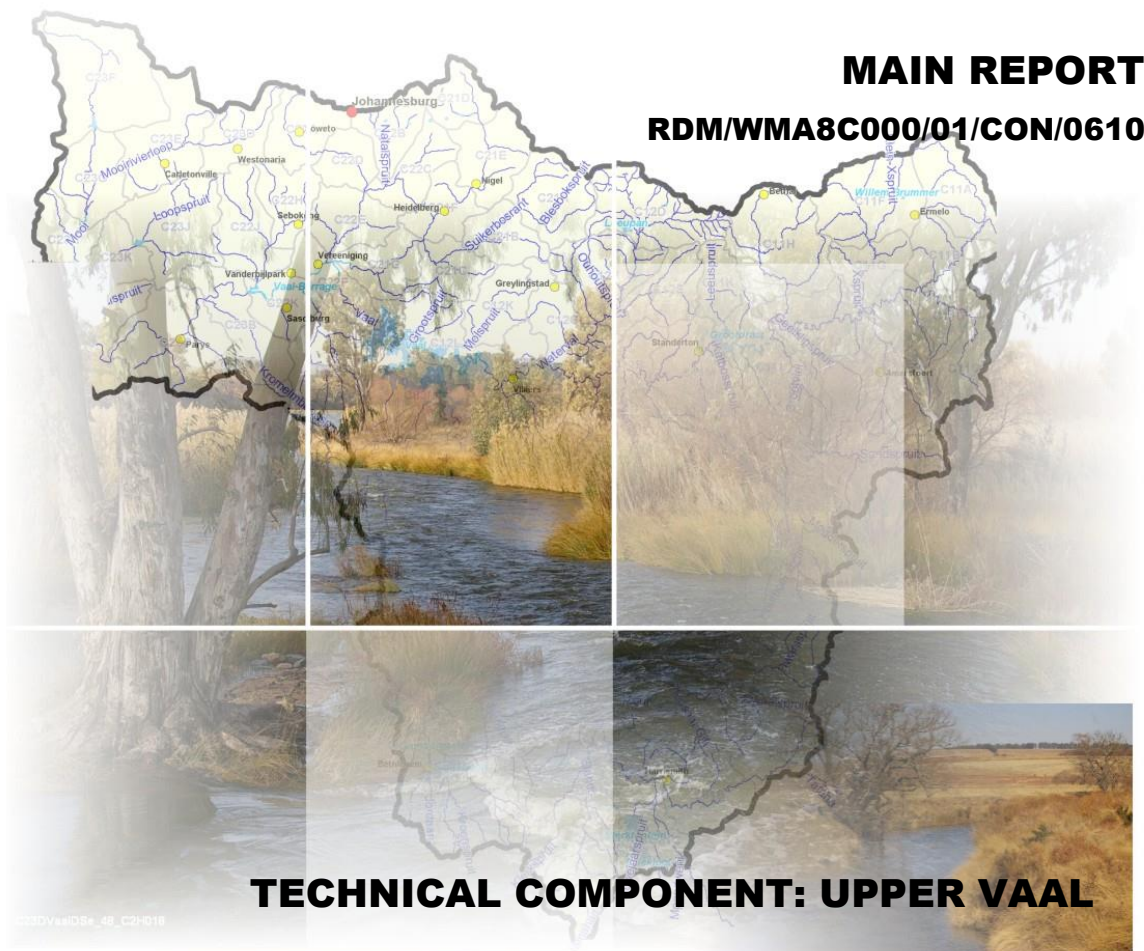


# COMPREHENSIVE RESERVE DETERMINATION

## INTEGRATED VAAL RIVER SYSTEM

### SURFACE WATER



**MAIN REPORT**

**RDM/WMA8C000/01/CON/0610**

**TECHNICAL COMPONENT: UPPER VAAL**

JULY 2010

REPORT NO.: RDM/WMA8C000/01/CON/0610

PROJECT NO.: 8829/1



**water affairs**

Department:  
Water Affairs  
REPUBLIC OF SOUTH AFRICA

# **COMPREHENSIVE RESERVE DETERMINATION STUDY OF THE INTEGRATED VAAL RIVER SYSTEM**

**UPPER VAAL WATER MANAGEMENT AREA  
TECHNICAL COMPONENT: MAIN REPORT  
Report number: RDM/WMA8C000/01/CON/0610**

**DECEMBER 2008**

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## Reports as part of this project:

Index number	RDM Report number	Report title
1.1	RDM/WMA8C000/01/CON/0107	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Inception Report
1.2	RDM/WMA8C000/01/CON/0207	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Desktop EcoClassification Report
1.3	RDM/WMA8C000/01/CON/0610	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Basic Human Needs Reserve. Included in the Main Report.
1.4	RDM/WMA8C000/01/CON/0208	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Resource Unit Report
1.5	RDM/WMA8C000/01/CON/0109	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoClassification Report
	Volume 1 and 2	
1.6	RDM/WMA8C000/01/CON/0209	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EWR Scenario Report
	Volume 1 and 2	
1.7	RDM/WMA8C000/01/CON/0110	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Ecological and Goods & Services Consequences of Various Operational Scenarios.
1.8	RDM/WMA8C000/01/CON/0210	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Socio Economic Consequences of Various Operational Scenarios.
1.9	RDM/WMA8C000/01/CON/0310	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoSpecs Report
1.10	RDM/WMA8C000/01/CON/0410	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Wetland Report
1.11	RDM/WMA8C000/01/CON/0510	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Estimation Report
<b>1.12</b>	<b>RDM/WMA8C000/01/CON/0610</b>	<b>Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Main Report</b>
1.13	RDM/WMA8C000/01/CON/0710	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Electronic information

**Bold** indicates this report

**APPROVAL**

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**TITLE:** Comprehensive Reserve determination study of the Integrated Vaal River System, Upper Vaal River Management Area. Technical Component: Main Report

**DATE:** July 2010

**EDITORS:** S Koekemoer and MD Louw

**REVIEW:** Ms Retha Stassen, Beyers Havenga

**LEAD CONSULTANT:** Koekemoer Aquatic Services and Rivers for Africa, Joint Venture

**FILE NO.:** 26/8/3/10/10

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Jacqueline Jay	Department of Water Affairs	Study Manager
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---

### **CHAPTER 3: DESKTOP ECOCLASSIFICATION**

The EcoQuat model used in this study was designed by DWA: RQS. Dr Kleynhans is especially thanked for his guidance, input and participation in the running of the EcoQuat model and the refinement of the EIS.

The specialists from the Project Team involved in this study were:

- Ms Delana Louw (Water for Africa);
- Mr Greg Huggins (Water for Africa);
- Dr Pieter Kotze (Clean Stream Biological Services).

The specialists from DWAF: RQS involved in this study were:

- Dr CJ Kleynhans
- Ms Christa Thirion

Input on water resource stress was provided by Mr Pieter van Rooyen and Ms Susan Swart from Water Resource Planning (WRP).

Input on water quality was provided by Dr Ralph Heath from Golder and Associates

Comments on the report were provided by the following:

- Retha Stassen

### **CHAPTER 4: BASIC HUMAN NEEDS**

The specialists from the Project Team involved in this study were:

- Mr Greg Huggins (Water for Africa);
- Ms Katie Maasdorp (Water for Africa)

### **CHAPTER 5: RESOURCE UNITS**

D:RQS, Dr CJ Kleynhans is especially thanked for this contribution in the continued method development and refinement.

The following specialists are thanked for their contributions to this report:

- Mr Mark Rountree (Fluvius Environmental Consultants)
- Mr James MacKenzie (BioRiver Solutions)
- Dr Rob Palmer (Nepid Consulting)
- Dr Pieter Kotze (Clean Stream Biological Services)
- Dr Drew Birkhead (Streamflow Solutions)

### **CHAPTER 6: ECOCLASSIFICATION (LEVEL IV) OF EWR SITES**

Dr Neels Kleynhans, DWA: RQS, for providing methods and approaches, review, and guidance.

#### **Contributors to the report and specialist meeting:**

Dr Heath, Ralph (Physico-chemical variables)

Ms Koekemoer, Shael (Diatoms and Editing)

Dr Kleynhans, Neels (Fish and EcoClassification specialist)  
Dr Kotze, Piet (Fish and report review)  
Ms Louw, Delana (IHI & process facilitator)  
Mr Mackenzie, James (Riparian vegetation)  
Dr Palmer, Rob (Macroinvertebrates)  
Mr Rountree, Mark (Fluvial Geomorphology)  
Dr Scherman, Patsy (Physico-chemical variables)

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Mr Hlongwane, Lindoh (Geomorphology)  
Mr Koekemoer, Johan (Fish)  
Ms Louw, Shileen (Administration)  
Ms Jay, Jackie, (Riparian vegetation)  
Ms Maseti, Pumza (Fish)  
Mr Niehaus, Brenton (Macroinvertebrates)  
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**CHAPTER 7: EWR SCENARIO ASSESSMENT**

Dr Neels Kleynhans, DWAF: RQS, for providing methods and approaches, review, and guidance.

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Mr Mackenzie, James (Riparian vegetation)  
Dr Palmer, Rob (Macroinvertebrates)  
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**Trainees:**

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Ms Jay, Jackie, (Riparian vegetation)  
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## **CHAPTER 8: ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS**

### **Ecological Consequences:**

Dr Neels Kleynhans, DWA: RQS, for providing methods and approaches, review, and guidance.

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Ms Louw, Delana (Process facilitator)  
Mr Mackenzie, James (Riparian vegetation)  
Dr Palmer, Rob (Macroinvertebrates)  
Mr Rountree, Mark (Fluvial Geomorphology)  
Dr Heath, Ralph (Physico-chemical variables)

### **Contributors to the process:**

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### **Trainees:**

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### **Goods and Services Consequences:**

The specialists from the Project Team involved in this study were:

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Dr Kotze, Piet  
Ms Louw, Delana  
Mr Mackenzie, James  
Dr Heath, Ralph

## **CHAPTER 9: PRESENT STATE EVALUATION AND MACRO ECONOMIC CONSEQUENCES**

WRP Engineering for support in interpreting the Operational Scenarios.

Eskom for supplying the water use at individual power stations.

Rand Water for supplying water use detail.

## **CHAPTER 10: IDENTIFICATION OF ECOSPECS**

Dr Neels Kleynhans, DWA: RQS, for providing methods and approaches, and guidance.

### **Contributors to the report and specialist meeting:**

Dr Heath, Ralph (Physico-chemical variables)  
Ms Koekemoer, Shael (Editing)  
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Mr Mackenzie, James (Riparian vegetation)  
Dr Palmer, Rob (Macroinvertebrates)  
Mr Rountree, Mark (Fluvial Geomorphology)

**Trainees:**

The following trainees participated in the workshop:

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Ms Jay, Jackie, (Riparian vegetation)

**Client attendance:**

Ms Stassen, Retha (Blue Science Consulting)

**CHAPTER 11 - WETLAND TYPING AND ECOCLASSIFICATION**

Ms. Jackie Jay and Mrs. Barbara Weston from the DWA, CD: RDM are thanked for the recommendations with regard to the wetland information requirements of the Department of Water Affairs. The assistance received from Mrs Nicolene Fourie (DWA: GIS Directorate) in obtaining relevant GIS layers for the desktop analysis is gratefully acknowledged. The South African National Biodiversity Institute (SANBI) kindly allowed use of their draft National Wetland Probability Map for this study.

The river Desktop Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) models, developed and provided by Dr Neels Kleynhans, were used as templates to develop similar catchment-based assessment tools to derive average PES and EIS scores for wetlands across quaternary catchment areas. Without the initial development of the river tools, modification to wetland-appropriate assessment tools would not have been easily possible. Dr Neels Kleynhans also very kindly assisted with sourcing old TPA wetland reports for the region.

The valuable reviewing and resultant comments and suggestions provided by Delana Louw and Shael Koekemoer for this report, and by Patsy Scherman, Delana Louw and Shael Koekemoer on similar wetland studies, have greatly improved this report, and their contributions are gratefully acknowledged. Mrs Nonkanyiso Zungu (currently at DWA, SD: SFRA) and Mr Adrian Pietersen assisted as trainees on this project; providing field-based and GIS-based assistance respectively.

The PES and EIS assessments of the quaternary catchments expanded the role and scope of this study from the initial proposed approach, and the patience of the project management team and client has been sincerely appreciated.

**CHAPTER 12: ESTIMATION AND EXTRAPOLATION OF EWRs AT SELECTED HYDRONODES**

The Desktop Reserve model adjustments for hydronodes in the Sabie, Crocodile and Mokolo River catchments were performed by AL Birkhead, A Desai, D Louw, J Mackenzie.

Dr CJ Kleynhans developed the approach to determine the biophysical similarity of sites and predict the indicator fish guilds. This was undertaken for this study by Dr Pieter Kotze.

## **EXECUTIVE SUMMARY**

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### **BACKGROUND**

In order for the Department of Water Affairs (DWA) to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments in the Vaal River System, higher levels of confidence is needed for the Reserve Determination within this study area. Therefore a Comprehensive Reserve determination study within Water Management Area (WMA) 8 has been undertaken to provide input to the Reconciliation studies and the integrated water quality management plan recently undertaken by the National Water Resources Planning Directorate (D: NWRP) of the DWA.

### **STUDY AREA**

The study area for the Reserve determination is the Upper Vaal system as represented by WMA 8. WMA 8 is part of a larger water supply system, which includes adjacent WMAs, and Lesotho. The Upper Vaal WMA is one of three WMAs in the Vaal River catchment, which is the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWAF, 2004).

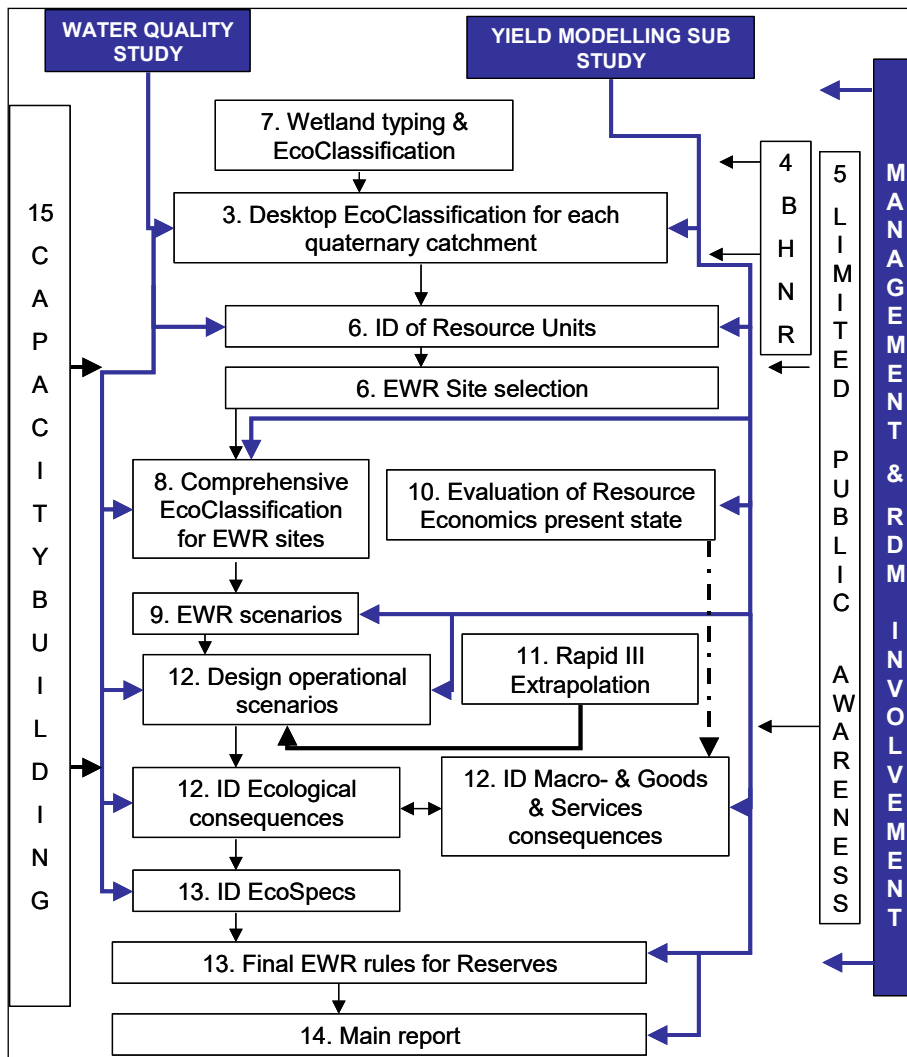
The Upper Vaal WMA includes the Vaal, Klip, Wilge, Liebenbergsvlei, Waterval, Suikerbosrand and Mooi Rivers and extends to the confluence of the Mooi and Vaal Rivers. It covers a catchment area of 55 565 km<sup>2</sup>. This WMA includes the very important Vaal, Grootdraai and Sterkfontein dams. The southern half of the WMA extends over the Free State, the north-east mainly falls within Mpumalanga and the northern and western parts in Gauteng and North West provinces respectively (DWAF, 2004).

The Upper Vaal is the uppermost WMA in the Vaal River catchment and one of five WMAs in the Orange River Basin. It is surrounded by the Crocodile (West) and Marico, Olifants, Inkomati, Usutu to Mhlathuze, Thukela, Upper Orange and Middle Vaal WMAs and adjoins Lesotho in the southern extreme. The National Water Resource Strategy (NWRS) describes and discusses the Upper Vaal WMA in three sub-areas *viz* the Vaal upstream of Vaal Dam, Wilge and the Vaal downstream of the Vaal Dam (DWAF, 2004).

### **PROJECT PLAN**

The project plan designed around the 8 step Reserve process is illustrated in the flow diagram below. The numbers in the flow diagram refers to the study tasks. Various reports have been produced for these tasks and these reports, with specific emphasis on the results, are summarised in this main report.

An extensive training programme was also followed as part of the study.



**Project plan – Upper Vaal River**

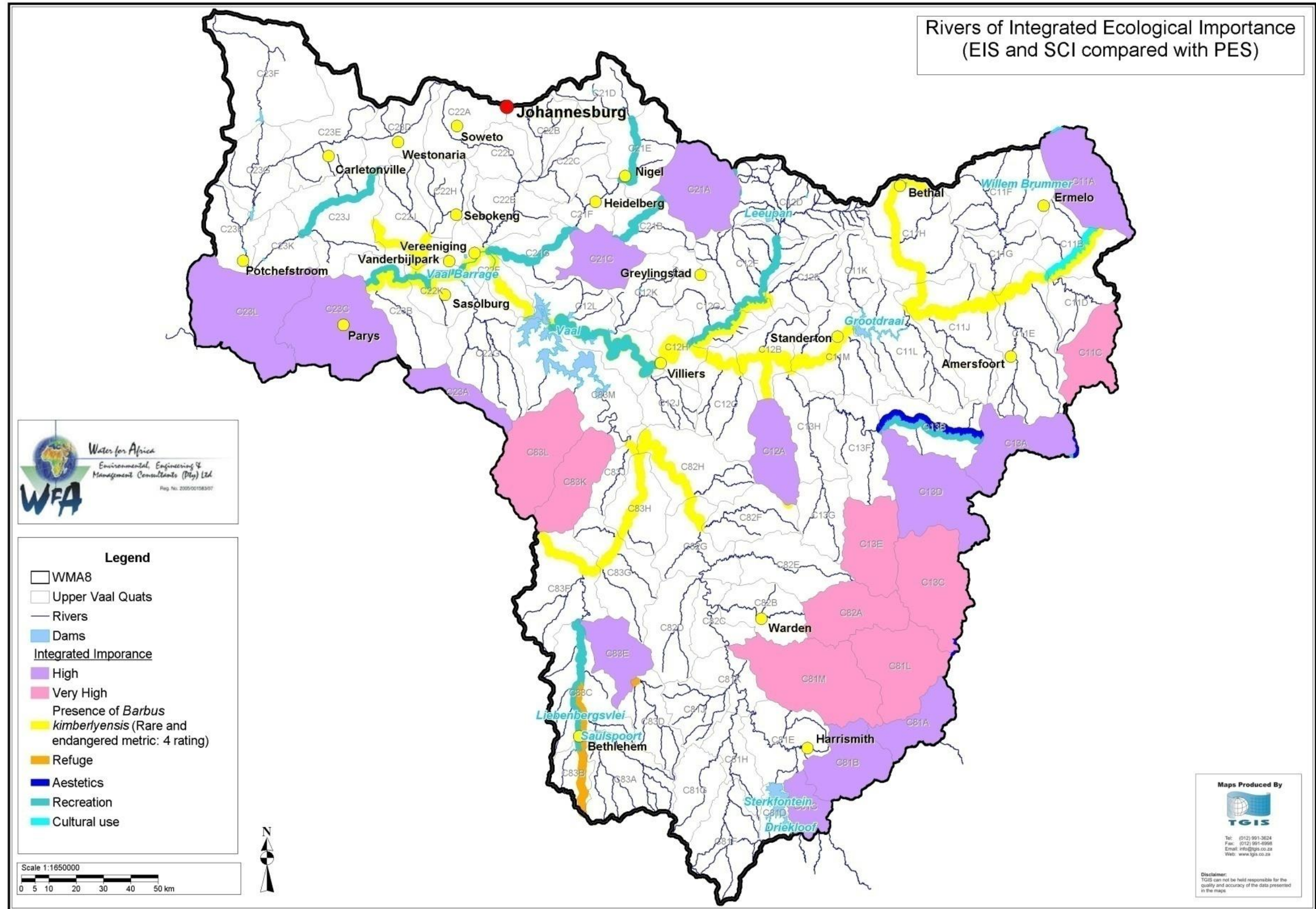
**DESKTOP ECOCLASSIFICATION: CATCHMENT SCALE**

**Rivers**

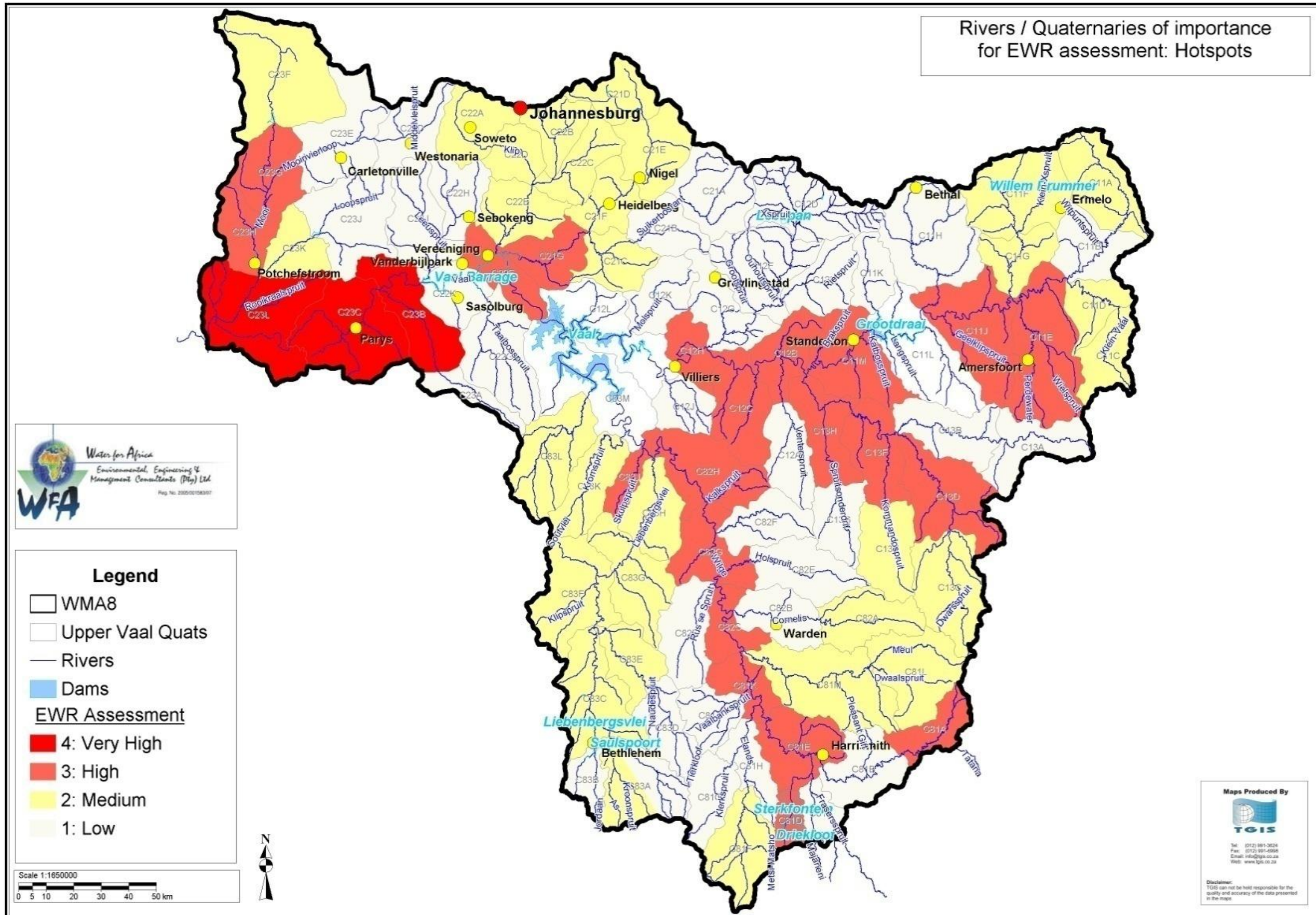
This task provides EcoClassification information at a scoping or desktop level, as well as a more detailed assessment. The purpose of EcoClassification is to gain insight into the causes and sources of the deviation of the PES from the reference condition. This provides the information needed to derive the desirable and attainable future ecological objectives for the river. The present state of the river is described in terms of Ecological Categories (A to F).

A combination of EIS, SCI, and PES provide an indication of overall / integrated importance with the emphasis on the restoration potential. The restoration potential refers to the probability of achieving the rehabilitation of the river to an improved state. The results are provided in the integrated importance map.

The integrated importance was compared to an assessment of Water Resource Use importance to identify quaternary catchments which are so called 'hotspots'. A biodiversity/ecological hotspot is a biogeographic region which is a significant reservoir of biodiversity which is threatened with destruction ([http://en.wikipedia.org/wiki/Biodiversity\\_hotspot](http://en.wikipedia.org/wiki/Biodiversity_hotspot)). In the context used in the Desktop EcoClassification, the hotspot represents a quaternary catchment with a high Integrated Importance which could be under threat due to its importance for water resource use. These hotspots indicate areas where Reserve assessments should ideally result in high confidence recommendations. This then guides the initial estimate of the level of the assessments required, and indicates areas where detailed investigations would be required if development was being considered.



Areas of high Integrated Importance in the Upper Vaal WMA areas with a high demand for licenses



Sections in rivers which are important for Reserve assessment (Hotspots) derived from overlaying Integrated Importance and Water Resource Use

**BASIC HUMAN NEEDS RESERVE**

In order to calculate the BHNR the following steps were required:

- Quaternary catchment boundaries were superimposed upon the smallest aggregations of census data available. For the 2001 National census these are known as “sub-place names”. The total population for the Upper Vaal catchment, as recorded by the 2001 Census, was 6 736 735.
- Those receiving water from a recognised formal water source and therefore not likely to be dependant on run of river were excluded. The majority of the population fall within the ambit of those likely to be receiving a formal water supply. The remainder are deemed to be the “qualifying population”. For the purposes of the BHNR estimate the population was split into those regarded, by the Census, as urban and rural. Urban residents were then further broken down into settlement type. All urban residents, bar informal settlement dwellers, were deemed to have access to a formal water supply. Further, examination of the most recent relevant Integrated Development Planning documentation showed that on average about 75% of informal settlement share access to one or other type of formal water scheme. As such the BHNR dependant population was deemed to be those classified as rural and 25% of those deemed to be urban residents in informal settlements. It may be argued that this is a relatively crude classification. Certainly more detailed analysis of the population would probably reveal that:
  - many of those regarded as rural have access to fairly secure water sources that are not run of river; and
  - the notion that 25% of informal settlements do not receive formal water can be shown to be a gross simplification.
- There may be many informal settlements in which 100% access to a water supply scheme is achieved. Conversely some settlements may have no access. Ultimately the population deemed to be “qualifying” was recorded as being 954 373, or 14% of the total population.
- Having calculated the qualifying population per quaternary catchment the next step in determining the BHNR was to project the population to a target date. For the purposes of this exercise the population was projected to 2015. The population projection was done using generic growth rates applicable to the kinds of municipalities in the Upper Vaal area. Urban population figures were calculated at a growth rate of 2.2% per annum until 2015. In line with current trends it was assumed that there was no growth rate for the rural population.
- Total BHNR at 25 litres per day for the year 2008 was estimated at 502 225 MCM per day. As a rate of flow this would be 5.8 litres per second. Total BHNR at 50 litres per day for the year 2008 was estimated at 1 004/450 MCM per day. As a rate of flow this would be 11.6 litres per second.

Using these figures a BHNR for the qualifying population has been estimated and the cumulative BHNR of the Upper Vaal River catchment results are provided in the tables below, based on 2008 and 2015 population rates at 25 litres per day.

**Water required for the BHNR per quaternary expressed in m<sup>3</sup> per day based on 2008 qualifying population estimate at 25 litres per day**

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2008	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C11A	6208	25	155193.95	155.19	0.06		
		C11B	4006	25	100142.35	100.14	0.04		
C11C	RE EWR1	C11C	2127	25	53180.00	53.18	0.02	53.18	0.02
		C11D	1935	25	48375.63	48.38	0.02		
		C11E	7396	25	184896.60	184.90	0.07		
		C11F	12575	25	314373.89	314.37	0.11		
		C11G	3125	25	78116.15	78.12	0.03		
		C11H	11111	25	277765.46	277.77	0.10		
C11A - C11J [excl C11H]	EWR 1	C11J	6209	25	155230.16	155.23	0.06	1089.51	0.40
		C11K	2675	25	66866.07	66.87	0.02		
C11A - C11L	EWR 2	C11L	7350	25	183744.22	183.74	0.07	1617.88	0.59
		C11M	12236	25	305897.01	305.90	0.11		
		C12A	1018	25	25445.00	25.45	0.01		

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2008	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C12B	2747	25	68677.50	68.68	0.03		
		C12C	1825	25	45615.46	45.62	0.02		
		C12D	17389	25	434722.27	434.72	0.16		
		C12E	3497	25	87433.83	87.43	0.03		
		C12F	5497	25	137412.50	137.41	0.05		
		C12G	3297	25	82430.44	82.43	0.03		
ALL C11, ALL C13, C12A - C [excl C12H]	EWR 3	C12H	2443	25	61068.53	61.07	0.02	2607.90	0.95
		C12J	746	25	18645.00	18.65	0.01		
		C12K	2684	25	67107.50	67.11	0.02		
		C12L	4509	25	112714.73	112.71	0.04		
		C13A	3341	25	83532.50	83.53	0.03		
		C13B	3923	25	98062.50	98.06	0.04		
		C13C	3177	25	79431.36	79.43	0.03		
C13C - C13D	EWR 6	C13D	3420	25	85511.16	85.51	0.03	164.94	0.06
		C13E	1478	25	36955.00	36.96	0.01		
		C13F	2149	25	53727.50	53.73	0.02		
		C13G	2412	25	60307.24	60.31	0.02		
		C13H	1874	25	46849.88	46.85	0.02		
		C21A	4009	25	100219.61	100.22	0.04		
		C21B	4054	25	101362.36	101.36	0.04		
C21A - C21C	EWR 9	C21C	2701	25	67522.50	67.52	0.02	269.10	0.10
		C21D	41292	25	1032293.95	1032.29	0.38		
		C21E	14355	25	358883.92	358.88	0.13		
C21D - C21F	EWR 11	C21F	14918	25	372939.07	372.94	0.14	1764.12	0.64
C21A - C21G	EWR 10	C21G	9104	25	227604.54	227.60	0.08	2260.83	0.83
		C22A	111456	25	2786394.83	2786.39	1.02		
		C22B	56609	25	1415234.25	1415.23	0.52		
		C22C	26361	25	659029.19	659.03	0.24		
		C22D	19467	25	486669.39	486.67	0.18		
		C22E	15528	25	388198.92	388.20	0.14	12003.90	4.38
ALL C11, C12, C13, C81, C82, C83 [EXCL C22F]	EWR 4	C22F	15991	25	399766.15	399.77	0.15		
		C22G	4499	25	112478.46	112.48	0.04		
		C22H	46494	25	1162338.96	1162.34	0.42		
		C22J	11408	25	285195.52	285.20	0.10		
		C22K	17081	25	427034.40	427.03	0.16		
		C23A	864	25	21597.50	21.60	0.01		
		C23B	3108	25	77695.90	77.70	0.03		
		C23C	6509	25	162718.24	162.72	0.06		
		C23D	31882	25	797046.07	797.05	0.29		
		C23E	18742	25	468546.39	468.55	0.17		
		C23F	12202	25	305059.98	305.06	0.11		
C23F - C23G	RE EWR2	C23G	4221	25	105529.37	105.53	0.04	410.59	0.15
		C23H	9272	25	231797.52	231.80	0.08		
		C23J	8076	25	201890.55	201.89	0.07		
		C23K	3248	25	81202.40	81.20	0.03		
C23L	EWR 5	C23L	10844	25	271106.44	271.11	0.10	271.11	0.10
C81A	EWR 7	C81A	1455	25	36365.00	36.37	0.01	36.37	0.01
		C81B	2646	25	66140.33	66.14	0.02		
		C81C	1120	25	27995.15	28.00	0.01		
		C81D	849	25	21222.65	21.22	0.01		
		C81E	5228	25	130705.46	130.71	0.05		
		C81F	251283	25	6282087.18	6282.09	2.29		
		C81G	1719	25	42977.54	42.98	0.02		
		C81H	1306	25	32657.50	32.66	0.01		
		C81J	2625	25	65622.50	65.62	0.02		
		C81K	1606	25	40145.00	40.15	0.01		
		C81L	2679	25	66972.50	66.97	0.02		
		C81M	4274	25	106860.00	106.86	0.04		
		C82A	1854	25	46350.00	46.35	0.02		
		C82B	2882	25	72055.93	72.06	0.03		
ALL C81, C82A - C82C	EWR 8	C82C	1261	25	31525.00	31.53	0.01	7069.68	2.58
		C82D	2646	25	66145.00	66.15	0.02		
		C82E	1718	25	42952.50	42.95	0.02		
		C82F	1215	25	30362.50	30.36	0.01		
		C82G	1985	25	49627.50	49.63	0.02		
		C82H	1686	25	42162.11	42.16	0.02		
		C83A	6494	25	162360.14	162.36	0.06		
		C83B	2303	25	57582.36	57.58	0.02		
		C83C	10015	25	250376.38	250.38	0.09		
		C83D	3818	25	95450.00	95.45	0.03		
		C83E	2148	25	53702.50	53.70	0.02		
		C83F	3450	25	86261.94	86.26	0.03		
		C83G	3949	25	98729.01	98.73	0.04		

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2008	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C83H	2107	25	52674.74	52.67	0.02		
		C83J	1644	25	41108.08	41.11	0.02		
		C83K	1488	25	37200.00	37.20	0.01		
		C83L	2624	25	65592.50	65.59	0.02		
		C83M	3700	25	92496.37	92.50	0.03		

**Water required for the BHNR per quaternary expressed in m<sup>3</sup> per day based on 2015 qualifying population estimate at 25 litres per day**

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2015	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C11A	6282	25	157042.03	157.04	0.06		
		C11B	4018	25	100449.61	100.45	0.04		
C11C	RE EWR1	C11C	2127	25	53180.00	53.18	0.02	53.18	0.02
		C11D	1935	25	48377.38	48.38	0.02		
		C11E	7642	25	191047.56	191.05	0.07		
		C11F	13074	25	326858.56	326.86	0.12		
		C11G	3125	25	78121.28	78.12	0.03		
		C11H	11547	25	288662.94	288.66	0.11		
C11A - C11J [excl C11H]	EWR 1	C11J	6211	25	155272.55	155.27	0.06	1110.35	0.41
		C11K	2702	25	67541.29	67.54	0.02		
C11A - C11L	EWR 2	C11L	7380	25	184510.46	184.51	0.07	1651.06	0.60
		C11M	12814	25	320354.26	320.35	0.12		
		C12A	1018	25	25445.00	25.45	0.01		
		C12B	2747	25	68677.50	68.68	0.03		
		C12C	1857	25	46420.98	46.42	0.02		
		C12D	18787	25	469666.65	469.67	0.17		
		C12E	3499	25	87483.41	87.48	0.03		
		C12F	5497	25	137412.50	137.41	0.05		
		C12G	3339	25	83481.96	83.48	0.03		
ALL C11, ALL C13, C12A - C [excl C12H]	EWR 3	C12H	2615	25	65376.08	65.38	0.02	2661.54	0.97
		C12J	746	25	18645.00	18.65	0.01		
		C12K	2684	25	67107.50	67.11	0.02		
		C12L	4514	25	112853.73	112.85	0.04		
		C13A	3341	25	83532.50	83.53	0.03		
		C13B	3923	25	98062.50	98.06	0.04		
		C13C	3223	25	80586.28	80.59	0.03		
C13C - C13D	EWR 6	C13D	3420	25	85511.36	85.51	0.03	166.10	0.06
		C13E	1478	25	36955.00	36.96	0.01		
		C13F	2149	25	53727.50	53.73	0.02		
		C13G	2573	25	64330.74	64.33	0.02		
		C13H	1875	25	46868.37	46.87	0.02		
		C21A	4073	25	101827.97	101.83	0.04		
		C21B	4247	25	106173.22	106.17	0.04		
C21A - C21C	EWR 9	C21C	2701	25	67522.50	67.52	0.02	275.52	0.10
		C21D	45219	25	1130479.00	1130.48	0.41		
		C21E	15657	25	391436.50	391.44	0.14		
C21D - C21F	EWR 11	C21F	16477	25	411928.26	411.93	0.15	1933.84	0.71
C21A - C21G	EWR 10	C21G	9186	25	229653.46	229.65	0.08	2439.02	0.89
		C22A	126758	25	3168959.02	3168.96	1.16		
		C22B	65283	25	1632073.98	1632.07	0.60		
		C22C	29684	25	742094.66	742.09	0.27		
		C22D	20934	25	523340.19	523.34	0.19		
		C22E	15918	25	397946.80	397.95	0.15	12150.65	4.43
ALL C11, C12, C13, C81, C82, C83 [EXCL C22F]	EWR 4	C22F	17436	25	435893.43	435.89	0.16		
		C22G	4636	25	115891.69	115.89	0.04		
		C22H	52955	25	1323878.78	1323.88	0.48		
		C22J	11858	25	296460.76	296.46	0.11		
		C22K	18404	25	460089.74	460.09	0.17		
		C23A	864	25	21597.50	21.60	0.01		
		C23B	3110	25	77742.94	77.74	0.03		
		C23C	7039	25	175986.04	175.99	0.06		
		C23D	34727	25	868172.06	868.17	0.32		
		C23E	20078	25	501950.08	501.95	0.18		
		C23F	12229	25	305714.86	305.71	0.11		
C23F - C23G	RE EWR2	C23G	4221	25	105530.09	105.53	0.04	411.24	0.15
		C23H	10054	25	251359.87	251.36	0.09		

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2015	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C23J	8638	25	215941.14	215.94	0.08		
		C23K	3257	25	81416.70	81.42	0.03		
C23L	EWR 5	C23L	11098	25	277456.06	277.46	0.10	277.46	0.10
C81A	EWR 7	C81A	1455	25	36365.00	36.37	0.01	36.37	0.01
		C81B	2654	25	66347.71	66.35	0.02		
		C81C	1120	25	27995.17	28.00	0.01		
		C81D	849	25	21222.67	21.22	0.01		
		C81E	5586	25	139646.50	139.65	0.05		
		C81F	251791	25	6294778.90	6294.78	2.30		
		C81G	1774	25	44347.38	44.35	0.02		
		C81H	1306	25	32657.50	32.66	0.01		
		C81J	2625	25	65622.50	65.62	0.02		
		C81K	1606	25	40145.00	40.15	0.01		
		C81L	2679	25	66972.50	66.97	0.02		
		C81M	4274	25	106860.00	106.86	0.04		
		C82A	1854	25	46350.00	46.35	0.02		
		C82B	2938	25	73439.90	73.44	0.03		
ALL C81, C82A - C82C	EWR 8	C82C	1261	25	31525.00	31.53	0.01	7094.28	2.59
		C82D	2646	25	66145.00	66.15	0.02		
		C82E	1718	25	42952.50	42.95	0.02		
		C82F	1215	25	30362.50	30.36	0.01		
		C82G	1985	25	49627.50	49.63	0.02		
		C82H	1696	25	42392.82	42.39	0.02		
		C83A	6499	25	162473.70	162.47	0.06		
		C83B	2306	25	57655.56	57.66	0.02		
		C83C	10636	25	265911.72	265.91	0.10		
		C83D	3818	25	95450.00	95.45	0.03		
		C83E	2148	25	53702.50	53.70	0.02		
		C83F	3451	25	86263.90	86.26	0.03		
		C83G	4116	25	102901.30	102.90	0.04		
		C83H	2152	25	53808.41	53.81	0.02		
		C83J	1839	25	45978.29	45.98	0.02		
		C83K	1488	25	37200.00	37.20	0.01		
		C83L	2624	25	65592.50	65.59	0.02		
		C83M	3776	25	94395.44	94.40	0.03		

## MANAGEMENT RESOURCE UNITS AND EWR SITES

Resource Units (RUs) are required as it would not be appropriate to set the same numerical Reserve for the headwaters of a river as for the lowland reaches. The breakdown of a catchment into RUs for the purpose of determining the Reserve for rivers is therefore done primarily on a biophysical basis within the catchment and called Natural Resource Units (NRUs). Management requirements (DWAf, 1999, volume 3) also play a role in the delineation. Furthermore, the type of disturbance/impact on river plays a role to select homogenous river reaches from a biophysical basis under present circumstances. These are called Management Resource Units (MRUs). MRUs can be further delineated in even smaller assessment units called Reserve Assessment Units (RAUs). It is preferred that a EWR site is selected within each MRU, and if a RAU occurs within the MRU, the EWR should, if possible, be selected within the RAU.

The results of the delineation are summarized in the table below and illustrated in the map.

### Description of MRUs

MRU	Delineation	Quaternary catchment
<b>VAAL RIVER</b>		
MRU Vaal A	From the origin to the Klein Vaal confluence.	C11A, C11B
MRU Vaal B	Klein Vaal confluence to Grootdraai Dam.	C11E, C11J, C11L
RUA Vaal B.1	Extensive rapids and riffles upstream of Grootdraai Dam and downstream of the Skulpspruit confluence.	C11J
MRU Vaal C	Grootdraai Dam to Vaal Dam.	C11L, C11M, C12B, C12C, C12H, 12L
RAU Vaal C.1	Riffle section immediately below Grootdraai Dam.	C11L
MRU Vaal D	Vaal Dam to Barrage.	C22F, C22K
MRU Vaal E	Barrage to end of Water Management Area (WMA).	C23B, C23C, C23L
<b>KLEIN VAAL RIVER</b>		





MRU	Delineation	Quaternary catchment
MRU Klein Vaal A	Origin of the river to the end of the Lower Foothills.	C11C
MRU Klein Vaal B	Beginning of Lowland geomorphological zone to Vaal River confluence.	C11C, C11D
<b>KLIP RIVER</b>		
MRU Klip A	Origin of Klip River to end of the Lower Foothill zone and start of the Lowland zone.	C13C
MRU Klip B	Lowland geomorphological zone to Lower Foothill zone.	C13C, C13D
MRU Klip C	Lower Foothill geomorphic zone to Lowland zone.	C13D
MRU Klip D	Lowland geomorphological zone to the confluence with the Vaal.	C13D, C13F, C13H
<b>WILGE RIVER</b>		
MRU Wilge A	Origin of Wilge River to confluence with the Nuwejaarspruit.	C81A, C81B
MRU Wilge B	Nuwejaarspruit to the Holspruit.	C81E, C81K, C82C, C82G
MRU Wilge C	Holspruit to the Liebenbergsvlei River confluence.	C82G, C82H
<b>LIEBENBERGsvLEI RIVER</b>		
MRU Lieb A	Origin of the Liebenbergsvlei River to end of the As River confluence.	C83A
MRU Lieb B	As River to the Wilge River confluence.	C83C
<b>WATERVAL RIVER</b>		
MRU Waterval A	Origin of the river to the Boesmanspruit confluence.	C12D, C12F
MRU Waterval B	Boesmanspruit to the Vaal River confluence.	C12F, C12G
<b>SUIKERBOSRAND RIVER and BLESBOKSPRUIT</b>		
MRU Suiker A	Origin of river to confluence with Blesbokspruit.	C21A, C21B, C21C
MRU Suiker B	Blesbokspruit to Vaal River confluence.	C21G
MRU Bles A	Blesbokspruit.	C21D, C21E, C21F
<b>MOOI RIVER</b>		
MRU Mooi A	Origin of river to Klerkskraal Dam.	C23F
MRU Mooi B	Klerkskraal Dam to Boskop Dam.	C23G
MRU Mooi C	Boskop Dam to the Vaal River.	C23H, C23L




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 perennial system since they are still able to function or at least maintain life during periods of no flow.


Details regarding the sites selected are provided in the table and figure below.

**Locality and characteristics of the Upper Vaal EWR sites**

Site information	EWR sites	Illustration
EWR nr and name	<b>EWR 1 Uitkoms</b>	
River	Vaal	
National RHP site	C1Geel_Unspe	
Decimal Degrees	-26.8728, 29.61384	
Decimal Minutes	S26 52.368, E29 36.830	
EcoRegion (Level II)	11.05	
Geomorphic Zone	Lowland	
Altitude (m)	1570	
RU	MRU Vaal B.1	
Quaternary	C11J	
Farm name	Uitkoms 489	
Hydrological gauge	C1H007	
EWR nr and name	<b>EWR 2 Grootdraai</b>	
River	Vaal	
National RHP site	C1Vaal Braks	
Decimal Degrees	-26.9211, 29.27929	
Decimal Minutes	S26 55.266, E29 16.758	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lowland	
Altitude (m)	1537	
RU	MRU Vaal C.1	
Quaternary	C11L	
Farm name	Verblyden 387	
Hydrological gauge	C1H019	
EWR nr and name	<b>EWR 3 Gladdedrift</b>	
River	Vaal	
National RHP site	C1Vaal-Villie	
Decimal Degrees	26.99087, 28.72971	
Decimal Minutes	S26 59.452, E28 43.783	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lowland	
Altitude (m)	1487	
RU	MRU Vaal C.1	
Quaternary	C12H	
Farm name	Groenfontein 262	
Hydrological gauge	C1H012	
EWR nr and name	<b>EWR 4 De Neys</b>	
River	Vaal	
National RHP site	C2Vaal-Deny	
Decimal Degrees	-26.8426, 28.1123	
Decimal Minutes	S26 50.557, E28 06.738	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1445	
RU	MRU Vaal D	
Quaternary	C22F	
Farm name	Veekraal 762/Zoekfontein 468(Benchmark)	
Hydrological gauge	C2H122	

Site information	EWR sites	Illustration
EWR nr and name	<b>EWR 5 Skandinavia</b>	
River	Vaal	
National RHP site	-	
Decimal Degrees	-26.9324, 27.01367	
Decimal Minutes	S26 55.946, E27 00.820	
EcoRegion (Level II)	11.08	
Geomorphic Zone	Lowland	
Altitude (m)	1309	
RU	MRU Vaal E	
Quaternary	C23L	
Farm name	Farm 396 Prospect	
Hydrological gauge	C2H018	
EWR nr and name	<b>RE-EWR 1 Klein Vaal</b>	
River	Klein Vaal	
National RHP site	C1KVaal-unspe	
Decimal Degrees	-26.9128, 30.17497	
Decimal Minutes	S26 54.765, E30 10.498	
EcoRegion (Level II)	11.02	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1620	
RU	MRU Kvaal A	
Quaternary	C11C	
Farm name	-	
Hydrological gauge	-	
EWR nr and name	<b>EWR 6 Klip</b>	
River	Klip River	
National RHP site	C1Klip-Unspe2	
Decimal Degrees	-27.3617, 29.48503	
Decimal Minutes	S27 21.700, E29 29.102	
EcoRegion (Level II)	11.06	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1593	
RU	MRU Klip C	
Quaternary	C13D	
Farm name	-	
Hydrological gauge	-	
EWR nr and name	<b>EWR 7 Upper Wilge</b>	
River	Wilge River	
National RHP site	C8Wilg-Belwh	
Decimal Degrees	-27.8002, 28.76778	
Decimal Minutes	S27 48.010, E28 46.067	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lowland	
Altitude (m)	1573	
RU	MRU Wilge A	
Quaternary	C82C	
Farm name	-	
Hydrological gauge	-	

Site information	EWR sites	Illustration
EWR nr and name	<b>EWR 8 Bavaria</b>	
River	Wilge	
National RHP site	-	
Decimal Degrees	-	
Decimal Minutes	-	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lowland	
Altitude (m)	-	
RU	MRU Wilge A	
Quaternary	-	
Farm name	-	
Hydrological gauge	-	
EWR nr and name	<b>EWR 9 Suikerbos US</b>	
River	Suikerbosrand	
National RHP site	C2Suik-Dehoe	
Decimal Degrees	-26.6467, 28.38197	
Decimal Minutes	S26 38.802, E28 22.918	
EcoRegion (Level II)	11.01	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1509	
RU	MRU Suiker A	
Quaternary	C21C	
Farm name	Modderfontein 410(benchmark)/Dehoek 411	
Hydrological gauge	-	
EWR nr and name	<b>EWR 10 Suikerbos DS</b>	
River	Suikerbosrand	
National RHP site	close to C2Suik-Badfo	
Decimal Degrees	-26.6814, 28.16798	
Decimal Minutes	S26 40.882, E28 10.079	
EcoRegion (Level II)	11.01	
Geomorphic Zone	Lowland	
Altitude (m)	1453	
RU	MRU Suiker B	
Quaternary	C21G	
Farm name	Goedverwachting 442	
Hydrological gauge	-	
EWR nr and name	<b>EWR 11 Blesbokspruit</b>	
River	Blesbokspruit	
National RHP site	C2Bles-Marai (locality incorrect)	
Decimal Degrees	-26.4789, 28.42488	
Decimal Minutes	S26 28.735, E28 25.493	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1528	
RU	MRU Bles A	
Quaternary	C21F	
Farm name	Maraisdrift 190	
Hydrological gauge	-	

Site information	EWR sites	Illustration
EWR nr and name	<b>RE-EWR 2 Mooi</b>	
River	Mooi River	
National RHP site	Close to C2Mooi-Klerk	
Decimal Degrees	-26.2587, 27.15973	
Decimal Minutes	S26 15.520, E27 09.584	
EcoRegion (Level II)	11.01	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1457	
RU	MRU Mooi B	
Quaternary	C23G	
Farm name	Varkenskraal 93	
Hydrological gauge		

MANAGEMENT RESOURCE UNITS (AND RESERVE ASSESSMENT UNITS)



Locality of EWR sites and MRUs of the Upper Vaal WMA

**ECOCLASSIFICATION (LEVEL 4) OF EWR SITES**

The procedure for the EcoClassification of the rivers and physico-chemical input was according to the revised methods for rivers as outlined in Louw and Hughes (2002), and the EcoClassification manual version 2 (Kleynhans and Louw, 2007) for the EWR sites in the Upper Val River WMA. The approach consisted broadly of the following steps:

- Determine reference conditions for each component.
- Determine PES for each component as well as for the EcoStatus.
- Determine the trend for each component as well as for the EcoStatus.
- Determine reasons for PES and whether these are flow or non-flow related.
- Determine the Ecological Importance and Sensitivity (EIS) for the biota and habitat.
- Considering the PES and the EIS, suggest a realistic Recommended Ecological Category (REC) for each component as well as for the EcoStatus.
- Determine alternative Ecological Categories (ECs) for each component as well as for the EcoStatus.

The EcoClassification results are summarised in the table below

**EcoClassification results – Upper Vaal River System**

EWR 1: UITKOMS (VAAL RIVER)																																																																						
<p><b>EIS: HIGH</b> Presence of rare and endangered <i>Labeobarbus kimberleyensis</i> and diversity of habitat.</p> <p><b>PES: B/C</b> Combination of flow and non-flow related impacts. Flow related impacts are mainly due to interbasin transfers (Heysope and Zaaihoek). Mining and agricultural activities in area has caused water quality deterioration and erosion.</p> <p><b>REC: B/C</b> The EIS at EWR 1 is <b>HIGH</b> and the PES warrants an improvement. An improvement in the PES EcoStatus would mean that fish and macroinvertebrates must improve from a C to a B EC. No improvement in riparian vegetation is needed as the current EC is an A/B. An improvement in the biotic component EC is dependent on <b>water quality</b> changes and not flow related issues. It seems that the water quality at this site is problematic as the fish show signs of serious bacterial infection and quality sensitive macroinvertebrates are absent. Diatoms also indicate that water quality is impaired; however, it is not certain what the water quality problems are. To improve the EC therefore, the water quality problems must be identified to determine how it can be addressed. As no improvement in flow is required, no EWR for the REC will be undertaken.</p> <p><b>AEC down 1: C</b> A hydrological regime with <b>increased</b> base flows for longer periods of time in the winter (longer than present transfer) as well as fluctuations in temperature.</p> <p><b>AEC down 2: C</b> A hydrological regime with <b>decreased</b> base flows below natural (no transfers) with potential for some low flows. Decreased moderate floods. Deteriorated water quality due to increased impacts of mining.</p>																																																																						
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EWR 2: GROOTDRAAI (VAAL RIVER)																																																																																					
<p><b>EIS: MODERATE</b>  <b>PES: C</b>                      Combination of flow and non-flow related impacts. Impacts mostly related to changes in flow regime due to Grootdraai Dam.  <b>REC: C</b>                      Maintain the PES due to the <b>MODERATE</b> EIS rating. However note that there is rare and endangered <i>Labeobarbus kimberleyensis</i> present which warrants improvement of the fish EC.  <b>AEC up: B</b>                      This ecological scenario is important due to the presence of <i>L. kimberleyensis</i>.                      Change in the operation of Grootdraai dam, which includes the release of flows (base flows) with more natural seasonal patterns and the release of moderate floods to remove fines and no bottom releases.  <b>AEC down: C/D</b>                      Less spilling (i.e. less floods) and decreased base flows. Increased bottom releases.</p>		<table border="1"> <thead> <tr> <th colspan="2">IHI</th> <th>Driver Components</th> <th>PES and REC Category</th> <th>Trend</th> <th>AEC↑</th> <th>AEC↓</th> </tr> </thead> <tbody> <tr> <td rowspan="3">I N S T R E A M</td> <td rowspan="3">D</td> <td>RIPARIAN</td> <td>C</td> <td></td> <td></td> <td></td> </tr> <tr> <td>HYDROLOGY</td> <td>D</td> <td></td> <td></td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>B/C</td> <td>Negative</td> <td>B</td> <td>B/C</td> </tr> <tr> <td></td> <td></td> <td>GEOMORPHOLOGY</td> <td>D</td> <td>Stable</td> <td>D</td> <td>D/E</td> </tr> <tr> <th colspan="2">IHI Hydro</th> <th>Diatoms</th> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>AEC↑</th> <th>AEC↓</th> </tr> <tr> <td>E</td> <td></td> <td>C</td> <td>FISH</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td></td> <td>MACRO INVERTEBRATES</td> <td>C</td> <td>Stable</td> <td>B/C</td> <td>C/D</td> </tr> <tr> <td></td> <td></td> <td></td> <td>INSTREAM</td> <td>C</td> <td></td> <td>B/C</td> <td>C/D</td> </tr> <tr> <td></td> <td></td> <td></td> <td>RIPARIAN VEGETATION</td> <td>B/C</td> <td>Stable</td> <td>B</td> <td>C</td> </tr> <tr> <td></td> <td></td> <td></td> <td>ECOSTATUS</td> <td>C</td> <td></td> <td>B</td> <td>C/D</td> </tr> </tbody> </table>					IHI		Driver Components	PES and REC Category	Trend	AEC↑	AEC↓	I N S T R E A M	D	RIPARIAN	C				HYDROLOGY	D				WATER QUALITY	B/C	Negative	B	B/C			GEOMORPHOLOGY	D	Stable	D	D/E	IHI Hydro		Diatoms	Response Components	PES Category	Trend	AEC↑	AEC↓	E		C	FISH	C	Stable	B	D				MACRO INVERTEBRATES	C	Stable	B/C	C/D				INSTREAM	C		B/C	C/D				RIPARIAN VEGETATION	B/C	Stable	B	C				ECOSTATUS	C		B	C/D
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<p><b>EIS: MODERATE</b>  <b>PES: C</b>                      Combination of flow and non-flow related impacts. Impacts mostly related to changes in flow regime due to Grootdraai Dam, illegal irrigation, livestock farming and vegetation removal.  <b>REC: C</b>                      Maintain the PES due to the <b>MODERATE</b> EIS rating. However note that there is rare and endangered <i>Labeobarbus kimberleyensis</i> present which warrants improvement of the fish EC.  <b>AEC Up: B</b>                      Improved base flows (no zero flows), and increased frequency of moderate floods.                      Improved water quality due to improved flow regime.                      Removal of cattle grazing in the marginal zone.  <b>AEC Down: C/D</b>                      Increased duration of zero flow periods.                      Decreased frequency of floods.                      Very low base flows in the dry season when flowing.                      Associated water quality deterioration.</p>		<table border="1"> <thead> <tr> <th colspan="2">IHI</th> <th>Driver Components</th> <th>PES and REC Category</th> <th>Trend</th> <th>AEC↑</th> <th>AEC↓</th> </tr> </thead> <tbody> <tr> <td rowspan="3">I N S T R E A M</td> <td rowspan="3">C</td> <td>RIPARIAN</td> <td>C</td> <td></td> <td></td> <td></td> </tr> <tr> <td>HYDROLOGY</td> <td>C</td> <td></td> <td></td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>C</td> <td>Stable</td> <td>B/C</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td>GEOMORPHOLOGY</td> <td>C</td> <td>Stable</td> <td>C</td> <td>D</td> </tr> <tr> <th colspan="2">IHI Hydro</th> <th>Diatoms</th> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>AEC↑</th> <th>AEC↓</th> </tr> <tr> <td>C</td> <td></td> <td>C</td> <td>FISH</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td></td> <td>MACRO INVERTEBRATES</td> <td>C</td> <td>Stable</td> <td>B/C</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td></td> <td>INSTREAM</td> <td>C</td> <td></td> <td>B</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td></td> <td>RIPARIAN VEGETATION</td> <td>C</td> <td>Stable</td> <td>B</td> <td>C</td> </tr> <tr> <td></td> <td></td> <td></td> <td>ECOSTATUS</td> <td>C</td> <td></td> <td>B</td> <td>C/D</td> </tr> </tbody> </table>					IHI		Driver Components	PES and REC Category	Trend	AEC↑	AEC↓	I N S T R E A M	C	RIPARIAN	C				HYDROLOGY	C				WATER QUALITY	C	Stable	B/C	D			GEOMORPHOLOGY	C	Stable	C	D	IHI Hydro		Diatoms	Response Components	PES Category	Trend	AEC↑	AEC↓	C		C	FISH	C	Stable	B	D				MACRO INVERTEBRATES	C	Stable	B/C	D				INSTREAM	C		B	D				RIPARIAN VEGETATION	C	Stable	B	C				ECOSTATUS	C		B	C/D
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EWR 4: DE NEYS (VAAL RIVER)																																																																																					
<p><b>EIS: HIGH</b>                      The presence of the rare and endangered <i>Labeobarbus kimberleyensis</i>.                      The Vaal River being a large river, which is rare in South Africa.                      The diversity of riparian and instream habitats which include runs, rocky outcrops and rapids as well as pools.                      Important refugia such as pools.                      Being the only area between the Vaal Dam and barrage where yellowfish can breed.  <b>PES: C</b>                      Impacts are mostly due to flow related problems, especially the presence of Vaal Dam and lack of flow variability. Increased base flows (dry season) occur as well as reduced frequencies of moderate floods due to releases from the Vaal Dam to maintain a target TDS concentration of 600 mg/l downstream of Vaal Barrage. .  <b>REC: B/C</b>                      Improvement of PES due to <b>HIGH</b> EIS rating. A B EcoStatus could not be attained due to the limited operational possibilities from the Vaal Dam. Scenario includes improvement of seasonal variability (decreased base flows during the dry season and increased wet season flows above the current base flows).  <b>AEC Down: D</b>                      Increased constant base flows if salinity problems are exacerbated leading to a loss of variability.                      Decreased frequency of floods.</p>		<table border="1"> <thead> <tr> <th colspan="2">IHI</th> <th>Driver Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC↓</th> </tr> </thead> <tbody> <tr> <td rowspan="3">I N S T R E A M</td> <td rowspan="3">D</td> <td>RIPARIAN</td> <td>D</td> <td></td> <td></td> <td></td> </tr> <tr> <td>HYDROLOGY</td> <td>D/E</td> <td></td> <td></td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>C</td> <td>Stable</td> <td>C</td> <td>C/D</td> </tr> <tr> <td></td> <td></td> <td>GEOMORPHOLOGY</td> <td>D</td> <td>Stable</td> <td>D</td> <td>D</td> </tr> <tr> <th colspan="2">IHI Hydro</th> <th>Diatoms</th> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>AEC↑</th> <th>AEC↓</th> </tr> <tr> <td>C</td> <td></td> <td>C</td> <td>FISH</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td></td> <td>MACRO INVERTEBRATES</td> <td>C/D</td> <td>Stable</td> <td>C</td> <td>C/D</td> </tr> <tr> <td></td> <td></td> <td></td> <td>INSTREAM</td> <td>C</td> <td></td> <td>B/C</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td></td> <td>RIPARIAN VEGETATION</td> <td>C</td> <td>Stable</td> <td>B/C</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td></td> <td>ECOSTATUS</td> <td>C</td> <td></td> <td>B/C</td> <td>D</td> </tr> </tbody> </table>					IHI		Driver Components	PES Category	Trend	REC	AEC↓	I N S T R E A M	D	RIPARIAN	D				HYDROLOGY	D/E				WATER QUALITY	C	Stable	C	C/D			GEOMORPHOLOGY	D	Stable	D	D	IHI Hydro		Diatoms	Response Components	PES Category	Trend	AEC↑	AEC↓	C		C	FISH	C	Stable	B	D				MACRO INVERTEBRATES	C/D	Stable	C	C/D				INSTREAM	C		B/C	D				RIPARIAN VEGETATION	C	Stable	B/C	D				ECOSTATUS	C		B/C	D
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EWR 5: SCANDINAVIA (VAAL RIVER)																																																																													
<b>EIS: HIGH</b> Presence of rare and endangered <i>Labeobarbus kimberleyensis</i> , and Rand Highveld Grassveld vegetation type. Most importantly, this site falls within the Vredefort Dome World Heritage Site and the river is an important feature within this World Heritage Site.																																																																													
<b>PES: C/D</b> Combination of flow and non-flow related impacts. Flow related impacts include increased base flows and reduced frequency of moderate floods due to Vaal Dam and Barrage and releases to regulated TDS levels. Non-flow related impacts include agriculture, and urban sewage and industrial waste and the occurrence of gauges, weirs and dams in the system.																																																																													
<b>REC: C</b> Improvement of the PES due to <b>HIGH</b> EIS rating. A B/C EcoStatus could not be attained due to the limited operational possibilities from the Vaal Dam. Scenario includes decreased base flows for 3 days (during winter) (to improve macroinvertebrates EC) and increased moderate floods in the wet season.																																																																													
<b>AEC down: D</b> Increased base flows. Possibility of further decrease of floods due to the development in tributaries and increased return flows.																																																																													
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		RIPARIAN VEGETATION	D	Negative	C	-D																																																																							
		ECOSTATUS	C/D		C	D																																																																							

EWR 6: KLIP (KLIP RIVER)																																																																			
<b>EIS: MODERATE</b> Combination of flow and non-flow related impacts. Flow related impacts include reduced base flows and moderate floods due to weirs and farm dams. Non-flow related impacts include agriculture, cattle grazing, and alien vegetation. The sole reason for the PES not being a B EcoStatus is the current vegetation EC (B/C EC) due to the high proportion of exotic species																																																																			
<b>PES: B/C</b> The EIS at EWR 6 is <b>MODERATE</b> and the REC is to maintain the PES.																																																																			
<b>REC: B/C</b> A B EC can be achieved by removal of alien vegetation. Improving flows will not improve the vegetation.																																																																			
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EWR 7: UPPER WILGE (WILGE RIVER)																																																																			
<b>EIS : HIGH</b> There are rare and endangered species i.e. the flufftail crowned crane, bald ibis, and 11 red data vegetation species. There is a good diversity of habitats that include wetlands, flood plains, oxbow lakes and peat lands.																																																																			
<b>PES: A/B</b> Non-flow related impacts that include small dams for agriculture and exotic fish species (MSAL).																																																																			
<b>REC A/B</b> As the PES is also relatively high, the attainable and realistic objective is to maintain the PES even though a <b>HIGH</b> EIS would normally warrant improvement.																																																																			
<b>AEC Down: C</b> The scenario includes decreased low flows, some periods of zero flows and decreased moderate floods.																																																																			
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		INSTREAM	B		C																																																														
		RIPARIAN VEGETATION	A/B	Stable	B/C																																																														
		ECOSTATUS	A/B		C																																																														

**EWR 8: BAVARIA (WILGE RIVER)**

**EIS: MODERATE**  
**PES: C**  
 Flow related impacts include alteration of hydrological regime due to interbasin transfers from Sterkfontein Dam, abstraction and agriculture. Non-flow related impacts include water quality problems, erosion and exotic species invasion.  
**REC: C.**  
 Maintain the PES due to the **MODERATE** EIS rating.  
**AEC Up: B/C**  
 Dry season base flow increase and no zero flows.  
 Ongoing improved management of the Sterkfontein Dam releases.  
 Reduced grazing, burning and removal of debris.  
 Removal of MSAL (although highly impractical, without this removal, the fish EC will not improve).  
**AEC Down: D**  
 Further decrease of base flows (e.g. an additional dam).  
 Decrease in small moderate floods.  
 Associated water quality deterioration.

