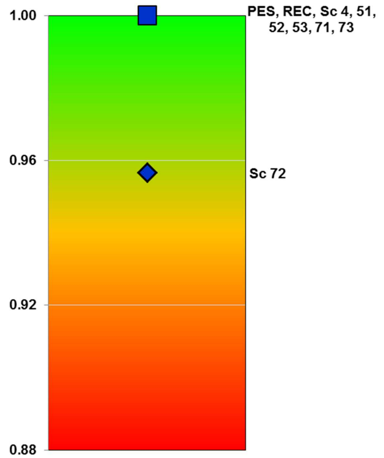
Ecological consequences as ECs

Component	PES	REC	Sc 4, 51, 52, 53, 71, 73	Sc 72
Physico chemical	B	B	B	B/C
Geomorphology	C	C	C	C
Fish	B	B	B	B
Invertebrates	B	B	B	B/C
Riparian vegetation	B	B	B	B
EcoStatus	B	B	B	B

Ecological consequences

The REC flows are met under all scenarios apart from Sc S72. Scenario S72 has marginally less base flows than the EWR resulting in invertebrates and water quality degrading by half a category.

Ranked scenarios



Ranking rationale

All the scenarios include return flows that are of such a scale that they ameliorate the impact of the proposed New Forest Dam and the reinstatement of forestry.

The ranking order is the same for both sites with Sc S72 being the worst case at both sites (Figure 5.5).

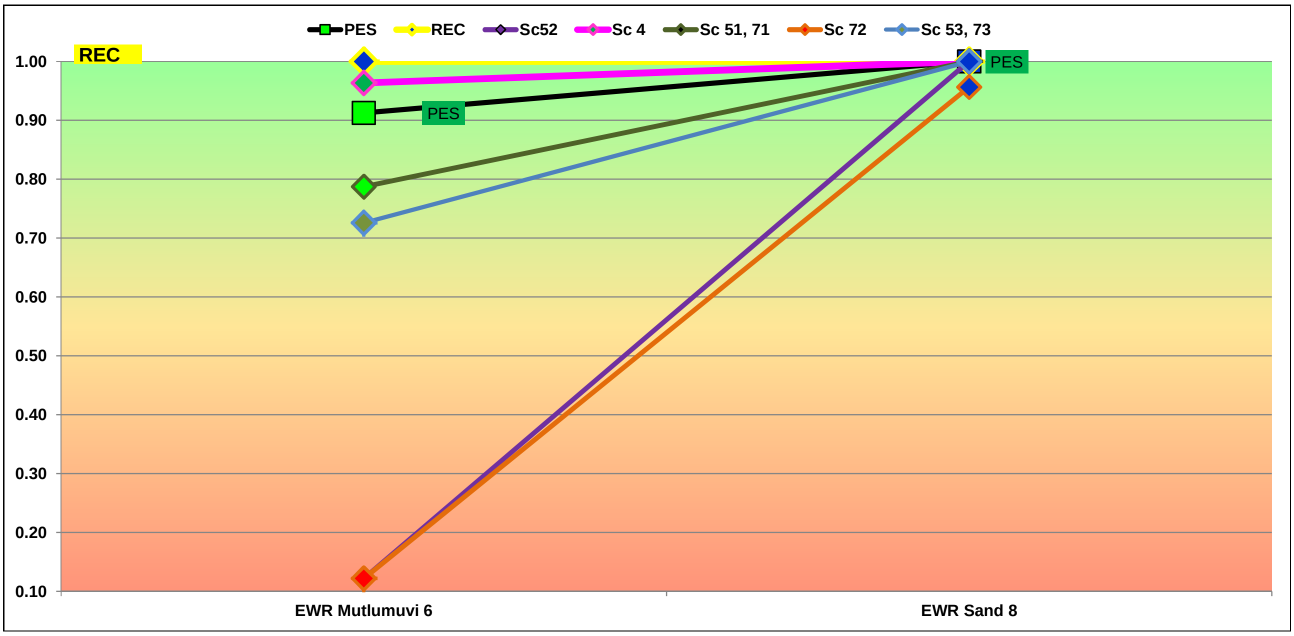


Figure 5.5 Sand River system: Ranking of scenarios at EWR 3 and EWR 5

5.4.2 Sand River system: Integrated ecological consequences

The process to determine an integrated ranking of the different scenarios is described below. The first step was to determine the relative importance of the different EWR sites. The site weight (Table 5.8) indicates that EWR S8 carries the highest weight due to its high ecological importance and as it represents the KNP.

The weights are provided in the Table 5.8. The weight is based on the conversion of the PES and EIS to numerical values to determine the normalised weight.

Table 5.8 Sand River system: Weights allocated to EWR sites relative to each other

EWR site	PES	EIS	Locality in protected areas (0 - 5)	Confidence	Normalised Weight
EWR 6	C	High	1	3.25	0.43
EWR 8	B	High	5	2.5	0.57

The weight is applied to the ranking value for each scenario at each EWR site and this provides an integrated score and ranking for the operational scenarios of the Sand River system. The ranking of '1' refers to the REC and the rest of the ranking illustrate the degree to which the scenarios meet the REC. The results are provided in Table 5.9 after the weights have been taken into account.

Table 5.9 Sand River system: Ranking value for each scenario resulting in an integrated score and ranking

EWR Site	PES	REC	Sc S4	Sc S51	Sc S52	Sc S53	Sc S71	Sc S72	Sc S73
EWR S6	0.40	0.43	0.42	0.34	0.05	0.32	0.34	0.05	0.32
EWR S8	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.54	0.57
Score	**0.96**	**1**	**0.98**	**0.91**	**0.62**	**0.88**	**0.91**	**0.59**	**0.88**

The above results are plotted on a traffic diagram (Figure 5.6) to illustrate the integrated ecological ranking.

5.4.3 Sand River system: Conclusions

Scenario S52 and S72 are not viable options as a section of the Mutlumuvi River will change to a seasonal system. Scenario S4, although the best option, was recognised not to be a realistic option as the return flows associated with this scenario are too high. Scenario S51 and S53 also include these return flows. The remaining scenarios are Sc S71 and S73. Scenario S71 includes a full EWR release which will have a major impact on the yield. To further optimise, it is recommended that Sc S73 be further investigated.

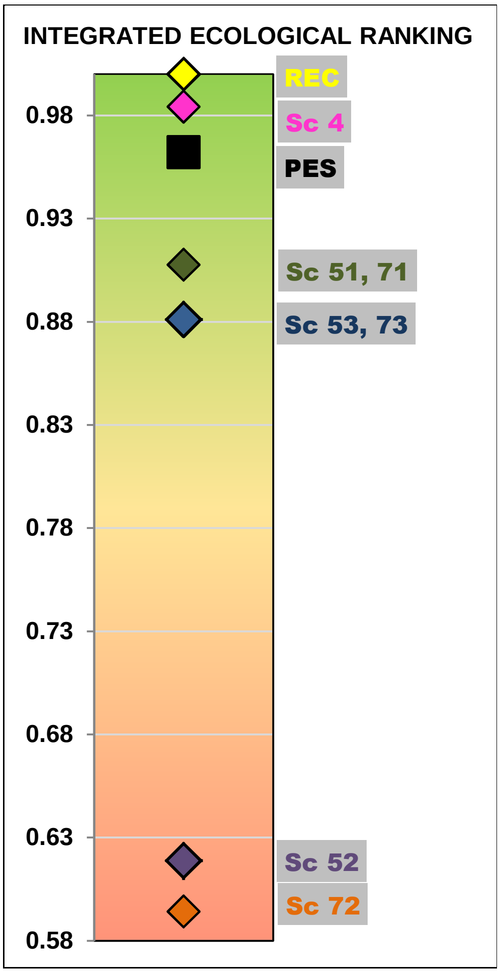


Figure 5.6 Sand River system: Integrated ecological ranking of the scenarios

6 ECOSYSTEM SERVICES

An analysis of the EWR 3, 5, 6,and 8 sites in the Sabie and Sand River system and EWR 3, 4, 5, 6 and 7 in the Crocodile River system was undertaken. Ecosystem Services associated with the sites, bearing in mind that they represent a wider area, were listed and where they were deemed to generate value they were evaluated against the scenarios applicable to the site.

6.1 SABIERIVER SYSTEM

6.1.1 EWR S3 (Sabie River)

This EWR site falls within the Kruger National Park. Given the nature of the site the cultural services, representing the recreational and aesthetic value associated with the Park is given the highest weighting at 0.4. Regulating services are given a weighting of 0.3 while supporting services are given a weighting of 0.2. As there is no legal access to provisioning services in the park these are given the lowest weighting at 0.1.

Scenarios that were evaluated include Sc S1 and S31 that were treated as equivalent in terms of impact on ecosystems services as well as Sc S32. The results are presented in Table 6.1.

Table 6.1 Sabie River system: Ranking value for each scenario resulting in an integrated score and ranking for EcoSystem Services at EWR S3

Service	Sc S1	Sc S31	Sc S32	Weight
Provisioning services	0.99	0.99	0.99	0.1
Regulating services	0.89	1.10	0.89	0.3
Cultural services	0.80	0.97	0.80	0.4
Supporting services	1.05	1.00	1.05	0.2
Score	**0.90**	**1.02**	**0.90**	**1**

Scenario S1 had an overall negative impact and is mainly related to lower flows having a negative impact on the condition of the river and its aesthetic appeal as well as on the ability of the river to deal with water quality issues. Scenario S32 has very similar negative impact. Scenario S31on the other hand was marginally positive. The positive impact is related largely to the improved conditions for regulating services linked to water quality.

6.1.2 EWR S5 (Sabie River)

The upper section of river represented by this EWR site passes the Marite A Township and Hazyview town. The remaining river extent comprised of open terrain and farmland. The EWR site itself is located in farmland. Given the nature of the site the provisioning services were given a much higher weight, at 0.4, than at EWR S3. Cultural services were given the second highest weight at 0.25, followed by regulating services at 0.2 and supporting services at 0.15.

As with EWR S3 scenarios that were evaluated include S1, S31 and S32. The results are presented in Table 6.2.

Table 6.2 Sabie River system: Ranking value for each scenario resulting in an integrated score and ranking for EcoSystem Services at EWR 5

Service	Sc S1	Sc S31	Sc S32	Weight
Provisioning services	0.98	1.02	0.98	0.40
Regulating services	0.85	1.02	0.78	0.20
Cultural services	0.93	1.00	0.80	0.25
Supporting services	1.05	1.00	1.05	0.15
Score	**0.95**	**1.01**	**0.90**	**1.00**

Scenario S32 was associated with the largest negative impact in the set. This relates largely to the impact on regulating services and associated water quality decline as well as potential increase in pathogens. The potential negative impact on cultural services also contributed to overall to the negative score. Provisioning services were likely to remain relatively unchanged bar some negative impact on some of the fish species. Scenario S1 had much the same impact as Sc S32 although not as severe. Scenario S31 were deemed to be moderately positive.

6.2 SAND RIVER SYSTEM

6.2.1 EWR S6 (Mutlumuvi River)

The EWR site is in a Mutlumuvi River reach that includes dense settlement associated with Orinoco and New Forest townships in the upper third of the reach. The middle third is given over to agriculture. Included in agriculture is high value greenhouse/tunnel development. The lower third is also made up of dense urban development of Thulamahase. Given the nature of the site the provisioning services were given a much higher weight, at 0.4, than at EWR S3 (Sabie River) (Table 6.3). Cultural services were given the second highest weight at 0.25, followed by regulating services at 0.2 and supporting services at 0.15.

For this site four scenarios were evaluated separately and include Sc S1, S4, S51 and S53 (Table 6.3).

Table 6.3 Sand River system: Ranking value for each scenario resulting in an integrated score and ranking for EcoSystem Services at EWR S6

Service	Sc S1	Sc S4	Sc S51	ScS53	Weight
Provisioning services	1.06	1.05	0.96	0.93	0.4
Regulating services	1.04	1.04	0.87	0.86	0.2
Cultural services	1.00	1.00	1.00	1.00	0.25
Supporting services	1.00	1.00	1.00	1.05	0.15
Score	**1.03**	**1.03**	**0.96**	**0.95**	**1**

Scenarios S1 and S4 had marginal positive impacts. These were associated with the provisioning services with both fish and riparian vegetation being deemed to react positively overall. Likewise Scenarios S51 and S53 were seen to be marginally negative. Here provisioning services with both fish and riparian vegetation being deemed to react negatively overall.

6.2.2 EWR S8 (Sand River)

This EWR site is situated in the KNP. All scenarios were examined as a single scenario. Provisioning services are not present as the site has restricted access being in the Park. Likewise supporting services providing access to utilised resources were also not present. All scenarios resulted in a positive score of 1.15.

6.3 CROCODILE RIVER SYSTEM

6.3.1 EWR C3 (Crocodile River)

This EWR site represents a river section that extends through a river valley with commercial agriculture/orchards noted along much of the river extent. Much of the agriculture is concentrated on the river banks. No concentrated settlements were noted, other than farm houses. Some tourism elements were observed. Given the nature of the river stretch, regulating and cultural services (largely as a result of associated tourism aspects) were given weights of 0.3 These were higher than the weights given to provisioning services and supporting services that were each given weights of 0.2 (Table 6.5).

For the purposes of the ecosystems services analysis Sc C1 and C5 were deemed to have the same or indistinguishably similar impacts. Likewise Sc C2, C4, C62 and C72 were treated as the same as were Sc C71, C81 and C82. Scenarios C61 and C3 were evaluated separately.

Table 6.4 Crocodile River system: Ranking value for each scenario resulting in an integrated score and ranking for EcoSystem Services at EWR C3

Service	Sc C1, C5	Sc C2, C4, C62, C72	Sc C61	Sc C71, C81, C82	Sc C3	Weight
Provisioning services	1.04	1.01	1.04	0.98	1.00	0.2
Regulating services	1.18	1.18	1.19	1.20	1.18	0.3
Cultural services	1.03	1.07	1.07	1.07	1.03	0.3
Supporting services	1.00	1.00	1.00	1.00	1.00	0.2
Score	**1.07**	**1.08**	**1.09**	**1.08**	**1.06**	**1**

All scenarios had marginally positive impacts over present day. The reversal of flow associated with many of the scenarios has ecological consequences for the fish and indigenous riparian vegetation but this is counteracted by the positive impact for some alien tree species (important in terms of utilisation) and by the overall positive impact on water quality that would accompany the proposed riverine regime. For geomorphological impacts all flow scenarios represent minor to moderate changes from the present day conditions and no change in access to floodplains (for cultivation) relative to the present day conditions were expected. As such the overall positive impact of the regulating services, given a higher weight at this site, largely counteracts some negative impact on indigenous species.

6.3.2 EWR C4 (Crocodile River)

At EWR 4 and environs the river section extends through a river gorge comprised of open/natural terrain. The township of Matsulu is situated in the lower reaches and as such there is a higher degree of dependence on provisioning services in this reach. Provisioning services were therefore given greater weight, at 0.4, for this site. All other services were given a weight of 0.2. In the scenario consideration Sc C1, C2, C3, C4, C61, C71, C81, and C82 were considered together and essentially had no impact and are the same as present day conditions. Scenarios C5, C62 and C72 are an improvement on present day conditions (Table 6.6).

Table 6.5 Crocodile River system: Ranking value for each scenario resulting in an integrated score and ranking for EcoSystem Services at EWR C4

Service	Sc C1, C2, C3, C4, C61, C71, C81, C82	Sc C5	Sc C62	Sc C72	Weight
Provisioning services	1.00	1.02	1.04	1.03	0.4
Regulating services	1.00	1.01	1.02	1.01	0.2
Cultural services	1.00	1.10	1.10	1.03	0.2
Supporting services	1.00	1.00	1.00	1.00	0.2
Score	**1.00**	**1.03**	**1.04**	**1.02**	**1**

Under Sc C5, C62 and C72 the regulating services were deemed to improve as were some cultural services associated with aesthetic benefits. For fish the *Barbus* species were seen to improve under Sc C5 and C62 and these, along with some improvement in sedges, reeds and riparian grazing were deemed to be of benefit to provisioning services. In summary, the ecosystem services under Sc C5, C62 and C72 improve marginally.

6.3.3 EWR C5 (Crocodile River)

This EWR site is close to Malelane and essentially within the KNP. Given restriction in terms of access, provisioning services are constrained and as such had little influence on the final outcome. Cultural services were however deemed to be important as were regulating services, particularly with regard to downstream impacts and, to a lesser degree the supporting services. Scenario C3 was seen to be the same as present day conditions. Scenario C1 was seen as much the same as present day conditions, but with an improvement in water quality linked to regulating services. Scenarios C2, C4, C61, C71 and C81 were treated as the same with an improvement in present day conditions. Scenario C5, C62 and C72 were treated as generally the same as present day conditions with some slight deterioration in all components bar the geomorphology, which remains stable. Scenario C82 was seen as largely the same as Sc C2 with some very minor variation in terms of invertebrate health. Although the scenario was examined as a separate entity the results were virtually identical to Sc S2. The results are presented in Table 6.7.

Table 6.6 Crocodile River system: Ranking value for each scenario resulting in an integrated score and ranking for EcoSystem Services at EWR C5

Service	Sc C3	Sc C1	Sc C2, C4, C61, C71, C81	Sc C5, C62, C72	Sc C82	Weight
Provisioning services	1	0.90	0.91	0.89	0.91	0.05
Regulating services	1	1.00	1.19	0.94	1.17	0.3
Cultural services	1	0.93	1.08	0.93	1.08	0.4
Supporting services	1	1.00	1.00	1.00	1.00	0.25
Score	**1**	**0.97**	**1.08**	**0.95**	**1.08**	**1**

Scenario C1, C5, C62 and C72 resulted in a negative impact for ecosystem services. This is largely related to the negative consequences for the regulating services and cultural services. The other scenarios were largely positive and again this is largely related to the regulating services showing a degree of overall improvement.

6.3.4 EWR C6 (Crocodile River)

The north bank of the river section is the KNP. As with EWR C5 this limits the use of some provisioning services, particularly fishing. The south bank is comprised of commercial agriculture but no major settlements are noted proximate to the stretch. Some tourism/recreational features were noted and obviously the KNP is a major tourism destination. As such the cultural services are given a greater weight at this site.

At EWR C6, Scenario C4, C61, C71 and C81 are essentially the same as present day, Sc C1 is lower than present day with some deterioration in water quality and the presence of fish.

Scenario C2 is an improvement from present day conditions with some positive consequences for water quality, fish, and riparian vegetation. Scenario C3, C62 and C82 largely maintains present day conditions with some slight deterioration in water quality and fish, with some riparian vegetation improving. Scenario C5 and C72 do not achieve present day conditions and there is some deterioration in all components. The results are provided in Table 6.8.

Table 6.7 Crocodile River system: Ranking value for each scenario resulting in an integrated score and ranking for EcoSystem Services at EWR C6

Service	Sc C4, C61, C71, C81	Sc 1	ScC5, C72	Sc C3, C62, C82	Sc C2	Weight
Provisioning services	1.00	1.00	1.00	1.01	1.01	0.05
Regulating services	1.00	0.97	0.81	1.04	1.19	0.3
Cultural services	1.00	0.93	0.93	0.93	1.00	0.4
Supporting services	1.00	1.00	1.00	1.00	1.00	0.25
Score	**1.00**	**0.96**	**0.91**	**0.98**	**1.06**	**1**

Overall Sc C1, along with C5, C72, C3, C62 and C82 show marginal decreases in the ecosystems services. For the most part this is driven by the decline in regulating services, particularly those associated with water quality as well as anticipated negative impacts on cultural services allied to the aesthetic appeal of ecotourism associated with the KNP. Scenario C2 shows some improvement.

6.3.5 EWR C7 (Kaap River)

The river section is comprised of commercial agriculture and open terrain. No denser settlement of consequence was noted. Some recreational/tourism facilities (lodges) were noted. For this site regulating services were given the highest weighting of 0.35 (Table 6.9) followed by cultural services (0.25) and the provisioning services and supporting services (0.20). Scenario C1, C5, and C82 were assessed together. They do not maintain the present state and most components associated with the ecosystem services were likely to show deterioration. Geomorphology and the riparian vegetation were the exceptions. Scenarios C2 and C4 were assessed together and they largely maintain the present day conditions but with some slight improvement in fish. Scenarios C3, C61, C71, C72, and C81 were considered together and see some deterioration in all components except geomorphology and riparian vegetation that remain largely stable. Scenario C62 was considered on its own. It does not maintain present conditions and there is deterioration in all components.

Table 6.8 Crocodile River system: Ranking value for each scenario resulting in an integrated score and ranking for EcoSystem Services at EWR C7

Service	Sc C62	Sc C81,C3, C61, C71, C72, C82	Sc C1, C5, C82	Sc C2, C4	Weight
Provisioning services	0.87	0.97	0.95	1.03	0.2
Regulating services	0.53	0.82	0.765	1.12	0.35
Cultural services	1	0.85	0.85	1	0.25
Supporting services	1	1	1	1	0.2
Score	**0.81**	**0.89**	**0.87**	**1.05**	**1**

Scenario C62 showed a fairly substantial deterioration over present day conditions. Regulating services, driven by water quality aspects is the key driver here. Scenario C1, C5, C82 and also C3, C61, C71, C72, C81 showed negative declines. Again regulating services, but also cultural services were determining factors. Scenario C2 and C4 showed an overall marginal improvement.

7 INTEGRATED MULTI-CRITERIA RESULTS

The results of the rating, weighting and scoring for the four variables, Economy, Employment, Ecology and Ecosystem Services presented in the previous chapters were integrated to obtain the overall ranking of the scenarios as described in this chapter. Provision was made in this process to incorporate all the biophysical nodes in each of the IUAs.

Integrated multi-criteria analysis models were compiled respectively for the Komati, Crocodile Sand and Sabie River systems.

7.1 ECOLOGICAL SCORING MATRIX RESULTS

Table 11.2 (Appendix B) provides an example (extract) of the full scoring calculation carried out for the ecological component of the Sand River system. The elements of the table are described below in accordance with the respective column alphabetic labels:

Column *a*: National biophysical node label identifier, where the first 4 characters "X32B" refers to the quaternary catchment in which the node is located. The remaining numbers represent the SQ reach number. The SQ river reaches as indicated in http://www.dwa.gov.za/iwqs/gis_data /river/rivs500k.html and http://www.dwa.gov.za/iwqs/gis_data/river/River_Report_01.pdf, forms the basis of the Desktop Present Ecological State (PES) and Ecological Importance (EI) - Ecological Sensitivity (ES) (DWS, 2014b) assessment (referred to PES (11)). A SQ changes when a significant tributary joins it. This means that a SQ may potentially be subdivided into various EcoRegions, geomorphic zones (slope zones) resource units (natural or management), etc. Such subdivisions are not addressed on a desktop level, and may be required when higher confidence assessments are done. The version of the 1:500 000 coverage that was used for the PES (11) (DWS, 2014b), was a version used during the determination of the Status Quo (DWA, 2013a).

The EWR sites are indicated as "EWR6" where the numerical number refers to the particulate site. These are the river sites where high confidence Reserve determination studies were undertaken and serve as the drivers for the water resource modelling and availability analysis.

Column *b*: River or stream name.

Columns *c* and *d*: These columns are the weights assigned to each node. Column c reflects the relative ecological importance of each node and **Column *d*** is the length of river reach the node represents. The length of river is a measure of the extent of the ecological habitat of the river reach (associated with the nodes) relative to each other. These two weights are combined into one weight, see description of **Column g** below.

Columns *e, f* and *g*: The weights of **Columns *c*** and ***d*** are respectively normalised in these columns.

Columns *e* and *f* (divide each nodes weight by the sum of the weights)***:*** The combined weight in **Column g** is determined by the sum of the product of the normalised values with the factors given in grey shading above the column labels. These factors must add up to one and represents the relative contribution of the "Importance" and the "Length" in the combined weight.

Columns *h* to *m*: This is the rating of the ecological status of each node as it is influenced by the scenario. Since most of the biophysical nodes are in tributary catchment and not affected by the scenarios their ratings are one, indicating the REC is achieved.

Columns *n* to *s*: This is the score, the product of the weight in **Column *g*** and respective ratings in **Columns h** to **m**. The sum of the scores of all the nodes for a scenario is listed at the bottom of each column. This is the metric representing the ecology for the scenario and taken into account when determining the integrated ranking of scenarios.

Similar calculations were carried out for all four river systems.

7.2 ECOSYSTEM SERVICES SCORING MATRIX RESULTS

The same calculation methodology as described in Section 7.1 is applied for the Ecosystem Services component for all four river systems.

7.3 INTEGRATED SCENARIO RANKING RESULTS

The summarised integrated results for the four river system are presented respectively in the following sections.

7.3.1 Sand River system

The scenario scores for the four variables, Ecology, Ecosystem Services, Economy and Employment are presented graphically in **Error! Reference source not found.**. The scenarios presented are identified in accordance with their labels presented in Table 3.3. Note that only the scenarios that are relevant for the discussion and decision making process are listed. The scenarios not shown provided intermediate perspectives for evaluation purposes and were superseded by other scenarios during the analysis process.

The four individual graphs shown in Figure 7.1 have the following interpretation:

- **Ecological Status relative to REC:** This is the measure of how each scenario's ecological status is ranked relative to the REC. As indicated **Sc S72** has the lowest ecological score while **Sc S71** the highest. **Sc S52** and **S72** is where no releases are made from the proposed New Forest Dam towards the ecology.
- **Ecosystem Services:** The score indicates to what extent each scenario changes the Ecosystem Services relative to the Present Day or PES conditions. The ranking follows largely the same ranking order as that for the ecological status.
- **Economic Indicator (GDP):** This metric represents GDP in Rand with **Sc S52** ranking the highest and **ScS73** the lowest.
- **Employment:** The number of people employed follows the same relative ranking position as the economic indicator.

The relative weight applied to each variable for calculating the overall ranking is indicated numerically at the bottom of each bar graph. Each weight has a value between zero and one and a set of selected weights for all four variables must add up to one. The rationale for the weights selected is to assess what the balance is between the ecological health and the socio-economic benefits, therefore a weight of 0.5 (or 50%) is assigned to the ecology and the remaining 50% is divided among the other three variables; Ecosystem Services (5%), Economy (20%) and Employment (25%).

The lines depicted in **Error! Reference source not found.** connect the variable points for a scenario and when opposing consequences are observed (among the variables) the lines cross. This indicates opposing outcomes and a compromise between ecological protection and socio economic benefits will most likely result in the optimum solution – "the desired balance between protection and use".

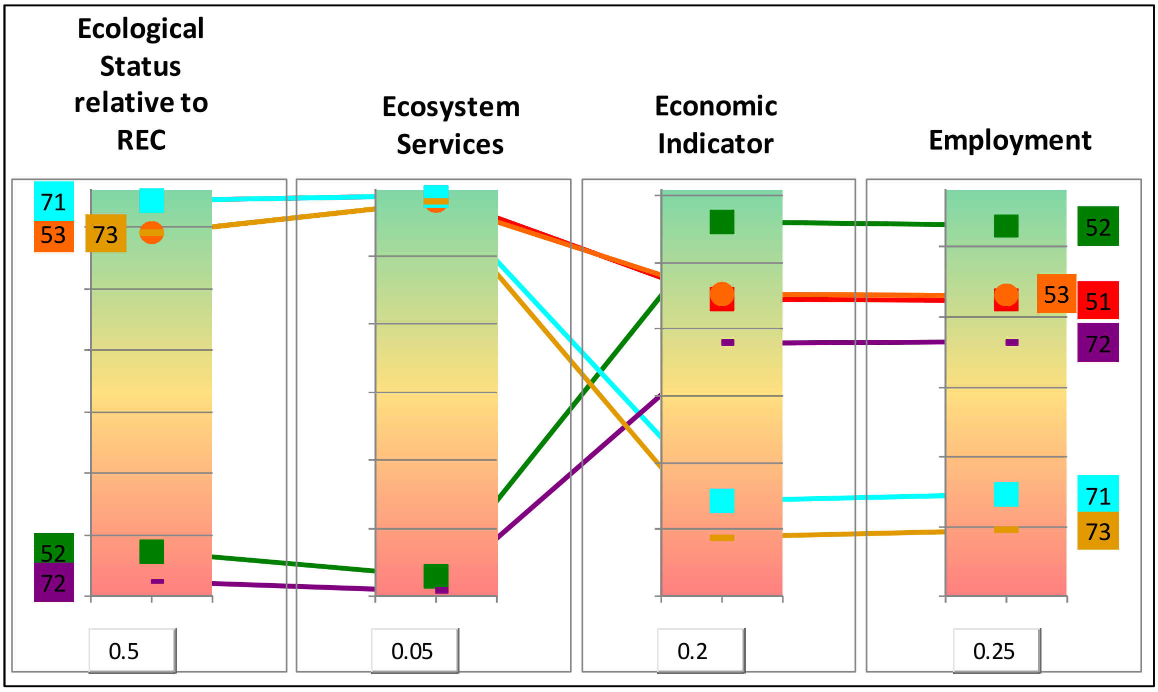


Figure 7.1 Sand River system: Graphical results of individual variables and all scenarios

A further aspect to consider is the probability of the underlying settings of the scenario variables materialising. The probability of achieving a 50% return flow factor (assumed for Sc S51, S52 and S53) is considered low and therefore Sc S71, S72 and S73 is more likely to be achieved in the medium term future. Figure 7.2 therefore represents a second set of scenario results where Sc S51, S52, and S53 are excluded.

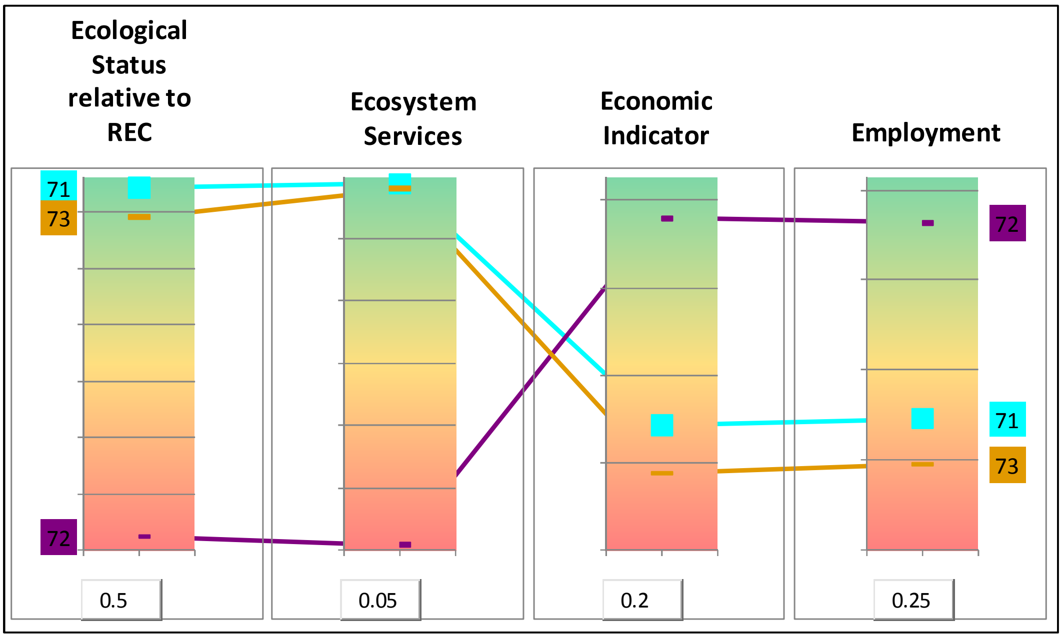


Figure 7.2 Sand River system: Graphical results of most probable scenarios

The final step in the multi-criteria analysis was to determine the integrated and overall rank of the scenarios and this is depicted in Figure 7.3a and Figure 7.3b.

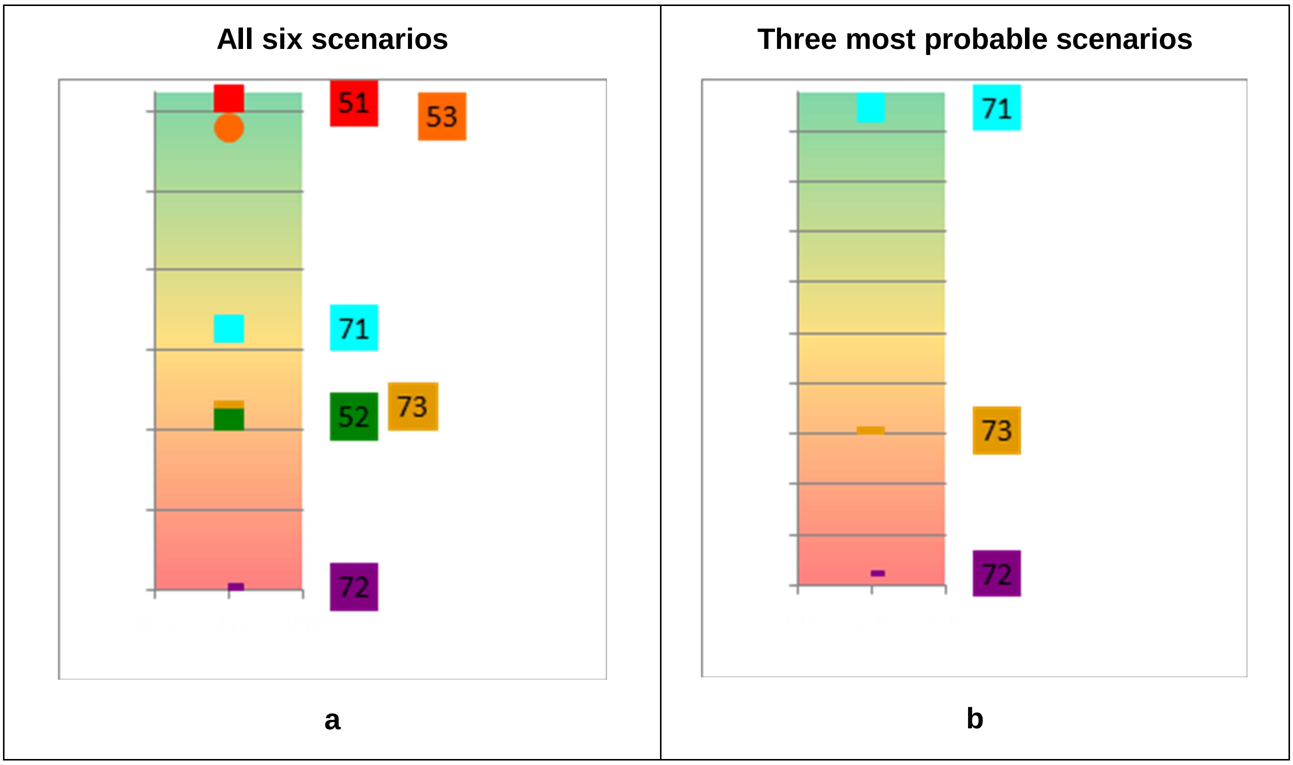


Figure 7.3 Sand River system: Graphical results of overall ranking from the multi-criteria analysis (Normalised Ranking Method)

Based on the set of six scenarios (Figure 7.3a), Sc S51 has overall the highest rank and if Sc S51, S52 and S53 are excluded, Sc S71 is the preferred scenario.

The integrated ranking calculations which give rise to the ranking order shown in Figure 7.3a are presented in Table 7.1 and are explained below by using the column and row labels.

Column *a*: This column contains headings describing the different sections in the table as well as labelling the variables for which the calculated data of the scenarios are provided in the subsequent columns.

Columns *b* and *c*: Contain parameters applied in the calculations, either the best and highest and lowest scores of the weights associated with each variable. The application of these parameters in the calculations is described below.

Columns *d* to *i*: Represent the values calculated for each of the scenarios.

Rows *A* to *D*: This is the numerical results (scores) of the scenarios.

Row *A* is the Ecological Scores for the scenarios, which originate from the calculations in Table 11.1 (Appendix B) and is obtained from the last row in that table.

Row *B* is the Ecosystem Services score which is calculated following the same procedure as above.

Rows *C* and *D*: Contain respectively the Economic Indicator (GDP in Rand) and the Employment numbers for each scenario. The calculations to derive these variables were described in Chapter 4.

