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PRELIMINARY RESERVE DETERMINATION AND ECOLOGICAL CATEGORISATION FOR SELECTED RIVERS AND WETLANDS IN THE CROCODILE (WEST) CATCHMENT (A20).

1. PURPOSE

This letter serves to provide a summary of the Preliminary Reserve[1] determinations and ecological categorisation that were undertaken for the surface water resources in the Crocodile (West) Catchment as part of the Crocodile West and Marico Intermediate Reserve Determination Study.

This submission not only provides a summary of the results of the Crocodile West Intermediate Reserve Study but also provides **specific water resource protection recommendations that should be implemented to give effect to the Ecological Reserve**.

2. INTRODUCTION

In order for the Department of Water Affairs (DWA) to make informed decisions regarding the authorisation of future water use and the magnitude of the impacts of the present and proposed developments in the Crocodile River System, higher levels of confidence are needed for the Reserve determination within this study area. The purpose of this Preliminary Reserve Determination study was to determine the ecological and basic human needs that include the water quantity and quality component of the Reserve for selected water resources at an intermediate level of confidence.
The intermediate Reserves will assist the DWA to make more informed decisions regarding the authorisation of future water uses as well as the operation and management of the water

[1] As per Section 17(1)(a):" *Until a Class of water resources has been determined the Minister may for all or part of a water resource make a preliminary determination of the Reserve*"

resources. Further to this, the evaluation of the magnitude of the impacts of the present and proposed developments in the Crocodile (West) catchment area, Present Ecological Status (PES) and Recommended Ecological Category (REC) has been undertaken.

This submission serves to present the results of the Intermediate Reserve Determination Study for water resources in the Crocodile West catchment. **It must also be noted that this submission does not include the results of the ground water Reserve study[2].**

This Intermediate Reserve supersedes all previously conducted low confident Reserves in the A20 Secondary catchment. Further to this, this Preliminary Reserve should be used to assess the present WULA as listed in Appendix 1 of this attached communiqué. It must be noted that the water resources in the Crocodile West and Marico WMA are currently also being classified. The results from the latter study will ultimately supersede all previously studies and will be gazetted in the government gazette for future reference.

3. DESCISION-MAKING APPROACH AND THE APPLICATION OF THE RESULTS OF THE CROCODILE WEST RESERVE STUDY.

In order to ensure that water resources are used in an environmentally sustainable manner, the provision of ecological water requirements should be balanced with the need to use water for further economic and social development. In order to determine possible tradeoffs between use and protection of the water resources in the Crocodile (West) catchment, a number of operational scenarios were developed and the effects on the Reserve, Ecological Goods and Services, yield of the system and thus the socio-economics of the catchment were assessed.

An aspect that is included in the future management of the Crocodile West catchment, for which the Reserve should guide decisions, is the future allocation of water resources.

The applicability of each Preliminary Reserve for use in the evaluation of Section 21 water use licence activities as described in the National Water Act (Act 36 of 1998) varies and is indicted in the attached template. These water uses include:

- Section 21(a): taking water from a water resource;
- Section 21(b): storing water;
- Section 21(c): impeding or diverting the flow of water in a watercourse;
- Section 21(d): engaging in a stream flow reduction activity contemplated in section 36;
- Section 21(e): engaging in a controlled activity identified as such in section 37(1) or declared under section 38(1);
- Section 21(f): discharging water into a water resource through a pipe, canal, sewer, sea outfall or other conduit;
- Section 21(g): disposing of waste in a manner which may detrimentally impact on a water resource;
- Section 21(h): disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process;

[2] The Groundwater Reserve study was undertaken at a Rapid Level of determination for the water quantity component only (water quality Reserve assessments were not included). The results were presented in a separate groundwater template. Also refer to Crocodile West and Marico Intermediate Reserve Determination study: Groundwater report. Report no: RDM/A000WMA 3/00/CON/0908.

- Section 21(i): altering the bed, banks, course or characteristics of a watercourse;
- Section 21(j): removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people;
- Section 21(k): using water for recreational purposes.

The signing off of this Preliminary Reserve thus enables water use activities to be considered, thereby giving effect to the Reserve as required by Section 18 of the Act. It also provides the short and long term ecological objectives which should be used in all future management plans for the Crocodile West catchment where a phased implementation of the Reserve should be monitored, audited and if necessary, adjusted within an adaptive integrated water resource management process.

4. THE STUDY AREA

The Crocodile West and Marico WMA (WMA 3), borders on Botswana to the north-west. It includes two major river systems; the Crocodile West and Marico, which give rise to the Limpopo River at their confluence. The water resources of the Crocodile West and Marico WMA support major economic activities in this WMA and have a population of approximately 5.0 million people. It is the second most populous WMA in the country with the largest proportionate contribution to the national economy, generating almost a third of the country's Gross Domestic Product. The majority of this WMA is highly altered by catchment development, with economic activities dominated by urban areas and industrial complexes of northern Johannesburg, Midrand and Tshwane and with platinum mining north-east of Rustenburg. Extensive irrigation activities occur along the major rivers, with game and livestock farming occurring in other parts of the WMA.

The two major rivers in the Crocodile (West) and Marico WMA, the Crocodile (West) River and the Groot Marico River, form the south-western part of the Limpopo River basin (Drainage Region A), which eventually drains into the Indian Ocean in Mozambique. The WMA also includes the headwaters of the Molopo River, which is a tributary of the Orange River, draining westwards to the Atlantic Ocean. The WMA includes the tertiary drainage regions A10, A21 to A24, A31, A32 and quaternary drainage region D41A. The WMA covers a total catchment area of 47 565 km^2.

The Pienaars, Apies, Moretele, Hennops, Jukskei, Magalies and Elands rivers are the major tributaries of the Crocodile River which together make up the A20 tertiary drainage catchment, with 39 quartenary catchments. The Crocodile River contributes to the flow of the Limpopo River, which has an international river basin shared with Botswana, Zimbabwe and Mozambique.

It is important to emphasize that the catchment area of the Crocodile (West) River is one of the **most developed** in the country with the river being one of the most influenced by human activities. Water quality is a driver of the overall Ecostatus of rivers in the study area. The other drivers are flow and geomorphology that also assist in determining the health of the river. The river is highly impacted in terms of water quality while some sub-catchments, such as the Upper Elands displaying a good to fair condition. The biggest impactors on water quality in the area are the large scale water and land users. Treated wastewater return flows from the Upper Vaal WMA play an important role downstream where the water is used in the Crocodile West catchment area (makes up approximately 27% of available water - 356 million m^3 per annum).

The quantities of return flows are increasing and while serving as potential source of water for future development in the catchment, the cascading effect of the return flows and the associated water quality have to be monitored and its impact determined.

Water quality issues are mainly related to nutrient status and salinity impacts due to wastewater discharges and flow regulation in the catchment. Microbial water quality issues are also expected to be a problem in the upper catchment but at the time of the study there was insufficient monitoring data to confirm this. Eutrophication due to increasing nutrient concentrations is posing a major threat to the Crocodile River system. This is also reflected in the aggressive invasion of aquatic invasive macrophytes such as water hyacinth, Myriophyllum, etc. present in almost all the dams in the study area. The excessive proliferation of these weeds leads to serious water quality problems and habitat destruction. Salinity impacts also need to be managed

5. RESOURCE UNITS AND ECOLOGICAL WATER REQUIREMENT SITES DELINEATION

5.1. Resource Units

Delineation of a river into Resource Units (RUs) is an important and essential component of river management and the assessment of ecological water requirements. When an Ecological Reserve determination is required for an entire catchment, it is necessary to delineate the selected rivers into Resource Units, as it would not be appropriate to set the same numerical Reserve for the headwaters of a river as for the lowland reaches. A RU is a section of a river that frequently has different natural flow patterns, reacts differently to stress according to their sensitivity, and requires individual specifications of the Reserve appropriate for that reach, as compared to the rest of the river.

The delineation of a catchment into RUs for the purpose of determining the Reserve for rivers is done primarily on biophysical characteristics of a catchment, and where the hydrology, geomorphic characteristics (*i.e.* geomorphic zone), physico-chemical attributes and river size remains relatively similar, a Natural Resource Units (NRU) can be demarcated. The delineation of a river into Resource Units is based on the assumption that rivers are made up of discrete sections that are ecologically different from each other. In addition to the biophysical (natural) characteristics of a catchment, management requirements also play a role in the delineation of a RU. That is, the type of disturbance/impact on the river plays a role to select homogenous river reaches from a biophysical basis under present circumstances. The purpose of distinguishing a RU of management requirements is to identify a management unit within which the EWR can be implemented and managed based on one set of identified flow requirements. These are called Management Resource Units (MRUs).

Based on the biophysical characteristics of the river, water quality, system characteristics, management and operation of the Crocodile River, eleven management resource units (MRUs) were delineated from the origin of the river to its confluence with the Limpopo River (Table 1). Tributaries of the Crocodile River were also delineated and the results are described in detail in the report ***"Crocodile West and Marico Intermediate Reserve Determination study: Crocodile (West) Delineation report".*** **Report no: RDM/ A000WMA3/00/CON/0208a.**

Table 1: Delineation of Resource units in the Crocodile River Catchment

MRU	Delineation	Quaternary Catchment
	CROCODILE RIVER	
MRU Crocodile 1	From origin of Jukskei to just downstream discharge of Jhb Northern Works	A21C
MRU Crocodile 2	From discharge of JW Northern Works to just upstream confluence of Hennops River, including Bloubankspruit	A21D, A21E, A21H
MRU Crocodile 3	From Hennops river confluence to upstream Hartbeespoort Dam	A21H
MRU Crocodile 4	Hartbeespoort Dam	A21H
MRU Crocodile 5	From downstream Hartbeespoort Dam to Brits town	A21J
MRU Crocodile 6	From Brits to upstream Roodekoppies Dam	A21J
MRU Crocodile 7	Roodekoppies Dam	A21K, A21J
MRU Crocodile 8	From Roodekoppies Dam to upstream confluence of the Elands River	A21L
MRU Crocodile 9	From Elands River confluence to upstream confluence of the Pienaars River	A24A
MRU Crocodile 10	From confluence of the Pienaars River to upstream confluence of the Bierspruit	A24A, A24B, A24C, A24H
MRU Crocodile 11	From Bierspruit confluence to confluence with the Limpopo River	A24J

5.2. Ecological Water Requirement (EWR) Sites

Ecological Water Requirement sites are set at specific points on the river which are critical sites within a reach of the river. The selection of EWR sites is guided by a number of considerations. The key considerations are:

- The suitability of the sites for accurate hydraulic modelling throughout the range of possible flows, especially low flows;
- Accessibility of the sites;
- An area or site that could be critical for ecosystem functioning. These are often represented by riffle units, where low flow conditions or the cessation of flow constitutes a break in the functioning of the river, and consequently, the biota dependant on this habitat and/or perennial flow are adversely affected. Pools are not considered critical habitats in a perennial system since they are still able to function or at least maintain life during periods of no flow.

Sites were selected to represent the widest possible range of river conditions within the catchment. Eleven Ecological Water Requirement (EWR) sites were selected in the Crocodile (West) River catchment, 8 at an intermediate level and 3 at a rapid level. Four sites were selected on the mainstream of the Crocodile River, and four sites were selected in the following tributaries: two on the Pienaars, and one each on the Jukskei and Hex Rivers. The three rapid sites were selected on the Elands, Magalies and Sterkstroom Rivers. An indication of EWR sites position, the Resource it's in and the quaternary catchment is shown below in Table 2, Figure 1 and Figure 2.

Table 2: Details of each of the River EWR sites

EWR Site number	EWR site name	River	Coordinates	Ecoregion (Level II)	Altitude (m)	Resource Unit	Quartenary catchment
EWR 1	Upstream of the Hartbeespoort Dam	Crocodile	E 27.896 S 25.8004	7.05	1167.93	MRU Crocodile 3	A21H
EWR 2	Heron Bridge School	Jukskei	E 27.9621 S 25.9539	11.01	1310.77	MRU Crocodile 1	A21C
EWR 3	Downstream of Hartbeespoort Dam in Mount Amanzi	Crocodile	E 27.8431 S 25.7168	7.04	1119.05	MRU Crocodile 5	A21J
EWR 4	Downstream of Roodeplaat Dam	Pienaars	E 28.312 S 25.4155	9.03	1089.468	MRU Pienaars 5	A23B
EWR 5	Downstream of the Klipvoor Dam in Borakalalo National Park	Pienaars	E 27.80457 S 25.12657	7.03 8.05	970.62	MRU Pienaars 8	A23J
EWR 6	Upstream of Vaalkop Dam	Hex	E 27.3749 S 25.5214	7.03 8.05	1026.21	MRU Hex 5	A22J
EWR 7	Upstream of the confluence with the Bierspruit	Crocodile	E 27.51743 S 24.88661	8.05	925.77	MRU Crocodile 10	A24C
EWR 8	Downstream of the confluence with the Bierspruit in Ben Alberts Nature Reserve	Crocodile	E 27.32569 S 24.64476	7.03	901.16	MRU Crocodile 11	A24H
Rapid EWR 9	Upstream of Malony's Eye	Magalies	E 27.56581 S 26.01689	7.05		MRU Magalies 1	A21F
Rapid EWR 10	Highveld	Elands	E 26.72044 S 25.72655	7.03		MRU Elands 1	A22A
Rapid EWR 11	Upstream of Buffelspoort Dam	Sterkstroom	E 27.47848 S 25.80739	8.05		MRU Sterkstroom 1	A21K

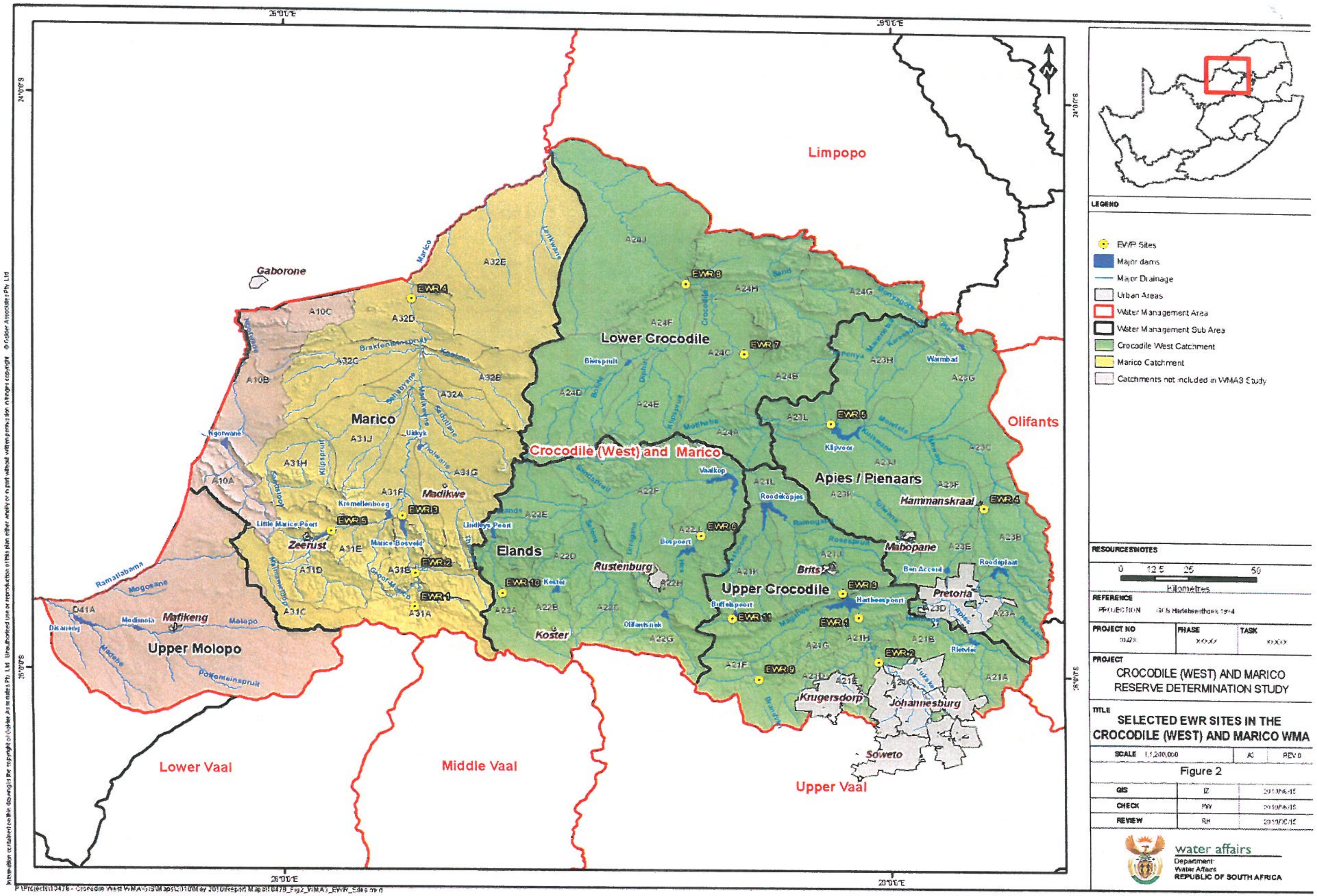

Figure 1: Location of the EWR sites in the Crocodile West and Marico WMA

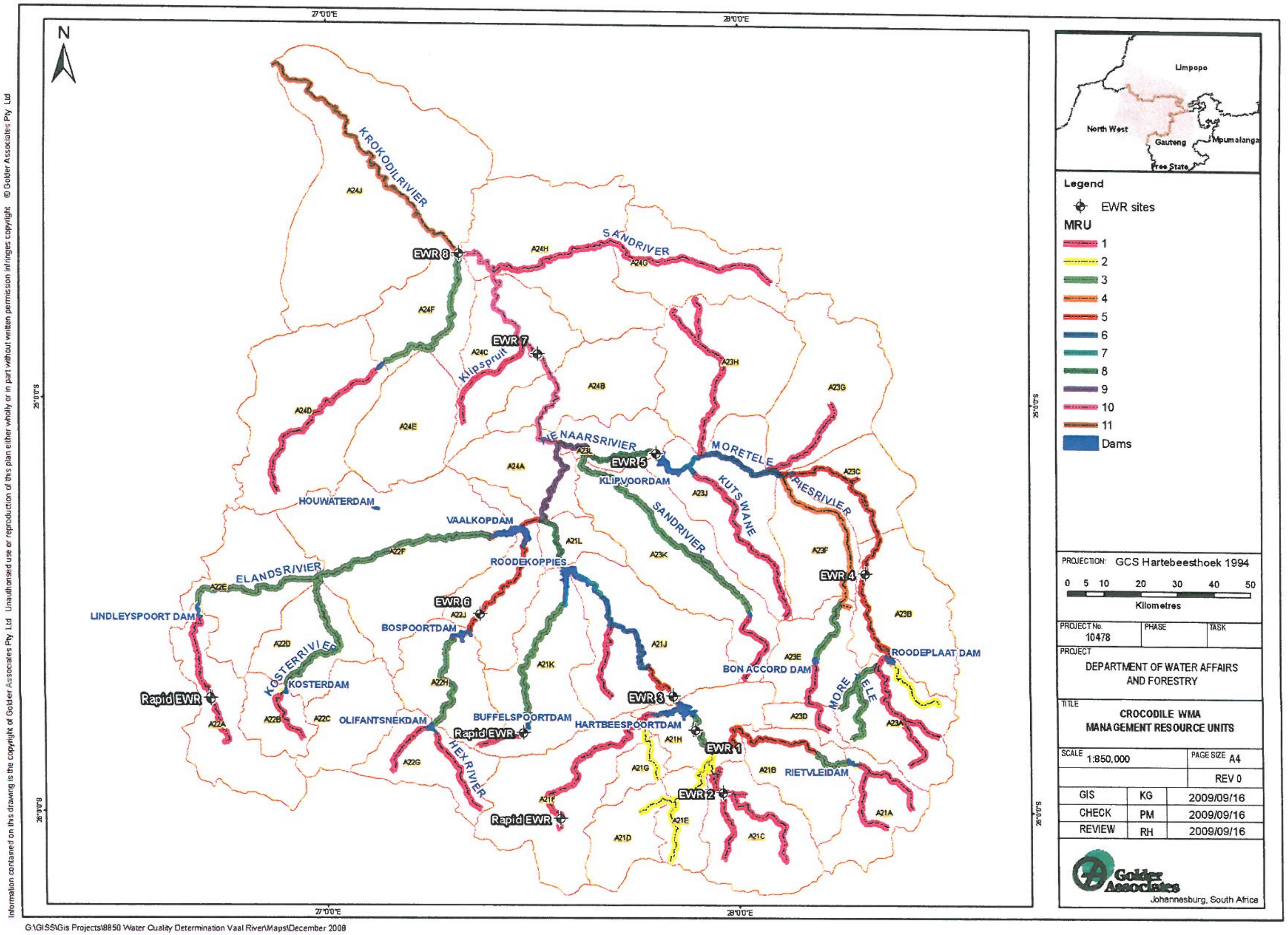

Figure 2: Resource units and EWR sites in the Crocodile (West) Catchment

6. ECOCLASSIFICATION AND PRELIMINARY RESERVE RESULTS

Table 3 below indicates a summary of EcoClassification (Present Ecological Status (PES), Ecological Importance and Sensitivity (EIS), Recommended Ecological Category (REC) and the Reserve results per EWR site. The REC is determined based on ecological criteria and considers the EIS, the restoration potential of the system and attainability there-of. **There was no potential to improve the PES in most of the EWR sites due to the continuous discharges from WWTWs in the catchment, irrigation, that impact on the water quality and quantity as well as the water transfers that further increases the flow. Therefore the REC for most of the sites remained the PES.**

Table 3: Summary of EcoClassification* and Preliminary Reserve for each EWR site

Table 3.1: Preliminary Reserve based on Present day flows

Water Resource	EWR Site	Catchment	PES	EIS	REC	PD MAR (Mm^3/a)	EWR (%PDMAR)	BHNR Requirement (%PDMAR)	Reserve Requirement (%PDMAR)
Crocodile	1	A21H	D	Moderate	D	231.05	24.07	0.27	24.34
Jukskei	2	A21C	E	Moderate	D	139.90	24.87	4.90	29.77

Table 3.2: Preliminary Reserve based on natural flows

Water Resource	EWR Site	Catchment	PES	EIS	REC	Natural MAR (Mm^3/a)	EWR (%nMAR)	BHNR Requirement (%nMAR)	Reserve Requirement (%nMAR)
Crocodile	3	A21J	C/D	High	C/D	143.30	21.70	0.85	22.55
Pienaars	4	A23B	C	High	C	28.21	30.81	0.61	31.42
Pienaars	5	A23J	D	High	D	113.03	11.82	4.23	16.05
Hex	6	A22J	D	Moderate	D	26.93	14.96	0.66	15.62
Crocodile	7	A24C	D	Moderate	D	463.36	9.14	0.05	9.19
Crocodile	8	A24H	C	Moderate	C	559.94	13.78	0.02	13.80
Upper Elands	10	A22A	C	High	B/C	10.1	30.48	1.79	32.27
Sterkstroom	11	A21K	C	High	C	13.96	28.41	3.61	32.02

Table 3.3: Preliminary Reserve based on Observed Simulated MAR

Water Resource	EWR Site	Catchment	PES	EIS	REC	Observed Simulated MAR (Mm^3/a)	EWR (% Ob Sim MAR)	BHNR Requirement (%Ob Sim MAR)	Reserve Requirement (% Ob Sim MAR)
Magalies	9	A21F	B	Very high	B	14.72	45.58	0.72	46.30

***Obtained from the Crocodile West and Marico Intermediate Reserve Determination study: Crocodile West Riverine RDM report, volume 1: Assessment Report no: RDM/ A000WMA3/01/CON/0408a**

7. WETLANDS OF THE CROCODILE WEST AND MARICO CATCHMENT

7.1. Wetland typing and ecoclassification

Wetlands form an integral part of aquatic ecosystems and the hydrological cycle, and can play a key role by contributing to river base flows and providing habitats that support aquatic biodiversity. An assessment of the EWR should therefore include an assessment of wetlands and their ecological functions.

Wetlands were typed and listed according to size, conservation status, and uniqueness in the study area and threats. Wetland polygons in the study area were sorted by size and the largest were investigated and assessed on Google Earth. Aspects that can possibly influence the wetland functionality and integrity were identified. A cross reference was then made between the larger wetlands found on GIS with those received via correspondence from specialists. From the above process a list of 14 wetlands was generated, and 6 of these wetlands are found in the Crocodile West catchment. The identified wetlands were discussed and adapted according to the specialists' experience in the field.

Aims

The brief for the wetland scoping as part of the study was as follows:

- Review existing information that can contribute to the identification of wetlands and to the extent thereof in the study area;
- Develop an inventory of wetlands within the study area (mapped at the 1:50 000 or (preferentially) 1:10 000 scale);
- Type the identified wetlands according to the HydroGeomorphic wetland classification system, which has been proposed as the wetland classification system for South Africa;
- Determine the general reference conditions of the wetlands in the catchment;
- Determine the general current ecological condition of the wetland types identified;
- Identify priority wetlands in the study area (based on size and/or ecological; social and/or economic criteria);
- Determine PES and EIS Categories for these priority systems;
- Undertake a Wetland Habitat Integrity (PES) assessment of a maximum of two of the high priority floodplain or channelled valley bottom wetlands, and
- Compile a report detailing the outcomes and results from the above tasks. This report indicates which wetlands in the study area required detailed studies (not part of this study).