IHI		Driver Components	PES and REC Category	Trend	AEC ↑	AEC ↓
I N S T R E A M	C / D	RIPARIAN	C			
		HYDROLOGY	D			
		WATER QUALITY	C	Stable	B/C	C/D
		GEOMORPHOLOGY	C	Positive	+C	C/D
IHI Hydro	Diatoms	Response Components	PES Category	Trend	AEC ↑	AEC ↓
C	C/D	FISH	C	Stable	B	D
		MACRO INVERTEBRATES	C/D	Stable	C	D
		INSTREAM	C		B/C	D
		RIPARIAN VEGETATION	C	Stable	B/C	D
		ECOSTATUS	C		B/C	D

**EWR 9: SUIKERBOS US (SUIKERBOSRAND RIVER)**

**EIS: HIGH**  
 There are endangered species at this site, which includes *Labeobarbus kimberleyensis* and the Soweto Highveld grassland vegetation type (conservation status: endangered).  
**PES: C**  
 Combination of flow and non-flow related impacts. Flow related impacts include altered flow regime due to Balfour and Harhoff Dams and non-flow related impacts include deteriorated water quality due to WWTW and agriculture, erosion and alien species (fish and vegetation).  
**REC: B/C**  
 Improvement of the PES due to **HIGH** EIS rating.  
 An improvement is based on increased base flows (released from upstream dams) as well as erosion control measures in the tributaries to address erosion and increased sediment loads in the reach and alien woody vegetation control.  
**AEC Down: D**  
 This scenario was not developed as the macroinvertebrates and fish are already in a D EC. A D AEC would involve the maintenance of the current ECs of fish and macroinvertebrates and a deterioration of the riparian vegetation EC. Any flow related changes will however cause deterioration in the riparian vegetation EC and would result in the instream and biota ECs to drop to an E.

IHI		Driver Components	PES Category	Trend	REC
I N S T R E A M	C	RIPARIAN	B		
		HYDROLOGY	E		
		WATER QUALITY	C/D	Negative D	C
		GEOMORPHOLOGY	B/C	Negative C	B
IHI Hydro	Diatoms	Response Components	PES Category	Trend	REC
B	C	FISH	D	Stable	C
		MACRO INVERTEBRATES	D	Stable	C
		INSTREAM	D		C
		RIPARIAN VEGETATION	B/C	Negative C/D	B
		ECOSTATUS	C		B/C

**EWR 10: SUIKERBOS DS (SUIKERBOSRAND RIVER)**

**EIS: MODERATE**  
**PES: C/D**  
 Combination of flow and non-flow related impacts. Flow related impacts include elevated base flow and increased floods due to mining, SAPPI, urban runoff and Blesbokspruit input. Non-flow related impacts include deteriorated water quality due to industries, agriculture and urban activities; erosion, and exotic alien invasion (fish and vegetation).  
**REC: C/D**  
 Maintain the PES due to the **MODERATE** EIS rating.  
**AEC up: C**  
 Improved water quality management in the Blesbokspruit catchment. The biotic condition of the biota will improve under this scenario although no improvement will be evident in the riparian vegetation component. The riparian vegetation EC is associated with increased flows rather than water quality. **NOTE:** The recommendations at EWR 9 are to improve the low flows in the dry season. This could increase flows to the level that is problematic at EWR 10. This will have to be treated as a scenario in a systems context and evaluated.  
**AEC down: D**  
 The scenario is increased base flows.

IHI		Driver Components	PES and REC Category	Trend	AEC ↑	AEC ↓
I N S T R E A M	C	RIPARIAN	C			
		HYDROLOGY	D			
		WATER QUALITY	D/E	Negative	D	D/E
		GEOMORPHOLOGY	C	Negative C	C	-C
IHI Hydro	Diatoms	Response Components	PES Category	Trend	REC	AEC ↓
B	C/D	FISH	C/D	Stable	C	D
		MACRO INVERTEBRATES	C/D	Stable	C	D
		INSTREAM	C/D		C	D
		RIPARIAN VEGETATION	C	Negative D	C	D
		ECOSTATUS	C/D		C	D

EWR 11: BLESBOKSPRUIT (BLESBOKSPRUIT RIVER)							
<p><b>EIS: LOW</b> Site is characterised by water quality problems and elevated flows.</p> <p><b>PES: D</b> Mainly non-flow related impacts that include increased base flows and floods due to mine water decants, urban runoff, agriculture and return flows from WWTW. Water quality is also heavily impacted due to these activities and erosion has increased. Alien fish species occur.</p> <p><b>REC: D</b> Maintain the PES due to the <b>LOW</b> EIS rating, <b>with invertebrates improving to D</b>.</p> <p>An improved EcoStatus based on a hypothetical flow regime is not feasible at this site. Decreased flows as a scenario is unattainable and will result in deteriorated water quality.</p> <p>The improvement of the macroinvertebrate EC is only possible with improved water quality. Improved water quality is only possible with better water quality management, which is unlikely, but feasible at a cost. Due to the huge amount of salts in the system, this improvement will only be a long term option.</p> <p>The implications for setting flows are the following: Flow requirements to maintain the present state would be based on present flows. Only increased flows can be evaluated as a scenario to determine whether increased flows (with either improved or the same water quality) will maintain the EcoStatus.</p>							
I N S T R E A M	D / E	R I P A R I A N	C	Driver Components	PES Category	Trend	REC
				HYDROLOGY	D/E		
				WATER QUALITY	D/E	Negative D/E	D
				GEOMORPHOLOGY	C	Negative C/D	C
IHI Hydro	Diatoms	Response Components	PES Category	Trend	REC		
E	C/D	FISH	D	Stable	C		
		MACRO INVERTEBRATES	D/E	Stable	D		
		INSTREAM	D/E		C/D		
		RIPARIAN VEGETATION	D	Negative D/E	D		
		ECOSTATUS	D		D		

RE-EWR 1: KLEIN VAAL						
<p><b>EIS: MODERATE</b> <b>PES: C</b> Flow related impacts include interbasin transfer and abstraction altering hydrological regime. Non-flow related impacts include deterioration in water quality, increased erosion due to cattle and agricultural activities. Loss of habitat due to farm dams.</p> <p><b>REC: C</b> Maintain the PES due to the <b>MODERATE</b> EIS rating. The C EcoStatus is due to the riparian vegetation EC of a D as the instream EC is an A/B. The riparian vegetation PES is due to non-flow related impacts (grazing and trampling) and highly likely a very localised impact.</p> <p><b>AEC down: C/D</b> A hydrological regime with decreased base flows. Increased periods of zero flows during dry season.</p>						
I N S T R E A M	B	R I P A R I A N	B	Driver Components	PES and REC Category	AEC↓
				HYDROLOGY	A/B	
				WATER QUALITY	B/C	B/C
				GEOMORPHOLOGY	B/C	B/C
IHI Hydro	Diatoms	Response Components	PES Category	REC		
A/B	B	FISH	B	C		
		MACRO INVERTEBRATES	A/B	C		
		INSTREAM	A/B	C		
		RIPARIAN VEGETATION	D	D		
		ECOSTATUS	C	C/D		

RE-EWR 2: MOOI RIVER					
<p><b>EIS: LOW</b> <b>PES: D</b> This naturally would have been a wetland with a badly defined channel. Wetland tools were used to represent the driver state and the river tools used to assess the responses.</p> <p>Some very rare constricted areas with small riffles occur. This site is downstream of the dam and about the only one with remnants of wetland intact. This is a short section. The rest of the MRU is very badly degraded and would be in a lower category. Downstream of the Wonderfontein inflow, the bad water quality would be the overriding concern. The PES is in a D and the rest of the MRU would be in an E or even lower. It will not be possible to improve the category by improving flows as the fish is already in a C EC and the riparian vegetation EC is due to non-flow related impacts. However, the macroinvertebrate EC might improve to at least a D with some improved flow.</p>					
	Driver Components	PES Category	Diatoms		
	HYDROLOGY	E	C		
	WATER QUALITY	C/D			
	WETLAND HABITAT INTEGRITY	E			
	Response Components	PES Category			
	FISH	C			
	MACRO INVERTEBRATES	E			
	INSTREAM	D			
	RIPARIAN VEGETATION	D			
	ECOSTATUS	D			

## EWR SCENARIO ASSESSMENT

This task consisted of determining the EWR for different ecological river states, i.e. different Ecological Categories. The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O'Keeffe *et al.*, 2002), a modification of the Building Block Methodology (BBM) (King and Louw, 1998) was used to determine the low (base) flow EWRs at 2, 3, 6, 7, 8, and 9. The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM. These results generated form the basis against which the ecological consequences of operational flow scenarios will be tested during a further task in this study.

RE-EWR 1 and 2 was assessed at Rapid level for low flows and therefore the HFSR method for setting low flows were not applied to this site. The Reserve was estimated using the Hughes Desktop Reserve Model for the Ecological Category (EC) set. Therefore for the low flow requirements, the estimated Reserve was verified and the DRM was adjusted if needed. High flows were set using the standard Comprehensive approach.

Five EWR sites (EWR 1, 4, 5, 10 and 11) were identified as having more flows than natural. Therefore the standard Habitat Flow Stressor Response method approach could not be applied to these sites to determine low flow requirements for the EWR scenarios. The HFSR method was refined to cater for these situations by Ms Delana Louw with input from all the specialists and the general approach is provided in detail in Report RDM/WMA8C000/01/CON/0209; Chapter 14.

The results are summarised in the table below for the different EWR sites as a percentage of the natural Mean Annual Runoff (nMAR).

### Upper Vaal WMA: EWR scenario results

EWR site	nMAR	PMAR	%PMAR OF nMAR	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
	MCM	MCM	MCM		MCM	% nMAR	MCM	% nMAR	MCM	% nMAR	MCM	% nMAR
<b>Virgin MAR</b>												
EWR 2	457.70	267.12	58%	C PES, REC	30.21	6.6	5.03	1.1	32.04	7	58.13	12.7
				B AEC up	0.00	11.3	0.00	1.1	0.00	7.6	0.00	16.2
				C/D AEC down	14.19	3.1	5.03	1.1	28.38	6.2	43.48	9.5
EWR 3	858.10	603.09	70%	C PES, REC	90.96	10.6	7.72	0.9	31.75	3.7	125.28	14.6
				B AEC up	90.96	10.6	7.72	0.9	31.75	3.7	125.28	14.6
				C/D AEC down	38.61	4.5	7.72	0.9	27.46	3.2	75.51	8.8
EWR 6	95.30	84.53	89%	B/C PES, REC	17.54	18.4	17.54	18.4	7.72	8.1	22.30	23.4
				C AEC down	8.39	8.8	1.62	1.7	6.19	6.5	14.20	14.9
EWR 7	23.50	23.50	100%	B/C PES, REC	8.18	34.8	0.66	2.8	3.10	13.2	5.64	24
				C AEC down	4.61	19.6	0.66	2.8	1.20	5.1	6.06	25.8
EWR 8	474.30	425.39	90%	C PES, REC	24.19	5.1	5.69	1.2	31.30	6.6	54.54	11.5
				B/C AEC up	31.30	6.6	5.69	1.2	33.20	7	59.76	12.6
				D AEC down	14.70	3.1	5.69	1.2	27.04	5.7	46.01	9.7
EWR 9	31.30	29.47	94%	C PES	4.41	14.1	1.82	5.8	2.07	6.6	6.60	21.1
				B/C REC	8.48	27.1	1.82	5.8	2.28	7.3	9.83	31.4
EWR 1	288.80	332.72	115%	B/C PES, REC	103.10	35.7	5.20	1.8	28.01	9.7	116.96	40.5
EWR 10	86.98	134.84	155%	C/D PES, REC	26.18	30.1	14.87	17.1	3.74	4.3	35.75	41.1
				C AEC down	25.49	29.3	10.09	11.6	3.57	4.1	29.23	33.6
EWR 11	29.4	80.64	274%	D PES (DRM D)	3.65	12.4	2.70	9.2	1.68	5.7	7.61	25.9
				D REC (DRM C)	4.15	14.1	2.09	7.1	1.68	5.7	6.23	21.2
EWR 4	1977.3	1130.72	57%	C PES	The current status quo will maintain the PES.							

EWR site	nMAR	PMAR	%PMAR OF nMAR	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
	MCM	MCM	MCM		MCM	% nMAR	MCM	% nMAR	MCM	% nMAR	MCM	% nMAR
				B/C REC	Both these requirements are higher than the reference time series during certain parts of the year. Therefore neither the PMAR nor nMAR can be used to generate a time series and therefore volumes could not be calculated.							
				C/D AEC down								
EWR 5	2288	1364.54	60%	C/D PES	The current status quo will maintain the PES.							
				C REC	Both these requirements are higher than the reference time series during certain parts of the year. Therefore neither the PMAR nor nMAR can be used to generate a time series and therefore volumes could not be calculated.							

The confidence in the low and high flow Ecological Reserve requirements for each EWR site is provided in the table below. A score of 1 – 2.4 indicates a low confidence (red), 2.5 – 3.9 a moderate confidence (yellow) and 4 - 5, high confidence (green) in the results.

### Overall Confidence in EWR results

Site	Hydrology	Biological responses			COMMENT	Biophysical responses:			COMMENT
		Low flows	Low Flows	LOW FLOWS		High flows	High Flows	HIGH FLOWS	
EWR 2	3	3.5	4	3.5	Macroinvertebrate requirements result in a slightly lower confidence than the fish due to uncertainties on the influence of water quality on the biota response.	3	4	3.5	High flow medium confidence due to the upstream dam and impact on sediment as well as the lack of morphological cues.
EWR 3	3	4	4	4	Biological responses medium due. Two-dimensional hydraulic modelling was undertaken. The hydraulic requirements for low flows largely within the range of measured flows.	3.5	5	3.5	Medium to high confidence due to bedrock nature of the site and lack of geomorphological cues.
EWR 6	1.9	4	3	3	Hydraulics: No measured flows between 0.003 and 1.0 m³/s. As many of the low flow requirements are within this range, the confidence is medium.	3.5	3	3	Hydraulics a medium confidence due to the lack of measured flows in the range of high flow recommendations.
EWR 7	2.8	2	2.5	2	Hydraulics is low confidence as there is uncertainty whether zero flows equate to zero depth. Only one low flow measurement was available. The biota confidence is also low due to the fact that macroinvertebrate requirements are based on depth – however, no flow dependant macroinvertebrates are present.	3.8	3	3	Complex site with floodplain and wetland components.
EWR 8	2.4	4	3	3	Hydraulics: Complex site. Non-horizontal water surfaces. No measurements in the range of most low flow requirements.	3.8	5	4	Hydraulics of very high confidence as a suitable range of measured flows exists.
EWR 9	1.8	4	4	4	Hydraulically this is a complex site with non-horizontal water surfaces. As a suitable range of flows were measured in the high flow range, the confidence is high. The biota confidence medium to high due to	3	3	3	Hydraulically this is a complex site with only a single high flow measurement. The bedrock nature of the site and lack of geomorphological cues resulted in a moderate confidence for the biophysical responses.
EWR 10	2.5	2.8	3	3	Low flows set are below measurements for hydraulic calibrations. There is also uncertainty for flow class modelling. The medium confidence for the biota is due to the complexity of the water quality issues and the higher flows than natural.	4	4	4	Suitable range of measured flows for high flows resulting in high confidence for the hydraulics.
EWR 11	2.3	4	2.5	2.5	The low flows fall below the recommendations and the hydraulic confidence is therefore medium to high.	4	5	4	Suitable range of measured high flows result in very high confidence for the hydraulics.

Site	Hydrology	Biological responses			COMMENT	Biophysical responses:			COMMENT
		Low flows	Low Flows	LOW FLOWS		High flows	High Flows	HIGH FLOWS	
EWR 1	2.9	4	2.5	2.5	The site is hydraulically complex. Most requirements fall below the measured minimum flow. There are also non-uniform flow conditions and uncertainty regarding the flow class modelling.	4	4	4	Hydraulics: Two of the three high flows fall within the range of measured flows.
EWR 4	2.8	1	3.5	1	Hydraulics: Recommendations are below measured minimum flows. There are non-uniform flow conditions and non-horizontal water surfaces and therefore uncertainty in the flow class modelling. The very low confidence of the biota is due to the macroinvertebrate uncertainty in their recommendations. The change in seasonality, water quality issues and increased flows in some seasons are difficult to interpret.	2.3	3	2.3	Low to Medium confidence due to the uncertainty in the geomorphological requirements due to the nature of the site, the effect of the Vaal Dam and the response in terms of habitat to the flood recommendations made.
EWR 5	2.8	3	3.5	3	Hydraulics: The recommendations are below the measured minimum. Non-uniform flow conditions exist. There is uncertainty for flow class modelling. See above for confidence motivation for biota.	4	3.5	3.5	The flood requirements are above the measured maximum resulting in a medium to high confidence only.

The confidences in the high flows ranged from MEDIUM to HIGH at all sites apart from EWR 4. The low confidence at EWR 4 was due to uncertainty regarding flooding requirements recommended for geomorphology. No additional surveys or collation of information would address this uncertainty.

Recommendations were determined based on the possibility and necessity of improving the confidence of the individual assessments (biological response and hydraulics) by implementing an Ecological Water Resource Monitoring Programme (EWRM), hydrological monitoring and hydraulic assessments. This will provide the additional information to improve confidence in the EWRs. These recommendations are summarised in the table below.

It was strongly recommended that an EWRM programme be initiated as soon as possible. The information gathered during this study was suitable for the baseline, but if too much time relapses between the baseline and monitoring, new surveys and EcoClassification process will have to be undertaken.

#### Summary of recommendations required to improve confidences

EWR sites	Low flow confidence	High flow confidence	Recommendations
2	3.5	3.5	EWRM.
3	4	3.5	EWRM.
6	3	3	EWRM. If any improvement is required at this site, it is firstly recommended that a better idea of the present hydrological regime is obtained.
7	2	3	The wetland as a whole must be addressed and this would require the floodplain to be surveyed and hydraulics to be supplied for the whole floodplain.
8	3	4	EWRM.
9	4	3	EWRM.
10	3	4	EWRM.
11	2.5	4	EWRM.
1	2.5	4	EWRM.

EWR sites	Low flow confidence	High flow confidence	Recommendations
4	1	2.3	EWRM.
5	3	3.5	EWRM.

### CONSEQUENCES OF OPERATIONAL SCENARIOS

During this part of an Ecological Reserve study, aspects other than ecology are also considered for the evaluation of various operational flow scenarios and/or future development scenarios. The purpose of this is to provide the decision-maker with sufficient information to make informed decisions regarding the implications of the flow scenario and the Ecological Category which will be signed off as the Ecological Reserve. This will in future form part of the Classification System.

Operational scenarios are any flow scenarios other than the present which could be implemented in future. Detailed information regarding operational scenarios is documented in RDM/C000/00/CON/0607 (DWA, 2010a). The table below provides a summarised description of the scenarios, as well as reasoning for evaluating the specific scenario at the respective EWR sites.

### Summary of the evaluated Scenarios

Sc No	Dev Level	EWR Status	Scenario description	Reasoning
1	2008	Excluded	Base scenario representing the status quo.	This is a new PRESENT DAY. This scenario was not evaluated, but differences from the old PD (used for determination of EWR) were noted and reasoning was provided.
4	2008	Included	Based on Scenario 1. EWR Scenario: With exception of EWR 4 and EWR 5 <sup>1</sup> , all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Although EWRs are provided as a demand, it was still evaluated. One EWR site (e.g. in the Lower Vaal), could drive the requirements and result in unacceptable situations at EWR sites in the Upper Vaal (too much flow e.g.). NB: The EWR was included as a priority demand and this has a knock on effect on other users, and the operating rules of dams. This is relevant for all scenarios where dams are included.
5	2020	Excluded	Sc 1 representing the future 2020 development conditions excluding the EWRs. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system. Includes proposed Polihali Dam and conveyance infrastructure. Includes proposed re-use of mine water. Includes projected possible transfer to the Crocodile catchment.	Key scenarios. Includes most likely future developments and illustrates resulting flows at EWR sites. NO EWRs were included as a demand in the system. Basically, this is the WHAT IF scenarios, i.e., what if we manage the system in this manner without providing EWRs – will the EcoStatus change and if so, how much.
6	2020	Included	Based on Sc 5. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 5 and Sc 4.
7	Full utilization (Future development scenario)	Excluded	Scenario representing the full utilization of available water. Based on current infrastructure. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system.	This is also a future scenario, but brings in new developments apart from the VRESSAP pipeline. Full utilisation means that there is allocated water, or water available in dams, which have not been used yet.
8	Full utilization (Future development scenario)	Included	Based on Sc 7. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 7 and Sc 4.

<sup>1</sup> To achieve the REC at EWR 4 and 5 less flow than present was required in the dry season and more flows in the wet seasons. Yield models will only include an EWR demand and then make provision if the flows passing the EWR site is less than required. It will therefore assume that if higher flows than the demand are achieved, this would be a positive outcome in terms of the Ecological Reserve. It was deemed impractical to set a high flow limit and therefore decrease supply to other users when the Reserve requires this. Including EWR 4 and 5 as a demand in a yield model would be contrary to the actual Reserve requirements.

EWR 7 was excluded from the scenario modeling due to the small catchment size, where the resolution is not compatible with that of the Water Resources Planning Model (WRPM).

**ECOLOGICAL CONSEQUENCES**

The purpose of this task was to predict the driver and biota responses to each operational scenario and derive the Ecological Category (EC) for the EWR site and Management Resource Unit (MRU).

An overall assessment was undertaken for the Vaal River system to compare the scenarios developed by WRP (DWA, 2010a). The table below provides a summary of the ecological consequences at each EWR site in the Upper Vaal WMA.

**Summary of the consequences of the operational scenarios (Sc 4 - 8) at each EWR site**

VAAL RIVER					
EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
EWR 1	✓	✓	✓	✓	✓
EWR 2	✓	✓	✓	✓	✓
EWR 3	✓	✓	✓	✓	✓
EWR 4	X	X	X	X	X
EWR 5	X	✓	✓	X	X
KLIP RIVER					
EWR 6	✓	✓	✓	✓	✓
WILGE RIVER					
EWR 8	✓	X	X	X	X
SUIKERBOSRAND					
EWR 9	✓	X	✓	X	✓
EWR 10	✓	X	X	✓	✓
BLESBOKSPRUIT					
EWR 11	X	X	X	X	X

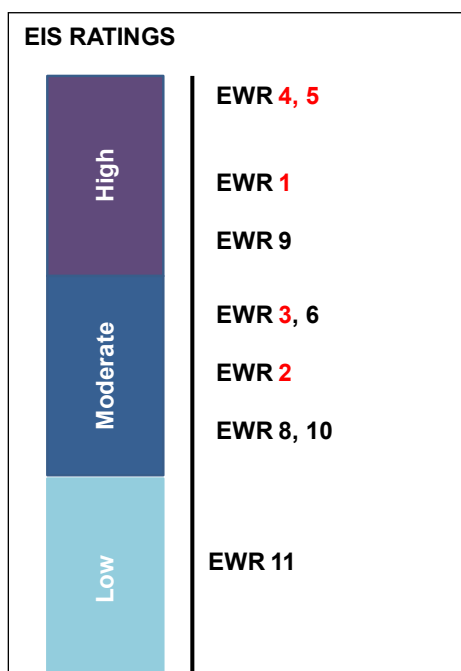
A simplified version of this table is provided below. There are three codes used in the table and indicate the following:

- ✓ EWR objectives (REC) are met.
- X EWR objectives (REC) are not met. The PES is also not being maintained (see below).
- X(PES) EWR objectives (REC) are not met but the PES is still being maintained. This is relevant for sites where the REC is an improvement of the PES. The improvement cannot be met, but the PES is still maintained.

**Summary of where the EWR objectives are met/achieved in the Upper Vaal River System**

Site	PES	REC	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
<b>VAAL RIVER MAIN STEM</b>							
EWR 1	B/C	B/C	√	√	√	X	√
EWR 2	C	C	X	√	√	√	X
EWR 3	C	C	√	√	√	√	√
EWR 4	C	B/C	X (PES)	X (PES)	X (PES)	X (PES)	X (PES)
EWR 5	C/D	C	X (PES)	√	√	X (PES)	X (PES)
<b>VAAL RIVER TRIBUTARIES</b>							
EWR 6 (Klip River)	B/C	B/C	√	√	√	√	√
EWR 8 (Wilge River)	C	C	√	X	X	X	X
EWR 9 (Suikerbosrand River)	C	B/C	√	√	√	PES	√
EWR 10 (Suikerbosrand River)	C/D	C/D	√	X	X	√	√
EWR 11 (Blesbokspruit River)	D	D	X (PES)	X	X	X (PES)	X (PES)

The two tables above are a comparison of the scenarios at all the sites within the Upper Vaal system. However some of the tributaries can be operated independently without influencing the main stem thereby potentially meeting EWRs by other means. For decision making purposes it was also necessary to take into consideration the relative Ecological Importance and Sensitivity (EIS) of the different EWR sites. Therefore the EWR sites were grouped according to their EIS score e.g. High, Moderate or Low. The sites within these groupings e.g. sites with a HIGH EIS score, were then ranked according to the number of individual EIS metrics that scored high. For example, an EWR site with 5 metrics which scored high (≥2.5) would be ranked higher than one with 4 HIGH metrics and a lot higher than one with 2 metrics. The results are supplied in the figure below. This figure indicates that the EWR sites in the main river (EWR numbers in red in figure below) are overall of more importance than the tributaries. The exception was EWR 9 situated in the upper Suikerbosrand River.



**Comparison of the Relative importance of the EWR sites within the Upper Vaal Water Management Area**

Evaluations therefore were based firstly on a comparison of consequences on the MAIN RIVER and then compared to the consequences on the tributaries of the Vaal River.

The scenarios were also grouped and compared separately. The grouping is according to the same situation WITH and WITHOUT the EWRs as follows:

- Scenario 4 (current situation WITH EWR) – compared against the current situation and resulting PES.
- Scenario 6 (future development scenario WITH EWR) – compared against Scenario 5 which represents the future development scenario WITHOUT EWR).
- Scenario 8 (full utilisation scenario WITH EWR) – compared against Scenario 7 which represents the full utilisation scenario WITHOUT EWR).

These comparisons led to the final traffic diagrams and conclusions discussed below.

**Consequences of supplying the EWR under current conditions (Sc 4)**

The results are summarised below in a traffic diagram for the main river and an evaluation of the tributaries.



**Ecological consequences of Sc 4**

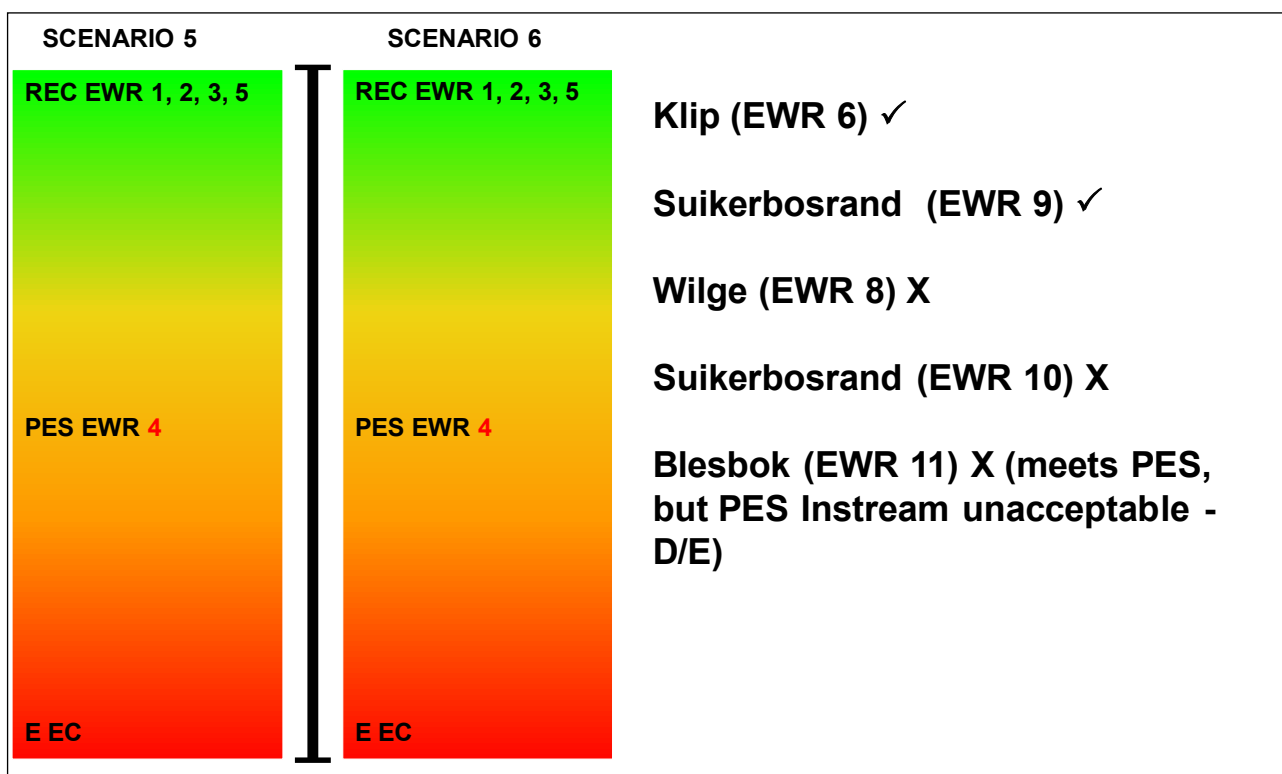
The conclusions are summarised as follows:

- Scenario 4 failed to meet the REC at EWR 4 and 5. Meeting the REC at EWR 4 is unlikely due to operational constraints and the significant demand on the Vaal Dam. To meet the REC at EWR 4, higher flows in summer is required and lower flows in winter.
- Scenario 4 did not meet the PES-REC at EWR 2 and the reason is probably that this scenario over-supplied EWR 2 to meet the requirements of EWR 3. However, Scenario 4 resulted in higher flows than required at EWR 3, which is possibly a result of the way in which the configuration model is set up and could be due to operational rules other than for the EWR. This requires further investigation.
- Scenario 4 did not meet the objectives at the Blesbokspruit River (EWR 11). This is not surprising as the Blesbokspruit River has significant water quality problems as well as to MUCH water. Decreasing flows could exacerbate the water quality problems, and this river actually requires a specific management plan which addresses its problems with the focus on water quality as first priority.

In conclusion, there was no significant advantage in supplying the EWR under current conditions as there were no improvements. The current operation of the system met the PES-REC at most sites.

**Consequences of supplying the EWR under future 2020 development conditions (Sc 6)**

The results are summarised below in a traffic diagram for the main river and an evaluation of the tributaries.



**Ecological consequences of Sc 5 and 6**

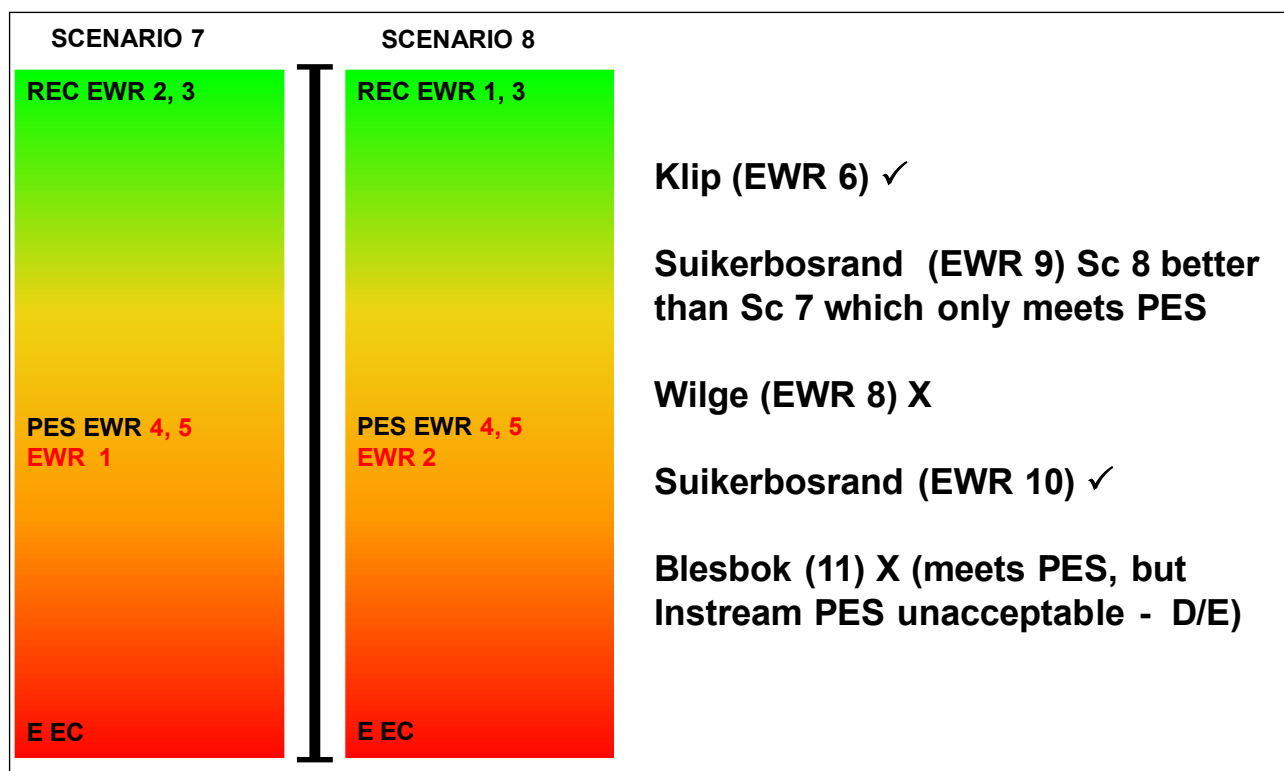
The conclusions are summarised as follows:

- There were no differences between Sc 5 and Sc 6.
- Scenario 5 and 6 failed to meet the REC at EWR 4. Meeting the REC at EWR 4 is unlikely due to operational constraints and the significant demand on the Vaal Dam. To meet the REC at EWR 4, higher flows in summer is required and lower flows in winter.
- Scenario 5 and 6 did not meet the EWR objectives at the Wilge River (EWR 8). This was due to the increased supply from Sterkfontein Dam which resulted in flows much higher than natural during the dry season (e.g. 15 m<sup>3</sup>/s during the driest month at 50% exceedence instream of the 2 m<sup>3</sup>/s which occurs during natural flows).
- Scenario 5 and 6 did not meet the objectives at the EWR 11 and the lower Suikerbosrand, EWR 10. This was not surprising as the Blesbokspruit has significant water quality problems as well as to MUCH water. Decreasing flows could exacerbate the water quality problems, and this river actually requires a specific management plan which addresses its problems with the focus on water quality as first priority.

In conclusion, there was no advantage in supplying the EWR under 2020 conditions as Sc 5 has the same ecological consequences as Sc 6.

**Consequences of supplying the EWR under full utilisation conditions (Sc 8)**

The results are summarised below in a traffic diagram for the main river and an evaluation of the tributaries.



### Ecological consequences of Sc 7 and 8

The conclusions are summarised as follows:

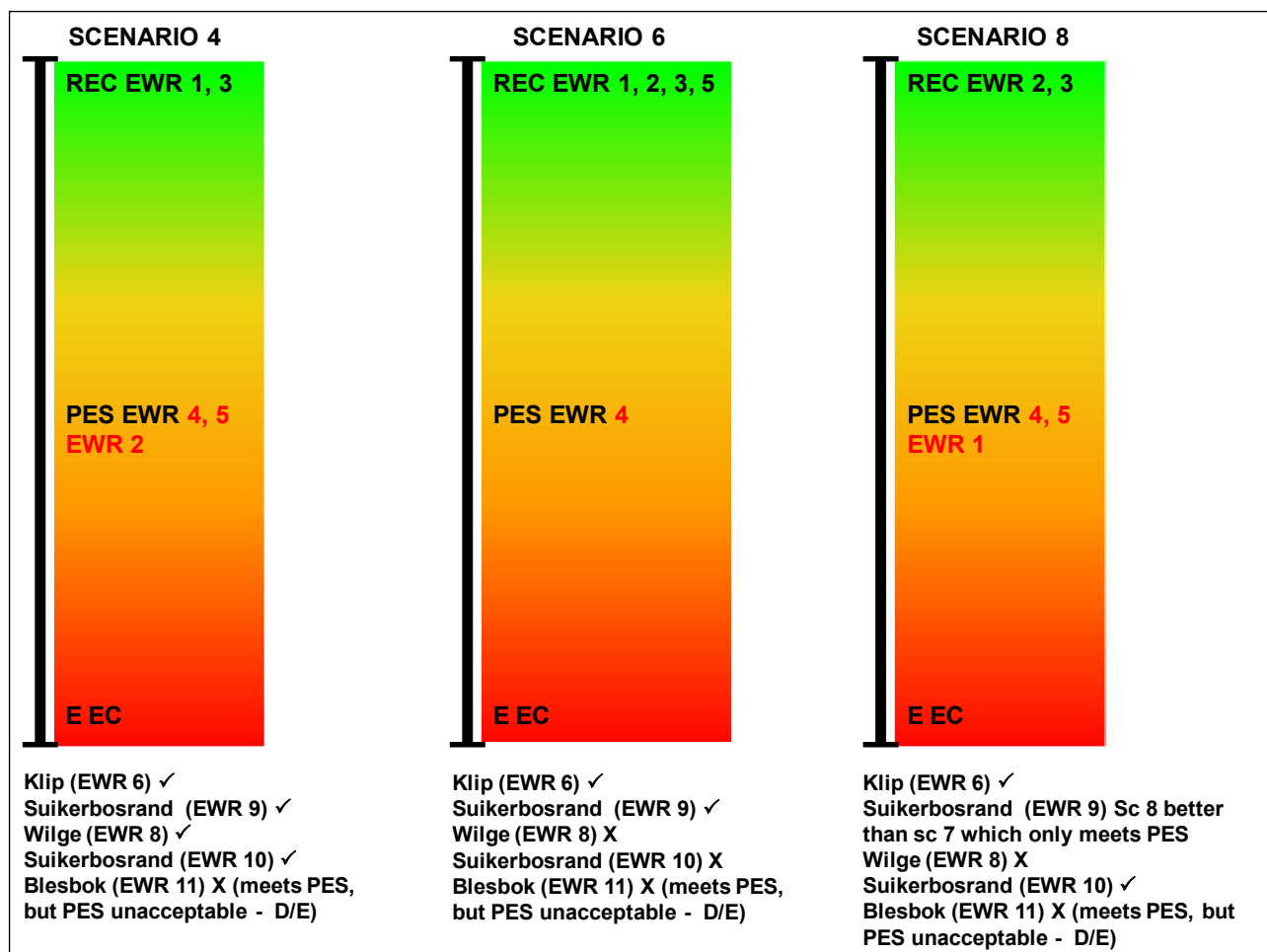
- There were minor differences between Sc 7 and Sc 8 as Sc 7 met the objectives at EWR 2 and not at EWR 1 and Sc 8 met the objectives at EWR 1 and not at EWR 2.
- Scenario 7 and 8 failed to meet the REC at EWR 4 and 5. Meeting the REC at EWR 4 is unlikely due to operational constraints and the significant demand on the Vaal Dam. To meet the REC at EWR 4, higher flows in summer is required and lower flows in winter.
- Scenario 7 and 8 did not meet the EWR objectives at the Wilge River (EWR 8). This is due to the increased supply from Sterkfontein Dam which results in flows much higher than natural during the dry season (e.g. 15 m<sup>3</sup>/s during the driest month at 50% exceedence instream of the 2 m<sup>3</sup>/s which occurs during natural flows).
- Scenario 7 and 8 did not meet the objectives at the Blesbokspruit EWR site 10. This is not surprising as the Blesbokspruit has significant water quality problems as well as to MUCH water. Decreasing flows could exacerbate the water quality problems, and this river actually requires a specific management plan which addresses its problems with the focus on water quality as first priority.

In conclusion, there is no advantage in supplying the EWR under full utilisation as Sc 7 has the basically the same ecological consequences as Sc 8.

### Comparison of Sc 4, 6 and 8

When comparing the 3 relevant traffic diagrams (figure below), that for the main Vaal River, the Sc 5 related to the 2020 future development was the most desired. This was based on the fact that it achieved the REC at EWR 5 which is situated in the Vredefort Dome which is a World Heritage site. However, one must remember that this statement is based on the evaluation of the scenario provided by WRP and as there is no guarantee that in the interim, the operation could change from what WRP provided, or that there could actually be various possible scenarios, this statement could not hold true. Additionally, it was also the only scenario that achieved the EWR objectives at both EWR 1 and 2. It must be noted however that Scenario 7 did not meet the PES at EWR 1 only because fish dropped with half a category. Taking into account the uncertainty coupled to the hydrological modelling and ecological interpretation, this could be evaluated as meeting the PES.

The tributaries were better off under current conditions, however, most of the issues relating to tributaries could be addressed separately and further refinement of the Planning model rules could address some of the problems.



**Comparison of Sc 4, 6 and 8**

**GOODS AND SERVICES CONSEQUENCES**

Assessment of the economic impacts of the various scenarios essentially identified the direction of change (either positive or negative), and estimated the magnitude of the change in benefits and costs that could be experienced within the River System (Chapter 9). The process adopted was the analysis of potential economic changes based on a valuation of the status quo, that was, the value of the Goods and Services (G&S) currently provided by the water in River systems, identifying the potential change that each of the key G&S may have undergone in each of the scenario clusters. And where required the current value of G&S was then multiplied by these factors for each scenario, to provide an indication of the potential future value of the Goods and Services. The change in value was thus measured.

Following a site visit and literature research the following goods and services were deemed to be essential to the area and warranted further assessment by the specialist team.

**List of Relevant Goods and Services**

Resources	Common Name	Scientific
<b>Vegetation</b>		
	Sedges	<i>Cyprus marginatus</i>
		<i>Schoenoplectus corymbosus</i>
	Grazing	<i>Cynodon dactylon</i>
	Terrestrial grasses	<i>Themeda triandra</i>
Medicinal	Vlei lily	<i>Crinum bulbisperrum</i>
Trees/Wood		<i>Diospyros lycioides</i>

Resources	Common Name	Scientific
		<i>Rhus pyroides</i>
		<i>Celtis africana</i>
		<i>Salix mucronata</i>
		<i>Rhus lancea</i>
		<i>Rhus pyroides</i>
<b>Fish</b>		
	Yellow Fish - small mouth	<i>Labeobarbus aeneus</i>
	Yellow Fish - largemouth	<i>Labeobarbus kimberleyensis</i>
	Sharptooth barbel	<i>Clarias gariepinus</i>
	Carp	<i>Cyprinus carpio</i>
	Largemouth bass	<i>Micropterus salmoides</i>
	Mudfish	<i>Labeo capensis (Umbratus)</i>
Subsistence fishing		
Recreational Fishing		
<b>Services</b>		
Waste assimilation		
Waste dilution		
Cultivated floodplains		
<b>Disservices as costs</b>		
Pathogens treatments		
Pathogens productivity loss		
Cholera treatment		
Cholera productivity loss		
Water treatment costs		

A schematic summary of the impacts by scenario and EWR are provided below. Where shading is green the impact is positive. Darker green is more positive than light green. Yellow indicates neutral or results so mixed as to render a judgment of the impacts virtually impossible. Red indicates negative impact. Again darker red is a more severe negative impact than lighter red.

**Consequences of the Operational scenarios on Goods and Services in the Upper Vaal**

EWR site	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
1	Light Green	Light Green	Yellow	Red	Yellow
2	Light Green	Dark Green	Light Green	Red	Red
3	Light Green	Light Green	Light Green	Light Green	Light Green
4	Light Green	Light Green	Light Green	Yellow	Light Green
5	Light Green	Light Green	Light Green	Light Green	Light Green
6	Yellow	Light Green	Light Green	Yellow	Yellow
8	Light Green	Red	Red	Red	Red
9	Red	Light Green	Yellow	Yellow	Yellow
10	Yellow	Red	Red	Yellow	Yellow
11	Yellow	Red	Red	Yellow	Yellow

Overall only two scenarios at EWR 2 and 11 could be said to be problematically negative from the perspective of goods and services.

Recommendations of further work required to confirm the results provided are described in the table below. The issues regarding each site which must be considered during any further development specifically around ad hoc monitoring is also provided in the table.

**Identified issues to be addressed and further work needed in future**

Site	Further work	Issues
EWR 1 Vaal	Yield modelling: Determine why there is a difference in hydrology under Sc 7 which results in fish dropping half an EC.	Unresolved water quality issues at this site that could be responsible for fish kills and the bad condition of fish. This site is critical (due to the unique and critical habitat) in this MRU in the Upper Vaal and monitoring is required which should also focus on identifying the cause of the problems regarding fish..
EWR 2 Vaal	Yield modelling: Determine why there is more water than required at both EWR 2 and 3.	There is currently too little flow at EWR 2 and 3. These two sites both consist of critical habitat in the stretch between Grootdraai and Vaal Dam. Any licenses that would require less flows must be tested to determine whether the EWR will be met.
EWR 3 Vaal	See above.	See above.
EWR 4 Vaal		This site is situated immediately below Vaal Dam in the short stretch of river available between the Vaal Dam and the Vaal Barrage and Lethabo Weir. EWR 4 requires an improvement under current conditions to meet the REC. It is acknowledged that the flow conditions are unlikely to be met. However, as this is the only stretch that still maintains viable breeding areas for the fish and therefore maintains the fish population in this stretch as well as acting as a refuge for tributaries, it is vital that there is no further degradation at the site. Monitoring is therefore required and any changes in the Vaal Dam's operation which exacerbates the current 'unfriendly' operating rules must be carefully considered.
EWR 5 Vaal	-	EWR 5 represents the stretch of river below the Vaal Barrage and upstream of the Mooi River confluence. This stretch runs through the Vredefort Dome and taking into account the importance of this world heritage site, no further degradation should be allowed. It is vital that non-flow related measures be considered that could improve this situation. No changes in flow operations that could be detrimental to this site should be considered. Monitoring is essential.
EWR 6 Klip	Although not part of this study, the hydrology regarding the present use must be updated. There are serious concerns on the illegal abstractions and it is highly likely that the modelled present day flows do not reflect reality. An update in hydrology for this site is important.	The biota seems to still be in good condition. However it is possible that they have not yet fully reacted to the obvious increase in abstractions and farm dams. Almost zero flow conditions were experienced during 2 field visits. There is also a very important wetland in the upper Klip River. Any licences that require further abstraction in flows should not be considered based on these results due to the uncertainty in the hydrology. A re-assessment would be required of the EWR once the updated hydrology is available. Monitoring is essential.
EWR 8 Wilge	Determine whether the operating rules associated with Sc 5 and 7 can be modified to accommodate the EWR. Test the EWR to determine whether any changes improve the situation. There is also uncertainty in the present hydrology as this does not reflect the extremely low flow conditions observed in the field. There is also potential of illegal abstractions.	The current problems at this site include too little flow and at times the river literally stops flowing. However, the fish species are mostly semi-rheophilic which means they can survive in pools and the macroinvertebrates could probably re-establish themselves after no-flow conditions. However, any licenses that further decrease flows must be carefully considered, taking into account the uncertainty regarding the hydrology.
EWR 9 Suikerbos- rand	Certain assumptions regarding the release capability of Balfour Dam has been made in the planning model. No information is presently available to determine whether actual releases can be made. The evaluation of scenarios based on this assumption must be confirmed.	The current problems at this site include too little flow and almost zero flow conditions at times. The present hydrology did not reflect this during the EWR assessment. Any license application that implies abstraction of flows must only be considered once more information on Balfour Dam is available. Balfour Dam (and Haarhoff) should be providing an EWR currently which it is not. Any decisions made on the basis of the evaluations of the scenarios must also be treated with care as these are based on an assumption that Balfour Dam can (and will) provide an EWR.
EWR10 Suikerbos- rand; EWR 11 Blesbok-spruit		Water quality issues with reference to urban run-off, mining and SAPPi are dominant at this site. Specific management plans that would probably not influence the main Vaal River are required to address the unacceptable PES in the Blesbokspruit.

The Upper Vaal River system has very high demands imposed on it by the irrigation sector, as well as industrial and domestic sectors and forms the backbone of the economic hub of South Africa.

No specific Ecological Reserve Monitoring has been initiated in this river system apart from the RHP monitoring conducted at EWR 9, 10, 11 and RE-EWR 2<sup>1</sup>. Immediate monitoring is necessary as the surveys undertaken during the Reserve study represent the baseline against which change is measured. These

<sup>1</sup> According to Ms Hermien Roux and Mr Piet Muller, River Health Champions for the North West and Gauteng Provinces respectively (*Pers. Comm.*, 2010).

surveys were undertaken during 2007 and 2008 and it can already (pending changes in the catchments), not be applicable. The longer monitoring is delayed, the bigger the chance is that the baseline surveys will have to be repeated because of outdated data.

The main recommendation is that effective monitoring is started as soon as possible due to the economic importance of the Upper Vaal River and the presence of the Vredefort Dome Heritage site that falls within this study area below the Vaal River Barrage. The Upper Vaal River is exposed to regular water quality related impacts due to industrial activities that are not monitored as well as a failing municipal infrastructure that leads to pollution levels that lead to fish kills and the recreational activities being banned by the Department of Health, especially in the reaches below the Vaal Dam.

## **PRESENT STATE EVALUATION AND MACRO ECONOMIC CONSEQUENCES**

The purpose of this Task was to determine the Present Economic State of the Upper Vaal WMA, and to evaluate both the social and economic returns of the existing water use by the various water users within this WMA (WMA 8) and the macro-economic impacts for the possible introduction of the operational EWR scenarios. The objective for determining the Present Economic State was to provide a baseline for the comparison of the impacts of the different operational scenarios.

To accommodate the different situations in the main stem of the Vaal River and the tributaries, two models were used to calculate the macro economic impacts of water use in the different economic zones. This was necessitated by the difference in water sources in the two main economic zone types. In the tributaries the irrigation water is drawn from local sources with a large percentage, if not all, of the required demand for the mining and other urban requirements pumped from the main stem.

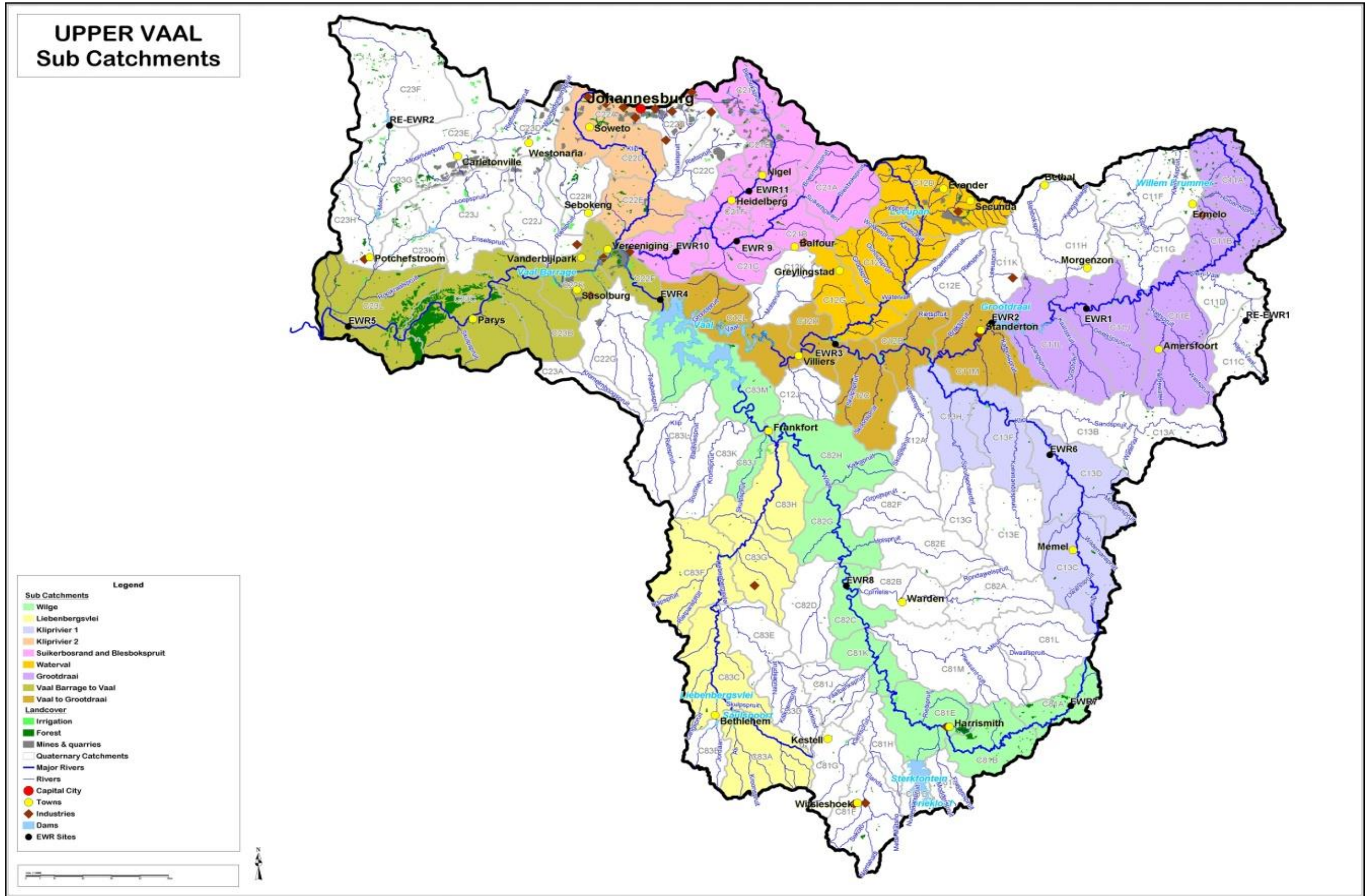
On the main stem the irrigation water, together with the rest of the demand, is sourced from the Vaal River. A decision was taken by the project team that water demand quantities drawn from the main stem will be supplied by external sources if needed.

On the main stem of the river and for the urban, mining and industrial requirements on the tributaries, the South African Inter-industry Model (SAFRIM) was used to calculate the impact of the introduction of the EWR. For the irrigation from the tributaries the Water Impact Model (WIM) was used to calculate the impact of the introduction of the EWR.

For analysis purposes the names given to the Economic Zones (EZs) were as follows:

- Economic Zone 1: Main stem – up to Grootdraai Dam
- Economic Zone 2: Main stem – between Grootdraai Dam and the Barrage
- Economic Zone 3: Main stem – between Barrage and the Middle Vaal WMA
- Economic Zone 4: Tributary – Wilge
- Economic Zone 5: Tributary – Klip River 1
- Economic Zone 6: Tributary – Waterval
- Economic Zone 7: Tributary – Suikerbosrand/Blesbok
- Economic Zone 8: Tributary – Klipriver 2 (Gauteng)
- Economic Zone 9: Tributary – Mooi

The Economic Zones of the Upper Vaal WMA is provided in the next figure.



Economic Zones of the Upper Vaal WMA

**Population distribution:** Fifty percent (50%) of the population in the WMA was in the Klip River 2 (Gauteng) Economic Zone (EZ 8). This applied to the total as well as the low-income section of the population.

**Contribution to GDP:** Klip River 2 (Gauteng) was the largest contributor to the GDP with 45%, followed by Blesbok-Suikerbos EZ with 17% and the Barrage to Middle Vaal EZ with 13%

**Total direct employment:** 58% of the employment was in the Klip River 2 (Gauteng) EZ, followed by 15% in Hartebeest-Suikerbos EZ, with 8% in the Barrage to Middle Vaal EZs.

## MACROECONOMIC CONSEQUENCES OF OPERATIONAL SCENARIOS

### *Main stem*

The approach to the economic impact of the application of the operational scenarios in the main stem was guided by the following directives:-

- The expected demand will be provided, and
- Water Conservation and Demand Management policies will be in place and applied.

The original projection was that the introduction of the EWR would reduce the available present supply, which would probably require that the Jana Dam be constructed before the Mielietuin Dam as the available supply would be less than the pre-EWR supply to accommodate the expected volume growth in demand. This could result in an earlier date of the Polihali Dam construction.

The Unit Reference Values (URV) for the three dams was within acceptable limits if kept in the same order of construction; the Rand per m<sup>3</sup> cost to deliver the water do not differ much. However, with the Polihali and Jana Dams being very large dams and the Mielietuin Dam being a much smaller dam, the result is that the total construction cost for the Mielietuin Dam will be much less than for Jana. Expressed in 2007 prices the estimated cost for the Polihali Dam is R5 175.35 million, for the Jana Dam R6 425.24 million and for the Mielietuin Dam R2 100.00 million.

Constructing the Jana Dam first would involve much more capital than the construction of the Mielietuin Dam, resulting in a large capital investment being required earlier than anticipated and resulting in higher water tariffs than originally projected.

This was the anticipated result on the main stem if the EWR is implemented; however, the water demand projections have now shown that it would not be necessary as the projected supply from Polihali and Mielietuin Dams will support the introduction of the EWR, with minor adjustments.

According to DWA (2010a):

- Implementation of the EWR resulted in more water to be transferred via the VRESSAP pipeline (an additional amount of 55.6 million m<sup>3</sup>/a is to be transferred for Scenario 8).
- Implementation of the EWR did not impact on the date on which the next augmentation scheme would be required; and
- Implementation of the EWR resulted in Sterkfontein Dam to be operated at lower storage levels (average storage for Scenario 7 was 2 367 million m<sup>3</sup> compared to the average storage of 2 294 million m<sup>3</sup> for Scenario 8).

From the above it appears that the only costs possibly foreseen are the additional pumping cost through the VRESSAP pipeline and possible monetary implications of the increased risk during times of drought because the Sterkfontein Dam storage is operating at a slightly lower level than without the EWR in place. However, further investigation into additional pumping and the related implied costs revealed that the lower operational storage levels of the Sterkfontein Dam did not affect the risk under which the system operates. After discussions with Pieter van Rooyen it was decided that it was not worthwhile to allocate a monetary value to the risk, if the proposed Polihali Dam was to be constructed within the projected period and therefore the extra pumping cost was discounted into the final calculations.

### **Tributaries**

The calculation of the macro-economic impacts of a specific scenario in a tributary was guided by a number of assumptions and operational realities. The base assumptions were the following:

- The population, industry and mining would receive the expected water demand within Water Conservation and Demand Management targets. These targets were determined outside of the present study and it was assumed that they will be applied.
- Eskom power stations would receive the water needed for power generation.
- Curtailments would be instituted against irrigation if necessary to implement EWR targets.

The operational realities referred to included the following:

- Except for certain smaller urban areas, the urban population receive their water from the main stem of the Vaal River, via Water Boards and pumping schemes.
- Water is pumped from the main stem into catchment of certain tributaries to satisfy the demand. The VRESSAP line pumping water to the Secunda complex is an example.
- A few mines and smaller industries still receive water from a source in the tributary.
- It is too expensive to pump water into the tributaries for irrigation purposes.

With the above in place the impact per EWR site was restricted to irrigation activities, accepting that all other demands would be met. According to DWA the volume of water allocated to irrigation in the Upper Vaal WMA has been ring fenced and no further volume increases will be allowed. However, nothing prevents farmers from improving their management practises and upgrading technology which will result in both vertical and horizontal expansion of their enterprises with the same volume of water.

Ecological consequences were determined at EWR sites which represent a Management Resource Unit. For comparison purposes, the EWR sites had to be allocated to the EZ zones. The table below shows the overlaying of the economic zones and the EWR sites of which quantitative analyses were performed.

#### **Detailed information regarding the distribution of Economic Zones to tributary catchments**

<b>Economic Zone</b>	<b>River Type</b>	<b>Economic Zones</b>	<b>Catchment for Scenarios</b>	<b>EWR sites in EZs</b>
EZ 1	Main Stem	Up to Grootdraai Dam	Klein Vaal; Vaal River at Uitkoms	RE-EWR 1; EWR 1
EZ 4	Tributary	Wilge	Wilge at Bavaria	EWR 8
EZ 5	Tributary	Klip River 1	Klip River	EWR 6
EZ 6	Tributary	Waterval	Waterval	EWR WA1 and EWR WA2
EZ 9	Tributary	Mooi	Mooi River (Klipdrift Dam)	EWR M2

In evaluating the impact of the scenarios it was necessary that the evaluation was done against the background of a number of factual realities and assumptions, namely:

- That the water demands at a specific EWR point was not representative of the total irrigation water use in the economic zone. However it gave a good indication of the situation in the rest of the zone.
- The multipliers used to calculate the impact at the specific point was calculated using the total irrigation activity in the zone, there was therefore a chance that the crop mix at the EWR point would differ from the mix in the total zone.
- The base irrigation water use was fixed in 2008 terms. It was assumed that the present crop mix would not change during the coming years.
- The impacts were based on the use of the total water per zone, without making a distinction between lawful and unlawful use.

The impact of the operational scenarios was extrapolated to compare the macroeconomic impacts on the total economic zones and the WMA and not only the area around the EWR point. The table below represents the results of the introduction of the EWR, comparing the impact with base situation for irrigation per economic zone.

**Comparison of the Impact of Scenario 7 and Scenario 8 in all the EZs of the Upper Vaal WMA**

Economic Zone	GDP		Employment		Households	
	Base	EWR Impact	Base	EWR Impact	Base	EWR Impact
EZ 1. Main Stem Up to Grootdraai Dam	R 160.55	R -3.59	2271	-28	R 56.18	R -1.18
EZ 2. Main Stem - Grootdraai to Vaal Barrage	R 238.09	R 0.00	3050	0	R 83.12	R 0.00
EZ 3. Main Stem - Vaal Barrage to Middle Vaal WMA	R 143.69	R 0.00	1841	0	R 50.16	R 0.00
EZ 4. Wilge Tributary	R 232.61	R 0.00	3999	0	R 79.63	R 0.00
EZ 5. Klip 1 Tributary	R 47.19	R -0.63	590	-15	R 15.39	R -0.23
EZ 6. Waterval Tributary	R 66.50	R -0.57	942	-15	R 22.25	R -0.21
EZ 7. Suikerbosrand Tributary	R 98.45	R 0.00	1975	0	R 114.10	R 0.00
EZ 8. Klip 2 Tributary	R 195.08	R 0.00	4285	0	R 69.50	R 0.00
EZ 9. Mooi Tributary	R 143.13	R 0.00	1925	0	R 47.73	R 0.00
<b>Total</b>	<b>R 1 325.29</b>	<b>R -4.79</b>	<b>20877</b>	<b>-59</b>	<b>R 538.07</b>	<b>R -1.62</b>

From the table above it appears that the operational scenarios are only impacting on three of the nine economic zones and that the projected impact on the three economic zones would be very small. With a possible 59 jobs lost compared to a total employment of over 20 000 in the sector and a loss of R1.62 million in payments to low-income households.

However, it is important to keep in mind that although irrigation agriculture was not a very important sector in the WMA, it still contributed to food security with over 40 000 irrigated hectares in grain production and overall it supports 20 877 employment opportunities, mostly in the rural areas. The grain (cereal) production is a mix of maize, wheat and grain sorghum, with maize and grain sorghum production in the summer, followed by wheat during the winter.

For two tributaries, Suikerbosrand and Klip River 2 (Gauteng), no operational scenarios were presented for analysis.

The weakness of the specific methodology used is that it only gives an overall picture of the impact with no indication of an impact on an individual irrigator. It was recommended that at the time of the introduction of the EWR a detailed study be implemented to identify the possible economic impacts on individual producers in areas where major irrigation water curtailments are foreseen.

**IDENTIFICATION OF ECOSPECS**

EcoSpecs and TPCs are listed in detail for each EWR site for:

- Physico-chemical variables
- Geomorphology
- Riparian vegetation
- Fish
- Macroinvertebrates

These are highly detailed and quantified data that must be refined during an Adaptive Management process within EWRM. A summary of the EcoSpecs and TPCs are provided as Appendix A.