Rows *E* to *O*: This section of the table shows the calculation results for the Rank Order method of determining the overall scenario rank.

Rows *E* to *H*: Contains the rank order position of each variable's score derived from the scored in **Rows *A* to *D***.

Row *I*: This is the sum of the rank positions of the scenario (note this is before the variable weight are applied. **Row *J*** is the ranked position of **Row *I***. Note that both **Rows *I*** and ***J*** are before the variables weights are applied.

Rows *K* to *N*: These rows show the scores where the Weights indicated in **Column *b*** are multiplied with the respective rank positions given in **Rows *E*** to ***H***.

Row *O*: This is the sum of the scenario values of **Rows *K*** to ***N*** – the overall score of the scenarios for the Rank Order method.

Row *P*: This is the rank order of the scenarios for the Rank Order method, indicating Sc S51 is the best (rank if one) and Sc S72 ranks the lowest with a rank of six.

Rows *Q* to *AB*: The results for the normalisation calculation are presented in these rows.

Rows *Q* to *T*: Shows the normalised values for the variables determined from **Rows *A* to *D*** respectively.

Rows *Q* to *T*: This is the normalised values calculated by assuming the worst scenario will have a normalised value of zero and the best scenario a value of one. All the other values then transposed to fit the zero to one normalised scale.

Rows *U* and *V*: This is the sum of the scores for the normalised values for each scenario and the rank order of the scores. Note that both **Rows *U*** and ***V*** are before the variables weights are applied.

Rows *W* to *Z*: These rows show the scores where the Weights indicated in Column b are multiplied with the respective rank positions given in **Rows *Q*** to ***T***.

Row *AA*: This is the sum of the scenario values of **Rows *W*** to ***Z*** – the overall score of the scenarios for the Normalisation Method.

Row *AB*: This is the rank order of the scenarios for the Normalisation Method, indicating **Sc S51** is the best (rank if one) and Sc S72 ranks the lowest with a rank of six.

Rows *AC* to *AF*: This is the respective results (integrated scores and rank positions) of the two ranking methods repeated for easy comparison.

In order to determine how sensitive the ranking results are for alternative weight settings, Table 7.2 provides scenario ranking results for a range of variable weights. Nine alternative weight options were evaluated labelled as such in the column with the heading "**Alternatives**". The weights are as presented in **Columns *a*** to **d**, with **Column *e*** showing the sum of the weights which must be one.

Both the scores and the rank order (pairs of results) for the scenarios are provided in **Columns *f*** to ***q***. The results for the Rank Order Method are presented in **Rows *A*** to **I** while the results for the Normalisation Method is shown in **Rows *J*** to ***R***. Note that the same alternative weight settings are used for the alternatives with the same label.

It can be observed that the Rank Order Method result is mostly consistent by indicating Sc S52 is the preferred scenario (except for **Alternatives 7 and 8** - **Row G *and H***).

The Normalisation Method is less sensitive with all the alternatives indication Sc S51 is the best.

Considering the ranking order of Sc S71, S72 and S73 together reveal that Sc S71 is ranked the best for all alternatives except for Alternatives 7 and 8 for the Normalisation Method.

It can therefore be concluded that Sc S71 is recommended as the preferred scenario for deriving the Water Resource Classes, Ecological Categories for the biophysical nodes and for setting the RQOs for the Sand River System.

Table 7.1 Sand River system: Integrated ranking calculations for the two ranking methods

Row	Description	Parameters		Scenarios 51	52	53	71	72	73
	a	b	c	d	e	f	g	h	i
	Variable Scores:								
		Highest	*Lowest*						
A	Ecological Status	0.91	0.60	0.91	0.62	0.88	0.91	0.60	0.88
B	Ecosystem Services	0.99	0.41	0.99	0.43	0.98	0.99	0.41	0.98
C	Economic Indicator (GDP) (R Millions)	244	220	237.93	243.70	238.31	222.82	234.63	220.07
D	Employment	2598	2380	2544.53	2597.73	2548.01	2405.14	2514.10	2379.82
	Rank Order Method:								
	Ranked order of variables (6 = higest, 1 = lowest, equals = average):								
E	Ecological Status			5.5	2.0	3.5	5.5	1.0	3.5
F	Ecosystem Services			5.5	2.0	3.5	5.5	1.0	3.5
G	Economic Indicator (GDP) (R Millions)			4.0	6.0	5.0	2.0	3.0	1.0
H	Employment			4.0	6.0	5.0	2.0	3.0	1.0
I	Total:			**19.0**	**16.0**	**17.0**	**15.0**	**8.0**	**9.0**
J	Rank (1 = best, 6 = worsed)			**1**	**3**	**2**	**4**	**6**	**5**
	Rank order x Weights:	Weights							
K	Ecological Status	0.50		2.75	1.00	1.75	2.75	0.50	1.75
L	Ecosystem Services	0.05		0.28	0.10	0.18	0.28	0.05	0.18
M	Economic Indicator (GDP) (R Millions)	0.20		0.80	1.20	1.00	0.40	0.60	0.20
N	Employment	0.25		1.00	1.50	1.25	0.50	0.75	0.25
O	**Total:**			**4.825**	**3.800**	**4.175**	**3.925**	**1.900**	**2.375**
P	**Rank (1 = best, 6 = worsed)**			**1**	**4**	**2**	**3**	**6**	**5**
	Normalisation Method:								
	Normilized (0 = minimum, 1 = maximum):								
Q	Ecological Status			1.000	0.078	0.915	1.000	0.000	0.915
R	Ecosystem Services			1.000	0.036	0.985	1.000	0.000	0.985
S	(R Millions)			0.756	1.000	0.772	0.116	0.616	0.000
T	Employment			0.756	1.000	0.772	0.116	0.616	0.000
U	Total:			**3.512**	**2.115**	**3.444**	**2.232**	**1.232**	**1.900**
V	Rank (1 = best, 6 = worsed)			1	4	2	3	6	5
	Normiliaed x Weights:	Weights							
W	Ecological Status	0.50		0.500	0.039	0.457	0.500	0.000	0.457
X	Ecosystem Services	0.05		0.050	0.002	0.049	0.050	0.000	0.049
Y	Economic Indicator (GDP) (R Millions)	0.20		0.151	0.200	0.154	0.023	0.123	0.000
Z	Employment	0.25		0.189	0.250	0.193	0.029	0.154	0.000
AA	Total:			**0.890**	**0.491**	**0.854**	**0.602**	**0.277**	**0.507**
AB	**Rank (1 = best, 6 = worsed)**			**1**	**5**	**2**	**3**	**6**	**4**
AC	**Overall Score (Rank Order method)**			4.825	3.8	4.175	3.925	1.9	2.375
AD	Rank (1 = best, 6 = worsed)			**1**	**4**	**2**	**3**	**6**	**5**
AE	**Overall Score (Normalisation Method)**			0.8901386	0.49105656	0.854064	0.602292111	0.277292	0.5067294
AF	Rank (1 = best, 6 = worsed)			**1**	**5**	**2**	**3**	**6**	**4**

Table 7.2 Sand River system: Sensitivity analysis of scenario ranking for alternative variable weights

Row	Alternative	Weighs					Scenarios											
							51		52		53		71		72		73	
		Ecological	Ecosystem Services	Economy (GDP)	Employment	Total	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
		a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*
		Rank Order Method:																
A	**1**	**0.50**	**0.05**	**0.20**	**0.25**	**1.00**	**4.825**	**1**	**3.800**	**4**	**4.175**	**2**	**3.925**	**3**	**1.900**	**6**	**2.375**	**5**
B	2	0.50	0.10	0.20	0.20	1.00	4.900	1	3.600	4	4.100	2.5	4.100	2.5	1.800	6	2.500	5
C	3	0.50	0.15	0.15	0.20	1.00	4.975	1	3.400	4	4.025	3	4.275	2	1.700	6	2.625	5
D	4	0.50	0.05	0.15	0.30	1.00	4.825	1	3.800	4	4.175	2	3.925	3	1.900	6	2.375	5
E	5	0.50	0.05	0.30	0.15	1.00	4.825	1	3.800	4	4.175	2	3.925	3	1.900	6	2.375	5
F	6	0.25	0.25	0.25	0.25	1.00	4.750	1	4.000	3	4.250	2	3.750	4	2.000	6	2.250	5
G	7	0.20	0.10	0.40	0.30	1.00	4.450	3	4.800	1	4.550	2	3.050	4	2.400	5	1.750	6
H	8	0.15	0.10	0.45	0.30	1.00	4.375	3	5.000	1	4.625	2	2.875	4	2.500	5	1.625	6
I	9	0.50	0.05	0.20	0.25	1.00	4.825	1	3.800	4	4.175	2	3.925	3	1.900	6	2.375	5
		Normalise Method:																
J	**1**	**0.50**	**0.05**	**0.20**	**0.25**	**1.00**	**0.890**	**1**	**0.491**	**5**	**0.854**	**2**	**0.602**	**3**	**0.277**	**6**	**0.507**	**4**
K	2	0.50	0.10	0.20	0.20	1.00	0.902	1	0.443	5	0.865	2	0.646	3	0.246	6	0.556	4
L	3	0.50	0.15	0.15	0.20	1.00	0.915	1	0.395	5	0.875	2	0.691	3	0.216	6	0.605	4
M	4	0.50	0.05	0.15	0.30	1.00	0.890	1	0.491	5	0.854	2	0.602	3	0.277	6	0.507	4
N	5	0.50	0.05	0.30	0.15	1.00	0.890	1	0.491	5	0.854	2	0.602	3	0.277	6	0.507	4
O	6	0.25	0.25	0.25	0.25	1.00	0.878	1	0.529	4	0.861	2	0.558	3	0.308	6	0.475	5
P	7	0.20	0.10	0.40	0.30	1.00	0.829	1	0.719	3	0.822	2	0.381	5	0.431	4	0.282	6
Q	8	0.15	0.10	0.45	0.30	1.00	0.817	1	0.765	3	0.815	2	0.337	5	0.462	4	0.236	6
R	9	0.50	0.05	0.20	0.25	1.00	0.890	1	0.491	5	0.854	2	0.602	3	0.277	6	0.507	4

(Note that since the calculation methods are the same for all four systems; the detail calculation descriptions provided in Section 7.3.1 are not repeated for the multi criteria analysis of the Sabie, Crocodile and Komati River systems. The descriptions for these systems focus on the discussion and interpretation of the results.)

7.3.2 Sabie River system

The scenario scores for the four variables, Ecology, Ecosystem Services, Economy and Employment are presented graphically in Figure 7.4.

The four individual graphs shown in Figure 7.4 have the following interpretation:

- **Ecological Status relative to REC:** This is the measure of how each scenario's ecological status is ranked relative to the REC. As indicated **Sc S32** has the lowest ecological score while **Sc6** the highest. **Sc S1** and **S32** is where no releases are made from Inyaka Dam towards the ecology.
- **Ecosystem Services:** The score indicates to what extent each scenario changes the Ecosystem Services relative to the Present Day or PES conditions. The ranking follows largely the same ranking order as that for the ecological status. In comparison to the Ecological Status, Sc S6 is lower relative to Sc S31 due to the impact on the Marite River. There are no impacts on the Sabie River.
- **Economic Indicator (GDP):** This metric represents GDP in Rand with **Sc S32** ranking the highest and **ScS31** the lowest.
- **Employment:** The number of people employed follows the same relative ranking position as the economic indicator.

The relative weight applied to each variable for calculating the overall ranking is indicated numerically at the bottom of each bar graph.

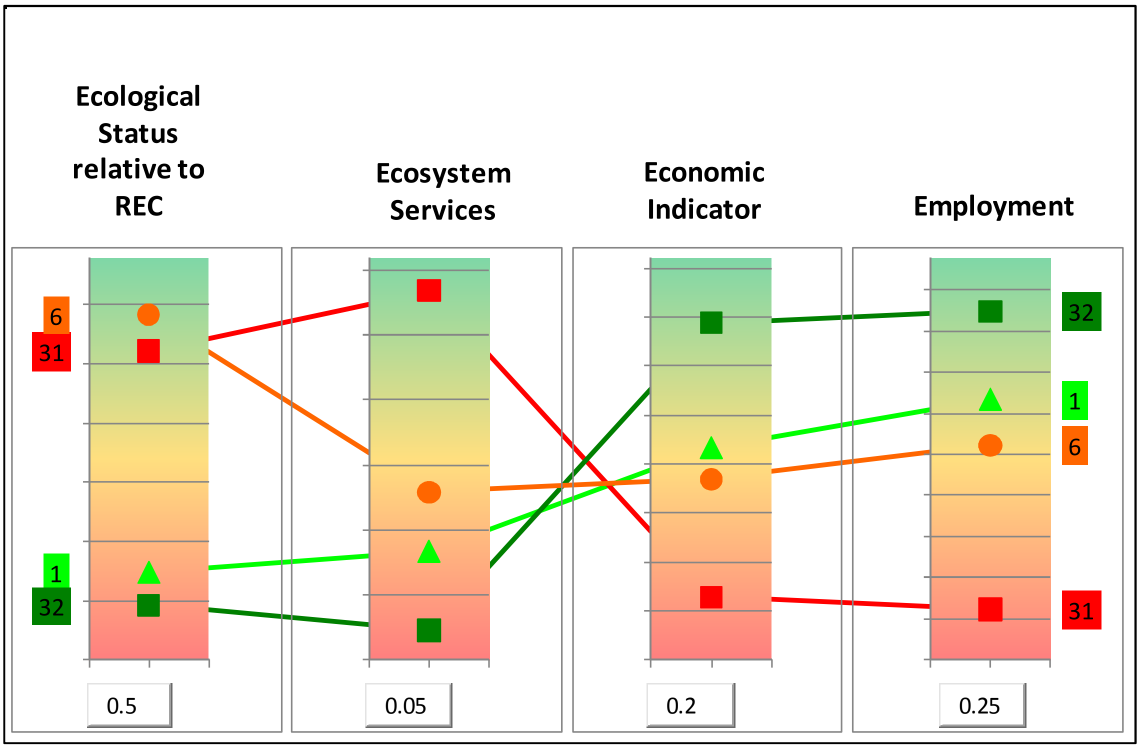


Figure 7.4 Sabie River system: Graphical results of the four variables and all scenarios

The integrated ranking of the scenarios are presented graphically in Figure 7.5, with both methods showing Sc6 has the highest rank. Further consideration of the implication of the scenarios therefore needs to be taken into account to select the preferred scenario – see description at the end of this section.

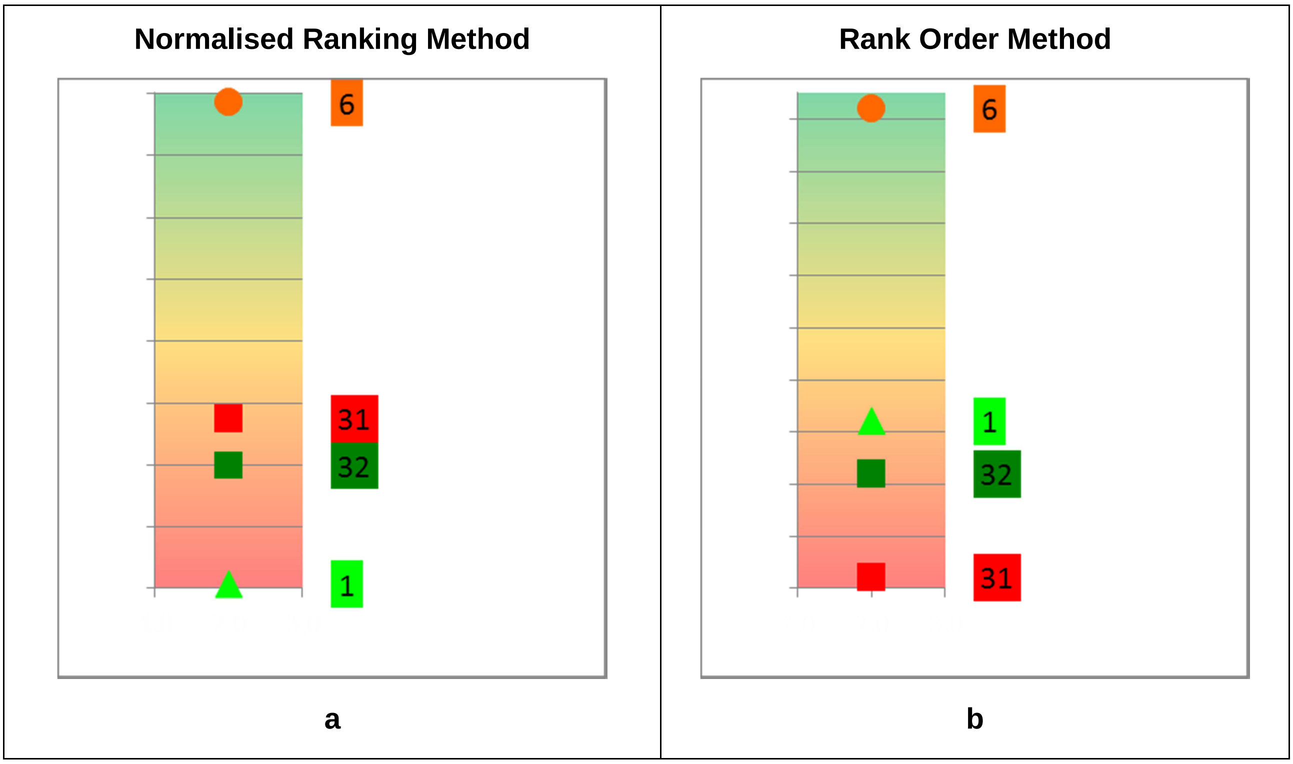


Figure 7.5 Sabie River system: Graphical results of overall ranking from the multi-criteria analysis (both ranking methods)

The integrated ranking calculations which give rise to the ranking order shown in Figure 7.5 are presented in Table 7.3.

In order to determine how sensitive the ranking results are for alternative weight settings, Table 7.4 provides scenario ranking results for a range of variable weights. Nine alternative weight settings were evaluated labelled as such in the column with the heading "**Alternatives**". The weights are as presented in **Columns *a*** to **d**, with **Column *e*** showing the sum of the weights which must be one.

Both the scores and the rank order (pairs of results) for the scenarios are provided in **Columns *f*** to ***m***. The results for the Rank Order Method are presented in **Rows *A*** to ***I*** while the results for the Normalisation Method is shown in **Rows *J*** to ***R***. Note that the same alternative weight settings are applied for the alternatives with the same number.

It can be observed that for both ranking methods seven out of the nine alternatives indicating Sc S6 is the best.

Discussion on the rationale for selecting the preferred scenario

Figure 7.4 show that Sc S31 and S32 represent the "extreme" cases where either the ecological protection or the socio-economic benefits is respectively the best or worst. Scenario S6 was therefore formulated as a "compromise" where the growth in water needs for rural/urban areas are supplied from the Sand River system in order to improve the ecological conditions of Sc S32 towards achieving the REC. Scenario S6 therefore represents the case where a balance is achieved between the need to supply growing water requirements for socio-economic activities while still providing protection of the ecology.

Scenario S6 in the Sabie implies that additional water for growth in water use in the urban domestic sector needs to be sourced and the proposed New Forest Dam (see description of Sc S71) in the Sand River system serves as a solution to make more water available.

Scenario S6 is therefore proposed as the preferred choice to achieve a balance between ecological protection and use for the Sabie River system.

Implications of selection of Sc S6 in the Sabie and Sc S72 in the Sand systems can be summarised as follows:

a. The ecology is almost achieving the REC in the Sabie.
b. Utility is lost in terms of Ecosystem Services in the Sabie (Sc S6 is lower compared to Sc S31).
c. The New Forest Dam will provide for the growth in the rural / urban areas and release water to supply REC at EWR 6 and8.
d. Wastewater management in the form of Waste Water Treatment Works needs to be implemented.
e. In other words the choice of scenarios aims to, protect the Sabie and offset the implications of the New Forest Dam by also providing base flow from wastewater discharges.
f. Items c and d will take time to implement – therefore the Sabie’s ecology will be below the selected protection level for the next 5 to 10 years.
g. A fall back option is to develop groundwater resources to support growth. Detail analysis need to be carried out to determine the implications of groundwater abstraction on base flow and the target EWR depicted by the selected scenario.

Table 7.3 Sabie River system: Integrated ranking calculations for the two ranking methods

Row	Description	Parameters		Scenarios: 1	31	32	6
	a	b	c	d	e	f	g
	Variable Scores:						
		Highest	*Lowest*				
A	Ecological Status	0.97	0.92	0.92	0.96	0.92	0.97
B	Ecosystem Services	1.01	0.91	0.93	1.01	0.91	0.95
C	Economic Indicator (GDP) (R Millions)	1339	1283	1313.61	1283.07	1339.06	1307.19
D	Employment	12976	12250	12761.54	12250.08	12976.49	12650.00
	Rank Order Method:						
	Ranked order of variables (6 = higest, 1 = lowest, equals = average):						
E	Ecological Status			2.0	3.0	1.0	4.0
F	Ecosystem Services			2.0	4.0	1.0	3.0
G	Economic Indicator (GDP) (R Millions)			3.0	1.0	4.0	2.0
H	Employment			3.0	1.0	4.0	2.0
I	Total:			**10.0**	**9.0**	**10.0**	**11.0**
J	Rank (1 = best, 4 = worsed)			**2.5**	**4**	**2.5**	**1**
	Rank order x Weights:	Weights					
K	Ecological Status	0.50		1.00	1.50	0.50	2.00
L	Ecosystem Services	0.05		0.10	0.20	0.05	0.15
M	Economic Indicator (GDP) (R Millions)	0.20		0.60	0.20	0.80	0.40
N	Employment	0.25		0.75	0.25	1.00	0.50
O	**Total:**			**2.450**	**2.150**	**2.350**	**3.050**
P	**Rank (1 = best, 4 = worsed)**			**2**	**4**	**3**	**1**
	Normalisation Method:						
	Normilized (0 = minimum, 1 = maximum):						
Q	Ecological Status			0.114	0.875	0.000	1.000
R	Ecosystem Services			0.233	1.000	0.000	0.407
S	(R Millions)			0.545	0.000	1.000	0.431
T	Employment			0.704	0.000	1.000	0.551
U	Total:			**1.596**	**1.875**	**2.000**	**2.388**
V	Rank (1 = best, 4 = worsed)			4	3	2	1
	Normiliaed x Weights:	Weights					
W	Ecological Status	0.50		0.057	0.438	0.000	0.500
X	Ecosystem Services	0.05		0.012	0.050	0.000	0.020
Y	Economic Indicator (GDP) (R Millions)	0.20		0.109	0.000	0.200	0.086
Z	Employment	0.25		0.176	0.000	0.250	0.138
AA	Total:			**0.354**	**0.488**	**0.450**	**0.744**
AB	**Rank (1 = best, 4 = worsed)**			**4**	**2**	**3**	**1**
AC	**Overall Score (Rank Order method)**			2.45	2.15	2.35	3.05
AD	Rank (1 = best, 4= worsed)			**2**	**4**	**3**	**1**
AE	**Overall Score (Normalisation Method)**			0.353743279	0.487699246	0.45	0.74414921
AF	Rank (1 = best, 4 = worsed)			**4**	**2**	**3**	**1**

Table 7.4 Sabie River system: Sensitivity analysis of scenario ranking for alternative variable weights

Row	Alternative	Weighs					Scenarios							
							1		31		32		6	
		Ecological	Ecosystem Services	Economy (GDP)	Employment	Total	Score	Rank	Score	Rank	Score	Rank	Score	Rank
		a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*
		Rank Order Method:												
A	**1**	**0.50**	**0.05**	**0.20**	**0.25**	**1.00**	**2.450**	**2**	**2.150**	**4**	**2.350**	**3**	**3.050**	**1**
B	2	0.50	0.10	0.20	0.20	1.00	2.400	2	2.300	3	2.200	4	3.100	1
C	3	0.50	0.15	0.15	0.20	1.00	2.350	3	2.450	2	2.050	4	3.150	1
D	4	0.50	0.05	0.15	0.30	1.00	2.450	2	2.150	4	2.350	3	3.050	1
E	5	0.50	0.05	0.30	0.15	1.00	2.450	2	2.150	4	2.350	3	3.050	1
F	6	0.25	0.25	0.25	0.25	1.00	2.500	2.5	2.250	4	2.500	2.5	2.750	1
G	7	0.20	0.10	0.40	0.30	1.00	2.700	2	1.700	4	3.100	1	2.500	3
H	8	0.15	0.10	0.45	0.30	1.00	2.750	2	1.600	4	3.250	1	2.400	3
I	9	0.50	0.05	0.20	0.25	1.00	2.450	2	2.150	4	2.350	3	3.050	1
		Normalise Method:												
J	**1**	**0.50**	**0.05**	**0.20**	**0.25**	**1.00**	**0.354**	**4**	**0.488**	**2**	**0.450**	**3**	**0.744**	**1**
K	2	0.50	0.10	0.20	0.20	1.00	0.330	4	0.538	2	0.400	3	0.737	1
L	3	0.50	0.15	0.15	0.20	1.00	0.315	4	0.588	2	0.350	3	0.736	1
M	4	0.50	0.05	0.15	0.30	1.00	0.362	4	0.488	2	0.450	3	0.750	1
N	5	0.50	0.05	0.30	0.15	1.00	0.338	4	0.488	2	0.450	3	0.732	1
O	6	0.25	0.25	0.25	0.25	1.00	0.399	4	0.469	3	0.500	2	0.597	1
P	7	0.20	0.10	0.40	0.30	1.00	0.475	3	0.275	4	0.700	1	0.578	2
Q	8	0.15	0.10	0.45	0.30	1.00	0.497	3	0.231	4	0.750	1	0.550	2
R	9	0.50	0.05	0.20	0.25	1.00	0.354	4	0.488	2	0.450	3	0.744	1

7.3.3 Komati River system

The scenario scores for the four variables, Ecology, Ecosystem Services, Economy and Employment are presented graphically in Figure 7.6.

The four individual graphs shown in Figure 7.6 have the following interpretation:

- **Ecological Status relative to PES:** This is the measure of how each scenario's ecological status is ranked relative to the PES. As indicated the scores of the scenarios form two groups with Sc K1, K2, K31 and K41 higher than Sc K5, K32, K42 and K43. The difference between the two groups is due to the ecological consequences in the Lomati River, while all the scores on the Komati River for all the scenarios are the same (The group with the higher score results in an EC of a C in the Lomati River while the lower score group has an EC of a C/D).

  The reason for the lower scores is that there are higher base flows in the Lomati River for those scenarios because of higher releases to supply downstream water needs. It may however be possible to implement certain mitigation measures for the lower scoring group to improve the EC which indicate the selection of the preferred scenario is primarily based on the socio-economic benefits attainable in the scenario.

  It should further be noted that the Water Resource Class for the Lomati River catchment (IUA X1-8) is III (Heavily used) for both the scenario sets and therefore a choice of any scenario will result in same Water Resource Class being selected.
- **Ecosystem Services:** The score indicates to what extent each scenario changes the Ecosystem Services relative to the PES conditions. The scoring results show that there is no distinction among the scenarios.
- **Economic Indicator (GDP):** This metric represents GDP in Rand with Sc K42 ranking the highest and Scenario 31 the lowest.
- **Employment:** The number of people employed is the highest for Sc K6 and the lowest for Sc K31. Scenario K6 ranks the highest due to increased irrigation made possible by the proposed Silingane Dam, however Sc K6 does not have the highest economic score due to the cost of the dam being prohibited.

The relative weight applied to each variable for calculating the overall ranking is indicated numerically at the bottom of each bar graph.

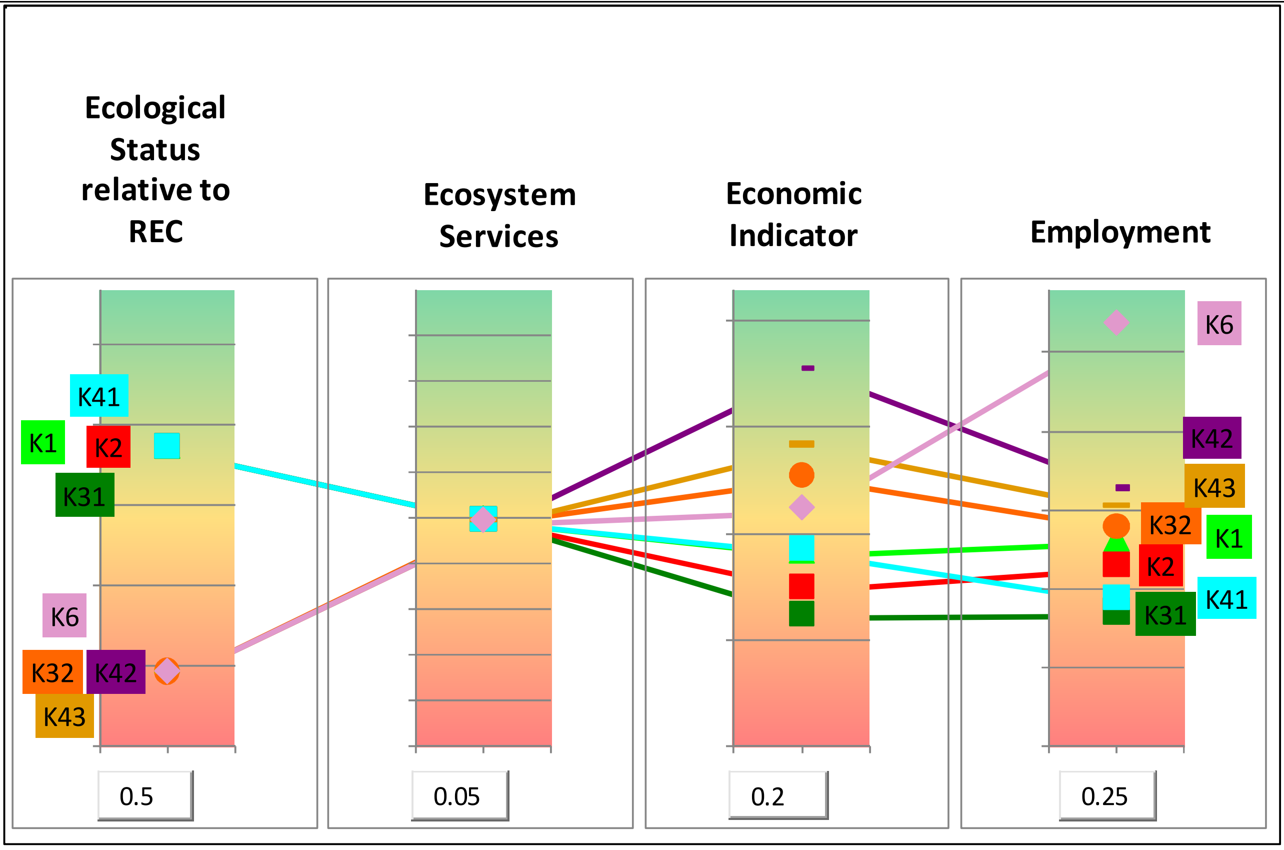


Figure 7.6 Komati River system: Graphical results of the four variables and all scenarios

Based on the discussion in the previous paragraphs the selection of a scenario rely primarily on the best socio-economic outcome therefore the integrated ranking of the scenarios with the ecology included are of limited importance in the case of the Komati River system. For completeness, Figure 7.7 provides the integrated raking by applying all the variables while of the ranking of the scenarios when only considering the socio-economic variables are presented in Figure 7.8 from which the following can be deduced.

Scenarios K42 and K6 rank the highest among the scenarios with both having similar scores. Sc K6 has the highest employment score (see Figure 7.6) while Sc K42 the highest economic score. The selection of either scenario for the purpose of classification would result in the same Water Resource Class and set of ECs for the biophysical nodes in the system.

It can therefore be concluded that for the Komati River system the Water Resource Class and the set of ECs for the biophysical nodes is not sensitive to the range of scenarios that were evaluated and analysed.

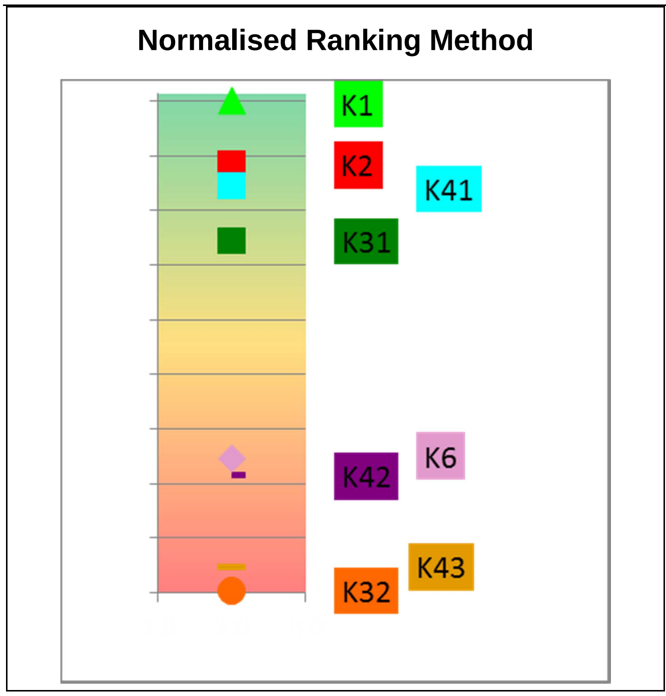


Figure 7.7 Komati River system: Graphical results of overall ranking (all variables) from the multi-criteria analysis)

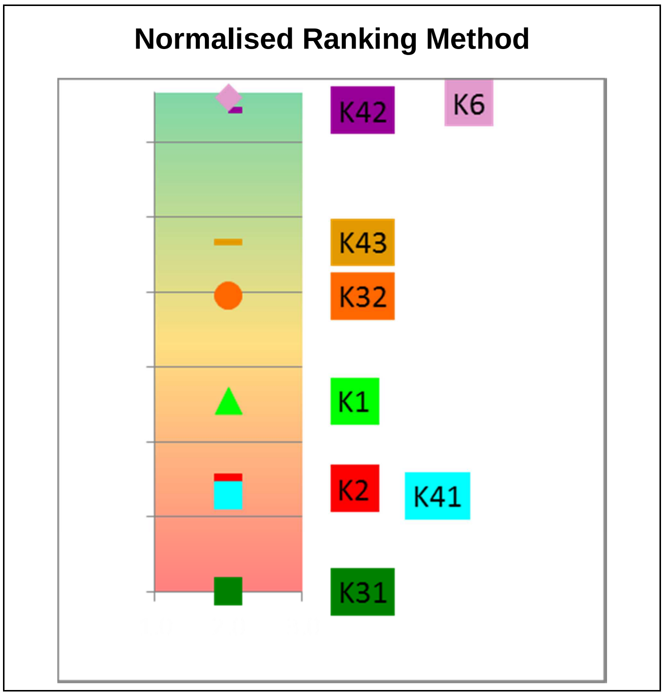


Figure 7.8 Komati River system: Graphical ranking results only considering socio-economic variables

7.3.4 Crocodile River system

The scenario scores for the four variables, Ecology, Ecosystem Services, Economy and Employment are presented graphically in Figure 7.9.

The four individual graphs shown in Figure 7.9 have the following interpretation:

- **Ecological Status relative to PES:** This is the measure of how each scenario's ecological status is ranked relative to the REC. As indicated Sc C72 has the lowest ecological scores while Sc C61 the highest.

- **Ecosystem Services:** The score indicates to what extent each scenario changes the Ecosystem Services relative to the PES conditions. The ranking follows largely the same ranking order as that for the ecological status.
- **Economic Indicator (GDP):** This metric represents GDP in Rand with Sc C72 ranking the highest and Sc C4 the lowest.
- **Employment:** The number of people employed follows the same relative ranking position as the economic indicator.

The relative weight applied to each variable for calculating the overall ranking is indicated numerically at the bottom of each bar graph.