7.2. Current status of the wetlands

Since no baseline information on the status of these wetlands is available, a generic attempt in assessing the current status or integrity of the wetlands was done. Basic principles of the Present Ecological Status (PES) were used to give guidance in this regard (WRC, 2008). Further, the procedure for determination of Resource Directed Measures for Wetland Ecosystems (DWAF, 1999) provided the basic criteria followed. The Ecological Integrity and Sensitivity (EIS) method were also used to assess the priority identified catchments. Land use activities in and around the different types of wetlands was used to make assumptions from and to supplement findings.

7.3. Wetland Types and Distribution (Table 4, Figure 3)

Several palustrine wetlands were identified in the study area which included:

- floodplains,
- valley bottom wetlands with a channel,
- valley bottom wetlands without a channel,
- hill slope seepage feeding a watercourse,
- hill slope seepage not feeding a watercourse, and
- depressions that includes pans.

Table 4: Priority Wetlands identified in the Groot Marico and Crocodile West River Catchments

Catchment	Priority Wetland	Locality	Reasons for being unique
Groot Marico	Marico Dolomitic Eye	S-25.78875 E 26.36678	Unique species aquatic biota, water supply towards the Groot Marico River.
	Molemane Dolomitic Eye	S-25.80158 E 26.03013	Unique species aquatic biota, water supply towards the aquifer's with associated wetlands.
	Malmane's Loop	S-25.62655 E 26.00737	Unique wetland system with peat.
	Bokkraal Wetland (Upstream of tufa waterfall) Eye	S-25.80029 E 26.45229	Protection of the tufa waterfall.
	Rietspruit Eye	S-25.81128 E 26.43460	Supply water to the Marico River.
	Ngotwane River Dinokana Eye	S-25. E 26.	Supply river to Ngotwane River and Dinokana community.
Crocodile West	Moretele Floodplain (Pienaar's River)	S-25.12780 E 27.80311	Floodplain protection and unique bird habitat.
	Waterval Valley Bottom Mire (Kgaswane Nature Reserve)	S-25.72641 E 27.20829	High lying Peat wetland in Nature Reserve.
	Apies River Floodplain	S-25.36999 E 28.27222	Floodplain protection and unique bird habitat.
	Tswaing Crator Valley Bottom Wetland	S-25.38110 E 28.08653	Unique landscape feature with associated wetland.
	Skeerpoort River Drainage Area	S-25.86302 E 26.74048	Priority in the Gauteng Conservation Plan. Occurrence of dolomitic eyes. High water quality and aquatic biota diversity.
	Rietvlei Mire (Rietvlei Nature Reserve)	S-25.86785 E 28.28616	Peat wetland in Nature Reserve.

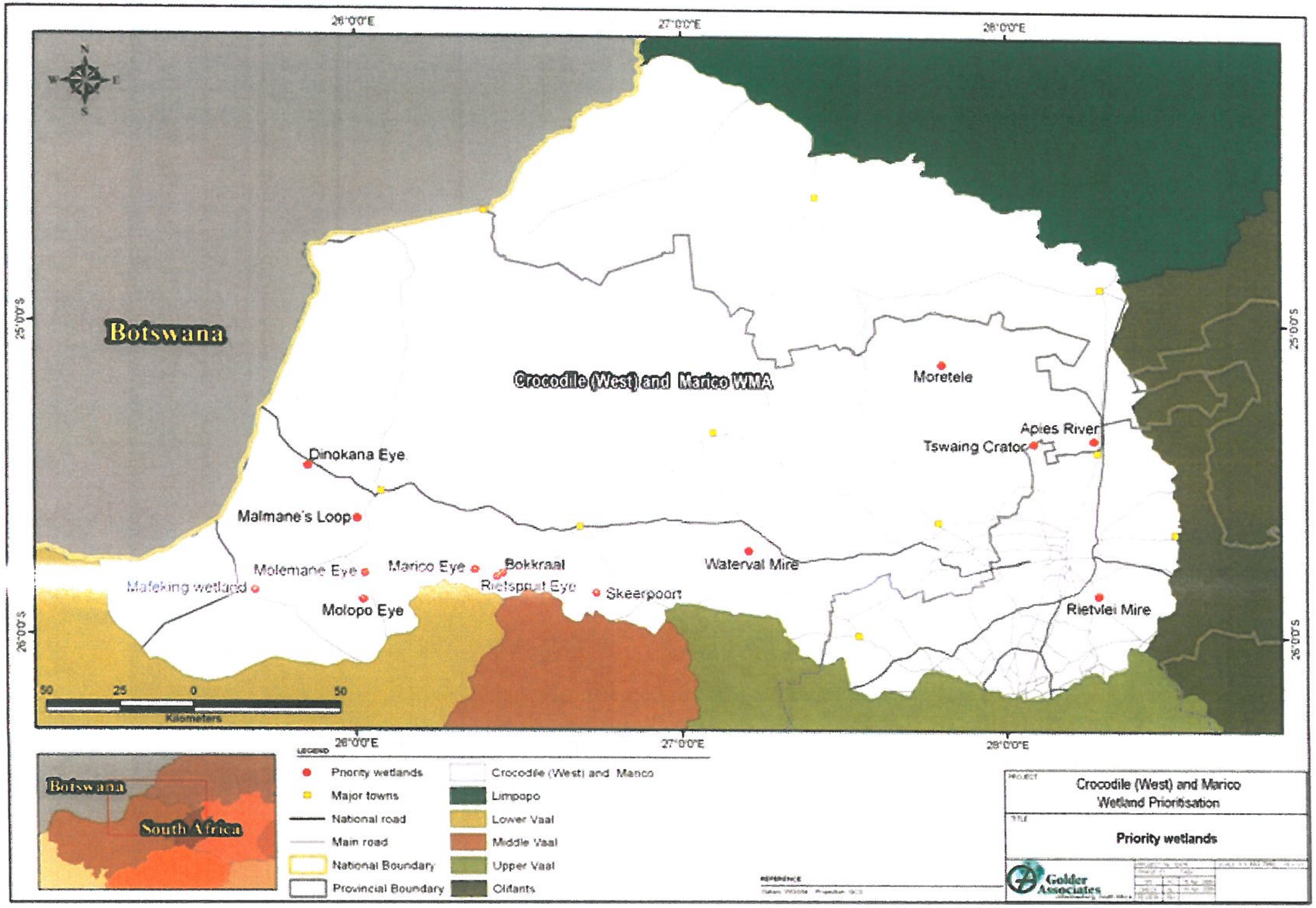

Figure 3: Map indicating priority wetlands identified in the Crocodile West and Marico WMA

7.4. Ecological Integrity and Sensitivity (EIS) Assessment of Priority Sites

Priority wetlands were rated according to the Wetland Ecological Importance and Sensitivity Scale as prescribed by DWAF (2005) (Table 5). Ratings for the EIS assessment on all the priority sites ranged from a B Ecological Category (high), considered to be ecologically important and sensitive to those of a C Ecological Category (moderate), considered ecologically important and sensitive on a provincial and local scale.

Table 5: EIS ratings for Priority Wetlands in the study area

Catchment Area	Priority Wetlands	EIS Category	Eco Category
Groot Marico	Marico Dolomitic Eye	High	B
	Molemane Dolomitic Eye	High	B
	Malmane's Loop	Moderate	C
	Bokkraal Wetland (Upstream of tufa	Moderate	C
	Rietspruit Eye	Moderate	C
	Ngotwane River Dinokana Eye.	High	B
Crocodile West	Moretele Floodplain (Pienaar's River)	High	C
	Waterval Valley Mire (Kgaswane NR)	High	B
	Apies River Floodplain	Moderate	C
	Tswaing Crator Valley Bottom Wetland	High	C
	Skeerpoort River Drainage Area	High	B
	Rietvlei Mire (Rietvlei Nature Reserve)	Moderate	C

7.5 Wetland Habitat Integrity (PES) assessment of Floodplain or Channelled Valley Bottom Wetlands

The Apies River Floodplain and the Rietvlei Peat Wetland were assessed according to the PES method as described by DWAF (2005). Both these wetlands were found to be largely modified with a large loss of natural habitats and basic ecosystem functions. Modifications are due to various anthropogenic activities.

The Apies River has been canalised and straightened in the urban areas. This has resulted in higher flows which in turn have also altered the channel and bed shape in the floodplain area lower down in the system. Urban runoff, sewage spills and litter from settlements impact heavily on water quality and the functional integrity of the river. Most of the riparian vegetation has been cleared due to high levels of development. Alien vegetation encroachment is high in some areas; mulberries, jacaranda and sesbania are the most common species (RHP, 2005).

The Rietvlei Peat wetland lies in the Rietvlei Nature Reserve. This wetland is in the process of being rehabilitated by Working for Wetlands. Due to river canalisation, urban runoff, sewage spills, major highways, power lines, clay and coal mining, the alteration of natural vegetation due to encroachment of popular species, etc. this wetland is largely modified.

8. SCENARIO ANALYSIS FOR THE CROCODILE (WEST) RIVER CATCHMENT.

The Ecological Water Requirement (quantity) scenarios developed are as sets of possible flows to achieve different river states (or Ecological Categories) for each EWR. To equip decision makers with higher confidence information, it was necessary to examine each of the scenarios and their full range of implications. All these operational scenarios were tested to determine the resulting state of the river, and the water quality consequences of each flow scenario were supplied.

The objective of this task was to develop a range of operational scenarios that result in different impacts on different users. The impacts of incorporating the EWR on the ecology, system yield, services and overall economic activities could then be assessed. Methods followed are described in detail in Annexure F of the attached template.

A summary of the scenario consequences for the Crocodile West catchment is shown in Table 6. Table 7 provides a summary of the EWR and total flow under different scenarios.

Scenarios and the method followed are described in detail in the report ***"Crocodile West and Marico Intermediate Reserve Determination study: Main integration report".*** **Report no RDM/ A000WMA3/00/CON/1008.**

Table 6: Flow Scenarios analysed for the Crocodile (West) EWR sites

Scenario	Number	Development level	Transfer	EWR
Natural	1	None	-	No
Present day	2 (a)	2003	-	No
	2 (b)		-	Yes
2015	3	2015	Crocodile River to Mokolo catchment	Yes
2030	4	2030	Crocodile River to Mokolo catchment and Klip River to Crocrodile River	Yes

Table 7: Summary of Ecological Water Requirements and Total Flow in million m^3/a at the EWR sites in the Crocodile River under different scenarios

EWR site	River	Quaternary Catchment	Description	REC	Ecological Water Requirement		Scenario 1 Natural	Scenario 2 Present - (2003)		Scenario 3 (2015)	Scenario 4 (2030)
					million m^3/a	% MAR		(a) No EWR	(b) With EWR	With EWR	With EWR
1	Upper Croc	A21H	Upstream of Hartbeespoort Dam	D	**55.7**	MH 6.03 ML 18.0 **Total 24.1**	87.8	272.3	272.3	302.5	477.7
2	Jukskei	A21C	U/S of confluence with Klein Jukskei	D	**34.8**	MH 11.40 ML 13.47 **Total 24.9**	34.4	162.6	162.6	177.3	339.0
3	Upper Croc	A21J	D/s of Hartbeespoort Dam	C/D	**31.1**	MH 10.32 ML 11.38 **Total 21.7**	153.6	136.8	149.1	142.8	300.4
4	Pienaars	A23B	D/s of Roodeplaat Dam	C	**8.7**	MH 13.81 ML 17.00 **Total 30.8**	28.4	33	42.7	48.9	52.7
5	Pienaars / Moretele	A23J	D/s of Klipvoor Dam	D	**13.4**	MH 5.38 ML 6.44 **Total 11.8**	113.8	146.2	145.7	159.2	175.3
6	Hex River	A22J	D/s of Bospoort Dam	D	**4.0**	MH 9.86 ML 5.10 **Total 15.0**	27.3	20.1	21.0	21.1	21.2
7	Lower Croc	A24C	U/s of confluence with Bier Spruit	D	**42.3**	MH 2.37 ML 6.77 **Total 9.1**	476.6	395.7	408.4	409.7	584.5
8	Lower Croc	A24H	D/s of conflu-ence with Bier Spruit	C	**77.2**	MH 2.51 ML 11.3 **Total 13.8**	574.7	414	433.8	389.4	412.8
9	Magalies	A21F	Maloney's Eye	B	**6.7**	MH 0.05 ML 45.53 **Total 45.6**	15	15	N/A	N/A	N/A
10	Upper Elands	A22A	U/s of Swartruggens Dam	B/C	**3.1**	MH 12.5 ML 17.98 **Total 30.5**	10	9	N/A	N/A	N/A
11	Sterkstroom	A21K	U/s of Buffelspoort Dam	C	**4.0**	MH 8.17 ML 20.24 **Total 28.4**	14	13	N/A	N/A	N/A

8.1. Ecological consequences of the operational scenarios

Ecological and water quality consequences of the various operational scenarios were assessed and are described in the sections below. The ecological evaluation is based on an assessment of the impacts on the status or ECs recommended for each component. **Information on the water quality assessment as a key driver** is provided below, followed by the overall assessment.

8.1.1 Water Quality Consequences

Each of the flow scenarios were checked through the Physico-Chemical Driver Assessment Index (PAI) driver tables, to determine whether the water quality objectives would be met under these flow conditions. The pollution sources and types of pollution were determined per EWR site. The different flow scenarios were then used to determine if the scenario would improve or decrease the water quality status per EWR site (Table 8).

Typically the water quality issues in the Crocodile (West) River catchment study area are driven by point source and run-off, such as:

- Large volumes of WWTWs discharges (nutrients)
- Agricultural runoff from intensive irrigation (fertilizers, salts, nutrients, pesticides)
- Large degree of urbanisation (microbiological, litter, turbidity)

The effluents from wastewater treatment works are consequently a major contributor to the water quality in the Crocodile catchment.

Table 8: Water Quality consequences of flow scenarios per EWR site

EWR site	PES: Water Quality	Overall REC (Quality ecospecs)	Water Quality: Scenario 2a PES	Water Quality: Scenario 2b PES	Water Quality: Scenario 3 PES	Water Quality: Scenario 4 PES
EWR 1	D/E	D	D	D	D/E	D
EWR 2	D/E	D	E	E	E	E/F
EWR 3	D/E	D	C/D	C	C	D
EWR 4	B	B	C	C	C	C
EWR 5	C	C	D	D	D	D
EWR 6	D	D	D	D	D	D
EWR 7	D	D	D	D	D	D
EWR 8	C/D	C/D	D	D	D	D/E

The flow scenarios that result in an improved water quality are those scenarios that would dilute the discharges into the Crocodile River and its tributaries. The scenarios do not result in an improved water quality situation at any of the EWR sites.

- **EWR 1**: With the different flows for the various scenarios water quality does deteriorate progressively with the development level (Scenario 3 and 4). Seasonal sedimentation (turbidity); nutrients increase; pH seasonal changes; seasonal temperatures slight changes, increased microbiology are the expected water quality issues. Water quality does change significantly under the flow scenarios. It is expected that water quality will remain relatively stable over the short-term (5 years); however, it will deteriorate over the long-term (20 years) due to continued urbanisation and wastewater discharges.

- **EWR 2**: It is expected that water quality will deteriorate over the short and long term due to increased urbanisation and increased wastewater discharges. Scenario 4 will continue to increase waste water impacts. There is no upstream regulation. Excess flow is present due to urbanization and waste water treatment works. Elevated nutrients, seasonal temperatures slight changes, increased microbiology will emerge as issues.

- **EWR 3**: It is important to note that the flows at EWR site 3 are in-stream and do not include the water released from the dam that goes down the irrigation canals. It is expected that water quality will remain relatively stable over the short-term (5 years) however it will deteriorate over the long-term (20 years) due to increased urbanisation, waste water discharges and transfer of water from the Klip River. High toxicants (ammonia), high microbiology contamination, high microcystis levels and exotic water hyacinth are expected under Scenarios 3 and 4.

- **EWR 4:** With the different flows for the scenarios water quality does deteriorate progressively with the development level (Scenario 3 and 4). Higher nutrients; turbidity increase; pH seasonal changes; toxicity increases, seasonal temperature slight changes, increased microbiology and exotic water hyacinth are expected in Roodeplaat Dam. It is important to note that the flows at EWR site 4 are in-stream and do not include the water released from the dam that goes down the irrigation canals. It is expected that water quality will remain relatively stable over the short-term (5 years) with some impacts in Roodeplaat Dam (nutrients) however it will deteriorate to some extent over the long-term (20 years) as the nutrient concentration increase even further. This is due to increased urbanisation and waste water discharges to the east of Pretoria.

- **EWR 5**: It is important to note that the flows at EWR site 5 are downstream of the Klipvoor Dam on the Pienaars River. This site will include water released from the dam for future irrigation and the Crocodile/Mokolo release supplementation. It is expected that water quality will remain relatively stable over the short-term and long term; however, it will be impacted by increased nutrients from upstream agriculture and urbanisation.

- **EWR 6**: The Hex River at this site is impacted by the Rustenburg industrial and urban development. It is expected that water quality will remain relatively stable over the short-term (5 years); however, it will deteriorate over the long-term (20 years) due to increased impacts from urbanisation and wastewater discharges. Impacts include high nutrients from upstream sewage and industries, salts due to mining activities upstream, high toxicants; high microbiological contamination and exotic water hyacinth.

- **EWR 7**: The Crocodile River will be impacted at this site by the extra supply of water for the Mokolo transfer. How this water is released is important (for example, will it be pulsed at a constant flow and will it take into account the seasonal requirements of the ecology). It is expected that water quality will remain relatively stable over the short-term (5 years) however it will deteriorate over the long-term due to increased land based activities (20 years). Impacts include high nutrients from upstream sewage, agriculture and industries, seasonal turbidity increases due to greater flows and increased salts as a result of mining and agricultural activities.

- **EWR 8**: It is assumed that this site is downstream from the Mokolo transfer scheme. The Mokolo transfer scheme will be regulated by an in-stream weir. How this water is released is important *i.e.* will it be pulsed at a constant flow and will it take into account the seasonal requirements of the ecology. The water released from this weir is for downstream users, EWR flows and international obligations. The water quality at this site will be impacted by

Scenarios 3 and 4 due to highly impacted water being released from upstream dams (Hartbeespoort and Roodeplaat). It is expected that water quality will remain relatively stable over the short-term (5 years); however, it will deteriorate over the long-term due to upstream wastewater discharges (20 years). Impacts include high nutrients from upstream sewage, agriculture and industries, seasonal turbidity, increased due to greater flows and increased salts due to mining and agricultural activities.

8.1.2. Ecological Consequences

Table 9: Summary of Ecological consequences results per EWR site

EWR site	REC	PES	Scenario 2a	Scenario 2b	Scenario 3	Scenario 4	ISSUES
EWR 1	D	D	☺	☺	X	X	Water Quality, Hydrology, Fish, Riparian Vegetation, Invertebrates
EWR 2	D	E	X	X	X	X	Water Quality, Hydrology Fish, Riparian Vegetation, Invertebrates
EWR 3	C/D	C/D	☺	>	>	X	Water Quality, Geomorphology, Hydrology, Invertebrates, Riparian Vegetation
EWR 4	C	C	☺	☺	☺	☺	Water Quality, Hydrology
EWR 5	D	D	☺	☺	☺	☺	Water Quality, Geomorphology, Riparian Vegetation
EWR 6	D	D	☺	☺	☺	☺	Water Quality, Riparian Vegetation
EWR 7	D	D	☺	☺	☺	☺	Water Quality, Riparian Vegetation, Geomorphology
EWR 8	C	C	☺	☺	☺	☺	Hydrology, Water Quality, Fish

☺ - Meets REC; X – does not meet REC; > = exceeds REC

8.2. Implementation of the ecological Reserve

The water resources that naturally occur in the Crocodile catchment have already been fully developed and most of the tributaries as well as the main stem of the Crocodile (West) River are highly regulated. There are at least eight dams in the Crocodile (West) River which are used for irrigation and domestic water supply. These being the Klivoor, Rietvlei, Roodeplaat, Hartebeespoort, Bon Accord, Buffelspoort, Roodekoppies and Vaalkop dams. In addition, the Crocodile-West River Catchment is already a much transformed system, with present state MARs exceeding natural MARs in the upper catchment areas.

It is clear from Table 9 that none of the Scenarios would meet the recommended Ecological Category at all the EWR sites. All the Scenarios are problematic at EWR sites 2. Scenarios 3 and 4 would be problematic at EWR Site 1 (Upstream Hartbeespoort Dam) and EWR site 2 (Jukskei). At EWR site 3 (just downstream Hartbeespoort Dam), the REC is exceeded (higher category) for Scenarios 2b and 3, however it cannot be met for Scenario 4. The present day situation does not meet the recommended ecological category at EWR site 2.

Scenario 2(b) implements the ecological water requirements (EWR) but does not significantly increase the assessed ecostatus of the Crocodile West system. Only at EWR site 3 does the ecostatus increase, but then only by a half category, from a category C/D to C. By 2030, the positive effect of the ecological reserve is negated by deteriorating water quality (resulting from increased development) and the implementation of the Klip-Crocodile transfer. Furthermore, the implementation of the ecological reserve also has negative effects. The key feature of the implementation of the EWR is timing at which water is released from dams, rather than the additional volume of water released. As a result, regular drawing down of Roodeplaat Dam and the Hartbeespoort Dam are expected. In the case of the Roodeplaat Dam, the wetland function provided by the dam to date will be reduced, with an expected reduction in water quality downstream of the Roodeplaat Dam.

Water use in the catchment by far exceeds the water available from the local sources due to extensive developments and the level of human activity in the catchment. There is large quantities of effluent from the urban and industrial users, most of which is discharged to the river system after treatment, for re-use downstream. In many of the streams and impoundments, water quality is severely compromised by the proportionate large return flows. In general, the increasing urban and mining related development in the Crocodile catchment is causing stress on water resources and is affecting the general health of the rivers and fresh water provisioning services. Currently, there is too much water in the riverine system from an ecological point of view.

The analysis conducted here finds scant evidence of the benefits of implementing the EWR. It is rather recommended that the detrimental effects of continued urbanization and of implementing the transfer schemes be mitigated through other means. The major issues that drive the Crocodile (West) River are increased base flows and water quality due to return waste water flows. **All the scenarios indicated that there would be deterioration in the water quality and the ecological status due to the increased flows. There is no scenario that would improve the current status of the system. Water quality management of the discharges in the catchment would be the only way in possibly improving the ecological status.**

8. RECOMMENDED CONDITIONS AND CONSIDERATIONS FOR THE FUTURE MANAGEMENT OF THE SURFACE WATER RESOURCES OF THE CROCODILE WEST AND MARICO WMA.

RECOMMENDATIONS

At the DWA meeting of 12 May 2010 the following was recommended:

- An ecological category of D is recommended for the Crocodile River;
- The river system should be managed to an upper "D" category to achieve an acceptable water quality;
- More studies need to be undertaken on the tributaries to assess the consequences of higher ecological categories for future resource protection purposes;
- Water quality needs to be stringently managed and the current water quality status in the catchment must be addressed as a matter of priority.
- The freshwater conservation plan for the catchment area must be considered. Pristine tributary catchment areas exist where biodiversity must be protected.

No further water use authorisations for the discharge of wastewater into the Crocodile River should be granted until the water quality state of the river is improved. Water quality in the Crocodile River requires special attention and it is recommended that resource water quality objectives be established as soon as possible to manage the system to an acceptable state.
It is also recommended that a Water Quality Management Plan be developed for the Crocodile River catchment. Water quality management of the discharges in the catchment would be the only way in possibly improving the ecological status. This would provide a framework for

evaluating mitigation measures for improving the health of the water resources in this study area. The management plan would also assist in allocating roles and responsibilities to all authorities and users managing activities and impacting on the system.
The following measures are required to improve the present health of the Crocodile River:

- Reduce the nutrient input from agricultural return flow and wastewater discharges into the Crocodile River. The impact of the wastewater discharges from the numerous wastewater treatment works needs revision and adjustment where relevant;
- There is a need for increased and more stringent source control;
- The proposed transfer from the Klip River need to have stringent water quality objectives and standards to prevent further deterioration of the receiving water quality in the Crocodile (West) catchment;
- The irrigation water users in the Middle to Lower Crocodile (West) River need to be verified and validated upstream of EWR 8, to calculate/verify use in the catchment.

8. REQUEST

It is requested that the recommendations and conditions stipulated in Section 7 above as well as in **Annexure D** of the Reserve template be included into the Record of Recommendation of the WUL assessment process.

Please do not hesitate to contact the Director: Reserve Requirements, **Mr. Yakeen Atwaru** at the above telephone number or email address should you have any further queries in this regard.