To date formal implementation of the monitoring step of the Reserve has not taken place (CJ Kleynhans, C Thirion, *pers. comm*). Furthermore, there has been minimal (only informally on the Palmiet River and on a private dam in the Western Cape) implementation (with reference to the supply of the flows and management of other drivers to achieve the required EC) of the Ecological Reserve. This is of major

concern as all EWRs, EcoSpecs; TPCs etc. are hypotheses until tested. With increased development and pressure on the water resources in this country there are no structures in place to monitor the further deterioration of our rivers. All methods related to monitoring and the identification of EcoSpecs and TPCs therefore require testing and refinement.

The Upper Vaal River system has very high demands imposed on it by the irrigation sector, as well as industrial and domestic sectors and forms the backbone of the economic hub of South Africa.

The RHAM was developed during 2007 - 2009 and it was recommended that a RHAM survey is undertaken at sites where applicable. It is foreseen that due to the size and nature of the Vaal River, the RHAM for wadeable rivers might not be possible at all sites. The semi - wadeable (still to be tested) RHAM could be applicable. RHAM data may provide additional information on habitat suitability and the biota associated with this habitat.

No specific Ecological Reserve Monitoring has been initiated in this river system apart from the RHP monitoring conducted at EWR 9, 10, 11 and RE-EWR 2<sup>2</sup>. Immediate monitoring is necessary as the surveys undertaken during the Reserve study represent the baseline against which change is measured. These surveys were undertaken during 2007 and 2008 and it can already (pending changes in the catchments), not be applicable. The longer monitoring is delayed, the bigger the chance is that the baseline surveys will have to be repeated because of outdated data.

The main recommendation is that effective monitoring is started as soon as possible due to the economic importance of the Upper Vaal River and the presence of the Vredefort Dome Heritage site that falls within this study area below the Vaal River Barrage. The Upper Vaal River is exposed to regular water quality related impacts due to industrial activities that are not monitored as well as a failing municipal infrastructure that leads to pollution levels that lead to fish kills and the recreational activities being banned by the Department of Health, especially in the reaches below the Vaal Dam.

## **WETLAND TYPING AND ECOCLASSIFICATION**

The purpose of this study was to identify the distribution and diversity of wetlands within the Upper Vaal catchment and conduct a primarily desktop assessment of the average current ecological state and ecological importance and sensitivity of these wetlands at a quaternary catchment scale.

Three Wetland Resource Units were identified for the Upper Vaal Water Management Area, namely the:

**WRU 1: Dolomitic Peatlands WRU** (low density and diversity of wetland types but very large individual wetlands generally associated with peats and usually associated with high EIS scores).

**WRU 2: Central Sedimentary WRU** (high density of wetlands with a moderate to high diversity, many of which may provide habitat for vulnerable to endangered vegetation. These wetlands are generally associated with moderate PES and EIS scores).

**WRU 3: Eastern Sedimentary WRU** (high density of wetlands with a high diversity many of which may provide habitat for vulnerable to endangered vegetation. These wetlands are generally associated with moderate to high PES and EIS scores).

Results from the desktop Wetland PES and EIS assessments (at the quaternary catchment scale), and comparison with the available quaternary river PES and EIS data are provided in the table below. Quaternaries with high-scoring wetland PES (A, B and B/C) and/or EIS (High and Very High) scores are shaded. The PES and EIS scores reflect the expected *average* scores of all wetlands within the quaternary catchment.

Given the high intensity of economic activity and land use activities across most of the WMA, it is not surprising that much of the WMA is characterised by wetlands in a moderate condition, with poorer condition

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<sup>2</sup> According to Ms Hermien Roux and Mr Piet Muller, River Health Champions for the North West and Gauteng Provinces respectively (*Pers. comm.*, 2010).

wetland areas concentrated around the highly urbanised and industrialised north and north-western margins of the WMA (first figure). Whilst PES is generally moderate, the EIS scores range from Moderate to High. The wetlands in the headwaters of the northwest and southernmost sections of the WMA have the highest EIS scores (second figure).

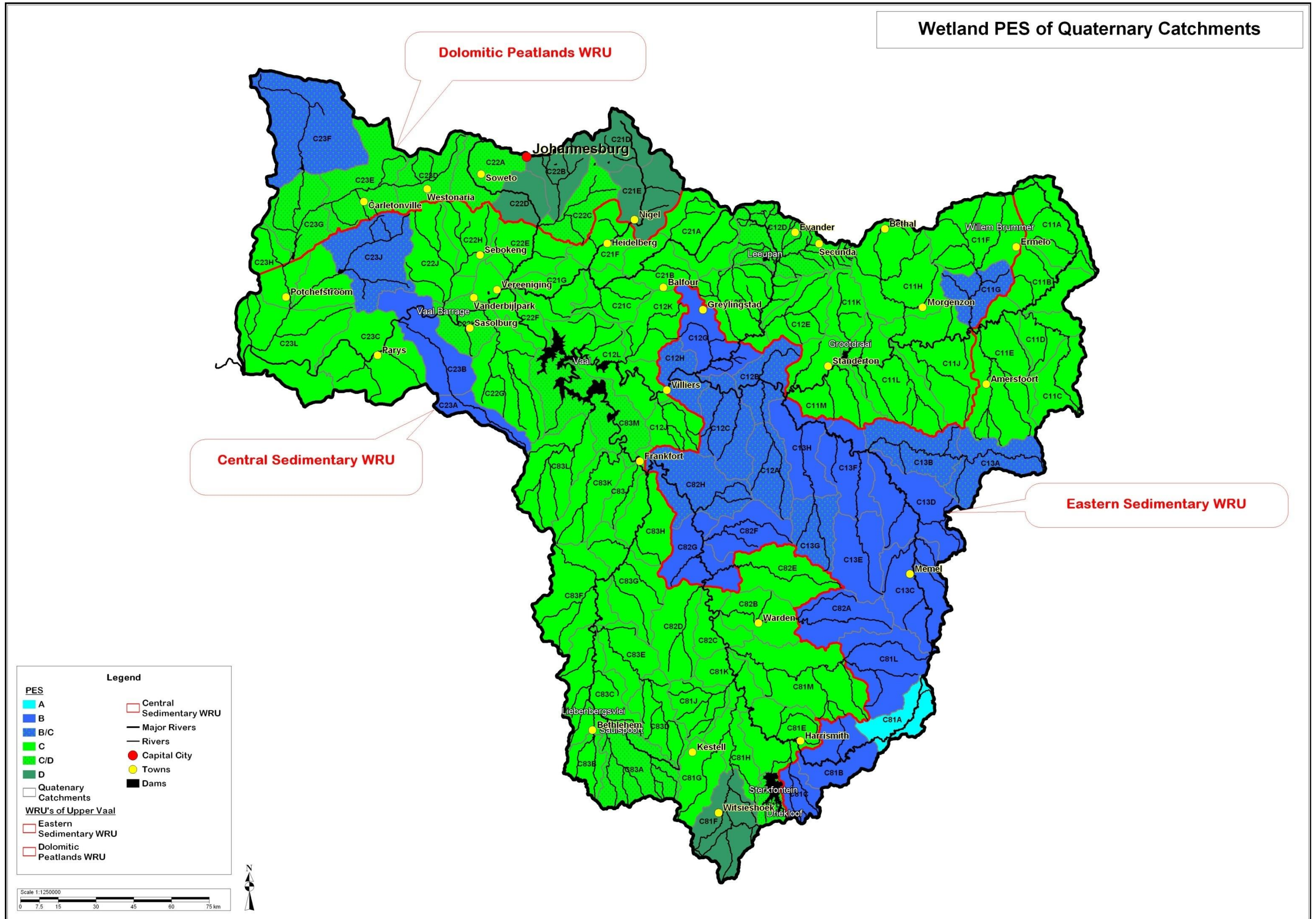
### Average EIS and PES for the wetlands in quaternary catchments of the Upper Vaal WMA

Quat. Catchment	Main river/s	Average Wetland EIS of the Quaternary	River EIS	Average Wetland PES of the Quaternary	River PES
C11A	Vaal	HIGH	Moderate	C	B/C
C11B	Vaal	HIGH	Moderate	C	C
C11C	Klein Vaal	MODERATE	Moderate	C	B
C11D	Klein Vaal (Rietspruit)	MODERATE	Low	C	C
C11E	Rietspruit	HIGH	Moderate	C	C
C11F	Kaffirspruit	MODERATE	Moderate	C	C
C11G	Kaffirspruit	MODERATE	Moderate	B/C	C
C11H	Blesbokspruit	MODERATE	Moderate	C	C/D
C11J	Vaal	MODERATE	Moderate	C	C
C11K		HIGH	Moderate	C	D
C11L	Grootdraai dam	MODERATE		C	
C11M	Vaal (downstream from Grootdraai)	MODERATE	Moderate	C	D
C12A	Ventersspruit	MODERATE	Moderate	B/C	B/C
C12B	Vaal (main)	MODERATE	Moderate	B/C	C
C12C	Vaal (main)	MODERATE	Moderate	B/C	C
C12D	Waterval (Kleinspruit)	MODERATE	Low	C/D	D
C12E	Rietspruit	MODERATE	Low	C	D
C12F	Waterval (Kleinspruit)	HIGH	Moderate	C	D
C12G	Waterval (Kleinspruit)	HIGH	Moderate	B	D
C12H	Vaal (main)	MODERATE	Moderate	B/C	C
C12J	Unnamed trib.	MODERATE	Low	C	C/D
C12K	Molspruit	MODERATE	Low	C	C/D
C12L	Vaal (Vaal dam backwater portion)	MODERATE		C	
C13A	Sandspruit	HIGH	Moderate	B/C	B/C
C13B	Sandspruit	HIGH	Moderate	B/C	C
C13C	Seekoeflei	VERY HIGH	High	B	B/C
C13D	Klip	VERY HIGH	Moderate	B	B/C
C13E	Komandospruit	MODERATE	Moderate	B	B
C13F	Klip	HIGH	Moderate	B	C
C13G	Spruitsonderdrif	MODERATE	Moderate	B/C	C
C13H	Klip	MODERATE	Moderate	B	C
C21A	Suikerbosrand	HIGH	Moderate	C	B/C
C21B	Suikerbosrand	HIGH	Moderate	C	C
C21C	Suikerbosrand	HIGH	High	C	C
C21D	Blesbokspruit	HIGH	Low	D	E/F
C21E	Blesbokspruit	HIGH	Moderate	D	D/E
C21F	Blesbokspruit (l	MODERATE	Low	C	D/E
C21G	Suikerbosrand	MODERATE	Moderate	C	C/D
C22A	Klipriver	HIGH	Moderate	C/D	E
C22B	Natalspruit	HIGH	Low	D	E
C22C	Rietspruit	HIGH	Low	C/D	E
C22D	Klip	HIGH	Moderate	D	D
C22E	Klip	MODERATE	Moderate	C	D/E
C22F	Vaal (downstream from Vaal dam)	MODERATE	Moderate	C	D
C22G	Taaibospruit	MODERATE	Moderate	C	C
C22H	Rietspruit	MODERATE	Low	C	D/E
C22J	Leeuspruit	MODERATE	Moderate	C	D/E
C22K	Vaal (Barrage portion)	MODERATE		C/D	
C23A	Vaal	MODERATE	Moderate	B	B/C
C23B	Vaal	MODERATE	Moderate	B	D

Quat. Catchment	Main river/s	Average Wetland EIS of the Quaternary	River EIS	Average Wetland PES of the Quaternary	River PES
C23C	Vaal (Parys)	MODERATE	High	<b>C</b>	D
C23D	Moorivierloop	<b>HIGH</b>	Low	C/D	E
C23E	Moorivierloop	<b>HIGH</b>	Moderate	C/D	E
C23F	Upper Mooi	<b>HIGH</b>	High	<b>B/C</b>	C/D
C23G	Mooi (upstream from Boskop)	<b>HIGH</b>	Moderate	C/D	D/E
C23H	Mooi (before confluence with Loopspruit)	<b>HIGH</b>	Moderate	C	D/E
C23J	Loopspruit (above Klipdrif dam)	MODERATE	Low	<b>B/C</b>	D
C23K	Loopspruit	MODERATE	Low	C	D
C23L	Vaal (downstream from Parys)	MODERATE	High	C	D
C81A	Wilge (main stem)	<b>HIGH</b>	Low	<b>A</b>	B
C81B	Wilge (main stem)	<b>HIGH</b>	Moderate	<b>B</b>	B/C
C81C	Nuwejaarspruit (Wilge trib.)	MODERATE	Moderate	<b>B</b>	B/C
C81D	Sterkfontein Dam	MODERATE		C/D	
C81E	Wilge (main stem)	MODERATE	Moderate	C	D
C81F	Elands (Wilge trib.)	MODERATE	Moderate	D	D
C81G	Elands (Wilge trib.)	MODERATE	Moderate	C	C
C81H	Elands (Wilge trib.)	MODERATE	Moderate	C	C
C81J	Vaalbanks (Wilge trib.)	MODERATE	Moderate	C	C
C81K	Wilge (main stem)	MODERATE	Moderate	C	C
C81L	Meul (Wilge trib.)	MODERATE	Moderate	<b>B</b>	B
C81M	Meul (Wilge trib.)	MODERATE	Moderate	C	B
C82A	Cornelis (Wilge trib.)	MODERATE	Moderate	<b>B</b>	B
C82B	Cornelis (Wilge trib.)	MODERATE	Moderate	C	C
C82C	Wilge (main stem) - EWR 8	MODERATE	Moderate	C	C
C82D	Rus se Spruit (Wilge trib.)	MODERATE	Moderate	C	C
C82E	Holspruit (Wilge trib.)	MODERATE	Moderate	C	C
C82F	Grootspruit (Wilge trib.)	MODERATE	Moderate	<b>B</b>	C
C82G	Wilge (main stem)	MODERATE	Moderate	<b>B</b>	C
C82H	Wilge (main stem)	MODERATE	Moderate	<b>B/C</b>	C
C83A	Ash	MODERATE	Low	C/D	D/E/F
C83B	Jordaans	MODERATE	Moderate	C	C
C83C	Liebenbergsvlei	MODERATE	Moderate	C	D/E
C83D	Tierkloof	MODERATE	Moderate	C	C/D
C83E	Tierkloof	MODERATE	High	C	C/D
C83F	Liebenbergsvlei	MODERATE	Moderate	C	D
C83G	Liebenbergsvlei	MODERATE	Moderate	C	D
C83H	Libenbergsvlei	MODERATE	Moderate	C	D
C83J	Wilge (main stem)	MODERATE	Moderate	C	D
C83K	Kromspruit	MODERATE	Moderate	C	B
C83L	Klipriver	MODERATE	Moderate	C	B
C83M	Wilge (main stem) - Vaal Dam	MODERATE		C/D	

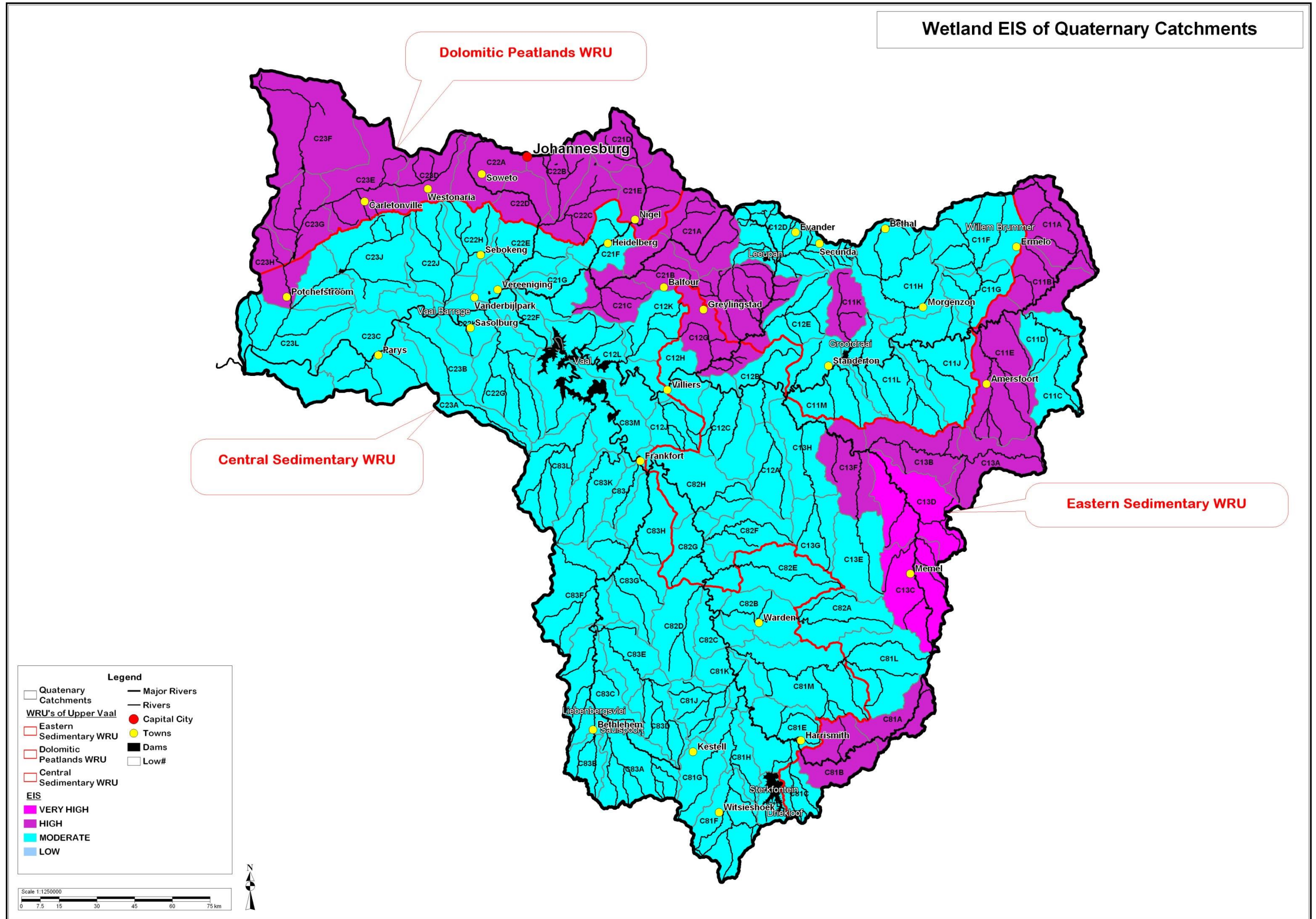
Within the Wetland Resource Units, PES and EIS attributes are generally more consistent than across the entire Water Management Area. Wetlands within the Dolomitic Peatlands WRU are characterised by low to moderate PES (first figure) but High EIS (second figure). The Central Sedimentary WRU is characterised by generally moderate PES (first figure) and EIS (second figure) scores, whereas the wetlands of the Eastern Sedimentary WRU generally have higher PES (first figure) with the same to higher EIS characteristics (second figure).

Wetland PES of Quaternary Catchments



Average wetland PES scores of the quaternary catchments of the Upper Vaal WMA

Wetland EIS of Quaternary Catchments



Average wetland EIS scores of the quaternary catchments of the Upper Vaal WMA

Of the several high priority areas requiring urgent assessment or more detailed Reserve studies the Seekoeivlei and lower Suikerbosrand (Heidelberg) Floodplain wetlands were assessed in more detail as part of this study. Rapid EcoClassification determinations were also undertaken for the Boovenste Oog Wetland (in Quaternary catchment C23F), Klip River Wetland (in Quaternary Catchment C22A, this study included a Reserve determination component) and the Bedford Wetland (in Quaternary Catchment C81A) as part of the WRC/RDM Rapid Wetland Reserve Method Development Project (the results of these studies and associated Reports can be obtained from the RDM).

Seekoeivlei is a RAMSAR site with a high (A/B) PES and Very High EIS. The wetland system is stable and there are few major current threats to this internationally recognised and protected water resource. The lower Suikerbosrand Floodplain has a low to moderate EIS and moderate (B/C) PES. The lower reach close to the Blesbokspruit confluence is currently under threat by proposed mining activities, the impacts from the surrounding cattle feedlots and upstream urbanisation of the catchment. The threats to the condition of this wetland are ubiquitous across the WMA – agricultural impacts; expansion of mining and urbanisation.

The approaches developed and information yielded through this assessment will be able to assist the CD:RDM in obtaining regional PES and EIS information for wetlands. This information can be used to guide more detailed Reserve studies, if required, as well as to assess the regional context of wetlands linked to WULA and EIA applications.

### **ESTIMATION AND EXTRAPOLATION OF EWRs AT SELECTED HYDRONODES**

A comprehensive Reserve study assesses EWRs at EWR sites that are usually situated on the main rivers and large tributaries. For the purpose of, amongst others, Compulsory Licensing and general licensing, Reserves have to be determined at many points (hydronodes) in the catchment. EWR sites at each of these nodes where EWRs are determined at a comprehensive level will become time consuming and therefore costly.

The objective of this task was to provide an estimate which will be of higher confidence than the Desktop Reserve Model at every hydronode in the Upper Vaal system.

Extrapolation consisted of

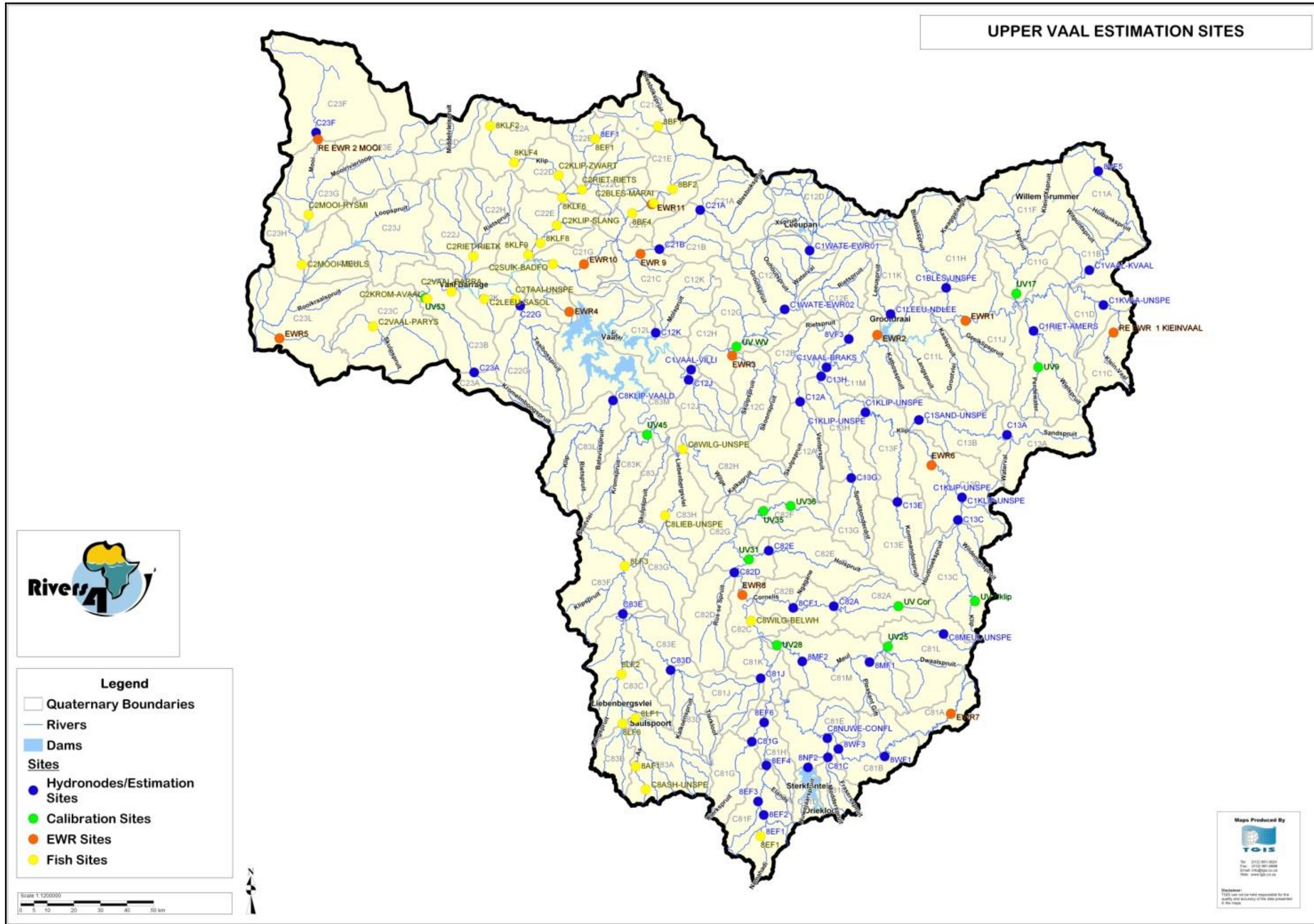
- determining which sites were sufficiently similar to the comprehensive EWR sites in terms of biophysical similarity as well as indicator guilds used for setting EWRs; and
- deriving the EWRs for these sites using the comprehensive EWR results at the EWR sites.

Estimation consists of a process to estimate the EWRs at each hydronode for the Recommended Ecological Category (REC) (using the information generated as part of the Desktop EcoClassification (Kleynhans & Louw, 2007)). This estimation will entail the prediction of indicator species at various hydronodes, and the determination of the EWRs at these hydronodes using a higher confidence method than the Desktop Ecological Reserve Model.

EWR estimates were supplied at 62 hydronodes as .rul and .tab tables.

Hydronodes are points on a map which represents a catchment, usually at the quinary scale. These points were selected by Rivers for Africa situated mostly at the outlet of quaternary catchments and other sites where surveys had been undertaken and were included in an Excel database. Additional points were also provided in the database, the so-called known fish sites. This inclusion was required as the database was used to compare the known fish sites with hydronodes to derive the indicator fish guild for which the EWR had to be set. For each point in the database, a range of biophysical information was provided to characterise the nodes and fish sites.

The locality of the hydronodes, fish and calibrations sites within the Upper Vaal WMA is provided below.



Localities of Upper Vaal hydronodes, fish and calibration sites

The hydronodes and method used to determine the EWRs are provided in the tables and figures below.

### Estimation methods followed at the Vaal hydronodes

Hydronode	Quat	River	Method
UV Uklip	C13C	Klip	Estimate
UV9	C11E	Skulpspruit	Estimate
UV17	C11G	Drinkwaterspruit	Estimate
UV25	C81L	Meul	Estimate
UV Cor	C82A	Cornelius	Estimate
UV28	C81M	Meul	Estimate
UV31	C82G	Holspruit	Estimate
UV WV	C12G	Waterval	Estimate
UV35	C82F	Grootspruit	Estimate
UV36	C82F	Grootspruit	Estimate
UV45	C83K	Kromspruit	Estimate
UV53	C23B	Kromelomboogspruit	Estimate
C1VAAL-KVAAL	C11B	Vaal	Yield model
C1VAAL-BRAKS	C11M	Vaal	Yield model
C1VAAL-VILLI	C12L	Vaal	Extrapolate from EWR 3
8VF3	C11M	Brakspruit	Estimate
8VF5	C11A		Estimate
C1BLES-UNSPE	C11H	Blesbokspruit	Estimate
C1KLIP-UNSPE (8KF2)	C13F	Klip (Grootdraai)	Estimate
C1KLIP-UNSPE (8KF1)	C13D	Klip (Grootdraai)	Estimate
C1LEEU-NDLEE	C11L	Leeuspruit	Estimate
C1RIET-AMERS	C11E	Rietspruit	Estimate
C1SAND-UNSPE	C13B	Sandspruit	Estimate
C1WATE-EWR01	C12F	Waterval	Existing EWR results
C1WATE-EWR02	C12F	Waterval	Existing EWR results
C8KLIP-VAALD	C83L	Klip (flows into Vaal Dam from FS)	Estimate
8WF1	C81B	Wilge	Estimate
8WF3	C81B	Wilge	Estimate
8EF1	C81F	Elands	Estimate
8EF2	C81F	Elands	Estimate
8EF3	C81F	Elands	Estimate
8EF4	C81H	Elands	Estimate
8EF6	C81H	Elands	Estimate
C8NUWE-CONFL	C81E	Nuwejaarspruit	Estimate
8NF2	C81D	Nuwejaarspruit	Estimate
C8MEUL-UNSPE	C81L	Meul	Estimate
8MF1	C81M	Meul	Estimate
8MF2	C81M	Meul	Estimate
8CF1	C82B	Cornelisspruit	Estimate
C23F	C23F	Mooi River	Estimate
C22G	C22G	Taaibospruit	Estimate
C23A	C23A	Kromelomboogspruit	Estimate
C21A	C21A	Suikerbosrand	Estimate
C21B	C21B	Suikerbosrand	Extrapolate from EWR 9
C12K	C12K	Molspruit	Estimate
C82E	C82E	Holspruit	Estimate
C82D	C82D	Rus-se-spruit	Estimate
C83E	C83E	Tierkloof	Estimate
C83D	C83D	Tierkloof	Estimate
C81J	C81J	Vaalbanksspruit	Estimate
C81G	C81G	Klerkspruit	Estimate
C81C	C81C	Fraser/Modder	Estimate
C13C	C13C	Klip	Estimate
C82A	C82A	Cornelis	Estimate
C13E	C13E	Komandospruit	Estimate
C13G	C13G	Spruitsonderdrif	Estimate

Hydronode	Quat	River	Method
C13H	C13H	Klip	Estimate
C12A	C12A	Skulpspruit	Estimate
C12J	C12J	??	Estimate
C13A	C13A	Sandspruit	Estimate

The final results as the .rul and .tab tables are provided as electronic data (RDM Report no RDM/WMA8C000/01/CON/0710; DWA, 2010b).

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## **APPENDICES**

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## **ACRONYMS**

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BHNR	Basic Human Needs Reserve
DWAF	Department of Water Affairs and Forestry
GDP	Gross Domestic Product
GGP	Gross Geographic Product
IDP	Integrated Development Planning
NWA	National Water Act
WMA	Water Management Area
WSAM	Water Situation Assessment Model

# 1 INTRODUCTION

---

In order for the Department of Water Affairs (DWA) to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments in the Vaal River System, higher levels of confidence is needed for the Reserve Determination within this study area. Therefore a Comprehensive Reserve determination study within Water Management Area (WMA) 8 has been undertaken to provide input to the Reconciliation studies and the integrated water quality management plan recently undertaken by the National Water Resources Planning Directorate (D: NWRP) of the DWA.

## 1.1 STUDY AREA

### 1.1.1 Description of the study area

The study area for the Reserve determination is the Upper Vaal system as represented by WMA 8. WMA 8 is part of a larger water supply system, which includes adjacent WMAs, and Lesotho. The Upper Vaal WMA is one of three WMAs in the Vaal River catchment, which is the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWAf, 2004).

The Upper Vaal WMA includes the Vaal, Klip, Wilge, Liebenbergsvlei, Waterval, Suikerbosrand and Mooi Rivers and extends to the confluence of the Mooi and Vaal Rivers. It covers a catchment area of 55 565 km<sup>2</sup>. This WMA includes the very important Vaal, Grootdraai and Sterkfontein dams. The southern half of the WMA extends over the Free State, the north-east mainly falls within Mpumalanga and the northern and western parts in Gauteng and North West provinces respectively (DWAf, 2004).

The Upper Vaal is the uppermost WMA in the Vaal River catchment and one of five WMAs in the Orange River Basin. It is surrounded by the Crocodile (West) and Marico, Olifants, Inkomati, Usutu to Mhlathuze, Thukela, Upper Orange and Middle Vaal WMAs and adjoins Lesotho in the southern extreme. The National Water Resource Strategy (NWRS) describes and discusses the Upper Vaal WMA in three sub-areas viz the Vaal upstream of Vaal Dam, Wilge and the Vaal downstream of the Vaal Dam (DWAf, 2004). A study area map is provided in Figure 1.1.

### 1.1.2 Economic characteristics

This WMA is economically one of the most important in the country and nearly 20% of the Gross Domestic Product (GDP) of South Africa originates from the Upper Vaal WMA. Only the adjacent Crocodile (West) and Marico WMA, with about 24%, contributes more to the GDP. The contribution of the different sectors to the Gross Geographic Product (GGP) in the Upper Vaal WMA reflects a diversified economy with a strong industrial and financial base. Despite the large areas under cultivation, agriculture only contributes about 2% of the GGP. Agriculture, however, has important linkages to other sectors and provides livelihood to a large proportion of the rural population (DWAf, 2004).

The potential for future growth in this WMA remains strong. Growth will largely be attracted to the already strong urban and industrial areas in the Johannesburg - Vereeniging-Vanderbijlpark complex. New mining developments will mainly replace worked out mines with a long term decline expected in this sector. There is however potential for further development of coal mining on the Eastern Highveld and in the Vereeniging area downstream of Vaal Dam (DWAf, 2004).

### 1.1.3 Mining

Products of the mining industry in the Upper Vaal WMA include coal, precious metals (gold, uranium, etc.), base metals, semi-precious stones and industrial minerals. The major impact of the mines on the water resource is the water pumped from the mines to dewater the underground workings mainly of the gold mines. The salinity loads associated with these mine discharges together with the sewage return flows contribute significantly to the salinity problems that are experienced in the Vaal Barrage and downstream river system. The mine dewatering and the diffuse salinity contributions from the highly developed urban and industrial areas in the Vaal Barrage catchment has resulted in the need for the currently applied blending and/or dilution operating rules applied downstream of Vaal Dam (DWAF, 2004).

### 1.1.4 Industry

Major industries in this WMA include Sasol I (Sasolburg), Mittal Steel, Sappi, the Sasol Midlands Plant and Sasol Synthetic Fuels (SSF) (Secunda). Sasol I is located in the Free State province near Sasolburg and abstracts water from the Vaal Barrage. The production of petro-chemicals is the main activity. Mittal Steel is located near Vanderbijlpark and is supplied with water from the Vaal Barrage. The production of iron and steel products is the main activity. SSF are located in Mpumalanga Province near the Secunda urban area. Water for SSF is supplied by pipeline from Grootdraai Dam. The production of petro-chemicals products is the main activity. Other important industries such as Sappi and Sasol Midlands Plant receive water from the urban centres where they are located. All these industries are economically important and provide significant employment. There are three operational coal fired power stations located in the WMA. The power stations are the Lethabo, Tutuka and Majuba Power Stations (DWAF, 2004).

### 1.1.5 Irrigated areas

The irrigation areas were estimated by Loxton Venn and Associates (LVA) in the report entitled: Report for the Vaal River Irrigation Study (DWAF, 1999a). Since the completion of the irrigation study, the registration of water use has been completed. Comparisons between the registered water use and the irrigation figures given in the report highlighted the uncertainties in the irrigation areas and water use, with the registered water use exceeding the LVA information. The verification process, which has been started in the WMA, will provide more certainty on the irrigation numbers. Regional DWAF personnel have indicated that the two major conveyance rivers are the Wilge and Liebenbergvlei and that major illegal irrigation occur along these rivers. Preliminary results from the Upper Vaal Water Management Area Validation Study indicated that as much as 236 million m<sup>3</sup>/annum of the year 2005 irrigation water use could be unlawful (DWAF, 2006).

About 75% of the irrigation is upstream of major storage dams and are supplied from run-of-river or farm dams. These areas will be supplied at a lower assurance of supply than the irrigation areas located in the Mooi sub-catchment (Mooi Government Water Scheme, Klipdrift and Vyfhoek Schemes) and Barrage to Mooi sub-catchment (Rietpoort and Koppieskraal Irrigation Boards) which are supported by major dams and conveyance infrastructure (DWAF, 2004).

### 1.1.6 Land use

The land use in the Upper Vaal WMA is characterised by the sprawling urban and industrial areas in the northern and western parts of the WMA. There are also extensive coal and gold mining activities located in the Upper Vaal WMA. These activities generate substantial return flow

volumes in the form of treated effluent from the urban areas and mine de-watering that are discharged into the river system. These discharges have significant impacts on the water quality in the main stem of the Vaal River (DWAF, 2004).

Land use is dominated by cultivated dry land, which occurs throughout the catchment with high density areas in the Wilge and Vaal Dam to Vaal Barrage sub areas with the main crops being maize and wheat.

### **1.1.7 The Social Environment**

The Upper Vaal WMA is the most populous WMA in South Africa. The total population is estimated at 5.6 million people in the year 1995. More than 80% of the population in the WMA reside in the area downstream of the Vaal Dam with nearly 97% living in an urban environment (DWAF, 2004).

The demography of the WMA will be influenced by economic opportunities and potential. Projections are therefore for continued strong growth in urban population in the sub-area downstream of Vaal Dam where most of the economic activity is centred. A decline in population is projected for the Wilge sub-area due to the movement of people out of Phuthaditjaba and the former QwaQwa area (DWAF, 2004).

### **1.1.8 Equity issues**

The poor in urban areas and rural villages are as important, in the consideration of the distribution and use of water resource, as the small (poor) rural subsistence farmer. This should not be forgotten in the urgencies of land reform and the enthusiasm to establish a substantial class of farmers from amongst the previously disadvantaged (DWAF, 2004).

Equity can be achieved through access to water in livelihood strategies, through small-farmer development programmes, through water supply and sanitation and especially the provision of good quality drinking water, and through the maintenance and growth of income-producing, job creating, and tax paying agricultural, commercial and industrial strategies (DWAF, 2004).

### **1.1.9 Recreational Water Use**

The use of water for recreational purposes is one of the 11 water uses regulated in terms of the NWA. Recreational use can take many forms and only occasionally has any direct impact on the water resource. Most obvious are activities such as power-boating, sailing and swimming which can have quality / pollution impacts. Far more significant in terms of both quantity and quality is the release of water to allow for canoeing and other water sports downstream (The Upper Vaal, Dusi and Fish River canoe marathons being prime examples). These activities can bring very significant economic benefits to the WMAs concerned, and where water releases can be accommodated, particularly through alignment with the needs of the ecological Reserve or other downstream users, then so much the better (DWAF, 2004).

Water resources offer a very significant recreational outlet and that recreation is an important public and social asset necessary for national health and productivity. A central philosophy is that recreational opportunity should not be unreasonably and unnecessarily denied to users, and that the implementation of policy should ensure that disadvantaged and poor people should also be able to avail themselves of opportunities (DWAF, 2004).

## 1.2 WATER AVAILABILITY

Due to the extensive development in the Vaal River System and in the Upper Vaal and Crocodile (West) WMA, which are supplied from the Upper Vaal WMA, the local surface water resources in all three of the Vaal WMAs had been fully exploited for more than 30 years. It was therefore necessary to augment the supply by developing various transfer schemes importing water from the Thukela and Usutu to Mhlathuze WMAs, as well as from the Kingdom of Lesotho through the Lesotho Highlands Water Project (LHWP) (DWAF, 2004).

The surface water availability in the Vaal River System is estimated through a set of water resource models, each fulfilling a particular function in the management of the water resources. Combined, these models serve as a decision support tool that contains a large and comprehensive database of hydrological and physical system characteristics, required to simulate the water resource systems as realistically as possible. Due to the interdependencies, the management and planning of the Vaal River System is undertaken at the national level and not by the Upper Vaal water managers (Catchment Management Agency (CMA) when it is established, until then the DWAF Regional Office) (DWAF, 2004).

The Upper Vaal water managers are, however, responsible for the assessment of the availability of the local groundwater and surface water resources used to supply local authorities and district councils without access to the Vaal River System water supply infrastructure (DWAF, 2004).

## 1.3 WATER REQUIREMENTS

The water requirement projections that are currently used for planning originate from the development of the NWRS. The total water requirement in the Upper Vaal WMA is 2424 million m<sup>3</sup>/annum. The total water requirements for the Upper Vaal are projected to reach 3071 million m<sup>3</sup>/annum by the year 2025 based on the August 2006 DWAF population scenario (DWAF, 2006a).

With the commissioning of Phase 1b of the LHWP (Mohale Dam and transfer tunnel) during the later part of 2003, an additional 320 million m<sup>3</sup>/annum is available. This surplus is expected to be gradually depleted over time (to supply the growing water requirements) until a deficit of about 56 million m<sup>3</sup>/annum is projected for the year 2019 using the base requirement scenarios (DWAF 2006a).

What is important to recognise is that this estimated excess in supply is qualified as “conditional” since it is only available if all the transfers are fully operational. In practice the volume of water conveyed through the Thukela-Vaal Transfer scheme will be determined annually, effectively operating the system such that the water demands are in balance with the supply. The quantity transferred will thus increase over time in line with the growth in the water requirements.

A further important perspective is that, although the system as a whole will experience surplus conditions over the medium to long term, this surplus is not available in Grootdraai Dam and supporting systems (also referred to as the Eastern Sub-system) due to the physical location of some of the transfer schemes. A pre-feasibility study into the need for augmentation of the Eastern Sub-system showed that further augmentation of this sub-system will be required by the year 2010. A number of options have been assessed as possible schemes to augment the supply and the latest recommendation is that a pipeline should be constructed to convey water from Vaal Dam to support the water requirements of the Eastern Sub-system.



Figure 1.1 Locality of EWR sites and Management Resource Units

## 2 PROJECT PLAN AND APPROACH

Author: MD Louw (Rivers for Africa)

### 2.1 INTRODUCTION

The approach to the Reserve study was within context of the eight-step Reserve procedure (Louw and Hughes, 2002). The eight step procedure is provided in Figure 2.1.

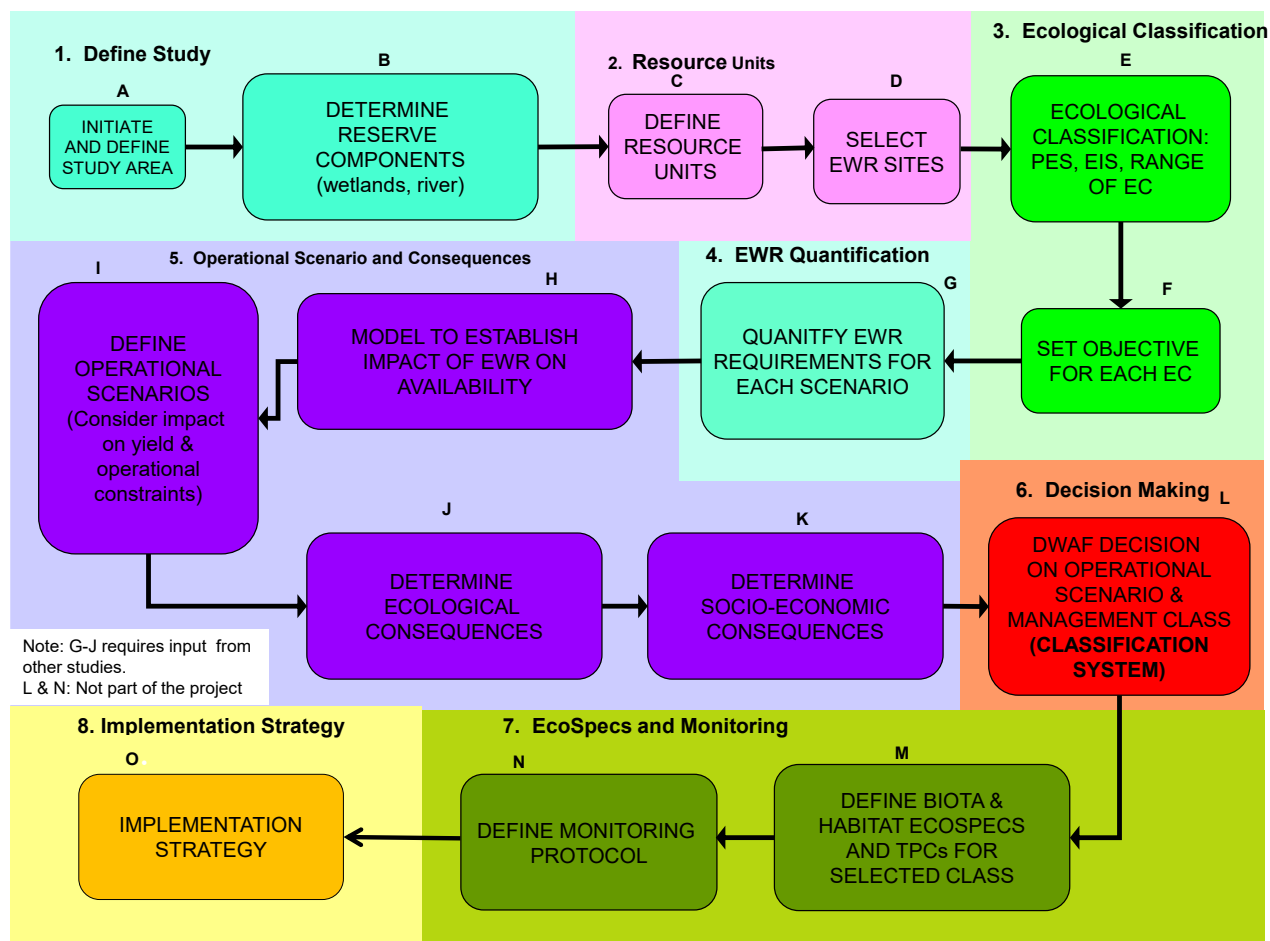


Figure 2.1 Diagram illustrating the process to be followed for the Upper Vaal WMA Reserve study (Adapted from **DWAF, 2006b**)

### 2.2 AIMS, OBJECTIVES AND OUTCOMES OF THE STUDY

The Reserve process is a scenario-based approach. The team therefore generated a series of likely scenarios that were determined by an interactive series of discussions between key specialists of the technical, the yield planning consultants (WRP) and management teams. This approach enabled the DWA to make management decisions using scenarios, based on a number of alternatives with anticipated consequences.

The overall aim of the project as described in the Terms of Reference (ToR) was to provide EcoClassification results and Comprehensive Reserves for WMA 8. The detailed aims, objectives and proposed outcomes of the study were as follows:

- Provide the typing, importance and habitat integrity of wetlands within WMA 8 and make recommendations regarding Reserve assessments.

- Provide a Desktop assessment per quaternary catchment of the Present Ecological State (PES), Ecological Importance and Sensitivity (EIS) and Socio-cultural Importance (SCI) as part of the EcoClassification process.
- Provide a Level 4 EcoStatus assessment for the Resource Units (RUs) represented by comprehensive Ecological Water Requirements (EWRs) sites as part of the EcoClassification process.
- Identify other Ecological Categories (ECs) and provide implications / consequences of these categories.
- Determine EWRs for each of these ECs.
- Determine the impact of EWRs on the allocatable yield and, based on the impacts, devise additional scenarios if needed to optimise the allocatable yield.
- Determine the ecological and resource-economic consequences of each of the additional scenarios.
- Provide the Ecological Specifications (EcoSpecs), as input to the Resource Quality Objectives (RQOs), associated with the Management Class provided to the PSP, if available.
- Train selected specialist trainees in specific tasks relating to Reserve determinations.

The output of the study is Ecological Water Requirement (EWR) Rules for every site and for a range of Ecological Categories, as well as the EcoSpecs.

## **2.3 PROJECT PLAN**

The project plan generally used by Rivers for Africa for Reserve studies was modified for the Upper Vaal Reserve Study and consisted of a range of tasks and sub-tasks listed in Table 2.1. These task numbers are linked to those in Figure 2.2.

The results of these tasks are described within this main report and the corresponding chapters are provided in the Table 2.1

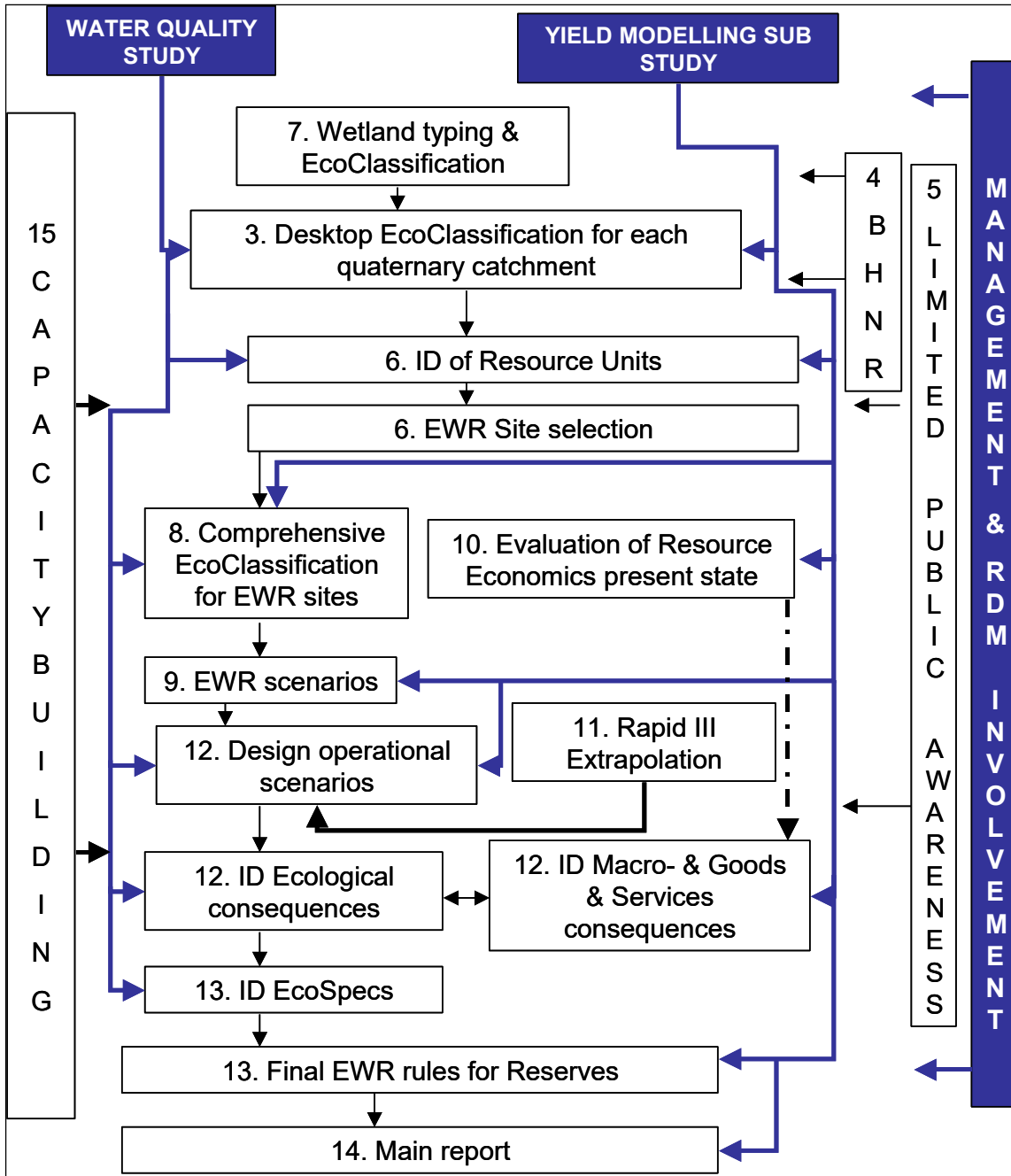


Figure 2.2 Project Plan for the Upper Vaal Reserve study

Table 2.1 List of tasks within the Project Plan

TASKS AND SUBTASKS	Corresponding chapters in main report
<b>TASK 1 - PROJECT MANAGEMENT</b>	
1.1 Internal technical team management and coordination	
1.2 PMT Meetings (Progress meetings)	
1.3 Liaison with other studies	
1.4 Financial management	
<b>PHASE I: STUDY INITIATION AND DESIGN</b>	
<b>TASK 2 - PROJECT PLANNING AND PROCESS INTEGRATION</b>	<b>Chapter 2</b>
2.1 Design of project plan and available current data collection	
Inception Report	
2.2 Mobilisation of study team	

<b>TASKS AND SUBTASKS</b>	<b>Corresponding chapters in main report</b>
<b>PHASE II: STUDY IMPLEMENTATION</b>	
<b>TASK 3 - PES, EIS and SCI: QUATERNARY BASIS</b>	<b>Chapter 3</b>
3.1 Preparation 3.2 Reconnaissance assessment (includes prelim site selection) 3.3 Application of EcoStatus models (PES, EIS and SCI) 3.4 Database and Reporting	
<b>TASK 4 - LIMITED PUBLIC AWARENESS: ASSESSMENT</b>	
<b>TASK 5 - BASIC HUMAN NEEDS RESERVE</b>	<b>Chapter 4</b>
<b>TASK 6 - RESOURCE UNITS</b>	<b>Chapter 5</b>
6.1 Geomorphological zones 6.2 EcoRegions 6.3 System operation 6.4 Water quality sub-units 6.5 Groundwater sub-units 6.6 Identification of Resource Units 6.7 EWR site selection and dry season survey (10 sites) A Prelim ID of sites B Dry season survey Week 1 B Dry season survey Week 2 C Habitat modelling survey 6.8 RU Report	
<b>TASK 7 - WETLAND TYPING AND ECOCLASSIFICATION</b>	<b>Chapter 11</b>
7.1 Wetland inventory 7.2 Wetland classification 7.3 Determination of Reference conditions 7.4 General current ecological conditions 7.5 Identification of priority wetlands 7.6 Ecological Importance and Sensitivity 7.7 WHI assessment 7.8 Reporting	
<b>TASK 8 – COMPREHENSIVE RIVER ECOCLASSIFICATION</b>	<b>Chapter 6</b>
8.1 Suite of EcoStatus models 8.2 Index of Habitat Integrity 8.3 EcoStatus assessment 8.4 EcoClassification specialist meeting: Workshop 8.5 Reporting	
<b>TASK 9 - EWR SCENARIO ASSESSMENT</b>	<b>Chapter 7</b>
9.1 Hydraulic calibration and wet season site visit (10 sites) A High flow calibration B Hydraulic calibration C Hydraulic calibration & field surveys 9.2 EcoHydraulic modelling and Sediment Transport Modelling 9.3 EcoHydrology analysis 9.4 Specialist meeting preparation 9.5 EWR scenario determination A Workshop 1 B Workshop 2 9.6 Reporting	
<b>TASK 10 -SOCIO ECONOMIC PRESENT STATE EVALUATION</b>	<b>Chapter 9</b>

TASKS AND SUBTASKS	Corresponding chapters in main report
10.1 Identification of the sectors directly and indirectly using water from the Vaal River System 10.2 Determination of economic zones and current water allocation to each category of use 10.3 Determination of the appropriate valuation technique for each use category 10.4 Economic value of water use by each category	
<b>TASK 11: RAPID III - EXTRAPOLATION</b>	<b>Chapter 12</b>
Rapid data collation	
<b>TASK 12 - DETERMINING OPERATIONAL SCENARIOS AND CONSEQUENCES</b>	<b>Chapter 8</b>
12.1 Liaison: Yield modelling 12.2 Determining ecological consequences 12.3 Determining consequences on socio economics & Ecosystem services A Change in value of the socio-economic activities for different EWR scenarios Ecological input B Changes in value of ecosystem services for different EWR scenarios C Optimisation of the overall benefits from water re-allocation scenarios 12.4 Reporting	
<b>TASK 13 – IDENTIFICATION OF ECOSPECS (Ecological RQO's)</b>	<b>Chapter 10</b>
13.1 Identification of EcoSpecs 13.2 Reporting	
<b>PHASE III: STUDY TERMINATION</b>	
<b>TASK 14 - STUDY TERMINATION</b>	
14.1 Preparation of final Reserve results 14.2 Training audit and report 14.3 Compilation of main report	
<b>TASK 15 CAPACITY BUILDING: TRAINING PROGRAMME</b>	<b>Chapter 13</b>
15.1 Design and application of training programme 15.2 Introductory EWR workshop 15.3 Individual training: Task 1 - Management 15.4 Individual training: Task 5 - BHNR 15.5 Task 6 - Field Survey: Resource Units 15.6 Individual training: Task 7 - Wetland 15.7 Individual training: Task 8 15.7.1 Hydrology + Hydraulics 15.7.2 Geomorphology 15.7.3 Macro Invertebrates 15.8 EcoClassification specialist workshop: Task 8 15.9 Field survey: Task 9 15.10 Technical EWR training workshop 15.11 EWR specialist workshop: Task 9 15.12 Individual training: Task 10 - Socio-economic study 15.13 Individual training: Task 12.1 - Operational scenarios Task 12.2 - Socio-economic consequences 15.14 Training evaluation and reporting	

## 2.4 VARIATION ORDERS

Two variation orders (VO) were approved during the course of the study. The VOs are outlined below:

### 2.4.1 Socio-Economics

Changes in the scope of work to undertake the assessment of the socio-economic implications of different scenarios of the Ecological Water Requirements of the Reserve for the upper Vaal River catchment were needed. The change in the scope of work and level of detail was a result of the need to ensure sufficient work was conducted on the upper Vaal River catchment and that the results were integrated with the work done in the Middle and Lower Vaal and Crocodile West sub catchments. Due to the current operation of the Upper Vaal system the approach to the assessment of the socio-economic impact of Reserve scenarios on the Vaal River main stem and the associated tributaries had to be re-assessed and is summarised below:

- Vaal River main stem

The upper Vaal River WMA is different to many of the water management areas in the country because the Vaal River receives more water than under natural flow conditions as a result of inter-basin transfers into the catchment to sustain the socio-economic activities of the area as it is the economic hub of the country. Although there was likely to be sufficient water in the main stem because of the transfers, changes in the flow regime to achieve ecological objectives would impact on the socio-economy of the WMA. Augmentation schemes of water would be required to maintain the current socio-economic activities. The timing of construction and the capacity of augmentation would be dependent on the level of the Ecological Water Requirements for the Reserve and the unit cost of the augmentation schemes (from a timing and capacity) would impact the costs of providing intermediate and final goods by the existing user sectors. The financial and economic implications of different augmentation options of the flow regime on the WMA had to be evaluated with a view to optimising the additional transfer requirements including the timing of the augmentation options.

- Tributaries

The reserve requirements for the tributaries of the Upper Vaal River system had to be assessed differently. The assessment focussed on analysis of the socio-economic impacts of reductions in water use entitlements to existing user sectors, specifically irrigation impacts.

### 2.4.2 Extrapolation process at 10 rapid sites in the Upper Vaal system

At the time of the onset of the project an estimation procedure was under development and pilot tested on the Komati System. This was a WRC-DWA funded project with D: RQS being the lead on the ecological input and Dr Birkhead the main input on the analysis of hydraulic data. A draft report on the estimation process was available (Kleynhans *et al.*, 2007) and further work on automising the process was planned and approved by the WRC (commencing April 2008/09). During the study, as part of the original budget the following actions were completed:

- Hydronodes were selected where EWRs had to be estimated or extrapolated.
- An approach was determined specifically for the Vaal River based on the Komati pilot testing.
- Available EWR and hydraulic data as well as specialist input was used to provide preliminary HabSpecs.
- Field work was undertaken to collate data to calibrate HabSpecs.

Additional funding was requested to analyse the field data collected at ten Rapid sites in the Upper Vaal WMA which included:

- Determining ecological similarity between all sites with biological information and EWR sites.

- Estimating the fish and invertebrate indicator assemblages.
  - Extrapolating information from EWR sites to appropriate hydronodes.
  - Estimating requirements at the other hydronodes using HabSpecs and an appropriate hydraulic conversion method.
-

### 3 DESKTOP ECOCLASSIFICATION

Department of Water Affairs and Forestry (DWAf), 2008. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Desktop EcoClassification report. Report produced by Koekemoer Aquatic Services and Water for Africa. Authored by Louw, D. Report no: RDM/WMA8C000/01/CON/0207.

#### 3.1 APPROACH

The objective of the EWR study is to provide information at two levels of detail, i.e. at scoping or desktop level, as well as a more detailed assessment. This task presents the results of the Desktop assessment of the EcoClassification process for each quaternary and sub-quaternary catchment. The term used for Ecological Classification "EcoClassification" (Kleynhans et al., 2005) refers to the determination and categorisation of the Present Ecological State (PES) - or health or integrity - of various biophysical attributes of rivers, compared with the natural or close to natural reference condition. The purpose of EcoClassification is to gain insight into the causes and sources of the deviation of the PES from the reference condition. This provides the information needed to derive the desirable and attainable future ecological objectives for the river. The present state of the river is described in terms of Ecological Categories (A to F). The EcoClassification process also includes an assessment of Ecological Importance and Sensitivity (EIS), and Socio-Cultural Importance (SCI). These are described in terms of Low to Very High (EIS) and Minimal to Very High (SCI). All assessments include a confidence rating that may range from 1 (low confidence) to 5 (high confidence).

#### 3.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The ecological importance of a river is an expression of its contribution to the maintenance of biological diversity and ecological functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience) (Resh et al., 1988; Milner, 1994).

No areas of Very High EIS were present in the WMA. The few areas of High EIS were the following:

- C13C (Klip River): Due to the presence of a RAMSAR site, the Seekoeivlei.
- C21C (Suikerbosrand): Due to species taxon richness and the presence of rare and endangered *Labeobarbus kimberleyensis*.
- C23C and C23L (Vaal River near and downstream of Parys): The river is situated in the Dome World Heritage site and the rare and endangered *Labeobarbus kimberleyensis* was present.
- C83E (Tierkloof): Most of the metrics rated high with specific emphasis on the diversity of habitat types and the species diversity and sensitivity.

The majority of the rest of the quaternary catchments were rated as Moderate. The confidence of the evaluation ranged mostly from Moderate to High with approximately 30% rated as Low. The results are summarised in Table 3.1 and in Figure 3.1.

The EIS evaluation was only undertaken for the main rivers in the quaternaries. Evaluation is still required to identify those rivers of high and very high importance on a sub-quaternary scale.

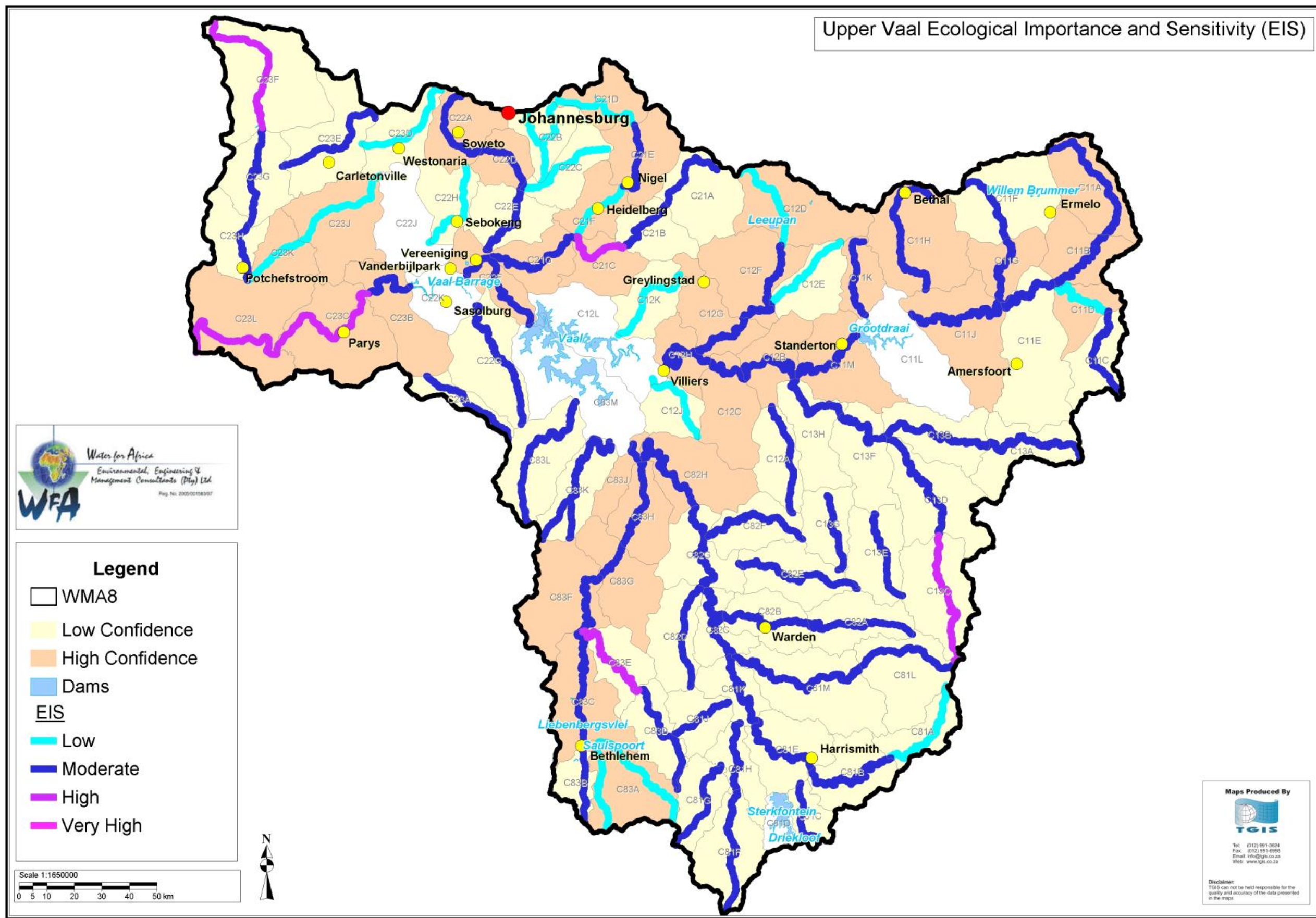


Figure 3.1 EIS per quaternary catchment with associated confidence for the Upper Vaal WMA

### 3.3 SOCIO-CULTURAL IMPORTANCE

The SCI was determined from:

- A site visit that covered points long the river; and
- extrapolation to sites not visited by reference to available literature, as well as to existing mapping.