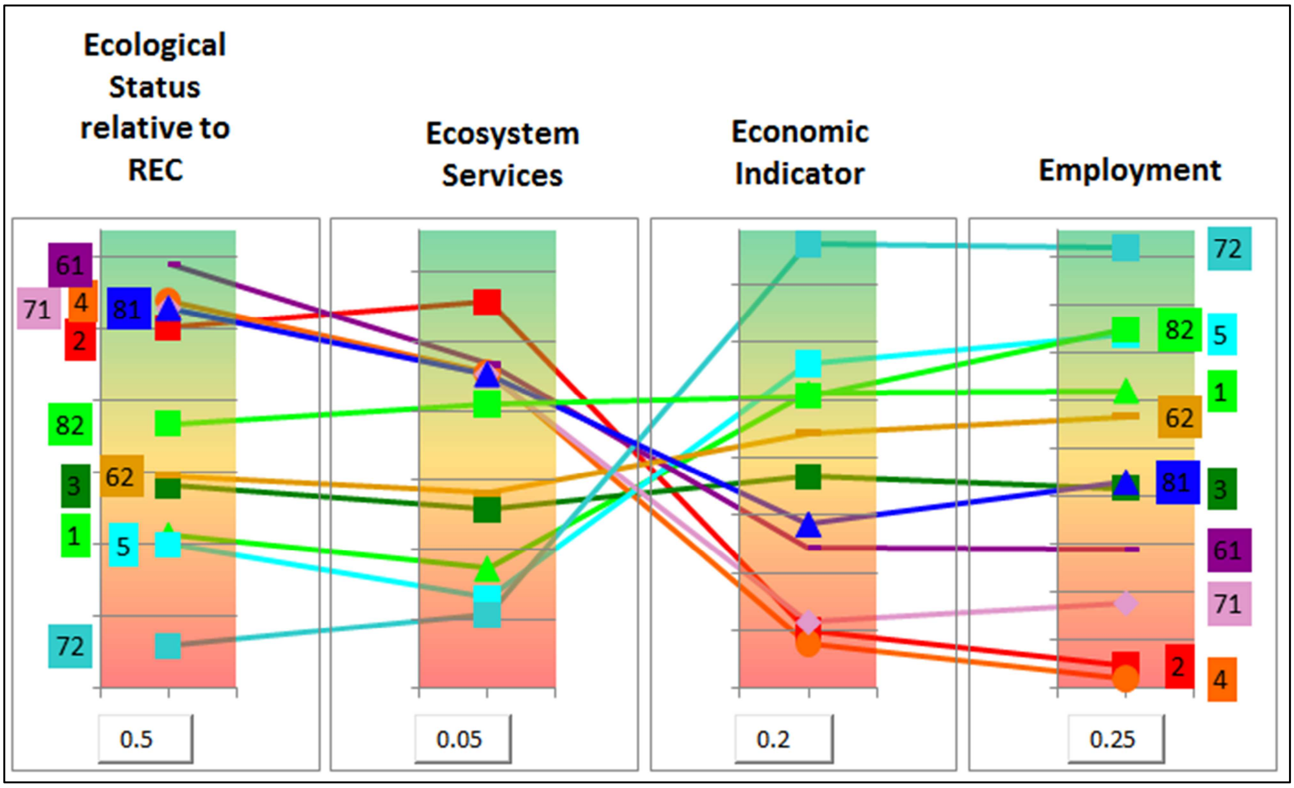


Figure 7.9 Crocodile River system: Graphical results of the four variables and all scenarios

The integrated ranking of the scenarios are presented graphically in Figure 7.10, with both ranking methods showing Sc C61 has the highest rank. The Normalised Ranking Method is preferred in the case of the Crocodile where there are groups of scenarios with similar scores for the variables and the Rank Order Methods would over emphasise the differences.

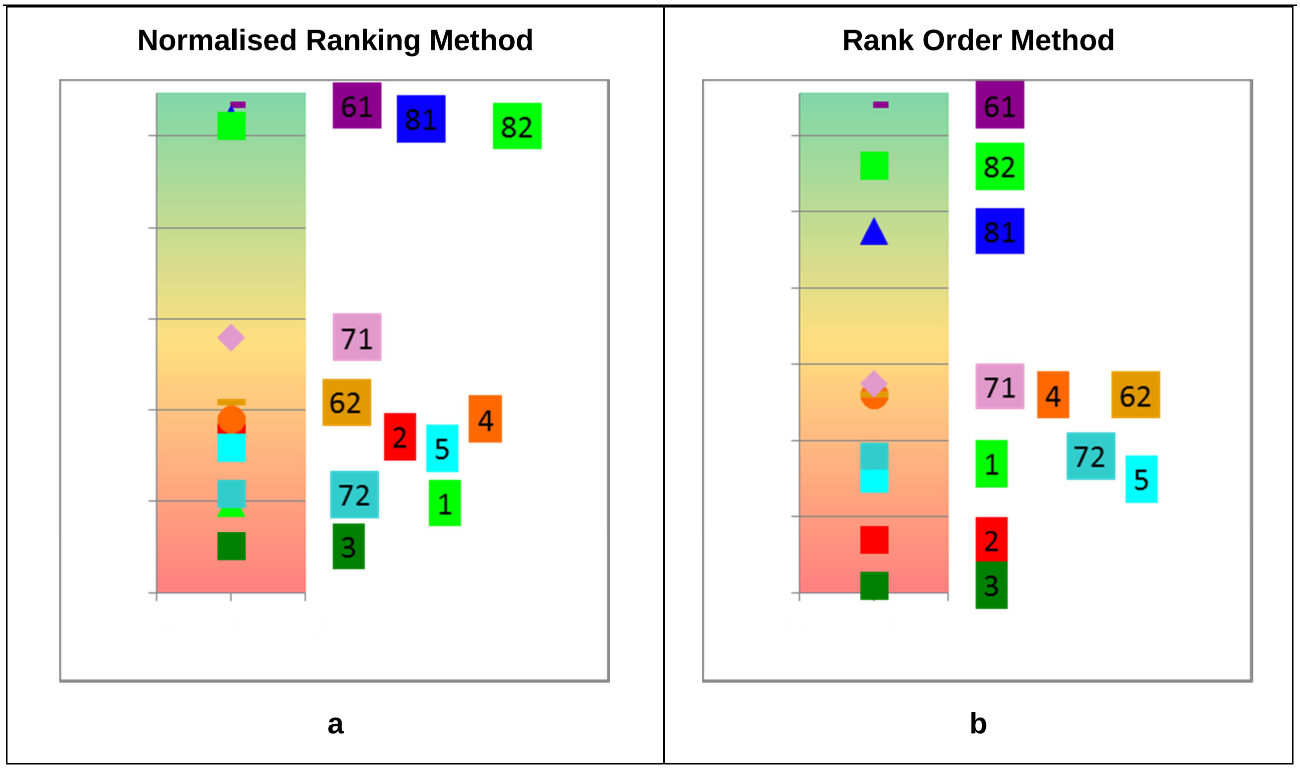


Figure 7.10 Crocodile River system: Graphical results of overall ranking from the multi-criteria analysis (both ranking methods)

The integrated ranking calculations which give rise to the ranking order shown in Figure 7.10 are presented in Table 7.7.

In order to determine how sensitive the ranking results are for alternative weight settings Table 7.8 provides scenario ranking results for a range of variable weights. Twenty seven alternative weight options were evaluated labelled as such in the column with the heading "**Nr**". The weights for the four variables are as presented in the columns under the heading "Alternative Weights". The rank order of the scenarios are presented under the columns with the heading "Scenarios and Ranking Order" for each of the scenarios analysed.

The first two alternative weight options, where the weight for the ecology is 0.15 and 0.20 respectively results in Sc C72 ranking first. Scenario C72 is an outlier scenario and therefore will not be selected as an option providing a balance results.

The alternatives 3 to 14 result in Sc C82 ranking first with the range of ecological weights from 0.25 up to 0.48.

Alternatives 15 and 16 also have weights of 0.48 for the ecology, however, due to changes in the weights of economy and employment the first raking is Sc C61 as well as for the remainder of the alternatives.

This implies that the outcome of the multi criteria analysis is sensitive to the weights with either Sc C82 or Sc C61 raking first.

Discussion and synthesis of results

Given that Sc C82 and C61 (also Sc C81) is similar for the Normalised Ranking Method (see Figure 7.10) the following should be considered. There is a large advantage in the socio-economic variable scores for Sc C82 compared to Sc C61 (see Figure 7.9), while the ecology is maintained at a levels slightly above the Present Ecological State (as represented by Sc C1). This implies Sc C82 is an improvement for both the ecology and socio-economics compared to current conditions (Sc C1) while Sc C61 only improves the ecology.

A further aspect to consider is that the ecological score for Sc C61 is the highest for all the scenarios and as such represents an “extreme” option and not a balanced outcome.

It is therefore proposed that Sc C82 be selected as the preferred scenario for the long term future.

Scenario C82 incorporates both the future development options (Mountain View and Boschjeskop dams), which have the risk that it will be a long time before both dams are developed. Sc C62 (includes only Mountain View Dam) is therefore proposed as the scenario to be aimed at over the medium term future since Mountain View Dam has a higher probability of being developed.

Over the short term the selection is between Sc C1 and Sc C3. Scenario C3 includes additional water for Mozambique, makes releases towards improving the current ecological conditions as well as allows for growth in domestic water supply and is therefore proposed for the preferred scenarios for the short term.

All three proposed scenarios (Sc C3, C62 and C82) are where the “PES” releases are the target EWR and allow progressive improvements in both the ecological health as well as the socio-economic conditions in future.

Table 7.5 Crocodile River system: Integrated ranking calculations for the two ranking methods

Row	Description	Parameters		Scenarios: 1	2	3	4	5	61	62	71	72	81	82
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*
	Variable Scores:													
		Highest	*Lowest*											
A	Ecological Status	0.97	0.86	0.89	0.95	0.91	0.96	0.89	0.97	0.91	0.96	0.86	0.96	0.92
B	Ecosystem Services	1.04	0.99	1.00	1.04	1.01	1.03	0.99	1.03	1.01	1.03	0.99	1.03	1.02
C	Economic Indicator (GDP) (R Millions)	5040.63	3655.75	4522	3699	4235	3656	4626	3988	4384	3729	5041	4069	4513
D	Employment	38167	29206	35197	29473	33167	29206	36377	31888	34653	30772	38167	33294	36475
	Rank Order Method:													
	Ranked order of variables (11 = higest, 1 = lowest, equals = average):													
E	Ecological Status			3.0	7.0	4.0	10.0	2.0	11.0	5.0	8.5	1.0	8.5	6.0
F	Ecosystem Services			3.0	11.0	4.0	9.0	2.0	10.0	5.0	7.5	1.0	7.5	6.0
G	Economic Indicator (GDP) (R Millions)			9.0	2.0	6.0	1.0	10.0	4.0	7.0	3.0	11.0	5.0	8.0
H	Employment			8.0	2.0	5.0	1.0	9.0	4.0	7.0	3.0	11.0	6.0	10.0
I	Total:			**23.0**	**22.0**	**19.0**	**21.0**	**23.0**	**29.0**	**24.0**	**22.0**	**24.0**	**27.0**	**30.0**
J	Rank (1 = best, 11 = worsed)			**6.5**	**8.5**	**11**	**10**	**6.5**	**2**	**4.5**	**8.5**	**4.5**	**3**	**1**
	Rank order x Weights:	Weights												
K	Ecological Status	0.50		1.50	3.50	2.00	5.00	1.00	5.50	2.50	4.25	0.50	4.25	3.00
L	Ecosystem Services	0.05		0.15	0.55	0.20	0.45	0.10	0.50	0.25	0.38	0.05	0.38	0.30
M	Economic Indicator (GDP) (R Millions)	0.20		1.80	0.40	1.20	0.20	2.00	0.80	1.40	0.60	2.20	1.00	1.60
N	Employment	0.25		2.00	0.50	1.25	0.25	2.25	1.00	1.75	0.75	2.75	1.50	2.50
O	**Total:**			**5.450**	**4.950**	**4.650**	**5.900**	**5.350**	**7.800**	**5.900**	**5.975**	**5.500**	7	7
P	**Rank (1 = best, 11 = worsed)**			**8**	**10**	**11**	**5.5**	**9**	**1**	**5.5**	**4**	**7**	**3**	**2**
	Normalisation Method:													
	Normilized (0 = minimum, 1 = maximum):													
Q	Ecological Status			0.291	0.835	0.421	0.905	0.265	1.000	0.447	0.886	0.000	0.886	0.583
R	Ecosystem Services			0.148	1.000	0.336	0.772	0.052	0.801	0.388	0.769	0.000	0.769	0.672
S	(R Millions)			0.626	0.031	0.418	0.000	0.700	0.240	0.526	0.053	1.000	0.298	0.619
T	Employment			0.669	0.030	0.442	0.000	0.800	0.299	0.608	0.175	1.000	0.456	0.811
U	Total:			**1.7**	**1.9**	**1.6**	**1.7**	**1.8**	**2.3**	**2.0**	**1.9**	**2.0**	2.4	2.7
V	Rank (1 = best, 11 = worsed)			9	6	11	10	8	3	5	7	4	2	1
	Normiliaed x Weights:	Weights												
W	Ecological Status	0.50		0.145	0.418	0.211	0.452	0.133	0.500	0.224	0.443	0.000	0.443	0.291
X	Ecosystem Services	0.05		0.007	0.050	0.017	0.039	0.003	0.040	0.019	0.038	0.000	0.038	0.034
Y	Economic Indicator (GDP) (R Millions)	0.20		0.125	0.006	0.084	0.000	0.140	0.048	0.105	0.011	0.200	0.060	0.124
Z	Employment	0.25		0.167	0.007	0.110	0.000	0.200	0.075	0.152	0.044	0.250	0.114	0.203
AA	Total:			**0.445**	**0.481**	**0.421**	**0.491**	**0.475**	**0.663**	**0.500**	**0.536**	**0.450**	**0.655**	**0.651**
AB	**Rank (1 = best, 11 = worsed)**			**10**	**7**	**11**	**6**	**8**	**1**	**5**	**4**	**9**	**2**	**3**
				1	2	3	4	5	61	62	71	72	81	82
AC	**Overall Score (Rank Order method)**			5.45	4.95	4.65	5.90	5.35	7.80	5.90	5.98	5.50	6.98	7.40
AD	Rank (1 = best, 11 = worsed)			**8**	**10**	**11**	**5.5**	**9**	**1**	**5.5**	**4**	**7**	**3**	**2**
AE	**Overall Score (Normalisation Method)**			0.4452	0.4814	0.4215	0.4910	0.4753	0.6628	0.5002	0.5359	0.4500	0.6553	0.6515
AF	Rank (1 = best, 11 = worsed)			**10**	**7**	**11**	**6**	**8**	**1**	**5**	**4**	**9**	**2**	**3**

Table 7.6 Crocodile River system: Sensitivity analysis of scenario ranking for alternative variable weights

Nr	Alternative Weights:				Scenario and Ranking Order										
	Ecological	Ecosystem Services	Economy (GDP)	Employment	1	2	3	4	5	61	62	71	72	81	82
1	0.15	0.10	0.45	0.30	4	10	8	11	3	7	5	9	**1**	6	2
2	0.20	0.10	0.40	0.30	4	10	8	11	3	7	5	9	**1**	6	2
3	0.25	0.25	0.25	0.25	9	6	11	10	8	3	5	7	4	2	**1**
4	0.25	0.25	0.25	0.25	9	6	11	10	8	3	5	7	4	2	**1**
5	0.30	0.05	0.30	0.35	7	10	8	11	3	6	5	9	2	4	**1**
6	0.35	0.05	0.25	0.35	7	10	8	11	5	4	6	9	2	3	**1**
7	0.40	0.05	0.25	0.30	7	10	9	11	5	3	6	8	4	2	**1**
8	0.45	0.05	0.20	0.30	8	10	11	9	5	3	4	6	7	2	**1**
9	0.45	0.05	0.22	0.28	8	10	11	9	5	3	4	7	6	2	**1**
10	0.45	0.05	0.28	0.22	8	10	11	9	6	2	4	7	5	3	**1**
11	0.45	0.05	0.30	0.20	8	10	11	9	6	2	4	7	5	3	**1**
12	0.45	0.05	0.32	0.18	8	10	11	9	6	2	5	7	4	3	**1**
13	0.48	0.05	0.22	0.25	10	9	11	7	6	2	5	4	8	3	**1**
14	0.48	0.05	0.25	0.22	10	9	11	7	6	2	5	4	8	3	**1**
15	0.48	0.05	0.30	0.17	10	9	11	7	6	**1**	5	4	8	3	2
16	0.48	0.05	0.35	0.12	10	9	11	6	7	**1**	5	4	8	3	2
17	0.50	0.05	0.15	0.30	10	7	11	6	8	**1**	5	4	9	2	3
18	*0.50*	*0.05*	*0.20*	*0.25*	*10*	*7*	*11*	*6*	*8*	***1***	*5*	*4*	*9*	*2*	*3*
19	0.50	0.05	0.30	0.15	10	7	11	6	8	**1**	5	4	9	2	3
20	0.50	0.10	0.20	0.20	9	5	10	6	8	**1**	7	4	11	2	3
21	0.50	0.15	0.15	0.20	10	5	8	6	9	**1**	7	4	11	2	3

8 WATER RESOURCE CLASSES & CATCHMENT CONFIGURATION

8.1 WATER RESOURCE CLASS CRITERIA TABLE

A range of alternative water resource criteria settings (alternative to the guideline criteria presented in Table 2.7) were evaluated by the study team leading to the recommended criteria parameters presented in Table 8.1.

Table 8.1 Recommended Water Resource Class criteria table

		% EC representation at units represented by biophysical nodes in an IUA				
		≥ A/B	≥ B	≥C	≥ D	< D
Class I		0	60	80	95	5
Class II			0	70	90	10
Class III	**Either**			0	80	20
	Or				100	

The above table was applied to the three secondary systems and the resulting Water Resource Classes and catchment configuration are provided in the next sections.

These Water Resource Classes and catchment configuration results are the recommendations that will be presented at the Project Steering Committee Meeting to be held in November 2014 for comments after which the final scenario and results will be prepared for gazetting.

8.2 KOMATI RIVER SYSTEM

8.2.1 Komati River system Water Resource Class

When applying the criteria presented in Table 8.1 to the resulting ECs for each scenario, the Water Resource Classes for the 10 IUAs in the Komati River system are as listed in Table 8.2.

Table 8.2 Komati River system: Resulting IUA Water Resource Classes for each scenario

IUA	Scenarios and Water Resource Class									
	PES	REC	K1	K2	K31	K32	K41	K42	K43	K6
X1-1	II	II	II	II	II	II	II	**II**	II	II
X1-2	II	II	II	II	II	II	II	**II**	II	II
X1-3	II	II	II	II	II	II	II	**II**	II	II
X1-4	III	III	III	III	III	III	III	**III**	III	III
X1-5	II	I	II	II	II	II	II	**II**	II	II
X1-6	II	I	I	I	I	I	I	**I**	I	I
X1-7	II	I	II	II	II	II	II	**II**	II	II
X1-8	III	II	III	III	III	III	III	**III**	III	III
X1-9	III	III	III	III	III	III	III	**III**	III	III
X1-10	XXX	III	XXX	XXX	XXX	XXX	XXX	**XXX**	XXX	XXX

Following on from the selection of Sc K42 as the preferred future scenario for the Komati River system, the embossed column in Table 8.2 gives the recommended Water Resource Classes. The results for IUA 10 indicated by "XXX" imply that these scenarios did not comply with the criteria for a Class III. This is due to a large portion of the river reach length in EC D, D/E or E (mostly due to inundation and the significant number of weirs) and therefore not complying with the criteria set in Table 8.1.

Acknowledging that Sc 42 represents a medium to long term situation, the following recommendations (Table 8.3) were made:

Recommendation: Water Resource Classes for the Komati River System

The Water Resource Classes that are recommended to be immediately applicable are set to maintain the current ecological state and operation of the main river systems (Komati and Lomati Rivers). Some non-flow related improvements are required in tributaries to improve the ecological state based on the ecological importance. Ecological improvements in the Lomati River downstream of Driekoppies Dam were investigated. This can however only be achieved by substantially changing the water release patterns of Driekoppies Dam resulting in significant socio-economic impacts. These ecological improvements were therefore considered to be unrealistic. There are therefore no implications for any users under this recommended present day scenario.

The WRC for a future scenario that has been tested and selected as the recommended future scenario (Sc K42 - see description below) is also provided. This scenario is based on the best economic scenario as the ecological state will be maintained, i.e. it will not change from the above immediate scenario. This scenario includes the implementation of increased cross border flows (as documented in the IIMA agreement) and allows for the reinstatement of fallow irrigation as suggested by DARDLA. It furthermore allows for domestic growth up to the year 2030. There are no negative implications of this scenario economically when viewed as a whole (GDP shows a 2.3% increase and job gains are 1.6% above present). Due to providing water for domestic growth, Swaziland making full use of their allocation, the irrigation associated with DARDLA and the cross border flows, there will be a reduction of the assurance of supply in irrigation downstream of Swaziland supplied from the Maguga and Driekoppies dams.

Sc K42 consists of the following:

- Providing water for domestic growth.
- Uptake of unutilised irrigation allocations upstream (6.6million m^3/annum and 8.8 million m^3/annum downstream of Swaziland through the intervention of DARDLA.
- Provision of IIMA flows.

Table 8.3 Komati River system: Recommended Water Resource Classes for each IUA

Green - immediately applicable
Blue - applicable in the medium to long term.

IUA (EWR site)	PES	REC	K42
X1-1	II	**II**	**II**
X1-2	II	**II**	**II**
X1-3 (K1)	II	**II**	**II**
X1-4 (G1)	III	**III**	**III**
X1-5 (K2)	II	**II**	**II**
X1-6 (T1)	II	**I**	**I**
X1-7	**II**	I	**II**
X1-8 (L1)	**III**	II	**III**
X1-9 (K3)	III	**III**	**III**
X1-10	XXX	**III**	**III**

8.2.2 Komati River system Catchment Configuration

Given the results and scenario selections presented in the section above, Table 8.4 provides respectively the proposed Water Resource Class and ECs for the IUAs and biophysical nodes for the Komati River system.

It must be noted that various nodes require improvements based on non flow-related/anthropogenic issues that have to be addressed. Where it is deemed that the REC is attainable, it has been included in the scenario configuration (Table 8.4).

Table 8.4 Komati River system nodes requiring improvements

IUA	Nodes	River	PES	REC	Comment
X1-1	X11B-01272	Boesmanspruit	C	B/C	Very difficult to achieve the REC. Many variables will have to drop and the presence of the Boesmanspruit Dam is irreversible. Probably also difficult to release water from the dam. Without changes to the flow regime, improvement is unlikely.
X1-2	X11G-01188	Ndubazi	B/C	B	Better forestry management is needed and an improved riparian buffer zone to achieve the REC. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X1-3	X11E-01237	Swartspruit	C	B	Catchment management to control erosion and remove aliens – this will decrease sedimentation. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X1-6	X12A-01305	Buffelspruit	C	B	Reinstate buffer zone to achieve the REC. Will have to significantly improve riparian vegetation to get to a B. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X1-6	X12D-01235	Seekoeispruit	C	B/C	To achieve the REC, most metrics will have to improve to a 1. This is very difficult as overall catchment management is required. It is not likely that the REC is attainable and therefore the PES has to be maintained.
X1-6	X12K-01333	Mlondozi	C	B/C	Improved water quality is needed to achieve the REC. Note, top sections of the river is in a B EC. If riparian vegetation can also be improved a B EC can be achieved. The aim is to achieve the B/C. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X1-7	X14A-01173	Lomati	B/C	B	This SQ ends in Swaziland which consists of the most impacted area. If one does not consider this area, the river reach in SA will already be a B EC.
X1-7	X14B-01166	Ugutugulo	C	B/C	Removal of alien vegetation is needed to achieve the REC as well as an improvement in the riparian zone buffer. However improvement in flow is also needed (EWR releases from dam) and water quality. It is not likely that the REC is attainable and therefore the PES has to be maintained.
X1-10	X13K-01038	Komati	E	E	The major impacts are linked to inundation and barriers and improvement is impossible.
X1-10	X13L-01027	Komati	E	E	The major impacts are linked to inundation and barriers and improvement is impossible.

The catchment configuration associated with Sc K42 is provided in Table 8.4. Sc K42 requires no new infrastructure development and is therefore immediately applicable.

Table8.5 Komati River system: Recommended ECs and Water Resource Classes

Note: The red blocks indicate SQs which require non flow-related improvements to achieve the REC and refers to Table 8.4.
Note: The purple blocks indicate a change of the target EC once Sc K42 or similar is applicable.

IUA	Water Resource Class	Nodes	River	KM	Target EC for:	
					Immediate[1]	Sc K42[2]
X1-1	II	X11A-01300		12.3	B	B
		X11A-01354		25.6	C	C
		X11A-01358	Vaalwaterspruit	23.6	C	C
		X11A-01295	Vaalwaterspruit	12.0	C	C
		X11A-01248	Vaalwaterspruit	30.2	C	C
		X11B-01370	Boesmanspruit	15.7	B	B
		X11B-01361		17.5	B/C	B/C
		X11B-01272	Boesmanspruit	29.1	C	C
X1-2	II	EWRK1	Komati	93	C	C
X1-3	II	X11C-01147	Witkloofspruit	33.5	C	C
		X11D-01129	Klein-Komati	39.6	C	C
		X11D-01137	Waarkraalloop	21.1	C	C
		X11E-01237	Swartspruit	29.3	B	B
		X11F-01133	Bankspruit	17.6	B	B
		X11G-01188	Ndubazi	22.3	B	B
		X11G-01143	Gemakstroom	14.9	C	C
X1-4	III	EWRG1	Mngubhudle	49.6	D	D
		X11K-01165	Poponyane	13.8	C	C
		X11K-01199		8.5	D	D
X1-5	II	EWRK2	Komati	80.8	C	C
X1-6	I	X12A-01305	Buffelspruit	33.6	B	B
		EWRT1	Teespruit	66.1	C	C
		X12B-01246	Hlatjiwe	22.8	C	C
		X12C-01242	Phophenyane	10.7	B	B
		X12C-01271	Buffelspruit	12.5	B	B
		X12D-01235	Seekoeispruit	26.7	C	C
		X12H-01338	Sandspruit	12.6	B	B
		X12H-01340		10.4	B	B
		X12H-01318	Sandspruit	8.3	C	C
		X12J-01202	Mtsoli	54.4	B	B
		X12K-01333	Mlondozi	23.8	B/C	B/C
		X12K-01332	Mhlangampepa	17.0	B	B
X1-7	II	X14A-01173	Lomati	47.7	B/C	B/C
		X14B-01166	Ugutugulo	24.8	C	C
		X14F-01085	Mhlambanyatsi	41.1	C	C

IUA	Water Resource Class	Nodes	River	KM	Target EC for:	
					Immediate[1]	Sc K42[2]
X1-8	III	EWRL1	Lomati	57.3	C	C/D
		X14G-01128	Lomati	23.5	D/E	D/E
X1-9	III	X13J-01214	Mgobode	24.2	C	C
		X13J-01205	Mbiteni	20.0	D	D
		X13J-01141	Mzinti	43.4	D	D
		EWRK3A	Komati	71.21	D	D
X1-10	III[3]	X13K-01114	Komati	5.2	D	D
		X13K-01136	Mambane	19.2	D	D
		X13K-01068	Nkwakwa	44.7	C/D	C/D
		X13K-01038	Komati	35.3	E	E
		X13L-01000	Ngweti	44.9	D	D
		X13L-01027	Komati	10.7	E	E
		X13L-00995	Komati	3.1	D	D

1Immediately applicable until Sc 42 or a similar scenario is implemented.
2Applicable in the medium to long term.
3Due to the large sections of E EC river, this IUA does not comply with a Level III WRC. The Level III that has been allocated is applicable to the rest of the IUA which is in a D and C/D EC.

It is proposed to gazette the WRCs and catchment configuration as in Table 8.5 and RQOs will be set for the short term Ecological Categories.

8.3 CROCODILE RIVER SYSTEM

8.3.1 Crocodile River system Water Resource Class

When applying the criteria presented in Table 8.1 to the resulting ECs for each scenario, the Water Resource Classes for the 13 IUAs in the Crocodile River system are as listed in Table 8.6.

Table 8.6 Crocodile River system: Resulting IUA Water Resource Classes for each scenario

IUA	Scenarios and Water Resource Class												
	PES	REC	C1	C2	C3	C4	C5	C61	C62	C71	C72	C81	C82
X2-1	II	II	II	II	II	II	II	II	II	II	II	II	II
X2-2	II	I	II	II	II	II	II	II	II	II	II	II	II
X2-3	I	I	I	I	I	I	I	I	I	I	I	I	I
X2-4	I	I	I	I	I	I	I	I	I	I	I	I	I
X2-5	I	I	I	I	I	I	I	I	I	I	I	I	I
X2-6	II	I	II	II	II	II	II	II	II	II	II	II	II
X2-7	II	I	I	I	I	I	I	I	I	I	I	I	I
X2-8	XXX	II	II	II	II	II	II	II	II	II	II	II	II
X2-9	II	I	II	II	II	II	II	II	II	II	II	II	II
X2-10	II	II	II	II	II	II	II	II	II	II	III	II	II
X2-11	II	I	II	I	II	I	III	I	II	I	III	I	II
X2-12	**II**	**II**	**II**	**II**	**II**	**II**	**II**	**II**	**II**	**II**	**II**	**II**	**II**
X2-13	I	I	I	I	I	I	I	I	I	I	I	I	I

Following on from the selection of Sc C3, C62 and C82 as the preferred future scenarios for the Crocodile River system, the embossed columns in Table 8.7 gives the recommended Water Resource Classes (note that the Water Resource Classes are the same for all three scenarios). The result for IUA X2-8, indicated by "XXX" for the PES implies that under the current situation, the Water Resource Class does not comply with the criteria for a Class III. This is due to a large portion of the river reach length in a D/EEC and therefore not complying with the criteria set out in Table 8.1.

It must be noted that as Sc C62 includes a new dam (Mountain View Dam in the Kaap River) and Sc C82 includes this dam as well as an additional new Dam in the Nels River (Boschjeskop Dam), these scenarios will not be immediately relevant. Scenario C62 will therefore be relevant in the medium term as the Mountain View Dam is a more likely option and Sc C82 will be relevant in the long term. Sc 3, although not requiring new dams, also requires changes to the current operation of the system. Acknowledging this, the following recommendations (Table 8.8) were made:

Recommendation: Water Resource Classes for the Crocodile River System

The current situation is recommended to be immediately applicable in the main rivers (Crocodile, Elands, Kaap). This scenario (referred to as C1) includes the release of a revised PES EWR flows. Some non-flow related improvements are required in tributaries to improve the ecological state based on the ecological importance. There are no economic implications (as this constitutes the economic baseline or current state) but the ecological status of the Crocodile River is expected to degrade in terms of the instream biota (measured at the lower end of the Crocodile River).

To allow for future domestic growth, give effect to IIMA and to address the ecological problems; Scenario C3 (Table 8.7) is suggested for the medium term or as a next phase. Scenario C3 has a negative impact on GDP (-6.8% from the current state) and in terms of job losses (-6.1%). Scenario C3 moves towards achieving the PES but it is predicted that the fish state will still be degraded. The economic implications are due largely to the increased EWR flows and not due to the IIMA requirements which are already being substantially met under the current operating rule. The catchment configuration will be provided for river reaches where it differs from the current state.

Two long term options that include dam development in the Kaap River (Sc C62) and in both the Kaap and Nels Rivers (Sc C82) are also recommended. Both these scenarios will have the same predicted ecological implications as for Sc C3 above. The economic situation is an improvement on Sc C3 but still largely a decrease from the current situation (base line). Predicted GDP losses would be -3.1% for scenario C62 and -0.2% for Sc C82. The GDP losses in scenario C62 is due to the decreased irrigation allocation and the costs involved in building the dam in the Kaap River. Scenario C82 will have almost no impact on the GDP. It provides a significantly higher allocation towards the domestic service sector, which will increase GDP growth, but the costs involved in building both dams on the Kaap and Nels Rivers basically nullifies any GDP improvement. Scenario C82 does not allow for additional growth in the irrigation sector.

Jobs would improve by 3.5% from the baseline for Scenario C82 but will decrease by -1.6% for Sc C62. Scenario C62 will see job losses mainly in the irrigation sector as additional water will only be allocated to the domestic service sector and the irrigation sector will see a substantial decrease in water allocation which will outweigh the increases in jobs created by the domestic service sector. Scenario C82 will see job increases due to the significant amount of water being added to the domestic service sector; most of the job opportunities will be created within this sector. Irrigation employment is expected to stay constant for Scenario C82. If these developments are therefore considered in the future, these two scenarios are recommended and the WRC and catchment configuration for both will be provided where it differs from the current state.

Table 8.7 Summary of the future Crocodile River scenario variables

Scenario	Scenario variables					
	Revised PES EWR (as under current operational rule)	Domestic growth	IIMA Flows	Mountain View Dam (Kaap)	Boschjeskop Dam (Nels)	EWR
C1	Yes	No	No	No	No	No
C3	No	Yes	Yes	No	No	PES
C62	No	Yes	Yes	Yes	No	PES
C82	No	Yes	Yes	Yes	Yes	PES

Table 8.8 Crocodile River system: Recommended Water Resource Classes for each IUA

Green - immediately applicable
Blue - applicable in the short term
Pink - applicable in the long term
Orange - applicable in the far long term.

IUA	Scenarios and Water Resource Class				
	PES	REC	C3	C62	C82
X2-1	II	**II**	**II**	**II**	**II**
X2-2	II	**II**	**II**	**II**	**II**
X2-3	I	**I**	**I**	**I**	**I**
X2-4	I	**I**	**I**	**I**	**I**
X2-5	I	**I**	**I**	**I**	**I**
X2-6	**II**	I	**II**	**II**	**II**
X2-7	II	**I**	**I**	**I**	**I**
X2-8	XXX	**II**	**II**	**II**	**II**
X2-9	**II**	I	**II**	**II**	**II**
X2-10	II	**II**	**II**	**II**	**II**
X2-11	**II**	I	**II**	**II**	**II**
X2-12	II	**II**	**II**	**II**	**II**
X2-13	I	**I**	**I**	**I**	**I**

8.3.2 Crocodile River system Catchment Configuration

Given the results and scenario selections presented in the section above, Table 8.6 provides respectively the proposed Water Resource Class and ECs for the IUAs and biophysical nodes for the Crocodile River system.

It must be noted that various nodes require improvements based on non flow-related/anthropogenic issues that have to be addressed. Where it is deemed that the REC is attainable, it has been included in the scenario configuration (Table 8.9).

Table 8.9 Crocodile River system nodes requiring improvements

IUA	Nodes	River	PES	REC	Comment
X2-1	X21B-00898	Lunsklip	C/D	C	Impacts that would be difficult to address are the barrier and inundation impacts of small farm dams as well as the impact on flow as these dams do not have operating capabilities. Water quality can also be addressed. It should be possible to increase by half a category but will be difficult and it must first be established what the driving impacts are. The necessity for improvement will be flagged, but due to uncertainty whether this is achievable, the catchment configuration of an overall C/D will be recommended.
X2-1	X21B-00929	Gemsbokspruit	C/D	C	Mostly non-flow related impacts with a similar situation to the above.
X2-2	X21D-00957	Buffelskloofspruit	C	B/C	Improved agricultural practices in general are needed to achieve the REC implying that most metrics will require improvement. All impacts are non flow-related. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X2-7	X22A-00824	Blystaanspruit	B/C	B	Non flow-related impacts are linked to forestry. Improvement is achievable with riparian zone improvement. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X2-7	X22A-00875	Houtbosloop	B/C	B	Non flow-related impacts are linked to forestry. Improvement is achievable with riparian zone improvement. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X2-7	X22A-00913	Houtbosloop	C	B	Non flow-related impacts are linked to agriculture. Improvement is achievable with improvement in general agricultural practices. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X2-8	X22F-00842	Nels	C	B/C	Impacts are mostly non flow-related and linked to forestry, bed and channel disturbance, vegetation removal and alien vegetation. Riparian zone improvement and management, as well as erosion control will be required to achieve the REC. It should be possible to increase by half a category but will be difficult and it must first be established what the driving impacts are. The necessity for improvement will be flagged, but due to uncertainty whether this is achievable, the catchment configuration of an overall C will be recommended.
X2-8	X22C-01004	Gladdespruit	C	B/C	The top section of the SQ is probably already in a better state than the C. General improvement will be difficult to achieve the REC. Therefore the top section should be maintained in a B/C and this category is then relevant for the whole SQ. No action required.
X2-8	X22H-00836	Wit	D/E	D	Remove alien vegetation, improve buffer zones and water quality from Wit River to achieve the REC. It is assumed these mitigation measures are more likely to occur rather than EWR releases from the dam, but this will be sufficient to improve to a D EC. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X2-10	X23B-01052	Noordkaap	D	C	Riparian zone improvement (forestry) and water quality improvement from mines are needed to achieve the REC.As none of the scenarios are relevant to this site,

IUA	Nodes	River	PES	REC	Comment
					the improvement is valid irrespective of the recommended scenario.
X2-10	X23C-01098	Suidkaap	C	B/C	Riparian zone improvement (forestry and agriculture) is needed to achieve the REC.As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X2-10	X23E-01154	Queens	C	B/C	Riparian zone improvement (forestry and agriculture) is needed to achieve the REC.As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.