CHIEF DIRECTOR: WATER ECOSYSTEMS

DATE: 2013-08-08

cc: LETSEMA TEAM MANAGER: Matlakala Mohlala
cc. DIRECTOR: RDM Compliance
cc. DIRECTOR: WRC
cc. CHIEF DIRECTOR: PLANNING
cc. CHIEF DIRECTOR: REGULATION
cc: SUB DIRECTORATE: ENVIRONMENT AND RECREATION

APPENDIX 1: LIST OF WATER USE LICENSE APPLICATIONS

Table 1: Water Use License Applications Received in the Crocodile (West) River Catchment

Number	Quat	Applicant Name	Water use(s)	Water Resource	Applicable Reserve Site
1.	A21A, A21C	Glen Balad Property	21 c, i	Sesmylspruit, Jukskei River	Desktop Reserve, Intermediate EWR 2
2.	A21A	Towndev (Pty) Ltd	21 e, g	Sesmylspruit	Desktop Reserve
3.		City of Tshwane Municipality for Sunderland Ridge Sewage works	21 f and g	Hennops River	
4.		HME Golfing Enterprise (Pty) Ltd	21 c, i	Hennops River	
5.		Department of Public Transport, Roads and Works- Upgrade of the Bridge at Hennops river on Road K71 (R55)	21 c and i	Hennops River	
6.	A21B	Norcros (Pty) Ltd	21 f and g	Hennops River	Intermediate EWR Site 1, Desktop Reserve
7.		All Seasons Water Pets	21 a, f and g	Hennops River	
8.		JR 209 Investments (K220 Road)	21 c & i	Hennops River	
9.		JR 209 Investments (K109 Road)	21 c & i	Hennops River	
10.		JR 209 Investments (Olivenhoutbosch Road)	21 c & i	Hennops River	
11.		City of Tshwane: Sunderland Ridge WWTW	21 f and g	Hennops River	
12.		Clidet Number 69 (Pty) Ltd for Waterfall City Development	21 a, b, c & i		
13.		Glen Balad Properties	21 c and i		
14.		Dry Creek Properties	21 c and i		
15.		Tshwane Metropolitan Municipality	21 b, c and i		
16.		Kelvin Power Station	21 f, g, h		
17.		PBA International Strathovon Hotel	21 c and i		
18.	A21C	Golden Creek Investments	21 a, b, c, e, f, i	Jukskei River	Intermediate EWR 2
19.		Johannesburg Water, Northern Wastewater Treatment Works	21 f		
20.		Country Club Johannesburg	21 a, b, c,& i		
21.		AECI Limited	21 a,b,c,i,g, j, f		
22.		Eskom Holdings Limited	21 c and i		
23.	A21E	Monoline Property Developers (Pty)	21 c and i	Wilgespruit	Desktop Reserve
24.	A21A	Teak Place (Pty) Ltd	21 a (gw) f, g,	Sesmylspruit	

Number	Quat	Applicant Name	Water use(s)	Water Resource	Applicable Reserve Site
			j (gw)		
25.	A21E	Crane Valley Country Estate	21 c, f and i	Crocodile River	Intermediate EWR Site 1, Desktop
26.		Blair Atholl Golf and Country Estate	21 a, b, c ,e, f, i		
27.	A21F	Red House	21 c, I, g	Magalies River	Rapid EWR 9
28.	A21H	Ivora Development (Pty) Ltd	21 (c), (i)	Crocodile River	Intermediate EWR 1
29.		NECSA	21 a, b, c, f, g, i, j		
30.		Madibeng Local Municipality	21 f & g		
31.	A21J	Pandora Platinum Limited	21a,b,c,g,i&j	Crocodile River	Intermediate EWR 3
32.	A21J	Hartsland Eco Estate	21 a, b, e, g		
33.	A21J A21K	Samancor	21 c, i		
34.	A21J	Ngwenya River Estate	21 c, i		
35.		Mr. D.C Nel	21 e, g		
36.	A21J&K	Xstrata South Africa-Vanadium division-Rhovan Operations	21 f		
37.	A21K	Buffelspoort Eco Park Home Owners Association	21 b, e, g, f	Gwatlhe River	Desktop Reserve
38.	A21K	Marikana Platinum Mine	21 a		
39.	A21K (A21J)	Tharisa Minerals (Pty) Ltd	21a,b,g,c,l,j		
40.	A21J	International Ferrochrome Metals (Pty) Ltd	21 ((a), (c), (g), (i) and (j)	Crocodile River	Intermediate EWR 3
41.	A22F	Rustenburg Local Municipality for Monakato Sewage Treatment Works	21a, b, c, i, e, f, g	Elands River	Desktop Reserve
42.		Rustenburg Local Municipality for Boitekong Sewage Treatment Works	21a, b, c ,i , e, f, g		
43.	A22H	Rustenburg Local Municipality for Rustenburg Sewage Treatment Works	21a, b, c, i, e, f, g	Hex River	Intermediate EWR 6
44.		Impala Platinum	21 a, b, c, f, g, j		
45.		Bakwena Platinum Corridor Concessionaire	21 c, i		
46.		Tierkloof developments Pty Ltd	21 (b) (c) (i)		
47.		Blue Cloud Investments	21 c, i		
48.		Waterkloof Hill Estate	21 a, e, g		
49.	A22J	Rustenburg LM for Lethabong Sewage Treatment Works	21 f and j		

Number	Quat	Applicant Name	Water use(s)	Water Resource	Applicable Reserve Site
50.	A23A	Sammy Marx Development	21(c) & (i)	Pienaars River	Intermediate EWR Site 4
51.		A Koster	21 b		
52.		Donkerhoek Quartzite Quarries	21 a, b		
53.		City of Tshwane Municipality for Zeekoegat WWTW	21 e, f, g		
54.		Rustenburg Platinum Mines	21 c, i		
55.		Leeuwfontein Development	21 c, i, e, g and f		
56.		African Renaissance	21 a, b. c, i		
57.	A23B	KROSA	21 a ,c, i,g		
58.		Boekenhout Sand	21 a, g		
59.	A23D	Arcelormittal Steel	21 f & g	Apies River	Desktop Reserve
60.	A23E	Safdev Land (Pty) Ltd	21 c and i		
61.		Thandamanzi Consultant	21 c, i		
62.	A23F	City of Tshwane Municipality, for Babelegi Waste Water Treatment works	21 a, f and g	Apies River	Intermediate EWR 5, Desktop
63.		City of Tshwane Municipality, for Temba Waste Water Treatment works	21 f and g		
64.		E.B. Mphaka	21 a		
65.		City of Tshwane Municipality	21 c and i		
66.	A23J	Dept: Housing	21 c and i	Pienaars	Intermediate ERW 5
67.	A24D	Pilanesburg Platinum Mine	21 a, c, g & i	Crocodile River	Intermediate EWR 8
68.	A24E	Anglo American Platinum: Union Section	21a, b, c, g, i,j,	Crocodile River	EWR 8, Desktop
69.	A24F	Northam Platinum Mine	21 e, f ,g, j		
70.		Thaba Cronimet Chrome Mine	21a, b, c, g, i,j,		
71.		Merafe Ferrochrome& Mining	21 a, b, c ,i, g, j		
72.	A24G	Lephalale Municipality	21a	Sand River	Desktop Reserve
73.	A24H	Adamson Nielson Yaphi	21c,i	Crocodile River	Intermediate EWR 8
74.		Thabazimbi WWTW	21 c, i, f, g		
75.	A22A, A31B	Western Crown Properties for Eagle's Nest Private Game Reserve	21 b, c & i, f and k	Upper Elands, Groot Marico	Rapid EWR 10, Intermediate EWR 2
76.	A23E	City of Tswane Municiplity	21 c & i	Apies River	Intermediate EWR site 5
77.	A23 F				Intermediate EWR site 5
78.	A23 K				Intermediate

PRELIMINARY DETERMINATION OF THE RESERVE AND ECOLOGICAL CATEGORISATION IN TERMS OF SECTION 17 (1) (b) OF THE NATIONAL WATER ACT, 1998 (ACT NO. 36 OF 1998)

I, **NDILEKA MOHAPI**, in my capacity as Chief Director: Water Ecosystems, and duly authorised in terms of section 63 of the National Water Act, 1998 (Act No. 36 of 1998), do hereby declare the preliminary determination of the Reserve and Ecological Categorisation as contained below.

NM Shapi

CHIEF DIRECTOR: WATER ECOSYSTEMS

DATE: 2013 -08- 08

This high confidence Reserve supersedes all previously conducted Reserves in these Quaternary Catchments.

1. Description of the Surface Water Resource.

River	:	Crocodile River (West)
Drainage Region	:	A20
Water Management Area	:	Crocodile (West) and Marico

2. Preliminary determination of the Reserve for Water Quantity (river) in terms of section 17(1)(b)

The preliminary Ecological Reserves for each site are summarised in Tables 1, 2 and 3.

Table 1: Preliminary Reserve based on Present Day (PD) Flows

Water Resource	EWR Site	Catchment	PES	REC	PD MAR (Mm^3/a)	EWR (%PDMAR)	BHNR Requirement (%PDMAR)	Reserve Requirement (%PDMAR)
Crocodile	1	A21H	D	D	231.05	24.07	0.27	24.34
Jukskei	2	A21C	E	D	139.90	24.87	4.90	29.77

Table 2: Preliminary Reserve based on Natural Flows

Water Resource	EWR Site	Catchment	PES	REC	Natural MAR (Mm^3/a)	EWR (%nMAR)	BHNR Requirement (%nMAR)	Reserve Requirement (%nMAR)
Crocodile	3	A21J	C/D	C/D	143.30	21.70	0.85	22.55
Pienaars	4	A23B	C	C	28.21	30.81	0.61	31.42
Pienaars	5	A23J	D	D	113.03	11.82	4.23	16.05
Hex	6	A22J	D	D	26.93	14.96	0.66	15.62
Crocodile	7	A24C	D	D	463.36	9.14	0.05	9.19
Crocodile	8	A24H	C	C	559.94	13.78	0.02	13.80
Upper Elands	10	A22A	C	B/C	10.1	30.48	1.79	32.27
Sterkstroom	11	A21K	C	C	13.96	28.41	3.61	32.02

Number	Quat	Applicant Name	Water use(s)	Water Resource	Applicable Reserve Site
					EWR site 7
79.	A21J, A22J, A23E	Bakwena Platinum Corridor Concessionaire	21 a, c & i	Crocodile, Hex and Apies Rivers	Intermediate EWR site 3, 6 & Desktop at the outlet of A23E
80.	A21 B	Dark Fibre Africa	21 c& i	Hennops River	Intermediate EWR site 1
81.	A 24 F	Thaba Cronimet Chrome Mine (Pty) Ltd & Roodedam Leadwood Estate	21 c & i	Bierspruit River	Intermediate EWR site 8
82.	A24 F	Roodedam Leadwood Estate	21 c& i	Bierspruit River	Intermediate EWR site 8
83.	A21J	Western Crown Properties 48 (Pty) Ltd.	21 f	Crocodile River	Intermediate EWR site 3
84.	A22H	Xstrata Alloys South Africa (Pty) Ltd- Kroondal Chrome Mine.	21 f	Sandspruit River	Intermediate EWR site 6
85.	A22F	Suncity Resort	21 a, b, c, e, f, g, i,	Elands River and tributaries	Intermediate EWR site 6
86.	A22F	Masevhe Investments II (Pty) Ltd	21 a, b, c, g, i, j	Elands River	Intermediate EWR site 6
87.	A24C, A24F	Rustenburg Platinum Mines: Amandelbult Section	21 a, b, c, e, f, g, i, j	Crocodile River, Bierspruit River	Intermediate EWR site 7 and EWR 8
88.	A22H	Rustenburg Municipality: Rustenburg South Reservoir to Cashan Reservoir pipeline	21 c, i	Waterval River	Intermediate EWR site 6

Table 3: Preliminary Reserve based on Observed Simulated MAR

Water Resource	EWR Site	Catchment	PES	REC	Observed Simulated MAR (Mm^3/a)	EWR (% Ob Sim MAR)	BHNR Requirement (%Ob Sim MAR)	Reserve Requirement (% Ob Sim MAR)
Magalies	9	A21F	B	B	14.72	45.58	0.72	46.30

3. Applicability

3.1 This preliminary determination of the Reserve in terms of section 17(1)(a) is applicable to the following water resource or part of the resource:

- Crocodile River (West), catchment A20.

3.2 This preliminary determination of the Reserve in terms of section 17(1)(b) is applicable to the authorising of the following water uses:

- Section 21(a) – taking water from a water resource;
- Section 21(b) – storing water;
- Section 21(c) – impeding or diverting the flow of water in a watercourse;
- Section 21(d) – engaging in a stream flow reduction activity;
- Section 21(e) – engaging in a controlled activity identified as such in section 37 (1) or declared under section 38 (1);
- Section 21(f) – discharging water into a water resource through a pipe, canal, sewer, sea outfall or other conduit;
- Section 21(g) – disposing of waste in manner which may detrimentally impact on a water resource;
- Section 21(h) – disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process;
- Section 21(i) – altering the bed, banks, course or characteristics of a watercourse;
- Section 21(j) – removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people;
- Section 21(k) – using water for recreational purposes;

4. Additional supporting documentation is provided in the following Annexure

Annexure A: Preliminary Ecological Reserve – Water Quantity	☒
Annexure B: Preliminary Ecological Reserve – Water Quality	☒
Annexure C: Basic Human Needs Reserve	☒
Annexure D: Special conditions and limitations	☒
Annexure E: Background	☒
Annexure F: Methodology	☒
Annexure G: Locality Map of Study Area	☒
Annexure H: References and Relevant Project Reports	☒

ANNEXURE A

PRELIMINARY ECOLOGICAL RESERVE

WATER QUANTITY

A1: RIVER ECOSYSTEMS COMPONENT – WATER QUANTITY (A20)

1. Level of confidence of the determination: Medium

2. The determination is applicable to the cumulative flow at the EWR sites (see Table A). This means that the Ecological Water Requirements (EWR) is based on the natural flow contribution of the catchments upstream of and up to the EWR site.

Table A: Location of EWR Sites and Level of Assessment

River Name	Quaternary Catchment	Name	Level of assessment	Geographic co-ordinates of EWR Site	
Crocodile	A21H	Upstream of the Hartbeespoort Dam	Intermediate	E 27.896	S 25.8004
Juskei	A21C	Heron Bridge School	Intermediate	E 27.9621	S 25.9539
Crocodile	A21J	Downstream of Hartbeespoort Dam in Mount Amanzi	Intermediate	E 27.8431	S 25.7168
Pienaars	A23B	Downstream of Roodeplaat Dam	Intermediate	E 28.312	S 25.4155
Pienaars	A23J	Downstream of the Klipvoor Dam in Borakalalo National Park	Intermediate	E 27.80457	S 25.12657
Hex	A22J	Upstream of Vaalkop Dam	Intermediate	E 27.3749	S 25.5214
Crocodile	A24C	Upstream of the confluence with the Bierspruit	Intermediate	E 27.51743	S 24.88661
Crocodile	A24H	Downstream of the confluence with the Bierspruit in Ben Alberts Nature Reserve	Intermediate	E 27.32569	S 24.64476
Magalies	A21F	Upstream of Malony's Eye	Rapid	E 27.56581	S 26.01689
Upper Elands	A22A	Highveld	Rapid	E 26.72044	S 25.72655
Sterkstroom	A21K	Upstream Buffelspoort Dam	Rapid	E 27.47848	S 25.80739

A2: DETAILED ECOLOGICAL WATER REQUIREMENT RESULTS (FLOW ECOSPECS)

The EWR rules and tables are generated from the Desktop Reserve Model at each EWR site. These are provided in the Tables below.

Tables A1 to A22 provide a summary of the flow characteristics and the EWR rule curves for the water quantity component of the ecological Reserve.

The river ecology, especially in the Upper Crocodile and the Apies River have adapted to the increased present day surface flow in some areas as well as the changes in the seasonal distribution in other areas. The present day flow was therefore used as the reference flow of Croc_EWR1 and Croc_EWR2. The natural flow was used as the reference flow for all the other EWR sites.

During the Reserve determination at Croc_EWR9 (Maloney's Eye) serious errors in flow data were rectified. The downstream flow records were however not changed, since the impact of this change on the hydrology of the other EWR sites, were considered to be negligible. For this EWR 9, observed simulated flow records were used. The simulated flow data for the Crocodile (West) River Catchment (A2-region) was obtained from the 2007 DWAF study executed by BKS and Arcus Gibb, namely "***The assessment of water availability in the Crocodile (West) River Catchment by means of water resource related models in support of the planned future licensing process***". **The simulated flow data, for the Crocodile (West) River Catchment, covers the hydrological years 1920 to 2003.**

EWR 1: CROCODILE RIVER, Upstream of the Hartbeespoort Dam

Table A1: Summary of EWR Estimate for EWR 1_A21H

```
Desktop Version 2, Printed on 2009/08/19
Summary of EWR estimate for: Croc_EWR1 Monthly present day
Determination based on defined BBM Table with site specific
assurance rules.

Annual Flows (Mill. cu. m or index values):
MAR                = 231.047
S.Dev.             = 76.198
CV                 = 0.330
Q75                = 14.030
Q75/MMF            = 0.729
BFI Index          = 0.759
CV(JJA+JFM) Index  = 1.054

REC = D

Total EWR          = 55.607 (24.07 %MAR)
Maint. Lowflow     = 41.687 (18.04 %MAR)
Drought Lowflow    = 41.689 (18.04 %MAR)
Maint. Highflow    = 13.921 ( 6.02 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type: Olifants
```

Month	Natural Flows			Modified Flows (EWR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	5.277	1.538	0.109	1.179	1.179	0.000	1.179
Nov	7.045	3.961	0.217	1.259	1.259	0.000	1.259
Dec	7.443	4.025	0.202	1.246	1.246	1.086	2.332
Jan	9.557	7.665	0.299	1.321	1.321	0.000	1.321
Feb	12.151	14.222	0.484	1.538	1.538	2.605	4.143
Mar	9.779	8.239	0.315	1.400	1.400	0.688	2.088
Apr	7.699	3.332	0.167	1.402	1.402	0.000	1.402
May	6.374	1.463	0.086	1.334	1.334	0.000	1.334
Jun	6.308	0.918	0.056	1.368	1.368	0.000	1.368
Jul	5.915	0.654	0.041	1.313	1.313	0.000	1.313
Aug	5.507	0.506	0.034	1.279	1.280	0.000	1.279
Sep	5.234	0.942	0.069	1.244	1.244	1.106	2.350

Table A2: Summary of EWR Rule Curves for EWR 1_A21H

Desktop Version 2, Printed on 2009/08/19
Summary of EWR rule curves for: Croc_EWR1 Monthly present day
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Olifants
REC = D

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.187	2.177	2.155	2.110	2.026	1.888	1.692	1.467	1.275	1.185
Nov	2.510	2.501	2.481	2.443	2.371	2.246	2.047	1.770	1.461	1.267
Dec	4.103	4.083	4.040	3.956	3.798	3.523	3.085	2.477	1.798	1.372
Jan	2.634	2.624	2.604	2.563	2.488	2.357	2.147	1.857	1.533	1.329
Feb	8.127	7.441	6.845	6.302	5.757	4.843	4.228	3.374	2.422	1.823
Mar	4.128	3.939	3.766	3.593	3.392	3.052	2.732	2.288	1.793	1.481
Apr	2.600	2.589	2.563	2.509	2.409	2.245	2.012	1.745	1.516	1.409
May	2.474	2.463	2.438	2.387	2.292	2.136	1.915	1.660	1.442	1.341
Jun	2.537	2.526	2.501	2.448	2.351	2.190	1.963	1.702	1.479	1.375
Jul	2.435	2.424	2.400	2.350	2.256	2.102	1.884	1.634	1.420	1.320
Aug	2.372	2.362	2.338	2.289	2.198	2.048	1.836	1.592	1.384	1.287
Sep	3.879	3.855	3.801	3.688	3.477	3.130	2.640	2.077	1.595	1.370
Reserve flows without High Flows										
Oct	2.187	2.177	2.155	2.110	2.026	1.888	1.692	1.467	1.275	1.185
Nov	2.510	2.501	2.481	2.443	2.371	2.246	2.047	1.770	1.461	1.267
Dec	2.484	2.475	2.456	2.418	2.347	2.223	2.026	1.751	1.446	1.254
Jan	2.634	2.624	2.604	2.563	2.488	2.357	2.147	1.857	1.533	1.329
Feb	3.066	3.055	3.031	2.985	2.897	2.744	2.500	2.162	1.785	1.548
Mar	2.791	2.781	2.759	2.717	2.637	2.498	2.276	1.968	1.625	1.409
Apr	2.600	2.589	2.563	2.509	2.409	2.245	2.012	1.745	1.516	1.409
May	2.474	2.463	2.438	2.387	2.292	2.136	1.915	1.660	1.442	1.341
Jun	2.537	2.526	2.501	2.448	2.351	2.190	1.963	1.702	1.479	1.375
Jul	2.435	2.424	2.400	2.350	2.256	2.102	1.884	1.634	1.420	1.320
Aug	2.372	2.362	2.338	2.289	2.198	2.048	1.836	1.592	1.384	1.287
Sep	2.307	2.297	2.274	2.226	2.138	1.992	1.785	1.548	1.345	1.251
Natural Duration curves										
Oct	7.183	5.888	5.216	4.917	4.798	4.637	4.540	4.398	4.219	3.879
Nov	10.405	7.921	7.068	6.385	5.961	5.667	5.231	5.012	4.541	4.213
Dec	11.865	8.296	7.501	6.661	6.213	5.832	5.354	5.070	4.842	4.361
Jan	15.267	11.354	9.808	8.031	7.266	6.414	5.813	5.559	5.044	4.480
Feb	22.557	12.306	10.491	8.552	7.329	6.982	6.238	5.994	5.799	5.002
Mar	17.708	12.123	8.692	7.616	7.217	6.175	5.895	5.682	5.261	4.480
Apr	10.779	8.904	8.272	7.326	6.682	6.254	6.003	5.791	5.633	4.904
May	8.072	7.112	6.455	6.157	5.892	5.757	5.612	5.503	5.227	5.052
Jun	7.542	6.779	6.551	6.154	6.038	5.930	5.768	5.718	5.482	5.258
Jul	6.821	6.332	6.127	5.821	5.739	5.675	5.541	5.440	5.317	5.130
Aug	6.209	5.877	5.563	5.444	5.350	5.302	5.234	5.152	5.055	4.891
Sep	5.984	5.602	5.243	5.073	4.938	4.869	4.830	4.765	4.680	4.495

EWR 2: JUKSKEI RIVER at Heron Bridge School

Table A3: Summary of EWR Estimate for EWR 2_A21C

```
Desktop Version 2, Printed on 2009/08/19
        Summary of EWR estimate for: Croc_EWR2 Monthly present day
        Determination based on defined BBM Table with site specific assurance
        rules.

        Annual Flows (Mill. cu. m or index values):
        MAR                = 139.901
        S.Dev.             = 37.054
        CV                 = 0.265
        Q75                = 8.770
        Q75/MMF            = 0.752
        BFI Index          = 0.766
        CV(JJA+JFM) Index  = 0.912

        REC = D

        Total EWR          = 34.798 (24.87 %MAR)
        Maint. Lowflow     = 18.850 (13.47 %MAR)
        Drought Lowflow    = 18.850 (13.47 %MAR)
        Maint. Highflow    = 15.949 (11.40 %MAR)

        Monthly Distributions (cu.m./s)
        Distribution Type: Olifants
```

Month	Natural Flows			Modified Flows (EWR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	3.297	1.023	0.116	0.540	0.540	0.958	1.498
Nov	4.418	2.672	0.233	0.578	0.578	0.000	0.578
Dec	4.721	2.733	0.216	0.574	0.574	0.994	1.568
Jan	5.953	4.432	0.278	0.607	0.607	0.994	1.601
Feb	7.214	7.464	0.428	0.698	0.698	2.116	2.814
Mar	5.686	4.187	0.275	0.630	0.630	0.549	1.179
Apr	4.510	1.529	0.131	0.625	0.625	0.000	0.625
May	3.760	0.643	0.064	0.593	0.593	0.000	0.593
Jun	3.714	0.318	0.033	0.607	0.607	0.000	0.607
Jul	3.547	0.278	0.029	0.585	0.585	0.000	0.585
Aug	3.374	0.191	0.021	0.577	0.577	0.000	0.577
Sep	3.250	0.638	0.076	0.568	0.568	0.567	1.135

Table A4: Summary of EWR Rule Curves for EWR 2_A21C

Desktop Version 2, Printed on 2009/08/19
Summary of EWR rule curves for : Croc_EWR2 Monthly present day
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Olifants
REC = D

Data are given in m^3/s mean monthly flow

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
	% Points									
Oct	2.364	2.347	2.310	2.232	2.088	1.851	1.516	1.130	0.800	0.647
Nov	1.152	1.148	1.139	1.122	1.089	1.031	0.940	0.812	0.671	0.582
Dec	2.627	2.612	2.582	2.522	2.410	2.214	1.903	1.471	0.989	0.686
Jan	3.140	2.879	2.651	2.443	2.234	1.883	1.646	1.316	0.947	0.716
Feb	5.501	4.949	4.473	4.049	3.637	2.950	2.538	1.965	1.327	0.926
Mar	2.322	2.175	2.045	1.921	1.789	1.566	1.388	1.141	0.865	0.692
Apr	1.159	1.154	1.142	1.119	1.074	1.001	0.897	0.778	0.676	0.628
May	1.100	1.095	1.084	1.061	1.019	0.949	0.851	0.738	0.641	0.596
Jun	1.126	1.121	1.110	1.086	1.043	0.972	0.871	0.755	0.656	0.610
Jul	1.085	1.080	1.069	1.047	1.005	0.937	0.840	0.728	0.633	0.588
Aug	1.070	1.065	1.055	1.033	0.992	0.924	0.828	0.718	0.624	0.580
Sep	1.859	1.848	1.821	1.766	1.663	1.493	1.254	0.978	0.742	0.632
Reserve flows without High Flows										
Oct	1.001	0.997	0.987	0.966	0.928	0.865	0.775	0.672	0.584	0.543
Nov	1.152	1.148	1.139	1.122	1.089	1.031	0.940	0.812	0.671	0.582
Dec	1.144	1.140	1.131	1.114	1.081	1.024	0.933	0.807	0.666	0.578
Jan	1.210	1.206	1.196	1.178	1.143	1.083	0.987	0.853	0.704	0.611
Feb	1.392	1.386	1.376	1.354	1.315	1.245	1.135	0.981	0.810	0.702
Mar	1.256	1.251	1.242	1.223	1.187	1.124	1.024	0.886	0.731	0.634
Apr	1.159	1.154	1.142	1.119	1.074	1.001	0.897	0.778	0.676	0.628
May	1.100	1.095	1.084	1.061	1.019	0.949	0.851	0.738	0.641	0.596
Jun	1.126	1.121	1.110	1.086	1.043	0.972	0.871	0.755	0.656	0.610
Jul	1.085	1.080	1.069	1.047	1.005	0.937	0.840	0.728	0.633	0.588
Aug	1.070	1.065	1.055	1.033	0.992	0.924	0.828	0.718	0.624	0.580
Sep	1.053	1.049	1.038	1.017	0.976	0.909	0.815	0.707	0.614	0.571
Natural Duration curves										
Oct	4.365	3.584	3.177	3.035	2.983	2.923	2.826	2.755	2.692	2.610
Nov	6.289	4.691	4.186	3.912	3.704	3.441	3.264	3.083	2.886	2.762
Dec	6.922	5.552	4.786	4.066	3.849	3.726	3.349	3.203	2.998	2.815
Jan	10.387	7.419	6.015	4.921	4.439	4.137	3.625	3.450	3.244	2.964
Feb	12.004	8.296	6.436	5.237	4.592	4.220	3.939	3.724	3.497	3.228
Mar	11.018	6.336	5.488	4.518	4.111	3.801	3.532	3.450	3.226	2.841
Apr	6.520	5.463	4.715	4.159	3.970	3.789	3.630	3.569	3.383	3.183
May	4.428	4.029	3.805	3.659	3.573	3.491	3.424	3.368	3.248	3.203
Jun	4.136	3.924	3.742	3.669	3.646	3.576	3.542	3.499	3.453	3.422
Jul	3.793	3.629	3.558	3.502	3.465	3.439	3.416	3.394	3.379	3.356
Aug	3.558	3.401	3.360	3.338	3.315	3.304	3.289	3.278	3.256	3.252
Sep	3.511	3.318	3.191	3.144	3.110	3.079	3.059	3.048	3.021	2.990