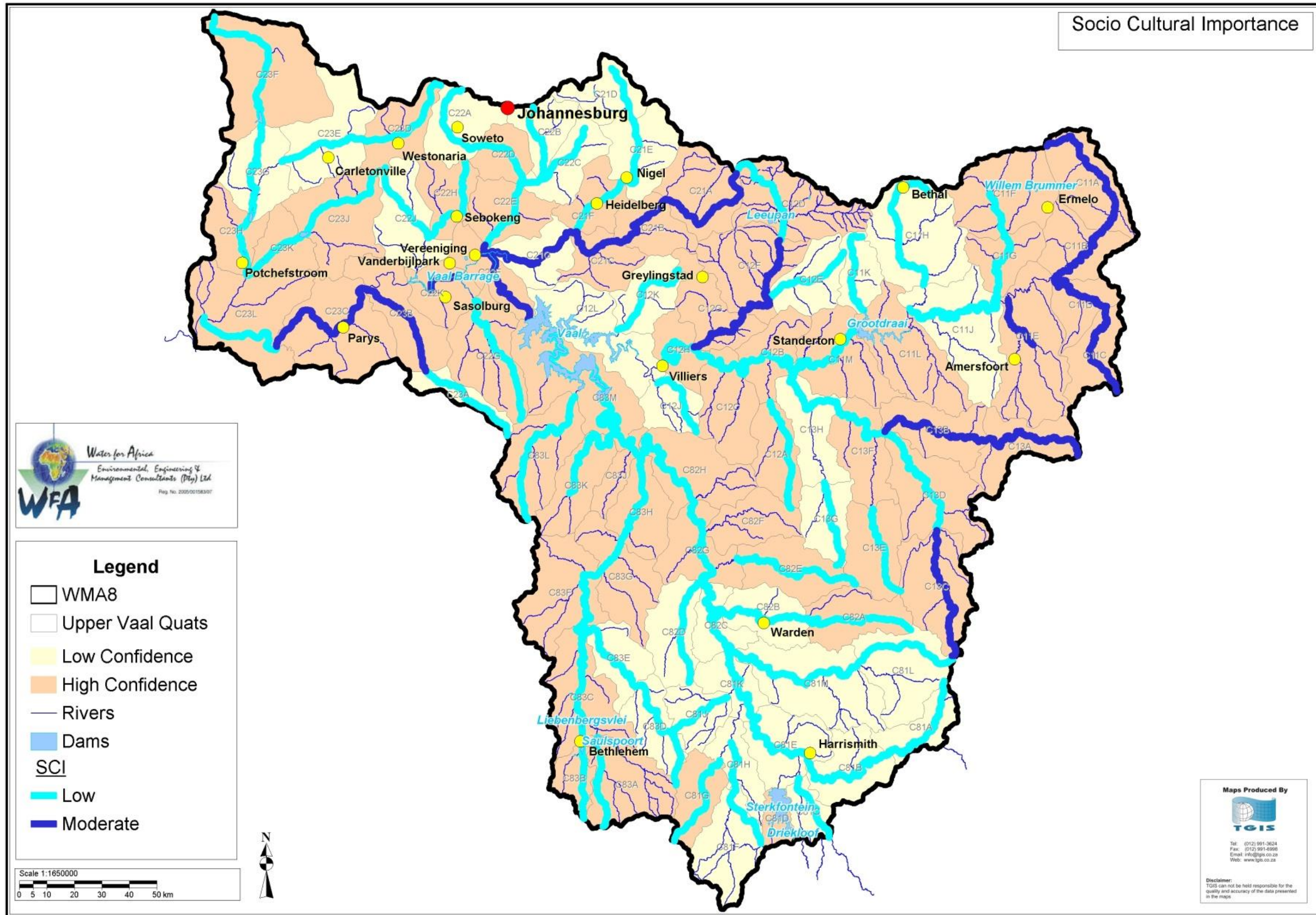
The SCI was generated by scoring each quaternary, based on the following features:

- Ritual Use (e.g., ceremonial purposes, spiritual/religious activities.).
- Aesthetic Value.
- Resource Dependence (it refers to the goods and services delivered by the river system and people's dependence on these components).
- Recreational Use.
- Historical/Cultural Value (e.g., Fugitives Drift on the Buffalo River or components of the Mzimvubu River that have played a central role in Xhosa cultural history).

Scores were then weighted to reflect the adjudged importance of each component relative to the other. The Resource Dependence component was given the highest weighting, because this component is designed to reflect the importance of a healthy riverine system to people who are often in the grips of poverty, and for whom the availability of such resources is a question of survival. In terms of the SCI all the river reaches scored Moderate or High. The reason for the scoring has a great deal to do with the low population densities and the structure of the communities that reside in the area and depend on the river. The categories "Recreational" and "Historical/Cultural" generally scored highly.

Areas dominated by relatively low population densities and given over to commercial farming enterprises (typically the upper parts of the catchment) as well as portions of the middle catchment tended to score relatively low in terms of SCI. An obvious exception is recreational use. Portions of the WMA with water related recreational activity scored slightly higher. Areas dominated by mining and industrialisation also scored generally low in terms of SCI. It should be emphasised that low SCI score does not indicate low economic importance. In terms of economic importance the catchment is obviously critical to the RSA.

The SCI for Upper Vaal was generally low and water quality issues do not seem to play a major role other than periodic issues attached to recreational aspects on the Vaal below the barrage. This does however not influence the SCI scoring. A SCI map illustrating the SCI rating and confidence is provided in Table 3.1 and Figure 3.2 for the Upper Vaal WMA.



**Figure 3.2** Map illustrating SCI rating and confidence of the Upper Vaal WMA

### 3.4 PRESENT ECOLOGICAL STATE

The PES of the river is expressed in terms of various components, i.e., drivers (Physico-chemical variables, geomorphology, hydrology) and biological responses (fish, riparian vegetation and aquatic invertebrates), as well as an integrated state, the EcoStatus.

A Desktop Level EcoStatus assessment was designed for use when assessments for planning purposes on large scale have to be undertaken. As the name indicates, this is done at desktop level, and is therefore based on available information and expert judgement. However, due to the lack of relevant information in some of the areas, a site visit was undertaken during this study to provide additional information.

The bulk of the rivers in WMA 8 are in a C, C/D and D category. Please note that this did not include all the smaller tributaries but only refers to the main rivers in the quaternaries. The rivers in a B category were the following:

- C11C: Klein Vaal
- C13E: Kommandospruit
- C81L & C81M: Meul
- C82A: Cornelis
- C83K: Kromspruit
- C83L: Klipspruit
- C81A & C81B Wilge
- C81C Modder/Fraser
- C21A Suikerbosrand

The results indicated that there were very few rivers in this large WMA which were potentially still in a good condition. The reason for this was the high utilisation of the catchment due to mining, irrigation and the urban sprawl of Gauteng. Water quality issues were prevalent in many streams as well as increased flows, i.e. more than natural. The results are summarised in Table 3.1 and in Figure 3.3.

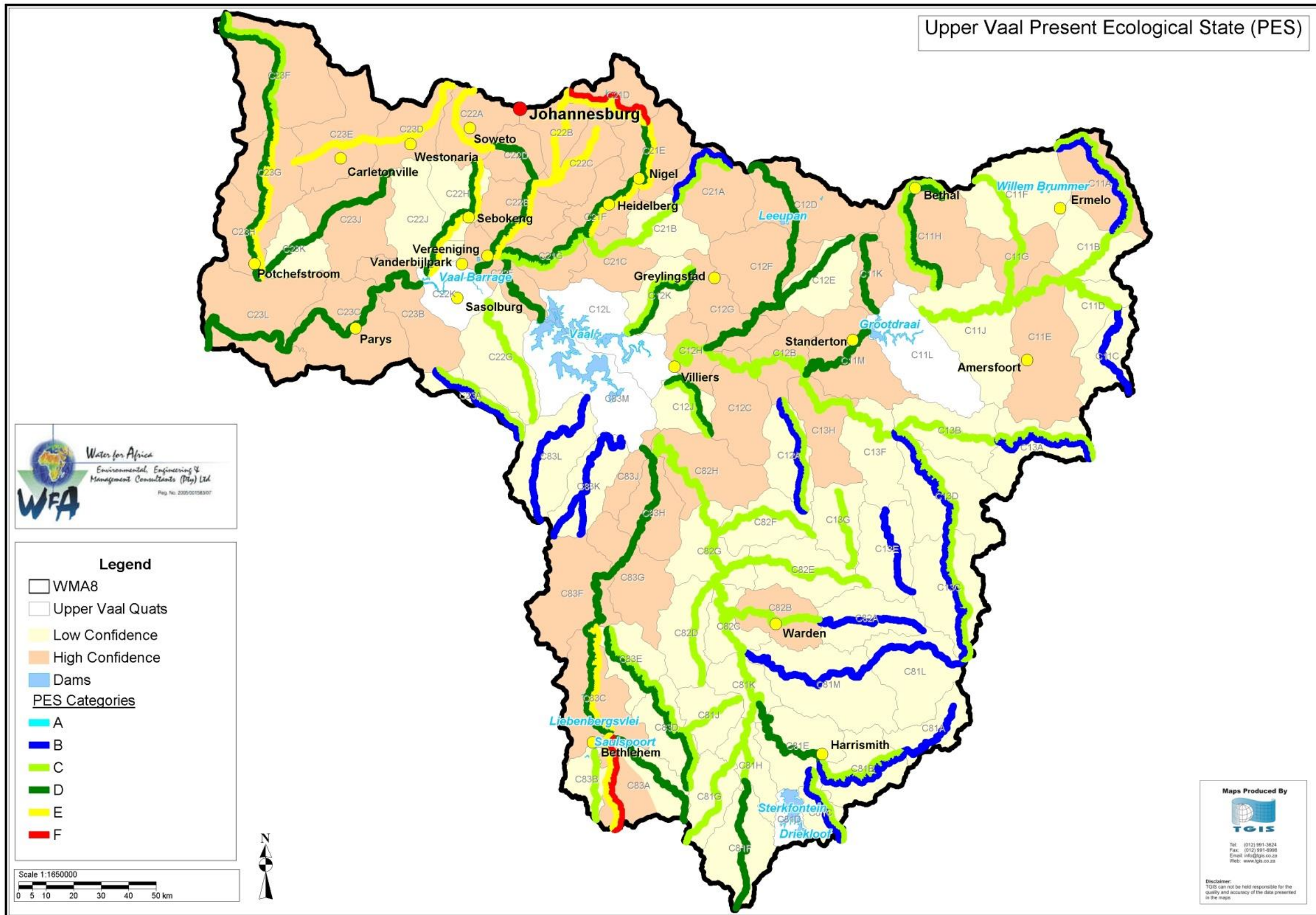


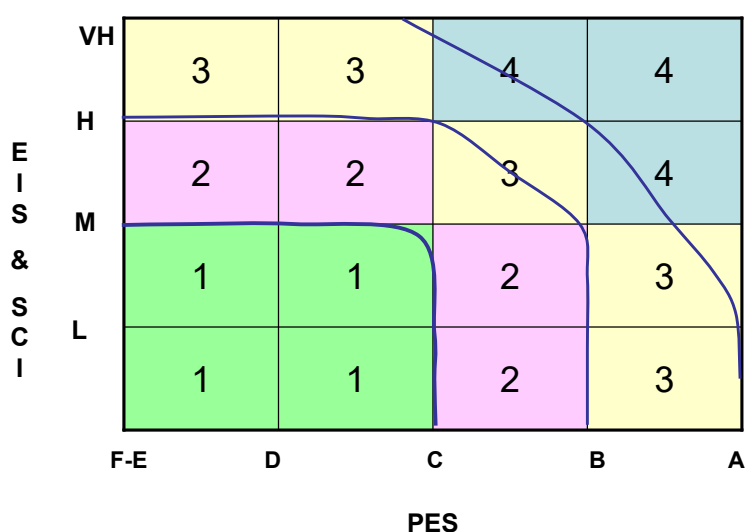
Figure 3.3 Map illustrating PES categories and confidence of the upper Vaal WMA

### 3.5 INTEGRATED IMPORTANCE CONSIDERING EIS, PES AND SCI

A combination of EIS, SCI, and PES provide an indication of overall / integrated importance with the emphasis on the restoration potential. The restoration potential refers to the probability of achieving the rehabilitation of the river to an improved state. For example, if a river has very high overall importance, but is in bad condition, the restoration potential is often low.

However, rivers in good condition are scarce, and therefore important in their own right. A river that is in very good condition, but of low EIS, and/or SCI; might still be important from an ecological perspective, as it could be one of a limited number of that type of river that is still in good condition.

According to the matrix below (Figure 3.4) (note, the curves have not been fitted, but have been 'hand drawn'), an Integrated Importance value is estimated from 1 (low importance to 4 high importance).



**Figure 3.4 Matrix used to determine an Integrated Importance value on a scale of 0 – 4 (modified from Louw and Huggins, 2007)**

The results of the evaluation are listed in the Table 3.1 and illustrated in Figure 3.5 and 3.6. This depicts the areas of high (3) and very high (4) Integrated Importance in the quaternary catchments on a spatial scale. Note that the highest score between EIS and SCI is used to compare to PES. The additional information provided in the figures are the rivers where a specific EIS was rated a 4. These are illustrated as lines on the rivers.

**Table 3.1 Quaternaries of high and very high Integrated Importance**

Quaternary Catchment	River	Importance Rating (0 – 4)	Reasons for Evaluation
C11A	Vaal	3	Moderate EIS and B/C PES
C11C	Klein Vaal	4	Moderate EIS and B PES
C12A	Ventersspruit	3	Moderate EIS and B/C PES
C13A	Sandspruit	3	Moderate EIS and B/C PES
C13C	Seekoeivlei (Klip River)	4	High EIS and B/C PES
C13D	Klip (after confluence with Modderspruit/Gansvleispruit system)	3	Moderate EIS and B/C PES
C13E	Kommandospruit	4	Moderate EIS and B PES

<b>Quaternary Catchment</b>	<b>River</b>	<b>Importance Rating (0 – 4)</b>	<b>Reasons for Evaluation</b>
C21A	Suikerbosrand	3	Moderate EIS and B PES
C21C	Suikerbosrand	3	High EIS and C PES
C23A	Kromelleboogspruit	3	Moderate EIS and B/C PES
C23C	Vaal	3	High EIS and D PES
C23L	Vaal	3	High EIS and D PES
C81A	Wilge (main stem)	3	Low EIS and B PES
C81B	Wilge (main stem)	3	Moderate EIS and B PES
C81C	Modder/Fraser	3	Moderate EIS and B PES
C81L	Meul	4	Moderate EIS and B PES
C81M	Meul	4	Moderate EIS and B PES
C82A	Cornelius	4	Moderate EIS and B PES
C83E	Tierkloof	3	High EIS and C/D PES
C83K	Kromspruit	4	Moderate EIS and B PES
C83L	Klip	4	Moderate EIS and B PES

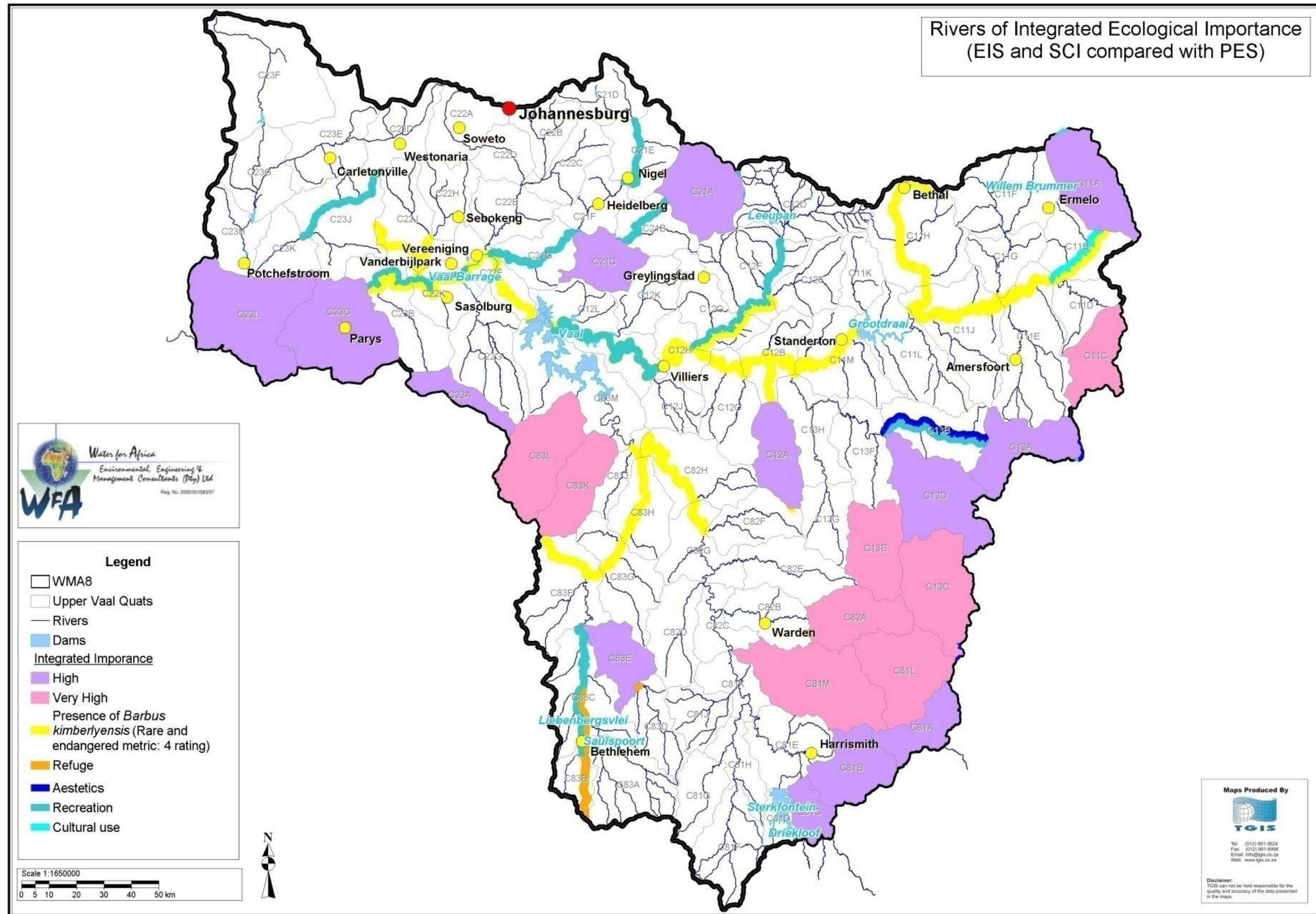
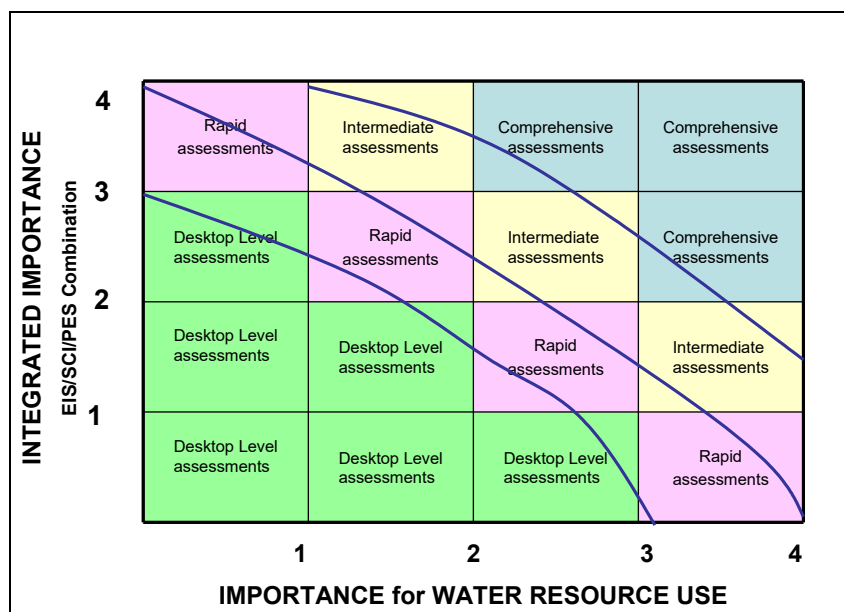


Figure 3.5 Map illustrating areas of high Integrated Importance in the Upper Vaal WMA

### 3.6 PRIORITY AREAS FOR EWR ASSESSMENT

A matrix (Figure 3.6) was again used to assess the rating of priority areas. The X-axis was based on the Integrated Importance value derived from the first matrix (Figure 3.5, Table 3.1 and results illustrated in Figure 3.4). The Y-axis depicts an estimate of water resource use (DWAf, 2007a), with a 0 being of no importance and 4 being of very high importance. This matrix was used to identify quaternary catchments which are so called ‘hotspots’. A biodiversity/ecological hotspot is a biogeographic region which is a significant reservoir of biodiversity which is threatened with destruction ([http://en.wikipedia.org/wiki/Biodiversity\\_hotspot](http://en.wikipedia.org/wiki/Biodiversity_hotspot)). In the context used in the Desktop EcoClassification, the hotspot represents a quaternary catchment with a high Integrated Importance which could be under threat due to its importance for water resource use. These hotspots indicate areas where Reserve assessments should ideally result in high confidence recommendations. This then guides the initial estimate of the level of the assessments required, and indicates areas where detailed investigations would be required if development was being considered. It must be noted that a detailed Reserve assessment does not necessarily provide high confidence results. This is usually due to constraints such as lack of available data (hydrology, biota etc.).



**Figure 3.6 Matrix indicating the level of EWR assessments required (modified from Louw and Huggins, 2007)**

#### 3.6.1 Importance of Water Resource Use

The priority rating method consisted of assigning a qualitative score to a river reach for four variables or factors that represented the status of the instream flow. The scores of the four variables were combined to determine (qualitatively) an overall score which represented the importance of the river reach in terms of the water resource use and guided decision making with regard to what level of assessment was needed (DWAf, 2007a).

### 3.6.2 Determine level of EWR

The matrix was used to compare the Integrated Importance with the Water Resource Use Importance (Louw and Huggins, 2007) and the results are provided in Table 3.2 and Figure 3.7. Important water resource use areas are highlighted in green in Table 3.2.

**Table 3.2 Quaternary catchments of high Integrated Importance and/or high Water Resource Use Importance**

Quaternary Catchment	River	Importance Rating (0 – 4)	Water Resource Stress Rating	Recommendations PRIORITY RATING	Reasons for Evaluation
C11A	Vaal	3	1	2	High EIS and PES
C11B	Vaal	2	1	1	
C11C	Klein Vaal	4	1	2	High ecological importance upstream of transfer
C11D	Klein Vaal	2	2	2	Important from a transfer point of view
<b>C11E &amp; C11J</b>	<b>Vaal</b>	<b>2</b>	<b>3</b>	<b>3</b>	<b>Transfer of water into Grootdraai Dam</b>
C11F & C11G	Drinkwaterspruit (Rietspruit)	2.5	2	2	Ermelo
C11H	Blesbokspruit	1.5	1	1	
C11K	Leeuspruit	1.5	1	1	
<b>C11M, C12B, C, H</b>	<b>Vaal</b>	<b>2.5</b>	<b>4</b>	<b>3</b>	<b>Transport of water to the Vaal River from Grootdraai Dam</b>
C12A	Ventersspruit	3	0	1	High integrated importance
C12D, F, G	Waterval (Kleinspruit)	1	2?	1	
C12E	Boesmanspruit	1	0	1	
C12J	Unnamed	1	0	1	
C12K	Molspruit	1	0	1	
C13A	Sandspruit	3	0	1	High integrated importance
C13B	Sandspruit	2	0	1	
C13C	Seekoeivlei (Klip River)	4	0	2	High integrated importance due to RAMSAR wetland
<b>C13D</b>	<b>Klip (after confluence with Modderspruit/ Gansvleispruit system)</b>	<b>3</b>	<b>2</b>	<b>3</b>	<b>Possible dam downstream</b>
C13E	Kommandospruit	4	0	2	High PES, moderate EIS
C13F	Klip	2.5	2	3	Possible dam downstream
C13G	Spruitsonderdrip	2	0	1	
<b>C13H</b>	<b>Klip</b>	<b>2.5</b>	<b>2</b>	<b>3</b>	<b>Possible dam</b>
C21A	Suikerbosrand	3	0	1	High PES, moderate EIS
C21B	Suikerbosrand	2	0	1	
C21C	Suikerbosrand	3	1	2	High PES, moderate EIS
C21D	Blesbokspruit	1	3	2	Water quality, and too much water
C21E	Blesbokspruit	1	3	2	Water quality, and too much water
C21F	Blesbokspruit	1	3	2	Water quality, and too much water
<b>C21G</b>	<b>Suikerbosrand</b>	<b>2</b>	<b>3</b>	<b>3</b>	<b>Water quality, and too much water</b>
C22A	Klip	1	4	2	Due to Water quality issues

Quaternary Catchment	River	Importance Rating (0 – 4)	Water Resource Stress Rating	Recommendations PRIORITY RATING	Reasons for Evaluation
C22B	Natalspruit	1	4	2	Due to Water quality issues
C22C	Rietspruit	1	4	2	Due to Water quality issues
C22D	Klip	1	4	2	Due to Water quality issues
C22E	Klip	1	4	2	Due to Water quality issues
<b>C22F</b>	<b>Vaal</b>	<b>2.5</b>	<b>4</b>	<b>3</b>	<b>Presence of BKIM<sup>1</sup> and releases from Vaal Dam</b>
<b>C22G</b>	<b>Taaibosspruit</b>	<b>2</b>	<b>1</b>	<b>1</b>	
C22H	Rietspruit	1	3	1	Due to water quality issues
C22J	Leeuspruit	1	3	1	Water quality
C22K	Taaibosspruit	1	3	1	Sasol water quality problems
C22K	Vaal	3	4	4	BKIM, high integrated importance and water use importance
C23A	Kromellemboogspruit	3	0	1	Integrated importance
<b>C23B</b>	<b>Vaal</b>	<b>3</b>	<b>4</b>	<b>4</b>	<b>BKIM, High integrated importance and water use importance</b>
<b>C23C</b>	<b>Vaal</b>	<b>3</b>	<b>4</b>	<b>4</b>	<b>BKIM, High integrated importance and water use importance</b>
C23D & E	Wonderfonteinspruit	1	3?	1	Significant radiation problems – Reserve will not address the problem, therefore low priority
C23F	Schoonspruit	1	4	2	
<b>C23G</b>	<b>Mooi</b>	<b>1.5</b>	<b>4</b>	<b>3</b>	<b>Water balance</b>
<b>C23H</b>	<b>Mooi</b>	<b>1.5</b>	<b>4</b>	<b>3</b>	<b>Water balance</b>
C23J	Loopspruit	1	1?	1	
C23K	Loopspruit	1	4	2	Water balance
<b>C23L</b>	<b>Vaal</b>	<b>3</b>	<b>4</b>	<b>4</b>	<b>BKIM, High integrated importance and water use importance</b>
<b>C81A</b>	<b>Wilge (main stem)</b>	<b>3</b>	<b>3</b>	<b>3</b>	<b>Proposed Braamhoek Pump Storage Scheme</b>
C81B	Wilge (main stem)	3	0	1	High integrated importance
C81C	Modder/Fraser	3	0	1	High integrated importance
<b>C81E &amp; DS quats</b>	<b>Wilge</b>	<b>2.5</b>	<b>3</b>	<b>3</b>	<b>Role of transporting water from Sterkfontein Dam</b>
C81F	Elands	1.5	3	2	Supply to Phuthaditjaba
C81G	Klerkspruit	2	0	1	
C81H	Elands	2	0	1	
C81J	Vaalbanks	2	0	1	
<b>C81K</b>	<b>Wilge</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>Role as conduit</b>
C81L	Meul	4	0	2	High PES EIS
C81M	Meul	4	0	2	High PES EIS
C82A	Cornelius	4	0	2	
C82B	Cornelis	2	0	1	
C82C	Wilge	2	4	3	Conduit
C82D	Rus se spruit	2	0	1	
C82E	Holspruit	2	0	1	
C82F	Grootspruit	2	0	1	
<b>C82G</b>	<b>Wilge</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>Proposed pump storage scheme</b>
<b>C82H</b>	<b>Wilge</b>	<b>2</b>	<b>4</b>	<b>3</b>	<b>Proposed pump storage scheme</b>
C83A	Liebenbergsvlei	1	0	1	

Quaternary Catchment	River	Importance Rating (0 – 4)	Water Resource Stress Rating	Recommendations PRIORITY RATING	Reasons for Evaluation
C83A	Axel River	1	4	2	Limited operational possibilities and impossible to work on site
C83B	Jordaans	2	0	1	
C83C	Liebenbergsvlei	2	4	2	Water balance and operational purposes. Limited operational possibilities and impossible to work on site
C83D	Tierkloof	2	0	1	
C83E	Tierkloof	3	0	2	High EIS
C83F, G, H	Liebenbergsvlei	1	4	2	Water balance and operational purposes
C83K	Kromspruit	4	0	2	High PES and EIS
C83L	Klip	4	0	2	High PES and EIS

1 *Labeobarbus kimberleyensis*

These areas are illustrated spatially on a map (Figure 3.7). These dark and light red quaternaries represent the main river reaches where considerable care should be taken when considering development and which would require intermediate or comprehensive EWR assessment.

This assessment guided the selection of EWR sites (See Chapter 7). It was attempted to place most of the EWR sites within the 'Very High' and 'High' areas. The selection of EWR sites was also dependant on other factors such as the suitability of potential sites for EWR assessments and areas with a high demand for licenses.

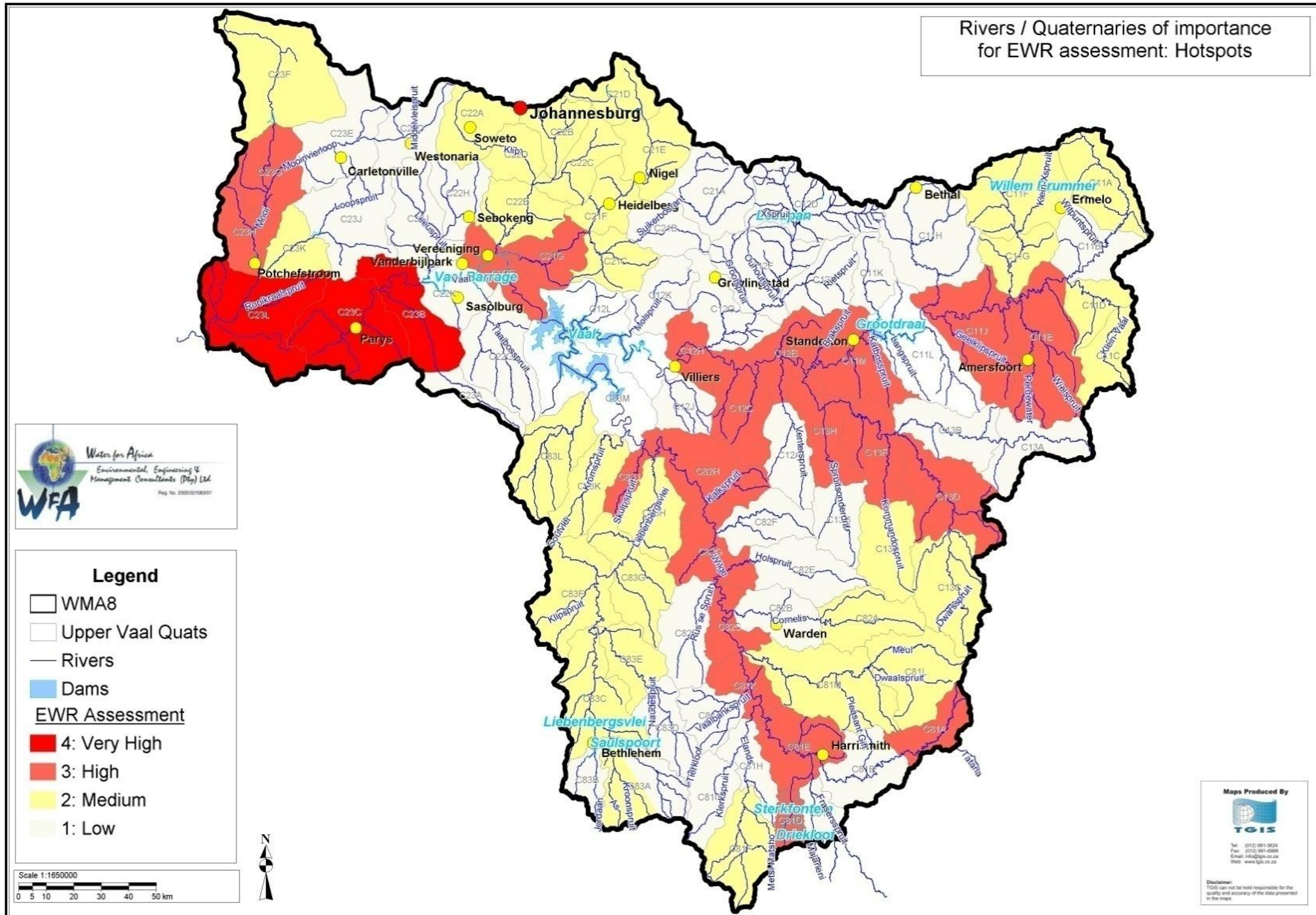


Figure 3.7 Priority areas (hotspots) needing detailed investigations

## 4 BASIC HUMAN NEEDS RESERVE

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Author: G Huggins (Nomad Consulting)

### 4.1 WHAT IS THE BASIC HUMAN NEEDS RESERVE?

The concept of a Basic Human Needs Reserve (BHNR) is deeply entrenched within the National Water Act (Act No 36 of 1998). In Chapter 1 (Interpretation and Fundamental Principles) the Act states that *“Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the **basic human needs** of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act.”*

Further, in defining the Reserve the National Water Act states that:

*“Reserve” means the quantity and quality of water required -*

*(a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be*

*(i) relying upon;*

*(ii) taking water from; or*

*(iii) being supplied from, the relevant water resource; and*

In Part 3 of the National Water Act, that dealing with the Reserve, the following definition occurs:

*The basic human needs reserve provides for the essential needs of individuals served by the water resource in question and includes water for drinking, for food preparation and for personal hygiene.*

### 4.2 HOW MUCH WATER IS NEEDED FOR BASIC HUMAN NEEDS?

Although the National Water Act gives the reader cues as to the importance of the BHNR and what it encompasses, there is no quantity of water set, which would be deemed to be adequate to satisfy these basic human needs. The Water Services Act (Act No. 108 of 1997) is no more insightful in determining the amount of water deemed to be satisfactory for basic human needs. Rather the Water Services Act sets out a definition not far removed from that of the National Water Act. The Water Services Act states that:

*“basic water supply” means the prescribed minimum standard of water supply services necessary for the reliable supply of a sufficient quantity and quality of water to households, including informal households, to support life and personal hygiene.*

The amount of water required for basic human needs is a question that encourages vigorous debate. Without repeating the debate it is probably sufficient to say that the minimum amount of water required to meet basic needs varies depending upon what is included as "basic needs". The figures generally vary from 20 to 50 litres per person per day.

In South Africa the RDP target of 25 litres per person per day has generally been accepted as the standard quantum for the purposes of the BHNR. This is slightly at odds with the “Free Basic

Water” recommended amount of 6 000 litres per household per month.<sup>3</sup> Given average household sizes in South Africa, the amount of 6 000 litres per month is closer to 40 litres per person per day than to 25 litres

### 4.3 THE BHNR UPPER VAAL WMA

The BHNR was based upon the current and projected population of those either living within the catchment and directly dependant on the catchment; or critically, not being supplied with water from a recognised formal source. It does not include the population outside of the catchment who may be utilizing the water. The population was derived from the 2001 National Census.

In order to calculate the BHNR the following steps were required:

- Quaternary catchment boundaries were superimposed upon the smallest aggregations of census data available. For the 2001 National census these are known as “sub-place names”. All “sub-place names” either wholly or partially within the quaternary catchments were captured. Where “sub-place names” were partially within the quaternary catchments then the percentage area that fell within was applied to the population. As such, where a “sub-place name” was only 50% within a quaternary catchment then only 50% of the population was deemed to fall within the area. These numbers were checked against the WSAM model for compatibility. The total population for the Upper Vaal catchment, as recorded by the 2001 Census, was 6 736 735.
- Those receiving water from a recognised formal water source and therefore not likely to be dependant on run of river were excluded. Given the nature of the Upper Vaal, as set out in Section 1, the majority of the population fell within the ambit of those likely to be receiving a formal water supply. The remainder were deemed to be the “qualifying population”. For the purposes of the BHNR estimate the population was split into those regarded, by the Census, as urban and rural. Urban residents were then further broken down into settlement type. All urban residents, bar informal settlement dwellers, were deemed to have access to a formal water supply. Further, examination of the most recent relevant Integrated Development Planning documentation showed that on average about 75% of informal settlement share access to one or other type of formal water scheme. As such the BHNR dependant population was deemed to be those classified as rural and 25% of those deemed to be urban residents in informal settlements. It may be argued that this is a relatively crude classification. Certainly more detailed analysis of the population would probably reveal that:
  - many of those regarded as rural have access to fairly secure water sources that are not run of river; and
  - the notion that 25% of informal settlements do not receive formal water can be shown to be a gross simplification.
- There may be many informal settlements in which 100% access to a water supply scheme is achieved. Conversely some settlements may have no access. In smaller catchments an analysis that examines access in greater detail is probably merited. In the case of the Upper Vaal however the size of the exercise would mean that such an analysis would be extremely costly. Further the dynamic nature of settlement in the area would render findings obsolete very quickly. Ultimately the population deemed to be “qualifying” was recorded as being 954 373, or 14% of the total population.
- In previous BHNR studies the river has been used as a geographical cue to demarcate populations potentially dependant on the water source. In effect, a 5 km buffer either side

<sup>3</sup> For the provenance of the recommended 6 000 litres see <http://www.dwaf.gov.za/Documents/FBW/QA brochure Aug 2002.pdf>.

of the river is drawn and only the qualifying populations within this strip are deemed to be part of BHNHR calculations. In the case of the Upper Vaal the demarcation of the 5 km zone had virtually no impact.

- Having calculated the qualifying population per quaternary catchment the next step in determining the BHNHR is to project the population to a target date. For the purposes of this exercise the population has been projected to 2015. The population has been projected using generic growth rates applicable to the kinds of municipalities in the Upper Vaal area. Strictly speaking a population projection exercise would involve an analysis of all settlement types within the study area and the application of different rates based on settlement type, economic forecasts and from historic trends. This type of demographic analysis is, however, a study on its own and beyond the scope and means of the current BHNHR determination. Urban population figures have been calculated at a growth rate of 2.2% per annum until 2015. In line with current trends it has been assumed that there is no growth rate for the rural population.
- Total BHNHR at 25 litres per day for the year 2008 was estimated at 502 225 MCM per day. As a rate of flow this would be 5.8 litres per second. Total BHNHR at 50 litres per day for the year 2008 was estimated at 1 004/450 MCM per day. As a rate of flow this would be 11.6 litres per second.

Using these figures a BHNHR for the qualifying population has been estimated and the cumulative BHNHR of the Upper Vaal River catchment results are provided in Table 4.1 to 4.5 based on 2001, 2008 and 2015 population rates at 25 litres per day and 50 litres per day.

**Table 4.1 Water required for the BHNHR per quaternary expressed in m<sup>3</sup> per day based on 2008 qualifying population estimate at 25 litres per day**

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2008	Litres required per person per day	BHNHR as total litres per day	BHNHR as m <sup>3</sup> per day	BHNHR as MCM	Cumulative BHNHR per day m <sup>3</sup>	Cumulative BHNHR as MCM
		C11A	6208	25	155193.95	155.19	0.06		
		C11B	4006	25	100142.35	100.14	0.04		
C11C	RE EWR1	C11C	2127	25	53180.00	53.18	0.02	53.18	0.02
		C11D	1935	25	48375.63	48.38	0.02		
		C11E	7396	25	184896.60	184.90	0.07		
		C11F	12575	25	314373.89	314.37	0.11		
		C11G	3125	25	78116.15	78.12	0.03		
		C11H	11111	25	277765.46	277.77	0.10		
C11A - C11J [excl C11H]	EWR 1	C11J	6209	25	155230.16	155.23	0.06	1089.51	0.40
		C11K	2675	25	66866.07	66.87	0.02		
C11A - C11L	EWR 2	C11L	7350	25	183744.22	183.74	0.07	1617.88	0.59
		C11M	12236	25	305897.01	305.90	0.11		
		C12A	1018	25	25445.00	25.45	0.01		
		C12B	2747	25	68677.50	68.68	0.03		
		C12C	1825	25	45615.46	45.62	0.02		
		C12D	17389	25	434722.27	434.72	0.16		
		C12E	3497	25	87433.83	87.43	0.03		
		C12F	5497	25	137412.50	137.41	0.05		
		C12G	3297	25	82430.44	82.43	0.03		
ALL C11, ALL C13, C12A - C [excl C12H]	EWR 3	C12H	2443	25	61068.53	61.07	0.02	2607.90	0.95
		C12J	746	25	18645.00	18.65	0.01		
		C12K	2684	25	67107.50	67.11	0.02		
		C12L	4509	25	112714.73	112.71	0.04		
		C13A	3341	25	83532.50	83.53	0.03		
		C13B	3923	25	98062.50	98.06	0.04		
		C13C	3177	25	79431.36	79.43	0.03		
C13C - C13D	EWR 6	C13D	3420	25	85511.16	85.51	0.03	164.94	0.06
		C13E	1478	25	36955.00	36.96	0.01		
		C13F	2149	25	53727.50	53.73	0.02		
		C13G	2412	25	60307.24	60.31	0.02		
		C13H	1874	25	46849.88	46.85	0.02		
		C21A	4009	25	100219.61	100.22	0.04		

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2008	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C21B	4054	25	101362.36	101.36	0.04		
C21A - C21C	EWR 9	C21C	2701	25	67522.50	67.52	0.02	269.10	0.10
		C21D	41292	25	1032293.95	1032.29	0.38		
		C21E	14355	25	358883.92	358.88	0.13		
C21D - C21F	EWR 11	C21F	14918	25	372939.07	372.94	0.14	1764.12	0.64
C21A - C21G	EWR 10	C21G	9104	25	227604.54	227.60	0.08	2260.83	0.83
		C22A	111456	25	2786394.83	2786.39	1.02		
		C22B	56609	25	1415234.25	1415.23	0.52		
		C22C	26361	25	659029.19	659.03	0.24		
		C22D	19467	25	486669.39	486.67	0.18		
		C22E	15528	25	388198.92	388.20	0.14	12003.90	4.38
ALL C11, C12, C13, C81, C82, C83 [EXCL C22F]	EWR 4	C22F	15991	25	399766.15	399.77	0.15		
		C22G	4499	25	112478.46	112.48	0.04		
		C22H	46494	25	1162338.96	1162.34	0.42		
		C22J	11408	25	285195.52	285.20	0.10		
		C22K	17081	25	427034.40	427.03	0.16		
		C23A	864	25	21597.50	21.60	0.01		
		C23B	3108	25	77695.90	77.70	0.03		
		C23C	6509	25	162718.24	162.72	0.06		
		C23D	31882	25	797046.07	797.05	0.29		
		C23E	18742	25	468546.39	468.55	0.17		
		C23F	12202	25	305059.98	305.06	0.11		
C23F - C23G	RE EWR2	C23G	4221	25	105529.37	105.53	0.04	410.59	0.15
		C23H	9272	25	231797.52	231.80	0.08		
		C23J	8076	25	201890.55	201.89	0.07		
		C23K	3248	25	81202.40	81.20	0.03		
C23L	EWR 5	C23L	10844	25	271106.44	271.11	0.10	271.11	0.10
C81A	EWR 7	C81A	1455	25	36365.00	36.37	0.01	36.37	0.01
		C81B	2646	25	66140.33	66.14	0.02		
		C81C	1120	25	27995.15	28.00	0.01		
		C81D	849	25	21222.65	21.22	0.01		
		C81E	5228	25	130705.46	130.71	0.05		
		C81F	251283	25	6282087.18	6282.09	2.29		
		C81G	1719	25	42977.54	42.98	0.02		
		C81H	1306	25	32657.50	32.66	0.01		
		C81J	2625	25	65622.50	65.62	0.02		
		C81K	1606	25	40145.00	40.15	0.01		
		C81L	2679	25	66972.50	66.97	0.02		
		C81M	4274	25	106860.00	106.86	0.04		
		C82A	1854	25	46350.00	46.35	0.02		
		C82B	2882	25	72055.93	72.06	0.03		
ALL C81, C82A - C82C	EWR 8	C82C	1261	25	31525.00	31.53	0.01	7069.68	2.58
		C82D	2646	25	66145.00	66.15	0.02		
		C82E	1718	25	42952.50	42.95	0.02		
		C82F	1215	25	30362.50	30.36	0.01		
		C82G	1985	25	49627.50	49.63	0.02		
		C82H	1686	25	42162.11	42.16	0.02		
		C83A	6494	25	162360.14	162.36	0.06		
		C83B	2303	25	57582.36	57.58	0.02		
		C83C	10015	25	250376.38	250.38	0.09		
		C83D	3818	25	95450.00	95.45	0.03		
		C83E	2148	25	53702.50	53.70	0.02		
		C83F	3450	25	86261.94	86.26	0.03		
		C83G	3949	25	98729.01	98.73	0.04		
		C83H	2107	25	52674.74	52.67	0.02		
		C83J	1644	25	41108.08	41.11	0.02		
		C83K	1488	25	37200.00	37.20	0.01		
		C83L	2624	25	65592.50	65.59	0.02		
		C83M	3700	25	92496.37	92.50	0.03		

**Table 4.2 Water required for the BHNH per quaternary expressed in m<sup>3</sup> per day based on 2015 qualifying population estimate at 25 litres per day**

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2015	Litres required per person per day	BHNH as total litres per day	BHNH as m <sup>3</sup> per day	BHNH as MCM	Cumulative BHNH per day m <sup>3</sup>	Cumulative BHNH as MCM
		C11A	6282	25	157042.03	157.04	0.06		
		C11B	4018	25	100449.61	100.45	0.04		
C11C	RE EWR1	C11C	2127	25	53180.00	53.18	0.02	53.18	0.02
		C11D	1935	25	48377.38	48.38	0.02		
		C11E	7642	25	191047.56	191.05	0.07		
		C11F	13074	25	326858.56	326.86	0.12		
		C11G	3125	25	78121.28	78.12	0.03		
		C11H	11547	25	288662.94	288.66	0.11		
C11A - C11J [excl C11H]	EWR 1	C11J	6211	25	155272.55	155.27	0.06	1110.35	0.41
		C11K	2702	25	67541.29	67.54	0.02		
C11A - C11L	EWR 2	C11L	7380	25	184510.46	184.51	0.07	1651.06	0.60
		C11M	12814	25	320354.26	320.35	0.12		
		C12A	1018	25	25445.00	25.45	0.01		
		C12B	2747	25	68677.50	68.68	0.03		
		C12C	1857	25	46420.98	46.42	0.02		
		C12D	18787	25	469666.65	469.67	0.17		
		C12E	3499	25	87483.41	87.48	0.03		
		C12F	5497	25	137412.50	137.41	0.05		
		C12G	3339	25	83481.96	83.48	0.03		
ALL C11, ALL C13, C12A - C [excl C12H]	EWR 3	C12H	2615	25	65376.08	65.38	0.02	2661.54	0.97
		C12J	746	25	18645.00	18.65	0.01		
		C12K	2684	25	67107.50	67.11	0.02		
		C12L	4514	25	112853.73	112.85	0.04		
		C13A	3341	25	83532.50	83.53	0.03		
		C13B	3923	25	98062.50	98.06	0.04		
		C13C	3223	25	80586.28	80.59	0.03		
C13C - C13D	EWR 6	C13D	3420	25	85511.36	85.51	0.03	166.10	0.06
		C13E	1478	25	36955.00	36.96	0.01		
		C13F	2149	25	53727.50	53.73	0.02		
		C13G	2573	25	64330.74	64.33	0.02		
		C13H	1875	25	46868.37	46.87	0.02		
		C21A	4073	25	101827.97	101.83	0.04		
		C21B	4247	25	106173.22	106.17	0.04		
C21A - C21C	EWR 9	C21C	2701	25	67522.50	67.52	0.02	275.52	0.10
		C21D	45219	25	1130479.00	1130.48	0.41		
		C21E	15657	25	391436.50	391.44	0.14		
C21D - C21F	EWR 11	C21F	16477	25	411928.26	411.93	0.15	1933.84	0.71
C21A - C21G	EWR 10	C21G	9186	25	229653.46	229.65	0.08	2439.02	0.89
		C22A	126758	25	3168959.02	3168.96	1.16		
		C22B	65283	25	1632073.98	1632.07	0.60		
		C22C	29684	25	742094.66	742.09	0.27		
		C22D	20934	25	523340.19	523.34	0.19		
		C22E	15918	25	397946.80	397.95	0.15	12150.65	4.43
ALL C11, C12, C13, C81, C82, C83 [EXCL C22F]	EWR 4	C22F	17436	25	435893.43	435.89	0.16		
		C22G	4636	25	115891.69	115.89	0.04		
		C22H	52955	25	1323878.78	1323.88	0.48		
		C22J	11858	25	296460.76	296.46	0.11		
		C22K	18404	25	460089.74	460.09	0.17		
		C23A	864	25	21597.50	21.60	0.01		
		C23B	3110	25	77742.94	77.74	0.03		
		C23C	7039	25	175986.04	175.99	0.06		
		C23D	34727	25	868172.06	868.17	0.32		
		C23E	20078	25	501950.08	501.95	0.18		
		C23F	12229	25	305714.86	305.71	0.11		
C23F - C23G	RE EWR2	C23G	4221	25	105530.09	105.53	0.04	411.24	0.15
		C23H	10054	25	251359.87	251.36	0.09		
		C23J	8638	25	215941.14	215.94	0.08		
		C23K	3257	25	81416.70	81.42	0.03		
C23L	EWR 5	C23L	11098	25	277456.06	277.46	0.10	277.46	0.10
C81A	EWR 7	C81A	1455	25	36365.00	36.37	0.01	36.37	0.01
		C81B	2654	25	66347.71	66.35	0.02		
		C81C	1120	25	27995.17	28.00	0.01		
		C81D	849	25	21222.67	21.22	0.01		
		C81E	5586	25	139646.50	139.65	0.05		
		C81F	251791	25	6294778.90	6294.78	2.30		
		C81G	1774	25	44347.38	44.35	0.02		
		C81H	1306	25	32657.50	32.66	0.01		
		C81J	2625	25	65622.50	65.62	0.02		

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2015	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C81K	1606	25	40145.00	40.15	0.01		
		C81L	2679	25	66972.50	66.97	0.02		
		C81M	4274	25	106860.00	106.86	0.04		
		C82A	1854	25	46350.00	46.35	0.02		
		C82B	2938	25	73439.90	73.44	0.03		
ALL C81, C82A - C82C	EWR 8	C82C	1261	25	31525.00	31.53	0.01	7094.28	2.59
		C82D	2646	25	66145.00	66.15	0.02		
		C82E	1718	25	42952.50	42.95	0.02		
		C82F	1215	25	30362.50	30.36	0.01		
		C82G	1985	25	49627.50	49.63	0.02		
		C82H	1696	25	42392.82	42.39	0.02		
		C83A	6499	25	162473.70	162.47	0.06		
		C83B	2306	25	57655.56	57.66	0.02		
		C83C	10636	25	265911.72	265.91	0.10		
		C83D	3818	25	95450.00	95.45	0.03		
		C83E	2148	25	53702.50	53.70	0.02		
		C83F	3451	25	86263.90	86.26	0.03		
		C83G	4116	25	102901.30	102.90	0.04		
		C83H	2152	25	53808.41	53.81	0.02		
		C83J	1839	25	45978.29	45.98	0.02		
		C83K	1488	25	37200.00	37.20	0.01		
		C83L	2624	25	65592.50	65.59	0.02		
		C83M	3776	25	94395.44	94.40	0.03		

**Table 4.3 Water required for the BHNR per quaternary expressed in m<sup>3</sup> per day based on 2001 qualifying population estimate at 50 litres per day**

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2001	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C11A	6144	50	307214	307.21	0.11		
		C11B	3995	50	199757	199.76	0.07		
C11C	RE EWR1	C11C	2127	50	106361.25	106.36	0.04	106.36	0.04
		C11D	1935	50	96748.25	96.75	0.04		
		C11E	7185	50	359229.5	359.23	0.13		
		C11F	12146	50	607306.5	607.31	0.22		
		C11G	3124	50	156223.5	156.22	0.06		
		C11H	10736	50	536815.5	536.82	0.20		
C11A - C11J [excl C11H]	EWR 1	C11J	6208	50	310387.5	310.39	0.11	2143.23	0.78
		C11K	2651	50	132572.5	132.57	0.05		
C11A - C11L	EWR 2	C11L	7323	50	366172.5	366.17	0.13	3178.79	1.16
		C11M	11739	50	586965	586.97	0.21		
		C12A	1018	50	50890	50.89	0.02		
		C12B	2747	50	137355	137.36	0.05		
		C12C	1797	50	89847.5	89.85	0.03		
		C12D	16189	50	809430.75	809.43	0.30		
		C12E	3496	50	174782.5	174.78	0.06		
		C12F	5497	50	274825	274.83	0.10		
		C12G	3261	50	163055	163.06	0.06		
ALL C11, ALL C13, C12A - C [excl C12H]	EWR 3	C12H	2295	50	114739.25	114.74	0.04	5123.67	1.87
		C12J	746	50	37290	37.29	0.01		
		C12K	2684	50	134215	134.22	0.05		
		C12L	4504	50	225190.75	225.19	0.08		
		C13A	3341	50	167065	167.07	0.06		
		C13B	3923	50	196125	196.13	0.07		
		C13C	3138	50	156879.25	156.88	0.06		
C13C - C13D	EWR 6	C13D	3420	50	171022	171.02	0.06	327.90	0.12
		C13E	1478	50	73910	73.91	0.03		
		C13F	2149	50	107455	107.46	0.04		
		C13G	2274	50	113704.5	113.70	0.04		
		C13H	1873	50	93668	93.67	0.03		
		C21A	3954	50	197677	197.68	0.07		
		C21B	3889	50	194462.5	194.46	0.07		
C21A - C21C	EWR 9	C21C	2701	50	135045	135.05	0.05	527.18	0.19
		C21D	37919	50	1895964	1895.96	0.69		
		C21E	13237	50	661861.75	661.86	0.24		
C21D - C21F	EWR 11	C21F	13578	50	678917.75	678.92	0.25	3236.74	1.18
C21A - C21G	EWR 10	C21G	9034	50	451690.25	451.69	0.16	4215.62	1.54
		C22A	98315	50	4915770.5	4915.77	1.79		

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2001	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C22B	49161	50	2458066	2458.07	0.90		
		C22C	23508	50	1175401	1175.40	0.43		
		C22D	18207	50	910360	910.36	0.33		
		C22E	15193	50	759656.75	759.66	0.28	23755.76	8.67
ALL C11, C12, C13, C81, C82, C83 [EXCL C22F]	EWR 4	C22F	14750	50	737487	737.49	0.27		
		C22G	4382	50	219095	219.10	0.08		
		C22H	40945	50	2047248	2047.25	0.75		
		C22J	11021	50	551044	551.04	0.20		
		C22K	15946	50	797299.25	797.30	0.29		
		C23A	864	50	43195	43.20	0.02		
		C23B	3106	50	155311	155.31	0.06		
		C23C	6053	50	302650.25	302.65	0.11		
		C23D	29439	50	1471939.75	1471.94	0.54		
		C23E	17595	50	879725	879.73	0.32		
		C23F	12180	50	608995.25	609.00	0.22		
C23F - C23G	RE EWR2	C23G	4221	50	211057.5	211.06	0.08	820.05	0.30
		C23H	8600	50	429998.5	430.00	0.16		
		C23J	7593	50	379650.5	379.65	0.14		
		C23K	3241	50	162036.75	162.04	0.06		
C23L	EWR 5	C23L	10626	50	531308	531.31	0.19	531.31	0.19
C81A	EWR 7	C81A	1455	50	72730	72.73	0.03	72.73	0.03
		C81B	2638	50	131924.5	131.92	0.05		
		C81C	1120	50	55990.25	55.99	0.02		
		C81D	849	50	42445.25	42.45	0.02		
		C81E	4921	50	246055.5	246.06	0.09		
		C81F	250848	50	12542377.5	12542.38	4.58		
		C81G	1672	50	83602.5	83.60	0.03		
		C81H	1306	50	65315	65.32	0.02		
		C81J	2625	50	131245	131.25	0.05		
		C81K	1606	50	80290	80.29	0.03		
		C81L	2679	50	133945	133.95	0.05		
		C81M	4274	50	213720	213.72	0.08		
		C82A	1854	50	92700	92.70	0.03		
		C82B	2835	50	141735	141.74	0.05		
ALL C81, C82A - C82C	EWR 8	C82C	1261	50	63050	63.05	0.02	14097.13	5.15
		C82D	2646	50	132290	132.29	0.05		
		C82E	1718	50	85905	85.91	0.03		
		C82F	1215	50	60725	60.73	0.02		
		C82G	1985	50	99255	99.26	0.04		
		C82H	1679	50	83928	83.93	0.03		
		C83A	6491	50	324525.25	324.53	0.12		
		C83B	2301	50	115039	115.04	0.04		
		C83C	9481	50	474072.25	474.07	0.17		
		C83D	3818	50	190900	190.90	0.07		
		C83E	2148	50	107405	107.41	0.04		
		C83F	3450	50	172520.5	172.52	0.06		
		C83G	3806	50	190292.5	190.29	0.07		
		C83H	2068	50	103402.5	103.40	0.04		
		C83J	1477	50	73852	73.85	0.03		
		C83K	1488	50	74400	74.40	0.03		
		C83L	2624	50	131185	131.19	0.05		
		C83M	3635	50	181731.25	181.73	0.07		

**Table 4.4 Water required for the BHNR per quaternary expressed in m<sup>3</sup> per day based on 2008 qualifying population estimate at 50 litres per day**

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2008	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C11A	6208	50	310387.91	310.39	0.11		
		C11B	4006	50	200284.70	200.28	0.07		
C11C	RE EWR1	C11C	2127	50	106360.00	106.36	0.04	106.36	0.04
		C11D	1935	50	96751.25	96.75	0.04		
		C11E	7396	50	369793.21	369.79	0.13		
		C11F	12575	50	628747.78	628.75	0.23		
		C11G	3125	50	156232.30	156.23	0.06		
		C11H	11111	50	555530.93	555.53	0.20		

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2008	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
C11A - C11J [excl C11H]	EWR 1	C11J	6209	50	310460.31	310.46	0.11	2179.02	0.80
		C11K	2675	50	133732.13	133.73	0.05		
C11A - C11L	EWR 2	C11L	7350	50	367488.45	367.49	0.13	3235.77	1.18
		C11M	12236	50	611794.02	611.79	0.22		
		C12A	1018	50	50890.00	50.89	0.02		
		C12B	2747	50	137355.00	137.36	0.05		
		C12C	1825	50	91230.91	91.23	0.03		
		C12D	17389	50	869444.54	869.44	0.32		
		C12E	3497	50	174867.65	174.87	0.06		
		C12F	5497	50	274825.00	274.83	0.10		
		C12G	3297	50	164860.88	164.86	0.06		
ALL C11, ALL C13, C12A - C [excl C12H]	EWR 3	C12H	2443	50	122137.07	122.14	0.04	5215.79	1.90
		C12J	746	50	37290.00	37.29	0.01		
		C12K	2684	50	134215.00	134.22	0.05		
		C12L	4509	50	225429.46	225.43	0.08		
		C13A	3341	50	167065.00	167.07	0.06		
		C13B	3923	50	196125.00	196.13	0.07		
		C13C	3177	50	158862.72	158.86	0.06		
C13C - C13D	EWR 6	C13D	3420	50	171022.33	171.02	0.06	329.89	0.12
		C13E	1478	50	73910.00	73.91	0.03		
		C13F	2149	50	107455.00	107.46	0.04		
		C13G	2412	50	120614.48	120.61	0.04		
		C13H	1874	50	93699.76	93.70	0.03		
		C21A	4009	50	200439.22	200.44	0.07		
		C21B	4054	50	202724.72	202.72	0.07		
C21A - C21C	EWR 9	C21C	2701	50	135045.00	135.05	0.05	538.21	0.20
		C21D	41292	50	2064587.89	2064.59	0.75		
		C21E	14355	50	717767.84	717.77	0.26		
C21D - C21F	EWR 11	C21F	14918	50	745878.14	745.88	0.27	3528.23	1.29
C21A - C21G	EWR 10	C21G	9104	50	455209.09	455.21	0.17	4521.65	1.65
		C22A	111456	50	5572789.67	5572.79	2.03		
		C22B	56609	50	2830468.49	2830.47	1.03		
		C22C	26361	50	1318058.38	1318.06	0.48		
		C22D	19467	50	973338.77	973.34	0.36		
		C22E	15528	50	776397.85	776.40	0.28	24007.79	8.76
ALL C11, C12, C13, C81, C82, C83 [EXCL C22F]	EWR 4	C22F	15991	50	799532.31	799.53	0.29		
		C22G	4499	50	224956.92	224.96	0.08		
		C22H	46494	50	2324677.93	2324.68	0.85		
		C22J	11408	50	570391.04	570.39	0.21		
		C22K	17081	50	854068.79	854.07	0.31		
		C23A	864	50	43195.00	43.20	0.02		
		C23B	3108	50	155391.79	155.39	0.06		
		C23C	6509	50	325436.48	325.44	0.12		
		C23D	31882	50	1594092.15	1594.09	0.58		
		C23E	18742	50	937092.79	937.09	0.34		
		C23F	12202	50	610119.96	610.12	0.22		
C23F - C23G	RE EWR2	C23G	4221	50	211058.73	211.06	0.08	821.18	0.30
		C23H	9272	50	463595.05	463.60	0.17		
		C23J	8076	50	403781.10	403.78	0.15		
		C23K	3248	50	162404.80	162.40	0.06		
C23L	EWR 5	C23L	10844	50	542212.89	542.21	0.20	542.21	0.20
C81A	EWR 7	C81A	1455	50	72730.00	72.73	0.03	72.73	0.03
		C81B	2646	50	132280.66	132.28	0.05		
		C81C	1120	50	55990.29	55.99	0.02		
		C81D	849	50	42445.29	42.45	0.02		
		C81E	5228	50	261410.92	261.41	0.10		
		C81F	251283	50	12564174.36	12564.17	4.59		
		C81G	1719	50	85955.08	85.96	0.03		
		C81H	1306	50	65315.00	65.32	0.02		
		C81J	2625	50	131245.00	131.25	0.05		
		C81K	1606	50	80290.00	80.29	0.03		
		C81L	2679	50	133945.00	133.95	0.05		
		C81M	4274	50	213720.00	213.72	0.08		
		C82A	1854	50	92700.00	92.70	0.03		
		C82B	2882	50	144111.85	144.11	0.05		
ALL C81, C82A - C82C	EWR 8	C82C	1261	50	63050.00	63.05	0.02	14139.36	5.16
		C82D	2646	50	132290.00	132.29	0.05		
		C82E	1718	50	85905.00	85.91	0.03		
		C82F	1215	50	60725.00	60.73	0.02		
		C82G	1985	50	99255.00	99.26	0.04		
		C82H	1686	50	84324.22	84.32	0.03		
		C83A	6494	50	324720.28	324.72	0.12		

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2008	Litres required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C83B	2303	50	115164.71	115.16	0.04		
		C83C	10015	50	500752.77	500.75	0.18		
		C83D	3818	50	190900.00	190.90	0.07		
		C83E	2148	50	107405.00	107.41	0.04		
		C83F	3450	50	172523.87	172.52	0.06		
		C83G	3949	50	197458.02	197.46	0.07		
		C83H	2107	50	105349.48	105.35	0.04		
		C83J	1644	50	82216.15	82.22	0.03		
		C83K	1488	50	74400.00	74.40	0.03		
		C83L	2624	50	131185.00	131.19	0.05		
		C83M	3700	50	184992.74	184.99	0.07		

**Table 4.5 Water required for the BHNR per quaternary expressed in m<sup>3</sup> per day based on 2015 qualifying population estimate at 50 litres per day**

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2015	Liters required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C11A	6282	50	314084.07	314.08	0.11		
		C11B	4018	50	200899.22	200.90	0.07		
C11C	RE EWR1	C11C	2127	50	106360.00	106.36	0.04	106.36	0.04
		C11D	1935	50	96754.75	96.75	0.04		
		C11E	7642	50	382095.12	382.10	0.14		
		C11F	13074	50	653717.12	653.72	0.24		
		C11G	3125	50	156242.55	156.24	0.06		
		C11H	11547	50	577325.89	577.33	0.21		
C11A - C11J [excl C11H]	EWR 1	C11J	6211	50	310545.10	310.55	0.11	2220.70	0.81
		C11K	2702	50	135082.57	135.08	0.05		
C11A - C11L	EWR 2	C11L	7380	50	369020.93	369.02	0.13	3302.13	1.21
		C11M	12814	50	640708.52	640.71	0.23		
		C12A	1018	50	50890.00	50.89	0.02		
		C12B	2747	50	137355.00	137.36	0.05		
		C12C	1857	50	92841.96	92.84	0.03		
		C12D	18787	50	939333.31	939.33	0.34		
		C12E	3499	50	174966.82	174.97	0.06		
		C12F	5497	50	274825.00	274.83	0.10		
		C12G	3339	50	166963.91	166.96	0.06		
ALL C11, ALL C13, C12A - C [excl C12H]	EWR 3	C12H	2615	50	130752.16	130.75	0.05	5323.07	1.94
		C12J	746	50	37290.00	37.29	0.01		
		C12K	2684	50	134215.00	134.22	0.05		
		C12L	4514	50	225707.46	225.71	0.08		
		C13A	3341	50	167065.00	167.07	0.06		
		C13B	3923	50	196125.00	196.13	0.07		
		C13C	3223	50	161172.55	161.17	0.06		
C13C - C13D	EWR 6	C13D	3420	50	171022.71	171.02	0.06	332.20	0.12
		C13E	1478	50	73910.00	73.91	0.03		
		C13F	2149	50	107455.00	107.46	0.04		
		C13G	2573	50	128661.47	128.66	0.05		
		C13H	1875	50	93736.74	93.74	0.03		
		C21A	4073	50	203655.94	203.66	0.07		
		C21B	4247	50	212346.44	212.35	0.08		
C21A - C21C	EWR 9	C21C	2701	50	135045.00	135.05	0.05	551.05	0.20
		C21D	45219	50	2260958.00	2260.96	0.83		
		C21E	15657	50	782873.00	782.87	0.29		
C21D - C21F	EWR 11	C21F	16477	50	823856.53	823.86	0.30	3867.69	1.41
C21A - C21G	EWR 10	C21G	9186	50	459306.93	459.31	0.17	4878.04	1.78
		C22A	126758	50	6337918.05	6337.92	2.31		
		C22B	65283	50	3264147.95	3264.15	1.19		
		C22C	29684	50	1484189.31	1484.19	0.54		
		C22D	20934	50	1046680.38	1046.68	0.38		
		C22E	15918	50	795893.60	795.89	0.29	24301.30	8.87
ALL C11, C12, C13, C81, C82, C83 [EXCL C22F]	EWR 4	C22F	17436	50	871786.86	871.79	0.32		
		C22G	4636	50	231783.38	231.78	0.08		
		C22H	52955	50	2647757.55	2647.76	0.97		
		C22J	11858	50	592921.53	592.92	0.22		
		C22K	18404	50	920179.48	920.18	0.34		
		C23A	864	50	43195.00	43.20	0.02		
		C23B	3110	50	155485.88	155.49	0.06		

Upstream Catchments used in Cumulative Calculations	EWR site	Quaternary Catchment	Qualifying Population Estimate 2015	Liters required per person per day	BHNR as total litres per day	BHNR as m <sup>3</sup> per day	BHNR as MCM	Cumulative BHNR per day m <sup>3</sup>	Cumulative BHNR as MCM
		C23C	7039	50	351972.07	351.97	0.13		
		C23D	34727	50	1736344.11	1736.34	0.63		
		C23E	20078	50	1003900.16	1003.90	0.37		
		C23F	12229	50	611429.73	611.43	0.22		
C23F - C23G	RE EWR2	C23G	4221	50	211060.17	211.06	0.08	822.49	0.30
		C23H	10054	50	502719.74	502.72	0.18		
		C23J	8638	50	431882.28	431.88	0.16		
		C23K	3257	50	162833.40	162.83	0.06		
C23L	EWR 5	C23L	11098	50	554912.12	554.91	0.20	554.91	0.20
C81A	EWR 7	C81A	1455	50	72730.00	72.73	0.03	72.73	0.03
		C81B	2654	50	132695.42	132.70	0.05		
		C81C	1120	50	55990.34	55.99	0.02		
		C81D	849	50	42445.34	42.45	0.02		
		C81E	5586	50	279293.00	279.29	0.10		
		C81F	251791	50	12589557.79	12589.56	4.60		
		C81G	1774	50	88694.77	88.69	0.03		
		C81H	1306	50	65315.00	65.32	0.02		
		C81J	2625	50	131245.00	131.25	0.05		
		C81K	1606	50	80290.00	80.29	0.03		
		C81L	2679	50	133945.00	133.95	0.05		
		C81M	4274	50	213720.00	213.72	0.08		
		C82A	1854	50	92700.00	92.70	0.03		
		C82B	2938	50	146879.80	146.88	0.05		
ALL C81, C82A - C82C	EWR 8	C82C	1261	50	63050.00	63.05	0.02	14188.55	5.18
		C82D	2646	50	132290.00	132.29	0.05		
		C82E	1718	50	85905.00	85.91	0.03		
		C82F	1215	50	60725.00	60.73	0.02		
		C82G	1985	50	99255.00	99.26	0.04		
		C82H	1696	50	84785.65	84.79	0.03		
		C83A	6499	50	324947.39	324.95	0.12		
		C83B	2306	50	115311.11	115.31	0.04		
		C83C	10636	50	531823.43	531.82	0.19		
		C83D	3818	50	190900.00	190.90	0.07		
		C83E	2148	50	107405.00	107.41	0.04		
		C83F	3451	50	172527.80	172.53	0.06		
		C83G	4116	50	205802.60	205.80	0.08		
		C83H	2152	50	107616.82	107.62	0.04		
		C83J	1839	50	91956.58	91.96	0.03		
		C83K	1488	50	74400.00	74.40	0.03		
		C83L	2624	50	131185.00	131.19	0.05		
		C83M	3776	50	188790.89	188.79	0.07		

## 5 MANAGEMENT RESOURCE UNITS AND EWR SITES

Department of Water Affairs and Forestry (DWAf), 2008. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Resource Unit. Report produced by Koekemoer Aquatic Services and Water for Africa. Authored by Louw, D. Report no: RDM/WMA8 C000/01/CON/0208.