The short term catchment configuration associated with Sc C3 is provided in Table 8.7. The medium and long term catchment configuration associated with Sc C62 and C82 and the construction of Mountain View and Boschjeskop Dams are also provided in Table 8.7.

Table 8.10 Crocodile River system: Recommended ECs and Water Resource Classes

Note, the red blocks indicate SQs which require non flow-related improvements to achieve the REC and refers to Table 8.7.

Note: The purple blocks indicate SQs where the catchment configuration (in terms of the Target EC) is different between the current state and future scenario.

IUA	Water Resource Class	Nodes	River	KM	Target EC for:			
					Im-mediate	ScC3	ScC62	ScC82
X2-1	II	X21B-00898	Lunsklip	11.0	C/D	C/D	C/D	C/D
		X21B-00929	Gemsbokspruit	8.8	C/D	C/D	C/D	C/D
		X21B-00925	Lunsklip	21.5	C	C	C	C
		EWRC1	Crocodile	30.8	A/B	A/B	A/B	A/B
		EWRC2	Crocodile	30.1	B	B	B	B
		X21C-00859	Alexanderspruit	36.9	C	C	C	C
X2-2	II	EWRC3	Crocodile	58.3	B/C	C	C	C
		X21D-00957	Buffelskloofspruit	27.1	B/C	B/C	B/C	B/C
		X21E-00897	Buffelskloofspruit	14.6	B	B	B	B
X2-3	I	X21F-01100	Leeuspruit	12.9	C	C	C	C
		X21F-01092	Leeuspruit	1.0	C/D	C/D	C/D	C/D
		X21F-01091	Rietvleispruit	13.2	C	C	C	C
		EWRE1	Elands	55.6	B	B	B	B
X2-4	I	X21G-01090	Weltevredespruit	13.8	C	C	C	C
		X21G-01016	Swartkoppiespruit	13.8	C	C	C	C
		X21H-01060	Ngodwana*	20	B	B	B	B
		X21K-01007	Lupelule	20.0	B	B	B	B
X2-5	I	EWRE2	Elands	59	B	B	B	B
X2-6	II	X22B-00987	Crocodile	**Linked to EWR C4** The results at EWR C4 (IUA X2-9) is relevant for these SQs as they fall in the same Resource Unit as EWR C4				
		X22B-00888	Crocodile					
		X22C-00946	Crocodile					
		X22J-00993	Crocodile					

IUA	Water Resource Class	Nodes	River	KM	Target EC for:			
					Im-mediate	ScC3	ScC62	ScC82
X2-7	I	X22A-00824	Blystaanspruit	19.4	B	B	B	B
		X22A-00887	Beestekraalspruit	7.4	B/C	B/C	B/C	B/C
		X22A-00875	Houtbosloop	10.4	B	B	B	B
		X22A-00919	Houtbosloop	0.7	B/C	B/C	B/C	B/C
		X22A-00920		4.5	B	B	B	B
		X22A-00917	Houtbosloop	2.7	C	C	C	C
		X22A-00913	Houtbosloop	28.3	B	B	B	B
		X22C-00990	Visspruit	10.0	B/C	B/C	B/C	B/C
X2-8	II	X22D-00843	Nels	24.9	C	C	C	C
		X22D-00846		16.7	C	C	C	C
		X22F-00842	Nels	35.1	C	C	C	C
		X22E-00849	Sand	12.7	C	C	C	C
		X22E-00833	Kruisfonteinspruit	9.8	C	C	C	C
		X22F-00886	Sand	29.7	C	C	C	C
		X22F-00977	Nels	6.7	C/D	C/D	C/D	C/D
		X22C-01004	Gladdespruit	36.7	B/C	B/C	B/C	B/C
		X22H-00836	Wit	59.2	D	D	D	D
X2-9	II	X22K-01042	Mbuzulwane	10.0	B	B	B	B
		X22K-01043	Blinkwater	16.3	B	B	B	B
		X22K-01029	Blinkwater	3.4	C	C	C	C
		EWRC4	Crocodile	41.3	C	C	B/C	C
X2-10	II	X23B-01052	Noordkaap	7.2	C	C	C	C
		X23C-01098	Suidkaap	22.9	B/C	B/C	B/C	B/C
		EWRK7	Kaap	11.2	C	C	C	C
		X23E-01154	Queens	31.0	B/C	B/C	B/C	B/C
		X23F-01120	Suidkaap	28.6	C	C	C	C
X2-11	II	EWRC5	Crocodile	23	C	C	C	B/C
		EWRC6	Crocodile	99	C	C	C	C
X2-12	II	X24A-00826	Nsikazi	27.8	C	C	C	C
		X24A-00860	Sithungwane	12.4	A	A	A	A
		X24A-00881	Nsikazi	10.3	B	B	B	B
		X24B-00903	Gutshwa	19.1	D	D	D	D
		X24B-00928	Nsikazi	11.9	A/B	A/B	A/B	A/B
		X24C-00969	Mnyeleni	12.4	A	A	A	A
		X24C-00978	Nsikazi	21.2	B	B	B	B
X2-13	I	X24E-00973	Matjulu	17.3	B	B	B	B
		X24E-00922	Mlambeni	39.2	A/B	A/B	A/B	A/B
		X24G-00902	Mitomeni	21.9	A	A	A	A

IUA	Water Resource Class	Nodes	River	KM	Target EC for:			
					Im-mediate	ScC3	ScC62	ScC82
		X24G-00876	Komapiti	16.0	**A**	**A**	**A**	**A**
		X24G-00844	Mbyamiti	19.8	**A**	**A**	**A**	**A**
		X24G-00823	Muhlambamadubo	21.0	**A**	**A**	**A**	**A**
		X24G-00820	Mbyamiti	28.9	**A**	**A**	**A**	**A**
		X24G-00904	Mbyamiti	5.2	**A**	**A**	**A**	**A**
		X24H-00882	Vurhami	36.6	**A**	**A**	**A**	**A**
		X24H-00892	Mbyamiti	28.8	**A**	**A**	**A**	**A**

*Note, the B is relevant upstream of Godwana Dam. The dam and the short river distance downstream of the dam is in an E category, but the management of the rest of the river upstream of the dam (20 km) must be in a B.

It is proposed to gazette the WRCs and catchment configuration as in Table 8.9 and RQOs will be set for the short term Ecological Categories.

8.4 SABIE-SAND RIVER SYSTEM

The Sabie and Sand River Catchments were originally evaluated separately. The results will be supplied separately but the final conclusion in terms of the WRC and the catchment configuration will be provided in a separate section.

8.4.1 Sabie River System Water Resource Class

When applying the criteria presented in Table 8.1 to the resulting ECs for each scenario, the Water Resource Classes for the three IUAs in the Sand River system are as listed in Table 8.8.

Table 8.11 Sabie River system: Resulting IUA Water Resource Classes for each scenario

IUA	Scenarios and Water Resource Class					
	PES	REC	S1	S31	S32	S6
X3-1	II	I	I	I	I	I
X3-2	II	I	I	I	I	I
X3-3	I	I	II	I	II	I
X3-4	III	III	III	III	III	III
X3-5	I	I	II	I	II	I
X3-6	I	I	I	I	I	I

It must be noted that Sc S6 consists largely of the current situation of the dam with no new proposed infrastructure. It therefore does not cater for future growth. A further scenario was investigated (Sc 61) in an attempt to optimise, but as this scenario required the transfer to the Sand to be minimised, this scenario was not investigated further and will not be reported on.

8.4.2 Sand River system Water Resource Class

When applying the criteria presented in Table 8.1 to the resulting ECs for each scenario, the Water Resource Classes for the three IUAs in the Sand River system are as listed in Table 8.13.

Table 8.12 Sand River system: Resulting IUA Water Resource Classes for each scenario

IUA	Scenarios and Water Resource Class				
	Status quo	REC	S71	S72	S73
X3-7	III	II	**II**	XXX	III
X3-8	II	II	**II**	II	II
X3-9	I	I	**I**	I	I

Following on from the selection of Sc S71 as the preferred scenario for the Sand River system, the embossed column in Table 8.13 gives the recommended Water Resource Classes. The result for IUA X3-7, indicated by "XXX" for S72 implies the scenarios did not comply with the criteria for a Class III. This is due to no releases made for the ecology from the proposed New Forest Dam in those scenarios, resulting in an EC of "F" for EWR 6.

It must be noted that as S71 includes a new dam (the New Forest Dam) that may only be constructed in the far future, the current state in the short term will be recommended and S71 in the long term if New Forest Dam is constructed.

8.4.3 Sabie-Sand River system Water Resource Class

The two systems are linked through the current transfer from Inyaka Dam to the Sand catchment. The recommendations therefore have to consider the implications on both systems.

The Water Resource Classes (Table 8.13) for the IUAs are set to largely maintain the current ecological state and operation of the system. Some non-flow related improvements are required in tributaries to improve the ecological state based on the ecological importance. This option does allow for the reinstatement of forestry in the Sand catchment acknowledging that additional environmental investigations may be required prior to such a decision being made. As this is the current scenario, there are no implications for the ecology or any user. It is acknowledged that under the current state, there is very limited additional yield available for future growth in the Sabie system and/or the Sand system. Additional management options or storage may be required in future to accommodate this and maintain the Water Resource Class. If there are no viable options, then re-classification may be required. It must be noted that the Sabie River is, from an environmental point of view, a critical river for SANPARKS and a flagship river for South Africa.

A new dam development in the Mutlumuvi River and various operating scenarios were investigated in the Sand Catchment. In order to make more water available in the Sabie River for domestic growth, the water transfer to the Sand River will have to be decreased. To make up for this loss of water in the Sand River dam storage in the Mutlumuvi River can be provided as configured in Scenario 71.

The Water Resource Class under Scenario 71 for the Sand Catchment will also be supplied as a long term option. The implications of Scenario 71 are that there will be a degradation of most ecological components in the Mutlumuvi River. These are however attributed to dam impacts and not to changes in the flow regime. The desired present state in the lower Sand River is expected to be maintained. GDP is expected to improve from the current state by 17.3% and job gains are predicted to be 28.9%.

Sc S71 consists of the following:
- New dam development in the Mutlumuvi River.

- Supply of the environmental flows supporting the REC in the Mutlumuvi River and downstream Sand River.
- Assumed increase in return flows of 25%.
- Decreased transfer from the Sabie River.

Table 8.13 Sabie-Sand system: Recommended Water Resource Classes for each IUA

Green - immediately applicable
Blue - applicable in the medium to long-term

IUA	Catchment	Scenarios and Water Resource Class		
		PES	REC	S71
X3-1	Sabie	II	**I**	**I**
X3-2	Sabie	II	**I**	**I**
X3-3	Sabie	I	**I**	**I**
X3-4	Sabie	III	**III**	**III**
X3-5	Sabie	I	**I**	**I**
X3-6	Sabie	I	**I**	**I**
X3-7	Sand	III	**II**	**II**
X3-8	Sand	II	**II**	**II**
X3-9	Sand	I	**I**	**I**

Given the results and scenario selections presented in the section above, Table 8.15 provides respectively the proposed Water Resource Class and ECs for the IUAs and biophysical nodes for the Sabie-Sand River system.

It must be noted that various nodes require improvements based on non flow-related/anthropogenic issues which have to be addressed. Where it is deemed that the REC is attainable, it has been included in the configuration (Table 8.14).

Table 8.14 Sabie Sand River system nodes requiring improvements

IUA	Nodes	River	PES	REC	Comment
X3-1	X31A-00741	Klein Sabie	**C**	**B/C**	Requires significant improvement of the riparian zone (in forestry area), reduced sediment (erosion control in forestry area) and improved water quality in lower reaches (Sabie formal and informal settlements) to achieve the REC. These improvements are seen to be difficult to implement with regards to the settlements, but the forestry practices can be improved. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X3-2	EWR S1	Sabie	**B/C**	**B**	Improvement based on the following non-flow related measures is needed to achieve the REC: Picnic site must be closed and rehabilitated and alien vegetation species removed. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X3-2	EWR S4	Mac-Mac	**B**	**A/B**	Improved water quality is required to improve the fish to a B EC. It is unknown how attainable this is as it is uncertain what the source of the water quality problems are. This will

IUA	Nodes	River	PES	REC	Comment
					be flagged, but due to this uncertainty, the catchment configuration of an overall B EC will be recommended.
X3-2	EWR S2	Sabie	C	B	Improvement based on the following non-flow related measures is needed to achieve the REC: Removal of alien vegetation species and cease moving in the riparian zone. Reduce recreational disturbance. Improve the nutrient status. As none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X3-2	X31E-00647a	Marite (US of dam)	B/C	B	Improved riparian zone is needed to achieve the REC. This is attainable and as none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X3-2	X31F-00695	Motitsi	C	B	Improved riparian zone is needed to achieve the REC. Water quality (Graskop influence). This is attainable and as none of the scenarios are relevant to this site, the improvement is valid irrespective of the recommended scenario.
X3-4	X31H-00819	White Waters	C	B/C	Da Gama Dam probably has insufficient outlets to release flows, and therefore an improvement in riparian vegetation is needed to achieve the REC. This will be flagged for further investigation but improvement may be unattainable due to the constraints associated with Da Gama Dam outlets. Due to this uncertainty, the catchment configuration of a C EC will be recommended.
X3-7	X32E-00629	Nwarhele	C/D	C	Riparian zone improvement will improve the upper reaches of the river. Lower reaches have very dense settlements – and improvement is unlikely. The riparian zone improvement can improve the EC by half a category. This is attainable and the EC of a C will then also be the result of Sc S71 as this flow scenario does not impact on this node and reach of the river.
X3-7	X32E-00639	Ndlobesuthu	D/E	D	Highly populated area. Unlikely to improve and the D/E are likely to be maintained in the future.

The catchment configuration is provided below in Table 8.15.

Table 8.15 Sabie-Sand River system: Recommended ECs and Water Resource Classes

Note, the red blocks indicate SQs which require non flow-related improvements to achieve the REC and refers to Table 8.7.

Note: The purple blocks indicate SQs where the catchment configurations (in terms of the Target EC) are different between the current state and future scenario.

IUA	Water Resource Class	Nodes	River	KM	Immediate	Sc S71
X3-1	I	X31A-00741	Klein Sabie	14.6	B/C	B/C
		X31A-00783		5.4	C	C
		X31A-00786		5.2	B	B
		X31A-00794		1.1	B	B
		X31A-00796		1.0	B	B
		X31A-00803		0.6	B/C	B/C
X3-2	I	EWR S1	Sabie	**57**	B	B
		X31B-00792	Goudstroom	8.8	B/C	B/C

IUA	Water Resource Class	Nodes	River	KM	Immediate	Sc S71
		EWR S4	Mac-Mac	46.8	B	B
		EWR S2	Sabie		B	B
		X31E-00647a	Marite (US of dam)	19.9	B	B
		X31F-00695	Motitsi	42.8	B	B
X3-3	I	EWR S5	Marite	8.0	B/C	B/C
		EWR S3	Sabie		A/B	A/B
X3-4	III	X31D-00773	Sabani	19.8	C/D	C/D
		X31H-00819	White Waters	32.6	C	C
		X31J-00774	Noord-Sand	16.9	D	D
		X31J-00835	Noord-Sand	13.4	D	D
		X31K-00713	Bejani	17.7	D	D
		X31L-00657	Matsavana	12.8	C	C
		X31M-00673	Musutlu	40.3	B/C	B/C
		X31L-00664	Saringwa	28.9	C	C
		X31L-00678	Saringwa	16.6	B/C	B/C
X3-5	I	X33A-00731	Sabie		A/B	A/B
		X33A-00737	Sabie		A/B	A/B
		X33B-00784	Sabie		A/B	A/B
		X33B-00804	Sabie		A/B	A/B
		X33B-00829	Sabie		A/B	A/B
		X33D-00811	Sabie		A/B	A/B
		X33D-00861	Sabie		A/B	A/B
X3-6	I	X31K-00771	Phabeni	19.2	B	B
		X31M-00763	Nwaswitshaka	56.0	A	A
		X33A-00661	Nwatindlopfu	25.9	A	A
		X33A-00806	Nwatimhiri	35.5	A	A
		X33B-00694	Salitje	35.4	A	A
		X33B-00834	Lubyelubye	20.7	A	A
		X33C-00701	Mnondozi	46.9	A	A
		X33D-00864	Mosehla	19.9	A	A
		X33D-00894	Nhlowa	9.9	A	A
		X33D-00908	Shimangwana	8.3	A	A
		X33D-00911	Nhlowa	5.7	A	A
X3-7	II	X32E-00629	Nwarhele	18.0	C	C
		X32E-00639	Ndlobesuthu	6.8	D/E	D/E
		EWR S6	Mutlumuvi		C	C
		X32F-00628	Nwarhele	6.5	C/D	C/D
X3-8	II	X32B-00551	Motlamogatsana	27.1	C	C
		EWR S7	Tlulandziteka		C	C
		X32C-00558	Nwandlamuhari	15.1	C	C
		X32C-00564	Mphyanyana	11.9	C	C
		X32C-00606	Nwandlamuhari	1.2	C	C
		X32G-00549	Khokhovela	28.0	C	C
X3-9	I	X32H-00560	Phungwe	**30.9**	A	A
		EWR S8	Sand		B	B

IUA	Water Resource Class	Nodes	River	KM	Immediate	Sc S71
		X32J-00651	Mutlumuvi	**24.8**	**A**	**A**

It is proposed to gazette the Water Resource Classes and catchment configuration as in bold above and RQOs will be set for the short term ECs.

8.5 X4 RIVER SYSTEMS

All these systems represent rivers that fall in their totality in the KNP. As such, they are not impacted by any scenarios and are all in a very good Ecological Category. The Water Resource Class will be set to maintain the PES (and REC) (Table 8.16).

Table 8.16 Sabie-Sand River system: Recommended ECs and Water Resource Classes

IUAs	Class for IUAs	Biophysical node	River Name	Target EC
IUA X4: Nwanedzi and Mwaswitsontso rivers	**I**	X40A-00437	Shinkelengane	**A**
		X40A-00454	Mmondzo	**A**
		X40A-00479	Nwanedzi	**A**
		X40A-00492	Rihlazeni	**A**
		X40A-00433	Mtomeni	**A**
		X40A-00420	Gudzani	**A**
		X40A-00426	Mavumbye	**A**
		X40A-00475	Mavumbye	**A/B**
		X40A-00459	Nwanedzi	**A**
		X40A-00486	Nwanedzi	**A/B**
		X40A-00469	Nwanedzi	**B**
		X40B-00534	Nungwini	**A**
		X40B-00537	Gwini	**A**
		X40B-00532	Mrunzuluku	**A**
		X40B-00497	Sweni	**A**
		X40B-00531	Mrunzuluku	**A**
		X40B-00530	Mrunzuluku	**A**
		X40B-00511	Sweni	**A**
		X40C-00592	Ripape	**A**
		X40C-00513	Nwaswitsontso	**B**
		X40D-00663	Shilolweni	**A**
		X40D-00594	Metsimetsi	**A**
		X40D-00598	Nwaswitsontso	**A/B**
		X40D-00660	Nwaswitsontso	**A**

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10 APPENDIX A: WATER RESOURCES MODELLING

10.1 CONFIGURING THE WATER RESOURCES YIELD MODEL

The Water Resources Modelling Platform (WReMP) configuration was obtained for the Komati, Crocodile and Sabie River systems from the following previous studies:

- Komati: Development of an Ecological Water Requirement Policy and Water Management Plan for the Komati River Basin (Nepid Consulting, 2009).
- Crocodile: Mbombela Reconciliation Strategy (DWA, 2013c).
- Sabie: Development of the Sabie/Sand Operating Rules (DWA, 2013d).

These models already included all the EWR sites as identified in previous studies (AfriDev, 2006; DWA, 2010a,b). However, it was necessary to updated the model to include all the bio-physical nodes which were derived from the PES (11) data (DWA 2014). While each bio-physical nodes or EWR site is defined in the models as a node, the flow out of the node I defined as a channel.

– 10.3 presents the details of the sites configured into the model, and relates to the schematic network diagrams presented in **Error! Reference source not found.** –10.3.

10.2 PREPARATION OF NATURAL AND PRESENT DAY FLOWS

10.2.1 Natural flows

The natural flow forms the baseline against which all scenarios will be considered. The hydrology for the baseline of natural flow in the Komati catchment was derived from the Inkomati Water Availability Assessment Study (IWAAS) completed by the Department of Water Affairs in 2009 (DWA, 2009b). The IWAAS hydrology was prepared at quinary catchment scale. With the addition of numerous bio-physical nodes as part of this Classification study, the quinary hydrology was down-scaled and scaled linearly where the catchment area of new nodes is less than the quinary catchment area.

10.2.2 Present Day flows

Komati River system

The water resources model was updated with the latest information available to produce the best possible estimate of present day flow. Some of the key features of the Present Day scenario are:

- Updated water requirement obtained from DWS's All Towns Strategies (DWA, 2011) and the Komati Basin Water Authority (*Pers. Comm*., S Dhlamini, 2013).
- KOBWA's operating rule of the system which strives for equal draw-down of the Maguga and Driekoppies dams.
- Full irrigation allocations in South Africa.
- Swaziland's irrigation is 20 million m^3/annum less than their full allocation.
- Minimum cross border flows of 1.1 m^3/s.
- A restriction of 30% is imposed on irrigators when the combined storage in the Maguga and Driekoppies dams drops below 75% of the full supply capacity.

A short coming of this present day scenario is that irrigation outside of the irrigation boards has not been verified and hence there is some uncertainty regarding this.

10.2.3 Presentation of results

Simulations were carried out using the present day configurations of three model setups (Komati, Crocodile and Sabie River systems) and cumulative natural and present day time series of flows at each of the biophysical nodes and EWR sites generated. These time series were provided to the EWR team for evaluation.

Error! Reference source not found. to 10.6 present graphs of the simulated storage in the six main dams within the Inkomati WMA, namely, the Nooitgedacht Dam, the Vygeboom Dam, the Maguga Dam, the Driekoppies Dam, the Kwena Dam and the Inyaka Dam.

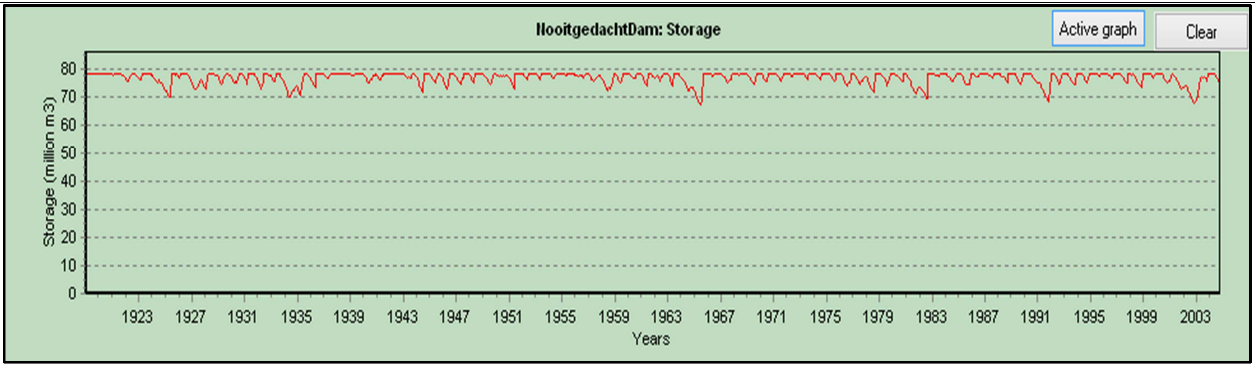


Figure 10.1 Storage in the Nooitgedacht Dam under the Present Day scenario

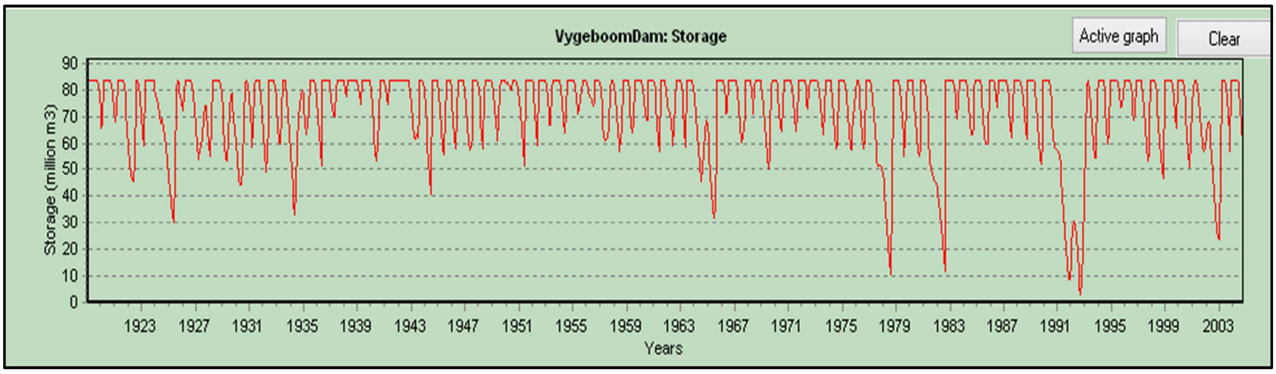


Figure 10.2 Storage in the Vygeboom under the Present Day scenario

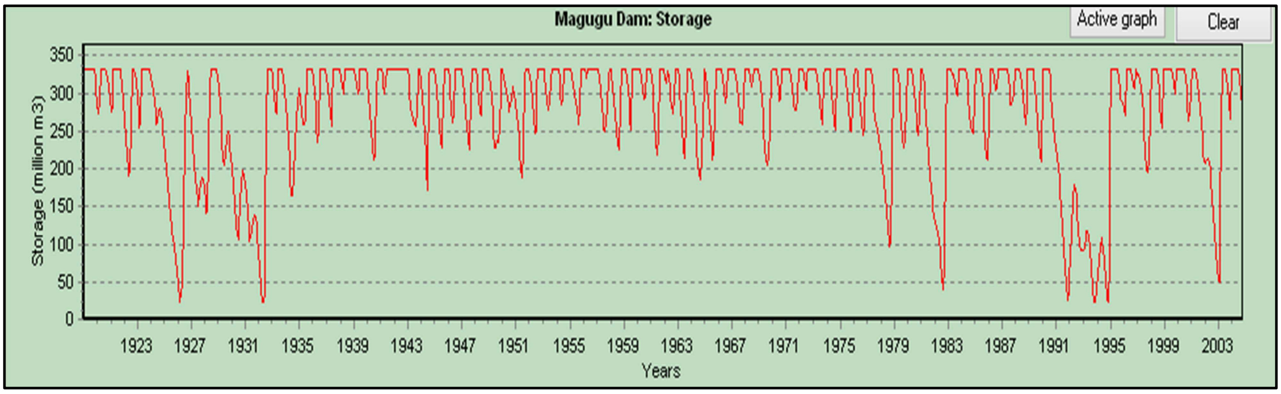


Figure 10.3 Storage in the Maguga Dam under the Present Day scenario

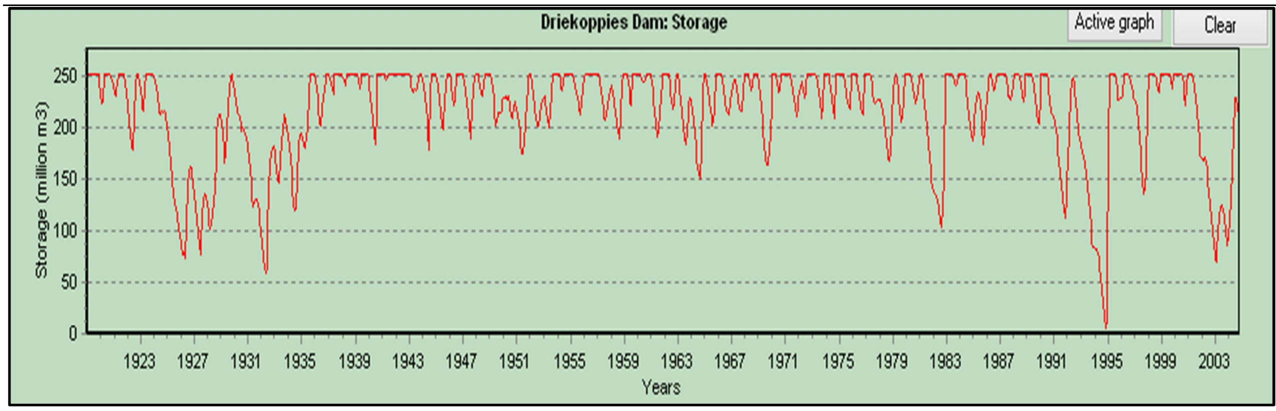


Figure 10.4 Storage in the Driekoppies Dam under the Present Day scenario

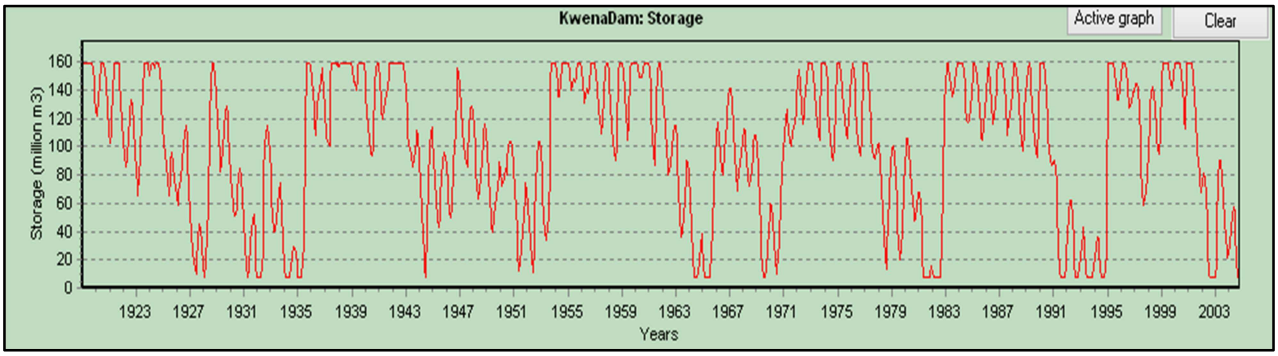


Figure 10.5 Storage in the Kwena Dam under the Present Day scenario

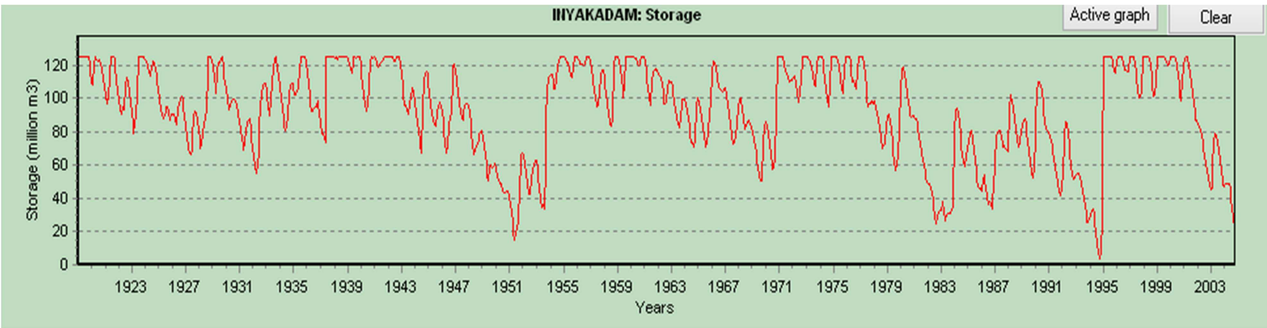


Figure 10.6 Storage in the Inyaka Dam under the Present Day scenario

Table 10.1 Komati River system: Nodes assigned to EWR sites and biophysical nodes

Node Number	Node Name	Hydrology File	Proportion	Cumulative Area	Cumulative Natural Flow	Present Day Flow
				km²	million m³/a	million m³/a
53	EWRG1	11J1	0.53	112.2	29.5	21.1
43	EWRK1	11F1	0.11	2595.6	158.6	120.2
104	EWRK2	12H3	0.409	5605.5	545.6	335.0
154	EWRk3	13J4	0.6	8961.4	1021.7	570.6
178	EWRL1	14G3	0.86	1217.1	294.3	235.7
126	EWRM1	13D1	1	7030.6	876.6	645.1
11	X11A-01248	11A1	0.224	676.0	26.3	22.3
7	X11A-01295	11A1	0.12	397.5	15.4	13.4
9	X11A-01300	11A1	0.039	43.7	1.7	1.2
3	X11A-01354	11A1	0.089	101.0	3.9	2.9
5	X11A-01358	11A1	0.102	169.6	6.6	5.9
20	X11B-01260	11B2	0.4	1346.7	56.0	45.9
19	X11B-01272	11B2	0.2	1204.7	51.2	41.2
15	X11B-01361	11B1	0.153	86.5	4.2	2.6
13	X11B-01370	11B1	0.173	99.2	4.8	3.5
22	X11C-01147	11C1	0.6	230.0	11.4	9.9
26	X11D-01129	11D1	0.52	258.0	21.0	18.2
30	X11D-01137	11D3	0.346	137.8	11.7	10.9
31	X11D-01196	11D3	0.04	1939.7	95.5	62.5
28	X11D-01219	11D2	0.6	1672.7	73.6	44.3
35	X11E-01157	1.10E+03	0.2	2212.6	118.3	83.3
37	X11E-01237	1.10E+02	0.6	156.0	14.8	14.2
42	X11F-01133	11F1	0.178	53.8	6.5	5.4
40	X11F-01163	11F1	0.596	2521.0	149.7	113.5
45	X11G-01142	11G1	0.227	2695.9	175.8	133.8
49	X11G-01143	11G1	0.138	61.0	10.4	6.8
47	X11G-01188	11G1	0.23	101.6	17.4	14.5
51	X11H-01140A	11H1	0.6	3124.5	258.1	204.1
63	X11H-01140B	11K3	0.91	3172.5	265.3	123.5
54	X11J-01106	11J1	0.4	187.0	49.2	39.6
56	X11K-01165	11K1	0.39	65.0	13.7	13.3
60	X11K-01179	11K2	0.18	262.5	64.4	36.5
62	X11K-01194	11K2	0.532	307.0	71.2	41.8
59	X11K-01199	11K2	0.19	16.5	2.4	1.4
65	X11K-012227	11K4	0.64	3520.5	341.6	165.4
68	X12A-01305	12A1	0.14	244.0	32.0	24.5
70	X12B-01246	12B1	0.73	155.0	22.1	18.1
71	X12C-01242	12C1	1	43.0	6.3	5.9
73	X12C-01271	12C2	0.278	514.9	71.1	58.1
78	X12D-01235	12D2	0.82	881.9	97.0	80.2
86	X12E-01287	12F3	0.8	648.0	56.4	47.4
95	X12G-01200	12G3	0.68	4640.4	458.7	262.2
116	X12H-01258	12K2	0.586	5625.7	550.0	339.4
102	X12H-01296	12H3	0.391	5318.4	517.4	307.8
101	X12H-01318	12H2	0.333	142.2	14.0	13.3
98	X12H-01338	12H2	0.255	44.6	4.5	4.4
100	X12H-01340	12H2	0.278	48.6	4.9	4.7
110	X12J-01202	12J3	0.8	297.0	66.5	59.4
117	X12K-01316	12K2	0.2	5874.9	577.0	365.9
114	X12K-01332	12K1	0.106	31.9	3.4	3.4
112	X12K-01333	12K1	0.694	207.7	22.4	22.3
155	X13J-01130	13J4	0.2	8967.4	1021.9	515.6
148	X13J-01141	13J2	0.55	159.0	6.4	3.9
152	X13J-01149	13J3	0.218	8777.8	1014.5	566.3
145	X13J-01205	13J3	0.2	174.0	5.9	5.1
150	X13J-01214	13J3	0.12	125.0	1.9	1.9
149	X13J-01221	13J3	0.267	8238.6	1000.3	552.8
185	X13K-01038	13K2	0.315	10913.8	1345.4	674.6
182	X13K-01068	13K1	1	256.0	5.4	5.4
184	X13K-01114	13K2	0.036	10705.1	1341.4	670.5
181	X13K-01136	13K2	0.253	93.0	1.8	1.8
190	X13L-00995	13L2	0.335	11455.5	1356.6	561.3
186	X13L-01027	13L2	0.52	11199.9	1351.4	558.4
188	X13L-01100	13L1	0.4	228.0	4.6	2.5
162	X14A-01173	14B2	0.623	233.6	84.4	73.8
161	X14B-01166	14B2	0.131	56.8	20.9	12.4
175	X14F-01085	14G1	0.2	155.3	47.1	46.4
176	X14G-01128	14G1	0.5	1040.8	246.1	202.2
180	X14H-01066	14H1	0.57	1578.1	316.4	249.6

Crocodile River system

The water resources model was updated with the latest information available to produce the best possible estimate of present day flow. Some of the key features of the Present Day scenario are:

- Updated water requirement obtained from DWS's Mbombela Reconciliation Strategy (DWA, 213d) as well as the All Towns Strategies (DWA, 2011).
- The IUCMA's operating rule of the system in which users along the main stem of the Crocodile River are supported by releases from the Kwena Dam.
- Minimum cross border flows of 0.9 m^3/s as currently implemented by the IUCMA.
- Restrictions are imposed on users based on the water level in the Kwena Dam as indicated in Table10.2 and 10.3.