EWR 3: CROCODILE RIVER, Downstream of the Hartbeespoort Dam

Table A5: Summary of EWR Estimate for EWR 3_A21J

```
Desktop Version 2, Printed on 2009/08/19
 Summary of EWR estimate for: Croc_EWR3 Natural flow mcm
 Determination based on defined BBM Table with site specific assurance
rules.

  Annual Flows (Mill. cu. m or index values):
  MAR                = 143.301
  S.Dev.             = 107.864
  CV                 = 0.753
  Q75                = 4.900
  Q75/MMF            = 0.410
  BFI Index          = 0.558
  CV(JJA+JFM) Index  = 2.019

  REC = C/D

  Total IFR          = 31.096 (21.70 %MAR)
  Maint. Lowflow     = 16.304 (11.38 %MAR)
  Drought Lowflow    = 11.102 ( 7.75 %MAR)
  Maint. Highflow    = 14.792 (10.32 %MAR)

  Monthly Distributions (cu.m./s)
  Distribution Type: Olifants
```

Month	Natural Flows			Modified Flows (EWR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	2.335	1.620	0.259	0.401	0.276	0.000	0.401
Nov	4.484	5.774	0.497	0.463	0.317	0.711	1.174
Dec	4.910	4.847	0.369	0.476	0.325	1.147	1.623
Jan	7.733	11.367	0.549	0.562	0.381	0.000	0.562
Feb	10.532	19.294	0.757	0.710	0.479	2.559	3.269
Mar	7.993	12.439	0.581	0.645	0.436	0.688	1.333
Apr	4.586	4.765	0.401	0.589	0.399	0.000	0.589
May	3.057	1.669	0.204	0.527	0.358	0.000	0.527
Jun	2.726	1.210	0.171	0.514	0.350	0.000	0.514
Jul	2.405	0.925	0.144	0.473	0.323	0.000	0.473
Aug	2.154	0.799	0.139	0.441	0.302	0.000	0.441
Sep	2.053	0.984	0.185	0.419	0.289	0.711	1.130

Table A6: Summary of EWR Rule Curves for EWR 3_A21J

Desktop Version 2, Printed on 2009/08/19
Summary of EWR rule curves for : Croc_EWR3 Natural flow mcm
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Olifants
REC = C/D

Data are given in m^3/s mean monthly flow

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.627	0.624	0.616	0.601	0.571	0.523	0.455	0.376	0.309	0.278
Nov	1.698	1.688	1.668	1.628	1.553	1.421	1.213	0.923	0.600	0.396
Dec	2.293	2.279	2.251	2.194	2.088	1.902	1.607	1.196	0.739	0.451
Jan	0.924	0.920	0.911	0.895	0.864	0.809	0.723	0.603	0.469	0.384
Feb	6.138	5.470	4.897	4.389	3.900	3.084	2.609	1.950	1.216	0.754
Mar	2.397	2.214	2.053	1.903	1.746	1.483	1.285	1.011	0.705	0.513
Apr	0.921	0.916	0.905	0.882	0.838	0.766	0.665	0.548	0.449	0.402
May	0.824	0.820	0.810	0.789	0.750	0.686	0.596	0.491	0.402	0.361
Jun	0.804	0.800	0.790	0.770	0.732	0.669	0.581	0.480	0.393	0.353
Jul	0.740	0.736	0.727	0.708	0.674	0.616	0.535	0.442	0.363	0.326
Aug	0.690	0.686	0.678	0.660	0.628	0.575	0.500	0.413	0.339	0.304
Sep	1.564	1.552	1.526	1.472	1.372	1.207	0.973	0.704	0.475	0.368
Reserve flows without High Flows										
Oct	0.627	0.624	0.616	0.601	0.571	0.523	0.455	0.376	0.309	0.278
Nov	0.761	0.758	0.751	0.737	0.712	0.667	0.597	0.498	0.389	0.320
Dec	0.783	0.779	0.772	0.758	0.732	0.686	0.613	0.512	0.399	0.328
Jan	0.924	0.920	0.911	0.895	0.864	0.809	0.723	0.603	0.469	0.384
Feb	1.167	1.162	1.151	1.130	1.091	1.022	0.912	0.760	0.590	0.483
Mar	1.060	1.056	1.046	1.027	0.991	0.929	0.829	0.691	0.537	0.440
Apr	0.921	0.916	0.905	0.882	0.838	0.766	0.665	0.548	0.449	0.402
May	0.824	0.820	0.810	0.789	0.750	0.686	0.596	0.491	0.402	0.361
Jun	0.804	0.800	0.790	0.770	0.732	0.669	0.581	0.480	0.393	0.353
Jul	0.740	0.736	0.727	0.708	0.674	0.616	0.535	0.442	0.363	0.326
Aug	0.690	0.686	0.678	0.660	0.628	0.575	0.500	0.413	0.339	0.304
Sep	0.656	0.652	0.644	0.628	0.597	0.547	0.476	0.394	0.324	0.291
Natural Duration curves										
Oct	4.029	2.811	2.520	2.068	1.807	1.650	1.497	1.396	1.228	0.821
Nov	9.020	4.826	4.201	3.654	2.971	2.377	2.022	1.647	1.354	0.887
Dec	9.465	6.672	4.842	3.879	3.196	2.867	2.513	2.027	1.781	1.191
Jan	14.195	10.376	6.922	5.597	4.309	3.424	2.688	2.270	1.755	1.206
Feb	26.356	10.119	7.449	5.064	3.972	3.381	2.827	2.331	1.959	1.298
Mar	18.362	10.372	6.631	4.555	3.521	2.871	2.524	2.221	1.882	1.366
Apr	7.959	6.065	4.857	3.746	3.364	2.728	2.431	2.195	1.906	1.246
May	5.283	3.678	3.300	2.923	2.703	2.375	2.139	1.941	1.602	1.146
Jun	4.329	3.418	2.998	2.724	2.542	2.226	1.975	1.887	1.532	1.157
Jul	4.040	3.114	2.602	2.431	2.263	2.001	1.837	1.688	1.415	1.064
Aug	3.539	2.737	2.330	2.143	2.046	1.856	1.661	1.549	1.307	0.971
Sep	3.256	2.542	2.315	1.995	1.798	1.613	1.532	1.408	1.273	0.837

EWR 4: PIENAARS RIVER, Downstream of the Roodeplaat Dam

Table A7: Summary of EWR Estimate for EWR 4_A23B

```
Desktop Version 2, Printed on 2009/08/19
Summary of EWR estimate for: Croc_EWR4 Natural flow mcm
Determination based on defined BBM Table with site specific assurance
rules.

 Annual Flows (Mill. cu. m or index values):
 MAR                = 28.210
 S.Dev.             = 29.621
 CV                 = 1.050
 Q75                = 0.640
 Q75/MMF            = 0.272
 BFI Index          = 0.443
 CV(JJA+JFM) Index  = 2.693

 REC = C

 Total EWR          = 8.693 (30.81 %MAR)
 Maint. Lowflow     = 4.797 (17.00 %MAR)
 Drought Lowflow    = 2.828 (10.03 %MAR)
 Maint. Highflow    = 3.896 (13.81 %MAR)

 Monthly Distributions (cu.m./s)
 Distribution Type: Olifants
```

Month	Natural Flows			Modified Flows (EWR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.378	0.420	0.415	0.104	0.063	0.000	0.104
Nov	0.981	1.523	0.599	0.136	0.081	0.210	0.346
Dec	1.049	1.329	0.473	0.146	0.086	0.339	0.485
Jan	2.203	5.178	0.878	0.211	0.122	0.203	0.414
Feb	2.104	4.804	0.944	0.242	0.140	0.560	0.802
Mar	1.617	3.483	0.804	0.208	0.119	0.203	0.411
Apr	0.827	1.387	0.647	0.174	0.102	0.000	0.174
May	0.443	0.396	0.334	0.144	0.085	0.000	0.144
Jun	0.362	0.182	0.194	0.133	0.080	0.000	0.133
Jul	0.314	0.126	0.149	0.120	0.072	0.000	0.120
Aug	0.281	0.109	0.145	0.111	0.067	0.000	0.111
Sep	0.255	0.104	0.157	0.103	0.063	0.000	0.103

Table A8: Summary of EWR Rule Curves for EWR 4_A23B

Desktop Version 2, Printed on 2009/08/19
Summary of EWR rule curves for : Croc_EWR4 Natural flow mcm
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Olifants
REC = C

Data are given in m^3/s mean monthly flow

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.141	0.140	0.139	0.135	0.129	0.118	0.103	0.085	0.070	0.063
Nov	0.440	0.438	0.433	0.422	0.403	0.369	0.313	0.240	0.157	0.104
Dec	0.608	0.604	0.597	0.582	0.554	0.497	0.358	0.280	0.199	0.123
Jan	0.689	0.635	0.588	0.544	0.498	0.422	0.365	0.287	0.200	0.145
Feb	1.426	1.279	1.095	0.666	0.517	0.467	0.376	0.322	0.269	0.200
Mar	0.685	0.631	0.584	0.540	0.437	0.370	0.325	0.283	0.196	0.142
Apr	0.236	0.235	0.232	0.226	0.214	0.196	0.170	0.140	0.115	0.103
May	0.195	0.194	0.192	0.187	0.178	0.162	0.141	0.116	0.095	0.086
Jun	0.180	0.179	0.177	0.173	0.164	0.150	0.131	0.109	0.090	0.081
Jul	0.163	0.162	0.160	0.156	0.148	0.136	0.118	0.098	0.081	0.073
Aug	0.150	0.150	0.148	0.144	0.137	0.126	0.109	0.091	0.075	0.068
Sep	0.140	0.139	0.137	0.134	0.127	0.117	0.102	0.085	0.070	0.063
Reserve flows without High Flows										
Oct	0.141	0.140	0.139	0.135	0.129	0.118	0.103	0.085	0.070	0.063
Nov	0.190	0.189	0.187	0.184	0.178	0.167	0.149	0.125	0.099	0.082
Dec	0.204	0.203	0.201	0.197	0.191	0.179	0.160	0.134	0.105	0.087
Jan	0.294	0.293	0.290	0.285	0.275	0.258	0.230	0.192	0.150	0.123
Feb	0.338	0.336	0.333	0.327	0.316	0.296	0.264	0.221	0.172	0.141
Mar	0.290	0.289	0.286	0.281	0.271	0.254	0.227	0.189	0.147	0.120
Apr	0.236	0.235	0.232	0.226	0.214	0.196	0.170	0.140	0.115	0.103
May	0.195	0.194	0.192	0.187	0.178	0.162	0.141	0.116	0.095	0.086
Jun	0.180	0.179	0.177	0.173	0.164	0.150	0.131	0.109	0.090	0.081
Jul	0.163	0.162	0.160	0.156	0.148	0.136	0.118	0.098	0.081	0.073
Aug	0.150	0.150	0.148	0.144	0.137	0.126	0.109	0.091	0.075	0.068
Sep	0.140	0.139	0.137	0.134	0.127	0.117	0.102	0.085	0.070	0.063
Natural Duration curves										
Oct	0.736	0.407	0.332	0.287	0.261	0.220	0.190	0.175	0.149	0.112
Nov	2.253	1.208	0.995	0.710	0.509	0.374	0.313	0.243	0.181	0.131
Dec	2.449	1.419	1.161	0.803	0.594	0.497	0.358	0.280	0.220	0.157
Jan	4.297	2.580	1.430	0.859	0.747	0.549	0.399	0.332	0.280	0.213
Feb	5.961	1.831	1.095	0.666	0.517	0.467	0.376	0.322	0.269	0.207
Mar	4.096	1.370	0.750	0.571	0.437	0.370	0.325	0.284	0.235	0.161
Apr	1.350	0.656	0.532	0.482	0.432	0.355	0.313	0.274	0.228	0.147
May	0.668	0.485	0.448	0.399	0.329	0.310	0.280	0.243	0.202	0.142
Jun	0.571	0.463	0.424	0.351	0.316	0.285	0.251	0.239	0.197	0.150
Jul	0.493	0.422	0.388	0.321	0.284	0.258	0.231	0.213	0.175	0.134
Aug	0.455	0.370	0.343	0.280	0.254	0.231	0.205	0.194	0.168	0.119
Sep	0.413	0.340	0.305	0.262	0.235	0.212	0.181	0.162	0.147	0.104

EWR 5: PIENAARS RIVER, Downstream of the Klipvoor Dam in Borakalalo National Park

Table A9: Summary of EWREstimate for EWR 5_A23J

```
Desktop Version 2, Printed on 2009/08/19
Summary of EWR estimate for: Croc_EWR5 Natural flow mcm
Determination based on defined BBM Table with site specific assurance
rules.

 Annual Flows (Mill. cu. m or index values):
 MAR                = 113.029
 S.Dev.             = 96.131
 CV                 = 0.850
 Q75                = 2.690
 Q75/MMF            = 0.286
 BFI Index          = 0.458
 CV(JJA+JFM) Index  = 2.310

 REC = D

 Total EWR          = 13.363 (11.82 %MAR)
 Maint. Lowflow     = 7.281 ( 6.44 %MAR)
 Drought Lowflow    = 7.163 ( 6.34 %MAR)
 Maint. Highflow    = 6.082 ( 5.38 %MAR)

 Monthly Distributions (cu.m./s)
 Distribution Type: Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.554	1.726	0.415	0.162	0.159	0.344	0.506
Nov	4.230	6.837	0.623	0.210	0.206	0.000	0.210
Dec	4.942	4.707	0.356	0.230	0.226	0.765	0.995
Jan	8.300	15.135	0.681	0.303	0.298	0.344	0.647
Feb	8.473	16.950	0.827	0.356	0.351	0.000	0.356
Mar	6.027	11.084	0.687	0.309	0.304	0.818	1.127
Apr	2.949	3.951	0.517	0.260	0.256	0.000	0.260
May	1.793	1.378	0.287	0.220	0.216	0.000	0.220
Jun	1.501	0.692	0.178	0.208	0.205	0.000	0.208
Jul	1.328	0.541	0.152	0.188	0.185	0.000	0.188
Aug	1.186	0.472	0.149	0.174	0.171	0.000	0.174
Sep	1.050	0.414	0.152	0.160	0.158	0.000	0.160

Table A10: Summary of EWR Rule Curves for EWR 5_A23J

Desktop Version 2, Printed on 2009/08/19
Summary of EWR rule curves for : Croc_EWR5 Natural flow mcm
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Olifants
REC = D

Data are given in m^3/s mean monthly flow

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.790	0.784	0.771	0.744	0.695	0.613	0.497	0.364	0.250	0.197
Nov	0.419	0.417	0.414	0.407	0.395	0.374	0.340	0.293	0.240	0.207
Dec	1.599	1.589	1.569	1.529	1.455	1.325	1.119	0.832	0.512	0.311
Jan	1.272	1.181	1.101	1.026	0.948	0.817	0.719	0.583	0.432	0.336
Feb	0.710	0.707	0.702	0.691	0.670	0.634	0.577	0.497	0.409	0.353
Mar	2.205	1.991	1.806	1.641	1.479	1.209	1.043	0.812	0.554	0.392
Apr	0.482	0.480	0.475	0.465	0.446	0.415	0.371	0.321	0.277	0.257
May	0.408	0.406	0.402	0.393	0.377	0.351	0.314	0.271	0.234	0.217
Jun	0.386	0.384	0.380	0.372	0.357	0.332	0.297	0.257	0.222	0.206
Jul	0.349	0.347	0.344	0.336	0.323	0.300	0.268	0.232	0.201	0.186
Aug	0.323	0.321	0.318	0.311	0.299	0.278	0.248	0.214	0.185	0.172
Sep	0.297	0.295	0.292	0.286	0.275	0.256	0.229	0.198	0.171	0.159
Reserve flows without High Flows										
Oct	0.300	0.299	0.296	0.290	0.278	0.258	0.231	0.199	0.172	0.160
Nov	0.419	0.417	0.414	0.407	0.395	0.374	0.340	0.293	0.240	0.207
Dec	0.459	0.457	0.453	0.446	0.433	0.409	0.372	0.321	0.264	0.227
Jan	0.604	0.602	0.597	0.588	0.570	0.539	0.491	0.423	0.347	0.300
Feb	0.710	0.707	0.702	0.691	0.670	0.634	0.577	0.497	0.409	0.353
Mar	0.616	0.614	0.609	0.599	0.581	0.550	0.500	0.431	0.354	0.306
Apr	0.482	0.480	0.475	0.465	0.446	0.415	0.371	0.321	0.277	0.257
May	0.408	0.406	0.402	0.393	0.377	0.351	0.314	0.271	0.234	0.217
Jun	0.386	0.384	0.380	0.372	0.357	0.332	0.297	0.257	0.222	0.206
Jul	0.349	0.347	0.344	0.336	0.323	0.300	0.268	0.232	0.201	0.186
Aug	0.323	0.321	0.318	0.311	0.299	0.278	0.248	0.214	0.185	0.172
Sep	0.297	0.295	0.292	0.286	0.275	0.256	0.229	0.198	0.171	0.159
Natural Duration curves										
Oct	2.628	1.680	1.411	1.217	0.974	0.874	0.814	0.758	0.582	0.489
Nov	9.877	5.883	4.186	3.129	2.242	1.890	1.300	0.980	0.772	0.590
Dec	11.869	7.501	5.847	4.163	3.032	2.617	2.020	1.557	0.993	0.724
Jan	19.321	10.615	6.941	4.211	3.420	2.860	2.233	1.594	1.337	1.053
Feb	20.482	7.717	5.419	3.410	2.741	2.253	1.724	1.587	1.385	0.885
Mar	18.149	6.272	4.264	3.017	2.326	1.773	1.426	1.273	0.986	0.668
Apr	6.686	2.820	2.446	2.095	1.740	1.551	1.312	1.161	0.995	0.706
May	3.162	2.207	1.871	1.564	1.430	1.258	1.120	1.008	0.866	0.635
Jun	2.527	2.025	1.667	1.443	1.327	1.173	1.053	0.961	0.826	0.648
Jul	2.192	1.848	1.482	1.254	1.187	1.086	0.930	0.889	0.773	0.631
Aug	2.005	1.542	1.363	1.180	1.057	1.001	0.851	0.803	0.721	0.579
Sep	1.667	1.373	1.173	1.046	0.953	0.876	0.791	0.737	0.621	0.532

EWR 6: HEX RIVER, Upstream of the Vaalkop Dam

Table A11: Summary of EWR Estimate for EWR 6_A22J

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Desktop Version 2, Printed on 2009/08/19
Summary of EWR estimate for: Croc_EWR6 Natural flow mcm
Determination based on defined BBM Table with site specific assurance
rules.

 Annual Flows (Mill. cu. m or index values):
 MAR                = 26.932
 S.Dev.             = 43.882
 CV                 = 1.629
 Q75                = 0.240
 Q75/MMF            = 0.107
 BFI Index          = 0.221
 CV(JJA+JFM) Index  = 3.687

 REC = D

 Total EWR          = 4.029 (14.96 %MAR)
 Maint. Lowflow     = 1.373 ( 5.10 %MAR)
 Drought Lowflow    = 1.117 ( 4.15 %MAR)
 Maint. Highflow    = 2.657 ( 9.86 %MAR)

 Monthly Distributions (cu.m./s)
 Distribution Type: Lowveld
```

Month	Natural Flows			Modified Flows (EWR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.131	0.129	0.369	0.024	0.015	0.000	0.024
Nov	0.216	0.205	0.367	0.026	0.023	0.210	0.236
Dec	0.696	1.401	0.751	0.035	0.022	0.000	0.035
Jan	1.456	3.937	1.009	0.052	0.022	0.203	0.255
Feb	3.228	8.761	1.122	0.093	0.070	0.423	0.516
Mar	2.664	6.040	0.846	0.084	0.067	0.203	0.287
Apr	1.030	2.142	0.803	0.055	0.054	0.000	0.055
May	0.375	0.704	0.700	0.039	0.039	0.000	0.039
Jun	0.221	0.299	0.522	0.035	0.035	0.000	0.035
Jul	0.160	0.163	0.380	0.030	0.030	0.000	0.030
Aug	0.129	0.129	0.375	0.028	0.028	0.000	0.028
Sep	0.112	0.109	0.374	0.025	0.023	0.000	0.025

Table A12: Summary of EWR Rule Curves for EWR 6_A22J

Desktop Version 2, Printed on 2009/08/19
Summary of EWR rule curves for : Croc_EWR6 Natural flow mcm
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Lowveld
REC = D

Data are given in m^3/s mean monthly flow

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.045	0.043	0.039	0.034	0.027	0.021	0.018	0.016	0.015	0.015
Nov	0.348	0.324	0.251	0.189	0.158	0.112	0.072	0.051	0.042	0.023
Dec	0.064	0.062	0.057	0.048	0.038	0.030	0.025	0.023	0.022	0.022
Jan	0.578	0.471	0.374	0.278	0.150	0.094	0.058	0.044	0.044	0.044
Feb	1.227	0.972	0.666	0.479	0.294	0.198	0.141	0.118	0.115	0.070
Mar	0.447	0.429	0.390	0.325	0.245	0.170	0.120	0.096	0.090	0.071
Apr	0.103	0.100	0.094	0.085	0.074	0.064	0.058	0.055	0.054	0.054
May	0.073	0.071	0.066	0.059	0.051	0.045	0.042	0.040	0.039	0.039
Jun	0.067	0.065	0.061	0.055	0.048	0.042	0.038	0.036	0.035	0.035
Jul	0.057	0.055	0.052	0.046	0.040	0.036	0.033	0.031	0.030	0.030
Aug	0.053	0.052	0.049	0.044	0.038	0.034	0.031	0.029	0.028	0.028
Sep	0.047	0.045	0.042	0.037	0.032	0.027	0.025	0.024	0.023	0.023
Reserve flows without High Flows										
Oct	0.045	0.043	0.039	0.034	0.027	0.021	0.018	0.016	0.015	0.015
Nov	0.049	0.048	0.045	0.040	0.034	0.029	0.025	0.024	0.023	0.023
Dec	0.064	0.062	0.057	0.048	0.038	0.030	0.025	0.023	0.022	0.022
Jan	0.097	0.093	0.085	0.072	0.054	0.037	0.027	0.022	0.022	0.022
Feb	0.171	0.166	0.153	0.133	0.109	0.088	0.076	0.071	0.071	0.070
Mar	0.158	0.154	0.144	0.127	0.107	0.088	0.075	0.069	0.068	0.068
Apr	0.103	0.100	0.094	0.085	0.074	0.064	0.058	0.055	0.054	0.054
May	0.073	0.071	0.066	0.059	0.051	0.045	0.042	0.040	0.039	0.039
Jun	0.067	0.065	0.061	0.055	0.048	0.042	0.038	0.036	0.035	0.035
Jul	0.057	0.055	0.052	0.046	0.040	0.036	0.033	0.031	0.030	0.030
Aug	0.053	0.052	0.049	0.044	0.038	0.034	0.031	0.029	0.028	0.028
Sep	0.047	0.045	0.042	0.037	0.032	0.027	0.025	0.024	0.023	0.023
Natural Duration curves										
Oct	0.280	0.183	0.127	0.108	0.090	0.082	0.063	0.045	0.034	0.019
Nov	0.475	0.324	0.251	0.189	0.158	0.112	0.085	0.066	0.042	0.023
Dec	1.613	0.874	0.399	0.287	0.209	0.179	0.123	0.101	0.078	0.030
Jan	3.121	0.971	0.750	0.493	0.377	0.265	0.194	0.149	0.086	0.056
Feb	11.884	1.290	0.666	0.479	0.347	0.273	0.207	0.169	0.128	0.070
Mar	9.214	2.587	0.877	0.418	0.336	0.276	0.202	0.172	0.105	0.071
Apr	3.013	1.038	0.517	0.367	0.301	0.243	0.181	0.135	0.096	0.066
May	0.732	0.422	0.302	0.224	0.187	0.161	0.131	0.097	0.067	0.045
Jun	0.397	0.258	0.231	0.166	0.158	0.127	0.100	0.081	0.054	0.039
Jul	0.317	0.205	0.168	0.138	0.127	0.105	0.082	0.071	0.049	0.034
Aug	0.231	0.168	0.127	0.116	0.105	0.090	0.071	0.056	0.041	0.030
Sep	0.270	0.147	0.116	0.096	0.093	0.081	0.054	0.042	0.035	0.027

EWR 7: CROCODILE RIVER, Upstream of the confluence with the Bierspruit River

Table A13: Summary of EWR Estimate for EWR 7_A24C

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Desktop Version 2, Printed on 2009/08/19
Summary of EWR estimate for: Croc_EWR7 Natural flow mcm
Determination based on defined BBM Table with site specific assurance
rules.