### 5.1 DELINEATION APPROACH

Resource Units (RUs) are required as it would not be appropriate to set the same numerical Reserve for the headwaters of a river as for the lowland reaches. The breakdown of a catchment into RUs for the purpose of determining the Reserve for rivers is therefore done primarily on a biophysical basis within the catchment and called Natural Resource Units (NRUs). Management requirements (DWAf, 1999, volume 3) also play a role in the delineation. Furthermore, the type of disturbance/impact on river plays a role to select homogenous river reaches from a biophysical basis under present circumstances. These are called Management Resource Units (MRUs). MRUs can be further delineated in even smaller assessment units called Reserve Assessment Units (RAUs). It is preferred that a EWR site is selected within each MRU, and if a RAU occurs within the MRU, the EWR should, if possible, be selected within the RAU.

The following is considered for selection of MRUs:

- EcoRegions (Level II).
- Geomorphic zones.
- Land cover.
- Presence of dams and other operational aspects.
- Water quality.
- Groundwater.
- Local knowledge.

### 5.2 DELINEATION RESULTS

Based on the above considerations RUs were selected in the main Vaal River and the associated tributaries which include the:

- Klein Vaal River.
- Klip River.
- Wilge River.
- Liebenbergsvlei River.
- Waterval River.
- Suikerbosrand River.
- Blesbokspruit River and
- Mooi River.

In the following sections the criteria for the delineation of the MRUs are provided and illustrated and a description of the MRUs and the rationale for selection is provided.

### 5.2.1 Vaal River: From origin to Klein Vaal confluence

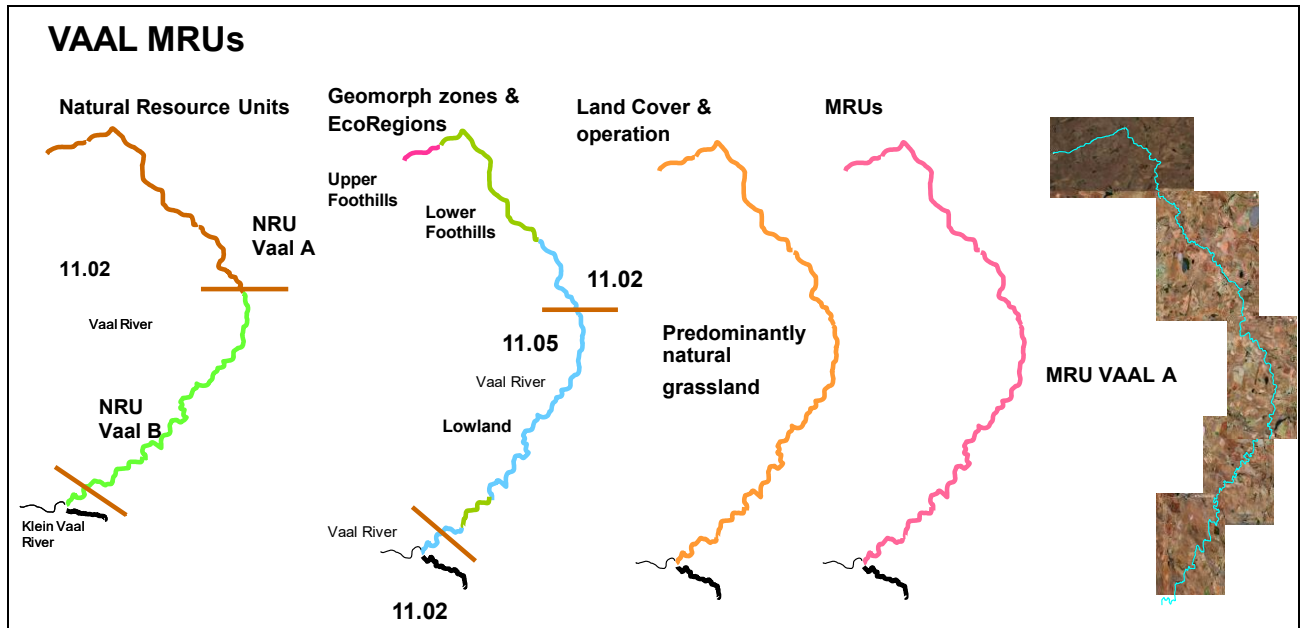


Figure 5.1 Management Resource Units: From origin to Klein Vaal confluence

Table 5.1 Description and rationale of the Vaal River MRUs (from origin to Klein Vaal confluence)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Vaal A	11.02 (55%) 11.05 (45)	Upper foothills (5%) Lower Foothills (40%) Lowland (55%)	Mostly natural grass land.	Land use is the same. Two NRUs too small to keep as separate MRUs therefore combination with the Klein Vaal confluence a more logical break. MRU A = NRU A +B This MRU lies in an area with a 2 and a 1 importance rating <sup>4</sup> which does not warrant the selection of a comprehensive/intermediate EWR site.	29.9824 - -26.3257 30.0079 - -26.7513	C11B C11A

<sup>4</sup> The priority rating refers to an overall qualitative score assigned to a river reach which reflects how important the biogeographic region is in terms of biodiversity (importance rating) and importance for water resource use (water resource stress rating). These scores guide the initial estimate where Reserve assessments should ideally result in high confidence recommendations. For further information see DWAF (2008) – Section 6.2.1 and Appendix A.

5.2.2 Vaal River: From Klein Vaal confluence to Vaal Dam

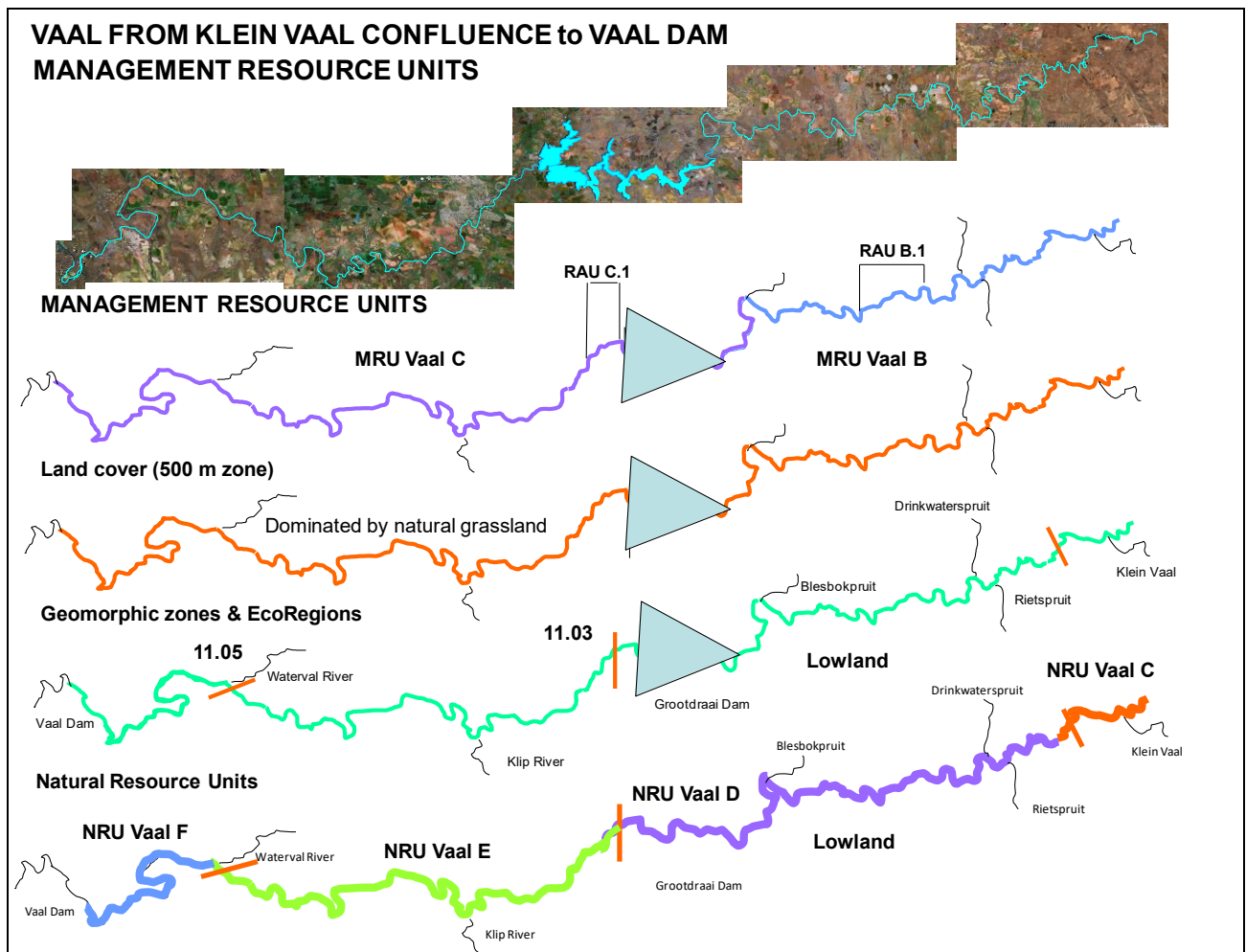


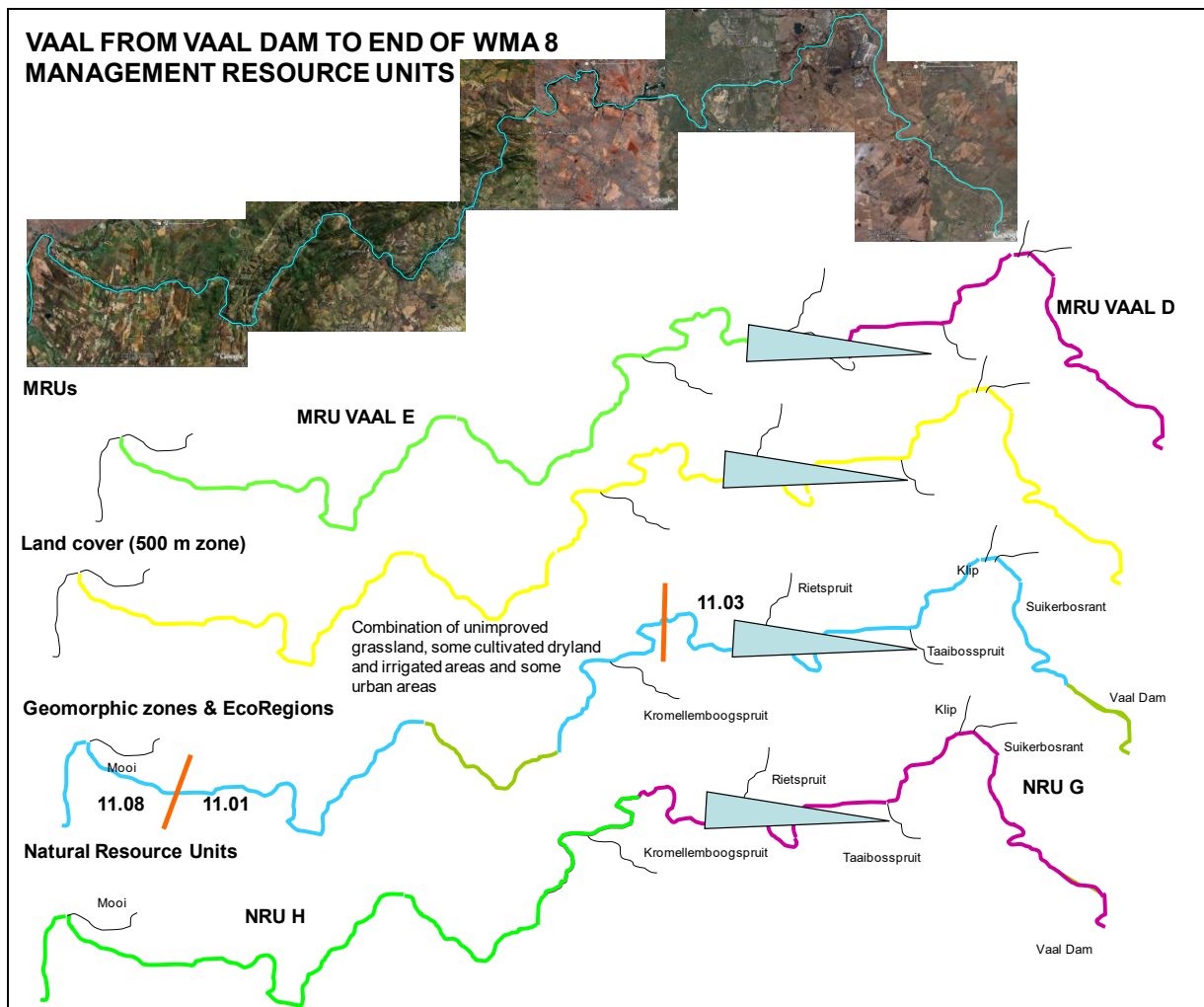
Figure 5.2 Management Resource Units: From Klein Vaal confluence to Vaal Dam

Table 5.2 Description and rationale of the Vaal River MRUs (from Klein Vaal confluence to Vaal Dam)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Vaal B	11.02 11.05	Lowland	Mostly natural grassland with some dryland crops.	This RU starts at the Klein Vaal River confluence to the upper inundation level of Grootdraai Dam approximately with the confluence of the Kaalbosspuit. As the river consists of one geomorphic zone with similar land cover, the lower section is delineated by the Grootdraai Dam. A transfer from Heyshope Dam takes place through the Perdewater, Skulpspruit and Rietspruit.	30.0063 - -26.7483 29.4913 - -26.9146	C11E C11J C11L
RAU Vaal B.1	11.05 (100%)	Lowland (100%)	Mostly natural grassland with some dryland crops.	Within the MRU there is a stretch of river downstream of the transfer which is characterised by extensive rapids and backwaters. These form unique and the most critical habitat within the section and therefore warrants an RAU. The RAU and MRU has also been selected as a 3 importance rating which indicates that an EWR should be situated in the MRU and preferably in the RAU as representing the more critical habitat.	29.62765 - -26.88141 29.60893 - -26.86531	C11J

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Vaal C	11.03 15.05	Lowland	Mostly natural grassland with some dryland crops.	RU Vaal C falls between Grootdraai and Vaal Dam. There is an EcoRegion Level II break immediately downstream of Grootdraai Dam to the upper inundation levels of the Vaal Dam. The river consists of one geomorphic zone and the RU is logically delineated by the Dams.	29.29476 - -26.91883 28.55902 - -27.05543	C11L C11M C12B C12C C12H C12L
RAU Vaal C.1	11.05 (100%)	Lowland	Mostly natural grassland with some dryland crops.	Immediately downstream of the Vaal Dam wall and gauging weir is an extensive riffle/rapid system. Due to the scarcity of such habitat between the two dams, this section forms a RAU. An EWR site should be selected within this section as it has been identified as being important (3 rating) for the selection of an EWR site. However, as this riffle system is right at the beginning of the MRU, a site further down would also be recommended to reflect some of the impacts.	29.29476 - -26.91883 29.27731 - -26.921978	C11L

**5.2.3 Vaal River: From Vaal Dam to the end of WMA 8**

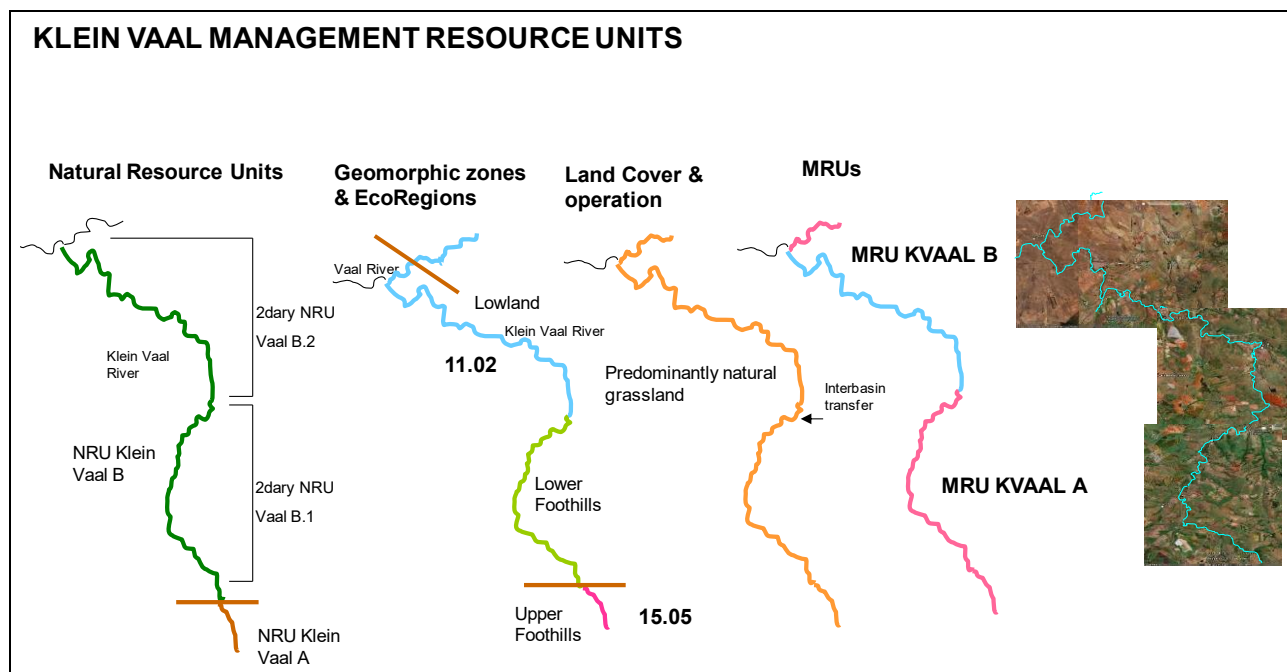


**Figure 5.3 Management Resource Units: From Vaal Dam to end of WMA8**

**Table 5.3 Description and rationale of the Vaal River MRUs (from Vaal Dam to end of WMA 8)**

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Vaal D	11.03 (100%)	Lowland (80%) Lower foothills (20%)	Combination of unimproved grassland (dominant), some cultivated dryland and irrigated areas as well as some urban areas.	Vaal Dam wall to the upper section is inundated by the Vaal Barrage. The river is logically delineated by the Vaal Dam and the Vaal Barrage. This reach is also dominated by the Lowland geomorphic zone and one EcoRegion. The area not inundated is characterised by extensive rapids. This forms a critical area and as most of the rest of the MRU is inundated from the Barrage, it is recommended that an EWR is selected here. This MRU was also identified as a hot spot (3 priority rating) and therefore requires a detailed EWR site (DWAF, 2008).	28.115368 - -26.882574 28.026476 - -26.797013	C22F C22K
MRU Vaal E	11.03 (8%) 11.01 (80%) 11.08 (12%)	Lowland (75%) Lower foothills (85%)	Combination of unimproved grassland (dominant), some cultivated dryland and irrigated areas as well as some urban areas.	This RU falls between the Vaal Barrage to the end of the WMA 8. The river consists of one geomorphic zone and the RU is logically delineated by the Vaal Barrage. An EWR site should be located within this MRU and preferably occurring within the scarce rapid/riffle habitats within this MRU. This MRU also has the highest priority rating in the WMA and it is vital that a detailed EWR site is selected here (DWAF, 2008).	27.682886 - -26.766311 26.95192 - -26.87589	C23B C23C C23L

**5.2.4 Klein Vaal**



**Figure 5.4 Management Resource Units: Klein Vaal River**

**Table 5.4 Description and rationale of the Klein Vaal River MRUs**

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Klein Vaal A	11.02 (70%) 15.05 (30%)	Upper Foothills (30%) Lower Foothills (70%)	Mostly natural grass land	This RU is delineated from the origin of the Klein Vaal to the end of the Lower Foothills. The change in operation (transfer from Heyshope Dam) that coincides with the	Origin of river to end of Lower Foothills 30.2330 - -27.1142 30.1899 - -26.8912	C11C

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
				change in geomorphic zone provides a logical break in the Klein Vaal River. Ideally an EWR site should be selected within this reach as it has ecological importance.		
MRU Klein Vaal B	11.02 (100%)	Lowland (100%)	Mostly natural grass land	This RU starts at the beginning of the Lowland geomorphic zone up to confluence with the Vaal River. This RU is defined by the change in flow regime caused by the interbasin transfer from Heyshope Dam as well as Lowland geomorphic zone. Ideally an EWR site should be selected within this reach. The constant transfer at high velocities makes it however impossible to work in the river and the options of any changes to the flow due to the power station requirements resulted in a decision not to place an EWR site within this reach.	30.1899 - -26.8912 30.0063 - -26.7483	C11C C11D

### 5.2.5 Klip River

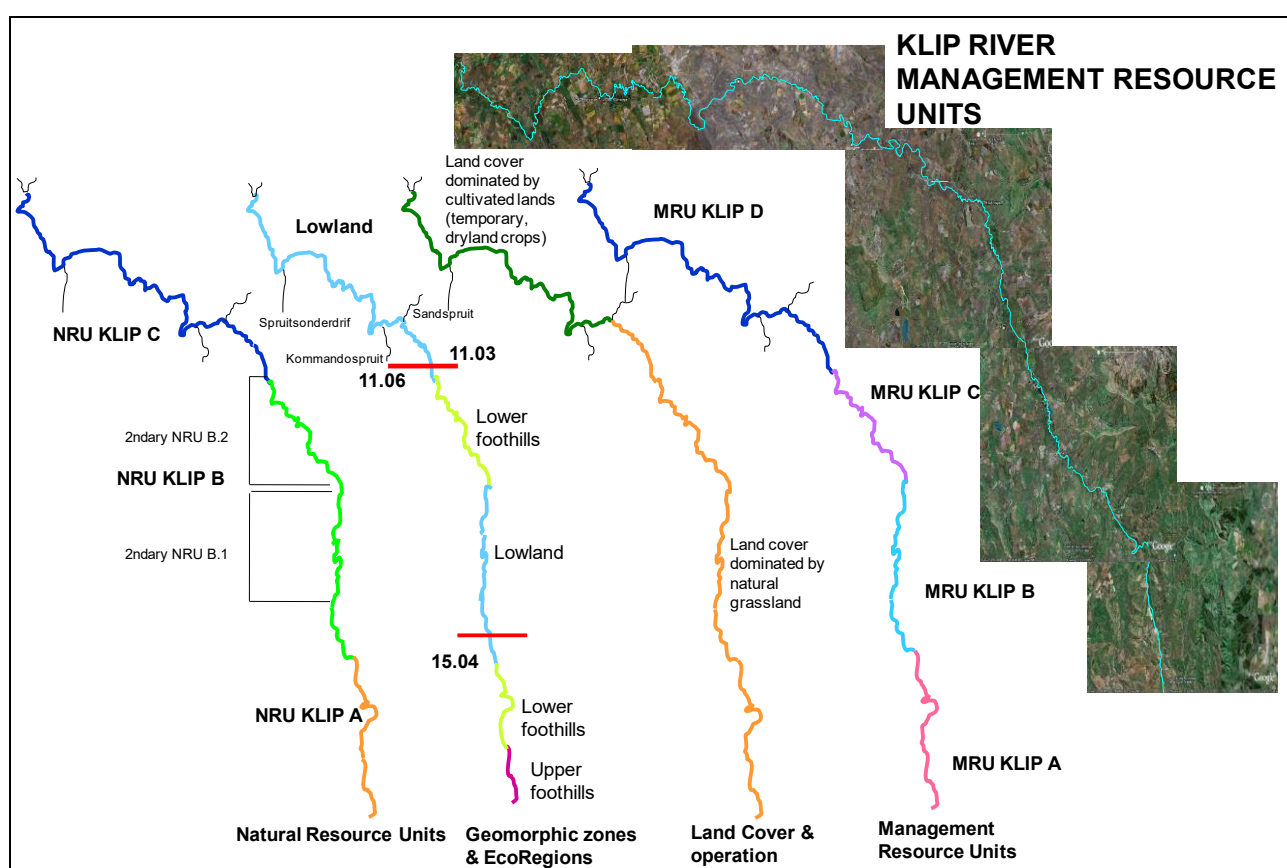


Figure 5.5 Management Resource Units: Klip River

Table 5.5 Description and rationale of the Klip River MRUs

MRU	EcoRegion Level 2	Geomorphic zone	Land cover	Rationale	Delineation	Quat
MRU Klip A	15.04 (10%)	Upper Foothills (30%) Lower Foothills (70%)	Mostly natural grass land.	Starts at the origin of the Klip River and ends at the end of lower foothills / start of lowland geomorphic zone. Consists of 1 Level II EcoRegion and 2 geomorphic zones, although the Upper Foothills zone is too small to warrant its own EcoRegion. Mostly upstream of the wetlands.	29.6409 - 27.9588 29.5804 - 27.6676	C13C

MRU	EcoRegion Level 2	Geomorphic zone	Land cover	Rationale	Delineation	Quat
MRU Klip B	11.06	Lowland	Mostly natural grass land.	Lies within the Lowland geomorphic zone. One geomorphic zone which mostly consists of wetlands, falls within one Level II EcoRegion and has the same type of land cover. It is recommended that a Wetland Reserve assessment be undertaken as this will be more valuable than a river assessment.	29.6409 - 27.9588 29.5578 - 27.4358	C13C C13D
MRU Klip C	11.06	Lower Foothills	Mostly natural grass land.	Lies within the Lower Foothills geomorphic zone. Distinctly different due to change in geomorphic zone from the upper and lower geomorphic zones and is not wetland dominated. The RU falls within one Level II EcoRegion and the same type of land cover. It is recommended that an EWR site is selected in this MRU. As this is lower foothills, it is more likely that rapids will occur here than in the lower Lowland section. The rapids/riffles would represent critical habitat. This section of river has also been identified as a 3 priority rating requiring a comprehensive/intermediate EWR site (DWAf, 2008).	29.5501 to - - 27.4305 29.4688 - -27.3188	C13D
MRU Klip D	11.03	Lowland	Dominated by cultivated lands (temporary, dryland crops).	Starts at the Lowland geomorphic zone and ends at the Vaal River confluence. One Level II EcoRegion and Lowland geomorphic zone. The land cover is different than the other RUs as this reach is now dominated by cultivated lands.	29.4688 - 27.3188 29.0727 - 27.0549	C13D C13F C13H

### 5.2.6 Wilge River

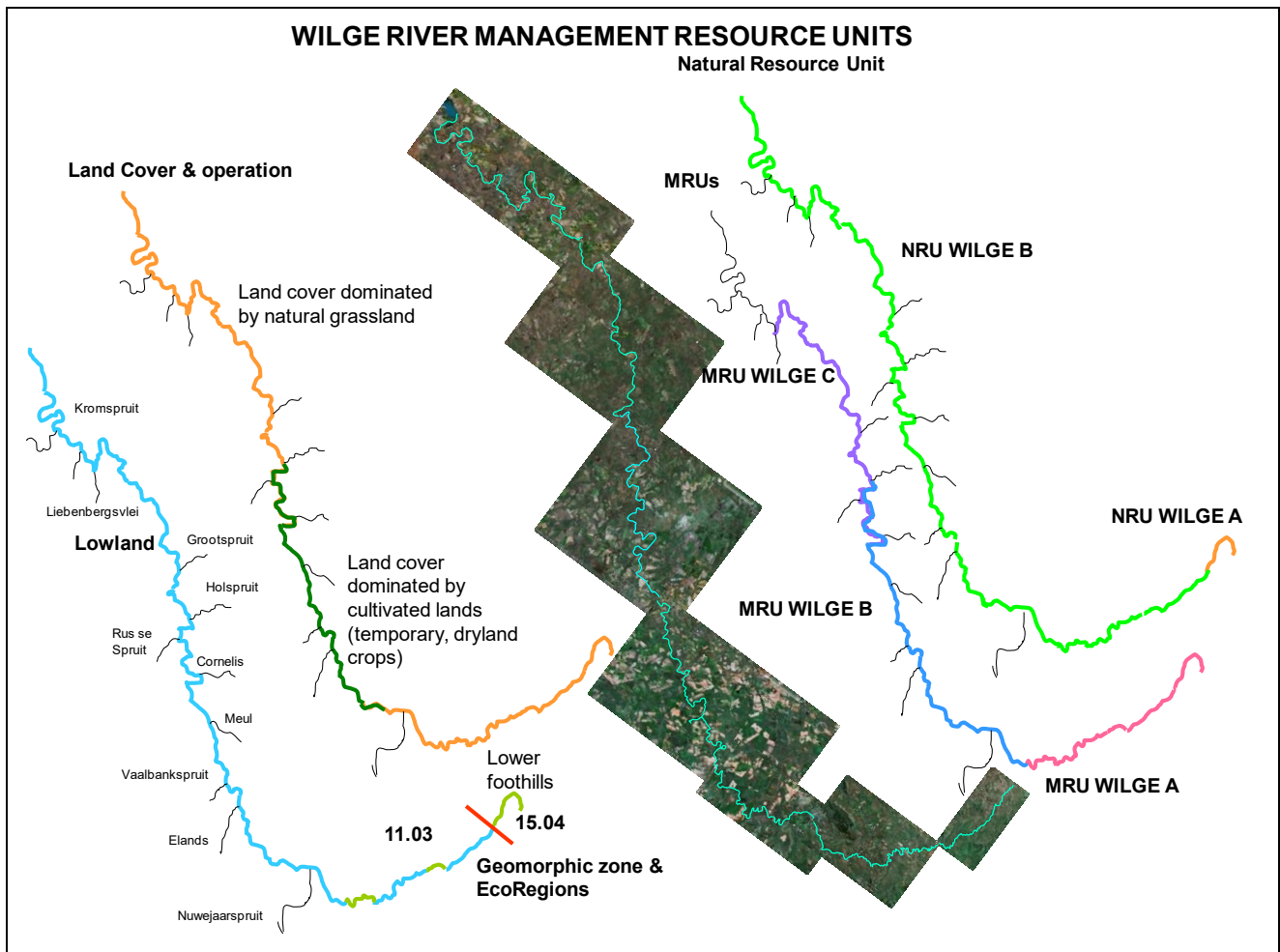


Figure 5.6 Management Resource Units: Wilge River

**Table 5.6 Description and rationale of the Wilge River MRUs**

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Wilge A	15.04 11.03	Lower Foothills Lowland	Mostly natural grass land.	Starts at the origin of Wilge River and ends at the confluence with the Nuwejaarspruit. The reach consists of two EcoRegions which coincides with two geomorphic zones. The 15.04 EcoRegion is too short to warrant its own RU. The operation of the river changes at the confluence with the Nuwejaarspruit (releases from Sterkfontein Dam) and therefore the RU ends here. It is recommended that an EWR site is selected in this MRU due to its different operation and wetland character. The whole Wilge River has been identified as a 3 priority rating that means that it requires a comprehensive or intermediate site (DWAF, 2007a).	29.6483 - 28.1293 29.0875 - 28.2714	C81A C81B
MRU Wilge B	11.03	Lowland	Dominated by temporary crops (dryland).	From the Nuwejaarspruit confluence to the Holspruit confluence. The RU has the same EcoRegion and geomorphic zone than RU C. However, the land cover is different; therefore warranting its own RU. An EWR site should be selected within this reach. The whole Wilge River has been identified as a 3 importance that means that it requires a comprehensive or intermediate site (RDM/WMA8C000/01/CON/0207).	29.6211 - 27.7493 28.7799 - 27.6865	C81E C81K C82C C82G
RU Wilge C	11.03	Lowland	Mostly natural grass land.	Between the Holspruit confluence and the Liebenbergsvlei confluence. The RU is warranted by the change in land use. Ends at Liebenbergsvlei confluence due to significant change in flow regime (increased flows from the LHWP). Downstream Wilge River does not form part of an RU as it is significantly changed by the LHWP, is a short distance and is mostly inundated by the Vaal Dam. An EWR site should be selected within this reach. The whole Wilge River has been identified as a 3 priority rating that means that it requires a comprehensive or intermediate site.	28.7799 - 27.6865 28.5187 - 27.3245	C82G C82H

### 5.2.7 Liebenbergsvlei River

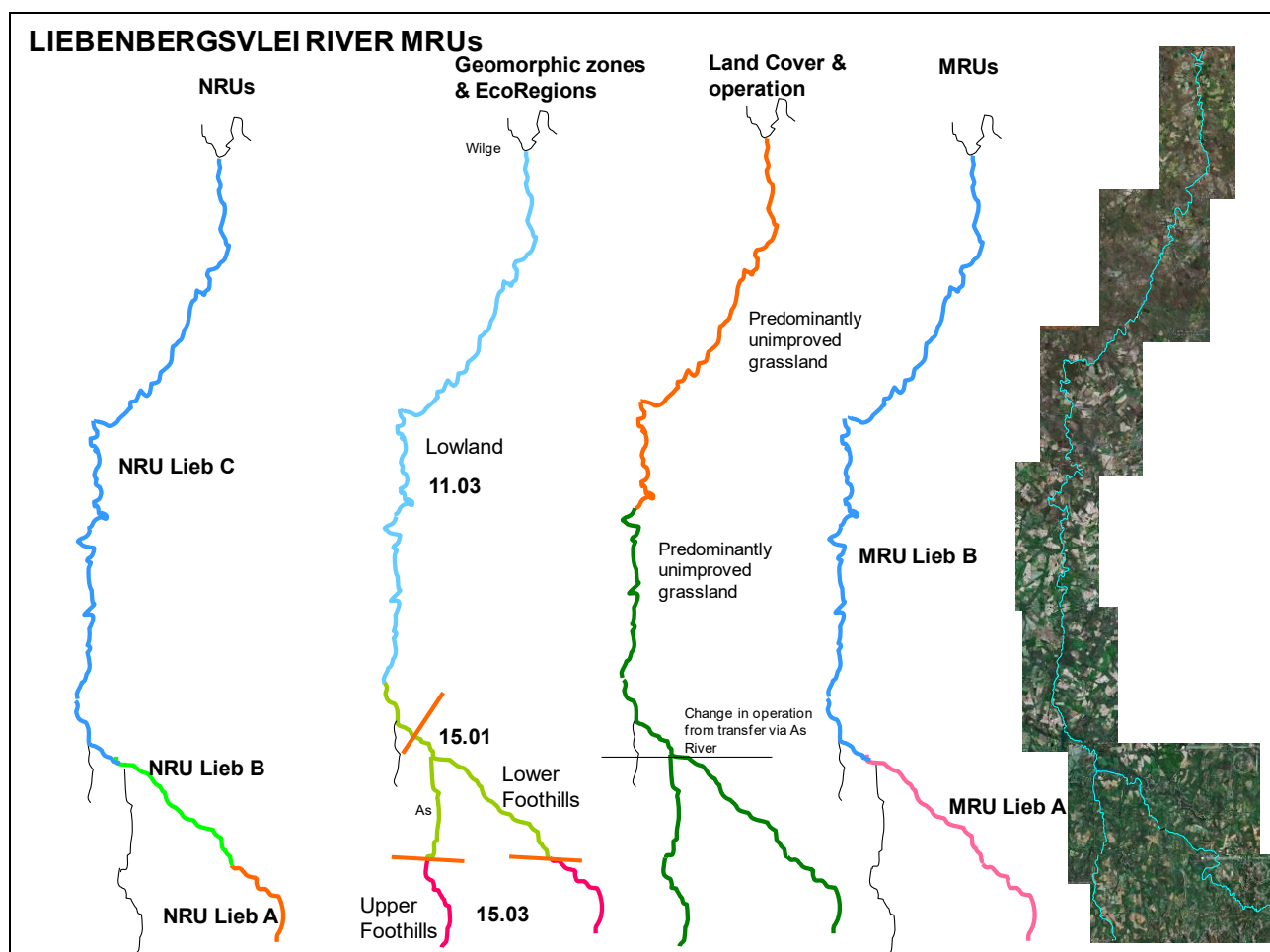


Figure 5.7 Management Resource Units: Liebenbergsvlei River

Table 5.7 Description and rationale of the Liebenbergsvlei River MRUs

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Lieb A	15.01 15.03	Upper Foothills Lower Foothills	Cultivated lands.	Origin of the Liebenbergsvlei River and end at the As River confluence. In 1 Level I EcoRegion (and 2 Level II EcoRegions) and falls within the Foothill geomorphic zone. The operation of the river changes significantly with the inflow of the As River and the transfer of water from the LHWP. Land cover is dominated more by cultivated lands than unimproved grassland.	28.3631 - -28.697 28.3631 - -28.2168	C83A
MRU Lieb B	11.03	Lowland	Cultivated lands and 'unimproved grassland'	From the As River confluence to the Wilge River confluence. The whole section is one RU as it falls within one Level II EcoRegion, one geomorphic zone and similar land cover. Due to the constant release from Lesotho and the lack of any opportunity for changes in operation, no EWR site is to be selected in either one of the MRUs.	28.3631 - -28.2168 28.3080 - -27.8667	C83C

### 5.2.8 Waterval River

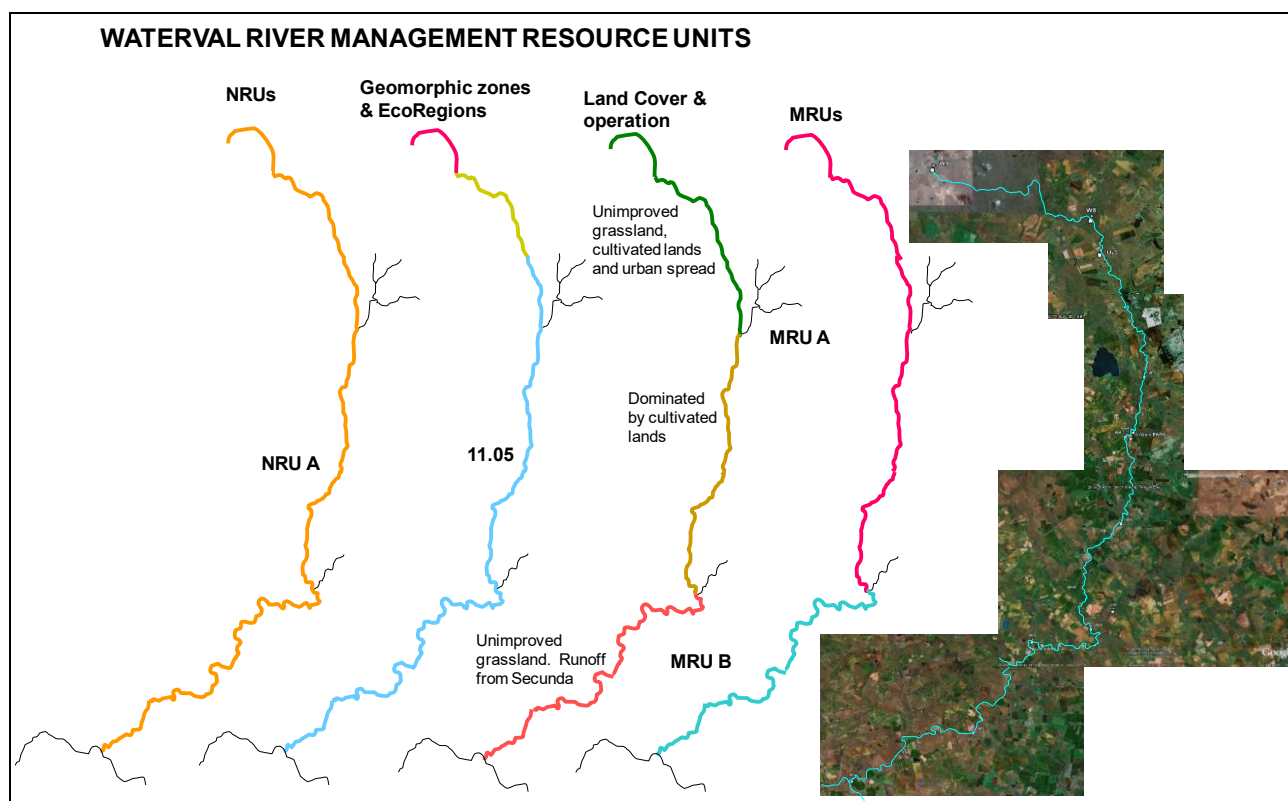


Figure 5.8 Management Resource Units: Waterval River

Table 5.8 Description and rationale of the Waterval River MRUs

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Waterval A	11.05 (100%)	Upper Foothills (20%) Lower Foothills (30%) Lowland (50%)	Dominated by cultivated lands with urban areas in the upper section (Leandra). River riparian mostly grassland.	From origin of river to the Boesmanspruit confluence. Although all in one EcoRegion, the change in land use (although gradual) warrants 2 MRUs. The water quality runoff from SASOL in the lower area forms the 2 <sup>nd</sup> MRU. An EWR site is recommended in this region .	28.8708, -26.3982 28.9791, -26.8207	C12D C12F
MRU Waterval B	11.05 (100%)	Lowland (100%)	Mostly grassland but affected by urban runoff and releases from Sasol Secunda.	From the Boesmanspruit confluence to the Vaal confluence. See above. As this is probably more of a water quality issue, an EWR site is not recommended here.	28.9791, -26.8207 28.7143, -26.9694	C12F C12G

### 5.2.9 Suikerbosrand River

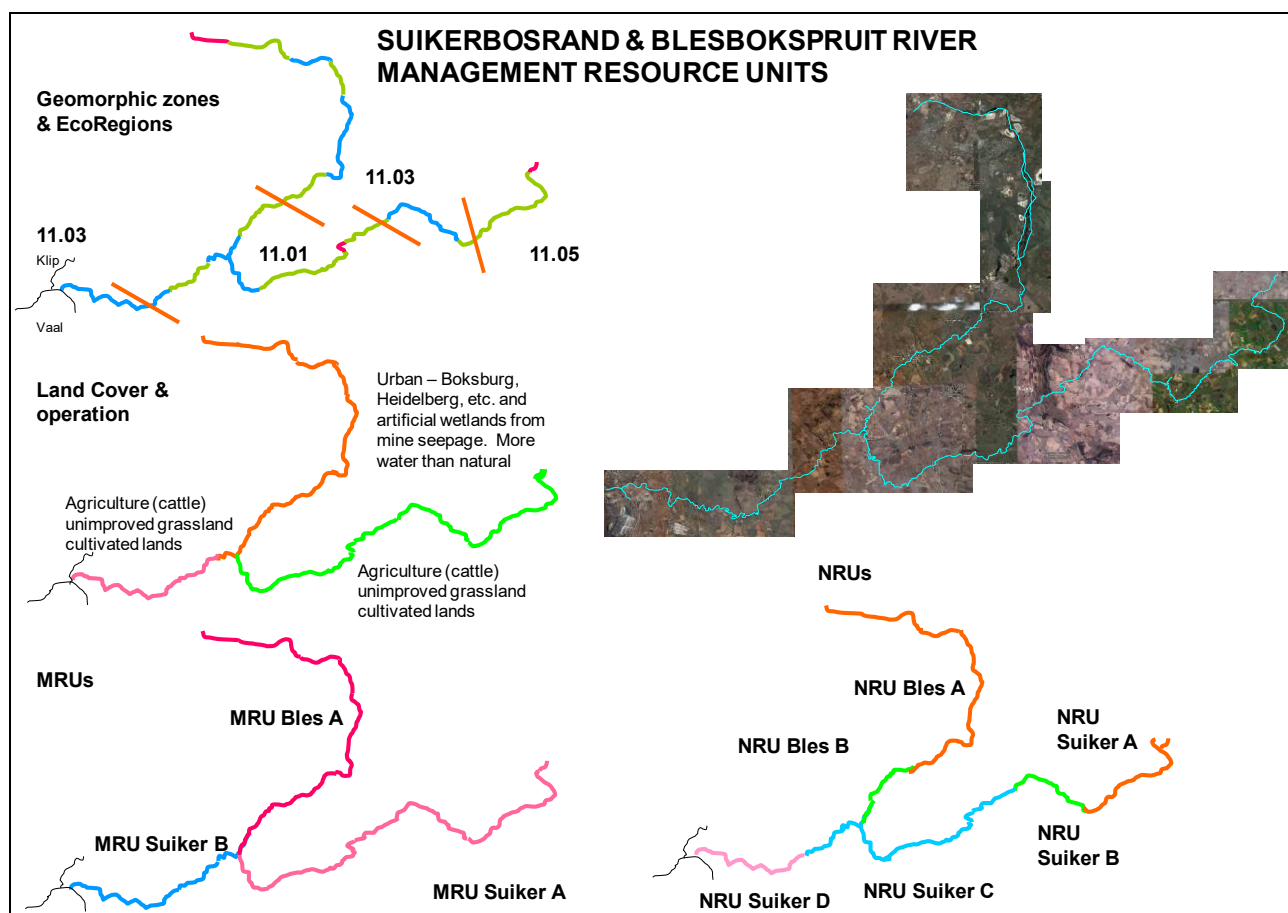


Figure 5.9 Management Resource Units: Suikerbosrand and Blesbokspruit River

Table 5.9 Description and rationale of the Suikerbosrand and Blesbokspruit River MRUs

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Suiker A	15.05 (20%) 11.03 (30%) 11.01 (60%)	Upper Foothills (3%) Lower Foothills (70%) Lowland (27%)	Agriculture (cattle), grassland, cultivated lands	This RU starts at the origin of the Suikerbosrand River to the confluence of the Blesbokspruit. The Blesbokspruit with its significant problems regarding water quality makes this the logical break for the MRU. It is recommended that an EWR site is situated in the lower sections of this reach. This area has high ecological importance.	28.866 - -26.4137 28.2900 - -26.5977	C21A C21B C21C
MRU Suiker B	11.03 (50%) 11.01 (50%)	Lower Foothills (40%) Lowland (60%)	Agriculture (cattle), grassland, cultivated lands Includes all the problems associated with the Blesbokspruit	This reach lies between the Blesbokspruit and Vaal confluences. The change in water quality due to the Blesbokspruit as well as the change in natural hydrology defines this MRU. It is recommended that an EWR site is situated in this reach. This MRU was identified as a 3 priority rating which warrants a detailed EWR sites (DWAF, 2008).	28.2900 - -26.5977 27.9719 - -26.6666	C21G
MRU Bles A	11.01 11.03	Upper Foothills (10%) Lower Foothills (45%) Lowland (45%)	Extensive urbanisation, mining, artificial wetlands.	This RU starts at the origin of the Blesbokspruit and ends at the confluence of the Suikerbosrand River. The Blesbokspruit is a significantly altered river down its whole length with the artificial Merrievale wetland in the middle. This river should be managed as a whole. It is recommended that an EWR site is situated in this reach.	28.2172 - -26.1557 28.2900 - -26.5977	C21D C21E C21F

### 5.2.10 Mooi River

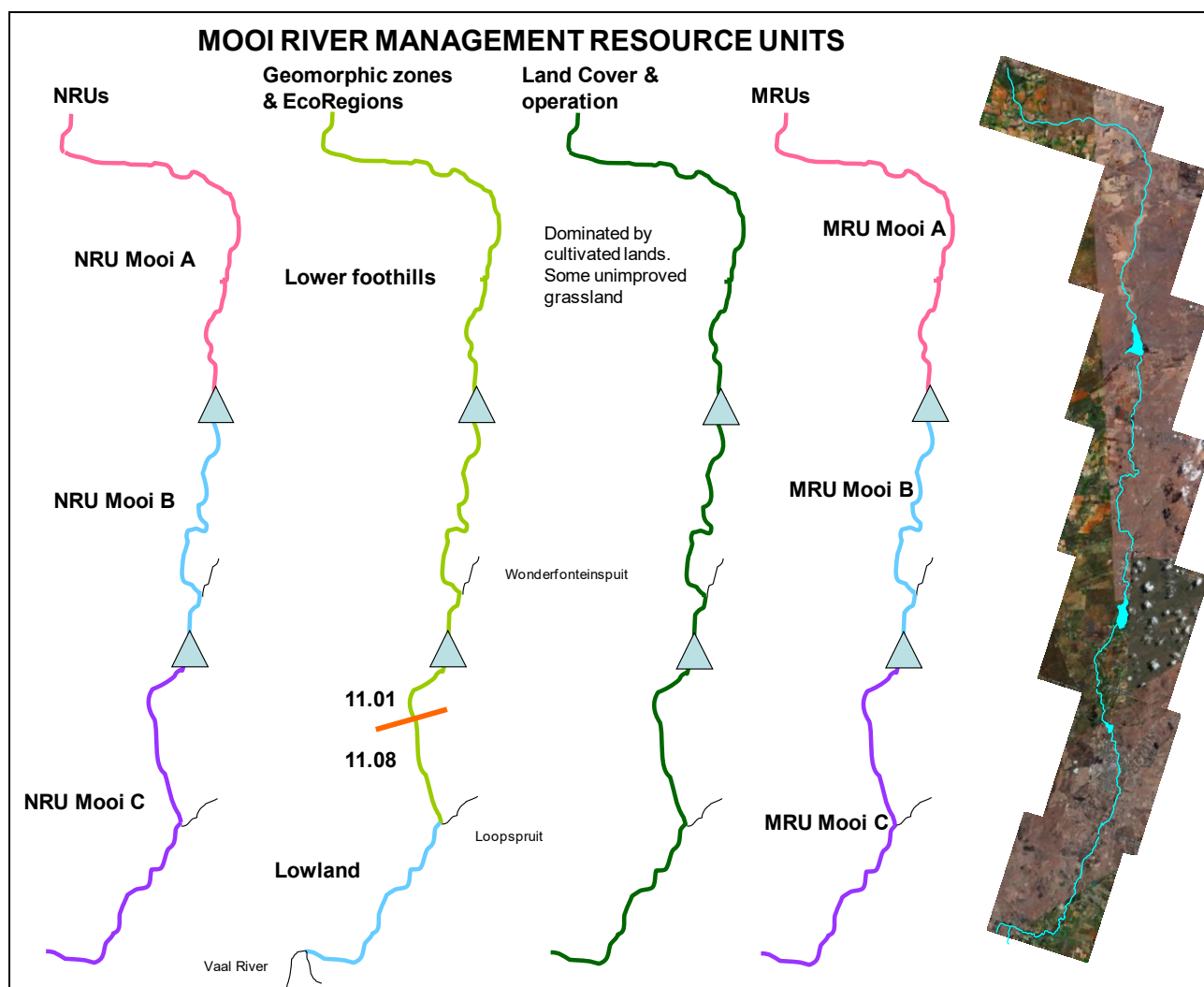


Figure 5.10 Management Resource Units: Mooi River

Table 5.10 Description and rationale of the Mooi River MRUs

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Mooi A	11.01	Lower Foothills	Cultivated lands, some 'unimproved grassland'.	This RU starts at the origin of Mooi River to start of Klerkskraal Dam. The reach consists of one EcoRegion, one geomorphic zone, a large wetland and the same land use. The Klerkskraal Dam forms a logical boundary for this RU. This MRU has been rated as a 3 priority which means that it requires a comprehensive or intermediate EWR site (DWAF, 2008). An EWR site in this reach is not recommended as it consists mostly of a wetland. A wetland Reserve could be undertaken.	26.99 - -25.91 27.150223 - -26.219878	C23F
MRU Mooi B	11.01	Lower Foothills	Cultivated lands, some 'unimproved grassland'.	This RU lies between Klerkskraal Dam wall and Boskop Dam. This reach consists of one EcoRegion, one geomorphic zone, a large wetland and the same land use. The Klerkskraal and Boskop Dams form a logical start and end of this RU. This MRU has a 3 priority rating which means that it requires a comprehensive or intermediate EWR site (DWAF, 2008). An EWR site should be selected in this reach – however the river naturally consisted of wetland	27.158998 - -26.255203 27.124953 - -26.533479	C23G

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
				which has and is being extensively modified. This makes the selection of an EWR site very difficult.		
MRU Mooi C	11.01 11.06	Lower Foothills Lowland	Cultivated lands, some 'unimproved grassland'. Potchefstroom	This RU starts at the Boskop Dam wall and ends at the confluence with the Vaal River. This RU consists mostly of one EcoRegion and two geomorphic zones. The Boskop Dam forms the logical upstream border of the RU ending at the confluence with the Vaal River. MRU has a 3 priority rating which means that it requires a comprehensive or intermediate EWR site (DWAF, 2008). An EWR site should be selected in this MRU. As most of the river is wetland and the presence of riffles in reasonable condition is scarce, this makes the selection of sites problematic.	27.110968 - -26.563909 26.953 - -26.8764	C23H C23L

The results of the delineation of the Crocodile River and Kaap River are summarized in Table 5.11 and illustrated in Figure 5.11.

**Table 5.11 Description of MRUs in the Upper vaal WMA**

MRU	Delineation	Quaternary catchment
<b>VAAL RIVER</b>		
MRU Vaal A	From the origin to the Klein Vaal confluence.	C11A, C11B
MRU Vaal B	Klein Vaal confluence to Grootdraai Dam.	C11E, C11J, C11L
RUA Vaal B.1	Extensive rapids and riffles upstream of Grootdraai Dam and downstream of the Skulpspruit confluence.	C11J
MRU Vaal C	Grootdraai Dam to Vaal Dam.	C11L, C11M, C12B, C12C, C12H, 12L
RAU Vaal C.1	Riffle section immediately below Grootdraai Dam.	C11L
MRU Vaal D	Vaal Dam to Barrage.	C22F, C22K
MRU Vaal E	Barrage to end of Water Management Area (WMA).	C23B, C23C, C23L
<b>KLEIN VAAL RIVER</b>		
MRU Klein Vaal A	Origin of the river to the end of the Lower Foothills.	C11C
MRU Klein Vaal B	Beginning of Lowland geomorphological zone to Vaal River confluence.	C11C, C11D
<b>KLIP RIVER</b>		
MRU Klip A	Origin of Klip River to end of the Lower Foothill zone and start of the Lowland zone.	C13C
MRU Klip B	Lowland geomorphological zone to Lower Foothill zone.	C13C, C13D
MRU Klip C	Lower Foothill geomorphic zone to Lowland zone.	C13D
MRU Klip D	Lowland geomorphological zone to the confluence with the Vaal.	C13D, C13F, C13H
<b>WILGE RIVER</b>		
MRU Wilge A	Origin of Wilge River to confluence with the Nuwejaarspruit.	C81A, C81B
MRU Wilge B	Nuwejaarspruit to the Holspruit.	C81E, C81K, C82C, C82G
MRU Wilge C	Holspruit to the Liebenbergsvlei River confluence.	C82G, C82H
<b>LIEBENBERGSVLEI RIVER</b>		
MRU Lieb A	Origin of the Liebenbergsvlei River to end of the As River confluence.	C83A
MRU Lieb B	As River to the Wilge River confluence.	C83C
<b>WATERVAL RIVER</b>		
MRU Waterval A	Origin of the river to the Boesmanspruit confluence.	C12D, C12F
MRU Waterval B	Boesmanspruit to the Vaal River confluence.	C12F, C12G

MRU	Delineation	Quaternary catchment
<b>SUIKERBOSRAND RIVER and BLESBOKSPRUIT</b>		
MRU Suiker A	Origin of river to confluence with Blesbokspruit.	C21A, C21B, C21C
MRU Suiker B	Blesbokspruit to Vaal River confluence.	C21G
MRU Bles A	Blesbokspruit.	C21D, C21E, C21F
<b>MOOI RIVER</b>		
MRU Mooi A	Origin of river to Klerkskraal Dam.	C23F
MRU Mooi B	Klerkskraal Dam to Boskop Dam.	C23G
MRU Mooi C	Boskop Dam to the Vaal River.	C23H, C23L

### 5.3 EWR SITES

The selection of EWR sites was guided by a number of considerations. The key considerations were:

- 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 were not considered critical habitats in perennial systems since they are still able to function or at least maintain life during periods of no flow.

#### 5.3.1 Locality and description of sites

The locality of the EWR sites within the MRUs as identified during this study is provided in Table 5.12.

**Table 5.12 MRUs and EWR sites**



MRUs	Recommendation)	EWR site
<b>VAAL RIVER</b>		
MRU Vaal A	This MRU lies in an area with a 2 and a 1 priority rating which does not warrant the selection of a comprehensive/intermediate EWR site.	A potential site – even if only a Rapid site was looked for in this area. Due to the meandering run pool nature of this river, no suitable site was found.
MRU Vaal RAU B.1	The RAU and MRU has a 3 priority rating which indicates that an EWR site should be situated in the MRU and preferably in the RAU as representing the more critical habitat (DWAF, 2008).	The RAU in totality consists of an anastomosing rapid section with off-channel pools and backwaters, making this a very critical habitat within this very homogenous section of the Vaal River. EWR 1 was selected in this reach.
MRU Vaal RAU C.1	An EWR site should be selected within this section as it has a 3 priority rating (DWAF, 2008). However, as this riffle system is right at the beginning of the MRU, a site further down would also be recommended to reflect some of the impacts.	EWR 2 and 3 was selected in this MRU with EWR 2 selected within the RAU C.1. A bedrock anastomosing section at Gladdedrift just upstream of Villiers was selected for the 2 <sup>nd</sup> site (EWR 3) in this reach. As it is close to the downstream section of this MRU, it is situated ideally to address all impacts upstream to Grootdraai Dam.
MRU Vaal D	The area not inundated by the Barrage is characterised by extensive rapids. This forms a critical area and as most of the rest of the MRU is inundated by the Barrage, it is recommended that an EWR site is selected here. This MRU was also identified as a hot spot (3 priority rating) and therefore requires a detailed EWR site (DWAF, 2008).	EWR 4 was selected in the rapid anastomosing section downstream of Vaal Dam and outside of Barrage inundation.
MRU Vaal E	An EWR site should be located within this MRU and preferably within the scarce rapid/riffle habitats within this MRU. This MRU also has the highest priority rating in the WMA and it is vital that a detailed EWR be selected here (DWAF, 2008).	EWR 5 was selected downstream of Skandinavia Drift.
<b>KLEIN VAAL RIVER</b>		





MRUs	Recommendation)	EWR site
MRU Klein Vaal A	Ideally an EWR site should be selected within this reach as it has ecological importance.	An EWR site (Klein Vaal RE-EWR 1) was selected. Due to the lack of operational capacity however, the site will only be addressed at a Rapid level.
MRU Klein Vaal B	Ideally an EWR site should be selected within this reach. The constant transfer at high velocities makes it however impossible to work in the river and the options of any changes to the flow due to the power station requirements resulted in a decision not to place an EWR site within this reach.	No EWR was selected in this reach even though the possibility of a site was extensively investigated.
<b>KLIP RIVER</b>		
MRU Klip B	The MRU lies within the lowland geomorphic zone, which mostly consists of wetlands, falls within one Level II EcoRegion and has the same type of land cover. It is recommended that a Wetland Reserve assessment be undertaken as this will be more valuable than a river assessment.	No EWR site was selected in this reach.
MRU Klip C	It is recommended that an EWR site is selected in this MRU. As this is lower foothills, it is more likely that rapids will occur here than in the lower lowland section. The rapids/riffles would represent critical habitat. This section of river has also been identified as a 3 priority rating requiring a comprehensive / intermediate EWR site (DWAF, 2008).	EWR 6 was selected in this reach.
MRU Klip D	This MRU starts at the lowland geomorphic zone and ends at the Vaal River confluence. One Level II EcoRegion and lowland geomorphic zone. The land cover is different than the other RUs as this reach is now dominated by cultivated lands.	No site was selected here as EWR 6 would cater for this reach.
<b>WILGE RIVER</b>		
MRU Wilge A	It is recommended that an EWR site is selected in this MRU due to its different operation and wetland character. The whole Wilge River has been identified as a 3 priority rating which means that it requires a comprehensive or intermediate site (DWAF, 2008).	EWR 7 was selected in this reach due to the planned Braamhoek pump storage scheme. The site is characterised by bedrock section with predominantly pool and run sections within a wetland environment. This site will be EWR 7.
MRU Wilge B	The land cover is different, therefore warranting its own RU. An EWR site should be selected within this reach. The whole Wilge River has been identified as a 3 priority rating which means that it requires a comprehensive or intermediate site (DWAF, 2008).	EWR 8 was selected within this MRU at a very large critical rapid area.
MRU Wilge C	An EWR site should be selected within this reach. The whole Wilge River has been identified as a 3 priority rating which means that it requires a comprehensive or intermediate site (DWAF, 2008).	The upper site would cater for this section. Due to the pool run nature of this section, it was impossible to find an accessible site with suitable criteria for an EWR site.
<b>LIEBENBERGVSLEI RIVER</b>		
MRU Lieb A, As A, Lieb B	Due to the constant release from Lesotho and the lack of any opportunity for changes in operation, no EWR site is to be selected in either one of the MRUs.	No EWR site selected.
<b>WATERVAL RIVER</b>		
MRU Waterval A	An EWR site is recommended in this region.	Two EWR sites were selected and EWRs determined during a previous study. These sites and results stand, so no new attention has been given to this river.
MRU Waterval B	As this is probably more of a water quality issue, an EWR site is not recommended here.	
<b>SUIKERBOSRAND AND BLESBOKSPRUIT RIVERS</b>		
MRU Suiker A	It is recommended that an EWR site is situated in the lower sections of this reach. This area has high ecological importance.	The river provided problems with regards to access to select a good EWR site. The best compromise was a riffle site (EWR 9) under the R101 bridge in the lower section of the MRU.
MRU Suiker B	It is recommended that an EWR site be situated in this reach. This MRU was identified as a 3 importance for detailed EWR sites to be selected.	A site (EWR 10) was selected in the reach.
MRU Bles A	It is recommended that an EWR site be situated in this reach.	A site (EWR 11) was selected in the reach.
<b>MOOI RIVER</b>		
MRU Mooi A	This MRU has been identified as a 3 priority rating which means that it requires a comprehensive or intermediate site (DWAF, 2008). An EWR site in this reach is not recommended as it consists mostly of a wetland. A wetland Reserve could be undertaken.	No EWR site was selected.
MRU Mooi B	This MRU has been identified as a 3 priority rating which means that it requires a comprehensive or intermediate site (DWAF, 2008). An EWR site should be selected in this reach – however the river naturally consisted of wetland	A Rapid EWR site (RE-EWR 2) has been selected downstream of Klerkskraal Dam. However the value of this site which is situated on an artificial riffle in a wetland (present due to rocks being placed over a pipeline that




MRUs	Recommendation)	EWR site
	which has and is being extensively modified. This makes the selection of an EWR site very difficult.	runs underneath the river), is doubtful. This site will be approached as a Rapid.
MRU Mooi C	This MRU has been identified as a 3 priority rating which means that it requires a comprehensive or intermediate site (DWAF, 2008). An EWR site should be selected in this MRU. As most of the river is wetland and the presence of riffles in reasonable condition is scarce, this makes the selection of sites problematic.	No EWR site was selected.