Table 10.2 Restriction rule for irrigators in the Crocodile River system

Storage in Kwena Dam (% full)	Supply (% of full allocation)
> 100%	100%
100 – 70%	100%
70 – 50%	65%
50 – 10%	40%
<10%	0%

Table 10.3 Restriction rule for domestic users in the Crocodile River system

Storage in Kwena Dam (% full)	Supply (% of full allocation)
> 100%	100%
50 – 20%	90%
20 – 10%	85%
< 10%	80%

Table 10.4 Crocodile River system: Nodes assigned to EWR sites and biophysical nodes

Node Number	Node Name	Hydrology File	Proportion	Cumulative Area	Cumulative Natural Flow	Present Day Flow
				km^2	million m^3/a	million m^3/a
28	EWR1	X21A1	0.728	101.9	15.63	13.91
40	EWR2	X21B3	0.587	697.6	76.14	66.87
59	EWR3	X21E2	0.859	1643.3	194.1	160.1
127	EWR4	X22K2	0	5538.57	824.81	540.68
195	EWR5	X24D2	0.922	8444.37	1117.35	701.41
208	EWR6	X24H2	0	10607.57	1165.62	595.48
159	EWR7	X23G2	0.526	1318.7	179.53	112.63
29	X21A-00930	X21A1	0.073	111.1	17.04	14.5
34	X21B-00898	X21B1	0.22	55.3	9.64	8.42
38	X21B-00925	X21B2	0.448	192.7	25.8	22.35
35	X21B-00929	X21B1	0.28	21.6	3.75	3.35
41	X21B-00962	X21B3	0.055	707.9	77.05	67.68
46	X21C-00859	X21C2	0.273	212.1	28.81	26.31
54	X21D-00938	X21D2	1	1163.4	124.81	105.32
53	X21D-00957	X21D1	0.107	147.9	16.88	12.92
57	X21E-00897	X21E1	0.277	58.2	8.39	6.71
60	X21E-00943	X21E2	0.141	1662.5	197.73	163
55	X21E-00947	X21E1	0.008	1165.4	125.05	105.51
4	X21F-01046	X21F2	0.184	276.7	35.09	32.37
8	X21F-01081	X21F2	0.02	397.5	50.77	46.45
7	X21F-01091	X21F2	0.133	25.4	3.3	3.13
6	X21F-01100	X21F2	0.239	91.4	11.88	11.23
13	X21G-01016	X21G2	0.222	110	11.36	9.72
11	X21G-01037	X21G2	0.24	512.7	70.59	63.38
16	X21G-01073	X21G2	0.06	580.8	78.68	70.22
14	X21G-01090	X21G2	0.216	46.5	5.52	4.73
19	X21H-01060	X21H2	1	165.6	59.64	50.78
22	X21J-01013	X21J2	1	1045.46	151.51	129.47
26	X21K-00997	X21K3	1	1456.66	269.47	213.58
23	X21K-01007	X21K1	1	111.7	29.4	23
24	X21K-01035	X21K2	0.614	1276.76	225.81	179.39
67	X22A-00824	X22A1	0.253	77.9	21	15.07
64	X22A-00875	X22A1	0.123	26	6.93	4.97
63	X22A-00887	X22A1	0.066	14	3.72	2.67
70	X22A-00913	X22B2	0.471	296.8	75.26	54.03
66	X22A-00917	X22A1	0.044	55	14.81	10.64
65	X22A-00920	X22A1	0.03	6	1.69	1.21
76	X22B-00888	X22C3	0.246	3637.96	593.58	458.52
61	X22B-00987	X22B2	0.283	3146.16	472.91	375.24
82	X22C-00946	X22C3	0.335	3824.06	609.96	454.05
77	X22C-00990	X22C3	0.186	38	3.36	3.01
80	X22C-01004	X22C2	0.168	160.8	16.26	9.83
86	X22D-00843	X22D3	0.326	85.6	20.58	14.96
87	X22D-00846	X22D3	0.471	57	13.78	10
93	X22E-00833	X22E2	0.38	34.4	11.12	5.27
94	X22E-00849	X22E2	0.62	30.1	8.65	6.39
103	X22F-00842	X22F2	0.057	465.9	74.94	55.65
101	X22F-00886	X22F1	0.73	276.29	48.9	25
104	X22F-00977	X22F2	0.161	759.19	125.39	70.91
114	X22H-00836	X22H3	0.185	303.9	42.99	20.92
117	X22J-00958	X22J1	0.458	4860.65	759.28	522.5
83	X22J-00993	X22J1	0.077	3992.86	626.75	446.92
122	X22K-00981	X22K2	0.211	5431.37	817.26	533.8
130	X22K-01018	X22K3	0.62	5719.27	837.5	552.1
126	X22K-01029	X22K2	0.038	107.2	7.55	6.88
123	X22K-01042	X22K2	0.108	17	1.19	1.09
125	X22K-01043	X22K2	0.537	84.3	5.93	5.41
140	X23B-01052	X23B3	0.109	392.2	50.91	36.03
147	X23C-01098	X23D2	0.624	222.1	61.75	39.38
153	X23E-01154	X23F1	0.722	272.2	39.54	32.48
155	X23F-01120	X23F2	0.699	663.2	109.8	76.1
171	X23G-01057	X23H5	0.578	1709.6	204.48	103.34
161	X23HKaap	X23H1	0.931	1402.8	186	94.65
176	X24A-00826	X24A2	0.205	20.3	1.97	1.91
185	X24A-00881	X24B3	0.166	194.9	11.67	11.37
182	X24B-00903	X24B3	0.088	200.4	25.41	24.8
187	X24C-00928	X24C1	0.134	460.5	42.39	41.42
188	X24C-00969	X24C1	0.136	35.3	1.55	1.53
190	X24C-00978	X24C1	0.718	685.5	52.25	51.18
192	X24C-01033	X24C2	0.424	7455.77	1043.27	635.25
198	X24D-00994	X24E1	0.208	8453.57	1118.69	657.27
203	X24F-00953	X24F1	0.48	9108.77	1139.21	652.34
206	X24H-00880	X24H1	0.89	9910.17	1164.7	652.64
207	X24H-00934	X24H2	1	10510.17	1165.62	595.67

Sabie River system

The water resources model was updated with the latest information available to produce the best possible estimate of Present Day flow. Some of the key features of the Present Day scenario are:

- Updated water requirements obtained from DWA's Mbombela Reconciliation Strategy (DWA, 2013d) as well as local knowledge (IUCMA and Bushbuckridge Water).
- The transfer from the Inyaka Dam to the Sand River is fully operational.
- The IUCMA's operating rule of the system in which users along the main stem of the Sabie River and the Ecological Reserve at EWR S3 are supported by releases from the Inyaka Dam (DWA, 2013d).
- Restrictions are imposed on users based on the storage in Inyaka Dam as indicated in Table 10.5 and 10.6.

Table 10.5 Restrictions applied to irrigators in the Sabie River system

Storage in Inyaka Dam (% full)	Supply (% of full allocation)
> 100%	100%
100 – 65%	100%
65 – 40%	60%
< 40%	40%

Table 10.6 Restrictions applied to domestic users in the Sabie River system

Storage in Inyaka Dam (% full)	Supply (% of full allocation)
> 100%	100%
15 – 10%	90%
10 – 5%	85%
< 5%	80%

Table 10.7 Sabie River system: Nodes assigned to EWR sites and biophysical nodes

Node Number	Node Name	Hydrology File	Proportion	Cumulative Area	Cumulative Natural Flow	Present Day Flow
				km^2	million m^3/a	million m^3/a
9	EWR1	31B1	0.437	335.2	132.03	102.98
22	EWR2	31D2	0	695.3	261.71	176.85
62	EWR3	31K4	0.32	1898.8	493.69	307.33
17	EWR4	31C2	0.68	148.9	65.78	50.59
40	EWR5	31G3	0.8	472	156.4	106.67
111	EWR6	32F1	0.173	238.2	44.99	45.32
88	EWR7	32C2	0.48	134.9	28.88	27.54
129	EWR8	32J1	0.93	1793.1	133.55	128.57
7	X31A-00741	31A2	0.91	55.9	14.62	11.79
5	X31A-00778	31A1	0.398	187.5	80	61.21
4	X31A-00783	31A1	0.093	26	12.12	9.48
3	X31A-00786	31A1	0.058	10	4.65	3.64
2	X31A-00799	31A1	0.358	92.5	35.95	28.13
19	X31B-00756	31D1	1	454.3	174.37	116.84
10	X31B-00757	31B1	0.134	360.4	142.32	111.23
11	X31B-00792	31B1	0.159	30	12.21	9.79
18	X31C-00693	31C2	0.06	154.9	68.11	52.4
25	X31D-00755	31G3	0.085	789.6	279.36	185.53
21	X31D-00773	31D2	0.15	86.1	19.23	7.6
31	X31E-00647a	31E3	0.96	214.2	79.88	62.79
36	X31E-00647b	31G1	0.2	330.5	106.21	62.37
38	X31F-00695	31G2	0.91	103.4	43.91	36.38
41	X31G-00728	31G3	0.1	476.2	157.09	105.68
49	X31H-00819	31J1	0.27	108.3	28.94	22.42
53	X31J-00774	31K1	0.54	236.4	45.08	30.88
51	X31J-00835	31J1	0.345	69	12.01	11
60	X31K-00713	31K4	0.353	93	2.38	2.36
64	X31K-00715	31K4	0.212	1954.6	495.12	308.72
58	X31K-00750	31K4	0.065	1659.7	485.82	299.54
55	X31K-00752	31K1	0.356	1543.6	482.88	312.65
42	X31K-00758	31K1	0.05	1269.8	436.59	291.34
57	X31K-00771	31K2	0.85	99.1	2.5	2.44
68	X31L-00657	31L2	0.98	69.9	3.84	3.83
70	X31L-00664	31L3	0.638	278.3	10.88	9.51
66	X31L-00678	31L1	0.93	48.9	3.24	3.22
76	X31M-00673	31M2	0.61	90.3	1.8	1.8
75	X31M-00681	31M2	0.12	2523.3	511.74	313.2
77	X31M-00739	31M2	0.088	2626.6	513.8	315.26
79	X31M-00747	31M4	1	2978.5	524.22	325.68
78	X31M-00763	31M3	1	266.9	5.21	5.21
89	X32A-00583	32C2	0.38	139.9	29.25	27.91
92	X32B-00551	32C4	1	112.4	15.36	12.16
98	X32C-00558	32C7	0.5	330	49.68	45.13
96	X32C-00564	32C6	0.9	59.8	3.13	3.07
99	X32C-00606	32C7	0.4	397	53.16	47.43
103	X32D-00605	32F1	0.305	117.5	29.07	27.92
106	X32E-00629	32E2	0.611	59.5	10.59	9.93
107	X32E-00639	32E2	0.175	9	1.2	1.13
117	X32F-00597	32F4	0.81	343.7	51.02	59.17
110	X32F-00628	32F1	0.362	103	14.78	16.25
121	X32G-00549	32G2	0.76	112.6	3.94	3.82
119	X32G-00565	32G1	0.82	940.6	111.59	107.2
127	X32H-00560	32H2	0.77	223.4	7.59	7.31
125	X32H-00578	32H1	0.51	1283.1	121.35	116.71
131	X32J-00602	32J1	0.02	1798.7	133.64	128.66
133	X32J-00651	32J2	0.95	111.6	2.23	2.23
134	X32J-00730	32J3	1	1917.7	135.96	130.97

10.3 SCENARIOS ANALYSED

The scenarios analysed are described in Chapter 3 while additional detail relating to these scenarios is repeated here.

10.3.1 Komati River system

Growth in water demands

The growth in water demands in the Komati River system consists of:

- 20 million m^3/annum of additional irrigation within Swaziland which they may develop in terms of the Komati Basin Treaty.
- Increased urban requirements sourced from the All Towns Strategies. These increased domestic water demands as summarised in Table 10.8.

Table 10.8 Details of future water demands

Town	Quaternary catchment	WReMP Channel number	Demand in 2014 (million m^3/annum)	Demands in 2030 (million m^3/annum)
Carolina	X11B	227	1.32	1.78
Badplaas	X12C	228	0.52	0.76
Elukawtini	X12E	229	5.20	7.73
Ekulendini	X12K	230	0.86	1.21
Tonga	X13J	232	7.80	10.82
Komatipoort	X13L	233	0.50	1.66
Driekoppies	X14G	234	8.35	12.57
Nyathi	X14H	235	0.90	2.30

Maintaining target assurance of supply

The operating rule for the Komati system presented in Chapter 3 maintains the following assurance of supply to users within the Komati system based on current water use:

- Transfers to the Olifants for the power generation: 99.5%
- Domestic and industrial:98%
- Irrigation: 70%

When new scenarios, that entail increased water use or increased ecological requirements are modelled, it is no longer possible to maintain the above assurance of supply. Solely for the purpose of evaluating the economic impact of a scenario, the assumption was made that irrigation is curtailed uniformly across the whole catchment (including Swaziland) in order to maintain the assurance of supply at an economically viable level. The scaling factors applied in each scenario are given in Table 10.9.

Table 10.9 Irrigation scaling factors applied to maintain the target assurance of supply

Scenario	Scaling factor
K1	1.0
K2	1.0
K31	0.9
K32	1.0
K41	0.87
K42	1.0

Scenario	Scaling factor
K43	1.0
K6	1.0

10.3.2 Crocodile River system

Growth in water demands

The growth in water demands in the Crocodile River system consists only of domestic requirements, the details of which are given in Table 10.10.

Table 10.10 Details of future urban water demands

Town	Quaternary catchment	WReMP Channel number	Demand in 2014 (million m^3/annum)	Demands in 2030 (million m^3/annum)
Machadadorp	X21F	130	0.84	1.20
Waterval Boven	X21G	131	0.84	1.10
Dullstroom	X21A	133	0.72	1.10
White River	X22G	134	3.39	4.84
Nelspruit	X22J	135	14.28	19.38
Kanyamazane	X22K	136	19.80	21.20
Malalane	X24E	138	5.10	7.70
Komatipoort	X24H	213	0.60	0.70
Malelane	X24F	203	1.00	1.46
Barbeton	X23E	141	4.90	6.44
Karino	X22K	371	2.20	4.40

Maintaining target assurance of supply

The operating rule for the Crocodile River system presented in Chapter 3 maintains the following assurance of supply to users within the Crocodile system based on current water use:

- Domestic and industrial: 98%
- Irrigation: 70%

When new scenarios, that entail increased water use or increased ecological requirements, are modelled it is no longer possible to maintain the above assurance of supply. Solely for the purpose of evaluating the economic impact of a scenario, the assumption was made that irrigation is curtailed uniformly across the whole catchment (including Swaziland) in order to maintain the assurance of supply at an economically viable level. The scaling factors applied in each scenario are given in Table 10.11.

Table 10.11 Irrigation scaling factors applied to maintain the target assurance of supply

Scenario	Scaling factor
C1	1.0
C2	0.62
C3	0.79
C4	0.58
C5	1.00
C61	0.70

Scenario	Scaling factor
C62	0.87
C71	0.63
C72	1.00
C81	0.67
C82	0.90

10.3.3 Sabie River system

Growth in water demands

The growth in water demands in the Sabie catchment consist only of domestic requirements and forestry, the details of which are given in Table 10.12.

Table 10.12 Details of future urban water demands

Town	Quaternary catchment	WReMP Channel number	Demand in 2014 (million m^3/annum)	Demands in 2030 (million m^3/annum)
Sabie	X31A	161	1.4	1.8
Graskop	X31C	162	1.0	1.2
Hoxani	X31K	166	8.8	18.8
Nsikazi North	X31K/X24A	163	8.0	8.0
Cork	X31L	164	2.1	2.1
Dwarsloop	X32E	236	6.0	12.0
Tulamahashe	X32F	165	9.0	14.0
Acornhoek	X32C/B73E	176	4.0	6.0

In addition to the above, the future scenario assumes an additional 10 million m^3/annum irrigation demand upstream of Inyaka Dam. This relates to a recent successful land claim coupled with an application for irrigation licence on the properties Waterval and Inyaka.

Transfers to the Sand River system

The additional water for the Sand River system will be sourced either from a new dam in the Sand River or additional transfers from the Inyaka Dam. While this water is supplied over a wide area to numerous villages, in order to simplify the modelling into a manageable system the domestic water demands in the Sand system have been simplified into three following three main systems:

- Dwarsloop in the X32E catchment.
- Thulamahashe in the X32F catchment; and
- Acornhoek which lied on the catchment divide (X32C and B73E).

The assumption is also made (in accordance with the Inyaka Dam White Paper) that existing abstractions from the Sand River and its tributaries will cease once the domestic users in the Sand River catchment are fully supplied from Inyaka Dam.

Since the Inyaka Dam is already close to fully utilised, attempts to transfer more water result in the dam failing, the EWR in the Sabie not being met, and the assurance of supply to most users becoming unacceptably low. Unlike the Komati and Crocodile catchments, reducing the irrigation demand does not have a significant influence on the water since the irrigators are not supplied out of the Inyaka Dam.

Table 10.13 lists the target transfers from the Inyaka Dam to the Sand River system for each scenario.

Table 10.13 Transfers from the Inyaka Dam to the Sand River system

Scenario	Target transfer (million m^3/annum)
S1	18
S2	18
S3	32
S4	32
S51	21
S52	21
S53	21
S6	25
S71	21
S72	21
S73	21

10.4 RESULTS

Modelling results were prepared in two formats. Firstly as flow time series (for ecological evaluation) and secondly as water supplied to various sectors for economic evaluation. In all cases the systems were optimised so that the EWR allowed for in the scenario was fully met. Since the water in all three catchments (Komati, Crocodile and Sabie) are fully utilised at the current level of development, the EWR was met by reducing water use. This will obviously have an economic impact which was determined by the economist.

10.4.1 Results for ecological evaluation

Error! Reference source not found. to Figure 10.11 present the monthly average distribution plots for selected scenarios at selected EWR sites. The EWR sites shown are those that are most affected by changes in flow, that is EWR K3 on the Komati River, EWR L1 on the Lomati River, EWR 6 on the Crocodile River, EWR3 on the Sabie River and EWR8 on the Sand River.

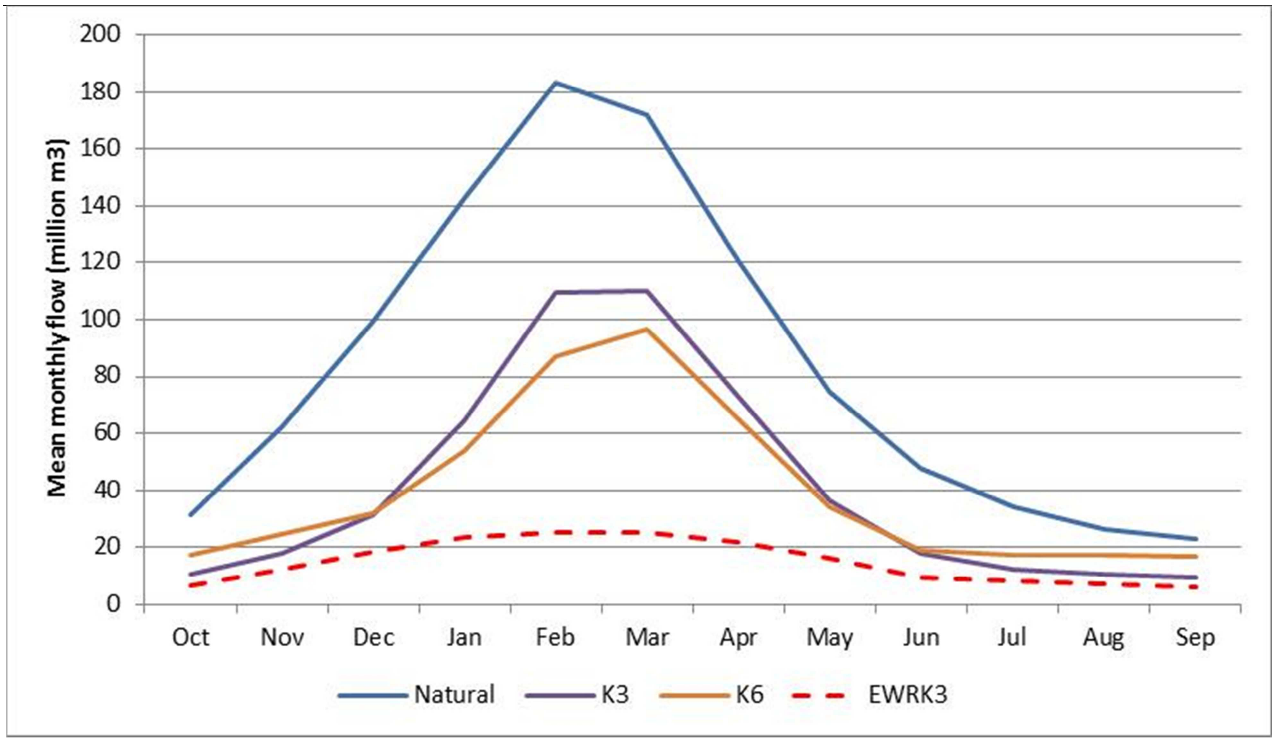


Figure 10.7 Komati River: Average monthly flows at EWR K3 for selected scenarios

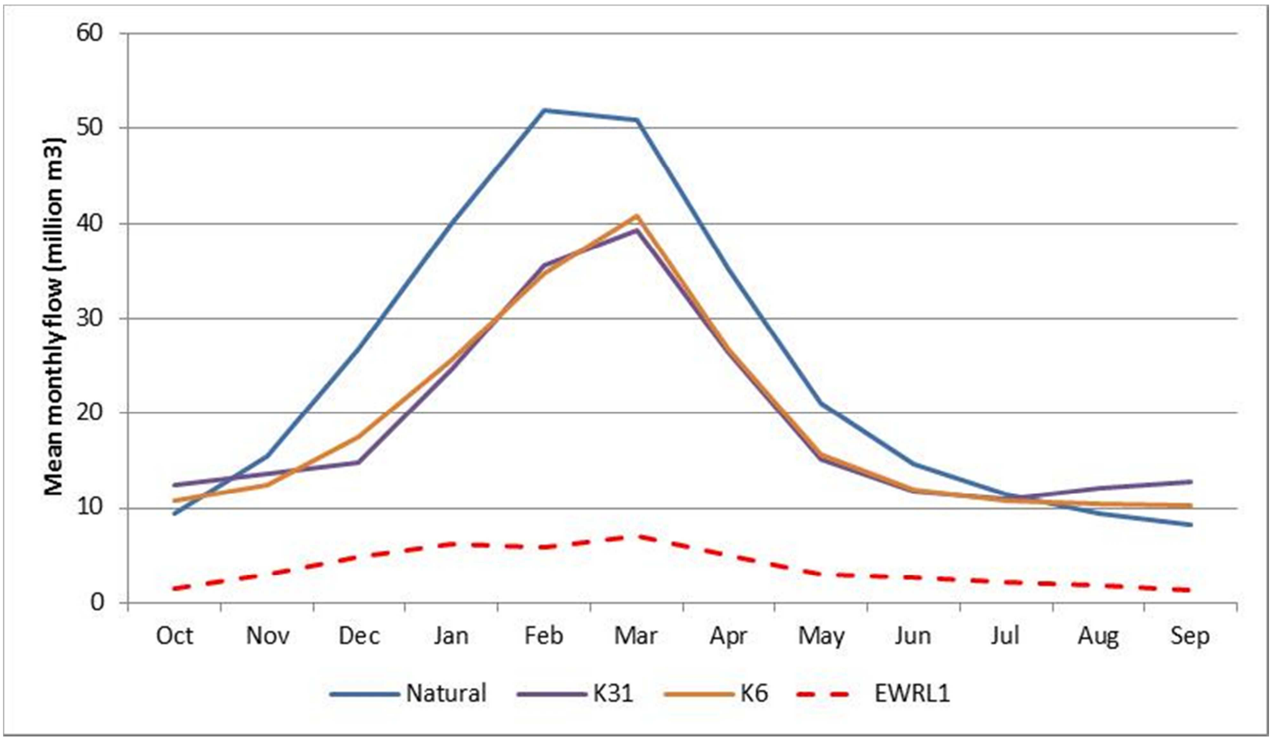


Figure 10.8 Lomati River: Average monthly flows at EWR L1 for selected scenarios

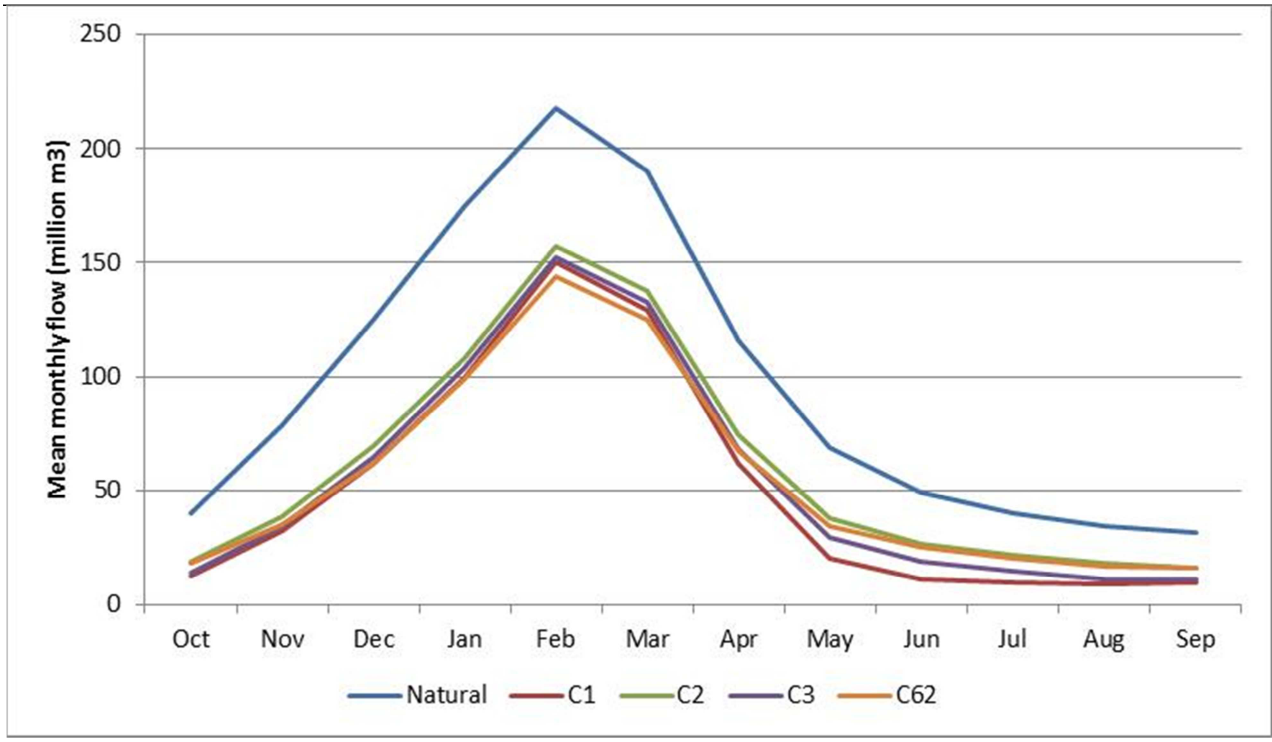


Figure 10.9 Crocodile River: Average monthly flows at EWR C6 for selected scenarios

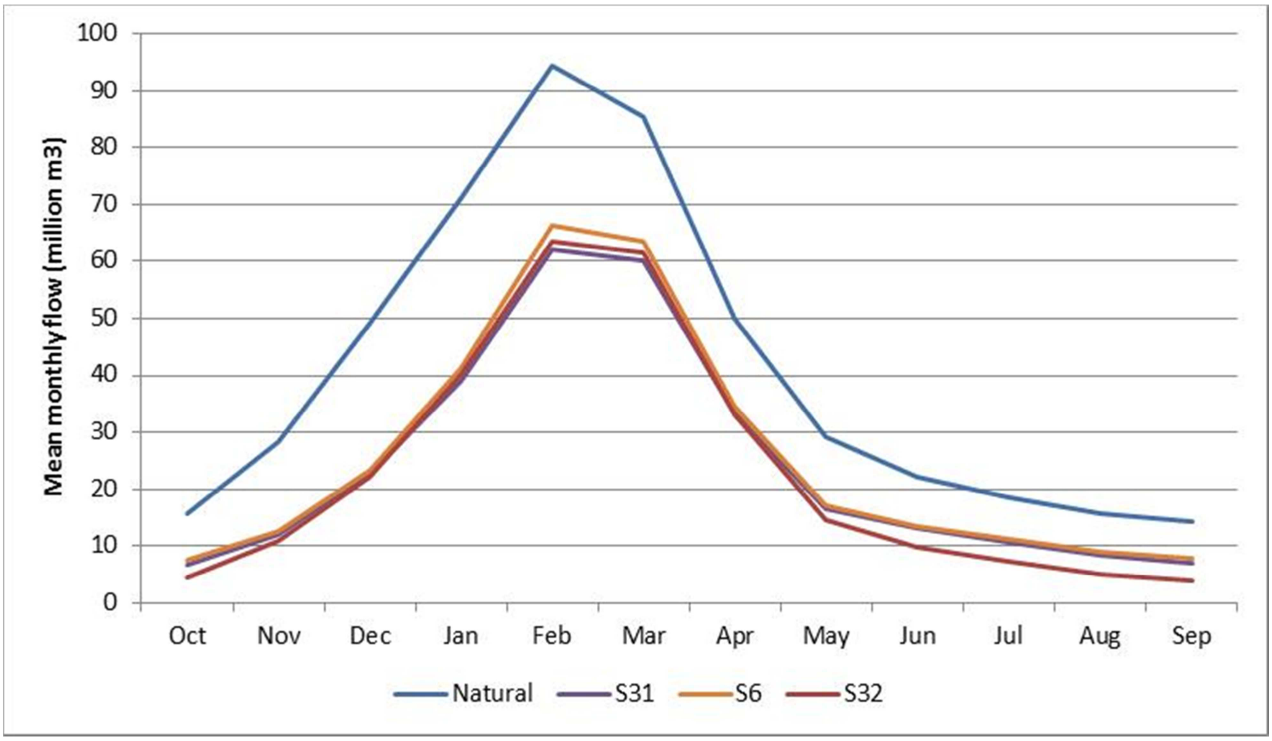


Figure 10.10 Sabie River: Average monthly flows at EWR S3 for selected scenarios

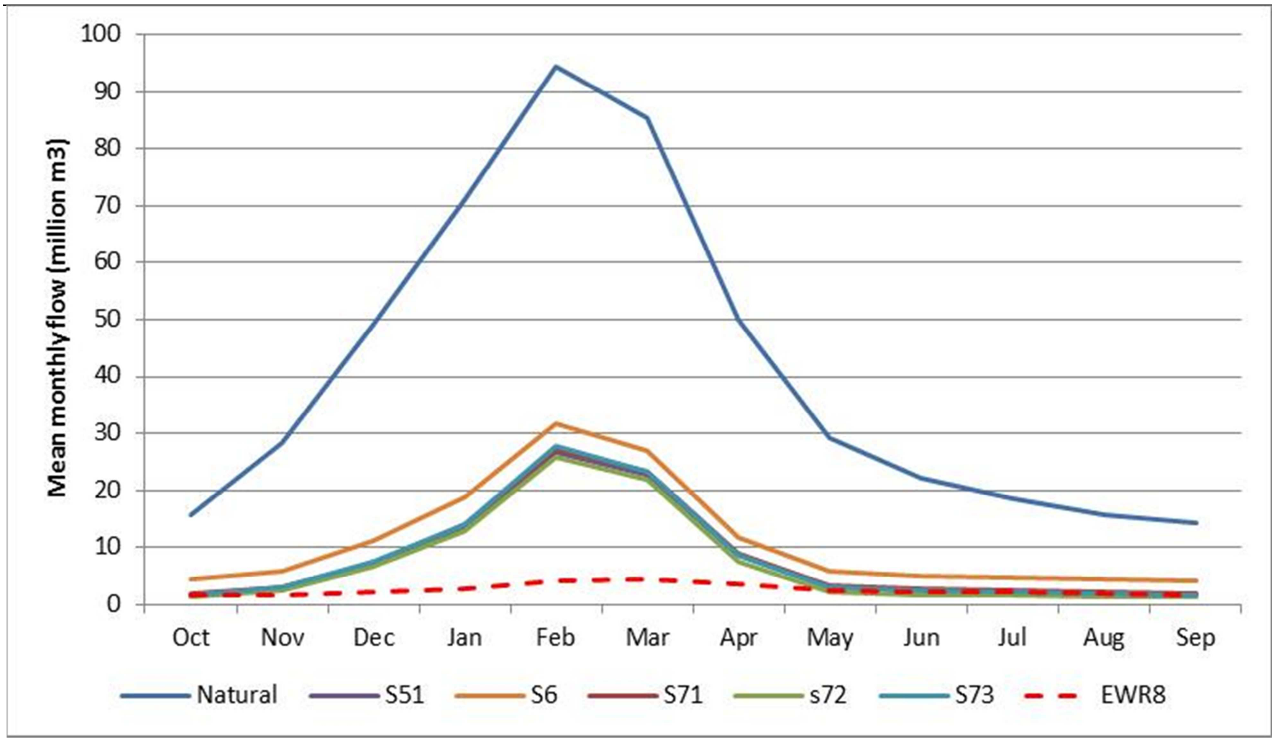


Figure 10.11 Sand River: Average monthly flows at EWR S8 for selected scenarios

10.4.2 Results for economic evaluation

Table 10.14 – 10.16 provide the water supplied to each sector within each zone and for each scenario. This information was provided to the economist for evaluation.