Annual Flows (Mill. cu. m or index values):
MAR                 = 463.356
S.Dev.              = 456.416
CV                  = 0.985
Q75                 = 10.830
Q75/MMF             = 0.280
BFI Index           = 0.458
CV(JJA+JFM) Index = 2.352

REC = D

Total EWR           = 42.351 ( 9.14 %MAR)
Maint. Lowflow      = 31.350 ( 6.77 %MAR)
Drought Lowflow     = 31.356 ( 6.77 %MAR)
Maint. Highflow     = 11.000 ( 2.37 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type: Olifants
```

Month	Natural Flows			Modified Flows (EWR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	5.395	4.095	0.283	0.669	0.669	0.000	0.669
Nov	11.999	16.092	0.517	0.804	0.804	0.790	1.594
Dec	15.377	14.071	0.342	0.874	0.874	1.529	2.403
Jan	27.674	46.262	0.624	1.143	1.144	0.000	1.143
Feb	40.004	82.423	0.852	1.557	1.557	1.161	2.718
Mar	31.423	56.557	0.672	1.464	1.464	0.000	1.464
Apr	16.360	24.876	0.587	1.250	1.250	0.790	2.040
May	8.536	8.706	0.381	1.030	1.030	0.000	1.030
Jun	6.587	3.891	0.228	0.929	0.929	0.000	0.929
Jul	5.539	2.658	0.179	0.819	0.820	0.000	0.819
Aug	4.820	2.188	0.169	0.744	0.744	0.000	0.744
Sep	4.425	2.194	0.191	0.691	0.691	0.000	0.691

Table A14: Summary of EWR Rule Curves for EWR 7_A24C

Desktop Version 2, Printed on 2009/08/19
Summary of EWR rule curves for : Croc_EWR7 Natural flow mcm
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Olifants
REC = D

Data are given in m^3/s mean monthly flow

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.241	1.235	1.223	1.197	1.150	1.071	0.960	0.832	0.723	0.673
Nov	2.781	2.767	2.738	2.679	2.571	2.380	2.078	1.658	1.190	0.895
Dec	4.023	4.000	3.954	3.862	3.690	3.390	2.913	2.250	1.511	1.046
Jan	2.279	2.270	2.253	2.218	2.153	2.039	1.859	1.607	1.327	1.151
Feb	5.360	5.048	4.769	4.500	4.207	3.713	3.301	2.729	2.091	1.689
Mar	2.919	2.908	2.885	2.841	2.757	2.612	2.380	2.058	1.699	1.473
Apr	3.441	3.421	3.375	3.281	3.105	2.814	2.405	1.933	1.530	1.342
May	1.910	1.902	1.883	1.843	1.770	1.649	1.478	1.282	1.114	1.036
Jun	1.723	1.715	1.698	1.663	1.596	1.487	1.333	1.156	1.004	0.934
Jul	1.519	1.512	1.497	1.466	1.408	1.312	1.176	1.020	0.886	0.824
Aug	1.380	1.374	1.360	1.332	1.278	1.191	1.068	0.926	0.804	0.748
Sep	1.282	1.276	1.263	1.237	1.187	1.106	0.992	0.860	0.747	0.695
Reserve flows without High Flows										
Oct	1.241	1.235	1.223	1.197	1.150	1.071	0.960	0.832	0.723	0.673
Nov	1.603	1.597	1.585	1.560	1.514	1.434	1.307	1.130	0.933	0.809
Dec	1.743	1.736	1.723	1.696	1.646	1.559	1.421	1.229	1.014	0.879
Jan	2.279	2.270	2.253	2.218	2.153	2.039	1.859	1.607	1.327	1.151
Feb	3.104	3.093	3.069	3.021	2.933	2.778	2.531	2.189	1.807	1.567
Mar	2.919	2.908	2.885	2.841	2.757	2.612	2.380	2.058	1.699	1.473
Apr	2.318	2.308	2.285	2.237	2.148	2.001	1.794	1.555	1.352	1.257
May	1.910	1.902	1.883	1.843	1.770	1.649	1.478	1.282	1.114	1.036
Jun	1.723	1.715	1.698	1.663	1.596	1.487	1.333	1.156	1.004	0.934
Jul	1.519	1.512	1.497	1.466	1.408	1.312	1.176	1.020	0.886	0.824
Aug	1.380	1.374	1.360	1.332	1.278	1.191	1.068	0.926	0.804	0.748
Sep	1.282	1.276	1.263	1.237	1.187	1.106	0.992	0.860	0.747	0.695
Natural Duration curves										
Oct	9.629	7.187	5.612	4.794	3.778	3.551	3.304	2.976	2.584	1.647
Nov	26.312	15.467	12.377	9.965	8.237	6.431	4.830	3.738	3.214	2.049
Dec	36.511	23.062	15.371	13.303	10.264	7.855	6.340	5.473	4.368	2.755
Jan	69.515	31.780	23.070	17.641	13.781	11.316	7.852	6.239	4.533	3.741
Feb	107.974	42.857	23.805	13.066	11.500	9.582	8.156	6.221	4.981	3.456
Mar	116.144	26.426	22.222	13.945	9.931	7.613	6.452	5.417	4.592	2.744
Apr	30.367	17.350	13.056	9.788	8.465	7.562	6.053	5.054	3.931	2.650
May	15.692	9.830	8.135	7.109	6.455	5.851	4.772	4.096	3.431	2.326
Jun	11.910	8.430	6.863	6.188	5.745	5.050	4.441	3.893	3.218	2.265
Jul	9.674	7.613	5.869	5.317	4.906	4.533	3.872	3.614	2.946	2.132
Aug	8.053	6.257	4.940	4.618	4.372	4.006	3.543	3.334	2.714	2.072
Sep	7.485	5.995	4.464	4.186	3.954	3.665	3.187	2.851	2.446	1.833

EWR 8: CROCODILE RIVER, Downstream of the confluence with the Bierspruit River

Table A15: Summary of EWR Estimate for EWR 8_A24H

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Desktop Version 2, Printed on 2009/08/20
Summary of EWR estimate for: Croc_EWR8 Natural flow mcm
Determination based on defined BBM Table with site specific assurance
rules.

Annual Flows (Mill. cu. m or index values):
MAR                 = 559.943
S.Dev.              = 572.203
CV                  = 1.022
Q75                 = 12.210
Q75/MMF             = 0.262
BFI Index           = 0.348
CV(JJA+JFM) Index = 2.356

REC = C

Total EWR           = 77.167 (13.78 %MAR)
Maint. Lowflow      = 63.113 (11.27 %MAR)
Drought Lowflow     = 30.204 ( 5.39 %MAR)
Maint. Highflow     = 14.054 ( 2.51 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type: Lowveld
```

Month	Natural Flows			Modified Flows (EWR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	6.092	4.712	0.289	1.505	0.735	0.000	1.505
Nov	13.940	17.468	0.483	1.770	0.855	0.395	2.165
Dec	18.890	16.919	0.334	1.878	0.902	2.829	4.707
Jan	35.188	57.628	0.611	2.384	1.127	0.000	2.384
Feb	50.987	108.443	0.879	3.071	1.441	2.254	5.325
Mar	37.622	66.782	0.663	2.630	1.237	0.000	2.630
Apr	18.980	30.317	0.616	2.199	1.047	0.000	2.199
May	9.678	10.019	0.387	1.888	0.906	0.000	1.888
Jun	7.428	4.318	0.224	1.856	0.894	0.000	1.856
Jul	6.253	3.032	0.181	1.733	0.837	0.000	1.733
Aug	5.435	2.509	0.172	1.631	0.791	0.000	1.631
Sep	4.961	2.450	0.191	1.554	0.759	0.000	1.554

Table A16: Summary of EWR Rule Curves for EWR 8_A24H

Desktop Version 2, Printed on 2009/08/20
Summary of EWR rule curves for : Croc_EWR8 Natural flow mcm
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Lowveld
REC = C

Data are given in m^3/s mean monthly flow

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.365	2.270	2.070	1.755	1.388	1.073	0.873	0.778	0.745	0.745
Nov	3.249	3.130	2.873	2.451	1.925	1.437	1.108	0.952	0.909	0.909
Dec	9.899	8.120	6.489	4.873	2.884	1.990	1.456	1.241	1.213	1.213
Jan	3.566	3.448	3.186	2.737	2.159	1.620	1.277	1.143	1.143	1.143
Feb	10.270	8.758	7.254	5.635	3.658	2.611	1.984	1.732	1.699	1.699
Mar	4.086	3.942	3.632	3.120	2.483	1.893	1.495	1.306	1.255	1.255
Apr	3.454	3.315	3.018	2.553	2.012	1.547	1.251	1.111	1.062	1.062
May	2.998	2.861	2.576	2.148	1.680	1.302	1.072	0.964	0.924	0.919
Jun	3.023	2.897	2.635	2.234	1.774	1.378	1.115	0.979	0.923	0.908
Jul	2.853	2.720	2.447	2.046	1.611	1.256	1.030	0.916	0.867	0.851
Aug	2.657	2.546	2.317	1.965	1.563	1.215	0.985	0.866	0.816	0.803
Sep	2.468	2.356	2.123	1.773	1.391	1.082	0.895	0.807	0.774	0.770
Reserve flows without High Flows										
Oct	2.365	2.270	2.070	1.755	1.388	1.073	0.873	0.778	0.745	0.745
Nov	2.750	2.655	2.448	2.108	1.684	1.292	1.027	0.901	0.867	0.867
Dec	2.842	2.732	2.493	2.106	1.647	1.255	1.021	0.926	0.914	0.914
Jan	3.566	3.448	3.186	2.737	2.159	1.620	1.277	1.143	1.143	1.143
Feb	4.646	4.464	4.069	3.431	2.672	2.025	1.637	1.481	1.461	1.461
Mar	4.086	3.942	3.632	3.120	2.483	1.893	1.495	1.306	1.255	1.255
Apr	3.454	3.315	3.018	2.553	2.012	1.547	1.251	1.111	1.062	1.062
May	2.998	2.861	2.576	2.148	1.680	1.302	1.072	0.964	0.924	0.919
Jun	3.023	2.897	2.635	2.234	1.774	1.378	1.115	0.979	0.923	0.908
Jul	2.853	2.720	2.447	2.046	1.611	1.256	1.030	0.916	0.867	0.851
Aug	2.657	2.546	2.317	1.965	1.563	1.215	0.985	0.866	0.816	0.803
Sep	2.468	2.356	2.123	1.773	1.391	1.082	0.895	0.807	0.774	0.770
Natural Duration curves										
Oct	11.399	7.732	6.403	5.787	4.305	4.036	3.640	3.319	2.882	1.755
Nov	30.131	17.288	15.347	12.029	9.279	7.623	5.633	4.236	3.511	2.334
Dec	54.159	30.936	21.726	15.737	12.463	9.618	7.904	6.773	5.007	3.480
Jan	93.586	36.104	27.505	21.233	15.800	12.720	9.039	7.363	5.328	3.973
Feb	141.158	45.160	29.353	16.245	13.934	11.256	8.978	7.407	6.424	3.964
Mar	145.311	33.968	25.508	16.730	12.761	9.517	6.859	6.201	5.302	3.241
Apr	33.326	18.596	15.918	11.628	9.537	8.299	6.902	5.768	4.306	3.032
May	17.201	11.268	9.043	8.162	7.348	6.556	5.354	4.562	3.659	2.658
Jun	13.410	9.525	8.129	6.941	6.478	5.629	4.853	4.317	3.453	2.573
Jul	10.405	8.953	6.638	5.966	5.559	5.007	4.387	4.043	3.151	2.412
Aug	9.218	6.959	5.641	5.324	4.917	4.469	4.058	3.670	2.942	2.281
Sep	8.322	6.848	5.058	4.684	4.471	4.051	3.549	3.098	2.631	1.968

Rapid EWR 9: MAGALIES RIVER, Upstream of Malony's Eye

Table A17: Summary of EWR Estimate for EWR 9_A21F

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Desktop Version 2, Printed on 2009/08/19
Summary of EWR estimate for: Croc_EWR9 patched ob
Determination based on defined BBM Table with site specific assurance
rules.

Annual Flows (Mill. cu. m or index values):
MAR                  = 14.723
S.Dev.               = 4.603
CV                   = 0.313
Q75                  = 1.000
Q75/MMF              = 0.815
BFI Index            = 0.919
CV(JJA+JFM) Index    = 0.919

REC = B

Total EWR            = 6.711 (45.58 %MAR)
Maint. Lowflow       = 6.703 (45.53 %MAR)
Drought Lowflow      = 6.703 (45.53 %MAR)
Maint. Highflow      = 0.008 ( 0.06 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type: Dolomites
```

Month	Natural Flows			Modified Flows (EWR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.464	0.151	0.121	0.211	0.211	0.000	0.211
Nov	0.463	0.150	0.125	0.216	0.216	0.000	0.216
Dec	0.463	0.150	0.121	0.211	0.211	0.000	0.211
Jan	0.464	0.149	0.120	0.212	0.212	0.000	0.212
Feb	0.467	0.150	0.133	0.224	0.224	0.000	0.224
Mar	0.465	0.149	0.119	0.206	0.206	0.001	0.207
Apr	0.467	0.145	0.120	0.212	0.212	0.000	0.212
May	0.468	0.146	0.116	0.208	0.208	0.000	0.208
Jun	0.472	0.148	0.121	0.214	0.214	0.000	0.214
Jul	0.474	0.148	0.117	0.210	0.210	0.000	0.210
Aug	0.470	0.146	0.116	0.211	0.211	0.000	0.211
Sep	0.465	0.148	0.123	0.217	0.217	0.000	0.217

Table A18: Summary of EWR Rule Curves for EWR 9_A21F

Desktop Version 2, Printed on 2009/08/19
Summary of EWR rule curves for : Croc_EWR9 patched ob
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Dolomites
REC = B

Data are given in m^3/s mean monthly flow

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.221	0.221	0.221	0.221	0.221	0.221	0.220	0.218	0.215	0.205
Nov	0.227	0.227	0.227	0.227	0.226	0.225	0.224	0.222	0.219	0.212
Dec	0.222	0.222	0.222	0.222	0.221	0.220	0.219	0.217	0.214	0.202
Jan	0.223	0.223	0.223	0.223	0.222	0.221	0.220	0.217	0.215	0.212
Feb	0.236	0.236	0.235	0.235	0.235	0.234	0.232	0.230	0.227	0.215
Mar	0.219	0.219	0.218	0.218	0.217	0.216	0.214	0.212	0.209	0.206
Apr	0.223	0.223	0.223	0.223	0.222	0.222	0.221	0.219	0.216	0.213
May	0.219	0.219	0.219	0.218	0.218	0.218	0.217	0.215	0.212	0.209
Jun	0.225	0.225	0.225	0.224	0.224	0.224	0.223	0.221	0.218	0.215
Jul	0.220	0.220	0.220	0.220	0.220	0.219	0.219	0.217	0.214	0.211
Aug	0.221	0.221	0.221	0.221	0.221	0.221	0.220	0.218	0.215	0.212
Sep	0.228	0.228	0.228	0.228	0.227	0.227	0.226	0.224	0.221	0.216
Reserve flows without High Flows										
Oct	0.221	0.221	0.221	0.221	0.221	0.221	0.220	0.218	0.215	0.205
Nov	0.227	0.227	0.227	0.226	0.226	0.225	0.224	0.221	0.219	0.212
Dec	0.221	0.221	0.221	0.221	0.221	0.220	0.219	0.216	0.213	0.202
Jan	0.223	0.223	0.222	0.222	0.222	0.221	0.220	0.217	0.214	0.212
Feb	0.235	0.235	0.235	0.235	0.234	0.234	0.232	0.230	0.227	0.215
Mar	0.216	0.216	0.216	0.216	0.216	0.215	0.213	0.211	0.208	0.206
Apr	0.223	0.223	0.222	0.222	0.222	0.222	0.221	0.219	0.216	0.213
May	0.218	0.218	0.218	0.218	0.218	0.217	0.216	0.215	0.212	0.209
Jun	0.225	0.225	0.225	0.224	0.224	0.224	0.223	0.221	0.218	0.215
Jul	0.220	0.220	0.220	0.220	0.220	0.219	0.219	0.217	0.214	0.211
Aug	0.221	0.221	0.221	0.221	0.221	0.221	0.220	0.218	0.215	0.212
Sep	0.228	0.228	0.228	0.228	0.227	0.227	0.226	0.224	0.221	0.216
Natural Duration curves										
Oct	0.661	0.523	0.493	0.459	0.448	0.414	0.388	0.362	0.340	0.205
Nov	0.652	0.525	0.494	0.455	0.448	0.413	0.386	0.367	0.328	0.212
Dec	0.661	0.519	0.485	0.459	0.448	0.414	0.388	0.358	0.325	0.202
Jan	0.661	0.526	0.482	0.459	0.448	0.414	0.388	0.358	0.332	0.228
Feb	0.674	0.521	0.500	0.459	0.438	0.417	0.393	0.368	0.339	0.215
Mar	0.672	0.515	0.485	0.459	0.437	0.418	0.396	0.370	0.340	0.231
Apr	0.679	0.521	0.486	0.459	0.444	0.417	0.394	0.370	0.351	0.239
May	0.676	0.526	0.493	0.459	0.444	0.418	0.396	0.377	0.343	0.243
Jun	0.675	0.529	0.494	0.459	0.448	0.421	0.397	0.378	0.347	0.258
Jul	0.672	0.519	0.493	0.459	0.448	0.418	0.396	0.381	0.347	0.261
Aug	0.668	0.515	0.493	0.459	0.448	0.418	0.392	0.373	0.347	0.243
Sep	0.660	0.513	0.490	0.459	0.448	0.421	0.390	0.363	0.347	0.216

Rapid EWR 10: ELANDS RIVER, Highveld

Table A19: Summary of EWR Estimate for EWR 10_A22A

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Desktop Version 2, Printed on 2009/08/19
Summary of EWR estimate for: Croc_EWR10 Natural flow mcm
Determination based on defined BBM Table with site specific assurance
rules.

Annual Flows (Mill. cu. m or index values):
MAR                   = 10.118
S.Dev.                = 13.604
CV                    = 1.345
Q75                   = 0.140
Q75/MMF               = 0.166
BFI Index             = 0.255
CV(JJA+JFM) Index     = 3.270

REC = B/C

Total EWR             = 3.084 (30.48 %MAR)
Maint. Lowflow        = 1.819 (17.98 %MAR)
Drought Lowflow       = 0.552 ( 5.45 %MAR)
Maint. Highflow       = 1.264 (12.50 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type: Lowveld
```

Month	Natural Flows			Modified Flows (EWR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.089	0.102	0.427	0.038	0.015	0.007	0.045
Nov	0.197	0.246	0.482	0.045	0.012	0.023	0.068
Dec	0.308	0.339	0.410	0.050	0.011	0.060	0.110
Jan	0.597	1.383	0.865	0.070	0.026	0.030	0.100
Feb	0.860	2.132	1.025	0.094	0.031	0.216	0.310
Mar	0.804	1.886	0.876	0.091	0.019	0.112	0.203
Apr	0.466	1.086	0.900	0.073	0.015	0.048	0.121
May	0.202	0.314	0.580	0.056	0.015	0.000	0.056
Jun	0.130	0.123	0.364	0.051	0.019	0.000	0.051
Jul	0.095	0.087	0.342	0.046	0.017	0.000	0.046
Aug	0.072	0.058	0.302	0.042	0.016	0.000	0.042
Sep	0.068	0.072	0.406	0.039	0.015	0.000	0.039

Table A20: Summary of EWR Rule Curves for EWR 10_A22A

Desktop Version 2, Printed on 2009/08/19
Summary of EWR rule curves for : Croc_EWR10 Natural flow mcm
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Lowveld REC = B/C

Data are given in m^3/s mean monthly flow

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.065	0.062	0.056	0.046	0.035	0.026	0.020	0.017	0.016	0.015
Nov	0.093	0.089	0.081	0.067	0.049	0.033	0.021	0.016	0.015	0.015
Dec	0.219	0.181	0.144	0.106	0.060	0.037	0.024	0.018	0.018	0.015
Jan	0.169	0.150	0.129	0.104	0.071	0.049	0.035	0.030	0.030	0.026
Feb	0.673	0.539	0.420	0.302	0.165	0.106	0.071	0.056	0.054	0.025
Mar	0.270	0.257	0.231	0.188	0.135	0.085	0.052	0.036	0.032	0.030
Apr	0.168	0.159	0.141	0.112	0.079	0.051	0.032	0.024	0.021	0.021
May	0.085	0.080	0.071	0.056	0.041	0.028	0.021	0.017	0.016	0.015
Jun	0.079	0.076	0.068	0.057	0.044	0.033	0.025	0.021	0.020	0.019
Jul	0.073	0.069	0.062	0.051	0.038	0.029	0.022	0.019	0.018	0.017
Aug	0.065	0.063	0.056	0.047	0.036	0.027	0.021	0.018	0.017	0.016
Sep	0.059	0.056	0.050	0.041	0.031	0.023	0.019	0.016	0.015	0.015
Reserve flows without High Flows										
Oct	0.057	0.054	0.049	0.041	0.032	0.024	0.019	0.016	0.015	0.015
Nov	0.066	0.063	0.057	0.048	0.036	0.024	0.017	0.013	0.012	0.012
Dec	0.071	0.068	0.060	0.048	0.034	0.022	0.015	0.012	0.011	0.011
Jan	0.098	0.095	0.087	0.074	0.057	0.041	0.030	0.026	0.026	0.026
Feb	0.134	0.128	0.115	0.095	0.070	0.050	0.037	0.032	0.032	0.025
Mar	0.133	0.127	0.115	0.094	0.069	0.045	0.029	0.022	0.020	0.020
Apr	0.108	0.103	0.092	0.073	0.052	0.034	0.023	0.017	0.016	0.016
May	0.085	0.080	0.071	0.056	0.041	0.028	0.021	0.017	0.016	0.015
Jun	0.079	0.076	0.068	0.057	0.044	0.033	0.025	0.021	0.020	0.019
Jul	0.073	0.069	0.062	0.051	0.038	0.029	0.022	0.019	0.018	0.017
Aug	0.065	0.063	0.056	0.047	0.036	0.027	0.021	0.018	0.017	0.016
Sep	0.059	0.056	0.050	0.041	0.031	0.023	0.019	0.016	0.015	0.015
Natural Duration curves										
Oct	0.213	0.127	0.093	0.063	0.056	0.041	0.030	0.022	0.019	0.015
Nov	0.513	0.289	0.185	0.139	0.108	0.073	0.054	0.039	0.023	0.015
Dec	0.709	0.504	0.381	0.280	0.179	0.119	0.093	0.075	0.045	0.015
Jan	1.359	0.635	0.433	0.321	0.261	0.179	0.138	0.097	0.063	0.026
Feb	1.848	0.587	0.442	0.302	0.215	0.178	0.124	0.095	0.070	0.025
Mar	1.579	0.829	0.609	0.343	0.228	0.157	0.119	0.093	0.067	0.030
Apr	0.702	0.432	0.363	0.243	0.212	0.147	0.116	0.081	0.069	0.023
May	0.426	0.239	0.187	0.142	0.119	0.105	0.086	0.067	0.049	0.019
Jun	0.293	0.162	0.139	0.108	0.100	0.073	0.062	0.054	0.042	0.019
Jul	0.187	0.116	0.101	0.082	0.067	0.063	0.052	0.045	0.037	0.019
Aug	0.123	0.082	0.078	0.067	0.056	0.052	0.049	0.037	0.034	0.019
Sep	0.154	0.089	0.069	0.050	0.039	0.039	0.031	0.031	0.023	0.023

Rapid EWR 11: STERKSTROOM RIVER, Upstream of the Buffelspoort Dam

Table A21: Summary of EWR Estimate for EWR 11_A21K

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Desktop Version 2, Printed on 2009/08/19
Summary of EWR estimate for: Ceoc_EWR11 nat monthly flow mc
Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):
MAR                 = 13.956
S.Dev.              = 7.517
CV                  = 0.539
Q75                 = 0.580
Q75/MMF             = 0.499
BFI Index           = 0.496
CV(JJA+JFM) Index   = 1.485