The locality and characteristics of the EWR sites are provided in Table 5.13.

**Table 5.13 Locality and characteristics of the Upper Vaal River EWR sites**

Site information	EWR sites	Illustration
EWR nr and name	<b>EWR 1 Uitkoms</b>	
River	Vaal	
National RHP site	C1Geel_Unspe	
Decimal Degrees	-26.8728, 29.61384	
Decimal Minutes	S26 52.368, E29 36.830	
EcoRegion (Level II)	11.05	
Geomorphic Zone	Lowland	
Altitude (m)	1570	
RU	MRU Vaal B.1	
Quaternary	C11J	
Farm name	Uitkoms 489	
Hydrological gauge	C1H007	
EWR nr and name	<b>EWR 2 Grootdraai</b>	
River	Vaal	
National RHP site	C1Vaal Braks	
Decimal Degrees	-26.9211, 29.27929	
Decimal Minutes	S26 55.266, E29 16.758	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lowland	
Altitude (m)	1537	
RU	MRU Vaal C.1	
Quaternary	C11L	
Farm name	Verblyden 387	
Hydrological gauge	C1H019	
EWR nr and name	<b>EWR 3 Gladdedrift</b>	
River	Vaal	
National RHP site	C1Vaal-Villie	
Decimal Degrees	26.99087, 28.72971	
Decimal Minutes	S26 59.452, E28 43.783	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lowland	
Altitude (m)	1487	
RU	MRU Vaal C.1	
Quaternary	C12H	
Farm name	Groenfontein 262	
Hydrological gauge	C1H012	

Site information	EWR sites	Illustration
EWR nr and name	<b>EWR 4 De Neys</b>	
River	Vaal	
National RHP site	C2Vaal-Deny	
Decimal Degrees	-26.8426, 28.1123	
Decimal Minutes	S26 50.557, E28 06.738	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1445	
RU	MRU Vaal D	
Quaternary	C22F	
Farm name	Veekraal 762/Zoekfontein 468(Benchmark)	
Hydrological gauge	C2H122	
EWR nr and name	<b>EWR 5 Skandinavia</b>	
River	Vaal	
National RHP site	-	
Decimal Degrees	-26.9324, 27.01367	
Decimal Minutes	S26 55.946, E27 00.820	
EcoRegion (Level II)	11.08	
Geomorphic Zone	Lowland	
Altitude (m)	1309	
RU	MRU Vaal E	
Quaternary	C23L	
Farm name	Farm 396 Prospect	
Hydrological gauge	C2H018	
EWR nr and name	<b>RE-EWR 1 Klein Vaal</b>	
River	Klein Vaal	
National RHP site	C1KVaal-unspe	
Decimal Degrees	-26.9128, 30.17497	
Decimal Minutes	S26 54.765, E30 10.498	
EcoRegion (Level II)	11.02	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1620	
RU	MRU Kvaal A	
Quaternary	C11C	
Farm name	-	
Hydrological gauge	-	
Site information	EWR sites	Illustration
EWR nr and name	<b>EWR 6 Klip</b>	
River	Klip River	
National RHP site	C1Klip-Unspe2	
Decimal Degrees	-27.3617, 29.48503	
Decimal Minutes	S27 21.700, E29 29.102	
EcoRegion (Level II)	11.06	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1593	
RU	MRU Klip C	
Quaternary	C13D	
Farm name	-	
Hydrological gauge	-	

Site information	EWR sites	Illustration
EWR nr and name	<b>EWR 7 Upper Wilge</b>	
River	Wilge River	
National RHP site	C8Wilg-Belwh	
Decimal Degrees	-27.8002, 28.76778	
Decimal Minutes	S27 48.010, E28 46.067	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lowland	
Altitude (m)	1573	
RU	MRU Wilge A	
Quaternary	C82C	
Farm name	-	
Hydrological gauge	-	
EWR nr and name	<b>EWR 8 Bavaria</b>	
River	Wilge	
National RHP site	-	
Decimal Degrees	-	
Decimal Minutes	-	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lowland	
Altitude (m)	-	
RU	MRU Wilge A	
Quaternary	-	
Farm name	-	
Hydrological gauge	-	
EWR nr and name	<b>EWR 9 Suikerbos US</b>	
River	Suikerbosrand	
National RHP site	C2Suik-Dehoe	
Decimal Degrees	-26.6467, 28.38197	
Decimal Minutes	S26 38.802, E28 22.918	
EcoRegion (Level II)	11.01	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1509	
RU	MRU Suiker A	
Quaternary	C21C	
Farm name	Modderfontein 410(benchmark)/Dehoek 411	
Hydrological gauge	-	
EWR nr and name	<b>EWR 10 Suikerbos DS</b>	
River	Suikerbosrand	
National RHP site	close to C2Suik-Badfo	
Decimal Degrees	-26.6814, 28.16798	
Decimal Minutes	S26 40.882, E28 10.079	
EcoRegion (Level II)	11.01	
Geomorphic Zone	Lowland	
Altitude (m)	1453	
RU	MRU Suiker B	
Quaternary	C21G	
Farm name	Goedverwachting 442	
Hydrological gauge	-	

Site information	EWR sites	Illustration
EWR nr and name	<b>EWR 11 Blesbokspruit</b>	
River	Blesbokspruit	
National RHP site	C2Bles-Marai (locality incorrect)	
Decimal Degrees	-26.4789, 28.42488	
Decimal Minutes	S26 28.735, E28 25.493	
EcoRegion (Level II)	11.03	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1528	
RU	MRU Bles A	
Quaternary	C21F	
Farm name	Maraisdrift 190	
Hydrological gauge	-	
EWR nr and name	<b>RE-EWR 2 Mooi</b>	
River	Mooi River	
National RHP site	Close to C2Mooi-Klerk	
Decimal Degrees	-26.2587, 27.15973	
Decimal Minutes	S26 15.520, E27 09.584	
EcoRegion (Level II)	11.01	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1457	
RU	MRU Mooi B	
Quaternary	C23G	
Farm name	Varkenskraal 93	
Hydrological gauge		

The locality of sites are illustrated in Figure 5.11 and summarised in Table 5.14.

**Table 5.14 EWR site detail**

EWR site number	EWR site name	River	National RHP site	Co-ordinates		EcoRegion (Level II)	Geomorphic Zone	Altitude (m)	RU	Quat	Hydrological gauge
				Longitude	Latitude						
EWR 1	Uitkoms	Vaal	C1Geel_Unspe	-26.8728	29.61384	11.05	Lowland	1570	MRU Vaal B	C11J	C1H007
EWR 2	Grootdraai	Vaal	C1Vaal Braks	-26.9211	29.27929	11.03	Lowland	1537	MRU Vaal C	C11L	C1H019
EWR 3	Gladdedrift	Vaal	C1Vaal-Villie	-26.99087	28.72971	11.03	Lowland	1487	MRU Vaal C	C12H	C1H012
EWR 4	De Neys	Vaal	C2Vaal-Deny	-26.84262	28.1123	11.03	Lower Foothills	1445	MRU Vaal D	C22F	C2H122
EWR 5	Skandinavia	Vaal		-26.93243	27.01367	11.08	Lowland	1309	MRU Vaal E	C23L	C2H018
EWR 6	Klip	Klip	C1Klip-Unspe2	-27.36166	29.48503	11.06	Lower Foothills	1593	MRU Klip C	C13D	
EWR 7	Upper Wilge	Wilge		-28.20185	29.55827	11.03	Lowland	1692	MRU Wilge A	C81A	Redmans Werf 319
EWR 8	Bavaria	Wilge	C8Wilg-Belwh	-27.80017	28.76778	11.03	Lowland	1573	MRU Wilge B	C82C	C8H028
EWR 9	Suikerbos US	Suikerbosrand	C2Suik-Dehoe	-26.6467	28.38197	11.01	Lower Foothills	1509	RU Suiker A	C21C	
EWR 10	Suikerbos DS	Suikerbosrand	Close to C2Suik-Badfo	-26.68137	28.16798	11.01	Lowland	1453	RU Suiker B	C21G	
EWR 11	Blesbokspruit	Blesbokspruit	C2Bles-Marai (locality incorrect)	-26.47892	28.42488	11.03	Lower Foothills	1528	RU Bles A	C21F	
<b>Rapid Level sites</b>											
RE-EWR 1	Klein Vaal	Klein Vaal	C1Kvaal-unspe	-26.9128	30.17497	11.02	Lower Foothills	1620	MRU Kvaal A	C11C	
RE-EWR 2	Mooi	Mooi	Close to C2Mooi-Klerk	-26.2587	27.15973	11.01	Lower Foothills	1457	RU Mooi B	C23G	

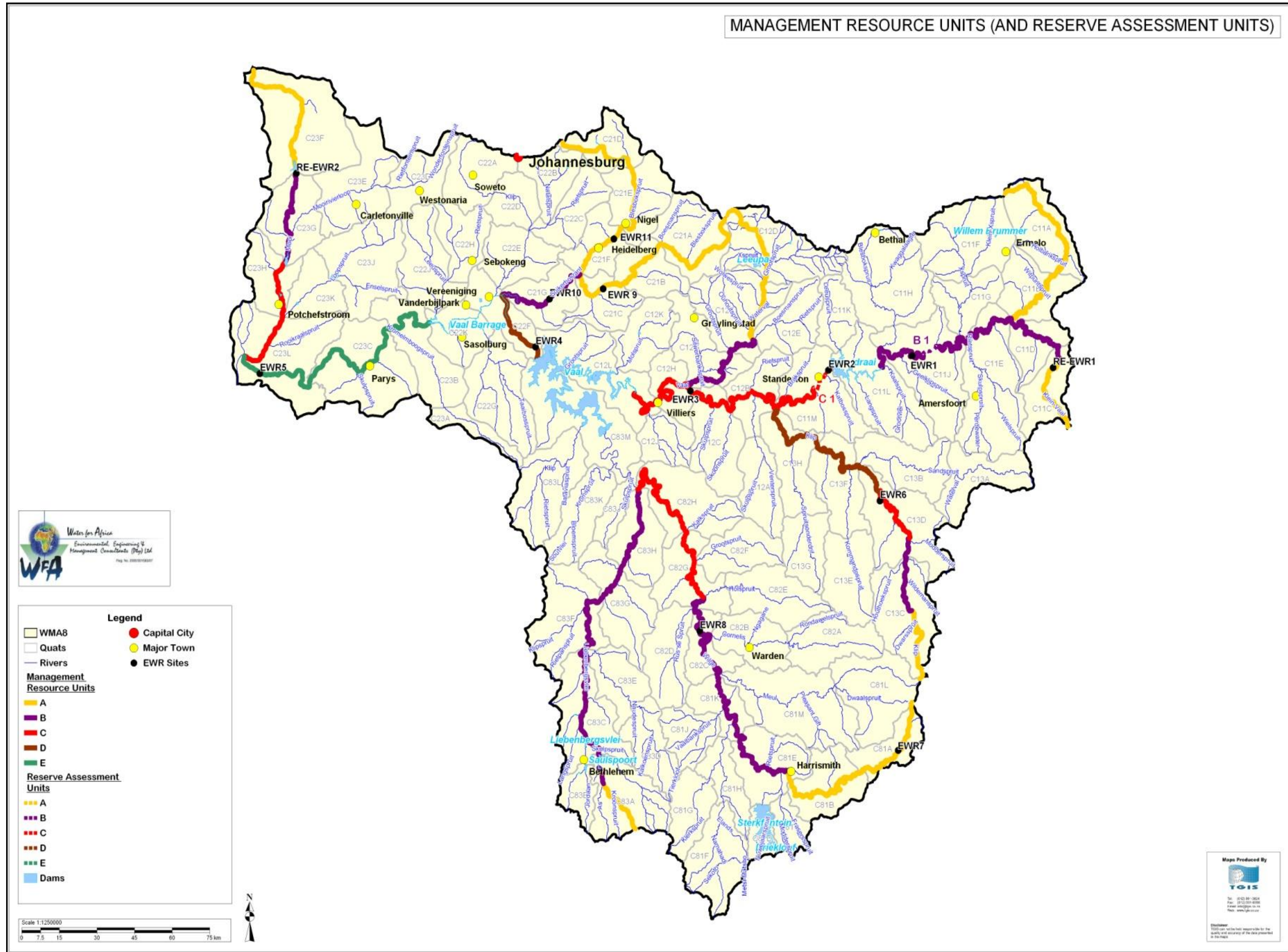


Figure 5.11 Locality of EWR sites and MRUs of the Upper Vaal WMA

### 5.3.2 Site suitability

The site suitability of each site was assessed and is provided in Table 5.15. The following scoring system was used to determine relative site suitability (Colour coding as used in Table 5.15 and 5.16):

0:	Not suitable
0.1 - 1	Very low suitability
1.1 - 2.0:	Low suitability
2.1 - 3.0:	Moderate suitability
3.1 - 4.0:	High suitability
4.1 - 5.0:	Very high suitability

Table 5.15 illustrates the site suitability from a biophysical point of view. Any comments regarding outliers are also provided. From a biophysical point of view, the sites were all moderately suitable apart from EWR 10 (very high) and RE-EWR 2 (low).

**Table 5.15 Biophysical site suitability for the Upper Vaal system**

EWR site	Geomorph	Riparian veg	Fish	Inverts	Average	Median	Max	Min	Comments
EWR 1	3.1	4.0	3.5	3.4	3.5	3.5	4.0	3.1	Suitability moderate to high for all components.
EWR 2	2.1	3.2	3.0	3.5	3.0	3.0	3.5	2.1	Below Grootdraai Dam therefore geomorphological cues are not present.
EWR 3	2.4	3.2	3.5	2.8	3.0	3.0	3.5	2.4	Lack of geomorphological cues and suitable macroinvertebrate habitats.
EWR 4	2.3	2.2	3.5	3.4	2.8	2.8	3.5	2.2	Below Vaal Dam therefore geomorphological cues not present.
EWR 5	3.9	2.5	3.0	3.2	3.1	3.1	3.9	2.5	Both banks are modified in terms of riparian vegetation.
EWR 6	3.8	4.0	3.0	3.4	3.5	3.5	4.0	3.0	Suitability moderate to high for all components.
EWR 7	3.8	3.5	2.0	1.5	2.7	2.7	3.8	1.5	Lack of suitable macroinvertebrate habitat.
EWR 8	2.1	3.0	3.0	3.0	2.8	3.0	3.0	2.1	Low geomorphological suitability as site is in a gorge with little geomorphological cues.
EWR 9	3.9	2.9	2.8	3.3	3.2	3.2	3.9	2.8	The site is disturbed by the bridge basically being situated almost on the site. Geomorphological disturbance not as high as expected as the riffles are representative and good cues are present.
EWR 10	4.3	3.2	4.0	4.6	4.0	4.0	4.6	3.2	Vegetation lower than other components due to the presence of exotic species.
EWR 11	3.4	3.1	3.0	3.0	3.1	3.1	3.4	3.0	Impacts concentrated around the road/bridge access make the banks in a poorer condition than generally seen along the reach.
RE-EWR 1			2.5	3.1	2.8	2.8	3.1	2.5	Lack of suitable macroinvertebrate habitat.
RE-EWR 2			1.5	2.3	1.9	1.9	2.3	1.5	Lack of suitable fish habitat.

Hydraulic suitability is however crucial as this converts the biophysical requirements to flow. For the purposes of determining flow requirements, the low flows and high flows are evaluated separately. Geomorphology and vegetation usually are the most crucial components for high flows and fish and invertebrate for low flows (Table 5.15). The suitability of the sites are therefore evaluated for both low and high flows and compared to the corresponding suitability for low and high flow hydraulics.

The rationale is that the lowest rating of either the biophysical or hydraulic components represents the overall suitability for either low or high flows. The reasoning is that even if a site has all the indicators for ecological flow assessment the overall suitability cannot be high if the hydraulic suitability is low as that will affect the final confidence in the flow assessment. And vice versa, if the suitability is high for hydraulics but low for the biophysical component, then the overall confidence will still be low as high suitability in hydraulics does not guarantee a high confidence answer if the indicators at the sites (indicating the biophysical suitability) is not present to interpret flow requirements. The low flow suitability was moderate to high apart from EWR 1, 5, 7 – 9 and RE-EWR 2 which was of low suitability (due to lack of mainly hydraulic suitability). The suitability for high flow determination was moderate to high at all sites apart from RE-EWR 2 (due to lack of hydraulic suitability; Table 5.16).

**Table 5.16 Integrated site suitability for the Upper Vaal system**

EWR SITES	Biophysical		Hydraulics		INTEGRATED SITE SUITABILITY		Comment
	Low flows	High flows	Low flows	High flows	Low flows	High flows	
EWR 1	3.5	3.6	2.0	3.0	2.0	3.0	Large resistance elements and non uniform flow problematic from a hydraulics perspective for low flows.
EWR 2	3.3	2.7	4.0	4.0	3.3	2.7	Lower than hydraulics due to moderate evaluation for both fish and invertebrate evaluation. Low geomorphologic evaluation causes a low high flow suitability. This must be seen however in the context that floods must be recommended with both site 2 and 3 in mind, with site 3 further down the system and not directly affected by Grootdraai Dam
EWR 3	3.2	2.8	2.0	4.0	2.0	2.8	Site hydraulically complex and lack of a range of low flow data will result in low suitability for low flows. Disturbed and eroded banks resulted in low geomorphologic suitability which then, in spite of the high hydraulic suitability, results in an overall lower suitability.
EWR 4	3.4	2.3	3.0	3.0	3.0	2.3	The site consists of a bedrock rapid with relatively large angular roughness elements (on bedrock substrate). A complicated cross-section that includes a lack of a range of low flow data (due to constant releases from Vaal Dam) resulted in low suitability for low flows. This reduces the confidence in the prediction of the stage-discharge relationship which is difficult at low flows.
EWR 5	3.1	3.2	2.0	4.0	2.0	3.2	Lack of low flow data to calibrate low flow requirements resulted in overall low suitability of the site as it is complex to model. Even though the hydraulic suitability for high flows are high, the geomorph/riparian components were low because the cross section is not geomorphologically representative of the reach and the banks are dissimilar due to landscaping on the right bank and exotic species occurrence is very high. This results in an overall moderate suitability for high flows
EWR 6	3.2	3.9	3.0	4.0	3.0	3.9	Large nature of the bed substrate (including small boulders) and the influence of the bend make resistance predictions difficult at low flows and during

EWR SITES	Biophysical		Hydraulics		INTEGRATED SITE SUITABILITY		Comment
	Low flows	High flows	Low flows	High flows	Low flows	High flows	
							medium to high flows when riffle bed-control becomes drowned-out. There are changes in the flow direction as flow increases.
EWR 7	1.8	3.7	4.0	3.0	1.8	3	Prismatic channel with approximately uniform flow conditions, which facilitates the measurement of discharge. Estimating floodplain resistance for overbank flows are difficult and therefore the high flows in this instance refer to discharges up to bankfull and does not include the flows for inundation of the floodplain (at various depths). In the case of the latter, the site suitability for the current river modelling approach would reduce to a 1 or 2.
EWR 8	3.0	2.6	2.0	3.0	2.0	2.6	Large nature of bed substrate will cause problems with low flow determination.
EWR 9	3.1	3.4	2.0	3.0	2.0	3.0	Due to the influence of the bridge and non-horizontal water levels, the confidence in the hydraulics is low for low flows and moderate for high flows.
EWR 10	4.3	3.8	3.0	4.0	3.0	3.8	Hydraulics at low flows moderate suitability due to the slack water on the right bank (RB) and tributary on the left bank (LB).
EWR 11	3.0	3.3	4.0	4.0	3.0	3.3	Uniform riffle resulted in high suitability for hydraulics. The biophysical suitability is however lower due to low biotope availability for macroinvertebrates because of the notable scarcity of stones-out-of current and sands and algal growth limits the suitability of biotopes. Vegetation is impacted by upstream bridges and increased erosion.
RE-EWR 1	2.8		3.0	5.0	2.8	5.0	Due to short length of rapid, only moderate suitability in terms of low flows. As a very high high flow calibration was experienced, the hydraulic suitability for high flows is high. As the Rapid method was followed for these sites, the geomorphological and riparian vegetation specialist did not participate in site selection.
RE-EWR 2	1.9		2.0	1.0	1.9	1.0	Very low suitability as the site is intensely modified, however this river site was the only option within a modified wetland system. As the Rapid method was followed for these sites, the geomorphological and riparian vegetation specialist did not participate in site selection.

## 6 ECOCLASSIFICATION (LEVEL 4) OF EWR SITES

Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoClassification Report: Volume 1. Report produced by Koekemoer Aquatic Services and Rivers for Africa. Edited by Louw, D and Koekemoer, S. Report no: RDM/ WMA8 C000/01/CON/0109.

Department of Water Affairs (DWA), 2009. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoClassification Report: Volume 2. Report produced by Koekemoer Aquatic Services and Rivers for Africa. Edited by Louw, D and Koekemoer, S. Report no: RDM/ WMA8 C000/01/CON/0109.

### 6.1 APPROACH

#### 6.1.1 EWR 1 – 11

The procedure for the EcoClassification of the rivers and physico-chemical input was according to the revised methods for rivers as outlined in Louw and Hughes (2002), and the EcoClassification manual version 2 (Kleynhans and Louw, 2007) for the EWR sites in the Upper Vaal River WMA. The approach consisted broadly of the following steps:

- Determine reference conditions for each component.
- Determine PES for each component as well as for the EcoStatus.
- Determine the trend for each component as well as for the EcoStatus.
- Determine reasons for PES and whether these are flow or non-flow related.
- Determine the Ecological Importance and Sensitivity (EIS) for the biota and habitat.
- Considering the PES and the EIS, suggest a realistic Recommended Ecological Category (REC) for each component as well as for the EcoStatus.
- Determine alternative Ecological Categories (ECs) for each component as well as for the EcoStatus.

#### 6.1.2 RE – EWR 1 and 2

Two Rapid III sites were identified; Klein Vaal (RE - EWR 1) and Mooi River (RE - EWR 2). For RE - EWR 1 the Level 4 EcoClassification method was followed and applied. RE-EWR 2 would naturally have been a wetland with a badly defined channel. Therefore Wetland tools (WETLAND – Index of Habitat Integrity) (WETLAND – IHI, DWAF, 2007b)) were used to represent the driver state and the river tools used to assess the responses. The section of the river examined for the Wetland-IHI is between the Klerkskraal and Boskop Dam.

Habitat assessments provided information on the quality, quantity and suitability of the physical environment that supported biota and the WETLAND – IHI assessed four components of a floodplain, namely:

- Alteration to vegetation due to landuse activities on the floodplain surface.
- Alteration to the natural hydrology (flooding regime) due to catchment as well as on-site activities.
- Alteration to the geomorphology of the site due to catchment as well as on-site activities.
- Alteration to the water quality aspects of the river due to upstream catchment activities.

### 6.2 RESULTS

The EcoClassification results of the Upper Vaal River system are summarised in Table 6.1.

**Table 6.1 EcoClassification results – Upper Vaal River System**

EWR 1: UITKOMS (VAAL RIVER)																																																																						
<p><b>EIS: HIGH</b> Presence of rare and endangered <i>Labeobarbus kimberleyensis</i> and diversity of habitat.</p> <p><b>PES: B/C</b> Combination of flow and non-flow related impacts. Flow related impacts are mainly due to interbasin transfers (Heysope and Zaaihoek). Mining and agricultural activities in area has caused water quality deterioration and erosion.</p> <p><b>REC: B/C</b> The EIS at EWR 1 is <b>HIGH</b> and the PES warrants an improvement. An improvement in the PES EcoStatus would mean that fish and macroinvertebrates must improve from a C to a B EC. No improvement in riparian vegetation is needed as the current EC is an A/B. An improvement in the biotic component EC is dependent on <b>water quality</b> changes and not flow related issues. It seems that the water quality at this site is problematic as the fish show signs of serious bacterial infection and quality sensitive macroinvertebrates are absent. Diatoms also indicate that water quality is impaired; however, it is not certain what the water quality problems are. To improve the EC therefore, the water quality problems must be identified to determine how it can be addressed. As no improvement in flow is required, no EWR for the REC will be undertaken.</p> <p><b>AEC down 1: C</b> A hydrological regime with <b>increased</b> base flows for longer periods of time in the winter (longer than present transfer) as well as fluctuations in temperature.</p> <p><b>AEC down 2: C</b> A hydrological regime with <b>decreased</b> base flows below natural (no transfers) with potential for some low flows. Decreased moderate floods. Deteriorated water quality due to increased impacts of mining.</p>			<table border="1"> <thead> <tr> <th>IHI</th> <th>Driver Components</th> <th>PES and REC Category</th> <th>Trend</th> <th>AEC<sub>1</sub></th> <th>AEC<sub>2</sub></th> </tr> </thead> <tbody> <tr> <td rowspan="3">I N S T R E A M  R I P A R I A N</td> <td>HYDROLOGY</td> <td>C</td> <td></td> <td></td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>C</td> <td>Stable</td> <td>C</td> <td>C</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>B/C</td> <td>Negative</td> <td>C</td> <td>C</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>IHI Hydro</th> <th>Diatoms</th> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>AEC<sub>1</sub></th> <th>AEC<sub>2</sub></th> </tr> </thead> <tbody> <tr> <td>E</td> <td>C</td> <td>FISH</td> <td>C (B)</td> <td>Negative</td> <td>D</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td>MACRO INVERTEBRATES</td> <td>C (B)</td> <td>Stable</td> <td>C</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td>INSTREAM</td> <td>C</td> <td></td> <td>C</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td>RIPARIAN VEGETATION</td> <td>A/B</td> <td>Stable</td> <td>B/C</td> <td>B/C</td> </tr> <tr> <td></td> <td></td> <td>ECOSTATUS</td> <td>B/C (B)</td> <td></td> <td>C</td> <td>C</td> </tr> </tbody> </table> <p>Note: Categories in red relates to a REC based on water quality improvements.</p>				IHI	Driver Components	PES and REC Category	Trend	AEC <sub>1</sub>	AEC <sub>2</sub>	I N S T R E A M  R I P A R I A N	HYDROLOGY	C				WATER QUALITY	C	Stable	C	C	GEOMORPHOLOGY	B/C	Negative	C	C	IHI Hydro	Diatoms	Response Components	PES Category	Trend	AEC <sub>1</sub>	AEC <sub>2</sub>	E	C	FISH	C (B)	Negative	D	D			MACRO INVERTEBRATES	C (B)	Stable	C	D			INSTREAM	C		C	D			RIPARIAN VEGETATION	A/B	Stable	B/C	B/C			ECOSTATUS	B/C (B)		C	C
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EWR 2: GROOTDRAAI (VAAL RIVER)																																																																						
<p><b>EIS: MODERATE</b> <b>PES: C</b> Combination of flow and non-flow related impacts. Impacts mostly related to changes in flow regime due to Grootdraai Dam.</p> <p><b>REC: C</b> Maintain the PES due to the <b>MODERATE</b> EIS rating. However note that there is rare and endangered <i>Labeobarbus kimberleyensis</i> present which warrants improvement of the fish EC.</p> <p><b>AEC up: B</b> This ecological scenario is important due to the presence of <i>L. kimberleyensis</i>. Change in the operation of Grootdraai dam, which includes the release of flows (base flows) with more natural seasonal patterns and the release of moderate floods to remove fines and no bottom releases.</p> <p><b>AEC down: C/D</b> Less spilling (i.e. less floods) and decreased base flows. Increased bottom releases.</p>			<table border="1"> <thead> <tr> <th>IHI</th> <th>Driver Components</th> <th>PES and REC Category</th> <th>Trend</th> <th>AEC<sub>1</sub></th> <th>AEC<sub>2</sub></th> </tr> </thead> <tbody> <tr> <td rowspan="3">I N S T R E A M  R I P A R I A N</td> <td>HYDROLOGY</td> <td>D</td> <td></td> <td></td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>B/C</td> <td>Negative</td> <td>B</td> <td>B/C</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>D</td> <td>Stable</td> <td>D</td> <td>D/E</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>IHI Hydro</th> <th>Diatoms</th> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>AEC<sub>1</sub></th> <th>AEC<sub>2</sub></th> </tr> </thead> <tbody> <tr> <td>E</td> <td>C</td> <td>FISH</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td></td> <td></td> <td>MACRO INVERTEBRATES</td> <td>C</td> <td>Stable</td> <td>B/C</td> <td>C/D</td> </tr> <tr> <td></td> <td></td> <td>INSTREAM</td> <td>C</td> <td></td> <td>B/C</td> <td>C/D</td> </tr> <tr> <td></td> <td></td> <td>RIPARIAN VEGETATION</td> <td>B/C</td> <td>Stable</td> <td>B</td> <td>C</td> </tr> <tr> <td></td> <td></td> <td>ECOSTATUS</td> <td>C</td> <td></td> <td>B</td> <td>C/D</td> </tr> </tbody> </table>				IHI	Driver Components	PES and REC Category	Trend	AEC <sub>1</sub>	AEC <sub>2</sub>	I N S T R E A M  R I P A R I A N	HYDROLOGY	D				WATER QUALITY	B/C	Negative	B	B/C	GEOMORPHOLOGY	D	Stable	D	D/E	IHI Hydro	Diatoms	Response Components	PES Category	Trend	AEC <sub>1</sub>	AEC <sub>2</sub>	E	C	FISH	C	Stable	B	D			MACRO INVERTEBRATES	C	Stable	B/C	C/D			INSTREAM	C		B/C	C/D			RIPARIAN VEGETATION	B/C	Stable	B	C			ECOSTATUS	C		B	C/D
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	WATER QUALITY	B/C	Negative	B	B/C																																																																	
	GEOMORPHOLOGY	D	Stable	D	D/E																																																																	
IHI Hydro	Diatoms	Response Components	PES Category	Trend	AEC <sub>1</sub>	AEC <sub>2</sub>																																																																
E	C	FISH	C	Stable	B	D																																																																
		MACRO INVERTEBRATES	C	Stable	B/C	C/D																																																																
		INSTREAM	C		B/C	C/D																																																																
		RIPARIAN VEGETATION	B/C	Stable	B	C																																																																
		ECOSTATUS	C		B	C/D																																																																

**EWR 3: GLADDEDRIFT (VAAL RIVER)**

**EIS: MODERATE**

**PES: C**

Combination of flow and non-flow related impacts. Impacts mostly related to changes in flow regime due to Grootdraai Dam, illegal irrigation, livestock farming and vegetation removal.

**REC: C**

Maintain the PES due to the **MODERATE** EIS rating. However note that there is rare and endangered *Labeobarbus kimberleyensis* present which warrants improvement of the fish EC.

**AEC Up: B**

Improved base flows (no zero flows), and increased frequency of moderate floods.

Improved water quality due to improved flow regime.

Removal of cattle grazing in the marginal zone.

**AEC Down: C/D**

Increased duration of zero flow periods.

Decreased frequency of floods.

Very low base flows in the dry season when flowing.

Associated water quality deterioration.

IHI		Driver Components	PES and REC Category	Trend	AEC↑	AEC↓
I N S T R E A M	C	R I P A R I A N	C			
			HYDROLOGY	C		
			WATER QUALITY	C	Stable	B/C
		GEOMORPHOLOGY	C	Stable	C	D
IHI Hydro	Diatoms	Response Components	PES Category	Trend	AEC↑	AEC↓
C	C	FISH	C	Stable	B	D
		MACRO INVERTEBRATES	C	Stable	B/C	D
		INSTREAM	C		B	D
		RIPARIAN VEGETATION	C	Stable	B	C
		ECOSTATUS	C		B	C/D

**EWR 4: DE NEYS (VAAL RIVER)**

**EIS: HIGH**

The presence of the rare and endangered *Labeobarbus kimberleyensis*.

The Vaal River being a large river, which is rare in South Africa.

The diversity of riparian and instream habitats which include runs, rocky outcrops and rapids as well as pools.

Important refugia such as pools.

Being the only area between the Vaal Dam and barrage where yellowfish can breed.

**PES: C**

Impacts are mostly due to flow related problems, especially the presence of Vaal Dam and lack of flow variability. Increased base flows (dry season) occur as well as reduced frequencies of moderate floods due to releases from the Vaal Dam to maintain a target TDS concentration of 600 mg/l downstream of Vaal Barrage.

**REC: B/C**

Improvement of PES due to **HIGH** EIS rating. A B EcoStatus could not be attained due to the limited operational possibilities from the Vaal Dam. Scenario includes improvement of seasonal variability (decreased base flows during the dry season and increased wet season flows above the current base flows).

**AEC Down: D**

Increased constant base flows if salinity problems are exacerbated leading to a loss of variability.

Decreased frequency of floods.

IHI		Driver Components	PES Category	Trend	REC	AEC↓
I N S T R E A M	D	R I P A R I A N	D			
			HYDROLOGY	D/E		
			WATER QUALITY	C	Stable	C
		GEOMORPHOLOGY	D	Stable	D	D
IHI Hydro	Diatoms	Response Components	PES Category	Trend	AEC↑	AEC↓
C	C	FISH	C	Stable	B	D
		MACRO INVERTEBRATES	C/D	Stable	C	C/D
		INSTREAM	C		B/C	D
		RIPARIAN VEGETATION	C	Stable	B/C	D
		ECOSTATUS	C		B/C	D

**EWR 5: SCANDINAVIA (VAAL RIVER)**

**EIS: HIGH**

Presence of rare and endangered *Labeobarbus kimberleyensis*, and Rand Highveld Grassveld vegetation type. Most importantly, this site falls within the Vredefort Dome World Heritage Site and the river is an important feature within this World Heritage Site.

**PES: C/D**

Combination of flow and non-flow related impacts. Flow related impacts include increased base flows and reduced frequency of moderate floods due to Vaal Dam and Barrage and releases to regulated TDS levels. Non-flow related impacts include agriculture, and urban sewage and industrial waste and the occurrence of gauges, weirs and dams in the system.

**REC: C**

Improvement of the PES due to **HIGH** EIS rating. A B/C EcoStatus could not be attained due to the limited operational possibilities from the Vaal Dam. Scenario includes decreased base flows for 3 days (during winter) (to improve macroinvertebrates EC) and increased moderate floods in the wet season.

**AEC down: D**

Increased base flows.

Possibility of further decrease of floods due to the development in tributaries and increased return flows.

IHI		Driver Components	PES Category	Trend	REC	AEC↓
I N S T R E A M	D	R I P A R I A N	D		C/D	D
			HYDROLOGY	D		
			WATER QUALITY	E	Negative	D/E
		GEOMORPHOLOGY	C	Negative	C	C/D
IHI Hydro	Diatoms	Response Components	PES Category	Trend	REC	AEC↓
C	C/D	FISH	C	Stable	B	D
		MACRO INVERTEBRATES	C	Stable	C	C/D
		INSTREAM	C		B/C	D
		RIPARIAN VEGETATION	D	Negative	C	-D
		ECOSTATUS	C/D		C	D

EWR 6: KLIP (KLIP RIVER)										
<p><b>EIS: MODERATE</b>  <b>PES: B/C</b>                      Combination of flow and non-flow related impacts. Flow related impacts include reduced base flows and moderate floods due to weirs and farm dams. Non-flow related impacts include agriculture, cattle grazing, and alien vegetation. The sole reason for the PES not being a B EcoStatus is the current vegetation EC (B/C EC) due to the high proportion of exotic species  <b>REC: B/C</b>                      The EIS at EWR 6 is <b>MODERATE</b> and the REC is to maintain the PES.  <b>AEC up: B</b>                      A B EC can be achieved by removal of alien vegetation. Improving flows will not improve the vegetation.  <b>AEC down: C</b>                      The scenario includes decreased low flows and zero flows and decreased moderate floods and deteriorated water quality.</p>			IHI		Driver Components	PES and REC Category	Trend	AEC ↓		
			I N S T R E A M	C	R I P A R I A N	C	HYDROLOGY	C		
							WATER QUALITY	B/C	Negative	C
							GEOMORPHOLOGY	B	Stable	C
			IHI Hydro	Diatoms	Response Components	PES Category	Trend	AEC ↓		
			B/C	B/C	FISH	B	Stable	C		
					MACRO INVERTEBRATES	B	Stable	C		
					INSTREAM	B		C		
					RIPARIAN VEGETATION	B/C	Stable	C		
					ECOSTATUS	B/C		C		

EWR 7: UPPER WILGE (WILGE RIVER)										
<p><b>EIS : HIGH</b>                      There are rare and endangered species i.e. the flufftail crowned crane, bald ibis, and 11 red data vegetation species. There is a good diversity of habitats that include wetlands, flood plains, oxbow lakes and peat lands.  <b>PES: A/B</b>                      Non-flow related impacts that include small dams for agriculture and exotic fish species (MSAL).  <b>REC A/B</b>                      As the PES is also relatively high, the attainable and realistic objective is to maintain the PES even though a <b>HIGH</b> EIS would normally warrant improvement.  <b>AEC Down: C</b>                      The scenario includes decreased low flows, some periods of zero flows and decreased moderate floods.</p>			IHI		Driver Components	PES and REC Category	Trend	AEC ↓		
			I N S T R E A M	B	R I P A R I A N	B	HYDROLOGY	A		
							WATER QUALITY	B	Negative B/C	-B
							GEOMORPHOLOGY	A	Negative B/C	B/C
			IHI Hydro	Diatoms	Response Components	PES Category	Trend	AEC ↓		
			A/B	B	FISH	B (D)	Negative D/E	C		
					MACRO INVERTEBRATES	B	Stable	C/D		
					INSTREAM	B		C		
					RIPARIAN VEGETATION	A/B	Stable	B/C		
					ECOSTATUS	A/B		C		

EWR 8: BAVARIA (WILGE RIVER)											
<p><b>EIS: MODERATE</b>  <b>PES: C</b>                      Flow related impacts include alteration of hydrological regime due to interbasin transfers from Sterkfontein Dam, abstraction and agriculture. Non-flow related impacts include water quality problems, erosion and exotic species invasion.  <b>REC: C.</b>                      Maintain the PES due to the <b>MODERATE</b> EIS rating.  <b>AEC Up: B/C</b>                      Dry season base flow increase and no zero flows.                      Ongoing improved management of the Sterkfontein Dam releases.                      Reduced grazing, burning and removal of debris.                      Removal of MSAL (although highly impractical, without this removal, the fish EC will not improve).  <b>AEC Down: D</b>                      Further decrease of base flows (e.g. an additional dam).                      Decrease in small moderate floods.                      Associated water quality deterioration.</p>			IHI		Driver Components	PES and REC Category	Trend	AEC ↑	AEC ↓		
			I N S T R E A M	C / D	R I P A R I A N	C	HYDROLOGY	D			
							WATER QUALITY	C	Stable	B/C	C/D
							GEOMORPHOLOGY	C	Positive	+C	C/D
			IHI Hydro	Diatoms	Response Components	PES Category	Trend	AEC ↑	AEC ↓		
			C	C/D	FISH	C	Stable	B	D		
					MACRO INVERTEBRATES	C/D	Stable	C	D		
					INSTREAM	C		B/C	D		
					RIPARIAN VEGETATION	C	Stable	B/C	D		
					ECOSTATUS	C		B/C	D		

EWR 9: SUIKERBOS US (SUIKERBOSRAND RIVER)							
<p><b>EIS: HIGH</b>                      There are endangered species at this site, which includes <i>Labeobarbus kimberleyensis</i> and the Soweto Highveld grassland vegetation type (conservation status: endangered).  <b>PES: C</b>                      Combination of flow and non-flow related impacts. Flow related impacts include altered flow regime due to Balfour and Harhoff Dams and non-flow related impacts include deteriorated water quality due to WWTW and agriculture, erosion and alien species (fish and vegetation).  <b>REC: B/C</b>                      Improvement of the PES due to <b>HIGH</b> EIS rating.                      An improvement is based on increased base flows (released from upstream dams) as well as erosion control measures in the tributaries to address erosion and increased sediment loads in the reach and alien woody vegetation control.  <b>AEC Down: D</b>                      This scenario was not developed as the macroinvertebrates and fish are already in a D EC. A D AEC would involve the maintenance of the current ECs of fish and macroinvertebrates and a deterioration of the riparian vegetation EC. Any flow related changes will however cause deterioration in the riparian vegetation EC and would result in the instream and biota ECs to drop to an E.</p>							
I N S T R E A M	C	R I P A R I A N	B	Driver Components	PES Category	Trend	REC
				HYDROLOGY	E		
				WATER QUALITY	C/D	Negative D	C
				Response Components	PES Category	Trend	REC
IHI Hydro		Diatoms		FISH	D	Stable	C
B		C		MACRO INVERTEBRATES	D	Stable	C
				INSTREAM	D		C
				RIPARIAN VEGETATION	B/C	Negative C/D	B
				ECOSTATUS	C		B/C

EWR 10: SUIKERBOS DS (SUIKERBOSRAND RIVER)								
<p><b>EIS: MODERATE</b>  <b>PES: C/D</b>                      Combination of flow and non-flow related impacts. Flow related impacts include elevated base flow and increased floods due to mining, SAPPI, urban runoff and Blesbokspruit input. Non-flow related impacts include deteriorated water quality due to industries, agriculture and urban activities; erosion, and exotic alien invasion (fish and vegetation).  <b>REC: C/D</b>                      Maintain the PES due to the <b>MODERATE</b> EIS rating.  <b>AEC up: C</b>                      Improved water quality management in the Blesbokspruit catchment. The biotic condition of the biota will improve under this scenario although no improvement will be evident in the riparian vegetation component. The riparian vegetation EC is associated with increased flows rather than water quality. <b>NOTE:</b> The recommendations at EWR 9 are to improve the low flows in the dry season. This could increase flows to the level that is problematic at EWR 10. This will have to be treated as a scenario in a systems context and evaluated.  <b>AEC down: D</b>                      The scenario is increased base flows.</p>								
I N S T R E A M	C	R I P A R I A N	C	Driver Components	PES and REC Category	Trend	AEC ↑	AEC ↓
				HYDROLOGY	D			
				WATER QUALITY	D/E	Negative	D	D/E
				Response Components	PES Category	Trend	REC	AEC ↓
IHI Hydro		Diatoms		FISH	C/D	Stable	C	D
B		C/D		MACRO INVERTEBRATES	C/D	Stable	C	D
				INSTREAM	C/D		C	D
				RIPARIAN VEGETATION	C	Negative D	C	D
				ECOSTATUS	C/D		C	D

EWR 11: BLESBOKSPRUIT (BLESBOKSPRUIT RIVER)							
<p><b>EIS: LOW</b>                      Site is characterised by water quality problems and elevated flows.  <b>PES: D</b>                      Mainly non-flow related impacts that include increased base flows and floods due to mine water decants, urban runoff, agriculture and return flows from WWTW. Water quality is also heavily impacted due to these activities and erosion has increased. Alien fish species occur.  <b>REC: D</b>                      Maintain the PES due to the <b>LOW</b> EIS rating, <b>with invertebrates improving to D.</b>                      An improved EcoStatus based on a hypothetical flow regime is not feasible at this site. Decreased flows as a scenario is unattainable and will result in deteriorated water quality.                      The improvement of the macroinvertebrate EC is only possible with improved water quality. Improved water quality is only possible with better water quality management, which is unlikely, but feasible at a cost. Due to the huge amount of salts in the system, this improvement will only be a long term option.                      The implications for setting flows are the following:                      Flow requirements to maintain the present state would be based on present flows. Only increased flows can be evaluated as a scenario to determine whether increased flows (with either improved or the same water quality) will maintain the EcoStatus.</p>							
I N S T R E A M	D / E	R I P A R I A N	C	Driver Components	PES Category	Trend	REC
				HYDROLOGY	D/E		
				WATER QUALITY	D/E	Negative D/E	D
				Response Components	PES Category	Trend	REC
IHI Hydro		Diatoms		FISH	D	Stable	C
E		C/D		MACRO INVERTEBRATES	D/E	Stable	D
				INSTREAM	D/E		C/D
				RIPARIAN VEGETATION	D	Negative D/E	D
				ECOSTATUS	D		D

RE-EWR 1: KLEIN VAAL																																		
<p><b>EIS: MODERATE</b>  <b>PES: C</b>                      Flow related impacts include interbasin transfer and abstraction altering hydrological regime. Non-flow related impacts include deterioration in water quality, increased erosion due to cattle and agricultural activities. Loss of habitat due to farm dams.  <b>REC: C</b>                      Maintain the PES due to the <b>MODERATE</b> EIS rating. The C EcoStatus is due to the riparian vegetation EC of a D as the instream EC is an A/B. The riparian vegetation PES is due to non-flow related impacts (grazing and trampling) and highly likely a very localised impact.  <b>AEC down: C/D</b>                      A hydrological regime with decreased base flows. Increased periods of zero flows during dry season.</p>		<table border="1"> <thead> <tr> <th colspan="2">IHI</th> <th>Driver Components</th> <th>PES and REC Category</th> <th>AEC↓</th> </tr> </thead> <tbody> <tr> <td rowspan="3">I N S T R E A M</td> <td rowspan="3">B</td> <td>HYDROLOGY</td> <td>A/B</td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>B/C</td> <td>B/C</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>B/C</td> <td>B/C</td> </tr> </tbody> </table>			IHI		Driver Components	PES and REC Category	AEC↓	I N S T R E A M	B	HYDROLOGY	A/B		WATER QUALITY	B/C	B/C	GEOMORPHOLOGY	B/C	B/C														
		IHI		Driver Components	PES and REC Category	AEC↓																												
I N S T R E A M	B	HYDROLOGY	A/B																															
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A/B	B	FISH	B	C																														
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		INSTREAM	A/B	C																														
		RIPARIAN VEGETATION	D	D																														
		ECOSTATUS	C	C/D																														
RE-EWR 2: MOOI RIVER																																		
<p><b>EIS: LOW</b>  <b>PES: D</b>                      This naturally would have been a wetland with a badly defined channel. Wetland tools were used to represent the driver state and the river tools used to assess the responses.                       Some very rare constricted areas with small riffles occur. This site is downstream of the dam and about the only one with remnants of wetland intact. This is a short section. The rest of the MRU is very badly degraded and would be in a lower category. Downstream of the Wonderfontein inflow, the bad water quality would be the overriding concern. The PES is in a D and the rest of the MRU would be in an E or even lower. It will not be possible to improve the category by improving flows as the fish is already in a C EC and the riparian vegetation EC is due to non-flow related impacts. However, the macroinvertebrate EC might improve to at least a D with some improved flow.</p>		<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES Category</th> <th>Diatoms</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>E</td> <td>C</td> </tr> <tr> <td>WATER QUALITY</td> <td>C/D</td> <td></td> </tr> <tr> <td>WETLAND HABITAT INTEGRITY</td> <td>E</td> <td></td> </tr> <tr> <th>Response Components</th> <th>PES Category</th> <td></td> </tr> <tr> <td>FISH</td> <td>C</td> <td></td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>E</td> <td></td> </tr> <tr> <td>INSTREAM</td> <td>D</td> <td></td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>D</td> <td></td> </tr> <tr> <td>ECOSTATUS</td> <td>D</td> <td></td> </tr> </tbody> </table>			Driver Components	PES Category	Diatoms	HYDROLOGY	E	C	WATER QUALITY	C/D		WETLAND HABITAT INTEGRITY	E		Response Components	PES Category		FISH	C		MACRO INVERTEBRATES	E		INSTREAM	D		RIPARIAN VEGETATION	D		ECOSTATUS	D	
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FISH	C																																	
MACRO INVERTEBRATES	E																																	
INSTREAM	D																																	
RIPARIAN VEGETATION	D																																	
ECOSTATUS	D																																	

### 6.3 CONCLUSIONS

A summary of confidences for all the sites are given below in Table 6.2. Red cells indicate low confidence, yellow cells indicate medium confidence and green cells indicate high confidence.

**Table 6.2 Confidence in EcoClassification**

EWR site	EWR 1		EWR 2		EWR 3		EWR 4		EWR 5		EWR 6		EWR 7		EWR 8		EWR 9		EWR 10		EWR 11		RE - EWR 1		RE - EWR 2	
	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification	Data availability	EcoClassification
Hydrology	3	4	4	4	4	4	4	4	3	3	1	2	2	4	1	1	1	2	2	4	2	5	1	3		
Physico-chemical	2	1.7	4	1.5	1.5	2.3	4	3	4	3.9	3.6	3.6	1.5	3.5	2.3	2.3	2.5	2.5	3	3	2.6	3	1.5	1.7		
Geomorphology	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4	3.5	4	4.5	3.5	3.5	3	3	3.5	3	3.5	3.5	2	2	3	4
IHI (instream & riparian)	4	3	4	4	4	3.6	4	3.5	4	3.5	4	2.9	4	3.4	4	3.2	4	2.9	4	2.7	4	2.5	4	2.8		
Fish	3.5	4	3.5	4	3.5	4	4	4	4	4	3.5	3	3.5	3	4	4	4	3.5	4	3.5	4	4	2.5	2	2.5	2
Macroinvertebrates	3	4	3	3	3	3	3	3	3	3	3	4	3	2	3	3	3	3	4	3.5	4	5	2	4	1	3
Vegetation	4.5	4	4.5	3.7	4.5	3.6	4.5	3.2	4.5	3.2	4.5	3.1	4.5	4	4.5	3.4	4.5	3.3	4.5	3.3	4.5	3.4	2	3.4	2	2
Average	3.36	3.46	3.79	3.39	3.43	3.43	3.86	3.46	3.71	3.44	3.37	3.16	3.21	3.49	3.19	2.91	3.14	2.89	3.57	3.29	3.51	3.77	2.14	2.70	2.13	2.75
Median	3.50	4.00	4.00	3.70	3.50	3.60	4.00	3.50	4.00	3.50	3.60	3.10	3.50	3.50	3.50	3.20	3.00	3.00	4.00	3.30	4.00	3.50	2.00	2.80	2.25	2.50

### 6.3.1 Comprehensive Reserve Sites: Data availability

The results indicated **MEDIUM TO HIGH** data availability at all the sites with **HIGH** data availability for EWR 4, 5 and 10. Driver information was particularly good at EWR 4 and 5. The present modelled hydrology did not reflect the observed hydrology and the monthly format could not be used, therefore the available observed daily data was used at EWR 4 and 5. There was good data and long data records available from the water quality stations at the respective sites as well as Rand Water data.

In general, the only low confidence in data availability was in the hydrology and physico-chemical variable information. Hydrology issues were mainly due to the fact that the modelled present hydrology was only relevant up to 1994, and that the present uses were aggregated for large areas.

### 6.3.2 Comprehensive Reserve Sites: EcoClassification Results

The results indicated **MEDIUM TO HIGH** confidence in EcoClassification results at all the sites with **HIGH** data availability for EWR 1 and 11. Even though data availability was poor at EWR 11, there was no uncertainty about the state of the poor hydrology and there was a good understanding of the biotic components especially fish and macroinvertebrates.

The major issues were the following:

- EWR 1: Limited data record from water quality station. There are fish kills and fish diseases which apparently relate from water quality issues. The links and causes were however unknown.
- EWR 2: There was uncertainty in the water quality data as there was uncertainty regarding the impact of Leeuspruit and Blesbokspruit water quality on the trophic status of Grootdraai Dam.
- EWR 3: The water quality measuring station was far from site and downstream of the Waterval River confluence. Data was therefore not representative of the EWR site.
- EWR 4: There was a discrepancy between modelled hydrology and actual releases being made for dilution purposes. This resulted in observed hydrology being used rather than the modelled hydrology.
- EWR 5: See above. The available gauge was also far from the EWR site and did not measure low flows accurately.
- EWR 6: The hydrological gauge was situated far from the site. The modelled present hydrology did not match observations of flow at the site, i.e. modelled present day hydrology predicted more flows than natural with actual observations of dry season flows being more common. The good aquatic macroinvertebrate state was also in contradiction with the hydrology information observed and available.
- EWR 7: Lack of water quality measuring station and hydrological gauge. C8H002 was far from the site and a 10-year intermittent data base exists. Low confidence in macroinvertebrates data due to limited sampling opportunities.
- EWR 8: Limited data available from water quality measuring station. There were discrepancies between modelled hydrological data and observed flows, and the gauge does not measure low and zero flows accurately.
- EWR 9: Limited data available from water quality measuring station. Hydrological data did not include impact of Balfour and Haarhoff Dams. Biological responses were therefore

difficult to interpret, as there was no correlation between the hydrology provided, and observations on site.

- EWR 10: The two hydrological gauges used for the assessment does not measure low and zero flows accurately and there was a 18-year gap in the data. The hydrology of EWR 9 and associated problems affects this site. There were however uncertainties regarding the hydrology due to the complexities of all the urban and industrial upstream activities. The higher than natural flows are difficult to interpret.
- EWR 11: There was only a 4-year flow record available. There were however uncertainties regarding the hydrology due to the complexities of all the urban and industrial upstream activities. The higher than natural flows are difficult to interpret.

### 6.3.3 Rapid Reserve sites

Data availability in the driver components for RE-EWR 1 was **LOW**. There was no hydrological data available and limited physico-chemical data. The confidence in the EcoClassification results for RE-EWR 1 was **LOW-MEDIUM** due to limited driver information on which biotic responses are based as well as one instream biota survey only.

The confidence at RE-EWR 2 was **LOW** for data availability and EcoClassification. Although there was a good understanding of the driver components, the biotic responses were poor. The situation is complex as this site used to be a wetland and now consists of a very disturbed area, with some small sections of artificial river channel due to anthropogenic changes.

## 6.4 RECOMMENDATIONS

In general, it did not seem to be practical to undertake any more detailed work to improve confidence in the EcoClassification results. Ecological Water Resource Monitoring (EWRM) has to be initiated as quickly as possible. The survey results undertaken for EcoClassification should be valid for a baseline.

Specific aspects that required attention as part of Ecological Water Resource Monitoring were the following:

- Due to the lack of nearby water quality monitoring stations at EWR 1, 2, 3, 8, 9 diatom assessments should be undertaken. This could provide good indication of the trend of the physico-chemical variables and if problems are indicated, more detailed physico-chemical analysis can be undertaken; however only based on available data. This was also relevant for 4, 5, 10 and 11.
- EWR 4: It was proposed that TDS levels and flow releases are monitored comprehensively.
- EWR 7: It was assumed that ESKOM would initiate ecological monitoring as part of the EIA recommendations designed for the Braamhoek pump storage scheme and according to Regulations. This should in any case improve base line information and overall confidence in the site evaluation.
- EWR 8, 10 and 11: Inaccurate gauges near these sites need to be serviced and maintained. EWRM will not be successful without the hydrological information being available.
- EWR 9: The impact of Balfour and Haarhoff Dams has to be included in the system model to ensure that the EWR assessment and specifically the design of operational scenarios include this. This therefore had to be undertaken within the latter phases of this study.

- Water quality management plans were proposed for EWR 1, 10 and 11 as the problems associated with these sites were water quality related and not flow related.
  - Alien eradication programme was required at EWR 6.
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## 7 EWR SCENARIO ASSESSMENT

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Department of Water Affairs (DWA), 2009. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EWR Scenario Report: Volume 1. Report produced by Koekemoer Aquatic Services and Rivers for Africa. Report no: RDM/WMA8C000/01/CON/0209.

Department of Water Affairs (DWA), 2009. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EWR Scenario Report: Volume 2. Report produced by Koekemoer Aquatic Services and Rivers for Africa. Report no: RDM/WMA8C000/01/CON/0209.

This task consisted of determining the EWR for different ecological river states, i.e. different Ecological Categories.

### 7.1 APPROACH

#### 7.1.1 Comprehensive EWR sites: EWR 2, 3, 6, 7, 8, and 9

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O’Keeffe *et al.*, 2002), a modification of the Building Block Methodology (BBM) (King and Louw, 1998) was used to determine the low (base) flow EWRs. The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM. These results generated form the basis against which the ecological consequences of operational flow scenarios will be tested during a further task in this study.

#### 7.1.2 Comprehensive EWR sites: 10, 11, 1, 4 and 5

During the Ecological Water Requirement (EWR) scenario assessment of the Upper Vaal, 5 EWR sites were identified as having more flows than natural. Therefore the standard Habitat Flow Stressor Response method approach could not be applied to these sites to determine low flow requirements for the EWR scenarios. The HFSR method was refined to cater for these situations by Ms Delana Louw with input from all the specialists and the general approach is provided in detail in Report RDM/WMA8C000/01/CON/0209; Chapter 14.

#### 7.1.3 Rapid EWR sites: RE-EWR 1 and 2

RE-EWR 1 and 2 was assessed at Rapid level for low flows and therefore the HFSR method for setting low flows were not applied to this site. The Reserve was estimated using the Hughes Desktop Reserve Model for the Ecological Category (EC) set. Therefore for the low flow requirements, the estimated Reserve was verified and the DRM was adjusted if needed. High flows were set using the standard Comprehensive approach.

### 7.2 EWR AND MOTIVATIONS

The low flow and high flow requirements and motivations are summarised per EWR site as follows:

## 7.2.1 EWR results for EWR 1: Uitkoms (Vaal River)

**Table 7.1 Low flow EWR results for EWR 1**

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment
<b>PES and REC: B/C EcoStatus</b>		<b>FISH: C</b>			<b>MACROINVERTEBRATES: C</b>
Aug	5% drought	8.8 FDI	8.8	0.336	Flows will provide an average depth of 0.16 m and flow of 0.10 m/s to ensure the survival of FDI taxa.
	35% maintenance	4.5 LSR	4.5	2.6	Adequate FS habitat for juveniles and SD habitat for adults to ensure survival during winter.
Feb	5% drought	5.2 LSR	5.2	1.956	Some critical FS habitats should be available for a period to enable spawning, egg and larvae development. Some FS and adequate SD habitats should then be maintained for the survival of juveniles and adults during this period.
	35% maintenance	2 LSR	2	5.5	Suitable FS and FD habitat to ensure spawning and development of all life stages. Adequate SD habitat for refuge of juveniles.

**Table 7.2 High flow EWR functions and motivations for EWR 1**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions					
			Migration cues	Migration habitat (depth etc.)	Clean spawning cues	Spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	8 - 10	<b>Vegetation:</b> Maintains sedges.		✓	✓	✓	✓	✓	✓		✓			
II	15 - 35	<b>Geomorphology:</b> Activates gravels, moves fines. <b>Vegetation:</b> Activates lower portion of grassland.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	50 - 120	<b>Geomorphology:</b> Critical to move fines, activates gravels. <b>Vegetation:</b> Activates lower portion of grassland.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IV	200 - 340	<b>Geomorphology:</b> Moves > 50% gravels. <b>Vegetation:</b> Activates upper portion of grassland.	✓	✓		✓		✓	✓					
V	420	<b>Geomorphology:</b> Moves > 10 cm cobbles. <b>Vegetation:</b> Activates macro channel bank shrub layer.	✓			✓		✓	✓					

**Table 7.3 EWR 1: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES <sup>1</sup>	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES and REC SCENARIO: B/C</b>									
I	8 - 10	5		4		5	Nov, Dec, Jan, Feb, Mar	6	3
II	15 - 35	3	3	2	2	3	Nov, Dec, Feb	18	5
III	50 - 120			1 - 1:2	1 - 1:2	1 - 1:2	Jan	60	5
IV	200 - 340			1:3 - 1:4	1:3 - 1:4	1:3 - 1:4	Wet Season		
V	420			1:5	1:5	1:5	Wet Season		

## 7.2.2 EWR results for EWR 2: Grootdraai (Vaal River)

### Table 7.4 Low flow EWR results for EWR 2

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment <sup>1</sup>
<b>PES and REC: C EcoStatus</b>		<b>FISH: C</b>		<b>MACROINVERTEBRATES: C</b>	
Aug	5% drought	9 LSR	9	0.15	At these flows critical habitat (Slow Deep (SD) and Slow Shallow (SS) are maintained to ensure survival of adults. Some FS in very low abundance is present to ensure juvenile survival and to maintain adequate oxygen levels in the pools.
	55% maintenance	6 LSR	6	0.65	Fast Deep (FD) habitats will be lost under this stress level, but adequate Fast Intermediate (FI) and Fast Shallow (FS) will be maintained to meet the requirements of the juveniles. SD with adequate depth should also be maintained to meet the requirements of adults, as well as juveniles
Feb	5% drought	7 LSR	7	0.4	Some critical FS habitats should be available for some period to enable spawning, egg and larvae development. Limited FS and adequate SD habitats should be maintained under these conditions for the survival of juveniles and adults during this period.
	55% maintenance	2 FDI	3.8	1.88	Average depth needed for wet season maintenance is 0.21 m, and average current velocity is 0.34 m/s. This will provide suitable habitats during summer.
<b>AEC UP: B EcoStatus</b>		<b>FISH: B</b>		<b>MACROINVERTEBRATES: B/C</b>	
Aug	5% drought	9 LSR	9	0.15	See PES.
	55% maintenance	3 FDI	5.3	0.825	Average depth needed for dry season maintenance is 0.19 m, and average current velocity is 0.29 m/s.
Feb	5% drought	7 LSR	7	0.4	See PES.
	55% maintenance	1.5 FDI	3.5	2.45	Average depth needed for wet season maintenance is 0.26 m, and average current velocity is 0.41 m/s (Spp Stress 1.5).
<b>AEC DOWN: C/D EcoStatus</b>		<b>FISH: D</b>		<b>MACROINVERTEBRATES: C/D</b>	
Aug	5% drought	9 LSR	9	0.15	See PES.
	55% maintenance	7 LSR	7	0.4	Very low abundance of fast habitats (approximately 20 % FS and FI), which would reduce the survival of especially juvenile BAEN, which has a preference for fast habitats. Decreased flows will also reduce the depth of SD habitats, which are important survival habitats for over wintering of juvenile and adult BAEN, as adequate depth is required in SD to buffer temperature fluctuations in dry (cold) season, which will result in decreased FROC and abundance of BAEN.
Feb	5% drought	7 LSR	7	0.4	See PES
	55% maintenance	5.3 FDI	5.3	0.825	Average depth needed for wet season maintenance is 0.34 m, and average current velocity is 0.29 m/s

<sup>1</sup> Applicable to all sites: For macroinvertebrates (FDI) the available indicator species at all sites in the Upper Vaal catchment tolerate wide fluctuations in flow and water quality conditions, and this makes it difficult to motivate for specific flow durations on the basis of indicator species alone. The assessment of macroinvertebrates requirements for all sites was therefore based largely on professional judgement of how overall macroinvertebrate biodiversity would respond to changes in hydraulic biotope availability. In general, a high diversity of macroinvertebrates can be expected when there are natural seasonal fluctuating water levels; when current speeds exceed 0.4 m/s; when depths exceed about 30 cm; and when there is an abundance of marginal vegetation.