Table 10.14 Summary of supply to users: Komati River system

ZONE	SCENARIO							
Zone 1	K1	K2	K31	K32	K41	K42	K43	K6
Strategic	115.95	115.98	115.98	115.98	115.98	115.98	115.98	115.98
Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.58	0.58	0.58	0.58	0.58	0.58	0.00	0.58
Domestic	7.92	7.92	11.48	11.48	11.48	11.48	11.48	11.48
Irrigation	15.11	15.11	13.70	15.11	18.53	18.53	18.53	18.62
Forestry	72.06	72.06	72.06	72.06	72.06	72.06	72.06	72.06
Zone 3								
Strategic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic	8.57	8.20	11.18	11.66	11.66	11.66	11.42	11.10
Irrigation	82.45	77.06	68.75	78.54	85.68	85.68	89.12	85.75
Forestry	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Zone 4								
Strategic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic	9.15	9.16	14.72	14.76	14.75	14.75	14.63	14.58
Irrigation	85.16	83.36	74.47	80.48	80.02	80.02	84.46	84.08
Forestry	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Zone 5								
Strategic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	0.47	0.47	0.48	0.47	0.47	0.47	0.46	0.47
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Domestic	0.45	0.45	1.62	1.49	1.48	1.48	1.50	1.54
Irrigation	164.67	162.13	146.76	156.20	155.02	155.02	162.81	162.82
Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL								
Strategic	115.95	115.98	115.98	115.98	115.98	115.98	115.98	115.98
Industrial	0.47	0.47	0.48	0.47	0.47	0.47	0.46	0.47
Mining	0.58	0.58	0.58	0.58	0.58	0.58	0.00	0.58
Domestic	26.09	25.73	39.00	39.39	39.37	39.37	39.02	38.70
Irrigation	347.39	337.66	303.69	330.33	339.26	339.26	354.92	351.26
Forestry	72.40	72.40	72.40	72.40	72.40	72.40	72.40	72.40

Table 10.15 Summary of supply to users: Crocodile River system

ZONE	SCENARIO									
Zone 1	**C1**	**C2**	**C3**	**C4**	C5	C61	C62	C71	C72	C81	C82
Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
Domestic	0.72	0.72	1.10	1.10	1.10	1.10	1.10	1.10	1.098	1.098	1.098
Irrigation	4.64	3.21	3.90	3.09	4.64	3.56	4.89	3.29	4.638	4.332	5.347
Forestry	4.11	4.11	4.11	4.11	4.11	4.11	4.11	4.11	4.114	4.114	4.114
Zone 2											
Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
Domestic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
Irrigation	8.86	5.43	7.00	4.92	9.25	6.23	8.14	5.61	9.529	6.486	8.647
Forestry	11.48	11.48	11.48	11.48	11.48	11.48	11.48	11.48	11.478	11.478	11.478
Zone 3											
Industrial	14.53	14.53	14.53	14.53	14.53	14.53	14.53	14.53	14.53	14.53	14.53
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
Domestic	1.68	1.68	2.30	2.30	2.30	2.30	2.30	2.30	2.299	2.299	2.299
Irrigation	5.75	3.53	4.54	3.16	6.06	4.04	5.09	3.64	6.279	4.008	5.332
Forestry	34.20	34.20	34.20	34.20	34.20	34.20	34.20	34.20	34.195	34.195	34.195
Zone 4											
Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
Domestic	3.42	3.42	4.87	4.87	4.87	4.87	4.87	4.87	4.865	4.87	4.87
Irrigation	35.66	22.81	29.02	21.63	35.65	25.97	31.98	24.15	38.004	25.957	34.838
Forestry	40.94	40.94	40.94	40.94	40.94	40.94	40.94	40.94	40.938	40.938	40.938
Zone 5											
Industrial	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0	0	0
Mining	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0	0	0
Domestic	29.27	29.27	36.38	**34.06**	38.61	36.62	37.27	36.43	40.606	38.356	37.919
Irrigation	90.71	55.88	71.97	**50.72**	90.71	64.11	83.20	61.49	103.762	70.734	93.888
Forestry	34.90	34.90	34.90	**34.90**	34.90	34.90	34.90	34.90	34.896	34.896	34.896
Zone 6											
Industrial	0.40	0.40	0.40	**0.40**	0.40	0.40	0.40	0.40	0.4	0.4	0.4
Mining	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0	0	0
Domestic	4.88	4.88	6.45	**6.42**	6.45	6.45	6.42	5.18	5.866	5.499	5.43
Irrigation	59.96	37.47	48.21	**33.21**	63.20	43.01	52.68	34.83	58.683	39.64	51.927
Forestry	40.94	40.94	40.94	**40.94**	40.94	40.94	40.94	40.94	40.938	40.938	40.938
Zone 7											
Industrial	7.28	7.31	7.30	**6.81**	7.78	7.35	7.49	7.32	8.2	7.721	7.624
Mining	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0	0	0
Domestic	5.00	5.02	8.12	**7.60**	8.61	8.17	8.32	8.13	9.056	8.559	8.457
Irrigation	168.33	103.13	133.53	**91.20**	180.14	119.10	150.92	106.68	190.317	119.888	158.95
Forestry	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0	0	0
TOTAL											
Industrial	22.21	22.24	21.83	21.34	22.31	21.88	22.02	21.85	22.73	22.251	22.154
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0
Domestic	44.97	44.99	59.21	56.35	61.93	59.51	60.27	58.01	63.79	60.681	60.073
Irrigation	373.91	231.45	298.17	207.92	389.65	266.03	336.91	239.68	411.212	271.045	358.929
Forestry	166.56	166.56	166.56	166.56	166.56	166.56	166.56	166.56	166.559	166.559	166.559

Table 10.16 Summary of supply to users: Sabie River system

Zone	Scenario											
	S1	S2	S31	S32	Sc4	S51	S52	S53	S6	S71	S72	S73
Zone 1												
Industrial	0	0	0	0	0	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0	0	0	0	0	0
Domestic	3.484	3.482	4.185	4.185	4.159	4.17	4.087	4.167	4.106	4.17	4.087	4.167
Irrigation	49.691	49.691	42.517	47.133	47.133	44.748	49.223	44.657	49.541	44.264	49.223	44.657
Forestry	63.004	63.004	63.004	63.004	63.004	63.004	63.004	63.004	63.004	63.004	63.004	63.004
Zone 2												
Industrial	0	0	0	0	0	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0	0	0	0	0	0
Domestic	26.997	26.934	37.944	37.944	43.008	37.989	41.06	37.904	22.231	37.989	41.06	37.904
Irrigation	17.654	17.654	21.116	25.546	25.546	24.817	27.491	24.344	17.654	24.268	27.491	24.344
Forestry	25.765	25.765	25.765	25.765	25.765	25.765	25.765	25.765	25.765	25.765	25.765	25.765
Zone 3												
Industrial	0	0	0	0	0	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0	0	0	0	0	0
Domestic	18.332	18.289	26.997	26.997	29.102	29.101	30.117	29.261	24.299	26.801	28.677	26.365
Irrigation	9	9	0	9	8.8	9	8.9	8.9	8.9	8.9	8.9	8.9
Forestry	3.465	3.465	3.465	3.465	5.712	5.712	5.712	5.712	5.712	5.712	5.712	5.712

10.5 WATER RESOURCES MODELLING: SYSTEMS DIARGRAMS

The schematic network diagrams for the Komati, Crocodile and Sabie systems are provided in Figure 10.12 – 10.22.