REC = C

Total EWR           = 3.965 (28.41 %MAR)
Maint. Lowflow      = 2.825 (20.24 %MAR)
Drought Lowflow     = 1.197 ( 8.58 %MAR)
Maint. Highflow     = 1.140 ( 8.17 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type: Lowveld
```

Month	Natural Flows			Modified Flows (EWR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	0.211	0.074	0.131	0.077	0.033	0.004	0.081
Nov	0.308	0.253	0.317	0.082	0.035	0.018	0.100
Dec	0.453	0.407	0.336	0.085	0.036	0.055	0.140
Jan	0.635	0.636	0.374	0.093	0.039	0.027	0.120
Feb	0.927	1.165	0.519	0.112	0.047	0.200	0.312
Mar	0.843	0.968	0.428	0.103	0.043	0.094	0.198
Apr	0.619	0.565	0.353	0.100	0.042	0.048	0.148
May	0.364	0.183	0.188	0.089	0.038	0.000	0.089
Jun	0.297	0.097	0.127	0.089	0.038	0.000	0.089
Jul	0.256	0.109	0.159	0.084	0.036	0.000	0.084
Aug	0.225	0.066	0.110	0.081	0.035	0.000	0.081
Sep	0.210	0.057	0.104	0.081	0.035	0.000	0.081

Table A22: Summary of EWR Rule Curves for EWR 11_A21K

Desktop Version 2, Printed on 2009/08/19
Summary of EWR rule curves for : Croc_EWR11 nat monthly flow mc
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Lowveld
REC = C

Data are given in m^3/s mean monthly flow

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.126	0.121	0.110	0.092	0.071	0.053	0.041	0.036	0.034	0.034
Nov	0.150	0.144	0.132	0.112	0.086	0.063	0.047	0.040	0.038	0.038
Dec	0.197	0.188	0.169	0.138	0.101	0.070	0.051	0.044	0.043	0.043
Jan	0.172	0.166	0.152	0.128	0.097	0.068	0.050	0.043	0.043	0.043
Feb	0.418	0.398	0.355	0.285	0.202	0.131	0.089	0.071	0.069	0.069
Mar	0.280	0.268	0.244	0.203	0.152	0.105	0.073	0.058	0.054	0.054
Apr	0.218	0.208	0.187	0.154	0.115	0.082	0.061	0.051	0.048	0.048
May	0.141	0.134	0.120	0.099	0.076	0.057	0.046	0.040	0.039	0.038
Jun	0.145	0.138	0.125	0.105	0.082	0.062	0.049	0.042	0.039	0.038
Jul	0.138	0.131	0.117	0.097	0.075	0.057	0.046	0.040	0.037	0.036
Aug	0.133	0.127	0.115	0.096	0.075	0.057	0.045	0.039	0.036	0.035
Sep	0.129	0.123	0.110	0.091	0.070	0.053	0.042	0.037	0.036	0.035
Reserve flows without High Flows										
Oct	0.121	0.116	0.105	0.088	0.068	0.051	0.040	0.035	0.033	0.033
Nov	0.128	0.123	0.113	0.096	0.076	0.056	0.044	0.037	0.036	0.036
Dec	0.129	0.124	0.112	0.094	0.072	0.053	0.042	0.037	0.037	0.037
Jan	0.139	0.134	0.123	0.105	0.081	0.059	0.045	0.040	0.040	0.040
Feb	0.169	0.163	0.147	0.123	0.094	0.069	0.055	0.049	0.048	0.048
Mar	0.161	0.155	0.142	0.121	0.095	0.070	0.054	0.046	0.044	0.044
Apr	0.157	0.150	0.136	0.114	0.088	0.066	0.052	0.045	0.043	0.043
May	0.141	0.134	0.120	0.099	0.076	0.057	0.046	0.040	0.039	0.038
Jun	0.145	0.138	0.125	0.105	0.082	0.062	0.049	0.042	0.039	0.038
Jul	0.138	0.131	0.117	0.097	0.075	0.057	0.046	0.040	0.037	0.036
Aug	0.133	0.127	0.115	0.096	0.075	0.057	0.045	0.039	0.036	0.035
Sep	0.129	0.123	0.110	0.091	0.070	0.053	0.042	0.037	0.036	0.035
Natural Duration curves										
Oct	0.265	0.246	0.220	0.205	0.194	0.187	0.179	0.172	0.153	0.116
Nov	0.525	0.320	0.301	0.274	0.255	0.235	0.204	0.193	0.170	0.150
Dec	1.109	0.612	0.437	0.332	0.284	0.269	0.228	0.220	0.187	0.142
Jan	1.706	0.829	0.612	0.452	0.362	0.317	0.273	0.246	0.224	0.183
Feb	1.901	1.376	0.938	0.587	0.471	0.380	0.322	0.293	0.265	0.194
Mar	2.274	1.296	0.784	0.646	0.511	0.373	0.321	0.291	0.250	0.205
Apr	1.485	0.814	0.602	0.509	0.397	0.340	0.309	0.278	0.247	0.193
May	0.728	0.467	0.355	0.321	0.291	0.276	0.261	0.246	0.228	0.187
Jun	0.475	0.355	0.301	0.285	0.266	0.247	0.239	0.231	0.224	0.177
Jul	0.332	0.284	0.261	0.239	0.228	0.224	0.217	0.205	0.187	0.157
Aug	0.273	0.250	0.235	0.220	0.217	0.205	0.198	0.194	0.172	0.142
Sep	0.266	0.228	0.224	0.212	0.204	0.197	0.193	0.181	0.162	0.131

ANNEXURE B

PRELIMINARY ECOLOGICAL RESERVE

WATER QUALITY

EWR 1: CROCODILE RIVER, Upstream of the Hartbeespoort Dam

Table B1: PES categories and overall site assessment for EWR Site 1

River	**Crocodile River**	**DWA Water Quality Monitoring points**		
WQSU	**3**	**RC**	**A2H013 Magalies River at Scheerpoort 2002-2007(*n*=205)**	
EWR Site	**EWR1**	**PES**	**A2H012 at Kalkheuwel on Crocodile River 2004-2008 (*n*=118)**	
Water Quality Constituents		**Value**		**Category/Comment**
Inorganic salts(mg/L)	$MgSO_4$	72.755		F(5)
	Na_2SO_4	13.465		A(0)
	$MgCl_2$	1.368		A(0)
	$CaCl_2$	15.198		A(0)
	NaCl	109.399		B(1)
Nutrients(mg/L)	PO_4	0.610		E(4)
	TIN	4.848		E(4)
Physical variables	pH (pH units)	7.4-8.3		B(1)
	Temperature(°C)	16 (Single measurement)		Raised due to sewage/sealed surfaces
	Dissolved oxygen (mg/L)	6.3		C(2)Riffles covered
	Electrical Conductivity (mS/m)	66.56		C(2)
Response variable	Chl-a: periphyton (mg/m^2)	-		D High algal concentrations
	Biotic community composition - macroinvertebrate (ASPT) score	4.07– 4.25		E
	Fish score (FRAI)	44.5		D
	In-stream toxicity	Weekly from waste water works, high in organics		
Toxics	Ammonia (mg/L)	32		B(1)
Overall site classification (from PAI model)		D		

**Source: Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Prepared by Scherman Consulting.
Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N. and Rowntree, K. 2006. River Classification: Manual for ecostatus determination, Module A-F (Version 2). Water Research Commission, Pretoria.

Table B2 Water quality specifications for the Reserve (Quality Ecospecs) at EWR 1: Upstream of the Hartbeespoort Dam

RIVER		**Crocodile(West)River**	**WATER QUALITY MONITORING POINTS**			
WQSU		**3**	**DWA WQ WMS**	**A2H012 Crocodile River at Kalkheuwel**		
EWRSITE		**EWR1**	**RHP**	**Currently several monitoring sites**		
Confidence in PES assessment		**Medium**				
Water Quality constituents		**PES Category**	**WQ Ecospecs**	**Improvement required?**	**TPC**	**Monitoring frequency**
Inorganic salts (mg/L)	$MgSO_4$		>45mg/L	N/A	95^{th}percentile to be<45mg/L	Monthly
	Na_2SO_4		<20mg/L		95^{th}percentile to be<20mg/L	
	$MgCl_2$		<15mg/L		95^{th}percentile to be<15mg/L	
	$CaCl_2$		<21mg/L		95^{th}percentile to be<21mg/L	
	NaCl		<191mg/L		95^{th}percentile to be<191mg/L	
Nutrients (mg/L)	SRP	Category= E	<0.125mg/L	Yes, to D	50^{th}percentile to be<0.125mg/L	Monthly
	TIN	Category= E	<4.0mg/L	Yes, to D	50^{th}percentile to be<4.0mg/L	Monthly
Physical Variables	pH	Neutral river	5^{th}percentile(5.9-6.5)95^{th}percentile (8.0–8.8)	No	5^{th}percentile (5.9-6.5) 95 thpercentile(8.0 –8.8)	Monthly
	Temperature	Limited data and is impacted by waste water treatment works and urbanisation.	Maintain range	N/A	Initiate baseline monitoring for this variable.	When Biotic assessments undertaken
	Dissolved oxygen		7-8mg/L	N/A	5^{th}percentile to be>6.1mg/L. Initiate Baseline monitoring for this variable.	
	Turbidity (NTU)	Turbid after heavy rains.	Moderate change allowed	N/A	Initiate baseline monitoring for this Variable and maintain natural range.	Quarterly
	Electrical conductivity (mS/m)	Category= C.	<85mS/m	No	95^{th}percentile to be<85mS/m	Quarterly
Response variables	Chla: periphyton	Category= D. Visual inspection indicates high algal concentrations on rocks and in pools	<84mg/m ^{2} (D category)	N/A	50^{th}percentile to be<84mg/m^2	Quarterly
	Chla: phytoplankton		<30µg/L (D category)		50^{th}percentile to be<30µg/L	
	Macro invertebrates (ASPT)	E (this study)	See Ecospecs for fish and invertebrates respectively			
	Fish community score	D(this study)				
	In-stream toxicity		Assess only if the bio-monitoring results indicate there is a serious problem and the cause is unknown. An impact is expected if the 95 th percentile of the data exceeds the Chronic Effects Value (CEV) as stated in DWAF (1996).			
Toxics	Ammonia	B	<43.7ug/L		95^{th}percentile to be <43.7ug/L	Monthly

EWR 2: JUKSKEI RIVER at Heron Bridge School

Table B3 PES categories and overall site assessment for EWR site 2

River	**Jukskei River**	**DWAF Water Quality Monitoring points**	
WQSU	**1**	**RC**	**A2H013 Magalies River at Scheerpoort 2002-2007(n=205)**
EWR Site	**EWR2**	**PES**	**A2H023 Jukskei River at Nietgedacht 2004-2008(n=114)**
Water Quality Constituents		**Value**	****Category/Comment**
Inorganic salts (mg/L)	$MgSO_4$	71.494	F(5)
	Na_2SO_4	26.244	B(1)
	$MgCl_2$	0.312	A(0)
	$CaCl_2$	20.236	A(0)
	NaCl	96.146	B(1)
Nutrients(mg/L)	PO_4	0.266	E(4)
	TIN	5.460	E(4)
Physical variables	pH(pH units)	7.1-8.1	B(1)
	Temperature (° C)	Raised temperatures from waste water treatment ponds	D
	Dissolved oxygen (mg/L)	-	D
	Electrical Conductivity (mS/m)	63	C(2)
Response variable	Chl-a: periphyton (mg/m^2)	14.41	D(1)
	Biotic community composition - macro invertebrate (ASPT) score	3.8– 4.0	E/F
	Fish score	21.4%	E/F
	In-stream toxicity	-	
Toxics	Ammonia (µg/L)	80	D(3)
Overall site classification (PAI model)		D	

**Source: Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Prepared by Scherman Consulting.
Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N. and Rowntree, K. 2006. River Classification: Manual for ecostatus determination, Module A-F (Version 2). Water Research Commission, Pretoria.

Table B4 Water quality specifications for the Reserve (Quality Ecospecs) at EWR 2: Jukskei River at Heron Bridge School

RIVER		**Juskei River**	**WATER QUALITY MONITORING POINTS**			
WQSU		**2**	**DWA WQ WMS**	**A2H023 Juskei River at Nietgedacht**		
EWRSITE		**EWR2**	**RHP**	**Currently several monitoring sites**		
Confidence in PES assessment		**Medium**				
Water Quality constituents		**PES Category**	**WQ Ecospecs**	**Improvement required?**	**TPC**	**Monitoring frequency**
Inorganic salts (mg/L)	$MgSO_4$		<45mg/L	N/A	95[th]percentile to be<45mg/L	Monthly
	Na_2SO_4		<33mg/L		95[th]percentile to be<33mg/L	
	$MgCl_2$		<15mg/L		95[th]percentile to be<15mg/L	
	$CaCl_2$		<21mg/L		95[th]percentile to be<21mg/L	
	NaCl		<191mg/L		95[th]percentile to be<191mg/L	
Nutrients (mg/L)	SRP	Category= E	<0.125mg/L	Yes, to D	50[th]percentile to be<0.125mg/L	Monthly
	TIN	Category= E	<4.0mg/L	Yes, to D	50[th]percentile to be<4.0mg/L	Monthly
Physical Variables	pH	Good	5[th]percentile(5.9-6.5)95[th]percentile (8.0–8.8)	Yes, to natural	5[th]percentile(5.9-6.5)95 [th]percentile(8.0 –8.8)	Monthly
	Temperature	Limited data and is impacted by waste water treatment works and urbanisation.	Maintain range	N/A	Initiate baseline monitoring for this variable.	When Biotic assessments undertaken
	Dissolved oxygen		7-8mg/L	N/A	5[th]percentile to be>6.1mg/L. Initiate Baseline monitoring for this variable.	
	Turbidity (NTU)	Turbid after heavy rains.	Moderate change allowed	N/A	Initiate baseline monitoring for this Variable and maintain natural range.	Quarterly
	Electrical conductivity (mS/m)	Category= C.	<85mS/m	No	95[th]percentile to be<85mS/m	Quarterly
Response variables	Chla: periphyton	Category= C. Visual inspection indicates high algal concentrations on rocks and in pools	<84mg/m ^{2} (D category)	N/A	50[th]percentile to be<84mg/m^2	Quarterly
	Chla: phytoplankton		<15µg/L (D category)		50[th]percentile to be<15µg/L	
	Macro invertebrates (ASPT)	E/F(this study)	See Ecospecs for fish and invertebrates respectively			
	Fish community score	E/F(this study)				
	In-stream toxicity	Some toxicity from industry and waste water treatment works	Assess only if the bio-monitoring results indicate there is a serious problem and the cause is unknown. An impact is expected if the 95[th]percentile of the data exceeds the Chronic Effects Value (CEV) as stated in DWAF (1996).			
Toxics	Ammonia	D	<100ug/L		95[th]percentile to be <100ug/L	Monthly

EWR 3: CROCODILE RIVER, Downstream of the Hartbeespoort Dam

Table B5 PES categories and overall site assessment for EWR site 3

River	**Crocodile River**	**DWAF Water Quality Monitoring points**		
WQSU	**5**	**RC**	**A2H013 Magalies River at Scheerpoort2002-2007(*n*=205)**	
EWR Site	**EWR3**	**PES**	**A2H083 Hartbeespoort Dam:d/sWeir2004-2008 (*n*=113)**	
Water Quality Constituents		**Value**		****Category/Comment**
Inorganic salts (mg/L)	$MgSO_4$	67.562		F(5)
	Na_2SO_4	9.867		A(0)
	$MgCl_2$	6.856		A(0)
	$CaCl_2$	27.569		B(1)
	NaCl	96.462		B(1)
Nutrients(mg/L)	PO_4	0.123		E(4)
	TIN	1.594		B(1)
Physical variables	pH (pH units)	7.51-8.73		B(1)
	Temperature(°C)	2data points		C(2)
	Dissolved oxygen (mg/L)	2data points		C/D
	Electrical Conductivity (mS/m)	59.24		C(2)
Response variable	Chl-a: periphyton (mg/m^2)	Visual observations		E
	Biotic community composition -macro invertebrate (ASPT) score	3.8		E
	Fish score	24.9		E
	In-stream toxicity	-		
Toxics	Ammonia (mg/L)	139		E(4)
Overall site classification		D/E		

**Source: Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Prepared by Scherman Consulting.
Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N. and Rowntree, K. 2006. River Classification: Manual for ecostatus determination, Module A-F (Version 2). Water Research Commission, Pretoria.

Table B6 Water quality specifications for the Reserve (Quality Ecospecs) at EWR 3: Crocodile River downstream of the Hartbeespoort Dam

RIVER		**Crocodile (West) River**	**WATER QUALITY MONITORING POINTS**			
WQSU		**5**	**DWA WQ WMS**	**A2H083 Hartbeespoort Dam downstream weir**		
EWR SITE		**EWR3**	**RHP**	**Currently several monitoring sites**		
Confidence in PES assessment		**Medium**				
Water Quality constituents		**PES Category**	**WQ Ecospecs**	**Improvement required?**	**TPC**	**Monitoring frequency**
Inorganic salts (mg/L)	$MgSO_4$		<45mg/L	N/A	95th percentile t obe<45mg/L	Monthly
	Na_2SO_4		<20mg/L		95th percentile to be<20mg/L	
	$MgCl_2$		<15mg/L		95th percentile to be<15mg/L	
	$CaCl_2$		<57mg/L		95th percentile to be<57mg/L	
	NaCl		<191mg/L		95th percentile to be<191mg/L	
Nutrients (mg/L)	SRP	Category= E	<0.125mg/L	Yes, to D	50th percentile to be<0.125mg/L	Monthly
	TIN	Category= D	<4.0mg/L	Yes, to D	50th percentile to be<4.0mg/L	Monthly
Physical Variables	pH	Good	5th percentile(5.9-6.5)95th percentile (8.0–8.8)	Yes, to natural	5th percentile(5.9-6.5)95 th percentile(8.0 –8.8)	Monthly
	Temperature	Limited data and is impacted by waste water treatment works and urbanisation.	Maintain range	N/A	Site is downstream from a dam which will result in fluctuations in temperature and possible biotic response. Biological assessments recommended. Initiate baseline monitoring.	When Biotic assessments undertaken
	Dissolved oxygen		7-8mg/L	N/A	5th percentile to be >6.1mg/L. Initiate Baseline monitoring for this variable.	
	Turbidity(NTU)	Turbid after heavy rains.	Moderate change allowed	N/A	Initiate baseline monitoring for this Variable and maintain natural range.	Quarterly
	Electrical conductivity (mS/m)	Category = C.	<85mS/m	No	95th percentile to be<85mS/m	Quarterly
Response variables	Chla: periphyton	Category = C. Visual inspection indicates high algal concentrations on rocks and in pools	<84mg/m ^{2} (D category)	N/A	50th percentile to be<84mg/m ^{2}	Quarterly
	Chla: phytoplankton		<30µg/L (D category)		50th percentile to be<30µg/L	
	Macro invertebrates (ASPT)	E (this study)	See Ecospecs for fish and invertebrates respectively			
	In-stream toxicity	Some toxicity from industry and waste water treatment works	Assess only if the bio-monitoring results indicate there is a serious problem and the cause is unknown. An impact is expected if the 95th percentile of the data exceeds the Chronic Effects Value (CEV) as stated in DWAF (1996).			
Toxics	Ammonia	E	<129ug/L		95th percentile to be<129ug/L	Monthly

EWR 4: PIENAARS RIVER, Downstream of the Roodeplaat Dam

Table B7 PES categories and overall site assessment for EWR site 4

River	**Pienaars River**	**DWA Water Quality Monitoring points**	
WQSU	**15**	**RC**	**A2H013 Magalies River at Scheerpoort 2002-2007 (*n*=205)**
EWR Site	**EWR4**	**PES**	**A2H006 Pienaars River at Klipdrift 2004-2008 (*n*=118)**

Water Quality Constituents		**Value**	****Category/Comment**
Inorganic salts(mg/L)	$MgSO_4$	51.250	F(5)
	Na_2SO_4	5.120	A(0)
	$MgCl_2$	3.704	A(0)
	$CaCl_2$	14.856	A(0)
	NaCl	81.789	B(1)
Nutrients(mg/L)	PO_4	0.049	B(1)
	TIN	0.442	A(0)
Physical variables	pH (pH units)	7.8-8.4	B(1)
	Temperature (°C)	1data point	B(1)
	Dissolved oxygen (mg/L)	5.5 (2 data points)	C(2)
	Electrical Conductivity (mS/m)	57.1	C(2)
Response variable	Chl-a: periphyton (mg/m^2)	-	Visual observations
	Biotic community Composition macro invertebrate (ASPT) score	5.8	C(2)
	Fish score	65.4%	C(2)
	In-stream toxicity	-	
Toxics	Ammonia (µg/L)	20	A(0)
Overall site classification		C	

**Source: Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Prepared by Scherman Consulting.
Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N. and Rowntree, K. 2006. River Classification: Manual for ecostatus determination, Module A-F (Version 2). Water Research Commission, Pretoria.

Table B8 Water quality specifications for the Reserve (Quality Ecospecs) at EWR 4: Pienaars River downstream of the Roodeplaat Dam

RIVER		**Pienaars River**	**WATER QUALITY MONITORING POINTS**			
WQSU		**15**	**DWA WQ WMS**	**A2H006 Pienaarsat Klipdrift weir**		
EWRSITE		**EWR4**	**RHP**	**Currently several monitoring sites**		
Confidence in PES assessment		**Medium**				
Water Quality constituents		**PES Category**	**WQ Ecospecs**	**Improvement required?**	**TPC**	**Monitoring frequency**
Inorganic salts (mg/L)	$MgSO_4$		<45mg/L	N/A	95th percentile to be<45mg/L	Monthly
	Na_2SO_4		<20mg/L		95th percentile to be<20mg/L	
	$MgCl_2$		<15mg/L		95th percentile to be<15mg/L	
	$CaCl_2$		<21mg/L		95th percentile to be<21mg/L	
	NaCl		<191mg/L		95th percentile to be<191mg/L	
Nutrients (mg/L)	SRP	Category= B	<0.015mg/L		50th percentile to be<0.15mg/L	Monthly
	TIN	Category= B	<0.25mg/L		50th percentile to be<0.25mg/L	Monthly
Physical Variables	pH	Category= B, Good	5th percentile(5.9-6.5)95th percentile (8.0–8.8)	Yes, to natural	5th percentile(5.9-6.5)95 th percentile(8.0 –8.8)	Monthly
	Temperature	Limited data and is impacted by waste water treatment works and urbanisation.	Maintain range	N/A	Site is downstream from a dam which will result in fluctuations in temperature and possible biotic response. Biological assessments recommended. Initiate baseline monitoring.	When Biotic assessments undertaken
	Dissolved oxygen		7-8mg/L	N/A	5th percentile to be >6.1mg/L. Initiate Baseline monitoring for this variable.	
	Turbidity (NTU)	Turbid after heavy rains.	Moderate change allowed	N/A	Initiate baseline monitoring for this Variable and maintain natural range.	Quarterly
	Electrical conductivity (mS/m)	Category = C	<85mS/m	No	95th percentile to be <85mS/m	Quarterly
Response variables	Chla: periphyton	Category = C. Visual inspection indicates high algal concentrations on rocks and in pools	<84mg/m ^{2} (D category)	N/A	50th percentile to be <84mg/m^2	Quarterly
	Chla: phytoplankton		<30µg/L (D category)		50th percentile to be <30µg/L	
	Macro invertebrates (ASPT)	C (this study)	See Ecospecs for fish and invertebrates respectively			
	In-stream toxicity	Some toxicity from industry and waste water treatment works	Assessonlyifthebiomonitoringresultsindicatethereisaseriousproblemandthecauseisunknown. An impact is expected if the 95th percentile of the data exceeds the Chronic Effects Value (CEV) as stated in DWAF (1996).			
Toxics	Ammonia	A	<15ug/L		95th percentile to be <15ug/L	Monthly

EWR 5: PIENAARS RIVER, Downstream of the Klipvoor Dam in Borakalalo National Park

Table B9 PES categories and overall site assessment for EWR site 5

River	**Pienaars River**	**DWA Water Quality Monitoring points**		
WQSU	**17**	**RC**	**A2H013 Magalies River at Scheerpoort 2002-2007 (*n*=205)**	
EWRSite	**EWR5**	**PES**	**A2H021 Pienaars River at Buffelspoort 2004-2008 (*n*=107)**	
Water Quality Constituents		**Value**		****Category/Comment**
Inorganic salts(mg/L)	$MgSO_4$	78.335		F(5)
	Na_2SO_4	16.527		A(0)
	$MgCl_2$	3.820		A(0)
	$CaCl_2$	24.153		B(1)
	NaCl	131.982		B(1)
Nutrients (mg/L)	PO_4	0.598		B(1)
	TIN	0.250		A(0)
Physical variables	pH (pH units)	7.7-8.7		B(1)
	Temperature (° C)	16(n=1)		Recovers from dam B
	Dissolved oxygen (mg/L)	5.2(n=1)		
	Electrical Conductivity (mS/m)	80.8		C(2)
Response variable	Chl-a: periphyton (mg/m^2)	-		
	Biotic community composition - macroinvertebrate (ASPT) score	5.5		D
	Fishs core (FRAI)	51.3%		D
	In-streamtoxicity	-		
Toxics	Ammonia (µg/L)	47		B(1)
	Fluoride (µg/L)	600		A(0)
Overall site classification		C		

**Source: Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Prepared by Scherman Consulting.
Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N. and Rowntree, K. 2006. River Classification: Manual for ecostatus determination, Module A-F (Version 2). Water Research Commission, Pretoria.

Table B10 Water quality specifications for the Reserve (Quality Ecospecs) at EWR 5: Pienaars River downstream of Klipvoor dam

RIVER		Pienaars River	WATER QUALITY MONITORING POINTS			
WQSU		17	DWA WQ WMS	A2H021 Pienaars River at Buffelspooort		
EWR SITE		EWR5	RHP	Currently several monitoring sites		
Confidence in PES assessment		Medium				
Water Quality constituents		**PES Category**	**WQ Ecospecs**	**Improvement required?**	**TPC**	**Monitoring frequency**
Inorganic salts (mg/L)	$MgSO_4$		<45mg/L	N/A	95th percentile to be <45mg/L	Monthly
	Na_2SO_4		<20mg/L		95th percentile to be <20mg/L	
	$MgCl_2$		<15mg/L		95th percentile to be <15mg/L	
	$CaCl_2$		<57mg/L		95th percentile to be <57mg/L	
	NaCl		<191mg/L		95th percentile to be <191mg/L	
Nutrients (mg/L)	SRP	Category= D	<0.015mg/L		50th percentile to be<0.015mg/L	Monthly
	TIN	Category= B	<0.25mg/L		50th percentile to be<0.25mg/L	Monthly
Physical Variables	pH	Category= B, Good	5th percentile(5.9-6.5)95th percentile (8.0–8.8)	Yes, to natural	5 percentile(5.9-6.5)95 percentile(8.0 –8.8)	Monthly
	Temperature	Limited data and is impacted by waste water treatment works and urbanisation.	Maintain range	N/A	Site is downstream from a dam which will result in fluctuations in temperature and possible biotic response. Biological assessments recommended. Initiate baseline monitoring.	When Biotic assessments undertaken
	Dissolved oxygen		7-8mg/L	N/A	5th percentile to be >6.1mg/L. Initiate Baseline monitoring for this variable.	
	Turbidity (NTU)	Turbid after heavy rains.	Moderate change allowed	N/A	Initiate baseline monitoring for this Variable and maintain natural range.	Quarterly
	Electrical conductivity (mS/m)	Category= C	<85mS/m	No	95th percentile to be <85mS/m	Quarterly
Response variables	Chla: periphyton	Category= C. Visual inspection indicates high algal concentrations on rocks and in pools	<84mg/m (D² category)	N/A	50th percentile to be<84mg/m²	Quarterly
	Chla: phytoplankton		<30µg/L (D category)		50th percentile to be<30µg/L	
	Macro invertebrates (ASPT)	D(this study)	See Ecospecs for fish and invertebrates respectively			
	Fish community score	D(this study)				
	In-stream toxicity	Some toxicity from industry and waste water treatment works	Assess only if the bio-monitoring results indicate there is a serious problem and the cause is unknown. An impact is expected if the 95th percentile of the data exceeds the Chronic Effects Value (CEV) as stated in DWAF (1996).			
Toxics	Ammonia	B	<43.75ug/L		95th percentile to be<43.75ug/L	Monthly

EWR 6: HEX RIVER, Upstream of the Vaalkop Dam

Table B11 PES categories and overall site assessment for EWR site 6

River	Hex River	DWAF Water Quality Monitoring points	
WQSU	9	RC	A2H013 Magalies River at Scheerpoort 2002-2007 (*n*=205)
EWR Site	EWR6	PES	A2H094 Bospoort Dam d/s weir at Tweedepoort 1999-2004 (*n*=22) LOW confidence
Water Quality Constituents		**Value**	****Category/Comment**
Inorganic salts(mg/L)	$MgSO_4$	133.123	F(5)
	Na_2SO_4		A(0)
	$MgCl_2$	33.113	C(2)
	$CaCl_2$	110.127	E(4)
	NaCl	170.523	B(1)
Nutrients(mg/L)	PO_4	0.234	E(4)
	TIN	0.775	A(0)
Physical variables	pH (pH units)	7.6-9.1	C(2)
	Temperature (°C)	2data points	C(2)
	Dissolved oxygen (mg/L)	3data points	D(3)
	Electrical Conductivity (mS/m)	95.3	D(3)
Response variable	Chl-a: periphyton (mg/m^2)	-	Visual observations
	Biotic community composition-macroinvertebrate (ASPT) score	4.6	E
	Fish score (FRAI)	49.1%	D
	In-stream toxicity	-	
Toxics	Ammonia (µg/L)	138	E(4)
	Fluoride (µg/L)	300	A(0)
Overall site classification		D	

**Source: Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Prepared by Scherman Consulting.
Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N. and Rowntree, K. 2006. River Classification: Manual for ecostatus determination, Module A-F (Version 2). Water Research Commission, Pretoria.

Table B12 Water quality specifications for the Reserve (Quality Ecospecs) at EWR 6: Hex River upstream of the Vaalkop Dam

RIVER		**Hex River**	**WATER QUALITY MONITORING POINTS**			
WQSU		**9**	**DWA WQ WMS**	**A2H094 Bospoort Dam downstream weir**		
EWR SITE		**EWR6**	**RHP**	**Currently several monitoring sites**		
Confidence in PES assessment		**Medium**				
Water Quality constituents		**PES Category**	**WQ Ecospecs**	**Improvement required?**	**TPC**	**Monitoring frequency**
Inorganic salts (mg/L)	$MgSO_4$		<45mg/L	N/A	95^{th}percentile to be<45mg/L	Monthly
	Na_2SO_4		<20mg/L		95^{th}percentile to be<20mg/L	
	$MgCl_2$		<36mg/L		95^{th}percentile to be<36mg/L	
	$CaCl_2$		<141mg/L		95^{th}percentile to be<141mg/L	