**Table 7.5 High flow EWR functions and motivations for EWR 2**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	4	<b>Vegetation:</b> <i>Gomphostigma</i> maintenance.	✓	✓	✓		✓			✓		
II	6 - 10	<b>Vegetation:</b> Activates marginal zone sedges. Maintains instream woody vegetation.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	11 - 50	<b>Geomorphology:</b> Responsible for more than 50% of transport of fines/gravels. <b>Vegetation:</b> Activation of lower zone sedges, inundation of marginal zone.	✓	✓	✓	✓	✓	✓				
IV	70 - 100	<b>Geomorphology:</b> Scour activates cobbles. <b>Vegetation:</b> Maintain <i>Schoenoplectus</i> (sedge) on lower/upper zone interface.	✓	✓	✓	✓	✓	✓				

**Table 7.6 EWR 2: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES and REC SCENARIO: C</b>									
I	4	6	6	6		6	Oct, Nov, Dec, Jan, Feb, Mar	2	3
II	6 - 10	4	4	4	4	4	Nov, Dec, Feb, Mar	7	5
III	11 - 50		1	1	1	1	Feb	30	5
IV	70 - 100		1:2	1:2	1:2	1:2	Jan	80	6
<b>AEC up SCENARIO: B</b>									
I	4	6	6	6		6	Oct, Nov, Dec, Jan, Feb, Mar	2	3
II	6 - 10	6	6	6	6	6	Oct, Nov, Dec, Jan, Feb, Mar	7	5
III	11 - 50		1	1	1	1	Feb	30	5
IV	70 - 100		1:2	1:2	1:2	1:2	Jan	80	6
<b>AEC down SCENARIO: C/D</b>									
I	2 - 4	4	4	4		4	Nov, Dec, Feb, Mar	2	3
II	6 - 10	2	2	2	2	2	Dec, Feb	7	5
III	11 - 50		1:2	1:2	1:2	1:2	Feb	30	5
IV	70 - 100		1:3	1:3	1:3	1:3	Jan	80	6

### 7.2.3 EWR results for EWR 3: Gladdedrift (Vaal River)

**Table 7.7 Low flow EWR results for EWR 3**

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment
<b>PES and REC: C EcoStatus:</b>		<b>FISH: C</b>		<b>MACROINVERTEBRATES: C</b>	
Aug	5% drought	10 LSR	10	0.001	Habitat is unsuitable for any life stages of the LSR species, however it is estimated that they will take refuge in pools or downstream reaches or rivers and recolonise this section when conditions improve.
	30%	9.3 LSR	9.3	0.098	8% of optimal dry season habitat suitability is present and will maintain the guild.
Feb	5% drought	6.9 LSR	6.9	1.37	At this stress 3% of the optimal wet season habitat is suitable. Very low to low habitat suitability but should allow this guild to survive these critical periods and maintain some level of recruitment.
	30%	4.5 LSR	4.5	5.89	At this stress 32% of the optimal wet season habitat is suitable. It is estimated that these habitat conditions should be adequate to maintain this guild within this reach during the dry season.
<b>AEC UP: B EcoStatus:</b>		<b>FISH: B</b>		<b>MACROINVERTEBRATES: B/C</b>	
Aug	5% drought	8 FDI	9.7	0.042	Average depth needed for dry season drought is 0.15 m, and average current velocity is 0.008 m/s. Wetted perimeter is significantly reduced (11.59 m). All current speeds are very slow.
	30%	8 LSR	8	0.71	At this stress 57% of the optimal wet season habitat is suitable. It is estimated that these habitat conditions should be adequate to maintain this guild within this reach during the dry season.
Feb	30%	2.3 LSR	2.3	12.351	At this stress 85% of the optimal wet season habitat is suitable. It is estimated that these habitat conditions should be adequate to maintain this guild within this reach during the dry season.
<b>AEC DOWN: C/D EcoStatus:</b>		<b>FISH: D</b>		<b>MACROINVERTEBRATES: D</b>	
Aug	5% drought	10 LSR	10	0.001	See PES.
	30%	10 LSR	10	0.001	Total habitat suitability would be 0% of what can be expected under natural conditions, resulting in very poor status of this fish assemblage during the dry period.
Feb	5% drought	6.9 LSR	6.9	1.37	See PES.
	30%	5.2 LSR	5.2	4.342	Total habitat suitability would be 52.5% of what can be expected under natural conditions, adequate to maintain this fish guild in a D EC in the wet season.

**Table 7.8 High flow EWR functions and motivations for EWR 3**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions					Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate
I	20 (ave)	<b>Geomorphology:</b> This flow class is responsible for more than 20% of the fines and gravels at the site. <b>Vegetation:</b> floods the marginal zone and approx 50% marginal zone riparian obligate species (activation & maintenance in wet season).	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	(40 - 80) 60 (ave)	<b>Geomorphology:</b> This flow class is responsible for more than 30% of the fines and gravels at the site. <b>Vegetation:</b> Floods the marginal zone and inundates about 50% of the lower zone. <i>Gomphostigma</i> , <i>Persecaria</i> and <i>Cyperus marginatus</i> populations completely flooded; majority of <i>Rumex</i> flooded.	✓	✓	✓	✓	✓	✓	✓	✓	✓

FLOOD CLASS	FLOOD RANGE (m³/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
III	100 - 130	<b>Vegetation:</b> Floods the lower zone and lower portions of the upper zone. Activates terrestrial grasses.	✓	✓	✓	✓	✓	✓				
IV	200 (ave)	<b>Geomorphology:</b> This flow class is responsible for more than 35% of the gravels at the site, and would activate the cobbles and boulders at the site.	✓	✓	✓	✓	✓	✓				

**Table 7.9 EWR 3: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m³/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES and REC SCENARIO: C</b>									
I	4	6	6	6		6	Oct, Nov, Dec, Jan, Feb, Mar	2	3
II	6 - 10	4	4	4	4	4	Nov, Dec, Feb, Mar	7	5
III	11 - 50		1	1	1	1	Feb	30	5
IV	70 - 100		1:2	1:2	1:2	1:2	Jan	80	6
<b>AEC up SCENARIO: B</b>									
I	4	6	6	6		6	Oct, Nov, Dec, Jan, Feb, Mar	2	3
II	6 - 10	6	6	6	6	6	Oct, Nov, Dec, Jan, Feb, Mar	7	5
III	11 - 50		1	1	1	1	Feb	30	5
IV	70 - 100		1:2	1:2	1:2	1:2	Jan	80	6
<b>AEC down SCENARIO: C/D</b>									
I	2 - 4	4	4	4		4	Nov, Dec, Feb, Mar	2	3
II	6 - 10	2	2	2	2	2	Dec, Feb	7	5
III	11 - 50		1:2	1:2	1:2	1:2	Feb	30	5
IV	70 - 100		1:3	1:3	1:3	1:3	Jan	80	6

**7.2.4 EWR results for EWR 4: De Neys (Vaal River)**

**Table 7.10 Low flow EWR results for EWR 4**

Month	% Stress duration	Component stress	Integrated stress	Flow m³/s	Comment
PES:C EcoStatus		FISH: C		MACROINVERTEBRATES: C/D	
Aug	5% drought	+4.3 FDI	+5.2	5.56	Average depth needed for dry season maintenance is 0.21 m, and average current velocity is 0.3 m/s. At these flows there is very limited very fast flow.

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment
	50% maintenance	+2.5 FDI	+3	12	Average depth needed for dry season maintenance is 0.29 m, and average current velocity is 0.45 m/s.
Feb	5% drought	+3.18 LSR	+3.18	11.406	These flows would enable the maintenance of this fish guild at this site in a category C during the wet season.
	20%	+2.14 LSR	+2.14	14.76	the habitat suitability will be 78% of the expected optimal wet season habitat suitability under natural conditions.
<b>REC: B/C EcoStatus</b>		<b>FISH: B</b>		<b>MACROINVERTEBRATES: C</b>	
Aug	5% drought	+3 FDI	+5.8	3.93	Average depth needed for dry season maintenance is 0.18 m, and average current velocity is 0.26 m/s. At these flows there is very limited very fast flow.
	50% maintenance	+3 FDI	+3.8	9.36	Average depth needed for dry season maintenance is 0.26 m, and average current velocity is 0.42 m/s
Feb	5% drought	+4 FDI	+4.8	6.6	Average depth needed for wet season drought is 0.23 m, and average current velocity is 0.35 m/s.
	50% maintenance	1.3 FDI	1.3	19.35	Average depth needed for wet season maintenance is between 0.37 m, and the average current velocity is 0.52 m/s. A wide range of current speeds and substrate types is available.
<b>AEC down: D EcoStatus</b>		<b>FISH: D</b>		<b>MACROINVERTEBRATES: C/D</b>	
Aug	5% drought	+1.7 LIM	+2.6	13.284	Although more suitable habitats are available, any shift from natural conditions will result in a negative impact on the ecological integrity.
	50% maintenance	+0.7 LIM	+0.8	26.904	This will be the result of habitat deterioration, change in food webs and population structures, etc.

**Table 7.11 High flow EWR functions and motivations for EWR 4**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions					Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate
I	15 - 25	<b>Vegetation:</b> Inundates the marginal zone, <i>Gomphostigma</i> , <i>Persecaria</i> and 50 - 60% of the <i>C. marginatus</i> population.	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	40 - 96	<b>Vegetation:</b> Inundates <i>C. marginatus</i> completely and 50% of the <i>S. mucronata</i> population. Also floods mid-channel features which will help prevent terrestrialization.	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	120 – 200 (80 ave)	<b>Geomorphology:</b> This near bankfull flood would scour the bed of the active channel, removing fines and cleaning the cobbles and boulders. <b>Vegetation:</b> Inundates the lower zone completely, as well as <i>S. mucronata</i> population.	✓	✓	✓	✓	✓	✓	✓	✓	✓

**Table 7.12 EWR 4: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES SCENARIO: C</b>									
I	15 - 25			4		4	Early summer/summer		3 - 5 days
II	40 - 96			1		1	Early to late summer		5 days
III	120 – 200 (80 ave)			1:2	1:2	1:2	Wet season		
<b>REC SCENARIO: B/C</b>									
I	15 - 25			6:1		6:1	Early summer/summer		3 - 5 days
II	40 - 96			2:1		2:1	Early to late summer		5 days
III	120 – 200 (80 ave)			1:2	1	1	Wet season		
<b>AEC down SCENARIO: D</b>									
I	20 (ave)			4		4	Early summer/summer		>5 days
II	(40 - 80) 60 (ave)			1		1	Early to late summer		>5 days
III	100 - 130			1:2	1:2	1:2	Wet season		

**7.2.5 EWR results for EWR 5: Scandinavia (Vaal River)**
**Table 7.13 Low flow EWR results for EWR 5**

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment
<b>PES:C/D EcoStatus</b>		<b>FISH: C</b>			<b>MACROINVERTEBRATES: C/D</b>
Aug	5% drought	8.7 LSR	8.7	3.75	Total habitat suitability is 70.9% of what can be expected under natural conditions, and it is estimated that it would maintain this guild in its present state during drought periods.
	50% maintenance	4.5 LSR	4.5	12.5	The total habitat suitability would be 135% of what can be expected under natural conditions, as a result of flows still being higher than expected under natural conditions. It is estimated that these habitat conditions should be adequate to maintain this guild within this reach in its present state. Although more suitable habitats will therefore be available, any shift from natural conditions will result in a negative impact on the ecological integrity. This will be the result of habitat deterioration, change in food webs and population structures, etc.
Feb	5% drought	7.3 LSR	7.3	6.55	This equates to a total habitat suitability score of 43% of optimal wet season habitat suitability expected during natural droughts. These flows would enable the maintenance of this fish guild at this site in its PES during the wet season droughts.
	20% assurance	3 LSR	3	20.9	The habitat suitability will be 68% of the expected optimal wet season habitat suitability under natural conditions. It is estimated that these habitat conditions should be adequate to maintain this guild within its present state.
<b>REC: C EcoStatus</b>		<b>FISH: B</b>			<b>MACROINVERTEBRATES: C</b>
Aug	5% drought	8.7 LSR	8.7	3.75	See PES.
	50% maintenance	5 LSR	5	11	The total habitat suitability would be 114% of what can be expected under natural conditions. This is a vast improvement of the present 142% habitat suitability.
Feb	5% drought	6.4 LSR	6.4	8.08	See PES.
	20% assurance	2 LSR	2	31.4	The total habitat suitability would be 89 % of what can be expected under natural conditions. It is estimated that these habitat conditions should be adequate to improve this guild with one ecological category.

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment	
<b>AEC down: D EcoStatus</b>		<b>FISH: D</b>			<b>MACROINVERTEBRATES: C/D</b>	
Aug	5% drought	8.4 LSR	8.4	7.9	See PES.	
	50% maintenance	1.7 LSR	1.7	37.73	The total habitat suitability would be 187% of what can be expected under natural conditions. Although more suitable habitats will therefore be available, any shift from natural conditions will result in a negative impact on the ecological integrity. This will be the result of habitat deterioration, change in food webs and population structures, etc.	

**Table 7.14 High flow EWR functions and motivations for EWR 5**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions					Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate
I	40 - 100 (50 ave)	<b>Geomorphology:</b> This flow class represents the effective discharge for the (1 – 3 mm) fines in the system. These floods will also inundate and activate the low active bench at the site. <b>Vegetation:</b> Inundates the marginal zone and marginal zone vegetation ( <i>Cyperus</i> , <i>Persecaria</i> , <i>Typha</i> , and <i>Phragmites</i> ).	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	180 - 260	<b>Vegetation:</b> Activates hydrophilic terrestrial grasses ( <i>S. nigrirostris</i> ) and <i>Crinum</i> , inundates 40% of the lower zone and floods lateral bars/terraces on uncut banks.	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	400 - 570	<b>Vegetation:</b> Inundates 60% of the lower zone, inundates <i>Crinum</i> and <i>Setaria</i> (important for reproductive productivity).	✓	✓	✓	✓	✓				
IV	800	<b>Geomorphology:</b> This large flood represents the effective discharge for (20 mm) gravels at the site, and this flood would also inundate the lower terrace at the site. <b>Vegetation:</b> Inundates 100% of the lower zone, activates the tree line (important to prevent terrestrialization).	✓	✓	✓	✓	✓				

**Table 7.15 EWR 5: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES SCENARIO: C/D</b>									
I	40 - 100 (50 ave)			3:1	4	3:1	Early summer/summer		3 days
II	180 - 260			1		1	Early to late summer		3 - 5 days
III	400 - 570			1:2		1:2	Summer		
IV	800			1:3	1:3	1:3	Wet season		
<b>REC SCENARIO: C</b>									
I	40 - 100 (50 ave)			4:1	4	4:1	Early summer/summer		3 days
II	180 - 260			2:1		2:1	Early to late summer		3 - 5 days
III	400 - 570			1:2		1:2	Summer		
IV	800			1:3	1:3	1:3	Wet season		
<b>AEC SCENARIO: D</b>									

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
I	40 - 100 (50 ave)			3:1	3	3:1	Early summer/summer		3 days
II	180 - 260			1		1	Early to late summer		3 - 5 days
III	400 - 570			1:2		1:2	Summer		
IV	800			1:3	1:5	1:3	Wet season		

## 7.2.6 EWR results for EWR 6: Klip (Klip River)

**Table 7.16 Low flow EWR results for EWR 6**

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment
<b>PES and REC: B/C EcoStatus</b>		<b>FISH: B</b>		<b>MACROINVERTEBRATES: B</b>	
Aug	5% drought	9 LSR	9	0.02	Refuge habitats critical for survival (SD and SS) will be maintained and the slight flows should at least maintain acceptable level of water quality for this moderately tolerant species.
	20%	6.5 FDI	8	0.06	Average depth needed is 0.07 m, and average current velocity is 0.08 m/s.
	55% maintenance	6.5 LSR	6.5	0.12	Very limited FS will be maintained, to allow for optimal survival habitat of juvenile BAEN. These flows will also ensure that adequate depth remains in the SD and SS (pools) for maintenance of especially adult BAEN in the reach.
Feb	5% drought	6.5 LSR	6.5	0.12	Some critical FS habitats should be available for some period to enable spawning, egg and larvae development. Very limited FS and adequate SD habitats should be available at the recommended stress level for the survival of juveniles and adults during this period.
	20%	4.5 FDI	4.5	0.364	Average depth needed is 0.15 m, and average current velocity is 0.22 m/s. Inflection point in wetted perimeter.
	55% maintenance	1 FDI	1	1.6	Average depth needed for wet season maintenance is 0.26 m, and average current velocity is 0.46 m/s (Spp Stress 1). This will inundate some marginal vegetation, and provide suitable habitats during summer.
<b>AEC down: C EcoStatus</b>		<b>FISH: C</b>		<b>MACROINVERTEBRATES: C</b>	
Aug	5% drought	9 LSR	9	0.02	See PES.
	20%	6.5 FDI	8	0.06	See PES.
	55% maintenance	7 LSR	7	0.15	Will result in very low abundance of FS habitats (no FI and FD), important for the survival of especially juvenile BAEN. Decreased flows will also reduce the depth of SD habitats, which are important survival habitats for over wintering of juvenile and adult BAEN, which will result in decreased FROC and abundance of BAEN.
Feb	5% drought	6.5 LSR	6.5	0.12	See PES.
	20%	5 FDI	5	0.358	Residual critical habitat (FCS) available, but insufficient current speeds for Perlidae.
	55% maintenance	3 LSR	3	0.572	Very limited FD habitats. Reduced FS and FI will however be available to allow for the requirements of the different life stages of BAEN during the wet season and would probably result in deterioration of the fish EC.

**Table 7.17 High flow EWR functions and motivations for EWR 6**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions					
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality	
I	5 – 7	<b>Vegetation:</b> Inundate marginal zone sedges.	✓	✓	✓	✓	✓	✓		✓				
II	10 -15	<b>Geomorphology:</b> Scours fines (2 mm sands) from the bed. <b>Vegetation:</b> Activates lower zone vegetation.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	20 - 50	<b>Geomorphology:</b> This flow class accounts for the majority of both fines (2 mm sands) and coarser gravels (20 mm) transport. <b>Vegetation:</b> Activation/inundation of the <i>Miscanthus</i> grassland.	✓	✓		✓	✓	✓						
IV	> 90	<b>Geomorphology:</b> Transport of gravels (20 mm) and scour/movement of cobble bed elements. <b>Vegetation:</b> Promotes woody vegetation recruitment.	✓	✓		✓	✓	✓						

**Table 7.18 EWR 6: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES and REC SCENARIO: B/C</b>									
I	5 – 7	6	6	4		6	Oct, Nov, Dec, Jan, Feb, Mar	5	3
II	10 -15	1	1	1	1	1	Jan	15	5
III	20 - 50		1:2	1:2	1:2	1:2			
IV	> 90		1:5	1:5	1:3 to 1:5	1:5			
<b>AEC down SCENARIO: C</b>									
I	5 – 7	4	4	2		4	Nov, Dec, Jan, Feb,	5	3
II	10 -15			1:2	1:2	1:2	Jan	15	5
III	20 - 50			1:3	1:3	1:3			
IV	> 90			1:5	1:5	1:5			

### 7.2.7 EWR results for EWR 7: Upper Wilge (Wilge River)

**Table 7.19 Low flow EWR results for EWR 7**

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment
PES: A/B EcoStatus		FISH: B			MACROINVERTEBRATES: B
Aug	5% drought	9 MVI	9.9	0.004	Average depth needed for dry season drought is 10 cm, and maximum depth is 54 cm to ensure survival of MVI taxa.

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment
	40%	7.25 SSR	8	0.09	The total habitat suitability would be adequate to sustain the semi-rheophilic fish species at this site and maintain it in the PES.
	60% maintenance	8.5 MVI	8.7	0.048	Average depth needed for dry season maintenance is 12 cm, and maximum depth is 60 cm, which is considered sufficient.
Feb	5% drought	6 MVI	6.3	0.141	Average depth needed for wet season drought is 0.13 m, and maximum depth is 0.78 m.
	40%	1.25 SSR	1.25	0.688	The habitat suitability will be 92% of the expected optimal wet season habitat suitability under natural conditions and adequate to maintain this guild within this reach.
	60% maintenance	1 MVI	1	0.74	Average depth needed for wet season maintenance is 0.34 m, and maximum depth is 1.2 m. This will provide suitable vegetation habitats during summer.
<b>AEC down: C EcoStatus</b>		<b>FISH: C</b>		<b>MACROINVERTEBRATES: C/D</b>	
Aug	5% drought	9 MVI	9.9	0.004	See PES.
	40%	8.3 SSR	8.3	0.072	Loss of suitable habitats for some life stages of the semi-rheophilic species.
	60% maintenance	9.8 FDI	9.8	0.024	Average depth needed for dry season maintenance is 0.1 m (i.e. some vegetation inundated).
Feb	5% drought	6 MVI	6.3	0.141	See PES.
	40%	2.15 SSR	2.15	0.71	Reduced habitat availability for the different life stages of the semi-rheophilic species. Habitat suitability will be 82% of what can be expected during the dry season under natural flow conditions.
	60% maintenance	3 FDI	3.8	0.32	Average depth needed for wet season maintenance is 0.25 m. Crucial marginal vegetation present and abundant.

**Table 7.20 High flow EWR functions and motivations for EWR 7**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
II	2 - 3	<b>Vegetation:</b> Required to maintain in-channel obligate riparian vegetation ( <i>Persecaria</i> and <i>Phragmites australis</i> )	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	8 - 9	<b>Geomorphology:</b> Breaches the levee and connects and recharges the ox-bow lake; inundates seasonal zone around lake. <b>Vegetation:</b> Required to breach the main channel upstream of the site in order to recharge oxbow lakes (which have specific and different communities from floodplain and channel) and flood lower lying floodplain grasses.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IV	< 11	<b>Vegetation:</b> Overtops the bank levees and recharges higher lying oxbow communities (which are also reliant on lateral inputs), also floods majority of floodplain grasses.	✓	✓	✓	✓	✓	✓				✓

**Table 7.21 EWR 7: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES and REC SCENARIO: A/B (B)</b>									
I	1	6				6	Oct - Mar	0.5	2
II	2 - 3	4		4		4	Nov, Dec, Jan, Feb	1	2
III	8 - 9	2		2	> 2 (?)	>2	Dec, Jan	3	3
IV	< 11	1		1		1	Feb	5	3
<b>AEC down SCENARIO: C</b>									
I	1	3				3	Nov, Jan, Mar	0.5	2
II	2 - 3	4		2		2	Dec, Feb	1	2
III	8 - 9			1:1	1		Feb	5	3
IV	< 11			1:1			Summer		

**7.2.8 EWR results for EWR 8: Bavaria (Wilge River)****Table 7.22 Low flow EWR results for EWR 8**

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment			
<b>PES and REC: C EcoStatus</b>			<b>FISH: C</b>			<b>MACROINVERTEBRATES: C/D</b>		
Aug	5% drought	9 LSR	9	0.015	The most critical habitat for survival of this species during drought periods in the dry season (adequate depths in pools - both SD and SS) will be maintained. Some FS habitats (no FD and FI) for especially juvenile survival, and to maintain adequate oxygen levels in the pools will also be present.			
	55% maintenance	7.5 LSR	7.5	0.33	Some fast habitat will be maintained (some FS, FI and limited FD) for adequate survival habitat for juveniles and feeding habitat for adults during the dry season. Some SD as refuge areas (especially at night by adults and juveniles to escape from extreme temperature fluctuations in shallow waters) will be maintained.			
Feb	5% drought	7 LSR	7	0.42	At this recommended stress level, all the fast habitats (FD, FS and FI) will still be present, albeit in a very low abundance.			
	55% maintenance	4.5 LSR	4.5	1.515	The recommended stress level should maintain adequate fast habitats (FS, FI and FD) to allow for the requirements for the different life stages.			
<b>AEC up: B/C EcoStatus</b>			<b>FISH: B</b>			<b>MACROINVERTEBRATES: C</b>		
Aug	5% drought	9 LSR	9	0.015	See PES.			
	55% maintenance	4 FDI	6.5	0.51	Average depth needed for dry season maintenance is 0.22 m, and average current velocity is 0.22 m/s to ensure survival of FDIs.			
Feb	5% drought	7 LSR	7	0.42	See PES.			
	55% maintenance	3.5 FDI	4	1.8	Average depth needed for wet season maintenance is 0.27 m, and average current velocity is 0.26 m/s which will maintain FDIs.			
<b>AEC down: D EcoStatus</b>			<b>FISH: D</b>			<b>MACROINVERTEBRATES: D</b>		
Aug	5% drought	9 LSR	9	0.015	See PES.			
	55% maintenance	8 LSR	8	0.24	Limited FS and FI will still be available, but FD will be lost during the dry season. This should be adequate to sustain the BAEN assemblage, through the provision of FS for juveniles, and adequate flow to sustain pools and acceptable flow related water quality for all life stages. The decreased abundance and overall condition of preferred habitat of this species will result in decreased FROC and abundance of the guild.			
Feb	5% drought	7 LSR	7	0.42	See PES.			

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment
	55% maintenance	5.75 LSR	5.75	0.7	Very limited fast habitats to maintain the different life stages of BAEN during the wet season. Decrease in abundance and condition of breeding, nursery and refuge habitats, as well as water quality deterioration as a result of decreased flows. Reduced depth of SD habitats will jeopardise the role these habitats play to provide refuge to juveniles and adults from night time temperature fluctuations.

**Table 7.23 High flow EWR functions and motivations for EWR 8**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions					Macroinvertebrate flood functions					
			Migration cues & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	6 - 12	<b>Vegetation:</b> Inundates the marginal zone sedges and lower limits of the <i>Cyperus</i> .	✓	✓	✓	✓	✓	✓		✓			
II	15 – 30	<b>Vegetation:</b> Activates and inundates <i>Persecaria</i> population.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	65 – 90	<b>Geomorphology:</b> This flow class accounts for about the transport of about one quarter of the fines (2 mm sands). <b>Vegetation:</b> Inundates the <i>Crinum</i> and <i>Cyperus</i> .	✓	✓	✓	✓	✓	✓					
IV	100 - 150	<b>Geomorphology:</b> Responsible for 50% of the transport of gravels and about 25% of the fines transported at this site, and would also clean the cobbles at the site and activates the backwater channel. <b>Vegetation:</b> Activates <i>Crinum</i> .	✓	✓	✓	✓	✓	✓					

**Table 7.24 EWR 8: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES and REC SCENARIO: C</b>									
I	6 - 12	4	5	4		5	Oct, Nov, Dec, Jan, Feb	8	4
II	15 - 30	2	2	2		2	Dec, Feb	20	5
III	65 - 90			1	1	1	Jan	70	6
IV	100 - 150			1:2	1:2	1:2	Summer		
<b>AEC↑ SCENARIO: B/C</b>									
I	6 - 12	5	6	5		6	Oct, Nov, Dec, Jan, Feb, Mar	8	4
II	15 - 30	2	2	2		2	Dec, Feb	20	5
III	65 - 90			1	1:1.5 (2:3)	1	Jan	70	6
IV	100 - 150			1:2	1:2	1:2			
<b>AEC↓ SCENARIO: D</b>									
I	6 - 12	2	4	2		5	Oct, Nov, Dec, Jan, Feb	8	4
II	15 - 30	1	1	1		1	Feb	20	5

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
III	65 - 90			1:2	1:2	1:2	Jan	70	6
IV	100 - 150			1:3	1:3	1:3			

### 7.2.9 EWR results for EWR 9: Suikerbos US (Suikerbosrand River)

Table 7.25 Low flow EWR results for EWR 9

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment	
<b>PES: C EcoStatus</b>		<b>FISH: D</b>			<b>MACROINVERTEBRATES: D</b>	
Aug	5% drought	9 LSR	9	0.04	Adequate depths in pools (both SD and SS) are maintained to ensure survival. Very limited FS habitats (no FD and FI) for especially juvenile survival and the maintenance of adequate oxygen levels in the pools will be available to maintain the LSR in the PES during drought conditions in the dry season.	
	55% maintenance	7 LSR	7	0.08	Very limited fast habitat will be maintained (some FS, FI and no FD) to provide adequate survival habitat for especially the juveniles, and feeding habitat for adults. Maintenance of some SD as refuge areas (especially at night by adults and juveniles to escape from extreme temperature fluctuations in shallow waters).	
Feb	5% drought	7 LSR	7	0.08	Very limited FD habitat will still be available, but at least adequate FS and FI will be maintained. This is critical habitat to enable spawning, egg and larvae development. Limited FS and adequate SD habitats should be maintained under these conditions for the survival of juveniles and adults during this period.	
	55% maintenance	2 SSR	3	0.28	At this stress level flow should be adequate to ensure some inundation of macrophytes (especially in SD) and thereby creating some preferred habitat in the form of overhanging vegetation and aquatic vegetation. The provision of adequate cover is especially important at the site due to the presence of alien predator MSAL.	
<b>REC: B/C EcoStatus</b>		<b>FISH: C</b>			<b>MACROINVERTEBRATES: C</b>	
Aug	5% drought	9 LSR	9	0.04	See PES.	
	55% maintenance	5 LSR	5	0.125	At this stress level, the abundance and availability of FS and FI habitat will be improved although FD habitats will still not be available during the dry season. The improvement in the FS and FI should however result in the habitat suitability for the guild, which should be reflected by improved FROC and abundance of this species, with a resultant improvement of the EC.	
Feb	5% drought	7 LSR	7	0.08	See PES.	
	55% maintenance	0.4 LSR	1.9	0.55	Improvement in habitat availability for guild. This can be expected to result in improved spawning success, increased survival of fry and juveniles and increased abundance and FROC of all live stages of BAEN. This will result in improved EC for BAEN and contribute to an overall improvement of the fish EC towards a C.	

**Table 7.26 High flow EWR functions and motivations for EWR 9**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	1 - 2	<b>Vegetation:</b> Activation of <i>Miscanthus</i> lower limits. <b>Geomorphology:</b> Scouring of fines from the bed of the active channel.	✓	✓	✓	✓	✓	✓		✓		
II	3 - 6	<b>Geomorphology:</b> Activates sedges in the backchannel of the bench; inundates and activates the active channel bench. <b>Vegetation:</b> Inundation of <i>Miscanthus</i> and about 50% of the <i>Cyperus</i> .	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	8 - 20	<b>Geomorphology:</b> Inundation and activation of the paired terraces (which are extensive upstream of the site). <b>Vegetation:</b> Inundation to the upper limits of the <i>Cyperus</i> , <i>Gomphostigma</i> and <i>Persecaria</i> .	✓	✓	✓	✓	✓	✓				
IV	> 40	<b>Geomorphology:</b> Activates the ephemeral terrace (floodplain). <b>Vegetation:</b> Activates the woody zone ( <i>Leucosidea</i> and <i>Rhus</i> spp.).	✓	✓	✓	✓	✓	✓				

**Table 7.27 EWR 9: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES SCENARIO: C</b>									
I	1 - 2	2	5	4	4	5	Oct, Nov, Dec, Jan, Feb (2)	1.5	3
II	3 - 6	1	4	1	1	1	Jan	5	4
III	8 - 20			1:2	1:2	1:2			
IV	> 40			1:3	1:5	1:5			
<b>REC SCENARIO: B/C</b>									
I	1 - 2	4	6	6	5 - 6	6	Oct, Nov, Dec (2), Feb (2)	1.5	3
II	3 - 6	2	5	1:1	1:1	1	Jan	5	4
III	8 - 20		1	1:2	1:2	1:2			
IV	> 40		1:2	1:3	1:5	1:5			

**7.2.10 EWR results for EWR 10: Suikerbos DS (Suikerbosrand River)**

**Table 7.28 Low flow EWR results for EWR 10**

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment <sup>1</sup>	
<b>PES and REC:C/D EcoStatus</b>		<b>FISH: C/D</b>			<b>MACROINVERTEBRATES: C/D</b>	
Aug	5% drought	+6.3 LSR	+6.3	0.78	182% of the habitats that can be expected under natural conditions, and it is estimated that it would maintain this guild in its PES during drought periods	
	50% maintenance	+4.5 LSR	+4.5	1.095	It is estimated that the total habitat suitability would be 186% of what can be expected under natural conditions, as a result of flows still being higher than expected under natural conditions (under present flows during the dry season, the habitat suitability percentage is 293% of natural condition).	
Feb	5% drought	+3.2 FDI	+4.2	1.146	Average depth needed for wet season drought is between 0.25 and 0.31 m, and average current velocity is between 0.25 and 0.34 m/s. Critical habitats (FCS) comprise between 21 and 29% of habitats available.	
	50% maintenance	-2 FDI	-2	3.7	Average depth needed for wet season maintenance is between 0.37 and 0.48 m, and average current velocity is 0.46 to 0.7 m/s. Critical habitats (FCS) comprise between 20 and 30% of habitats available.	
<b>AEC up: C EcoStatus</b>		<b>FISH: C</b>			<b>MACROINVERTEBRATES: C</b>	
Aug	5% drought	+6.8 LSR	+6.8	0.682	See PES.	
	50% maintenance	+4 FDI	+5.5	0.91	Average depth needed for dry season maintenance is between 0.25 and 0.29 m, and average current velocity is between 0.25 and 0.31 m/s (Spp Stress between + 3 and + 1.5). Critical habitats (FCS) comprise between 21 and 28 % of habitats available.	
Feb	5% drought	+2.2 LIM	+7	0.64	Flows will ensure enough habitat that it would maintain this guild in its PES during drought periods.	
	50% maintenance	0 FDI	0	2.5	Average depth needed is between 0.32 and 0.37 m, and average current velocity is 0.37 and 0.46 m/s. Critical habitats (FCS) comprise between 30 and 31% of habitats available.	
<b>AEC down: D EcoStatus</b>		<b>FISH: D</b>			<b>MACROINVERTEBRATES: C/D</b>	
Aug	5% drought	0 FDI	0	2.5	Average depth needed for dry season drought is between 0.32 and 0.34 m, and average current velocity is between 0.37 and 0.39 m/s.	
	50% maintenance	-1 FDI	-1	2.9	Average depth needed for dry season maintenance is between 0.31 and 0.37 m, and average current velocity is between 0.34 and 0.46 m/s.	
Feb	5% drought	1 FDI	1	2.2	Average depth needed for wet season drought is between 0.3 and 0.32 m, and average current velocity is 0.34 and 0.37 m/s.	
	50% maintenance	-4 FDI	-4	8.3	Average depth needed for wet season maintenance is 0.48 and 0.55 m, and average current velocity is between 0.70 and 0.78 m/s.	

**Table 7.29 High flow EWR functions and motivations for EWR 10**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	5 - 6 (3.5 ave)	<b>Geomorphology:</b> This flow class would scour fines and inundate the lower bench. <b>Vegetation:</b> Inundates 50% of the marginal zone and 40 - 50% of the <i>Cyperus</i> population. Activates the lower limit of <i>Miscanthus</i> population.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	8 - 12 (6 ave)	<b>Geomorphology:</b> This flow class would scour fines, inundate and activate the lower bench, and is responsible for more than 10% of the transport of fines and gravels.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

FLOOD CLASS	FLOOD RANGE (m³/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions				
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	
		<b>Vegetation:</b> Inundates the marginal zone and majority of the <i>Cyperus</i> population as well as lower limits of <i>Miscanthus</i> .											
III	20 - 40 (10 - 12 ave)	<b>Geomorphology:</b> This flow class would inundate the lower terrace on the left bank, and is responsible for more than 20% of the transport of fines and gravels. <b>Vegetation:</b> Inundates the majority of the lower zone and <i>Miscanthus</i> population.	✓	✓	✓	✓	✓	✓		✓	✓	✓	
IV	70 + (75 ave)	<b>Geomorphology:</b> This flow class would inundate the upper terrace on the left bank, and is the effective discharge for the small cobbles at the site (activation and transport of cobbles). <b>Vegetation:</b> Floods the lower zone and activates the woody zone. Helps prevent terrestrialization by woody vegetation.	✓	✓	✓	✓	✓	✓					

**Table 7.30 EWR 10: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m³/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES and REC SCENARIO: C/D</b>									
I	5 – 6 (3.5 ave)			3	4	4	Nov, Dec, Jan and Feb	3.5	3
II	8 – 12 (6 avg)			1	2	2	Jan, Mar	6	4
III	20 – 40 (10 - 12 ave)			1:2	1	1	Feb	11	4
IV	70 + (75 ave)			1:3	1:2	1:2			
<b>AEC up SCENARIO: C</b>									
I	5 – 6 (3.5 ave)			3	4	4	Nov, Dec, Jan and Feb	3.5	3
II	8 – 12 (6 avg)			1	2	2	Jan, Mar	6	4
III	20 – 40 (10 - 12 ave)			1:2	1	1:2	Feb	11	4
IV	70 + (75 ave)			1:3	1:2	1:2			
<b>AEC down SCENARIO: D'</b>									
I	5 – 6 (3.5 ave)			5+	5	5	Nov, Dec, Jan, Feb, Mar	3.5	3
II	8 – 12 (6 avg)			2	3	3	Dec, Jan, Mar	6	4
III	20 – 40 (10 - 12 ave)			1	1	1	Feb	11	4
IV	70 + (75 ave)			1:3	1:2	1:2			

**7.2.11 EWR results for EWR 11: Blesbokspruit (Blesbokspruit River)**
**Table 7.31 Low flow EWR results for EWR 11**

Month	% Stress duration	Component stress	Integrated stress	Flow m <sup>3</sup> /s	Comment	
<b>PES: D EcoStatus</b>		<b>FISH: D</b>			<b>MACROINVERTEBRATES: D/E</b>	
Aug	5% drought	4.5 LSR	4.5	0.3	Presence of 204% of the habitats that can be expected under natural conditions. It is estimated that it would maintain this guild in its PES during drought periods.	
	50% maintenance	3.2 LSR	3.2	0.38	The total habitat suitability would be 129% of what can be expected under natural conditions. The habitat composition at the site is higher than expected during natural conditions as a result of flows still being higher than under natural conditions. It is estimated that fish would remain in the PES at this fish stress level. Although more suitable habitats will therefore be available, any shift from natural conditions will result in a negative impact on the ecological integrity of the system. This will be the result of habitat deterioration through scouring and flooding, change in natural habitat composition at the site, altered food webs and population structures, etc.	
Feb	5% drought	3 LSR	3.3	0.379	Presence of 162% of the habitats that can be expected under natural conditions, and it is estimated that it would maintain this guild in its PES during drought periods.	
	50% maintenance	-1 FDI	-1.1	1.268	Average depth needed for wet season maintenance is between 0.19 m, and average current velocity is 0.37 m/s. Critical habitat (FCS) comprises 19% of habitats available.	
<b>REC: D EcoStatus</b>		<b>FISH: C</b>			<b>MACROINVERTEBRATES: D</b>	
					Flows will ensure enough habitat that it would maintain this guild in its PES during drought periods.	
		4.5 LSR	4.5	0.3	The total habitat suitability would be 126% of what can be expected under natural conditions. Although more suitable habitats will therefore be available, any shift from natural conditions will result in a negative impact on the ecological integrity. This will be the result of habitat deterioration, change in food webs and population structures, etc.	
		3.89 LSR	3.89	0.31	Flows will ensure enough habitat that it would maintain this guild in its PES during drought periods.	
		1.1 FDI	1.1	0.47	Average depth needed for wet season maintenance is between 0.19 and 0.25 m, and average current velocity is 0.37 and 0.5 m/s. Critical habitats (FCS) comprise between 16 and 19% of habitats available.	

**Table 7.32 High flow EWR functions and motivations for EWR 11**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	RIPARIAN VEGETATION MOTIVATION	Fish flood functions					Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate
I	4 - 6	Inundates marginal zone and <i>Persecaria</i> population. Inundates <i>P. australis</i> and <i>T. capensis</i> lower limits to 50 cm at least, which will prevent in-channel migration.	√	√	√	√	√	√	√	√	√
II	8 - 10	Inundates the lower zone and <i>T. capensis</i> and <i>P. australis</i> populations completely.	√	√	√	√	√	√	√	√	√
III	17 - 25	Inundates the lower zone and lower portions of the upper zone. Activates <i>Cyperus hexamita</i> and <i>M. junceus</i> populations and floods <i>C. bulbispermum</i> (triggers flowering).	√	√	√	√	√				

**Table 7.33 EWR 11: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES and REC SCENARIO: D</b>									
I	4 - 6			3:1		3	Dec, Jan, Feb	3	3
II	8 - 10			2:1		2	Jan, Mar	6	4
III	17 - 25			1		1	Feb	12	4

**7.2.12 EWR results for RE-EWR 1: Klein Vaal (Klein Vaal)**
**Table 7.34 Low flow EWR results for RE-EWR 1**

Season	Initial desktop flows		Adjusted desktop flows		Response
	Drought (m <sup>3</sup> /s)	Maintenance (m <sup>3</sup> /s)	Drought (m <sup>3</sup> /s)	Maintenance (m <sup>3</sup> /s)	
<b>PES and REC: C EcoStatus FISH: B MACROINVERTEBRATES: A/B</b>					
Aug	0	0.025	0	0.033	<p><b>Dry Season drought</b> There are no rheophilic species present in this reach, and the semi-rheophilic and limnophilic species will be able to survive short periods of no flow, especially if adequate depths are maintained in the SD habitats. These would become important refuge areas during the winter drought periods.</p> <p><b>Dry Season maintenance</b> At this flow very limited FVS (4%) and FS (1%) will be available, which would be suitable for the survival of all semi-rheophilic species (BAEN, BANO, LCAP, BPAL and LUMB) during the dry season. These flows will not create optimal habitats, but should sustain at least the flow related water quality to ensure survival during the dry season. These flows should also maintain acceptable levels of SS and SD (with adequate depth) for maintenance of the expected species. Under severe conditions, this flow should allow the fish to undertake limited downstream avoidance migrations to seek adequate refuge habitats.</p>
Feb	0.073	0.174	No change		<p><b>Wet Season drought</b> Under this condition, crucial FS and FVS will still be available, although the FI habitats will be lost. These habitats should however be adequate for the survival of most species under these drought conditions during the wet season.</p> <p><b>Wet Season maintenance</b> At these flows, adequate FVS, FS and FI will be available. The maintenance of these flows will be important to meet the habitat requirements of especially the semi rheophilic species (BAEN, LCAP) that require these habitats for spawning and early life stage development. Juvenile BAEN also has a preference for these habitats (especially during the day), while SD areas would be used as refuge areas during the night.</p>
<b>AEC down: C/D EcoStatus FISH: C MACROINVERTEBRATES: C</b>					
Aug	0	0.019	0	0.024	<p><b>Dry Season maintenance</b> At this flow very limited Fast Very Shallow (FVS) will still be available but FS (and other fast habitats) will be lost. These flows would not be optimal for the survival of the fish species present, but due to the fact that they are all semi-rheophilic and limnophilic species, they should be able to survive the dry season at this flow rate. These flows should maintain acceptable levels of SS and SD (with adequate depth) for maintenance of the expected species. Although the fast habitats (riffle/rapids) will not be available for the fish species due to its relative shallowness, the flow will be important to maintain acceptable depth and water quality levels within the SS and SD habitats, which will be important refuge habitats. It is however estimated that under these flows the present status of the fish will deteriorate towards a lower category.</p>
Feb	0.073	0.125	No change		<p><b>Dry Season maintenance</b> At these flows, adequate FVS and FS will be available, with limited FI habitat. The maintenance of these habitats will be important to meet the habitat requirements of especially the semi-rheophilic species (BAEN,</p>

Season	Initial desktop flows		Adjusted desktop flows		Response
	Drought (m³/s)	Maintenance (m³/s)	Drought (m³/s)	Maintenance (m³/s)	
					and LCAP) that require these habitats for spawning and early life stage development. Juveniles BAEN also has a preference for these habitats (especially during the day), while SD areas would be used as refuge areas during the night. Condition and availability of fast habitats at these flows will be less than that under present conditions, and it can be expected that the fish assemblage would deteriorate and result in a decrease in the category.

**Table 7.35 High flow EWR functions and motivations for RE-EWR 1**

FLOOD CLASS	FLOOD RANGE (m³/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions					Macroinvertebrate flood functions				
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	1-3	<b>Geomorphology:</b> Activates the fines and gravels of the active channel (removes the fines) and allows for some deposition and recreation of low bars. <b>Vegetation:</b> Inundation of the marginal zone ( <i>Miscanthus</i> are in this zone downstream of the cross-section).	✓	✓	✓	✓	✓	✓		✓		
II	7-12	<b>Geomorphology:</b> Activates and inundates the lower terrace and scours the cobbles on the channel bed. <b>Vegetation:</b> Activates or inundates <i>Crinum</i> and <i>Miscanthus</i> .	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	>20	<b>Vegetation:</b> Activates the woody zone ( <i>Leucosidea</i> ) and the upper ephemeral terrace.	✓	✓	✓	✓	✓	✓				

**Table 7.36 RE-EWR 1: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m³/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
<b>PES and REC SCENARIO: C</b>									
I	1-3	6		4	3	6	Oct, Nov, Dec, Jan, Feb, Mar	1.5	3
II	7-12	2		1:1	1	2?	Jan, Feb	8	3
III	>20			1:3	1:5	1:3			
<b>AEC down: SCENARIO: C/D</b>									
I	1-3	4		2	2	4	Oct, Nov, Dec, Feb	1.5	3
II	7-12	1		1	1	1	Jan	8	3
III	>20			1:3	1:5	1:3			

### 7.2.13 EWR results for RE-EWR 2: Mooi (Mooi River)

**Table 7.37 Low flow EWR results for RE-EWR 2**

Season	Initial desktop flows	Adjusted Desktop flows	Response
	Maintenance (m <sup>3</sup> /s)	Maintenance (m <sup>3</sup> /s)	
PES: D EcoStatus		FISH: C	MACROINVERTEBRATES: E
Aug	0.11	0.12	<b>Dry Season maintenance</b> Discharge of 0.12 m <sup>3</sup> /s is recommended for the PES. The average depth needed for indicator taxa during dry season maintenance is 0.13 m, and average current velocity is 0.11 m/s. At the recommended flows in the dry season sufficient hydraulic habitat is present to maintain a few flow-dependent macroinvertebrates, such as Simuliidae and Baetidae and improve the EC to a D.
Feb	0.12	0.16	<b>Wet Season maintenance</b> Discharge of 0.16 m <sup>3</sup> /s is recommended for the PES. Average depth for these taxa during wet season maintenance is 5 cm higher than dry season maintenance in order to provide seasonal variation in conditions and improve the presence of flow dependant taxa. Average current speeds remain unchanged at 0.11 m/s. Only 9 taxa were collected at this site.

**Table 7.38 High flow EWR functions and motivations for RE-EWR 2**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION
I	1 - 2	<b>Geomorphology:</b> Several small floods throughout the wet season to recharge the floodplain (which has peat wetlands) and provide for evapotranspiration of reeds. <b>Vegetation:</b> Maintain the floodplain vegetation and bank vegetation ( <i>T. capensis</i> mainly).
II	>8	<b>Geomorphology:</b> Annual flood to spread across the floodplain, recharging the peats, activating cut off channels, inundating the floodplain vegetation and reedbeds

**Table 7.39 RE-EWR 2: The recommended number of high flow events required**

FLOOD CLASS	FLOOD RANGE (m <sup>3</sup> /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES D									
I	1 - 2			6					
II	>8			1					

## 7.3 RESULTS

The results are summarised in Table 7.40 for the different EWR sites as a percentage of the natural Mean Annual Runoff (nMAR).

**Table 7.40 Upper Vaal WMA: EWR scenario results**

EWR site	nMAR	PMAR	%PMAR OF nMAR	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
	MCM	MCM	MCM		MCM	% nMAR	MCM	% nMAR	MCM	% nMAR	MCM	% nMAR
<b>Virgin MAR</b>												
EWR 2	457.70	267.12	58%	C PES, REC	30.21	6.6	5.03	1.1	32.04	7	58.13	12.7
				B AEC up	0.00	11.3	0.00	1.1	0.00	7.6	0.00	16.2
				C/D AEC down	14.19	3.1	5.03	1.1	28.38	6.2	43.48	9.5
EWR 3	858.10	603.09	70%	C PES, REC	90.96	10.6	7.72	0.9	31.75	3.7	125.28	14.6
				B AEC up	90.96	10.6	7.72	0.9	31.75	3.7	125.28	14.6
				C/D AEC down	38.61	4.5	7.72	0.9	27.46	3.2	75.51	8.8
EWR 6	95.30	84.53	89%	B/C PES, REC	17.54	18.4	17.54	18.4	7.72	8.1	22.30	23.4
				C AEC down	8.39	8.8	1.62	1.7	6.19	6.5	14.20	14.9
EWR 7	23.50	23.50	100%	B/C PES, REC	8.18	34.8	0.66	2.8	3.10	13.2	5.64	24
				C AEC down	4.61	19.6	0.66	2.8	1.20	5.1	6.06	25.8
EWR 8	474.30	425.39	90%	C PES, REC	24.19	5.1	5.69	1.2	31.30	6.6	54.54	11.5
				B/C AEC up	31.30	6.6	5.69	1.2	33.20	7	59.76	12.6
				D AEC down	14.70	3.1	5.69	1.2	27.04	5.7	46.01	9.7
EWR 9	31.30	29.47	94%	C PES	4.41	14.1	1.82	5.8	2.07	6.6	6.60	21.1
				B/C REC	8.48	27.1	1.82	5.8	2.28	7.3	9.83	31.4
EWR 1	288.80	332.72	115%	B/C PES, REC	103.10	35.7	5.20	1.8	28.01	9.7	116.96	40.5
EWR 10	86.98	134.84	155%	C/D PES, REC	26.18	30.1	14.87	17.1	3.74	4.3	35.75	41.1
				C AEC down	25.49	29.3	10.09	11.6	3.57	4.1	29.23	33.6
EWR 11	29.4	80.64	274%	D PES (DRM D)	3.65	12.4	2.70	9.2	1.68	5.7	7.61	25.9
				D REC (DRM C)	4.15	14.1	2.09	7.1	1.68	5.7	6.23	21.2
EWR 4	1977.3	1130.72	57%	C PES	The current status quo will maintain the PES.							
				B/C REC	Both these requirements are higher than the reference time series during certain parts of the year. Therefore neither the PMAR nor nMAR can be used to generate a time series and therefore volumes could not be calculated.							
				C/D AEC down								
EWR 5	2288	1364.54	60%	C/D PES	The current status quo will maintain the PES.							
				C REC	Both these requirements are higher than the reference time series during certain parts of the year. Therefore neither the PMAR nor nMAR can be used to generate a time series and therefore volumes could not be calculated.							
				D AEC								

## 7.4 CONCLUSIONS AND RECOMMENDATIONS

The confidence in the low and high flow Ecological Reserve requirements for each EWR site is provided in the table below. A score of 1 – 2.4 indicates a low confidence (red), 2.5 – 3.9 a moderate confidence (yellow) and 4 - 5, high confidence (green) in the results.

**Table 7.41 Overall Confidence in EWR results**

Site	Hydrology	Biological responses Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	COMMENT	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	COMMENT
EWR 2	3	3.5	4	3.5	Macroinvertebrate requirements result in a slightly lower confidence than the fish due to uncertainties on the influence of water quality on the biota response.	3	4	3.5	High flow medium confidence due to the upstream dam and impact on sediment as well as the lack of morphological cues.
EWR 3	3	4	4	4	Biological responses medium due. Two-dimensional hydraulic modelling was undertaken. The hydraulic requirements for low flows largely within the range of measured flows.	3.5	5	3.5	Medium to high confidence due to bedrock nature of the site and lack of geomorphological cues.
EWR 6	1.9	4	3	3	Hydraulics: No measured flows between 0.003 and 1.0 m <sup>3</sup> /s. As many of the low flow requirements are within this range, the confidence is medium.	3.5	3	3	Hydraulics a medium confidence due to the lack of measured flows in the range of high flow recommendations.
EWR 7	2.8	2	2.5	2	Hydraulics is low confidence as there is uncertainty whether zero flows equate to zero depth. Only one low flow measurement was available. The biota confidence is also low due to the fact that macroinvertebrate requirements are based on depth – however, no flow dependant macroinvertebrates are present.	3.8	3	3	Complex site with floodplain and wetland components.
EWR 8	2.4	4	3	3	Hydraulics: Complex site. Non-horizontal water surfaces. No measurements in the range of most low flow requirements.	3.8	5	4	Hydraulics of very high confidence as a suitable range of measured flows exists.
EWR 9	1.8	4	4	4	Hydraulically this is a complex site with non-horizontal water surfaces. As a suitable range of flows were measured in the high flow range, the confidence is high. The biota confidence medium to high due to	3	3	3	Hydraulically this is a complex site with only a single high flow measurement. The bedrock nature of the site and lack of geomorphological cues resulted in a moderate confidence for the biophysical responses.
EWR 10	2.5	2.8	3	3	Low flows set are below measurements for hydraulic calibrations. There is also uncertainty for flow class modelling. The medium confidence for the biota is due to the complexity of the water quality issues and the higher flows than natural.	4	4	4	Suitable range of measured flows for high flows resulting in high confidence for the hydraulics.
EWR 11	2.3	4	2.5	2.5	The low flows fall below the recommendations and the hydraulic confidence is therefore medium to high.	4	5	4	Suitable range of measured high flows result in very high confidence for the hydraulics.
EWR 1	2.9	4	2.5	2.5	The site is hydraulically complex. Most requirements fall below the measured minimum flow. There are also non-uniform flow conditions and uncertainty regarding the flow class modelling.	4	4	4	Hydraulics: Two of the three high flows fall within the range of measured flows.
EWR 4	2.8	1	3.5	1	Hydraulics: Recommendations are below measured minimum flows. There are non-uniform flow conditions and non-horizontal water surfaces and therefore uncertainty in the flow class modelling. The very low confidence of the biota is due to the macroinvertebrate uncertainty in their recommendations. The change in seasonality, water quality issues and increased flows in some seasons are difficult to interpret.	2.3	3	2.3	Low to Medium confidence due to the uncertainty in the geomorphological requirements due to the nature of the site, the effect of the Vaal Dam and the response in terms of habitat to the flood recommendations made.
EWR 5	2.8	3	3.5	3	Hydraulics: The recommendations are below the measured minimum. Non-uniform flow conditions exist. There is uncertainty for flow class modelling. See above for confidence motivation for biota.	4	3.5	3.5	The flood requirements are above the measured maximum resulting in a medium to high confidence only.

The confidences in the high flows ranged from MEDIUM to HIGH at all sites apart from EWR 4. The low confidence at EWR 4 was due to uncertainty regarding flooding requirements recommended for geomorphology. No additional surveys or collation of information would address this uncertainty.

Recommendations were determined based on the possibility and necessity of improving the confidence of the individual assessments (biological response and hydraulics) by implementing an Ecological Water Resource Monitoring Programme (EWRM), hydrological monitoring and hydraulic assessments. This will provide the additional information to improve confidence in the EWRs. These recommendations are summarised in Table 7.42.

It was strongly recommended that an EWRM programme be initiated as soon as possible. The information gathered during this study was suitable for the baseline, but if too much time relapses between the baseline and monitoring, new surveys and EcoClassification process will have to be undertaken.

**Table 7.42 Summary of recommendations required to improve confidences**

EWR sites	Low flow confidence	High flow confidence	Recommendations
2	3.5	3.5	EWRM.
3	4	3.5	EWRM.
6	3	3	EWRM. If any improvement is required at this site, it is firstly recommended that a better idea of the present hydrological regime is obtained.
7	2	3	The wetland as a whole must be addressed and this would require the floodplain to be surveyed and hydraulics to be supplied for the whole floodplain.
8	3	4	EWRM.
9	4	3	EWRM.
10	3	4	EWRM.
11	2.5	4	EWRM.
1	2.5	4	EWRM.
4	1	2.3	EWRM.
5	3	3.5	EWRM.

## 8 ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Ecological and Goods & Services Consequences of various Operational Scenarios. Report produced by Koekemoer Aquatic Services and Rivers for Africa. Report no: RDM/WMA8C000/01/CON/0110.

### 8.1 APPROACH

The purpose of this task was to predict the driver and biota responses to each operational scenario and derive the Ecological Category (EC) for the EWR site and Management Resource Unit (MRU).

All information used during the EcoClassification step (the suite of EcoClassification models set up for different ECs) (Chapter 6) and the Ecological Water Requirement (EWR) scenario step (Chapter 7) was used as baseline for this assessment.

The following steps were required to determine the ecological consequences of the flow scenarios.

- The operational scenarios (Chapter 7; Volume 1) were modelled and a time series was provided for each scenario at each EWR site.
- The time series was converted to a flow duration table and both was provided to the physico chemical and geomorphology specialist.
- These specialists had to provide a conclusion and resulting EC of the operational scenario assessed at the EWR to the biological responses team.
- These specialists completed the Physico-chemical Assessment Index (PAI) and Geomorphology Assessment Index (GAI) models to predict the driver EC.
- The riparian vegetation specialist then assessed the response on the marginal and other riparian zones and supplied this information to the instream biota specialists. This was done prior to the instream biota assessment as riparian vegetation is a driver in terms of important habitat for the instream biota.
- Where required, the riparian vegetation specialist ran the Vegetation Response Assessment Index (VEGRAI) model to predict the EC for the operational scenario.

Assessment of the economic impacts of the various scenarios essentially identified the direction of change (either positive or negative), and estimated the magnitude of the change in benefits and costs that could be experienced within the River System (Chapter 9). The process adopted was the analysis of potential economic changes based on a valuation of the status quo, that was, the value of the Goods and Services (G&S) currently provided by the water in River systems, identifying the potential change that each of the key G&S may have undergone in each of the scenario clusters. And where required the current value of G&S was then multiplied by these factors for each scenario, to provide an indication of the potential future value of the Goods and Services. The change in value was thus measured.

### 8.2 OPERATIONAL SCENARIOS

Detailed information regarding operational scenarios is documented in RDM/C000/00/CON/0607 (DWA, 2010a). Table 8.1 provides a summarised description of the scenarios, as well as reasoning for evaluating the specific scenario at the respective EWR sites.

**Table 8.1 Summary of the evaluated Scenarios**

Sc No	Dev Level	EWR Status	Scenario description	Reasoning
1	2008	Excluded	Base scenario representing the status quo.	This is a new PRESENT DAY. This scenario was not evaluated, but differences from the old PD (used for determination of EWR) were noted and reasoning was provided.
4	2008	Included	Based on Scenario 1. EWR Scenario: With exception of EWR 4 and EWR 5 <sup>1</sup> , all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Although EWRs are provided as a demand, it was still evaluated. One EWR site (e.g. in the Lower Vaal), could drive the requirements and result in unacceptable situations at EWR sites in the Upper Vaal (too much flow e.g.). NB: The EWR was included as a priority demand and this has a knock on effect on other users, and the operating rules of dams. This is relevant for all scenarios where dams are included.
5	2020	Excluded	Sc 1 representing the future 2020 development conditions excluding the EWRs. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system. Includes proposed Polihali Dam and conveyance infrastructure. Includes proposed re-use of mine water. Includes projected possible transfer to the Crocodile catchment.	Key scenarios. Includes most likely future developments and illustrates resulting flows at EWR sites. NO EWRs were included as a demand in the system. Basically, this is the WHAT IF scenarios, i.e., what if we manage the system in this manner without providing EWRs – will the EcoStatus change and if so, how much.
6	2020	Included	Based on Sc 5. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 5 and Sc 4.
7	Full utilization (Future development scenario)	Excluded	Scenario representing the full utilization of available water. Based on current infrastructure. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system.	This is also a future scenario, but brings in new developments apart from the VRESSAP pipeline. Full utilisation means that there is allocated water, or water available in dams, which have not been used yet.
8	Full utilization (Future development scenario)	Included	Based on Sc 7. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 7 and Sc 4.

<sup>1</sup> To achieve the REC at EWR 4 and 5 less flow than present was required in the dry season and more flows in the wet seasons. Yield models will only include an EWR demand and then make provision if the flows passing the EWR site is less than required. It will therefore assume that if higher flows than the demand are achieved, this would be a positive outcome in terms of the Ecological Reserve. It was deemed impractical to set a high flow limit and therefore decrease supply to other users when the Reserve requires this. Including EWR 4 and 5 as a demand in a yield model would be contrary to the actual Reserve requirements.

EWR 7 was excluded from the scenario modeling due to the small catchment size, where the resolution is not compatible with that of the Water Resources Planning Model (WRPM).

### 8.3 ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

The results are summarised according to whether the scenarios meet the REC or not, and if not, to what degree. Colour coding and symbols should be interpreted as follows:

- ✓ REC EcoStatus or REC instream IS met.
- X REC EcoStatus or REC instream is NOT met.

Light green with black ✓:	Meets REC EcoStatus including all components.
Dark Green with black ✓:	Meets the REC EcoStatus, but not all the components.
Orange with X:	The scenario does not meet REC requirements but meets the PES.
Purple with X:	The scenario results in an EC below the PES; D EC.
Red with X:	The results are below a D EC.

Table 8.2 provides the consequences at each of the EWR sites on the Ecological Category and the changes from the PES are shown. This is followed by a summary comparison of the consequences.

**Table 8.2 The consequences of the operational scenarios at each EWR site in the Upper Vaal WMA**

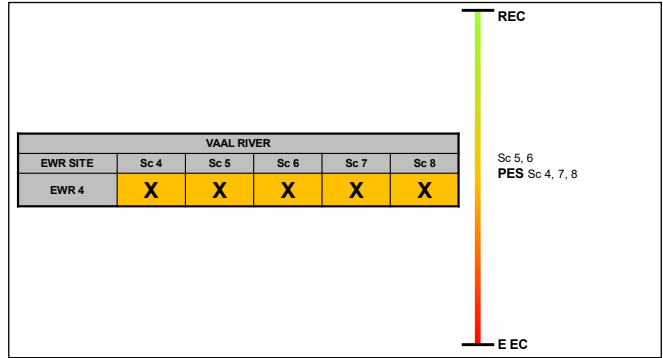
Ecological consequences of the operational flow scenarios							Degree to which each scenario meets the REC																							
<b>EWR 1: UITKOMS (VAAL RIVER)</b>																														
Driver Components	PES and REC	Sc 4	Sc 5, 6	Sc 7	Sc 8		<table border="1" style="margin: 10px auto;"> <thead> <tr> <th colspan="6">VAAL RIVER</th> </tr> <tr> <th>EWR SITE</th> <th>Sc 4</th> <th>Sc 5</th> <th>Sc 6</th> <th>Sc 7</th> <th>Sc 8</th> </tr> </thead> <tbody> <tr> <td>EWR 1</td> <td>✓</td> <td>✓</td> <td>✓</td> <td>✓</td> <td>✓</td> </tr> </tbody> </table>						VAAL RIVER						EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8	EWR 1	✓	✓	✓	✓	✓
VAAL RIVER																														
EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8																									
EWR 1	✓	✓	✓	✓	✓																									
WATER QUALITY	C	C	C	C/D	C																									
GEOMORPHOLOGY	B/C	B/C	C	B	B/C																									
Response Components	PES and REC	Sc 4	Sc 5, 6	Sc 7	Sc 8																									
FISH	C (B)	C	C	C/D	C																									
MACROINVERTEBRATES	C (B)	C	C	C	C																									
INSTREAM	C	C	C	C	C																									
RIPARIAN VEGETATION	A/B	A/B	A/B	A/B	A/B																									
ECOSTATUS	B/C (B)	B/C	B/C	B/C	B/C																									
<p>Scenario 4 and 8 achieved the REC requirements for all the components. Scenario 5 and 6 resulted in a deterioration in geomorphology as the increased base flows accelerated incision, while Sc 7 resulted in improved geomorphology due to decreased base flows. Increased base flows resulted in the fish deteriorating half a category.</p>																														
<b>EWR 2: GROOTDRAAI (VAAL RIVER)</b>																														
Driver Components	PES and REC	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8	<table border="1" style="margin: 10px auto;"> <thead> <tr> <th colspan="6">VAAL RIVER</th> </tr> <tr> <th>EWR SITE</th> <th>Sc 4</th> <th>Sc 5</th> <th>Sc 6</th> <th>Sc 7</th> <th>Sc 8</th> </tr> </thead> <tbody> <tr> <td>EWR 2</td> <td>✓</td> <td>✓</td> <td>✓</td> <td>✓</td> <td>✓</td> </tr> </tbody> </table>						VAAL RIVER						EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8	EWR 2	✓	✓	✓	✓	✓
VAAL RIVER																														
EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8																									
EWR 2	✓	✓	✓	✓	✓																									
WATER QUALITY	B/C	B/C	B	B/C	C	C																								
GEOMORPHOLOGY	D	D	D	D	D	E																								
Response Components	PES and REC	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8																								
FISH	C	C	C	C	C	C																								
MACROINVERTEBRATES	C	D	C	B/C	C	D																								
INSTREAM	C	C	C	C	C	C																								
RIPARIAN VEGETATION	B/C	C	B	B	B/C	C																								
ECOSTATUS	C	C	B/C	B/C	C	C																								
<p>Scenario 5 and 6 resulted in a B/C EcoStatus which was an improvement of the PES-REC. Scenario 5 resulted in an improvement in water quality and riparian vegetation, while Sc 6 resulted in the same improvements including macroinvertebrates as well. Sc 4 met the PES and REC although there was deterioration in macroinvertebrates due to no flow periods in the dry season drought which would eliminate flow dependent taxa. The future development scenarios met the PES and REC to different extents. Scenario 7 excluded EWR releases and resulted in water quality deteriorating to a C EC while the rest of the components were similar to the PES and REC. Scenario 8 included EWR release and the high volume release impacted negatively on the geomorphology of the site as well as water quality and macroinvertebrates. Scenario 4 and 8 would result in the PES being maintained although the requirements of the REC will not be met.</p>																														
<b>EWR 3: GLADDEDRIFT (VAAL RIVER)</b>																														
Driver Components	PES and REC	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8	<table border="1" style="margin: 10px auto;"> <thead> <tr> <th colspan="6">VAAL RIVER</th> </tr> <tr> <th>EWR SITE</th> <th>Sc 4</th> <th>Sc 5</th> <th>Sc 6</th> <th>Sc 7</th> <th>Sc 8</th> </tr> </thead> <tbody> <tr> <td>EWR 3</td> <td>✓</td> <td>✓</td> <td>✓</td> <td>✓</td> <td>✓</td> </tr> </tbody> </table>						VAAL RIVER						EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8	EWR 3	✓	✓	✓	✓	✓
VAAL RIVER																														
EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8																									
EWR 3	✓	✓	✓	✓	✓																									
WATER QUALITY	C	C	C	C	C	C																								
GEOMORPHOLOGY	C	D	C	C	D	C+																								
Response Components	PES and REC	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8																								
FISH	C	B	B	B	B	B																								
MACROINVERTEBRATES	C	B	B/C	B/C	B/C	B																								
INSTREAM	C	B	B/C	B	B	B																								
RIPARIAN VEGETATION	C	C	C	C	C	B/C																								
ECOSTATUS	C	B/C	B/C	B/C	B/C	B																								

**Ecological consequences of the operational flow scenarios** **Degree to which each scenario meets the REC**

All the scenarios resulted in an improvement of the PES-REC. Sc 8 was the best performer and resulted in the improvements of all the components with water quality remaining in the PES EC. Sc 4 resulted in a B/C EcoStatus and although fish and macroinvertebrates improved there was deterioration in geomorphology. The consequences of Sc 6 and 7 were similar although Sc 7 resulted in a deterioration of geomorphology. Scenario 5 improved the instream condition to a lesser extent than the other scenarios and it is important to note that the improvement of fish under Sc 5 and 7 was based on the assumption that the non-flow related problems i.e. exotic fish were to be addressed.