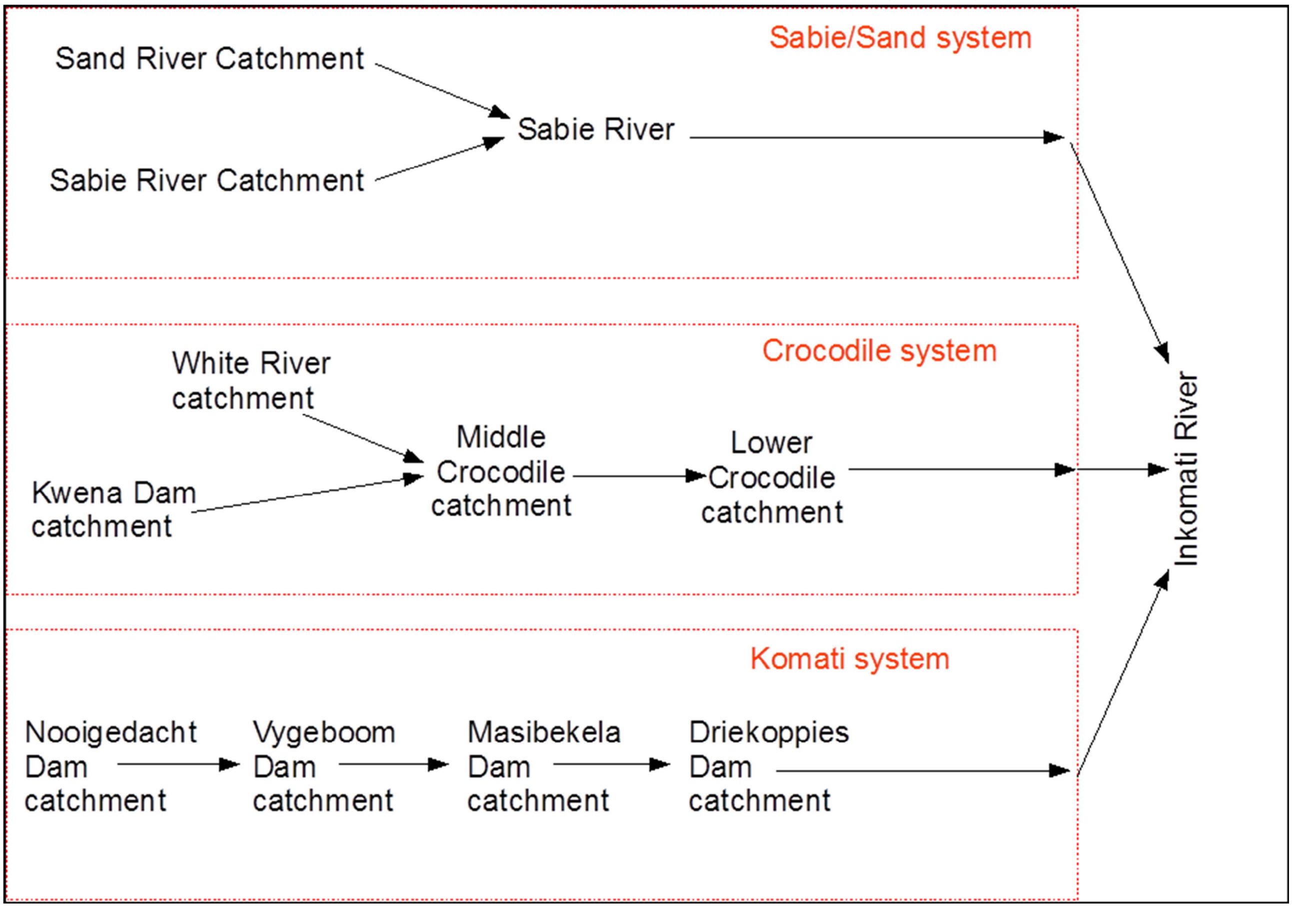


Figure 10.12 Schematic network for the Komati River system

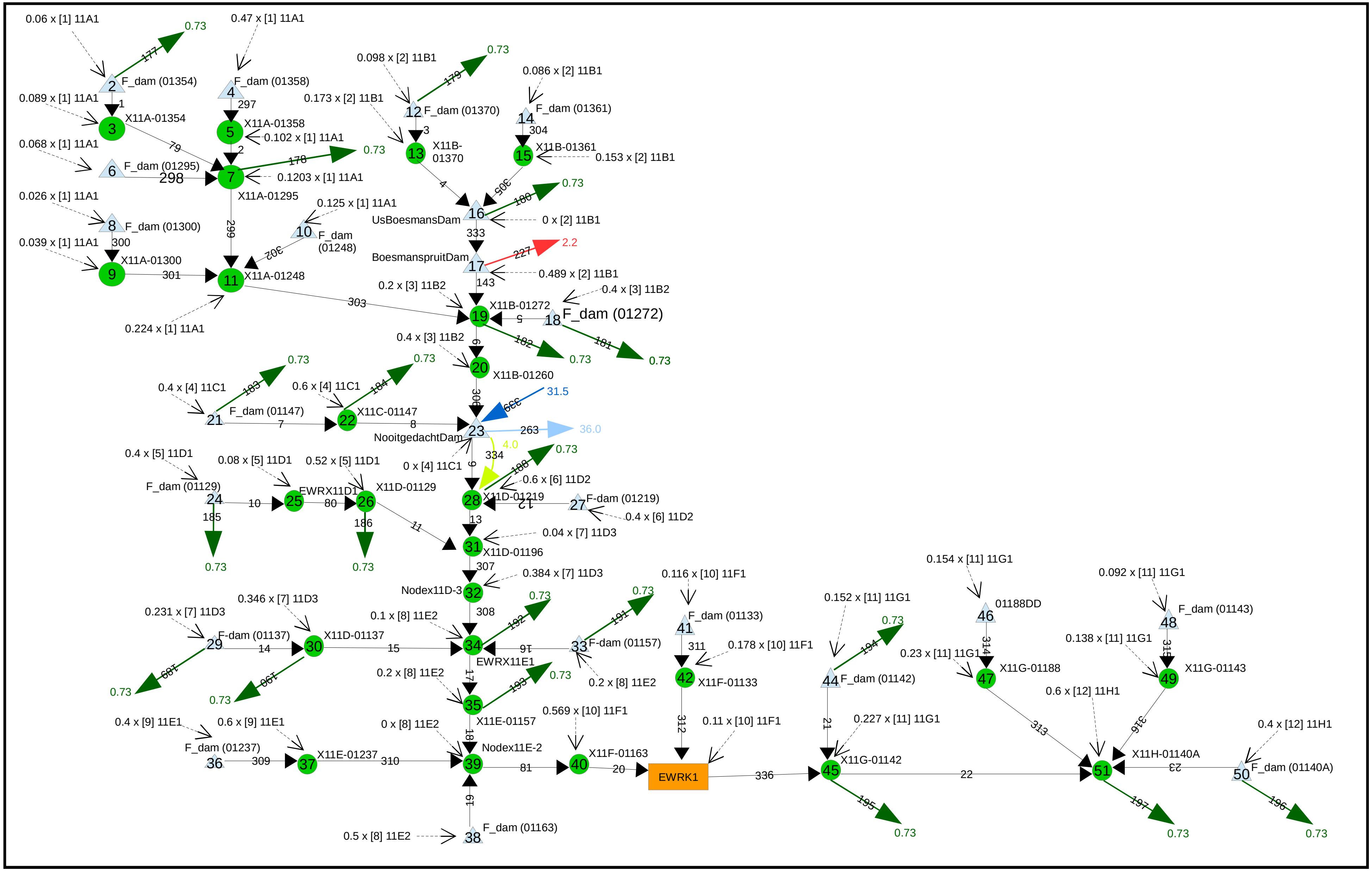


Figure 10.13 Systems diagram of the X11 System

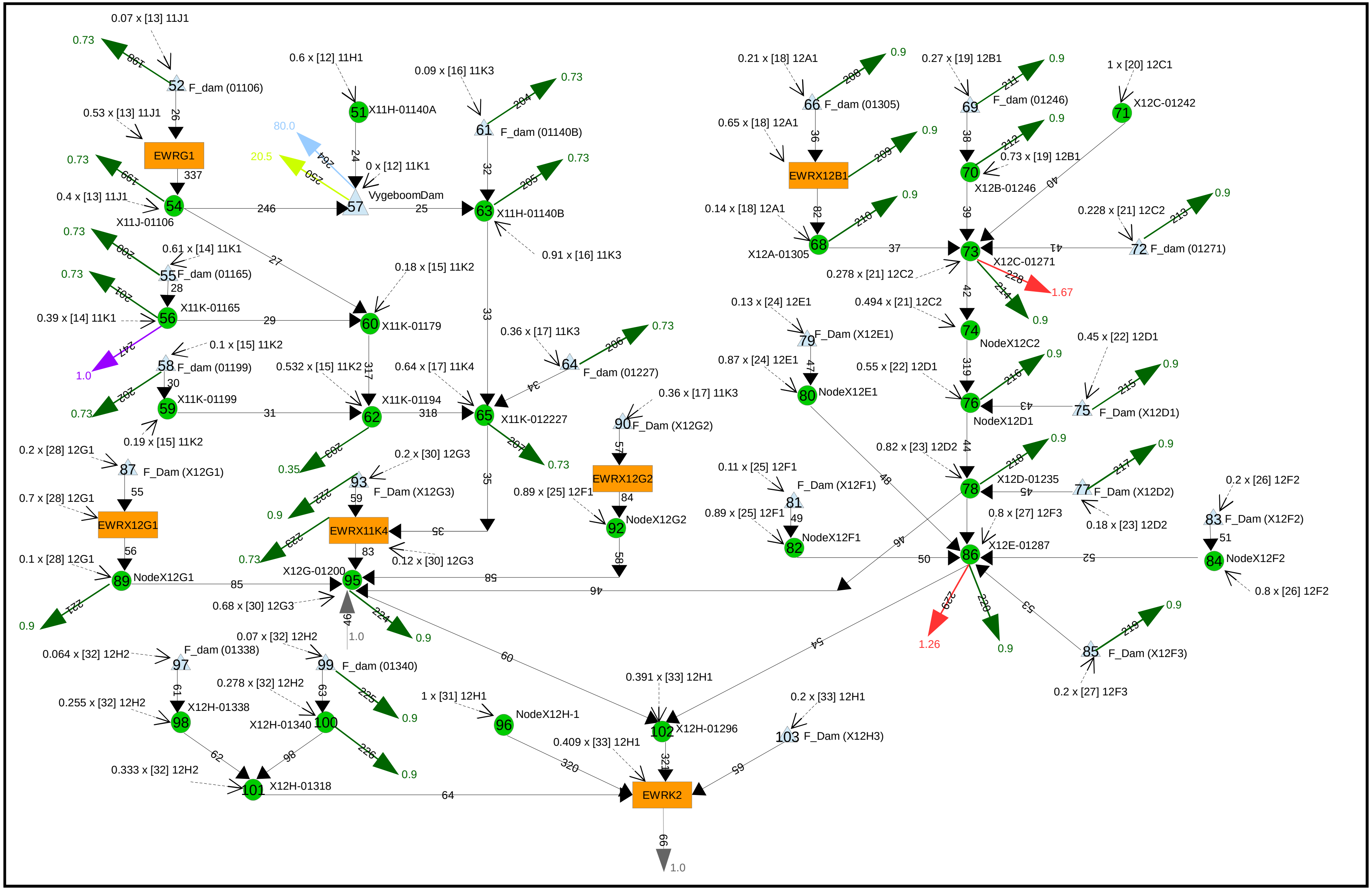


Figure 10.14 Systems diagram of the Vygeboom Dam System

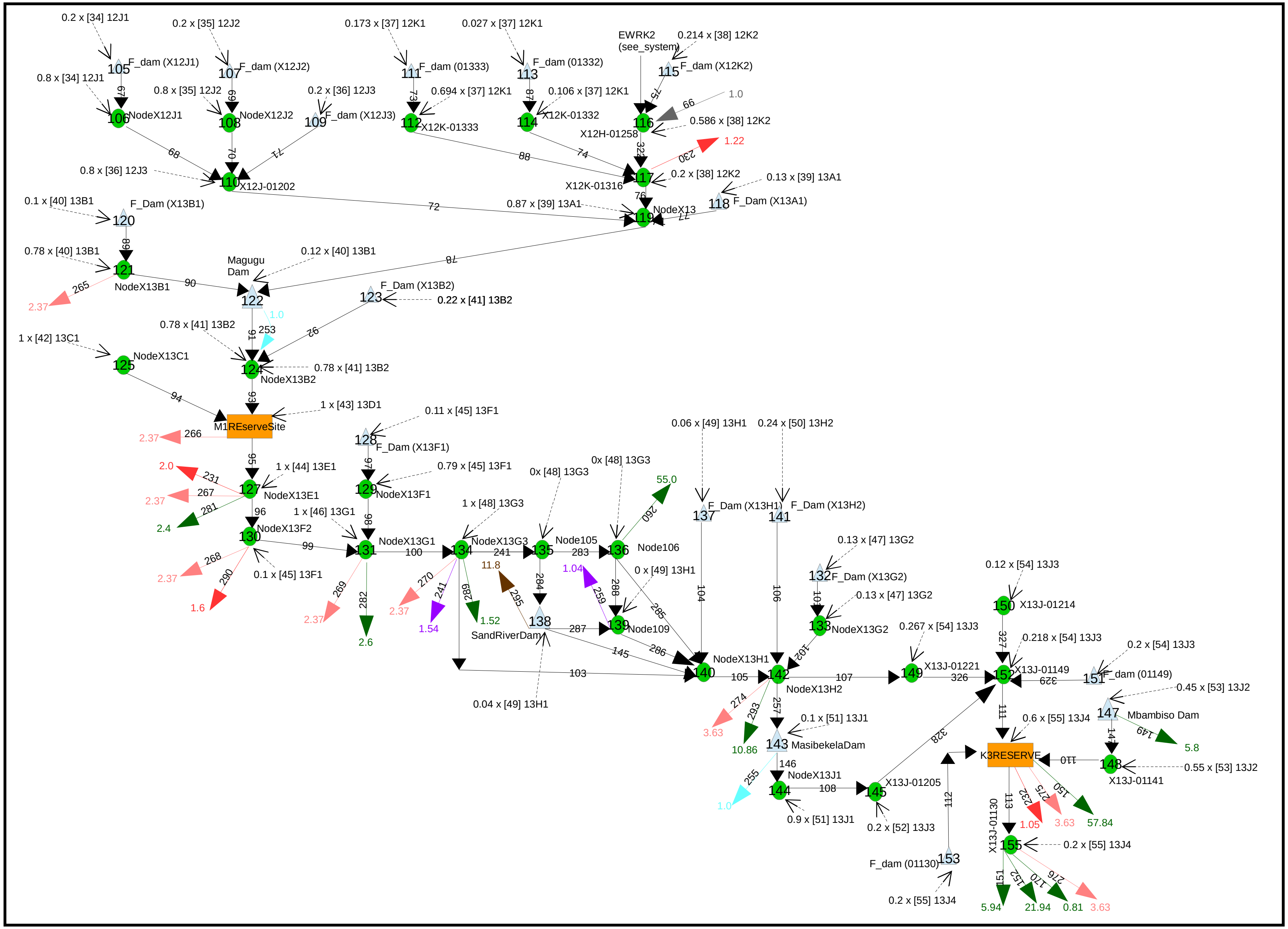


Figure 10.15 Systems diagram of the Middle Komati

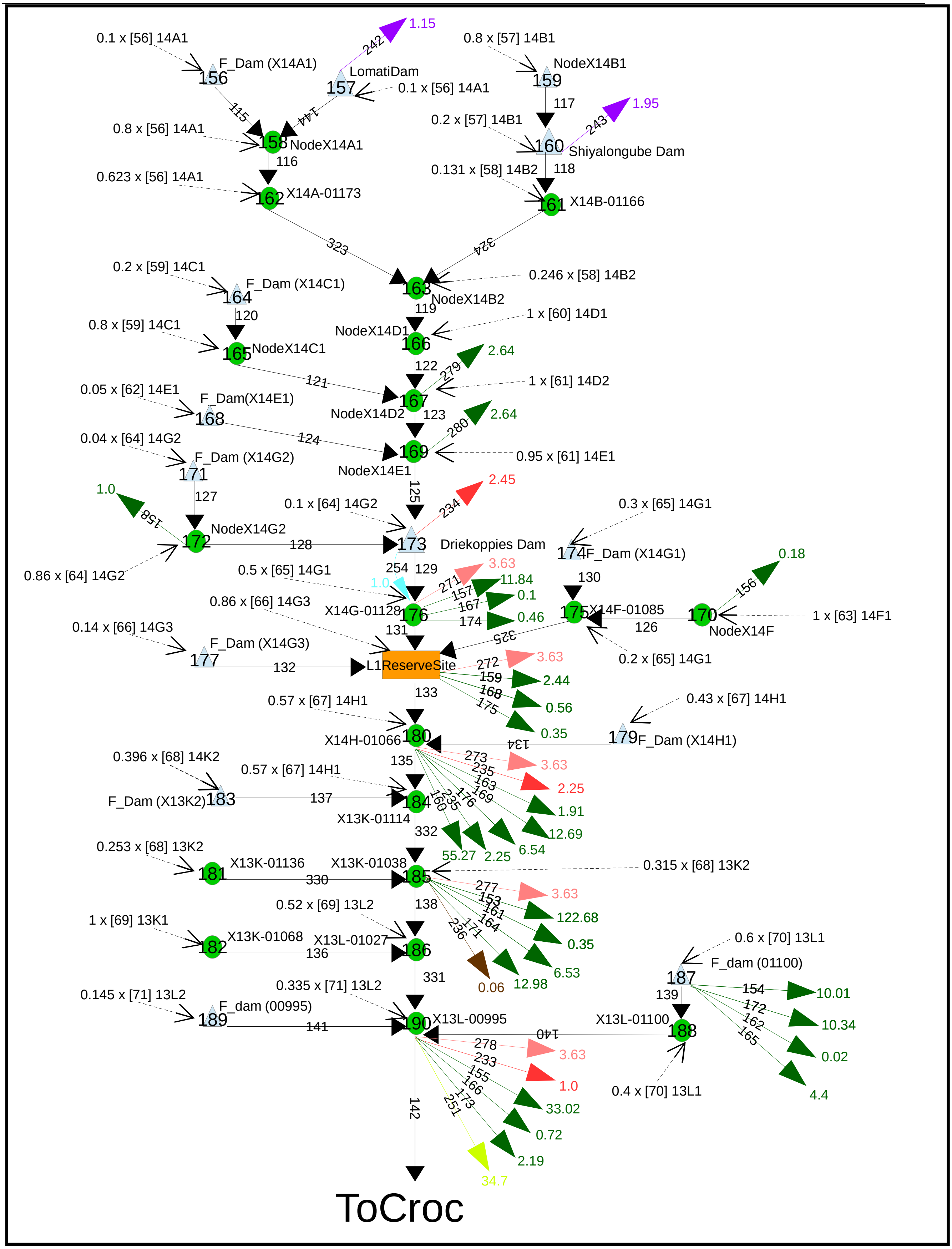


Figure 10.16 Systems diagram of the Lomati and lower Komati

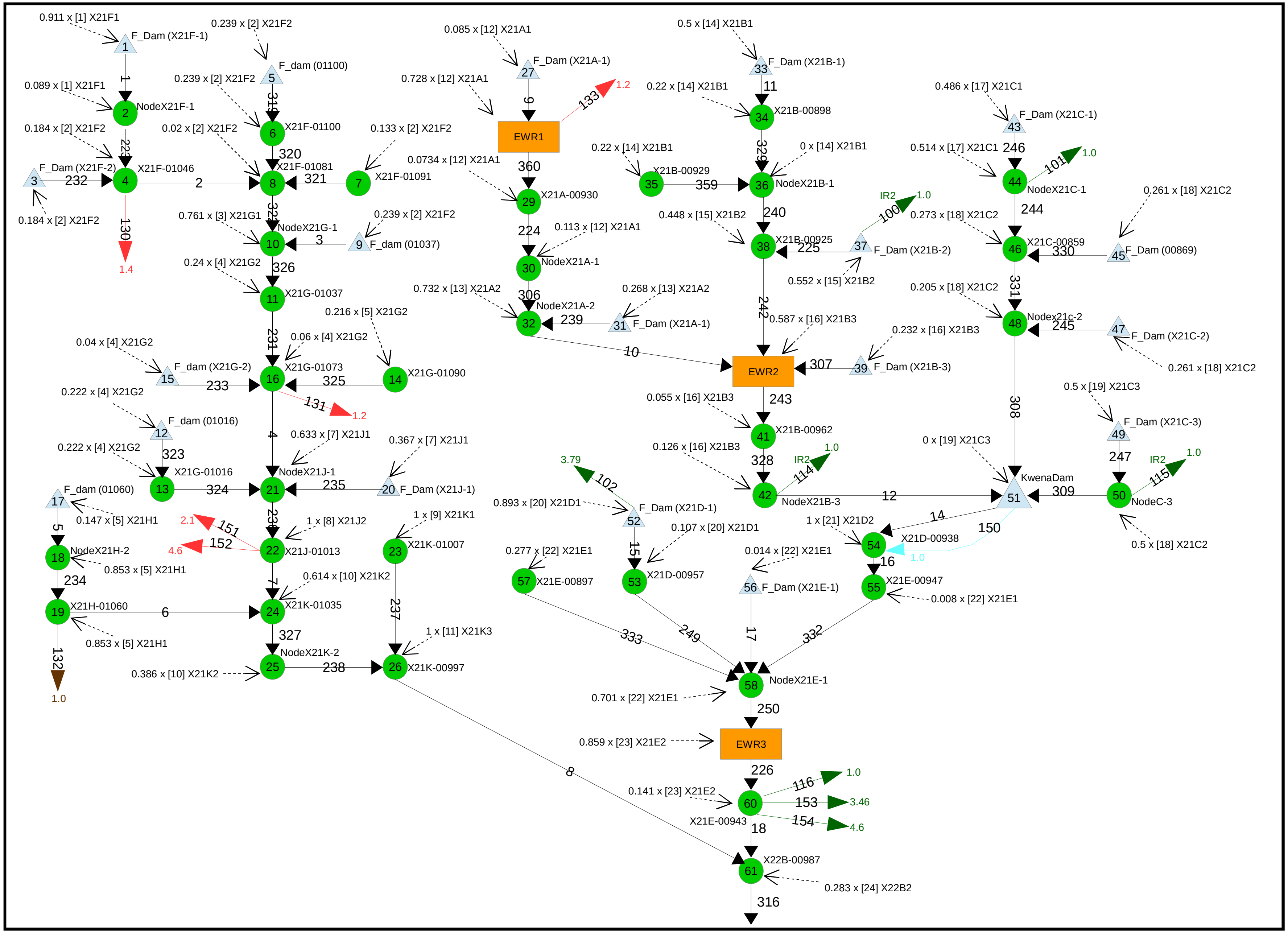


Figure 10.17 Systems diagram of the Upper Crocodile and Elands catchments

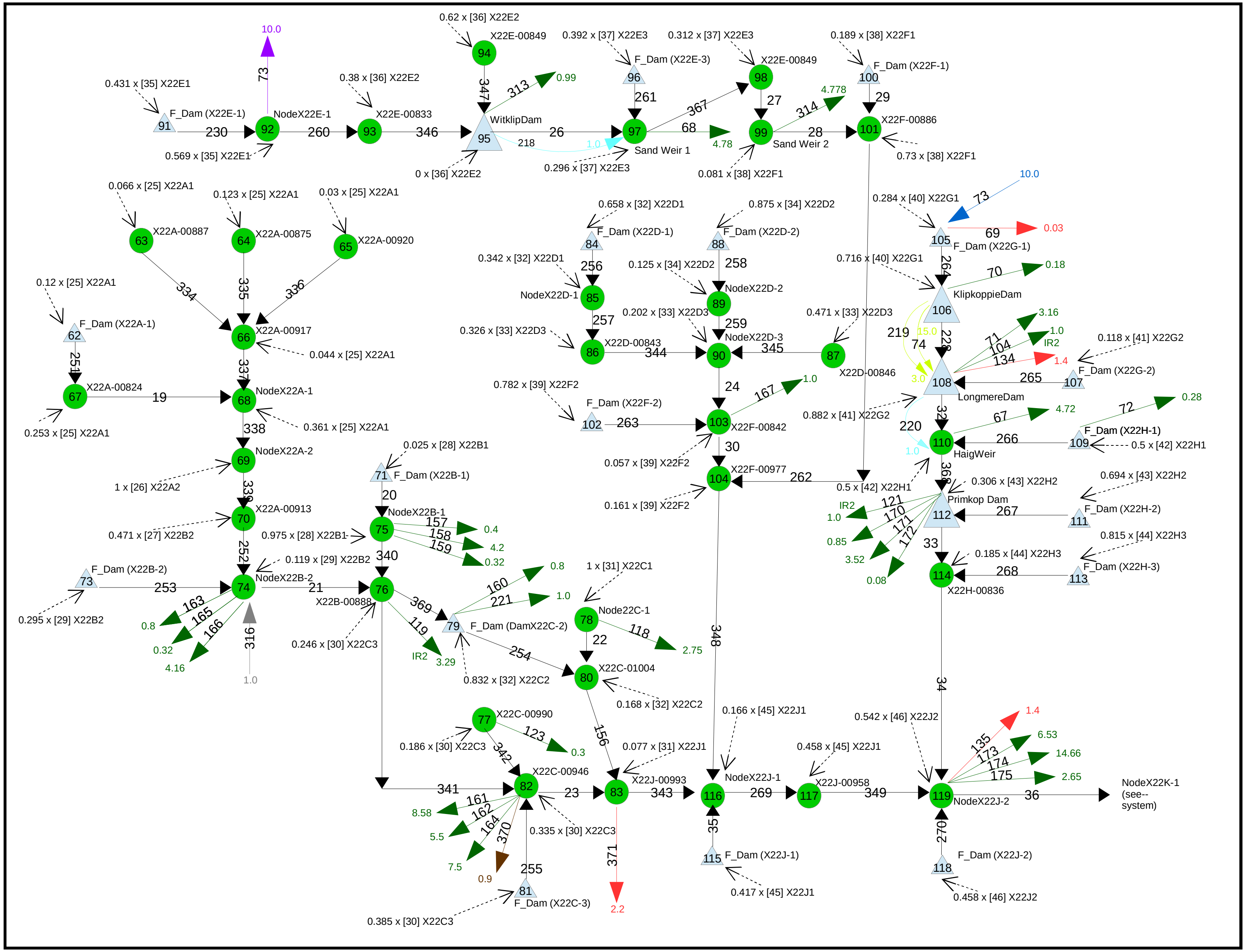


Figure 10.18 Systems diagram of the Middle Crocodile

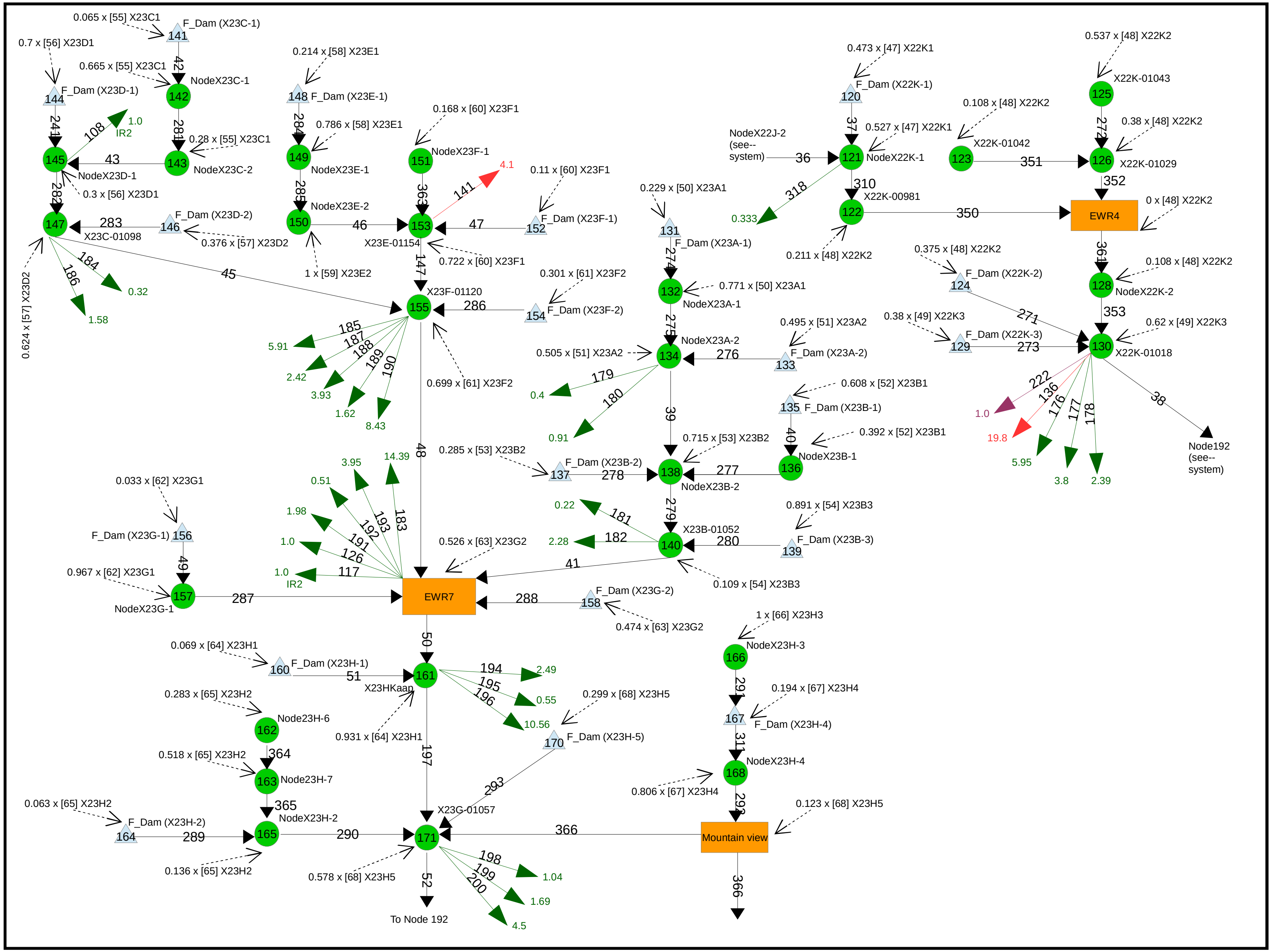


Figure 10.19 Systems diagram of the Kaap River

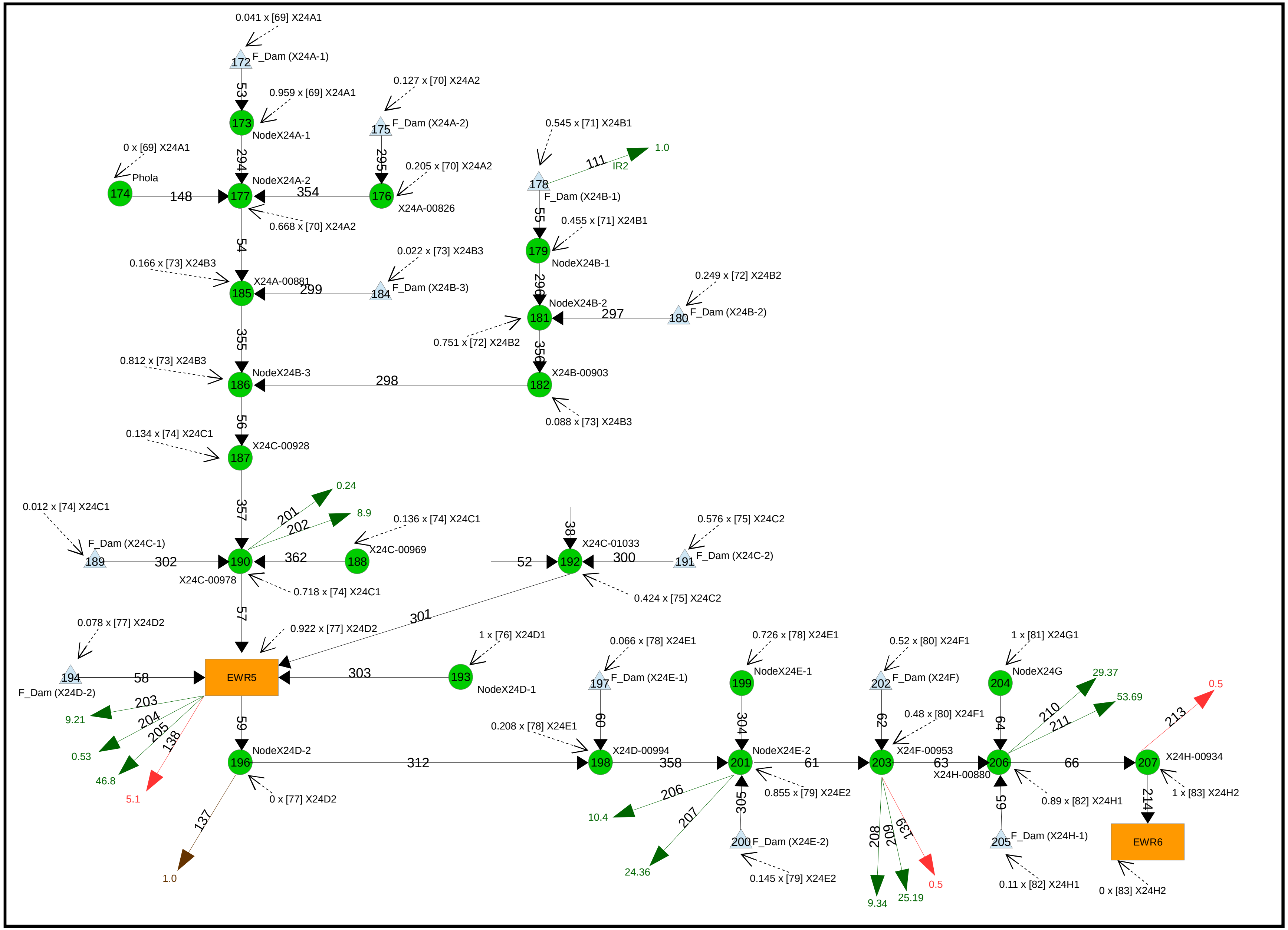


Figure 10.20 Systems diagram of the Lower Crocodile River

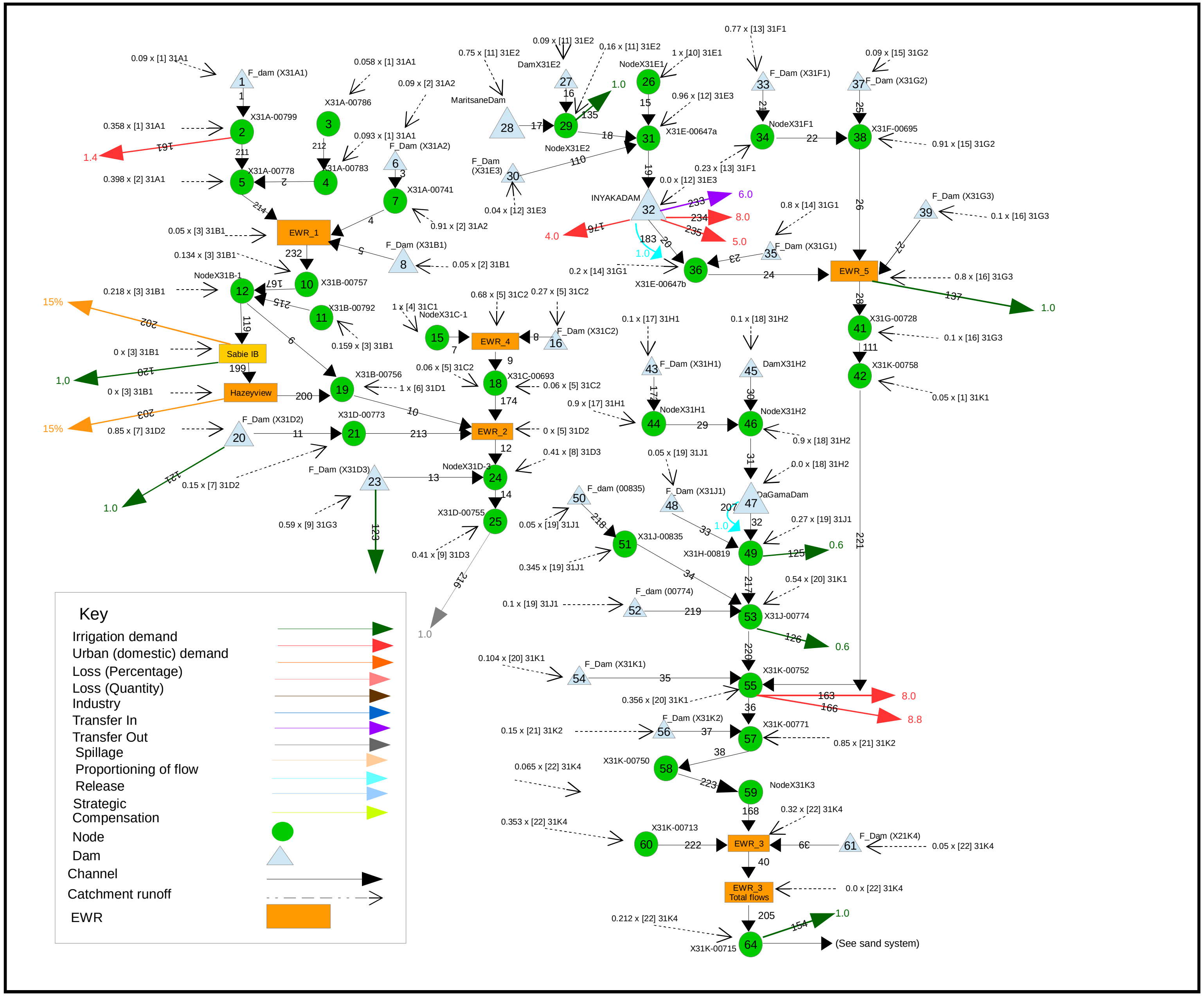


Figure 10.21 Systems diagram of the Sabie River system

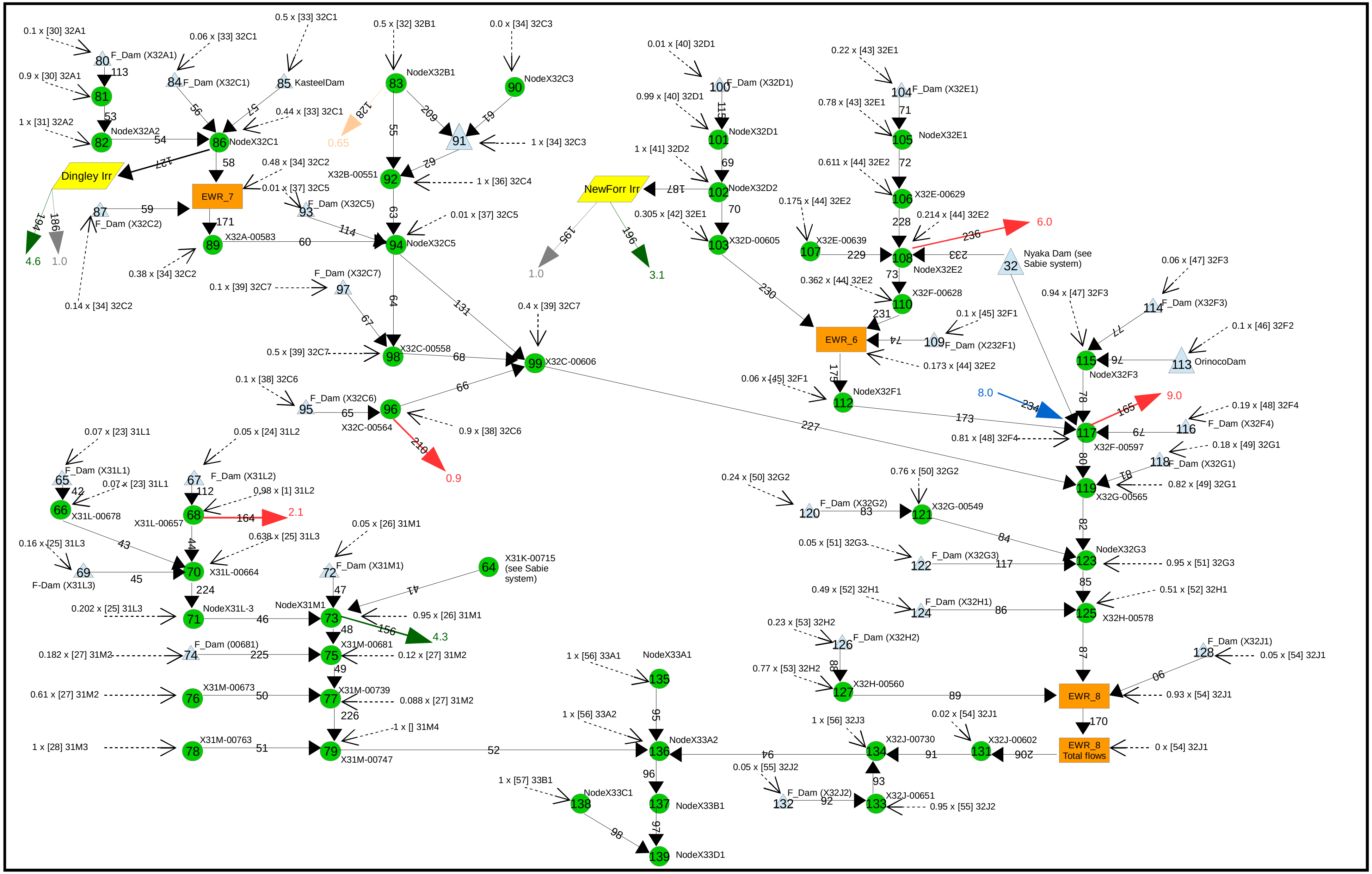


Figure 10.22 Systems diagram of the Sand River system

11 APPENDIX B: EXAMPLE OF RATING, WEIGHTING AND SCORING

Table 11.1 Sand River system: Example extract of the rating, weights and scoring table for the ecological component)

Nodes	River	Weights:		Normalisation:			Scenario Rating:						Scenario Score:					
		Importance	Length (km)	Importance 1	Length 0	Combined	51	52	53	71	72	73	51	52	53	71	72	73
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*q*	*r*	*s*
X32B-00551	Motlamogatsana	1.0	27.1	0.001	0.093	0.001	1.000	1.000	1.000	1.000	1.000	1.000	0.001	0.001	0.001	0.001	0.001	0.001
X32C-00558	Nwandlamuhari	1.0	15.1	0.001	0.052	0.001	1.000	1.000	1.000	1.000	1.000	1.000	0.001	0.001	0.001	0.001	0.001	0.001
X32C-00564	Mphyanyana	1.0	11.9	0.001	0.041	0.001	1.000	1.000	1.000	1.000	1.000	1.000	0.001	0.001	0.001	0.001	0.001	0.001
X32C-00606	Nwandlamuhari	1.0	1.2	0.001	0.004	0.001	1.000	1.000	1.000	1.000	1.000	1.000	0.001	0.001	0.001	0.001	0.001	0.001
X32D-00605	Mutlumuvi	1.0	27.7	0.001	0.095	0.001	0.787	0.122	0.726	0.787	0.122	0.726	0.001	0.000	0.001	0.001	0.000	0.001
X32E-00629	Nwarhele	1.0	18.0	0.001	0.062	0.001	0.857	0.857	0.857	0.857	0.857	0.857	0.001	0.001	0.001	0.001	0.001	0.001
X32E-00639	Ndlobesuthu	1.0	6.8	0.001	0.023	0.001	0.800	0.800	0.800	0.800	0.800	0.800	0.001	0.001	0.001	0.001	0.001	0.001
EWR6	Mutlumuvi	434.2	15.4	0.428	0.053	0.428	0.787	0.122	0.726	0.787	0.122	0.726	0.337	0.052	0.311	0.337	0.052	0.311
X32F-00628	Nwarhele	1.0	6.5	0.001	0.022	0.001	1.000	1.000	1.000	1.000	1.000	1.000	0.001	0.001	0.001	0.001	0.001	0.001
X32G-00549	Khokhovela	1.0	28.0	0.001	0.096	0.001	1.000	1.000	1.000	1.000	1.000	1.000	0.001	0.001	0.001	0.001	0.001	0.001
X32G-00565	Sand	1.0	16.4	0.001	0.056	0.001	1.000	1.000	1.000	1.000	0.957	1.000	0.001	0.001	0.001	0.001	0.001	0.001
X32H-00560	Phungwe	1.0	30.9	0.001	0.106	0.001	1.000	1.000	1.000	1.000	1.000	1.000	0.001	0.001	0.001	0.001	0.001	0.001
X32H-00578	Sand	1.0	21.8	0.001	0.075	0.001	1.000	1.000	1.000	1.000	0.957	1.000	0.001	0.001	0.001	0.001	0.001	0.001
EWR8	Sand	565.8	35.2	0.558	0.121	0.558	1.000	1.000	1.000	1.000	0.957	1.000	0.558	0.558	0.558	0.558	0.534	0.558
X32J-00651	Mutlumuvi	1.0	24.8	0.001	0.085	0.001	1.000	1.000	1.000	1.000	1.000	1.000	0.001	0.001	0.001	0.001	0.001	0.001
X32J-00730	Sand	1.0	4.2	0.001	0.014	0.001	1.000	1.000	1.000	1.000	0.957	1.000	0.001	0.001	0.001	0.001	0.001	0.001
									Ecological Scores:				**0.908**	**0.623**	**0.882**	**0.908**	**0.598**	**0.882**

12 APPENDIX C: USER WATER QUALITY CONSEQUENCES TO OPERATIONAL SCENARIOS

12.1 INTRODUCTION

In the Inkomati Classification study water quality consists of the following two broad components:

- Ecological, i.e. as part of the EWR or Reserve process. A standard process is followed for scenario evaluation.
- User, i.e. UserSpecs (uses such as irrigation and stock-watering, domestic, recreation and industrial).

Water quality is therefore incorporated in the consequence assessment as:

- Part of ECOLOGICAL consequences;
- A service identified in ECOSYSTEM SERVICES; and
- Indirectly in the ECONOMICS in terms of water treatment costs.

Steps 4 and 5 of the WRCS function as one step and are integrated as such into Step 4 of the Integrated Approach. One of the objectives of this task is to describe and document an approach as to how operational scenarios may impact on water quality for users other than the aquatic ecosystem (i.e. water quality related to users other than ecology, for example: Domestic Use, Agriculture - Stock Watering, Agriculture – Irrigation, Industrial - Category 3 and Recreation - Intermediate Contact).

This document therefore presents the approach undertaken to include user water quality (WQ) into the consequences evaluation and the results of this assessment.

12.2 WATER QUALITY OVERVIEW

A description of water quality issues in WMA5 includes the following:

- Non-point source pollution from agriculture (pesticides, fertilizers).
- Non-point source pollution from residential areas (urban and rural townships) e.g. stormwater run-off, washing in rivers.
- Point source pollution from urban infrastructure (e.g. non-compliant wastewater treatment works, saw mills and paper and pulp mills in the X3 Sabie catchment, sugar mills and processing facilities in the X2 Crocodile catchment).
- Microbiological counts and elevated nutrient concentrations.
- Erosion and sedimentation from vegetation removal and overgrazing.
- Dams are scattered throughout the catchments, which impact on the movement of sediment, and temperature and oxygen levels.
- Mining and manufacturing water quality issues.

12.3 APPROACH

12.3.1 Study area: Consequences for user water quality

The approach undertaken for the study area is listed below as bullet points.

- Identify the RU or nodes of interest (nested within IUAs) which may potentially be impacted by the scenarios.
- Gather background information on water users in the catchment and previously set objectives for water quality (where available).

- Use land use information, the Water Quality Status Quo task conducted for the study and other background information to identify which users are located where, and where the water quality hotspot areas are found.
- Link users to the RUs or nodes of interest which may potentially be impacted by the scenarios.
- Identify the user groups' water quality requirements and drivers of water quality.
- Utilize the ecological information from the Reserve study to describe aquatic ecosystem requirements.
- Identify primary users and driving water quality variables.
- Test this information with the Technical Task Group and update as required. This meeting was held on 28 August 2014 in Nelspruit.
- Provide an impact rating of selected scenarios on water quality at identified sites for the driving user(s).
- Weight sites to achieve ranks relative to each other and rank the rank the scenarios in terms of water quality impact, if required.

To summarize, user water quality state per scenario and per relevant RU and IUA was scored using the driving water quality variables linked to the primary water quality user(s). Note that although the aquatic ecosystem is the resource base rather than a "user", it was grouped and evaluated with other users for purposes of this step of the Classification process.

The identified IUAs or RUs were evaluated by specialists for a range of consequences (ecological, ecosystem services and economic). The scenario evaluation process therefore estimates the consequences that a set of plausible scenarios will have on these elements by quantifying selected metrics to compare the scenarios on relative bases with one another. The scenarios were ranked, first, for the individual variables and secondly an overall integrated ranking was derived based on multi-criteria analysis methods. Consequences on user water quality were evaluated using a qualitative process and any problem areas identified.

Figure 12.1 is a diagrammatic representation of the steps shown in the approach. The various steps are referred to as Phases 1 to 5. This notation is followed during the explanation of data collection and results.

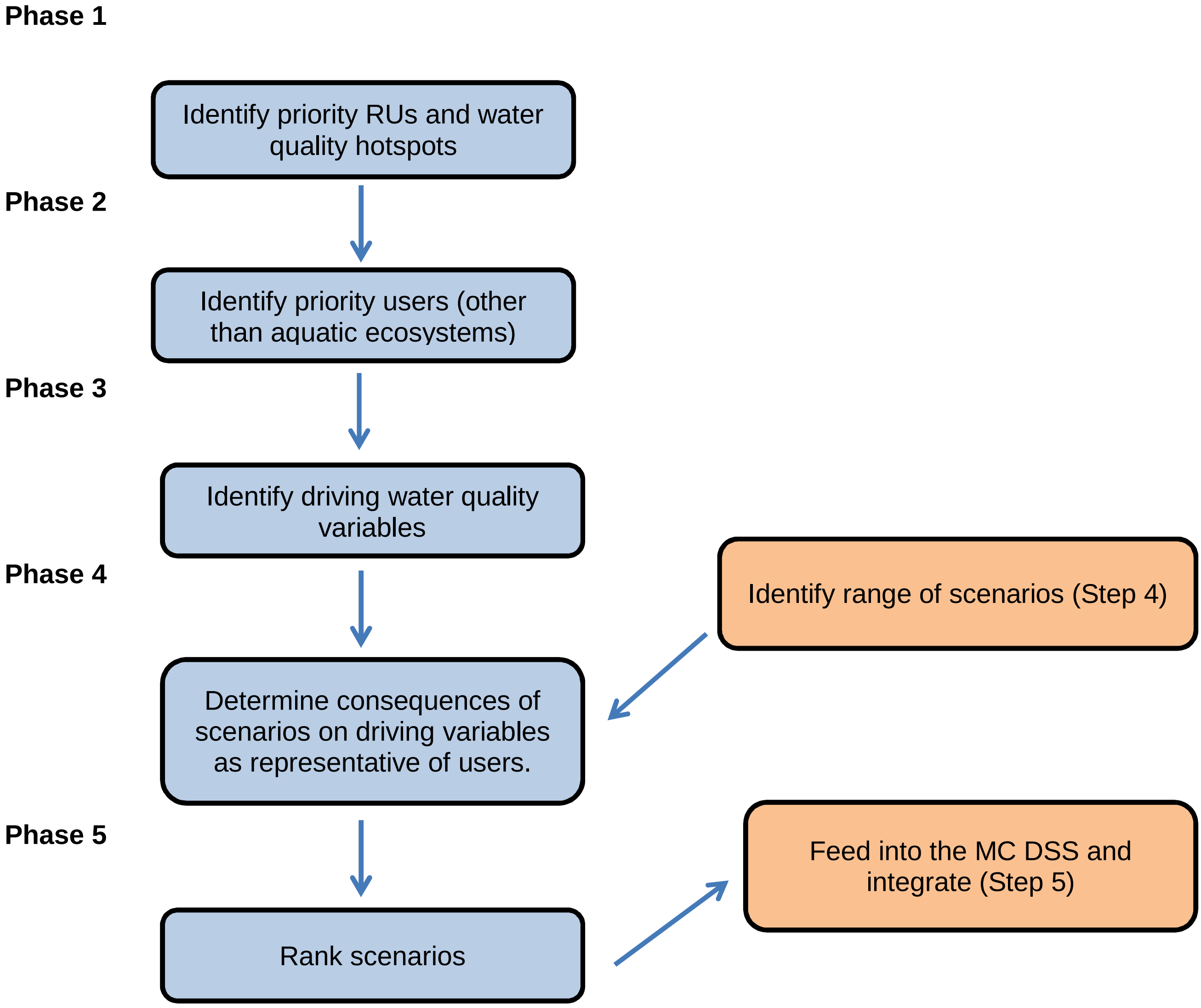


Figure 12.1 A diagrammatic representation of the approach followed for determining consequences of scenarios to user water quality

12.3.2 Upper Komati River: Impacts of coal mining

A scenario (with and without transfers from the Usuthu; Scenario K5) was selected for the Upper Komati catchment to test the impacts of additional coal mining in the area, and the impacts of increasing Acid Mine Drainage (AMD) levels. A modelling exercise was conducted by Stephen Mallory of IWR Water Resources to simulate increasing levels of AMD, represented by increasing sulphate (SO_4) levels. The impact area was confined to the Upper Komati due to the presence of the two large dams, Nooitgetdacht and Vygeboom, which are expected to prevent the potential contaminant plume from migrating into Swaziland and beyond.

The model used for the exercise was the Water Resources Yield Model known as the WRYM and set up for previous studies such as the WAAS (DWAF, 2009a). The following figures were used for the modelling exercise. Note that no estimates are available for the Komati mines as modelling has not previously been undertaken and little information exists on potential volumes. The AMD figure below is therefore a guesstimate in the absence of any other information, and based on the smaller number of mines in the Komati versus an area such as the Olifants where detailed modelling has been undertaken and expected volumes can be predicted with higher confidence.

- An AMD volume of 5 million m^3/a; equating to a concentration of 2 000 mg/L of SO_4.

- A background concentration of 50mg/L SO_4 in surface runoff.
- Two scenarios were run for each of the Nooitgedacht and Vygeboom dams, i.e. with and without the Usutu transfer.

12.4 DATA COLLECTION

Data collection steps for the priority RUs are shown for Phases 1 to 3.

12.4.1 Phase 1: Identify priority RUs and water quality hotspots

Priority RUs or Management Resource Units (MRUs) MRUs for the determination of consequences to users are those reaches containing the EWR sites, which are listed below. Note that the impact of operational scenarios has been assessed at the key biophysical nodes in the study area, i.e. the EWR sites. All consequences, i.e. ecological, economic, ecological services and user water quality, were therefore been assessed at these driving nodes or reaches of the rivers. Water quality hotspots per area are also depicted - information is taken from DWA (2013a).

Komati (X1) catchment

- This reach is MRU Komati M in IUA X1-8 and includes EWR L1 on the Lomati River. This IUA consists of the Lomati River downstream of the Swaziland border to the confluence with the Komati River, with the MRU being the main stem of the Komati River. The IUA contains Driekoppies Dam.
- This reach is MRU Komati D in IUA X1-9 and includes EWR K3 on the Komati River. This IUA consists of the lower Komati River from the Swaziland border to the confluence with the Lomati River.

Water Quality hotspots

1. <u>Gladdespruit (X11K-01194):</u> Impacts are related to a reduction in low-flows due to forestry, water quality problems due to acid mine drainage from old gold mines, sulphates and raw sewage, erosion and sedimentation, alien invasives and trout dams. **WQ RATING: 3.**
2. <u>Komati River (X13J-01130):</u> Sewage effluent and extensive settlements resulting in elevated nutrients. **WQ RATING: 3.**
3. <u>Teespruit (X12E-01287):</u> Lower reaches only due to sewage effluent resulting in elevated nutrients. **WQ RATING: 3.**
4. <u>Boesmanspruit (X11B-01272):</u> Four open-cast mines in the Boesmanspruit catchment have impacted on water quality in the area. **WQ RATING: 3.**
5. <u>Seekoeispruit (X12D-01235):</u> Number of WWTW result in elevated nutrients and increased salination around Badplaas. **WQ RATING: 3.**
6. <u>Lomati River (X14E-01151, X14G-01128, X14H-01066):</u> Stretch includes Driekoppies Dam and impacts on temperature and oxygen; also elevated nutrients from irrigation return flows. **WQ RATING: 3.**
7. <u>Middle Komati River (X13G-01282, X13H-01281, X13H-01277, X13H-01280):</u> Irrigation return flows. **WQ RATING: 3.**
8. <u>Lower Komati River (X13K-01114, X13J-012210, X13J-01210, X13J-01149):</u> Irrigation return flows. **WQ RATING: 3.**
9. <u>Lower Komati River (X13K-01114, X13J-012210, X13J-01210, X13J-01149):</u> Irrigation return flows. **WQ RATING: 3.**
10. <u>Lower Komati River (X13K-01038, X13L-01027, X13L-00995):</u> Extensive agricultural activities and irrigation return flows, exacerbated by low flows. **WQ RATING: 4.**

Crocodile (X2) catchment

- This reach is MRU Croc B in IUA X2-1 and includes EWR C3.This IUA consist of the Crocodile River and tributaries from the Kwena Dam to the confluence of the Elands River, with this MRU being the main stem of the Crocodile River from the Buffelskloofspruit to the confluence with the Elands River.
- This reach is MRU Croc C in IUA X2-9 and includes EWR C4. The main stem of the Crocodile River this IUA is subject to upstream flow modification all the way to the Kwena Dam, as well as additional abstraction for irrigation as it flows towards the Lowveld. The MRU is comprised of X22K-01018 on the main stem of the Crocodile River.
- This reach is MRU Croc E in IUA X2-11 and includes EWR C5. This MRU stretches from the confluence with the Kaap River to the end of the system, i.e. the confluence with the Komati River.
- This reach is MRU Croc E in IUA X2-11 and includes EWR C6. This EWR sites is located at the bottom end of the system on the Crocodile River in the KNP and is therefore the key site of the system.
- This reach is MRU Kaap A in IUA X2-10 and includes EWR C7. This site is located on the Kaap River before the confluence with the Crocodile River.

Water Quality hotspots

1. Crocodile River (X22K-00981): Extensive urban impacts from the Kanyamazane and Kabokweni area, including High Risk WWTW at Kabokweni which drains into the Crocodile River. **WQ RATING: 4.**
2. Crocodile River (X24C-01033):Impacts are from extensive settlements on the left bank and irrigation on the right bank. **WQ RATING: 3.**
3. Crocodile River (X24D-00994):Urban impacts, including extensive irrigation effluent impacting on water quality due to the Critical Risk WWTW at Malelane and the High Risk WWTW at Mhlatikop.**WQ RATING: 4.**
4. Crocodile River (X24H-00880): Irrigation effluent and upstream impacts. **WQ RATING: 3.**
5. Crocodile River (X24H-00934): Extensive irrigation effluent impacting on water quality and a Critical Risk WWTW at Komatipoort. **WQ RATING: 4.**
6. Crocodile River (X24F-00953):Extensive irrigation effluent impacting on water quality and a Critical Risk WWTW at Hectorspruit. **WQ RATING: 3.**
7. Gutshwa River (X24B-00903): Extensive urban and rural impacts from the Kabokweni and Malekutu towns. **WQ RATING: 3.**
8. Elands River (X21F-01046; around Machadodorp only): Urban impacts, including the Critical Risk WWTW at Machadodorp and ferro-chrome processing. **WQ RATING: 3.**
9. Noordkaap (X23B-01052): Mining and water treatment impacts present. **WQ RATING: 3.**
10. Kaap River (X23G-01057): Mining activities and forestry in the upper catchment. **WQ RATING: 3.**
11. Elands River (X21K-01035): Impacts from Sappi Ngodwana directly into the Elands, and from impacts on the lower end of the Ngodwana Dam. **WQ RATING: 4.**
12. Crocodile River (X22J-00993): Urban impacts from Nelspruit. Diffuse source releases from Papas Quarry at the confluence with the Gladdespruit, is a source of increased manganese concentrations in the Crocodile River. **WQ RATING: 3.**
13. Crocodile River (X22J-00958): Urban impacts from Nelspruit. **WQ RATING: 3.**
14. Crocodile River (X22K-01018): Upstream impacts from Nelspruit, Kanyamazane and Kabokweni areas. **WQ RATING: 3.**
15. Wit River (X22H-00836): Urban impacts from White River and Kabokweni and agricultural impacts. **WQ RATING: 3.**

Sabie-Sand (X3) catchment

- This reach is MRU Sabie B in IUA X3-3 and includes EWR 3 on the Sabie River downstream of the Marite confluence. This IUA consists of the main stem of the Marite and Sabie rivers from Inyaka Dam to the confluence with the Sand River.
- This reach is MRU Marite A in IUA X3-3 and includes EWR 5 on the lower Marite River, downstream of Inyaka Dam.
- This reach is MRU Mut A in IUA X3-7 and includes EWR 6 on the Mutlumuvi River, a major tributary of the Sand River.
- This reach is MRU Sand B in IUA X3-10 and includes EWR 8 (Thulandziteka) on the Sand River.

Water Quality hotspots

1. A tributary of the Sabie River (X31K-00752): Effluent discharge from the Manghwazi WWTW causing high nutrient levels and introducing hazardous microbiological organisms into the system. **WQ RATING: 3.**
2. Sabie River (X31D-00755): Hazyview WWTW. In addition, vegetation removal is high and irrigation is extensive within this catchment, with moderate irrigation effluent impacting on water quality. **WQ RATING: 3.**
3. Ndlobesuthu (X32E-00639): Urban run-off, effluent discharge and vegetation removal represent predominant and critical impacts. Sedimentation and erosion is serious. Indirect impacts are probably high turbidity and nutrient levels, the latter indicated by elevated algal growth. **WQ RATING: 4.**
4. A tributary - Klein Sand River/Acornhoek (into Marite River: X31E-00647): Effluent discharge from the Acornhoek WWTW causing high nutrient levels and introducing hazardous microbiological organisms into the system. According to the DWA State of Rivers report, conditions are poor in the Klein Sand River, due to clearing of riparian vegetation and resultant erosion, coupled with alien plant infestation (DWAF, 2002). **WQ RATING: 3.**
5. Marite River (X31E-00647): Urban run-off and effluent from urban areas are the predominant water quality related impacts, along with extensive afforestation, vegetation removal and erosion, which most likely results in high turbidity levels and nutrient concentrations. **WQ RATING: 3.**
6. Marite River (X31G-00728): High algal growth is evident probably due to high nutrient inputs from irrigation run-off and agriculture. Erosion, alien vegetation, vegetation removal are also evident, with small impacts relating to urban run-off/effluent, sedimentation, and overgrazing. Indirect impacts are probably high turbidity and nutrient levels. According to the Inkomati Reserve Study (DWA, 2009c), increased suspended solids loads, elevated nutrients and toxics, as well as temperature and oxygen fluctuations at low flows occur. This is due to extensive citrus cultivation in the area and clearing for subsistence farming. The diatom *A. minutissimum* indicates anthropogenic disturbances and the presence of diffuse pollutants (upstream citrus farming) (EWR 5). According to the PES Fact Sheets irrigation run-off is moderate, which may result in pesticide and fertilizers discharging into the river. **WQ RATING: 4.**
7. Noord-Sand (X31J-00774): High algal growth is evident probably due to urban and irrigation run-off/effluent. Extensive vegetation removal and moderate afforestation probably results in high turbidity levels. Moderate impacts associated with erosion, alien vegetation, overgrazing and irrigation effluent are also evident. Indirect impacts are probably high turbidity and nutrient levels. **WQ RATING: 3.**
8. Noord-Sand (X31J-00835): Urban run-off and effluent from urban areas are the predominant impacts, with moderate levels of algal growth being the likely result of effluent discharges. Alien vegetation, overgrazing and irrigation effluent are also evident. Indirect impacts are probably high turbidity and nutrient levels. **WQ RATING: 3.**

9. Bejani (X31K-00713): Urban run-off, effluent discharge (i.e. Mkhuhlu WWTW) and vegetation removal represent serious impacts. Sedimentation and algal growth is high, with moderate erosion impacts. Indirect impacts are probably high turbidity and nutrient levels, especially since algal levels are high, as well as hazardous microbiological organisms. **WQ RATING: 3.**
10. A tributary that flows into Inyaka Dam, proximate to Marite River (X31G-00728): Effluent discharge from the Maviljan WWTW causing high nutrient levels and introducing hazardous microbiological organisms into the system. **WQ RATING: 3.**
11. Tlulandziteka (X32A-00583): The Reserve study of 2010 indicated a C category for this river, with elevated nutrients, turbidity and toxics present. Impacts on temperature and oxygen were also seen due to fluctuating flows. **WQ RATING: 3.**

12.4.2 Phase 2: Identify primary water users in priority reaches

Primary user groups in the priority river reaches are shown in Table 12.1 – 12.3 for the Komati, Crocodile and Sabie-Sand systems respectively.