	NaCl		<191mg/L		95^{th}percentile to be<191mg/L	
Nutrients (mg/L)	SRP	Category= E	<0.125mg/L	Yes, to D	50^{th}percentile to be<0.125mg/L	Monthly
	TIN	Category= C	<0.25mg/L		50^{th}percentile to be<25mg/L	Monthly
Physical Variables	pH	Category= C, moderate	5^{th}percentile (5.6-5.9) 95^{th}percentile (8.8–9.2)	Yes	5^{th}percentile(5.6-5.9)95 thpercentile(8.8 –9.2)	Monthly
	Temperature	Limited data and is impacted by waste water treatment works and urbanisation.	Maintain range	N/A	Initiate baseline monitoring for this variable.	When Biotic assessments undertaken
	Dissolved oxygen		7-8mg/L	N/A	5^{th}percentile to be >6.1mg/L. Initiate baseline monitoring for this variable.	
	Turbidity (NTU)	Turbid after heavy rains.	Moderate change allowed	N/A	Initiate baseline monitoring for this variable and maintain natural range.	Quarterly
	Electrical conductivity (mS/m)	Category= D	<85mS/m	Yes, to C	95^{th}percentile to be<85mS/m	Quarterly
Response variables	Chla: periphyton	Category = C. Visual inspection indicates high algal concentrations on rocks and in pools	<84mg/m (D^2 category)	N/A	50^{th}percentile to be<84mg/m^2	Quarterly
	Chla: phytoplankton		<30µg/L (D category)		50^{th}percentile to be<30µg/L	
	Macro invertebrates (ASPT)	E (this study)	See Ecospecs for fish and invertebrates respectively			
	Fish community score	D (this study)				
	In-stream toxicity	Some toxicity from industry and waste water treatment works	Assess only if the biomonitoring results indicate there is a serious problem and the cause is unknown. An impact is expected if the 95^{th}percentile of the data exceeds the Chronic Effects Value (CEV) as stated in DWAF (1996).			
Toxics	Ammonia	E	<129ug/L	Yes to D	95^{th}percentile to be <129ug/L	Monthly

EWR 7: CROCODILE RIVER, Upstream of the confluence with the Bierspruit River

Table B13 PES categories and overall site assessment for EWR site 7

River	**Crocodile River**	**DWA Water Quality Monitoring points**		
WQSU	**21**	**RC**	**A2H013 MagaliesRiver at Scheerpoort 2004-2007 (*n*=205)**	
EWR Site	**EWR7**	**PES**	**A2H060 Crocodile River at Nooitgedacht 2004-2008 (*n*=113)**	
Water Quality Constituents		**Value**		****Category/Comment**
Inorganic salts(mg/L)	$MgSO_4$	112.138		F(5)
	Na_2SO_4	12.102		A(0)
	$MgCl_2$	1.507		A(0)
	$CaCl_2$	20.658		A(0)
	NaCl	187.768		B(1)
Nutrients(mg/L)	PO_4	0.243		E(4)
	TIN	0.302		A(0)
Physical variables	pH(pH units)	7.8-8.5		B(1)
	Temperature (° C)	Raised temp due to lower and shallower flows		D(3)
	Dissolved oxygen (mg/L)	As above		
	Electrical Conductivity (mS/m)	92.3		D(3)
Response variable	Chl-a: periphyton (mg/m²)	-		Algal growth on sand (visual observation)
	Biotic community composition - macroinvertebrate (ASPT) score	4.6		C
	Fish score (FRAI)	46.2%		D
	In-stream toxicity	-		
Toxics	Ammonia (µg/L)	20		B(1)
Overall site classification		D		

**Source: Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Prepared by Scherman Consulting.

Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N. and Rowntree, K. 2006. River Classification: Manual for ecostatus determination, Module A-F (Version 2). Water Research Commission, Pretoria.

Table B14 Water quality specifications for the Reserve (Quality Ecospecs) at EWR 7: Crocodile River upstream of confluence with Bierspruit River

RIVER		**Crocodile (West) River**	**WATER QUALITY MONITORING POINTS**			
WQSU		**21**	**DWA WQ WMS**	**A2H060 Crocodile River at Nooitgedacht**		
EWR SITE		**EWR7**	**RHP**	**Currently several monitoring sites**		
Confidence in PES assessment		**Medium**				
Water Quality constituents		**PES Category**	**WQ Ecospecs**	**Improvement required?**	**TPC**	**Monitoring frequency**
Inorganic salts (mg/L)	$MgSO_4$		<45mg/L	N/A	95th percentile to be<45mg/L	Monthly
	Na_2SO_4		<20mg/L		95th percentile to be<20mg/L	
	$MgCl_2$		<15mg/L		95th percentile to be<15mg/L	
	$CaCl_2$		<21mg/L		95th percentile to be<21mg/L	
	NaCl		<191mg/L		95th percentile to be<191mg/L	
Nutrients (mg/L)	SRP	Category= E	<0.125mg/L	Yes, to D	50th percentile to be<0.125mg/L	Monthly
	TIN	Category= A	<0.25mg/L		50th percentile to be<0.25mg/L	Monthly
Physical Variables	pH	Category= B, Good	5th percentile(5.9-6.5)95th percentile (8.0–8.8)	N/A	5 percentile(5.9-6.5) 95 percentile(8.0 –8.8)	Monthly
	Temperature	Limited data and is impacted by waste water treatment works and urbanisation.	Maintain range	N/A	Initiate baseline monitoring for this variable.	When Biotic assessments undertaken
	Dissolved oxygen		7-8mg/L	N/A	5th percentile to be>6.1mg/L. Initiate baseline monitoring for this variable.	
	Turbidity (NTU)	Turbid after heavy rains.	Moderate change allowed	N/A	Initiate baseline monitoring for this Variable and maintain natural range.	Quarterly
	Electrical conductivity (mS/m)	Category = D	<85mS/m	Yes, to C	95th percentile to be<85mS/m	Quarterly
Response variables	Chla: periphyton	Category = C. Visual inspection indicates high algal concentrations on rocks and in pools	<84mg/m^2 (D category)	N/A	50th percentile to be<84mg/m^2	Quarterly
	Chla: phytoplankton		<30µg/L (D category)		50th percentile to be<30µg/L	
	Macro invertebrates (ASPT)	E (this study)	See Ecospecs for fish and invertebrates respectively			
	Fish community score	D (this study)				
	In-stream toxicity	Some toxicity from industry and waste water treatment works	Assess only if the biomonitoring results indicate there is a serious problem and the cause is unknown. An impact is expected if the 95th percentile of the data exceeds the Chronic Effects Value (CEV) as stated in DWAF (1996).			
Toxics	Ammonia	B	≤44ug/L	Yes to D	95th percentile to be<44ug/L	Monthly

EWR 8: CROCODILE RIVER, Downstream of the confluence with the Bierspruit River

Table B15 PES categories and overall site assessment for EWR site 8

River	**Crocodile River**	**DWA Water Quality Monitoring points**		
WQSU	**24**	**RC**	**A2H013 Magalies River at Scheerpoort 2002-2007 (*n*=205)**	
EWR Site	**EWR8**	**PES**	**A2H116 Haakdoorndrift d/s weir Paul Hugo Dam2003-2008(*n*=104)**	
Water Quality Constituents		**Value**		****Category/Comment**
Inorganic salts (mg/L)	$MgSO_4$	113.147		F(5)
	Na_2SO_4	10.358		A(0)
	$MgCl_2$	2.622		A(0)
	$CaCl_2$	38.530		B(1)
	NaCl	180.659		B(1)
Nutrients (mg/L)	PO_4	0.107		D(3)
	TIN	0.187		A(0)
Physical variables	pH (pH units)	7.7-8.6		B(1)
	Temperature(°C)	1record		B(1)
	Dissolved oxygen (mg/L)	1record		
	Electrical Conductivity (mS/m)	91		D(3)
Response variable	Chl-a: periphyton (mg/m^2)	-		Visual observation: no algae
	Biotic community composition-macroinvertebrate (ASPT) score	4.39		C
	Fish score (FRAI)	54.7%		C/D
	In-stream toxicity	-		
Toxics	Ammonia (µg/L)	25		B(1)
Overall site classification		C/D		

**Source: Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Prepared by Scherman Consulting.
Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N. and Rowntree, K. 2006. River Classification: Manual for ecostatus determination, Module A-F (Version 2). Water Research Commission, Pretoria.

Table B16 Water quality specifications for the Reserve (Quality Ecospecs) at EWR 8: Crocodile River downstream of confluence with Bierspruit

RIVER		**Crocodile (West) River**	**WATER QUALITY MONITORING POINTS**			
WQSU		**24**	**DWA WQ WMS**	**A2H116 Crocodile River at Haakdooringdrift downstream weir**		
EWR SITE		**EWR8**	**RHP**	**Currently several monitoring sites**		
Confidence in PES assessment		**Medium**				
Water Quality constituents		**PES Category**	**WQ Ecospecs**	**Improvement required?**	**TPC**	**Monitoring frequency**
Inorganic salts (mg/L)	$MgSO_4$		<45mg/L	N/A	95^{th}percentile to be<45mg/L	Monthly
	Na_2SO_4		<20mg/L		95^{th}percentile to be<20mg/L	
	$MgCl_2$		<15mg/L		95^{th}percentile to be<15mg/L	
	$CaCl_2$		<57mg/L		95^{th}percentile to be<57mg/L	
	NaCl		<191mg/L		95^{th}percentile to be<191mg/L	
Nutrients (mg/L)	SRP	Category= D	<0.125mg/L	Yes, to C	50^{th}percentile to be<0.125mg/L	Monthly
	TIN	Category= A	<0.25mg/L		50^{th}percentile to be<0.25mg/L	Monthly
Physical Variables	pH	Category= B, Good	5^{th}percentile(5.9-6.5)95^{th}percentile (8.0–8.8)	N/A	4 5 th percentile (5.9-6.5) th 95 percentile(8.0 –8.8)	Monthly
	Temperature	Limited data and is impacted by waste water treatment works and urbanisation.	Maintain range	N/A	Initiate baseline monitoring for this variable.	When Biotic assessments undertaken
	Dissolved oxygen		7-8mg/L	N/A	5^{th}percentile to be>6.1mg/L. Initiate Baseline monitoring for this variable.	
	Turbidity(NTU)	Turbid after heavy rains.	Moderate change allowed	N/A	Initiate baseline monitoring for this Variable and maintain natural range.	Quarterly
	Electrical conductivity (mS/m)	Category= D	<85mS/m	Yes, to C	95^{th}percentile to be<85mS/m	Quarterly
Response variables	Chla: periphyton	Category= C. Visual inspection indicates high algal concentrations on rocks and in pools	<84mg/m^2 (D category)	N/A	50^{th}percentile to be<84mg/m^2	Quarterly
	Chla: phytoplankton		<30µg/L (D category)		50^{th}percentile to be<30µg/L	
	Macro invertebrates (ASPT)	E (this study)	See Ecospecs for fish and invertebrates respectively			
	Fish community score	C/D (this study)				
	In-stream toxicity	Some toxicity from industry and waste water treatment works	Assess only if the biomonitoring results indicate there is a serious problem and the cause is unknown. An impact is expected if the 95^{th}percentile of the data exceeds the Chronic Effects Value (CEV) as stated in DWAF (1996).			
Toxics	Ammonia	B	<44ug/L	Yes to D	95^{th}percentile to be<44ug/L	Monthly

Table B17: Summary of the output of the Crocodile (West) River study and the REC for water quality

Site (River)	EWR site	Overall PES	PES: Water Quality	Overall REC	REC for Water Quality
Upper Crocodile	EWR 1	D	D	D	D
Juskei	EWR 2	E	D	D	D
Upper Crocodile	EWR 3	C/D	D/E	C/D	D
Pienaars	EWR 4	C	B	C	B
Pienaars	EWR 5	D	C	D	C
Hex	EWR 6	D	D	D	D
Lower Crocodile	EWR 7	D	D	D	D
Lower Crocodile	EWR 8	C	C/D	C	C/D
Maloney's Eye	EWR 9	B	B	B	B
Elands	EWR 10	C		B/C	
Sterkstroom	EWR 11	C		C	

ANNEXURE C

PRELIMINARY BASIC HUMAN NEEDS RESERVE

Annexure C: Basic Human Needs

Quantity requirements for the Basic Human Needs Reserve (BHNR)

The total population figure in the quaternary catchment was used to calculate the Basic Human Needs Reserve. The population figures used were based on the 1991 census and extensive field verification project initiated in 1994.

The basic human needs Reserve provides for the essential needs of individuals served by the water resource in question and includes water for drinking, food preparation and for personal hygiene. A life-line amount of 25 litres per person per day was used.

Table C1: BHNR required for the Crocodile (West) catchment area

Water Resource	EWR Site	Catchment	Population	BHNR (MCM/a)
Crocodile	1	A21H	67279	0.614
Jukskei	2	A21C	750650	6.850
Crocodile	3	A21J	133750	1.220
Pienaars	4	A23B	18880	0.172
Pienaars	5	A23J	523987	4.781
Hex	6	A22J	19483	0.178
Crocodile	7	A24C	25809*	0.236*
Crocodile	8	A24H	15000	0.137
Magalies	9	A21F	11636	0.106
Upper Elands	10	A22A	19829	0.181
Sterkstroom	11	A21K	55258	0.504

***Average for the A24 tertiary catchment**

ANNEXURE D

SPECIAL CONDITIONS AND LIMITATIONS

RECOMMENDED CONDITIONS AND CONSIDERATIONS FOR THE FUTURE MANAGEMENT OF THE SURAFCE WATER RESOURCES INTHE CROCODILE WEST AND MARICO WATER MANAGEMENT AREA.

1. RECOMMENDATIONS

At the DWA meeting of 12 May 2010 the following was recommended:

- An ecological category of D is recommended for the Crocodile River;
- The river system should be managed to an upper "D" category to achieve an acceptable water quality;
- More studies need to be undertaken on the tributaries to assess the consequences of higher ecological categories for future resource protection purposes;
- Water quality needs to be stringently managed and the current water quality status in the catchment must be addressed as a matter of priority.
- The freshwater conservation plan for the catchment area must be considered. Pristine tributary catchment areas exist where biodiversity must be protected.

No further water use authorisations for the discharge of wastewater into the Crocodile River should be granted until the water quality state of the river is improved. Water quality in the Crocodile River requires special attention and it is recommended that resource water quality objectives be established as soon as possible to manage the system to an acceptable state.

It is also recommended that a Water Quality Management Plan be developed for the Crocodile River catchment. Water quality management of the discharges in the catchment would be the only way in possibly improving the ecological status. This would provide a framework for evaluating mitigation measures for improving the health of the water resources in this study area. The management plan would also assist in allocating roles and responsibilities to all authorities and users managing activities and impacting on the system. The following measures are required to improve the present health of the Crocodile River:

- Reduce the nutrient input from agricultural return flow and wastewater discharges into the Crocodile River. The impact of the wastewater discharges from the numerous wastewater treatment works needs revision and adjustment where relevant;
- There is a need for increased and more stringent source control;
- The proposed transfer from the Klip River need to have stringent water quality objectives and standards to prevent further deterioration of the receiving water quality in the Crocodile (West) catchment;
- The irrigation water users in the Middle to Lower Crocodile (West) River need to be verified and validated (upstream) of EWR 8, to calculate/verify use in the catchment.

2. GENERAL ECOLOGICAL MANAGEMENT RECOMMENDATIONS AND CONSIDERATIONS FOR THE DIFFERENT SECTION 21 WATER USES OF THE NATIONAL WATER ACT (ACT 36 OF 1998)

2.1 CONSIDERATIONS AND CONDITIONS FOR SECTION 21 (A) AND (B) WATER USE AUTHORISATIONS OF THE NATIONAL WATER ACT (ACT 36 OF 1998)

Section 21 (a)

Considerations for the management of the abstraction of water from rivers

Increasing human populations and escalating demand on freshwater resources, coupled with mounting concerns about environmental change, raise the need to protect, maintain and restore natural riverine flows. Precautionary decisions must be made now to prevent future ecological damage. Comprehensive scientific studies provide evidence showing the damage which may be caused by artificially low flows. Thus, it is critical that the following management practices are followed in order to ensure that aquatic ecosystems are protected from the above impacts resulting from river abstractions.

Conditions

- It should be ensured that over-abstraction does not occur. Thus, water balances should be used to quantify how much water is available in an aquatic system before allocating to new users. The ecological water requirements (EWR's) specified in the Reserve for each resource must also be included in the water balance as a user, before quantifying the allocatable potion.
- The environmental flow variability specified in the Reserve template for the determined REC of that resource is important as the integrity of a healthy aquatic ecosystem depends on the high and low flow variability. High flow events are also important to reset the ecosystems (i.e. to scour out accumulated sediment, release nutrients, etc.). Thus, it should be ensured that the WULA for abstraction will not compromise the natural variability of the system before it is approved.

Section 21 (b)

Considerations for storage of water

Storage of water should not impact negatively on the integrity of the water resource. Considerations to be taken into account include:

- Management of environmental releases from dams should mimic the natural flow pattern;
- The cumulative effect of dams on downstream users;
- The reduction in base flows due to increased evaporation from the dam's surface;
- Attenuation of small freshets by dams;
- Increased erosion during construction and operational phase;
- Creating a barrier to the migration of aquatic biota;
- Physiochemical changes; and
- Loss of river or wetland habitat within the footprint of the dam.

Conditions

- Allow and/or manage environmental flows to maintain water quality and quantity, daily and seasonal flows, stream velocities, instream-, riparian and/or wetland vegetation;
- Erosion control surveys should be undertaken upstream and downstream of the dam and control measures should be implemented;
- Eradicate and control alien invasive species;
- Instream structures must allow for the free passage of aquatic biota;
- Biomonitoring must be conducted upstream and downstream of the impacted site;
- During the construction phase of the dam, the following aspects need to be complied with:

- Activities & storage of equipment in the watercourse[1] to be prevented as far as possible;
- Where applicable, disturbed riparian zones (i.e. for those areas that will not form part of the operational footprint but that were disturbed as part of the construction activities) should be re-vegetated using site-appropriate indigenous vegetation;
- Alien invasive vegetation must be eradicated and not be allowed to colonize the disturbed water course;
- Rehabilitation of disturbed riparian zone must occur during and after completion of construction. An aquatic ecologist must oversee this process;
- Construction camps must be at least 100m from the edge of the riparian zone;
- Toilet facilities must be located at least 100m from the edge of the riparian zone;
- No harvesting of indigenous plants and animals in and adjacent to the construction area;
- No stockpile areas should be located within 100m from the edge of the riparian zone;
- Slope/bank stabilization measures must be implemented where necessary, to prevent erosion during the construction and operational phases;
- The use of machinery within the riparian zone may lead to compaction of soils and vegetation. This will lead to decreases of infiltration of rain water, increases in run-off water and will limit re-vegetation from taking place. It is thus recommended that all compacted areas that do not form part of the footprint activity be ploughed, landscaped to approximate the natural slope of the area and aerated followed by re-vegetation;
- Methods used during construction of infrastructure must limit turbidity, sedimentation and chemical changes to the composition of the water;
- The possibility of spillages should be catered for in the design of the infrastructure. If a spill occurs during the operational phase of the road, a suitably qualified team of experts will need to be consulted and rehabilitation plan drawn up and implemented;
- Any disturbance to the riparian zone that can cause undercutting and/or bank slumping must be prevented. Disturbed areas should be rehabilitated; and
- All reasonable steps must be made to minimize noise and mechanical vibrations in the vicinity of the river.

2.2. CONSIDERATIONS AND CONDITIONS FOR SECTION 21 (C) AND (I) WATER USE AUTHORIZATIONS OF THE NATIONAL WATER ACT 36 OF 1998

Considerations

The construction of infrastructure for example roads, bridges and associated structures

[1] **Note: According to the National Water Act the definition of a watercourse and riparian zone/habitat are as follows:**
"riparian habitat" includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas;
"watercourse" means -
(a) a river or spring;
(b) a natural channel in which water flows regularly or intermittently;
(c) a wetland, lake or dam into which, or from which, water flows; and
(d) any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes, where relevant, its bed and banks.

in or adjacent to the riparian zone and instream habitat should be managed and strictly controlled to minimize damage to these areas. The diversion of a river or the construction, operation and maintenance of infrastructure has the potential to cause serious environmental damage to the physical, biological and chemical components of the aquatic ecosystem. The methods used for construction and maintenance of these activities should therefore apply practices that minimize and avoid problems including unnecessary habitat modification, riparian clearance, increased sedimentation and turbidity, erosion, bank instability and altered chemical composition.

Conditions

Riparian zone conditions:

- Operation activities & storage of equipment in the riparian zone to be prevented as far as possible;
- Where applicable, disturbed riparian zones (i.e. for those areas that will not form part of the operational footprint but that were disturbed as part of the construction activities) should be re-vegetated using site-appropriate indigenous vegetation;
- Alien invasive vegetation must be eradicated and not be allowed to colonize the disturbed riparian and instream areas;
- Rehabilitation of disturbed riparian zone must occur during and after completion of construction. An aquatic ecologist must oversee this process;
- Construction camps must be at least 100m from the edge of the riparian zone;
- Toilet facilities must be located at least 100m from the edge of the riparian zone;
- No harvesting of indigenous plants and animals in and adjacent to the construction area;
- No stockpile areas should be located within 100m from the edge of the riparian zone;
- Slope/bank stabilization measures must be implemented where necessary, to prevent erosion during the construction and operational phases;
- The use of machinery within the riparian zone may lead to compaction of soils & vegetation. This will lead to decreases of infiltration of rain water, increases in run-off water and will limit revegetation from taking place. It is thus recommended that all compacted areas that do not form part of the footprint activity be ploughed, landscaped to approximate the natural slope of the area and aerated followed by re-vegetation;
- Methods used during construction of infrastructure must limit turbidity, sedimentation and chemical changes to the composition of the water;
- The possibility of spillages should be catered for in the design of the infrastructure where for example, attenuation ponds prior to the discharge of storm water could be employed or the storm water systems themselves could be designed in such a way that it can be easily sealed off after the occurrence of a spill. If a spill occurs during the operational phase of the infrastructure, a suitably qualified team of experts will need to be consulted and rehabilitation plan drawn up and implemented;
- Any disturbance to the riparian zone that can cause undercutting and/or bank slumping must be prevented. Disturbed areas should be rehabilitated;
- All reasonable steps must be made to maintain the wilderness qualities of the river. In particular, visual impacts as seen from a boat in the river should be minimized; and
- All reasonable steps must be made to minimize noise and mechanical vibrations in the vicinity of the river.

Instream habitat conditions:

- Rehabilitation of disturbed instream habitat must occur during and after completion of construction. An aquatic ecologist should oversee this process;
- Construction must take place during the low flow/winter months in order to minimize the risk of sediment and debris being washed into the streams and rivers. Natural instream hydrology must be used to determine which months constitute the low flow months;
- Areas in and around the rivers must not be cleared, graded and ditched/trenched more than a week before the construction. The aim is to prevent erosion and sedimentation and the collection of run-off trench water which has high sediment content;
- Stockpiling of soil must be located at least 100m from the riparian zone to prevent soil being washed into the river. Soil stockpiles should be covered to prevent wind and rain erosion;
- Stockpiles and overburden must be removed or rehabilitated after construction;
- During the construction and operation phase erosion and siltation measures must be implemented e.g. the use of temporary silt traps downstream of construction areas must be implemented;
- Alteration of the river channel outside of the construction footprint must be avoided; and
- Where permanent stream diversions lead to a shorter length of river/loss in aquatic habitat, the loss in aquatic habitats must be compensated by an improvement in habitat quality.

Alteration of flow regime and migration routes of aquatic biota conditions:

- Any instream structures used for construction purposes should not stop the natural flow in the river;
- The structure of the river crossings/river diversions must maintain flows across the width of the natural river channel (or mimic it) without significantly increasing velocities;
- Energy dissipaters, for example gabion structures must be utilized at the downstream point of culverts;
- Instream structures must not create an obstruction to the normal flow of water, impounding water upstream thereof;
- Instream structures must be constructed in such a way that it prevents the build-up of debris;
- Culverts must be constructed to allow for instream organisms to migrate during both high- and low flow conditions; and
- Infrastructure should not prevent the lateral movement of flood waters.

Storm water management conditions:

- Storm water discharge points with energy dissipaters should be constructed strategically in and around infrastructure to discharge storm water into the surrounding area to avoid concentration of discharges;
- Reduce runoff from hardened surfaces by strategically placing structures such as grassed swales, Hyson Cells or grass blocks to enhance infiltration; and
- Sediment and debris/litter must be trapped before entering the main drainage system by constructing retention structures. These structures should be regularly maintained.

Considerations and conditions when authorising sand mining or gravel extraction operations

The following are fundamental considerations that must be taken into account when reviewing all sand mining or gravel extraction applications (as summarized by Hill and Kleynhans, 1999):

- Abandoned stream channels on terraces and inactive floodplains should be used preferentially to active channels, their deltas and floodplains. Sand or gravel extraction sites should be situated outside the active floodplain and excavation should not take place from below the water table. Dry-pit mining is therefore preferable to other mining methods;
- Streams should not be diverted to form an inactive channel and isolated ponded areas that could cause fish entrapment should be avoided;
- Sand or gravel extraction activities for a single project should be located on the same side of the floodplain to eliminate the need for crossing active channels with heavy equipment;
- Larger rivers and streams should be used preferentially to small rivers and streams. Larger rivers and streams are preferable because they have more sand or gravel with a wider floodplain. The proportionally smaller disturbance in large systems will reduce the overall impact of sand or gravel extraction;
- Braided river systems should be used preferentially to other river systems. Other river channel types, listed in the order of sensitivity to physical changes caused by sand or gravel extraction activities, are: split, meandering, sinuous and straight. Because braided systems are dynamic and channel shifting is a frequent occurrence, theoretically, channel shifting resulting from sand/gravel extraction might have less of an overall impact because it is analogous to a naturally occurring process. Floodplain width progressively decreases in the aforementioned series of river systems and if sand or gravel extraction is to occur in the adjacent floodplain, it is likely that these four system types will experience greater environmental impacts than the braided system;
- Mitigation must occur concurrently with sand and gravel extraction activities. Rehabilitation is therefore a part of mitigation and the aim of this should be to restore the biotic integrity of a riverine ecosystem, not just to repair the damaged abiotic components; and
- Individual sand or gravel extraction operations must be judged from a perspective that includes their potential adverse cumulative impacts. This is because, the cumulative impacts on instream habitat caused by multiple extractions and sites along a given stream or rivers are compounded by other riverine impacts and land use disturbances in the catchment. These additional impacts may be caused by river diversions/impoundments, flood control projects, logging, and grazing.

Specific conditions for instream and riparian habitat - sand mining or gravel extraction

Gravel bar skimming or "scalping" should only be allowed under restricted conditions:

- Sand or gravel should be removed only during low flows and from above the low-flow water level;
- Berms and buffer strips must be used to control stream flow away from the site; and
- Bar skimming operations need to be monitored to prevent erosion.

Floodplain pits to be considered as instream pits:

- Pit excavations located on the floodplain or terraces should be separated from the active channel by a buffer; and
- Mining pits located on the floodplain should not be excavated below the water table.

Limitation to quantities of sand or gravel removal:

- Limit quantities of sand or gravel removed so that substrate transport processes are not disrupted to an extent that will be detrimental to the integrity of the channel morphology and instream habitat.

Removal or disturbance of instream roughness elements:
- Maintain instream roughness elements such as rocks, boulders and logs;
- Avoid removing or disturbing instream roughness elements during gravel extraction activities; and
- Those that are disturbed should be replaced or restored.

Potential toxic sediment contaminants:
- Potential sediment toxicity needs to be determined before mining;
- Extracted aggregates and sediments must not be washed directly in the stream or river or within the riparian zone; and
- Turbidity levels must not be increased.

Minimize or avoid damage to stream/river banks and riparian habitats:
- Avoid or minimize damage to the riparian zone during extraction operations;
- No sand or gravel extraction in vegetated riparian areas;
- Large woody debris in the riparian zone must not be disturbed;
- All support operations (e.g. gravel washing) must be conducted outside the riparian zone;
- Sand or gravel stockpiles, overburden and/or vegetative debris must not be stored within the riparian zone;
- Redistribute overburden evenly over exposed areas as soon as possible after the operation has been completed;
- Operation and storage of heavy equipment within riparian zone must be restricted to the mining area; and
- Access roads within the riparian zone must be restricted within the mining area.

Direction of mining:
- Mining activities must start upstream and continue downstream, so that rehabilitation and recovery process can start immediately.

2.3. CONSIDERATIONS AND CONDITIONS FOR SECTION 21 (D) STREAM FLOW REDUCTION ACTIVITIES (SFRAS) WATER USE AUTHORIZATIONS OF THE NATIONAL WATER ACT 36 OF 1998:

Considerations

The following fundamental considerations must always be taken into account for Section 21(d) activities, stream flow reduction activities (SFRAs):
- Activities that may result in significant adverse effects on in stream and riparian habitat should be avoided where less environmentally harmful alternatives are available. Alternatives must therefore be considered by the applicant. Environmentally sound engineering and management practices should be employed for all actions which may adversely affect the in stream and riparian habitat;
- The proposed activity should not increase bank instability and the erosive potential of a stream;
- Planning and maintenance of forestry roads should ensure minimal erosion and sedimentation of associated watercourses. A road management plan should be developed and implemented; and

- Measures to counteract soil erosion during harvesting should be implemented to minimize sedimentation of the nearest water resources.

Conditions

- Avoid destabilizing and eroding river banks;
- Make use of the following document when afforestation occurs in the vicinity of a watercourse: *"A practical field procedure for identification and delineation of wetlands and riparian areas."* A 20m buffer must be implemented around delineated watercourses. Should the distance differ between the requirements of other Government Departments, the greater buffer must be applied. Develop and implement a forestry road management plan. Maintain forestry roads to ensure minimal erosion and sedimentation of associated watercourses;
- Alien invasive vegetation must be eradicated, example all Category 1 plants (CARA, 2001); and
- Prevent soil erosion during harvesting.

2.4. CONSIDERATIONS AND CONDITIONS FOR SECTION 21 (E), (F) AND (G) WATER USE AUTHORIZATIONS OF THE NATIONAL WATER ACT, ACT 36 OF 1998

Conditions and Considerations for section 21(e) applications

Considerations and Potential impacts of irrigating with wastewater

Irrigation of land with treated wastewater has the potential to introduce effluent-derived organic micro-contaminants into surface waters through runoff (Pederson *et al.* 2005; Stockle, 2005). The latter is likely to cause an increase in the occurence of wastewater-borne diseases as well as more rapid degradation of the environment (Mahmood and Maqbool, 2006). Additionally, through excessive loads of nutrients the shift in water quality will lead to increased primary and secondary production, which will lead to algal bloom formation and possible oxygen depletion, lower survival and productivity of the biota and the increased eutrophication rate of standing waters. Certain nutrients (e.g. non-ionized ammonia, some metals) are also possibly toxic at high concentrations.

Stockle (2005) revealed that not only are nutrients and other chemicals transported with return flows, but that excess transport of sediments also occurs because runoff of irrigation water causes soil erosion. This aggravates the impact in the streams and rivers even more, because it is not only water quality that is negatively impacted, sedimentation also creates significant problems to fish habitat and the aquatic ecosystem as a whole.

Furthermore, infiltration of irrigated wastewater in excess of available root zone storage will penetrate beyond the reach of roots and eventually recharge groundwater. Light-textured soils and shallow-rooted crops (like the turf grass for the golf course) under irrigation can lead to considerable leaching of wastewater to groundwater. Nitrates, salts, and other chemicals dissolved in the soil water will move with the water and adversely affect groundwater quality (Stockle, 2005; Mahmood and Maqbool, 2006).

Conditions for section 21(e) applications

When considering the approval of an application for irrigating with waste water, the following conditions should be taken into consideration:

Consideration of alternatives:

- Activities that may result in significant adverse effects on instream and riparian habitat should be avoided where less environmentally harmful alternatives are available. Less environmentally harmful alternatives must therefore be provided and should none of these alternatives deem feasible, environmentally sound engineering and management practices should be employed for all actions, which may adversely affect the instream and riparian habitat.

Proper wastewater treatment:

- Water containing waste must be treated to comply with the water quality requirements specified in the general and special standards, as published in Government Notice 991 of 18 May 1984.

Soil type:

- The soil type of the land to be irrigated must be determined, purely because soils of the poorly drained classes are seldom suitable for waste application unless some form of artificial drainage is installed. If wastewater applications are limited by drainage conditions, then the water has to be applied in small amounts at very frequent intervals. Also, a water balance should be performed in all cases. This would be important in determining capacity of land to dilute wastewater constituents to the water quality guidelines for Aquatic Ecosystem levels, and also give an idea of potential sterilisation of groundwater resources.

Turbidity:

- Activities that lead to elevated levels of turbidity must be minimized. The use of a proper irrigation method could limit soil erosion and the subsequent sediment transport to surface water with excess runoff, i.e. drip and sprinkler irrigation instead of furrow irrigation.

Buffer zone:

- There should be a buffer zone that prevents any irrigation to be allowed within the 1:100 year flood line or within a 100 meter horizontal distance from a water course (whichever one is furthest). Otherwise, the applicant could build attenuation dams that will prevent or minimise the wastewater runoff from seeping into the water resource.

Quality of the wastewater:

- The wastewater to be irrigated with must be monitored to comply with the water quality requirements specified in the general standards, as published in Government Notice 991 of 18 May 1984. Additionally, wastewater that irrigates land must comply with DWA's Guidelines for Agricultural use. When the water enters a watercourse it must comply with DWA's Guidelines for Aquatic Ecosystems.

Rehabilitation:

- To compensate for the proposed activity, it should be proposed that the applicant addresses any water quality issues from failed sewage systems, etc., to prevent further degradation of the environment in the area and also take measures to remove any proliferating exotic vegetation in the area and mitigate against future recruitment of exotic species.

Prevention of invasive vegetation:

- Invasive alien vegetation that may arise especially due to the wastewater irrigation activity should be prevented at all cost. It is easy for opportunistic species to take over if a change in the environment like this occurs.

Considerations for section 21(f) and (g) applications

The main land use activities which contribute to diffuse pollution are mining, power stations, industry, urban developments, and agriculture. The point source discharges are from the wastewater treatment plants, mine and industrial discharges. The pollution from these sources can impact acidity, salinity, nutrients, toxicity and public health. It, thus, should be ensured that the RWQOs are considered when evaluating these types of activities to ensure the suitable management of the aquatic ecosystems.

Measures must always be provided to avoid disposal or spillage of any material (dredge material, sludge, waste, or other potentially harmful materials), that would destroy or degrade the instream and riparian habitat. Compensation measures for damage and/or mitigation measures must be recommended, if avoidance or minimization of the impacts of the proposed activity is not possible, or if mitigation measures fail to adequately protect the instream and riparian habitat.

In addition to the above considerations, the following fundamental conditions must always be taken into account for section 21(f) and (g) applications:

- Water containing waste or effluent must be treated to comply with the water quality requirements specified in the general and special standards, as published in Government Notice 991 of 18 May 1984;
- Any sludge or slurry removed from a sewage treatment plant shall be disposed of according to the specifications of the guidelines published by the Department of Health in collaboration with other departments: Permissible utilisation and disposal of sewage sludge dated August 1999; and
- Measures should be implemented to re-use water containing waste or appropriate technological treatment options investigated and implemented.

Conditions for section 21(f) and (g) applications

Conditions are site specific and can only be set for a site taking into account the above-mentioned considerations.

3. MONITORING CONDITIONS

A baseline assessment needs to be conducted prior to the commencement of proposed activities. A post construction assessment also needs to be conducted in order to determine the success of rehabilitation which would have been conducted during and after construction, as well as the overall success of mitigation measures implemented during construction.

Biomonitoring

A monitoring and maintenance plan must be implemented by the applicant. This plan needs to be specific to the water use application applied for and should be compiled by an aquatic specialist. The nature of the water use activity needs to be taken into consideration when deciding on the type of specialist monitoring required. For example, it may be necessary to only monitor the macroinvertebrates and habitat component. Other components, for example fish, riparian vegetation or diatoms may also need to be assessed. It is therefore imperative that a specialist decide which components need to be monitored for and at what frequency. The specialist must submit a monitoring programme for aquatic macroinvertebrates and instream habitat integrity, at a minimum.

To be noted, SASS (South African Scoring System) for macroinvertebrate assessment is only applicable to rivers and streams – i.e. systems that are flowing. It is not applicable to wetlands, dams and estuaries.

Macroinvertebrate sampling using sass (south african scoring system)

Aquatic macroinvertebrates must be sampled using the latest SASS (South African Scoring System) methods. The aquatic scientist must be an accredited SASS practitioner. A list of accredited SASS practitioners is available on the River Health Programme website: http://www.dwaf.gov.za/iwps/rhp/quality.html or alternatively Ms. C Thirion (thirionc@dwa.gov.za) from the Directorate: Resource Quality Services, DWA, can supply this information.

SASS sampling must be conducted once before any disturbance takes place. During and after the disturbance, SASS surveys must be conducted at an appropriate sampling frequency at a site upstream and downstream of the disturbance. An annual report on the SASS surveys must be submitted to the Regional Director.

Annual habitat integrity assessments

An aquatic scientist approved by the Regional Director must be appointed by the applicant to submit a monitoring programme for Habitat Integrity. Habitat integrity must be assessed using the method described by the then Department of Water Affairs and Forestry (DWAF, 2008), now Department of Water Affairs. An assessment must be conducted once before any operations, or disturbances take place, and thereafter annually for the duration of the operations. The baseline Habitat Integrity data must be accompanied with predevelopment photographs of the study area.

ANNEXURE E

BACKGROUND TO STUDY

D1: Background to Study

The CD: RDM initiated the Intermediate Reserve Determination Study for selected water resources (rivers and wetlands) in the Crocodile (West) and Marico Water Management Area (WMA). The purpose of the Reserve Determination Study was to assist the DWA in making informed decisions regarding the authorisation of future water uses and the operation and management of the system to ensure sustainability of the water resources in the catchment. This Template addresses the Preliminary Reserve for the Crocodile west river and the associated tributaries.

D2: Study Team

Technical assessments:

Person	Organisation	Reserve Component	Position on Team
WATER RESOURCES			
Dr Ralph Heath	Zitholele Consulting	River Quality	Project Leader and River Task Leader
PriyaMoodley	Zitholele Consulting	River Quality	Water Quality - trainee
BrentonNiehaus	Clean Stream	River Quantity	Invertebrate specialist
Angelina Jordanova	Golder Associates	River Quantity	Hydraulics engineer
Mark Rountree	Fluvius Consulting CC	River Quantity	Geomorphologist
LindokuhleHlongwane	Fluvius Consulting CC	River Quantity	Geomorphologist - trainee
Adrian Hudson	Golder Associates	River Quantity	Riparian vegetation
Dr Johan Engelbrecht	Golder Associates	River Quantity	River fish ecologist
Estelle van Niekerk	BKS	River Quantity	Hydrologist
Johan Rossouw	BKS	River Quantity	System Analyst
Retha Stassen	Own company	River Quantity	Hydrologist
AnelleLotter	Zitholele Consulting	Quantity and Quality	Public participation/stakeholder engagement
Danie Otto	Golder Associates	Wetands	Wetlands specialist
Frank Wiegmans	Zitholele Consulting	Groundwater	Groundwater specialist
SOCIO-ECONOMICS			
Jackie Crafford	Prime Africa	Socioeconomics	Socio-economist
Aimee Ginsburg	Prime Africa	Socioeconomics	Trainee

Drafting Reserve template: Tlou Consulting (Pty) Ltd: T. Sibanda
A Singh
RDM Directorate: J. Machaba
V. Muthelo

D3: Scope of Study

The following levels of EWR determination were applied:

- Intermediate Ecological Reserve at EWR 1, 3, 7 and 8 on the Crocodile River.
- Intermediate Ecological Reserve at EWR 4 and 5 on the Pienaars River.
- Intermediate Ecological Reserve at EWR 6 on the Hex River.
- Rapid Ecological Reserve determination at EWR 9 on the Magalies River.
- Rapid Ecological Reserve determination at EWR 10 on the Elands River.
- Rapid Ecological Reserve determination at EWR 11 on the Sterkstroom.

D4: Presentation of results

The Preliminary Reserve configurations scenarios in this template were arrived at through consideration of driving ecological, social and economic considerations, in particular those pertaining to the need to supply water to meet the growing demands of the users in the study area, national strategic uses and existing and proposed water resource developments.

Discussions on the desirability and necessity of tradeoffs within the catchment formed the focus of a DWA stakeholder Workshop (relevant Chief Directorates of DWA) held in Pretoria on the 12th of May 2010. The aims of the workshop were to:

- Present findings of study to DWA management;
- Discuss issues in catchments;
- Discuss Reserve results of the Crocodile (West) catchment;
- Evaluate options/scenarios per catchment/group of catchments;
- Decide on recommended preliminary ecological management class;
- Obtain stakeholder views on the scenario(s), and to
- Decide on the associated management scenario to be recommended to the DWA.

The preliminary Reserves presented in this template reflect the outcome of the discussions at the DWA Stakeholder Workshop.

ANNEXURE F

METHODOLOGY

E1. Eco-classification -Rivers

Eco-classification refers to the categorization of the Present Ecological State (PES) of various biophysical attributes compared to the natural (or near natural) reference condition. The Eco-classification process supports the scenario-based approach were a range of ecological endpoints (Ecological Categories) are considered. The approach and methodology used is contained within *Kleynhans CJ, Louw MD. 2007. Module A: and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report.*

E2. Ecological Water Requirements - Rivers

Ecological Water Requirement (EWR) refers to the flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. The process did not consider whether these flows could be supplied or managed and impacts on users were not considered. The generic framework of the Building Block Method of assessing EWRs was used in the study, as outlined in *DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 3: River Ecosystems Version 1.0.*

E3. Water quality

The procedures used followed those in *Methods for determining the Water Quality component of the Ecological Reserve.* Prepared by Scherman Consulting for the Department of Water Affairs and Forestry, South Africa. (2008).

E4. Scenario Analysis

The approach followed to provide the results was a combination of published South-African environmental flow requirement methods. The overall approach of this study was based on the Building Block Method (BBM) (King and Louw 1998). The Habitat-Flow-Stress-Response Method (HFSR) was used to provide low flow requirements. The methods focus on identifying the size, duration and timing of specific flows and flow patterns that are considered to be the most important for maintaining the key ecological drivers (hydrology, geomorphology and water quality) and the key biological response indicators (riparian vegetation, aquatic invertebrates and fish), within a defined length of river, referred to as a Resource Unit, in a particular condition, or Ecological Category (EC).

These flow results were used as input to the Water Resource Yield Model (WRYM). Consequences of providing flow scenarios can then be tested based on the outputs of the WRYM.

E5. Basic Human Needs

The process followed in determining the BHNR for the Crocodile (West) management area was followed as per that specified by the CD: RDM. The BHNR was analysed using the following factors:

- The population of those living within the catchment (per quaternary) was determined based on the 1991 census and extensive field verification done in 1994. The estimated growth in this population was determined up to 2025. This estimate is based on Census the DWAF, National Water Services project progress and project implementation from October 2001 to March 2007.

ANNEXURE G

LOCALITY MAP OF THE STUDY AREA

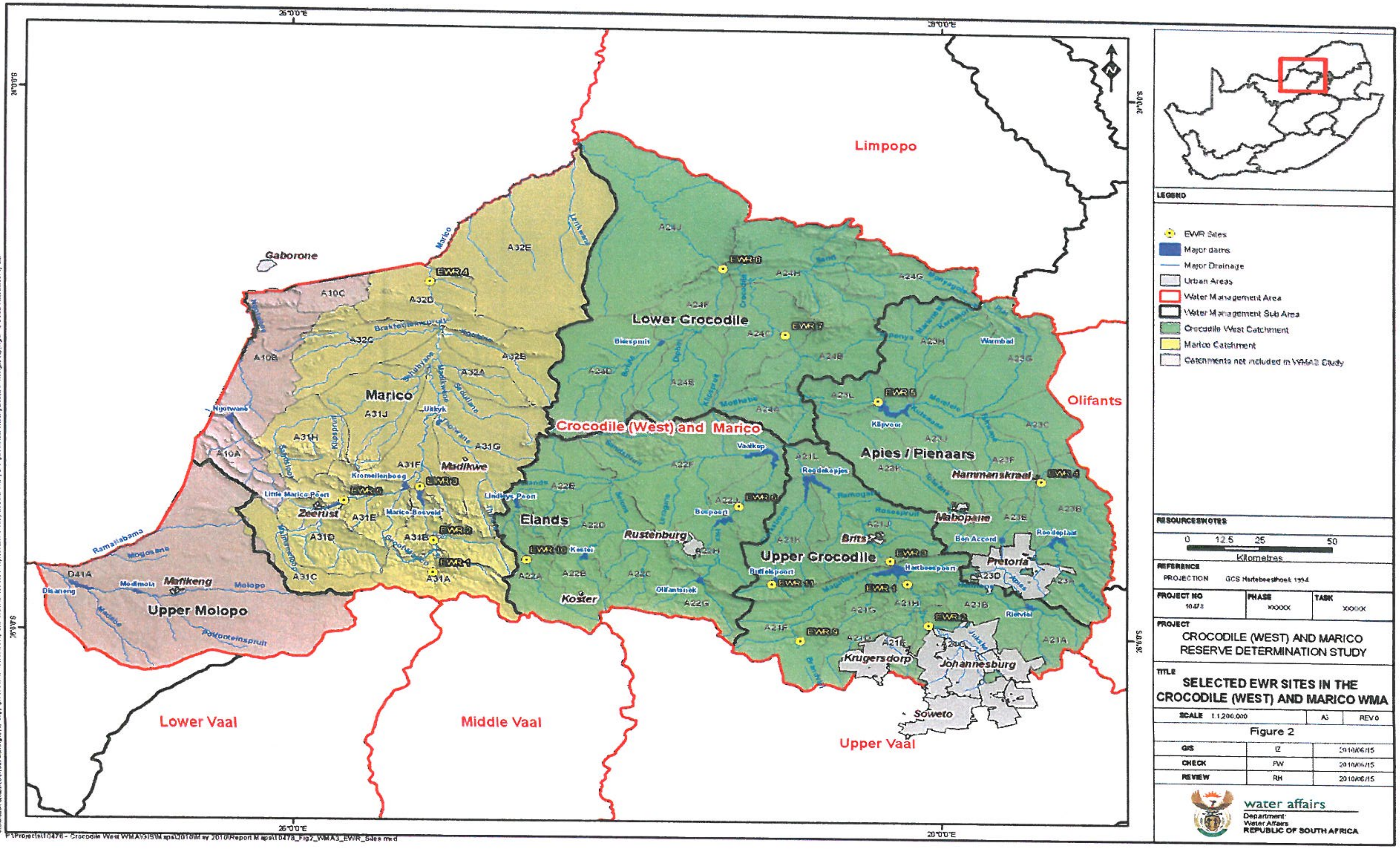

Figure 1: Location of the EWR sites in the Crocodile West and Marico Water Management Area

ANNEXURE H

REFERENCES AND RELEVANT PROJECT REPORTS

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