Table 12.1 Primary users groups in river reaches considered during the scenario impact assessment process – Komati (X1)

Reach number	Priority river reaches	Primary user groups
1	MRU Komati M, including EWR L1 on the Lomati River.	Settlements, WWTW, sand-mining, extensive crop farming.
2	MRU Komati D, including EWR K3 on the Komati River.	Irrigation return flows, Tongo WWTW.

Table 12.2 Primary users groups in river reaches considered during the scenario impact assessment process – Crocodile (X2)

Reach number	Priority river reaches	Primary user groups
1	MRU Croc B, including EWR C3 on the Crocodile River.	Irrigation, particularly citrus.
2	MRU Croc C, including EWR C4 on the Crocodile River.	Kanyamazane urban and industrial area.
3	MRU Croc E, including EWR C5 on the Crocodile River.	Urban (Malelane, Marloth Park, Komatipoort) impacts impacting on water quality, including sugar mill and fruit processing. Critical Risk WWTW at Malelane, Hectorspruit and Komatipoort, and a High Risk WWTW at Mhlatikop.
4	MRU Croc E, including EWR C6 on the Crocodile River.	
5	MRU Kaap A, including EWR K7 on the Kaap River.	Some irrigation; Lily and Barbrooke Goldmines.

Table 12.3 Primary users groups in river reaches considered during the scenario impact assessment process – Sabie-Sand (X3)

Reach number	Priority river reaches	Primary user groups
1	MRU Sabie B, including EWR S3 on the Sabie River.	Rural settlements and urban areas such as Hazyview. Manghwazi WWTW; extensive irrigation return flows and Pabeni quarry.
2	MRU Marite A, including EWR S5 on the Marite River.	Impacts from extensive settlements and irrigation activities, including fertilizer use.
3	MRU Mut A, including EWR S6 on the Mutlumuvi River, a tributary of the Sand River.	Settlements and irrigation return flows.
4	MRU Sand B, including EWR S8 on the Sand River	Thulmahaxi WWTW (outside the nature

Reach number	Priority river reaches	Primary user groups
	(Thulandziteka).	reserve).

12.4.3 Phase 3: Identify driving water quality variables per primary user

Driving water quality variable per user group are shown in Table 12.4 – 12.6 for the Komati, Crocodile and Sabie-Sand systems respectively. Current state of integrated water quality is also shown.

Table 12.4 Driving water quality variable per primary user groups in identified river reaches – Komati (X1)

Reach number	Priority river reaches	Primary user group	Driving water quality variables	Current State
1	MRU Komati M, including EWR L1 on the Lomati River.	Settlements, WWTW, sand-mining, extensive crop farming.	Nutrients, salts, toxics, turbidity, *E.coli*/coliforms.	Good - Fair (B/C)
2	MRU Komati D, including EWR K3 on the Komati River.	Irrigation return flows, Tongo WWTW.	Nutrients, turbidity, *E.coli*/coliforms.	Fair - Poor (C/D) *

* Note that the PES of a C/D was taken from a PAI table prepared using the data in the water quality table for K3 in AfriDev (2006), i.e. the Water Quality Report for the Komati EWR study. It is not known what Present Day (or Scenario 1) refers to in this report, as it mentions a water quality category of a D/E (PAI table for K3 Scenario: PD = Sc1; pg 64), while the overall site classification for water quality on the table for EWR site K3 was a C/D (pg 42).

Table 12.5 Driving water quality variable per primary user groups in identified river reaches – Crocodile (X2)

Reach number	Priority river reaches	Primary user group	Driving water quality variables	Current State
1	MRU Croc B, including EWR C3 on the Crocodile River.	Irrigation, particularly citrus.	Elevated nutrients, salts and toxics (e.g. pesticides).	Fair (C)
2	MRU Croc C, including EWR C4 on the Crocodile River.	KaNyamazane urban and industrial area.	Nutrients, salts, toxics, *E.coli*/coliforms.	Fair (C)
3	MRU Croc E, including EWR C5 on the Crocodile River.	Urban (Malelane, Marloth Park, Komatipoort) impacts impacting on water quality, including sugar mill and fruit processing. Critical Risk WWTW at Malelane, Hectorspruit and Komatipoort, and a High Risk WWTW at Mhlatikop. KNP on one bank, so biodiversity and conservation. EWR C6 is at the end of the system so international agreements must be met.	Nutrients, salts, toxics, *E.coli*/coliforms, temperature (sugar mill impact); international obligations at EWR C6.	Fair (C)
4	MRU Croc E, including EWR C6 on the Crocodile River.			Fair (C)
5	MRU Kaap A, including EWR K7 on the Kaap River.	Some irrigation; Lily and Barbrooke Goldmines.	Elevated nutrients, salts and toxics (As, Cn).	Good (B)

Table 12.6 Driving water quality variable per primary user groups in identified river reaches – Sabie-Sand (X3)

Reach number	Priority river reaches	Primary user group	Driving water quality variables	Current State
1	MRU Sabie B, including EWR S3 on the Sabie River.	Rural settlements and urban areas such as Hazyview. Manghwazi WWTW; extensive irrigation return flows and Pabeni quarry.	Nutrients, salts, toxics, turbidity/suspended solids, *E.coli*/coliforms.	Good (B)
2	MRU Marite A, including EWR S5 on the Marite River.	Impacts from extensive settlements and irrigation activities, including fertilizer use.	Nutrients, salts, toxics.	Good (B)
3	MRU Mut A, including EWR S6 on the Mutlumuvi River, a tributary of the Sand River.	Settlements and irrigation return flows.	Nutrients, salts, toxics, turbidity, *E.coli*/coliforms.	Good – Fair (B/C)
4	MRU Sand B, including EWR S8 on the Sand River (Thulandziteka).	Thulmahaxi WWTW (outside the nature reserve).	Nutrients, *E.coli*/coliforms.	Good (B)

12.5 RESULTS

12.5.1 Study area: Consequences for user water quality

Results are presented as bar diagrams (Figures 12.2 – 12.7) per identified reach. Note the following explanatory points:

- No scale is shown on the bars as the process undertaken was qualitative and in relation to Current State (CS).
- CS shown on the bar relates to the water quality state, for example, a Good CS will be located along the upper third and in the green portion of the bar.
- CS per river reach can therefore be assessed comparatively, that is, if CS is lower on one bar than the other, then water quality is assumed to be poorer at that site.
- The impact of operational scenarios (denoted as Sc x) have been considered in relation to CS. So therefore, if Sc 1 (for example) results in a small impact on the water quality of the primary user in the river reach, the small impact of that scenario will be shown by placing the symbol for the scenario close or alongside that denoting the CS.
- It is expected that if a scenario has little impact on ecological water quality, it is unlikely to have a large impact on the water quality linked to any user.
- Scenarios relevant to the site are shown on the bars. See Appendix A for an explanation of operational scenarios.
- As a water quality model and load calculations were not available for most of the Inkomati catchments at the time of assessment, a qualitative assessment was conducted for the scenario assessment phase of the study.

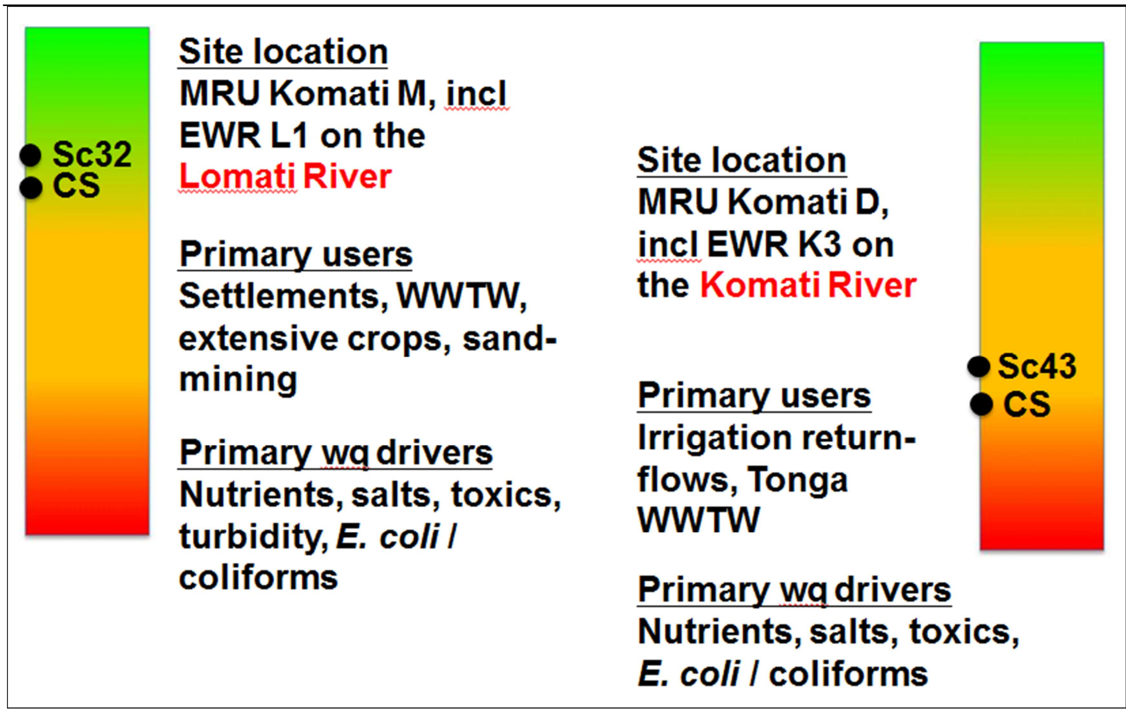


Figure 12.2 Consequences of selected scenarios on user water quality drivers of selected reaches of the Komati (X1)

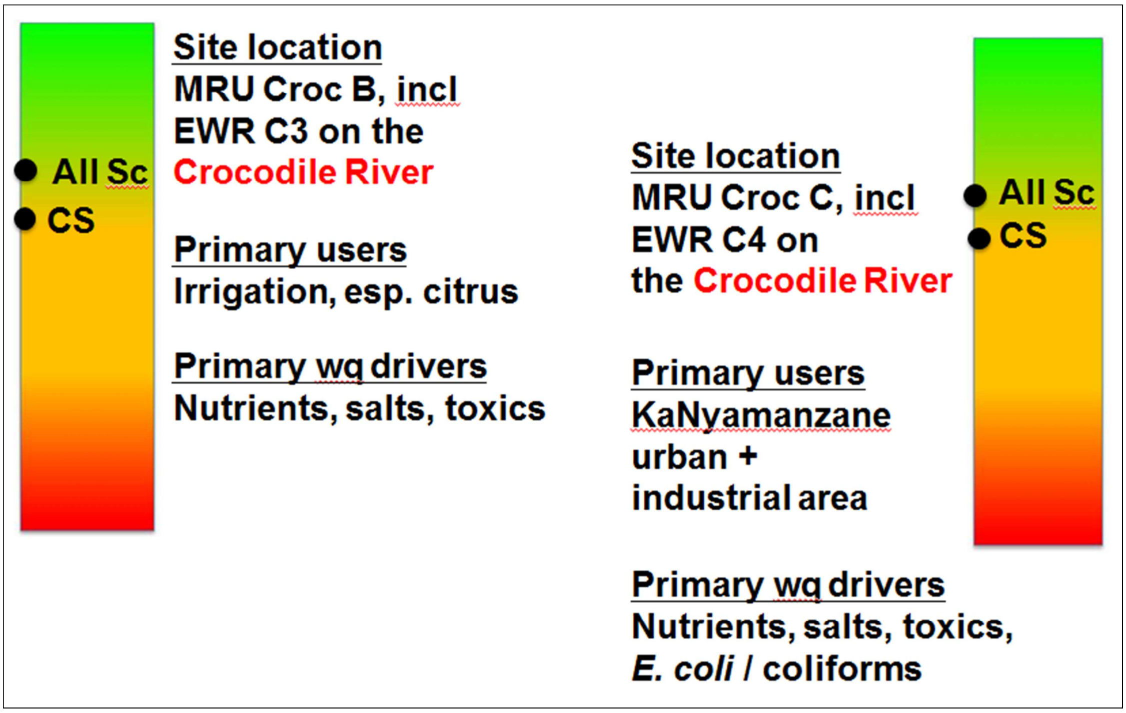


Figure 12.3 Consequences of selected scenarios on user water quality drivers of selected reaches of the Crocodile (X2)

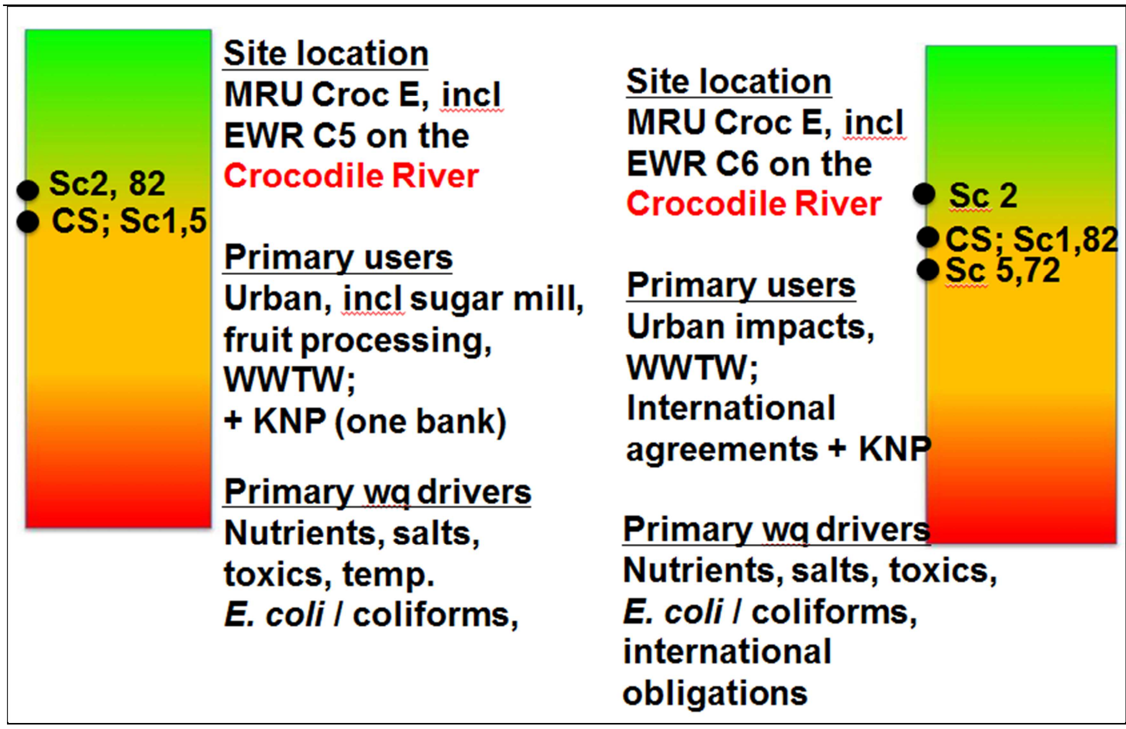


Figure 12.4 Consequences of selected scenarios on user water quality drivers of selected reaches of the Crocodile (X2)

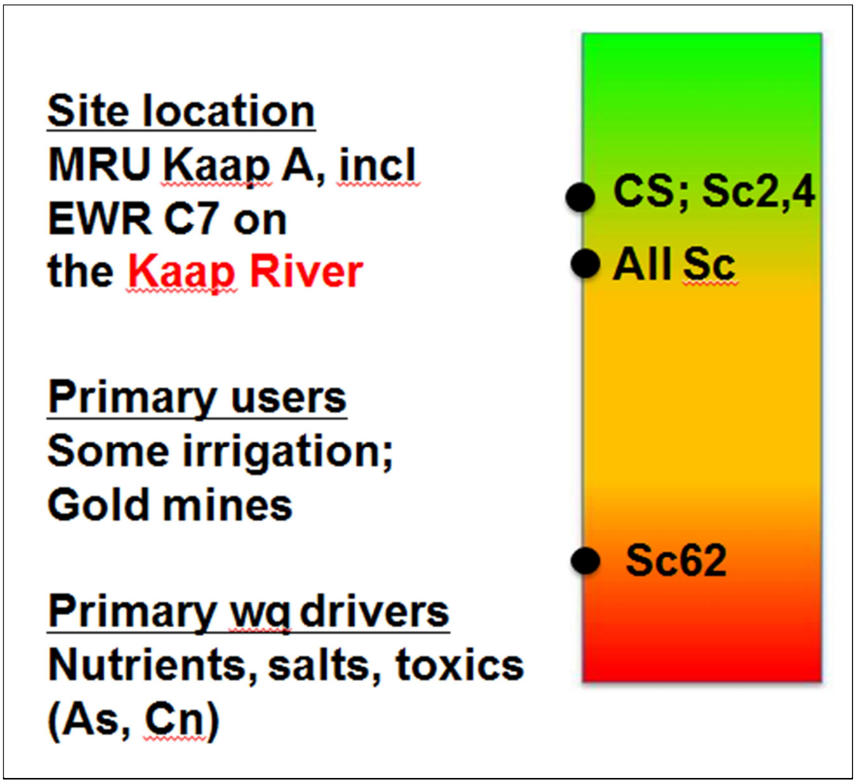


Figure 12.5 Consequences of selected scenarios on user water quality drivers of selected reaches of the Crocodile (X2)

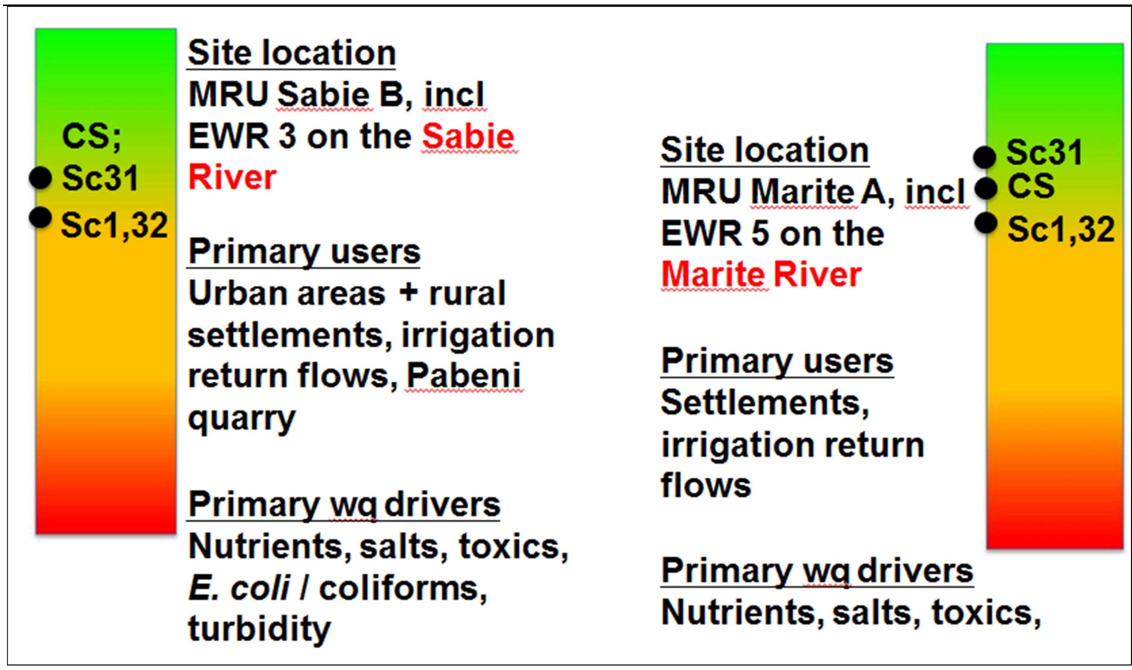


Figure 12.6 Consequences of selected scenarios on user water quality drivers of selected reaches of the Sabie - Sand (X3)

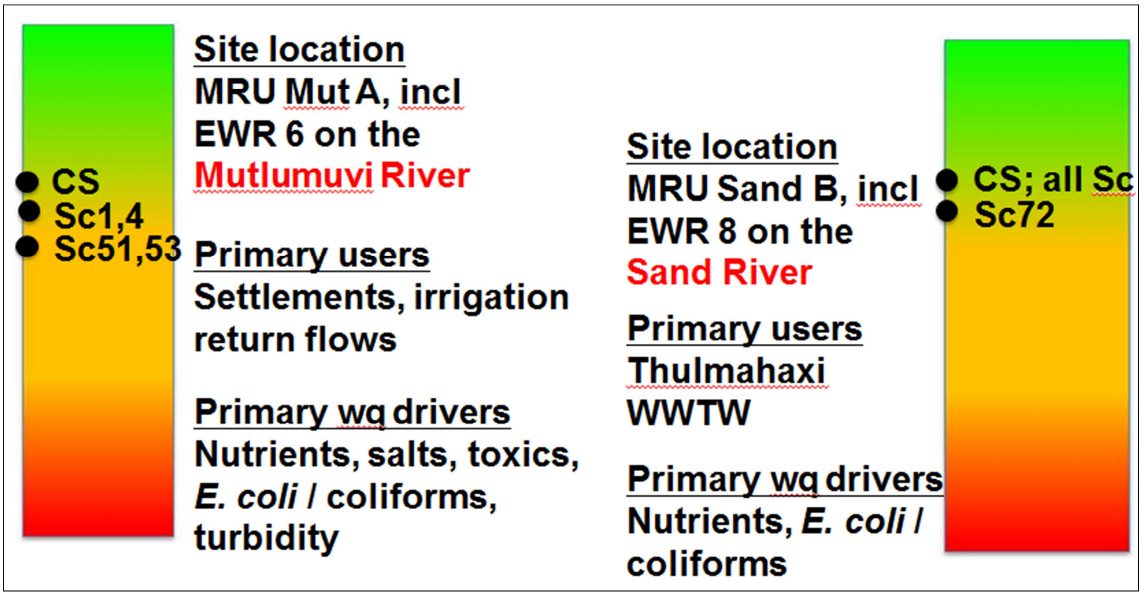
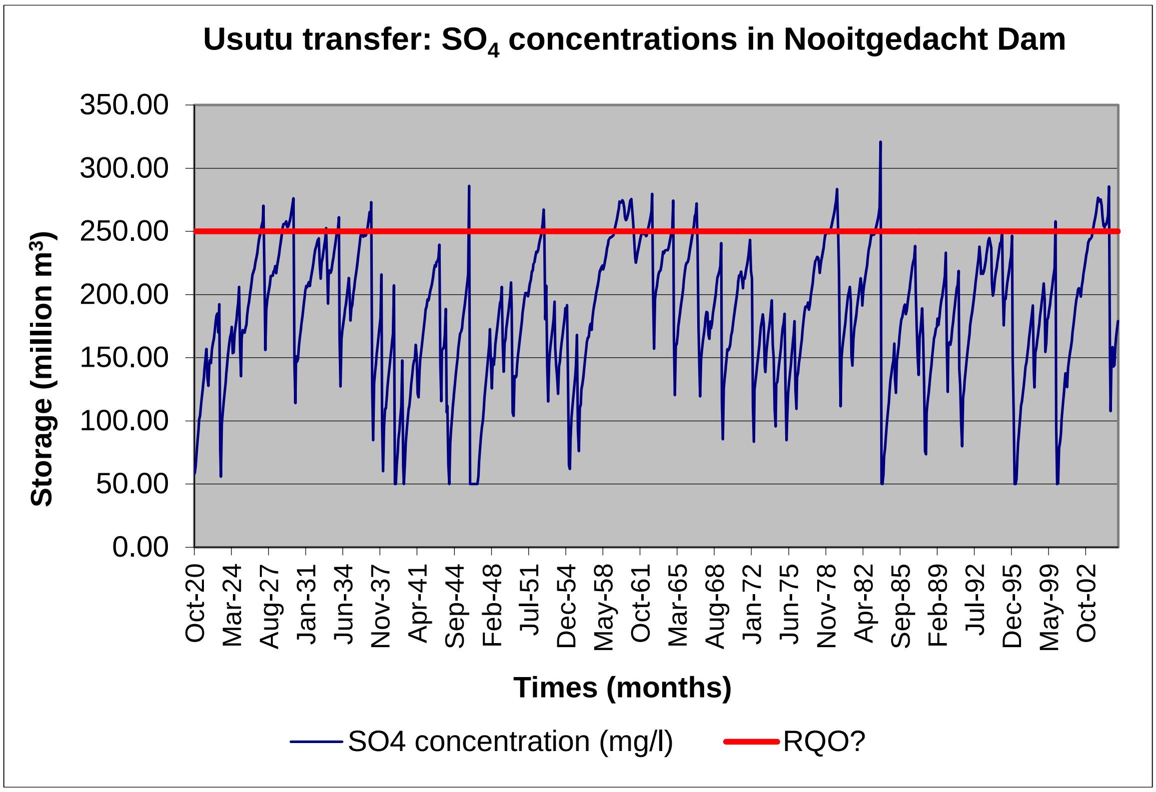


Figure 12.7 Consequences of selected scenarios on user water quality drivers of selected reaches of the Sabie - Sand (X3)

12.5.2 Upper Komati River: Additional coal mining

The results of the modelling exercise are shown in Figure 5 for the scenario with transfers from Usuthu, and Figure 6 without transfers from Usuthu. Note that transfers from the Usuthu are currently being phased out. A tentative RQO for sulphate of 250 mg/L (i.e. Acceptable levels; DWA, 2012) is shown on the graphs.

(A)



(B)

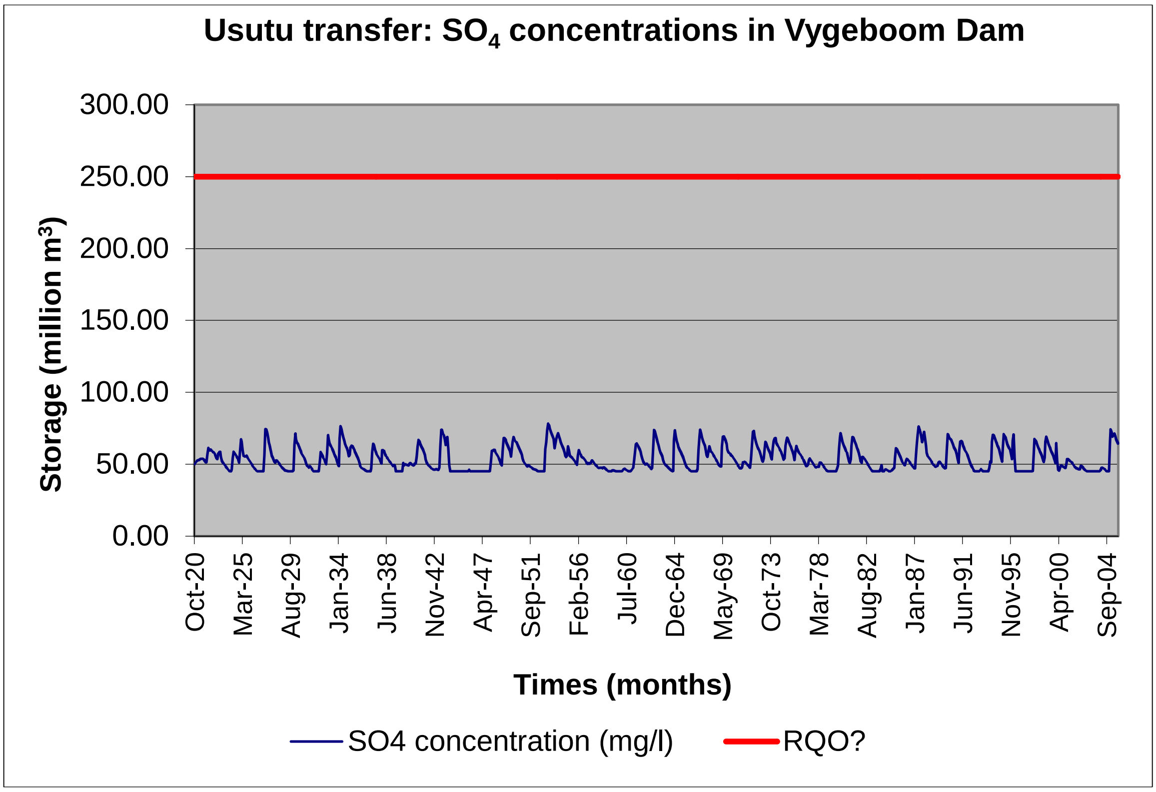
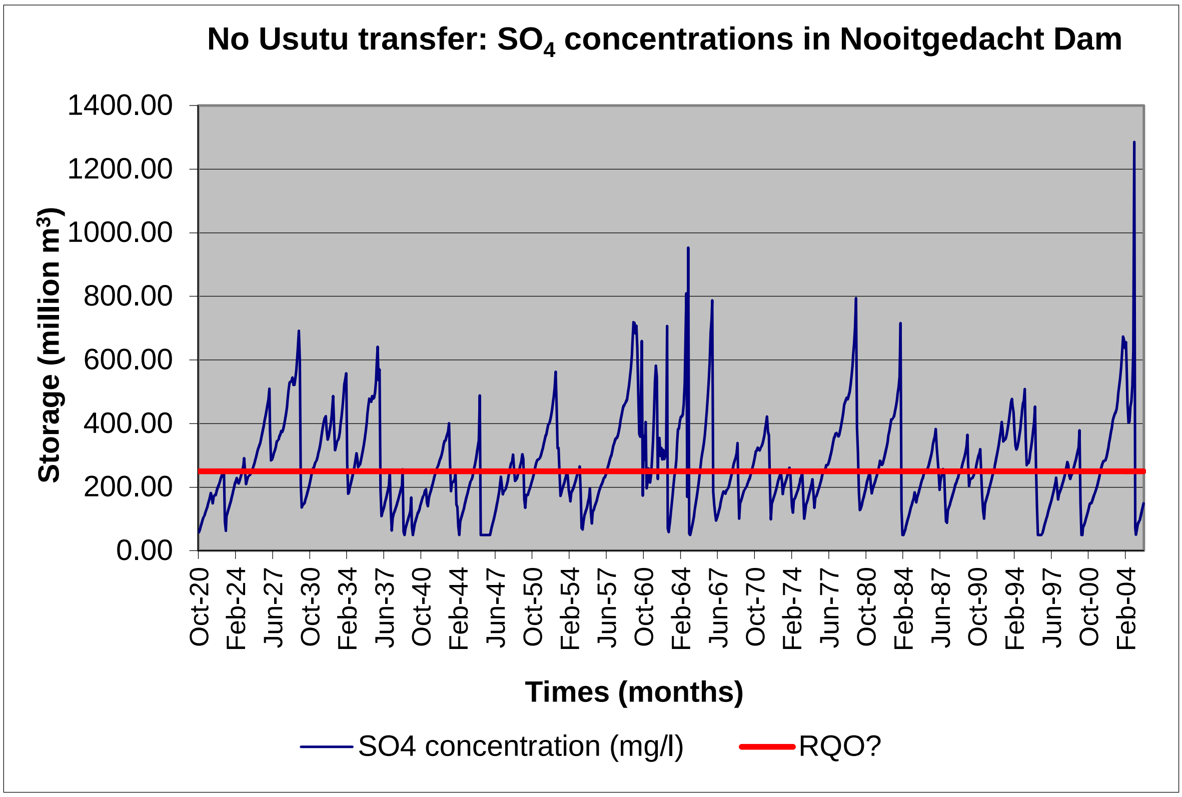


Figure 12.8 Results of the scenario WITH TRANSFERS FROM USUTHU for Nooitgedacht (A) and Vygeboom (B) dams

(A)



(B)

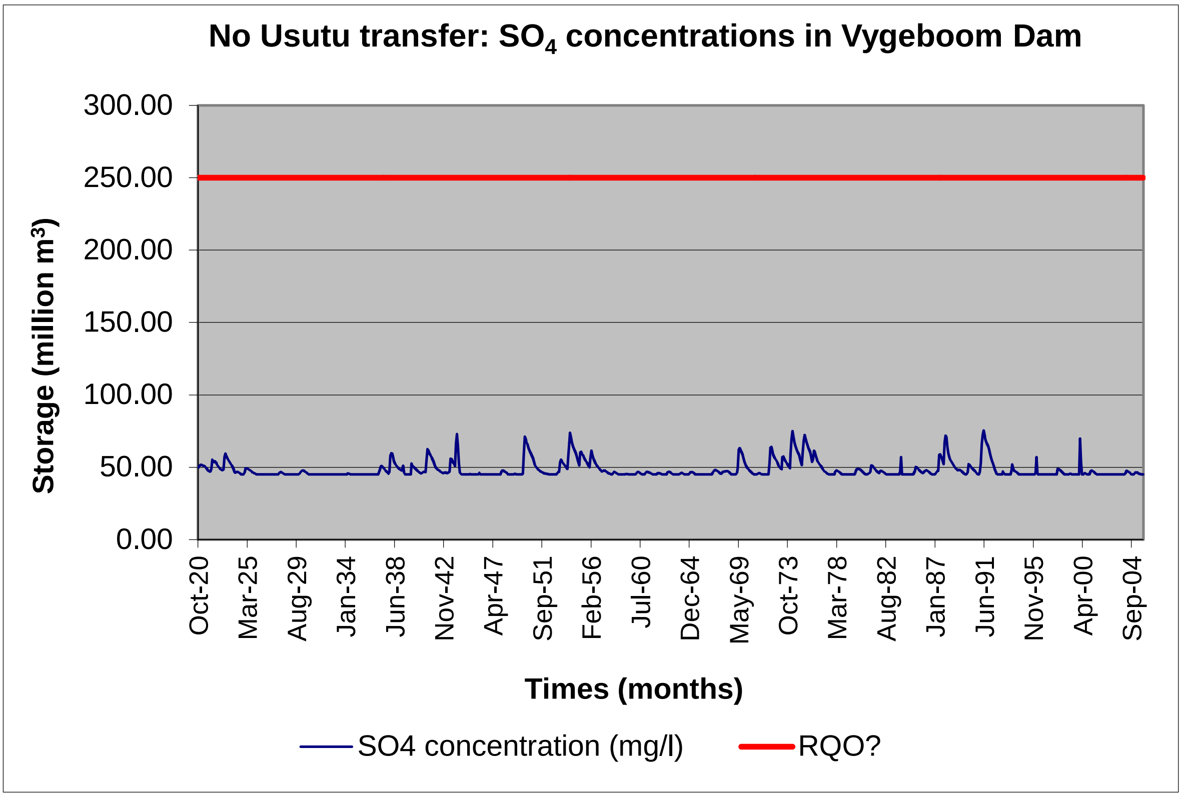


Figure 12.9 Results of the scenario WITH NO TRANSFERS FROM USUTHU for Nooitgedacht (A) and Vygeboom (B) dams

12.6 CONCLUSION

12.6.1 General

The qualitative assessment of the consequences of operational scenarios on user water quality, i.e. users such as agriculture – irrigation and stock-watering to urban and rural settlements, shows that little impact is expected under any of the operational scenarios for these users. Phase 5 of the process would be to rank the scenarios. This step was not undertaken for the Inkomati study due to the small differences and lack of resolution to actually differentiate between the scenarios for the various sites.

12.6.2 Coal mining scenario

Figures 12.8 and 12.9 show the dilutory effect of pumping water from the Usuthu into the Vygeboom Dam, and particularly the Nooitgedacht Dam. Results also show that the poor quality of water in the Nooitgedacht Dam would not significantly affect the quality of the Vygeboom Dam, even without the Usuthu transfer. However, should AMD volumes and sulphate concentrations reach those modelled, a significant impact would be seen on the water quality in Nooitgedacht Dam, which will be exacerbated well above sulphate guideline levels without the Usuthu transfer. Note that the tentative SO_4 level shown on the graphs is the Acceptable level set by Water Quality Planning in 2012. The Target Water Quality Range (TWQR) set at that time was 38 mg/L, based on industrial and domestic users. This level would be well exceeded in both dams under both transfer scenarios.

13 APPENDIX D: REPORT COMMENTS

Page &/ or section	Report statement	Comments	Changes made?	Author comment
All comments – largely editorial – received from Ms M Sekoele on the second master version of the report has been addressed.				