**EWR 4: DE NEYS (VAAL RIVER)**

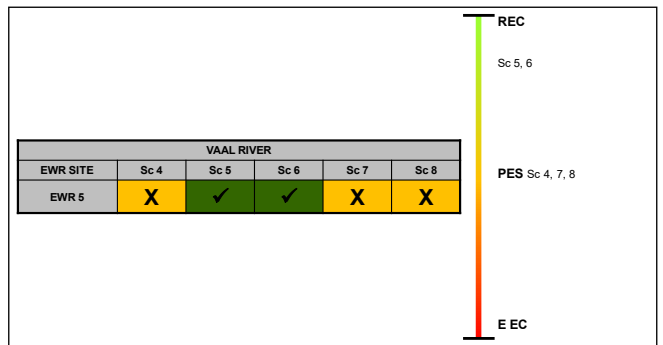
Driver Components	PES	REC	Sc 4, 8	Sc 5, 6	Sc 7=PES
WATER QUALITY	C	C	C	C	C
GEOMORPHOLOGY	D	D	D	D	D
Response Components	PES	REC	Sc 4, 8	Sc 5, 6	Sc 7=PES
FISH	C	B	C	C	C
MACROINVERTEBRATES	C/D	C	C/D	C	C/D
INSTREAM	C	B/C	C	C	C
RIPARIAN VEGETATION	C	B/C	C	C	C
ECOSTATUS	C	B/C	C	C	C



Scenario 4 – 8 did not meet the REC requirements at EWR 4. All the scenarios do however meet the PES EcoStatus. Of these scenarios Sc 5 and 6 were optimal as the increased wet season base flows and lower dry season base flows along with improved seasonality addressed (to an extent) the seasonal reversal that has occurred here. The other scenarios were very similar to PD conditions.

**EWR 5: SCANDINAVIA (VAAL RIVER)**

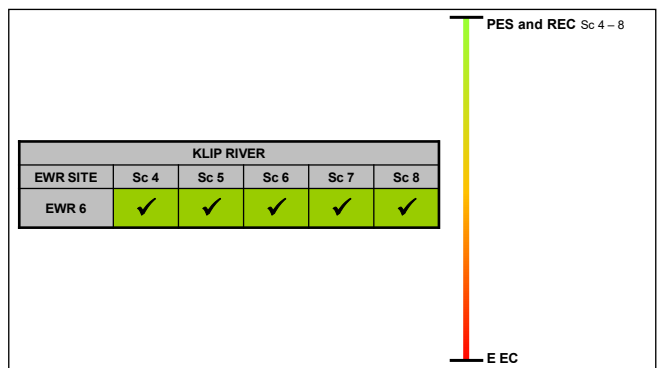
Driver Components	PES	REC	Sc 4, 7, 8	Sc 5, 6
WATER QUALITY	E	D/E	E	E
GEOMORPHOLOGY	C	C	C	C+
Response Components	PES	REC	Sc 4	Sc 5
FISH	C	B	C	B/C
MACROINVERTEBRATES	C	C	C	C
INSTREAM	C	B/C	C	C
RIPARIAN VEGETATION	D	C	D	C/D
ECOSTATUS	C/D	C	C/D	C



Scenario 4, 7 and 8 were very similar to PD and resulted in the PES being maintained. Scenario 5 and 6 resulted in an improvement of the PES but did not achieve the REC.

**EWR 6: KLIP (KLIP RIVER)**

Driver Components	PES and REC	Sc 4, 7, 8	Sc 5, 6
WATER QUALITY	B/C	B/C	B/C
GEOMORPHOLOGY	B	B	B
Response Components	PES and REC	Sc 4, 7, 8	Sc 5, 6
FISH	B	B	A/B
MACROINVERTEBRATES	B	B	B
INSTREAM	B	B	A/B
RIPARIAN VEGETATION	B/C	B/C	B/C
ECOSTATUS	B/C	B/C	B

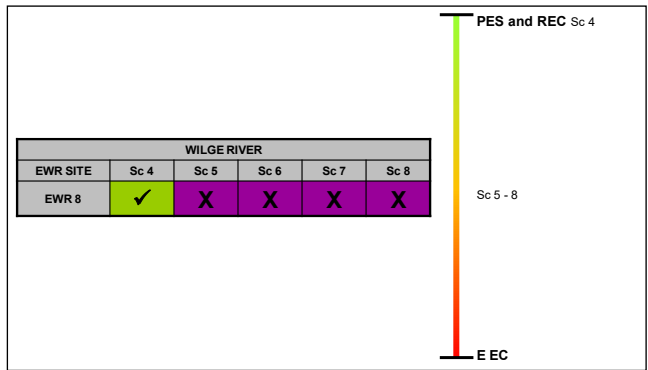


**Ecological consequences of the operational flow scenarios** **Degree to which each scenario meets the REC**

Scenario 4, 7, and 8 resulted in conditions similar to the PES-REC. Scenario 5 and 6 resulted in improved conditions for fish and an improvement of the REC EcoStatus.

**EWR 8: BAVARIA (WILGE RIVER)**

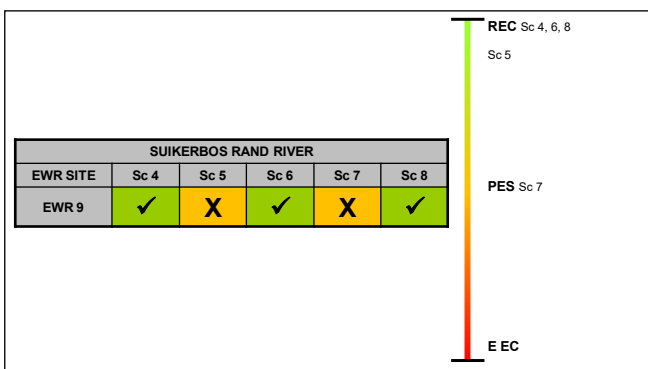
Driver Components	PES and REC	Sc 4	Sc 5, 6, 7, 8
WATER QUALITY	C	B/C	C
GEOMORPHOLOGY	C	C	D/E
Response Components	PES and REC	Sc 4	Sc 5, 6, 7, 8
FISH	C	C	D
MACROINVERTEBRATES	C/D	C	D
INSTREAM	C	C	D
RIPARIAN VEGETATION	C	C	D
ECOSTATUS	C	C	D



Scenario 4 met the requirements of the PES-REC and was a slight improvement within the C EcoStatus as macroinvertebrates improved. The impact of Sc 5 – 8 was similar, and these scenarios resulted in the deterioration of the PES-REC. The significant increase in base flows during dry and wet season has an adverse effect on this site. Although water quality stays stable the geomorphology deteriorates. Riparian vegetation deteriorated due to inundation stress and loss of the marginal zone. This leads to significant loss of important habitat for fish and aquatic macroinvertebrates and therefore the instream condition and the EcoStatus deteriorates to a D EC.

**EWR 9: SUIKERBOS US (SUIKERBOSRAND RIVER)**

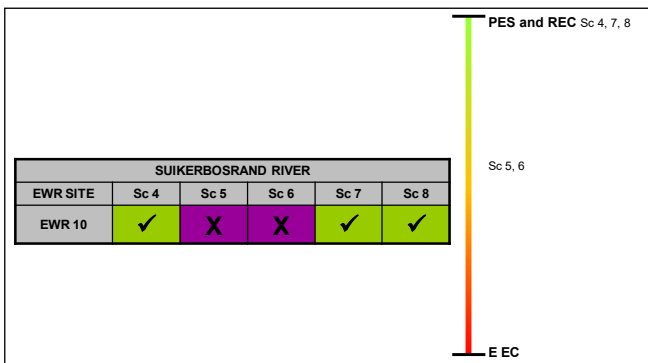
Driver Components	PES	REC	Sc 4, 6, 8	Sc 5	Sc 7=PES
WATER QUALITY	C/D	C	C	C/D	C/D
GEOMORPHOLOGY	B/C	B	B/C	B/C	B/C
Response Components	PES	REC	Sc 4, 6, 8	Sc 5	Sc 7
FISH	D	C	C	C/D	D
MACROINVERTEBRATES	D	C	C	C	D
INSTREAM	D	C	C	C	D
RIPARIAN VEGETATION	B/C	B	B	B	B/C
ECOSTATUS	C	B/C	B/C	C	C



Scenario 4, 6, and 8 resulted in conditions similar to the REC with only geomorphology not improving, and therefore this scenario was an improvement from the PES and achieved the REC. Scenario 5 resulted in drivers remaining stable and macroinvertebrates, instream and riparian vegetation improving similar to the REC. Fish improved a half a category from the PES and as a consequence there was an improvement in instream conditions from the PES, but overall the EcoStatus improved within the PES EcoStatus. Scenario 7 was virtually the same as modelled 2008 hydrology and resulted in no change from the PES.

**EWR 10: SUIKERBOS DS (SUIKERBOSRAND RIVER)**

Driver Components	PES and REC	Sc 4, 7, 8	Sc 5, 6
WATER QUALITY	D/E	D/E	D/E
GEOMORPHOLOGY	C	C	C/D
Response Components	PES and REC	Sc 4, 7, 8	Sc 5, 6
FISH	C/D	C/D	C/D
MACROINVERTEBRATES	C/D	C/D	D
INSTREAM	C/D	C/D	D
RIPARIAN VEGETATION	C	C	D
ECOSTATUS	C/D	C/D	D



Scenario 4, 7 and 8 were very similar to PD and therefore the requirements of the PES-REC were met at EWR 10. Scenario 5 and 6

Ecological consequences of the operational flow scenarios					Degree to which each scenario meets the REC																						
resulted in the deterioration of the PES for most components. These scenarios therefore did not meet the requirements of the PES-REC.																											
EWR 11: BLESBOKSPRUIT (BLESBOKSPRUIT RIVER)																											
Driver Components	PES	REC	Sc 4, 7, 8	Sc 5, 6																							
WATER QUALITY	D/E	D	D/E	E																							
GEOMORPHOLOGY	C	C	C	D																							
Response Components	PES	REC	Sc 4, 7, 8	Sc 5, 6																							
FISH	D	C	D	E																							
MACROINVERTEBRATES	D/E	D	D/E	D/E																							
INSTREAM	D/E	C/D	D/E	D/E																							
RIPARIAN VEGETATION	D	D	D	D/E																							
ECOSTATUS	D	D	D	D/E																							
										<table border="1"> <thead> <tr> <th colspan="6">BLESBOKSPRUIT</th> </tr> <tr> <th>EWR SITE</th> <th>Sc 4</th> <th>Sc 5</th> <th>Sc 6</th> <th>Sc 7</th> <th>Sc 8</th> </tr> </thead> <tbody> <tr> <td>EWR 11</td> <td>X</td> <td>X</td> <td>X</td> <td>X</td> <td>X</td> </tr> </tbody> </table>					BLESBOKSPRUIT						EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8	EWR 11
BLESBOKSPRUIT																											
EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8																						
EWR 11	X	X	X	X	X																						
Scenario 4, 7 and 8 were very similar to PD and therefore maintained the PES. Scenario 5 and 6 resulted in deterioration of the driver components and the fish and riparian vegetation deteriorated due to the inundation stress and decreased habitat suitability (especially limnophilic species) caused by increased base flows. The PES and REC requirements were not met and the EcoStatus under Sc 5 and 6 deteriorated to a D/E EC.																											

Table 8.3 provides a summary of the ecological consequences at each EWR site in the Upper Vaal WMA. An overall assessment was undertaken for the Vaal River system to compare the scenarios developed by WRP (DWA, 2010a).

**Table 8.3 Summary of the consequences of the operational scenarios (Sc 4 - 8) at each EWR site**

VAAL RIVER					
EWR SITE	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
EWR 1	✓	✓	✓	✓	✓
EWR 2	✓	✓	✓	✓	✓
EWR 3	✓	✓	✓	✓	✓
EWR 4	X	X	X	X	X
EWR 5	X	✓	✓	X	X
KLIP RIVER					
EWR 6	✓	✓	✓	✓	✓
WILGE RIVER					
EWR 8	✓	X	X	X	X
SUIKERBOSRAND					
EWR 9	✓	X	✓	X	✓
EWR 10	✓	X	X	✓	✓
BLESBOKSPRUIT					
EWR 11	X	X	X	X	X

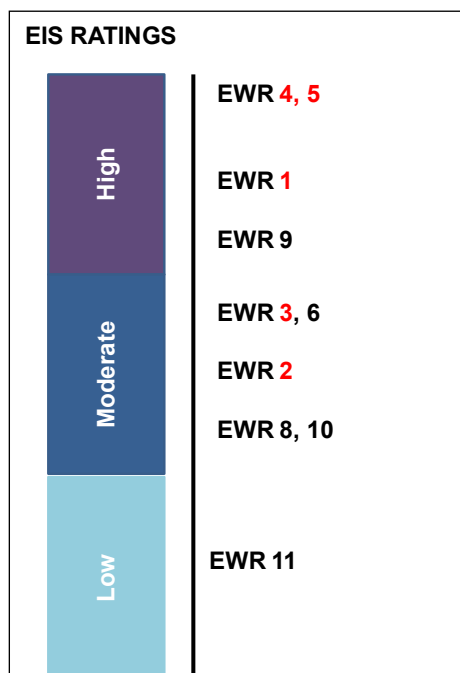
A simplified version of this table is provided in Table 8.4. There are three codes used in the table and indicate the following:

- ✓ EWR objectives (REC) are met.
- X EWR objectives (REC) are not met. The PES is also not being maintained (see below).
- X(PES) EWR objectives (REC) are not met but the PES is still being maintained. This is relevant for sites where the REC is an improvement of the PES. The improvement cannot be met, but the PES is still maintained.

**Table 8.4 Summary of where the EWR objectives are met/achieved in the Upper Vaal River System**

Site	PES	REC	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
<b>VAAL RIVER MAIN STEM</b>							
EWR 1	B/C	B/C	√	√	√	X	√
EWR 2	C	C	X	√	√	√	X
EWR 3	C	C	√	√	√	√	√
EWR 4	C	B/C	X (PES)	X (PES)	X (PES)	X (PES)	X (PES)
EWR 5	C/D	C	X (PES)	√	√	X (PES)	X (PES)
<b>VAAL RIVER TRIBUTARIES</b>							
EWR 6 (Klip River)	B/C	B/C	√	√	√	√	√
EWR 8 (Wilge River)	C	C	√	X	X	X	X
EWR 9 (Suikerbosrand River)	C	B/C	√	√	√	PES	√
EWR 10 (Suikerbosrand River)	C/D	C/D	√	X	X	√	√
EWR 11 (Blesbokspruit River)	D	D	X (PES)	X	X	X (PES)	X (PES)

Tables 8.3 and 8.4 are a comparison of the scenarios at all the sites within the Upper Vaal system. However some of the tributaries can be operated independently without influencing the main stem thereby potentially meeting EWRs by other means. For decision making purposes it was also necessary to take into consideration the relative Ecological Importance and Sensitivity (EIS) of the different EWR sites. Therefore the EWR sites were grouped according to their EIS score e.g. High, Moderate or Low. The sites within these groupings e.g. sites with a HIGH EIS score, were then ranked according to the number of individual EIS metrics that scored high. For example, an EWR site with 5 metrics which scored high (≥2.5) would be ranked higher than one with 4 HIGH metrics and a lot higher than one with 2 metrics. The results are supplied in Figure 8.1. This figure indicates that the EWR sites in the main river (EWR numbers in red Figure 8.1) are overall of more importance than the tributaries. The exception was EWR 9 situated in the upper Suikerbosrand River.



**Figure 8.1 Comparison of the Relative importance of the EWR sites within the Upper Vaal Water Management Area**

Evaluations therefore were based firstly on a comparison of consequences on the MAIN RIVER and then compared to the consequences on the tributaries of the Vaal River.

The scenarios were also grouped and compared separately. The grouping is according to the same situation WITH and WITHOUT the EWRs as follows:

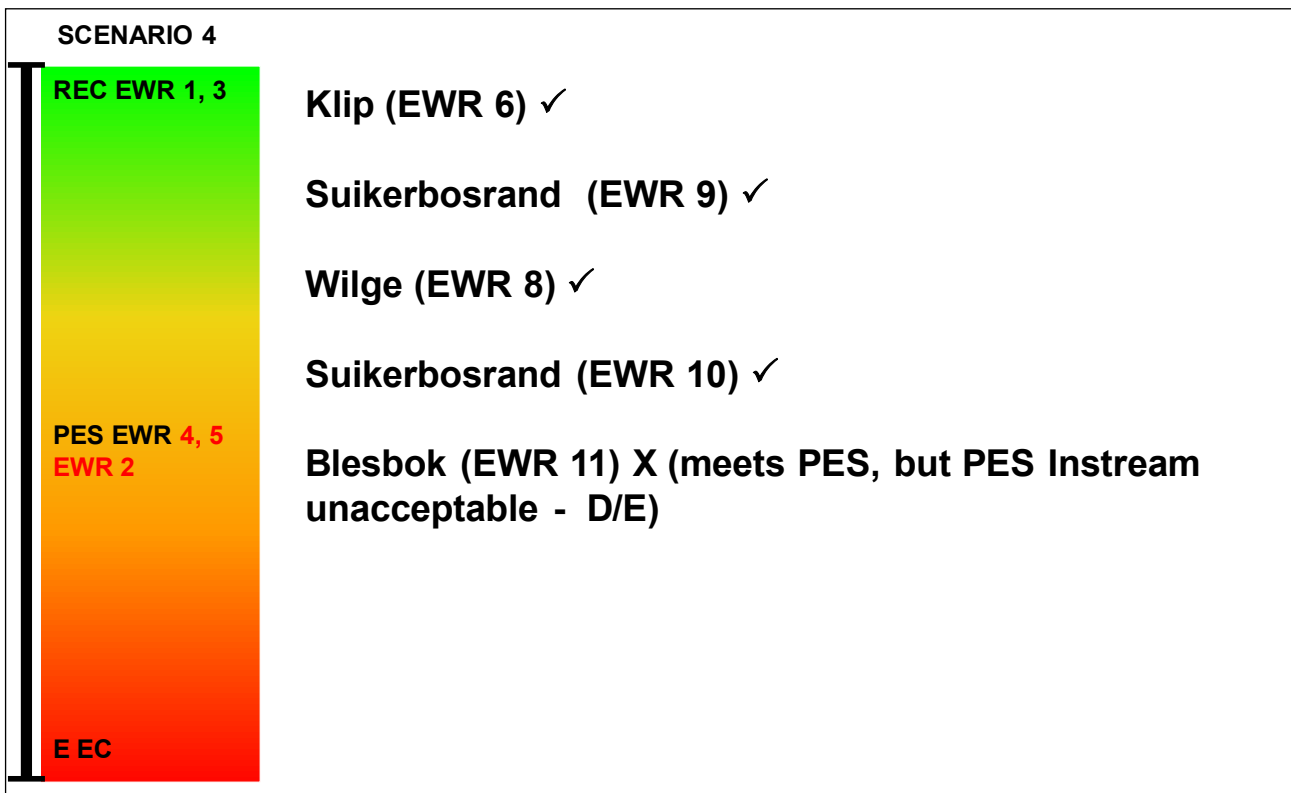
- Scenario 4 (current situation WITH EWR) – compared against the current situation and resulting PES.
- Scenario 6 (future development scenario WITH EWR) – compared against Scenario 5 which represents the future development scenario WITHOUT EWR).
- Scenario 8 (full utilisation scenario WITH EWR) – compared against Scenario 7 which represents the full utilisation scenario WITHOUT EWR).

These comparisons led to the final traffic diagrams and conclusions discussed below.

## 8.4 CONCLUSIONS

### 8.4.1 Consequences of supplying the EWR under current conditions (Sc 4)

The results are summarised in a traffic diagram for the main river and an evaluation of the tributaries in Figure 8.2.



**Figure 8.2 Ecological consequences of Sc 4**

The conclusions are summarised as follows:

- Scenario 4 failed to meet the REC at EWR 4 and 5. Meeting the REC at EWR 4 is unlikely due to operational constraints and the significant demand on the Vaal Dam. To meet the REC at EWR 4, higher flows in summer is required and lower flows in winter.
- Scenario 4 did not meet the PES-REC at EWR 2 and the reason is probably that this scenario over-supplied EWR 2 to meet the requirements of EWR 3. However, Scenario 4

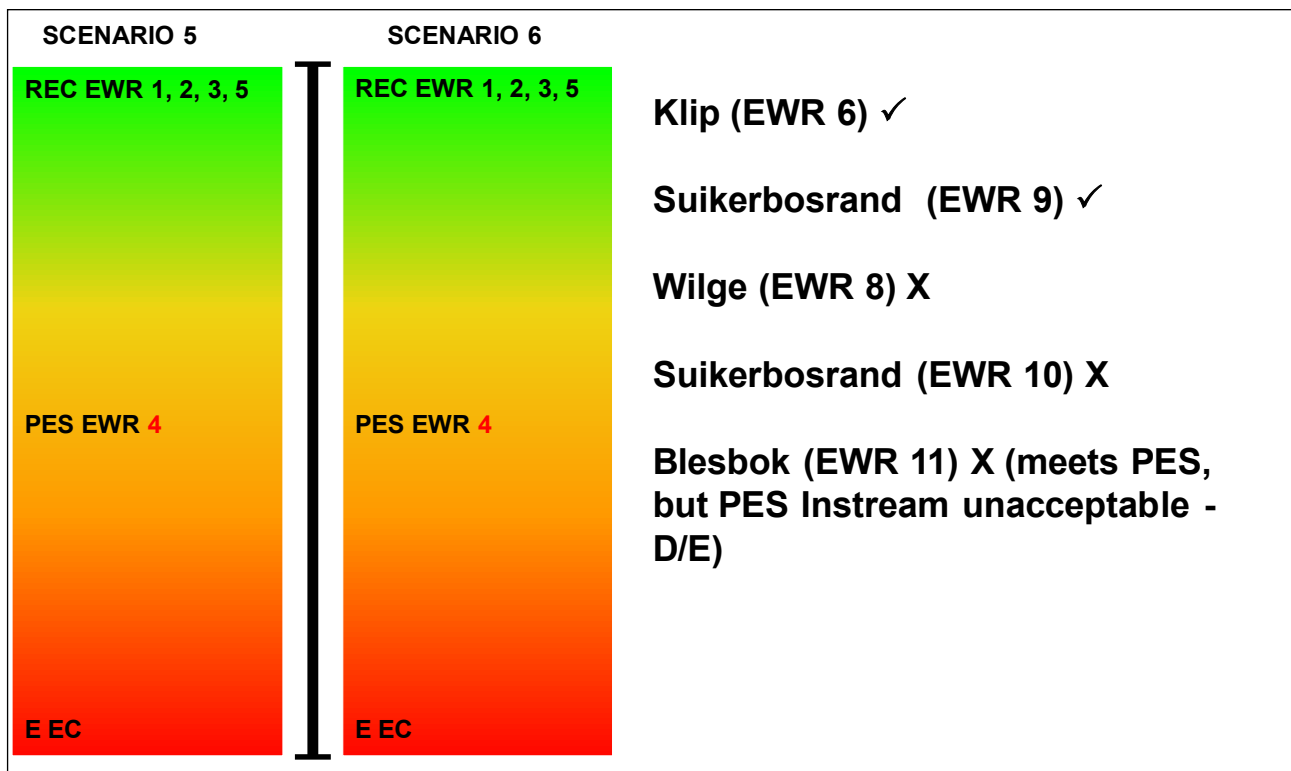
resulted in higher flows than required at EWR 3, which is possibly a result of the way in which the configuration model is set up and could be due to operational rules other than for the EWR. This requires further investigation.

- Scenario 4 did not meet the objectives at the Blesbokspruit River (EWR 11). This is not surprising as the Blesbokspruit River has significant water quality problems as well as to MUCH water. Decreasing flows could exacerbate the water quality problems, and this river actually requires a specific management plan which addresses its problems with the focus on water quality as first priority.

In conclusion, there was no significant advantage in supplying the EWR under current conditions as there were no improvements. The current operation of the system met the PES-REC at most sites.

### 8.4.2 Consequences of supplying the EWR under future 2020 development conditions (Sc 6)

The results are summarised in a traffic diagram for the main river and an evaluation of the tributaries in Figure 8.3.



**Figure 8.3 Ecological consequences of Sc 5 and 6**

The conclusions are summarised as follows:

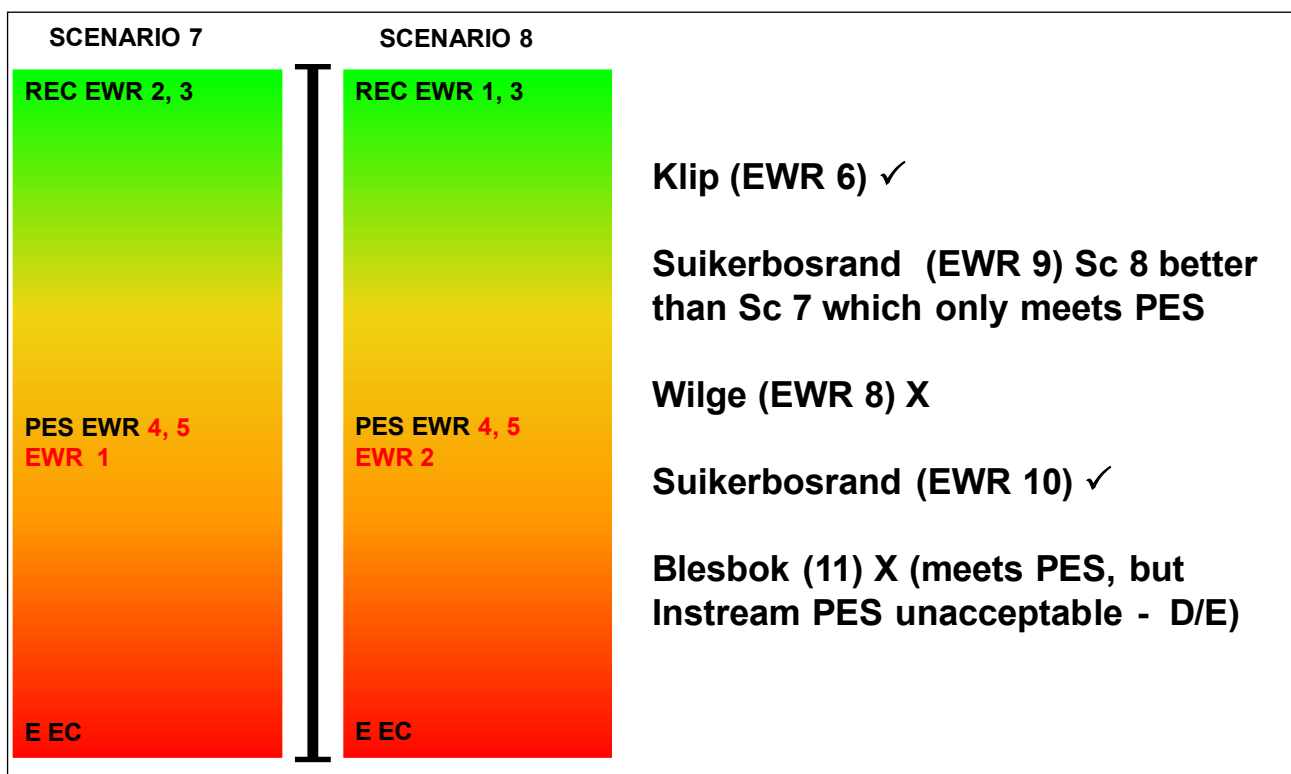
- There were no differences between Sc 5 and Sc 6.
- Scenario 5 and 6 failed to meet the REC at EWR 4. Meeting the REC at EWR 4 is unlikely due to operational constraints and the significant demand on the Vaal Dam. To meet the REC at EWR 4, higher flows in summer is required and lower flows in winter.
- Scenario 5 and 6 did not meet the EWR objectives at the Wilge River (EWR 8). This was due to the increased supply from Sterkfontein Dam which resulted in flows much higher than natural during the dry season (e.g. 15 m<sup>3</sup>/s during the driest month at 50% exceedence instream of the 2 m<sup>3</sup>/s which occurs during natural flows).

- Scenario 5 and 6 did not meet the objectives at the EWR 11 and the lower Suikerbosrand, EWR 10. This was not surprising as the Blesbokspruit has significant water quality problems as well as to MUCH water. Decreasing flows could exacerbate the water quality problems, and this river actually requires a specific management plan which addresses its problems with the focus on water quality as first priority.

In conclusion, there was no advantage in supplying the EWR under 2020 conditions as Sc 5 has the same ecological consequences as Sc 6.

### 8.4.3 Consequences of supplying the EWR under full utilisation conditions (Sc 8)

The results are summarised in a traffic diagram for the main river and an evaluation of the tributaries in Figure 8.4.



**Figure 8.4 Ecological consequences of Sc 7 and 8**

The conclusions are summarised as follows:

- There were minor differences between Sc 7 and Sc 8 as Sc 7 met the objectives at EWR 2 and not at EWR 1 and Sc 8 met the objectives at EWR 1 and not at EWR 2.
- Scenario 7 and 8 failed to meet the REC at EWR 4 and 5. Meeting the REC at EWR 4 is unlikely due to operational constraints and the significant demand on the Vaal Dam. To meet the REC at EWR 4, higher flows in summer is required and lower flows in winter.
- Scenario 7 and 8 did not meet the EWR objectives at the Wilge River (EWR 8). This is due to the increased supply from Sterkfontein Dam which results in flows much higher than natural during the dry season (e.g. 15 m<sup>3</sup>/s during the driest month at 50% exceedence instream of the 2 m<sup>3</sup>/s which occurs during natural flows).
- Scenario 7 and 8 did not meet the objectives at the Blesbokspruit EWR site 10. This is not surprising as the Blesbokspruit has significant water quality problems as well as to MUCH water. Decreasing flows could exacerbate the water quality problems, and this

river actually requires a specific management plan which addresses its problems with the focus on water quality as first priority.

In conclusion, there is no advantage in supplying the EWR under full utilisation as Sc 7 has the basically the same ecological consequences as Sc 8.

#### 8.4.4 Comparison of Sc 4, 6 and 8

When comparing the 3 relevant traffic diagrams (Figure 8.5), that for the main Vaal River, the Sc 5 related to the 2020 future development was the most desired. This was based on the fact that it achieved the REC at EWR 5 which is situated in the Vredefort Dome which is a World Heritage site. However, one must remember that this statement is based on the evaluation of the scenario provided by WRP and as there is no guarantee that in the interim, the operation could change from what WRP provided, or that there could actually be various possible scenarios, this statement could not hold true. Additionally, it was also the only scenario that achieved the EWR objectives at both EWR 1 and 2. It must be noted however that Scenario 7 did not meet the PES at EWR 1 only because fish dropped with half a category. Taking into account the uncertainty coupled to the hydrological modelling and ecological interpretation, this could be evaluated as meeting the PES.

The tributaries were better off under current conditions, however, most of the issues relating to tributaries could be addressed separately and further refinement of the Planning model rules could address some of the problems.

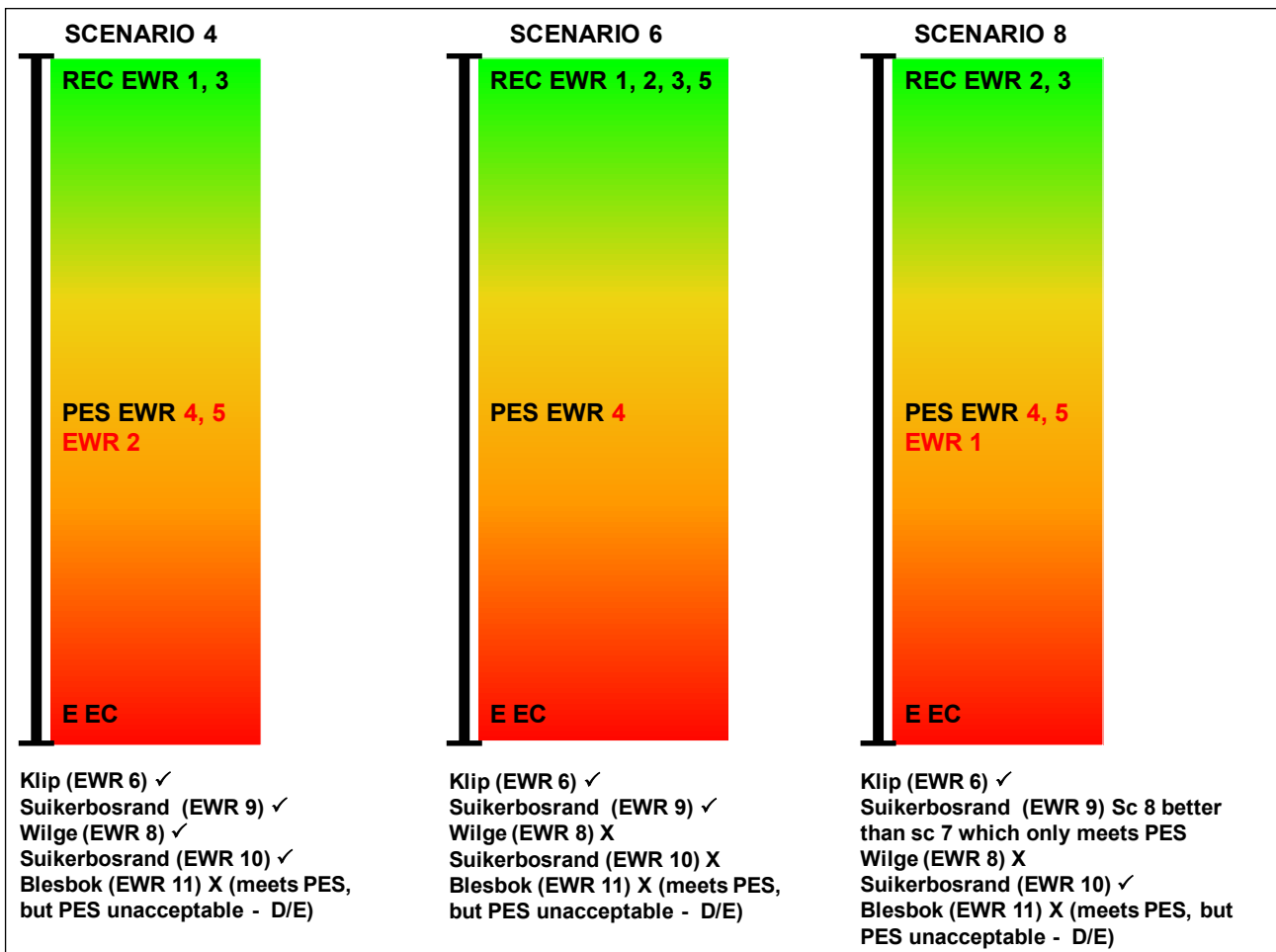


Figure 8.5 Comparison of Sc 4, 6 and 8

## 8.5 GOODS AND SERVICES CONSEQUENCES OF OPERATIONAL SCENARIOS

Author G Huggins (Nomad Consulting)

### 8.5.1 Approach

The assessment provided the outcomes of the evaluation and forecast for each EWR scenario, the social and economic values of changes in the water availability to the socio-economic sectors as well as the value of the ecosystem services by leaving different amounts of water in the river reaches of the Upper Vaal WMA:

- Changes in value of ecosystem services for different EWR scenarios.
- Optimisation of the overall benefits from water re-allocation.

The method that was employed is essentially scenario based. Assessment of the economic impacts of the various scenarios essentially identifies the direction of change (either positive or negative), and estimates the magnitude of the change in benefits and costs that may be experienced within the River System. The process adopted was as follows:

The analysis of potential economic changes was based on a valuation of the status quo, that is, the value of the Goods and Services currently provided by the water in the catchment systems.

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

Where required the current value of Goods and Services was then multiplied by these factors for each scenario, to provide an indication of the potential future value of the Goods and Services. The change in value is thus measured.

The Scenarios evaluated are as set out in Table 8.6. Scenarios were considered, where relevant, against the EWR sites.

Following a site visit and literature research the following goods and services were deemed to be essential to the area and warranted further assessment by the specialist team. These are set out in Table 8.5 below.

**Table 8.5 List of Relevant Goods and Services**

Resources	Common Name	Scientific
<b>Vegetation</b>		
	Sedges	<i>Cyprus marginatus</i>
		<i>Schoenoplectus corymbosus</i>
	Grazing	<i>Cynodon dactylon</i>
	Terrestrial grasses	<i>Themeda triandra</i>
Medicinal	Vlei lily	<i>Crinum bulbispermum</i>
Trees/Wood		<i>Diospyros lycioides</i>
		<i>Rhus pyroides</i>
		<i>Celtis africana</i>
		<i>Salix mucronata</i>
		<i>Rhus lancea</i>
		<i>Rhus pyroides</i>

Resources	Common Name	Scientific
<b>Fish</b>		
	Yellow Fish - small mouth	<i>Labeobarbus aeneus</i>
	Yellow Fish - largemouth	<i>Labeobarbus kimberleyensis</i>
	Sharptooth barbel	<i>Clarias gariepinus</i>
	Carp	<i>Cyprinus carpio</i>
	Largemouth bass	<i>Micropterus salmoides</i>
	Mudfish	<i>Labeo capensis (Umbratus)</i>
Subsistence fishing		
Recreational Fishing		
<b>Services</b>		
Waste assimilation		
Waste dilution		
Cultivated floodplains		
<b>Disservices as costs</b>		
Pathogens treatments		
Pathogens productivity loss		
Cholera treatment		
Cholera productivity loss		
Water treatment costs		

### 8.5.2 Summary of scenarios and impacts

A schematic summary of the impacts by scenario and EWR are provided in Table 8.6. Where shading is green the impact is positive. Darker green is more positive than light green. Yellow indicates neutral or results so mixed as to render a judgment of the impacts virtually impossible. Red indicates negative impact. Again darker red is a more severe negative impact than lighter red.

**Table 8.6 Consequences of the Operational scenarios on Goods and Services in the Upper Vaal**

EWR site	Sc 4	Sc 5	Sc 6	Sc 7	Sc 8
1	Light Green	Light Green	Yellow	Light Red	Yellow
2	Light Green	Dark Green	Light Green	Dark Red	Dark Red
3	Light Green	Light Green	Light Green	Light Green	Light Green
4	Light Green	Light Green	Light Green	Yellow	Light Green
5	Light Green	Light Green	Light Green	Light Green	Light Green
6	Yellow	Light Green	Light Green	Yellow	Yellow
8	Light Green	Light Red	Light Red	Light Red	Light Red
9	Light Red	Light Green	Yellow	Yellow	Yellow
10	Yellow	Light Red	Light Red	Yellow	Yellow
11	Yellow	Dark Red	Dark Red	Yellow	Yellow

Overall only two scenarios at EWR 2 and 11 could be said to be problematically negative from the perspective of goods and services.

## 8.6 RECOMMENDATIONS

Recommendations of further work required to confirm the results provided are described in Table 8.6. The issues regarding each site which must be considered during any further development specifically around ad hoc monitoring is also provided in the table.

**Table 8.7 Identified issues to be addressed and further work needed in future**

Site	Further work	Issues
EWR 1 Vaal	Yield modelling: Determine why there is a difference in hydrology under Sc 7 which results in fish dropping half an EC.	Unresolved water quality issues at this site that could be responsible for fish kills and the bad condition of fish. This site is critical (due to the unique and critical habitat) in this MRU in the Upper Vaal and monitoring is required which should also focus on identifying the cause of the problems regarding fish..
EWR 2 Vaal	Yield modelling: Determine why there is more water than required at both EWR 2 and 3.	There is currently too little flow at EWR 2 and 3. These two sites both consist of critical habitat in the stretch between Grootdraai and Vaal Dam. Any licenses that would require less flows must be tested to determine whether the EWR will be met.
EWR 3 Vaal	See above.	See above.
EWR 4 Vaal		This site is situated immediately below Vaal Dam in the short stretch of river available between the Vaal Dam and the Vaal Barrage and Lethabo Weir. EWR 4 requires an improvement under current conditions to meet the REC. It is acknowledged that the flow conditions are unlikely to be met. However, as this is the only stretch that still maintains viable breeding areas for the fish and therefore maintains the fish population in this stretch as well as acting as a refuge for tributaries, it is vital that there is no further degradation at the site. Monitoring is therefore required and any changes in the Vaal Dam's operation which exacerbates the current 'unfriendly' operating rules must be carefully considered.
EWR 5 Vaal	-	EWR 5 represents the stretch of river below the Vaal Barrage and upstream of the Mooi River confluence. This stretch runs through the Vredefort Dome and taking into account the importance of this world heritage site, no further degradation should be allowed. It is vital that non-flow related measures be considered that could improve this situation. No changes in flow operations that could be detrimental to this site should be considered. Monitoring is essential.
EWR 6 Klip	Although not part of this study, the hydrology regarding the present use must be updated. There are serious concerns on the illegal abstractions and it is highly likely that the modelled present day flows do not reflect reality. An update in hydrology for this site is important.	The biota seems to still be in good condition. However it is possible that they have not yet fully reacted to the obvious increase in abstractions and farm dams. Almost zero flow conditions were experienced during 2 field visits. There is also a very important wetland in the upper Klip River. Any licences that require further abstraction in flows should not be considered based on these results due to the uncertainty in the hydrology. A re-assessment would be required of the EWR once the updated hydrology is available. Monitoring is essential.
EWR 8 Wilge	Determine whether the operating rules associated with Sc 5 and 7 can be modified to accommodate the EWR. Test the EWR to determine whether any changes improve the situation. There is also uncertainty in the present hydrology as this does not reflect the extremely low flow conditions observed in the field. There is also potential of illegal abstractions.	The current problems at this site include too little flow and at times the river literally stops flowing. However, the fish species are mostly semi-rheophilic which means they can survive in pools and the macroinvertebrates could probably re-establish themselves after no-flow conditions. However, any licenses that further decrease flows must be carefully considered, taking into account the uncertainty regarding the hydrology.
EWR 9 Suikerbos- rand	Certain assumptions regarding the release capability of Balfour Dam has been made in the planning model. No information is presently available to determine whether actual releases can be made. The evaluation of scenarios based on this assumption must be confirmed.	The current problems at this site include too little flow and almost zero flow conditions at times. The present hydrology did not reflect this during the EWR assessment. Any license application that implies abstraction of flows must only be considered once more information on Balfour Dam is available. Balfour Dam (and Haarhoff) should be providing an EWR currently which it is not. Any decisions made on the basis of the evaluations of the scenarios must also be treated with care as these are based on an assumption that Balfour Dam can (and will) provide an EWR.
EWR10 Suikerbos- rand; EWR 11 Blesbok-spruit		Water quality issues with reference to urban run-off, mining and SAPPI are dominant at this site. Specific management plans that would probably not influence the main Vaal River are required to address the unacceptable PES in the Blesbokspruit.

The Upper Vaal River system has very high demands imposed on it by the irrigation sector, as well as industrial and domestic sectors and forms the backbone of the economic hub of South Africa.

No specific Ecological Reserve Monitoring has been initiated in this river system apart from the RHP monitoring conducted at EWR 9, 10, 11 and RE-EWR 2<sup>5</sup>. Immediate monitoring is necessary

<sup>5</sup> According to Ms Hermien Roux and Mr Piet Muller, River Health Champions for the North West and Gauteng Provinces respectively (*Pers. Comm.*, 2010).

as the surveys undertaken during the Reserve study represent the baseline against which change is measured. These surveys were undertaken during 2007 and 2008 and it can already (pending changes in the catchments), not be applicable. The longer monitoring is delayed, the bigger the chance is that the baseline surveys will have to be repeated because of outdated data.

The main recommendation is that effective monitoring is started as soon as possible due to the economic importance of the Upper Vaal River and the presence of the Vredefort Dome Heritage site that falls within this study area below the Vaal River Barrage. The Upper Vaal River is exposed to regular water quality related impacts due to industrial activities that are not monitored as well as a failing municipal infrastructure that leads to pollution levels that lead to fish kills and the recreational activities being banned by the Department of Health, especially in the reaches below the Vaal Dam.

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## 9 PRESENT STATE EVALUATION AND MACRO ECONOMIC CONSEQUENCES

Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Socio Economic Consequences of various Operational Scenarios. Report authored by Conningarth Consultants and Tlou Consulting Pty (Ltd.). Produced by Koekemoer Aquatic Services and Rivers for Africa. Report no: RDM/WMA8C000/01/CON/0210.

The purpose of this Task was to determine the Present Economic State (PES) of the Upper Vaal WMA, and to evaluate both the social and economic returns of the existing water use by the various water users within this WMA (WMA 8) and the macro-economic impacts for the possible introduction of the operational EWR scenarios. The objective for determining the PES was to provide a baseline for the comparison of the impacts of the different operational scenarios.

### 9.1 PRESENT STATE EVALUATION

To accommodate the different situations in the main stem of the Vaal River and the tributaries, two models were used to calculate the macro economic impacts of water use in the different economic zones. This was necessitated by the difference in water sources in the two main economic zone types. In the tributaries the irrigation water is drawn from local sources with a large percentage, if not all, of the required demand for the mining and other urban requirements pumped from the main stem.

On the main stem the irrigation water, together with the rest of the demand, is sourced from the Vaal River. A decision was taken by the project team that water demand quantities drawn from the main stem will be supplied by external sources if needed.

On the main stem of the river and for the urban, mining and industrial requirements on the tributaries, the South African Inter-industry Model (SAFRIM<sup>6</sup>) was used to calculate the impact of the introduction of the EWR. For the irrigation from the tributaries the Water Impact Model (WIM<sup>7</sup>) was used to calculate the impact of the introduction of the EWR.

#### 9.1.1 Approach to the SAFRIM/WSM Model

This section presents water multipliers which were calculated using the integrated SAFRIM/WSM infrastructure in such a way that, wherever an exogenous impact is administered, its ultimate impact on endogenous economic aggregates (i.e. GDP, employment, investment, household consumption demand, etc.) represents the total effect (i.e. direct, indirect and induced impacts).

The following steps were followed in preparing the model for the calculation of water multipliers:

**Step 1:** The SAFRIM produces, *inter alia*, 46 sectoral production figures as the endogenous outcomes of an exogenous change originating from any part of the model's configurations, e.g., changes in government expenditure, exports, etc. A change in water demand per sector was proportionately aligned with a production increase/decrease. This ratio is directly based on the average water consumption per unit of production, or average water coefficients. For the purpose

<sup>6</sup> Water Research Commission: K5/1570 – Development of an Econometric Model to Predict the Effect that Various Water Resource Scenarios Would Have on South Africa's Economic Development.

<sup>7</sup> Department of Water Affairs: 2005 – High Confidence Reserve Determination of the Letaba River Catchment: Development of a Water Impact Model.

of this calculation, it is assumed that each sector in turn receives an additional one million m<sup>3</sup> of water, whilst keeping water demand of the other sectors in the economy constant.

**Step 2:** Having established the production value equivalent of one million m<sup>3</sup> of water consumed per sector, it is now possible to increase the final demand of each sector with this calculated amount. This demand vector is then fed into SAFRIM which then in turn estimates the total increase in production per sector (46) flowing from this increase in water input per sector. It is important to emphasise again that the increase in production estimated by the model encompasses the total (i.e. direct, indirect and induced) impact of an increase in water consumption.

**Step 3:** The third and crucial step is to use these resultant production impact figures to “shock” the WSM. As is well-known by now, this WSM consists of 65 sectors, and that agriculture is “driven” by the number of hectares irrigated. As such, the production figure derived at in Step 2 has to be converted into hectares in order to activate that part of the model. Ultimately, the WSM provides the total water consumption per sector which is associated with a one million m<sup>3</sup> increase in water consumption per sector.

**Step 4:** Lastly, the results of Steps 2 and 3 are divided by one another to provide a Water Multiplier as such – i.e. the amount of GDP, employment, investment and household income per (additional) cubic meter of water consumed (this can, to some extent, be construed as a crude measure of water’s marginal productivity).

### 9.1.2 Approach for Production Inputs: Macro-economic Forecasting Model

The Macro-economic Forecasting Model (MFM)<sup>8</sup> model, developed by Conningarth Economists, in this study forecasts economic activity (measured as production output) and household growth (measured in household units) for the national economy, as well as at Magisterial District<sup>9</sup> level for the 14 year period from 2006 to 2026.

The MFM model captures the integrated nature of the South African economy in terms of the linkages that occur between economic sectors and households throughout the national economy and between geographical areas as represented by the Magisterial Districts. Furthermore, the model also captures the linkages that exist between the South African national economy and its international trading partners by incorporating imports and exports into the model. As such, the forecasts produced by the MFM model are based on macroeconomic data which provides a 'top-down' perspective on the broader national economy.

The output of the MFM model was compared with that produced by the strategic socio economic study undertaken by Conningarth Economists. In this way, it was possible to compare the results of a bottom-up and a top-down approach to forecasting economic activity and household growth, with the result that it will be possible to produce more accurate and more reliable forecasts for production demand.

For the purpose of this Upper Vaal study the production estimates for the year 2006 was used. The sectoral classification reflected in the MFM estimates do not conform to the SAFRIM Water Satellite Model classification in respect to every sector. Electricity and water, for example, are reflected as one sector in the model while mining and industry are again sub-divided into more

<sup>8</sup> ESKOM: Thabile Engineering – 2008- Economic Modelling for the Load Forecast and Strategic Study of the Watershed Network Master Plan.

<sup>9</sup> It is important to note that the Magisterial Districts used in this study have been derived from Census 2001 data. As such, these Magisterial Districts reflect their old, original names and boundaries.

detail than is required by the SAFRIM model. In such cases of non-conformity, either a realistic percentage division was made of the sector or the sector sub-divisions were totalled.

## **9.2 THE WATER IMPACT MODEL (WIM)**

### **9.2.1 Description of the WIM**

Although reduced water allocation and/or lowering assurances of supply will directly impact on water users, there are also broader macroeconomic implications at a regional level. In order to assess the indirect impacts of re-allocation of water a WIM developed by the project team, was constructed for each tributary. This model is based on the Input-Output Model. The economic model is based on a steady state social (i.e. low income household, employment and levels of income) and financial contribution made by water users with a water allocation. Gross revenue, gross margins, cash returns and net profits calculated for the base case will be used to compare with the gross revenues and margins of the other allocation scenarios. One of the key inputs is the water allocation to each sector which is provided from the Water Resource Planning Model (WRPM) as basis.

The WIM was structured by economic zones which comprises the quaternary catchment in a specific tributary. It is structured to determine the implications of sectoral changes in water allocations to the social and economic well-being of the communities in the economic zone. In doing so, the impact of changes in water use patterns can be uniquely measured for each water user sector in the economic zone and comparative analyses between various user sectors can be performed in terms of the economic impacts emanating from each water re-allocation scenario.

### **9.2.2 Economic Multipliers**

All economic models incorporate a number of “multipliers” which form the nucleus of the modelling system. The nature and extent of the impact of a change in a specific economic quantity (e.g. exports) on that of another economic quantity or quantities (e.g. production output or employment) is determined by a “multiplier”.

A multiplier summarises the total impact that can be expected from change in a given economic activity. One Rand is received into the local economy of a Water Management Area (WMA) from sales beyond the WMA borders. Of this one Rand, 40 cents is spent for goods and services within the WMA. The economic sectors and individuals who receive the 40 cents spend 16 cents within the WMA. Of the 16 cents, only six (6) cents is spent locally and so on. The total amount of money received by local firms and residents as a result of the initial one Rand in added exported earnings is R1.66. Therefore the multiplier is R1.66.

The change in economic activity resulting from the change in one factor of production, such as water resources, is measured by different multipliers. Four multipliers are commonly used to assess the impacts of an initial increase in production resulting from an increase in sales, usually called final demand in a multiplier analysis. The four are: (1) Output, (2) Employment; (3) Income; and (4) Value Added Multipliers.

### **9.2.3 Calculation of Multipliers**

Sectoral multipliers are calculated using information contained in the applicable Provincial Social Accounting Matrix (SAM), the National RSA SAM and data obtained from the Reserve Bank of South Africa and Statistics South Africa. These inverse matrices capture all of the direct and

indirect relationships among the inputs and outputs of the various entities included in the applicable provincial SAM.

Direct GDP, labour and capital multipliers for each sector were calculated using the following formula:

$$\text{GDP multiplier} = \frac{\text{Value Added}}{\text{Production}}$$

$$\text{Labour multiplier} = \frac{\text{Employment}}{\text{Production}}$$

$$\text{Capital multiplier} = \frac{\text{Capital stock}}{\text{Production}}$$

These Multipliers were incorporated into the Water Impact Model and used to calculate the macro-economic impacts.

By using a SAM for the applicable region, the above multipliers can be calculated. The multipliers that were used in this study to determine the economic impacts are as follows:

- Economic growth (i.e. the impact on GDP).
- Employment creation (i.e. the impact on labour requirements).
- Income distribution (i.e. the impact on low-income, poor households and the total income households).

A breakdown of the different effects of the agricultural sector multipliers used in this study is as follows:

- Direct Impacts: Refer to effects occurring directly in the agriculture sector.
- Indirect Impacts: Refer to those effects occurring in the different economic sectors that link backward to agriculture due to the supply of intermediate inputs, i.e. fertilisers, seeds, etc.
- Induced Impacts: Refer to the chain reaction triggered by the salaries and profits (less retained earnings) that are ploughed back into the economy in the form of private consumption expenditure.
- Total Impacts: Refer to the direct, indirect and induced summed effects.

### 9.3 ECONOMIC ZONES

For analysis purposes the names given to the Economic Zones (EZs) were as follows:

- Economic Zone 1: Main stem – up to Grootdraai Dam
- Economic Zone 2: Main stem – between Grootdraai Dam and the Barrage
- Economic Zone 3: Main stem – between Barrage and the Middle Vaal WMA
- Economic Zone 4: Tributary – Wilge
- Economic Zone 5: Tributary – Klip River 1
- Economic Zone 6: Tributary – Waterval
- Economic Zone 7: Tributary – Suikerbosrand/Blesbok
- Economic Zone 8: Tributary – Klipriver 2 (Gauteng)
- Economic Zone 9: Tributary – Mooi

The Economic Zones of the Upper Vaal WMA is provided in Figure 9.1.

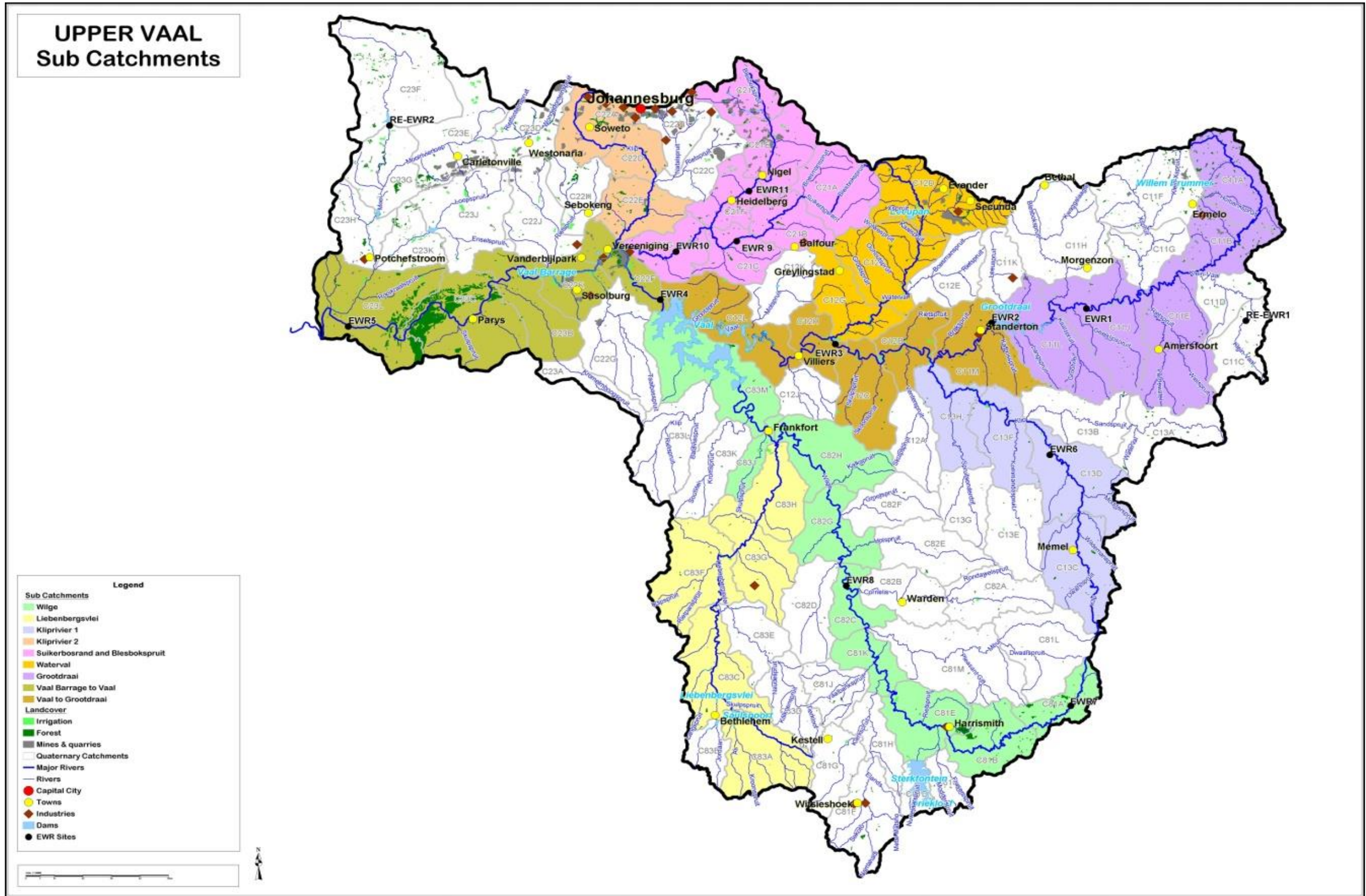


Figure 9.1 Economic Zones of the Upper Vaal WMA

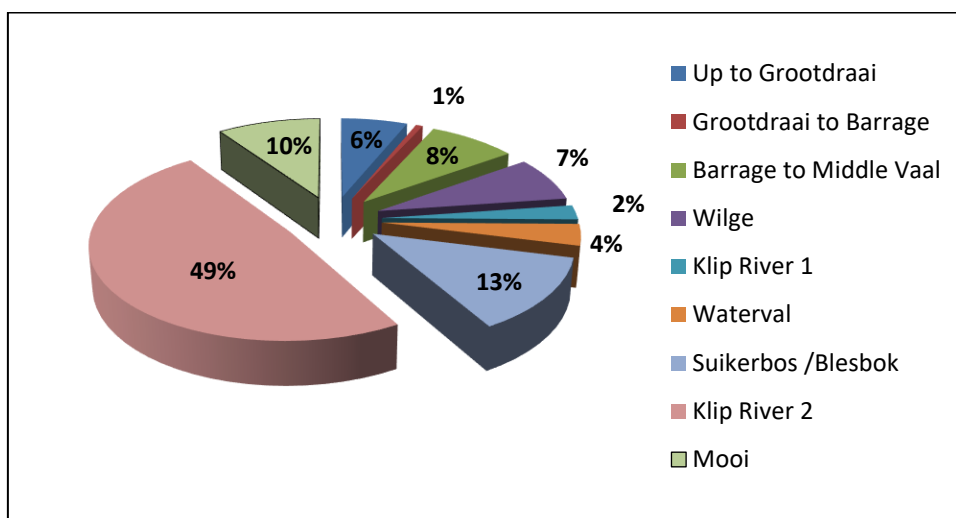
## 9.4 RESULTS

Table 9.1 below shows the population distribution in the Upper Vaal EZs.

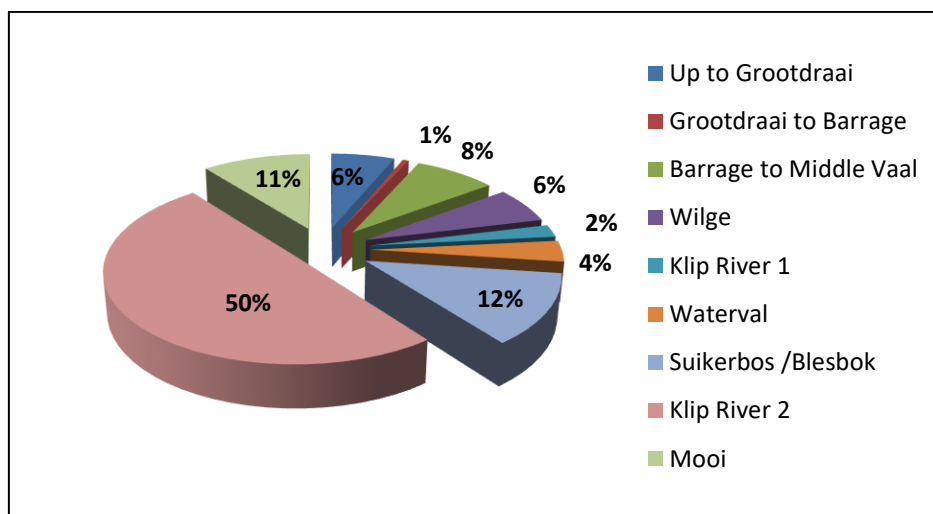
**Table 9.1 Population distribution for the Upper Vaal WMA for 2006 (Numbers)**

Description	EZ 1	EZ 2	EZ 3	EZ 4	EZ 5	EZ 6	EZ 7	EZ 8	EZ 9	Total
	Up to Grootdraai	Grootdraai to Barrage	Barrage to Middle Vaal	Wilge	Klip River 1	Waterval	Suikerbos	Klip River 2	Mooi	
<b>HOUSEHOLDS</b>										
High income	11 905	626	29 105	7 048	2 779	15 593	57 173	166 295	22 054	312 577
Low income	272 300	26 121	351 182	276 795	96 130	162 608	546 187	2 179 298	463 066	4 373 686
Rural	132 577	17 129	176 682	224 906	66 178	67 366	249 630	923 067	160 878	2 018 414
<b>Total</b>	<b>416 782</b>	<b>43 876</b>	<b>556 966</b>	<b>508 749</b>	<b>165 087</b>	<b>245 567</b>	<b>852 991</b>	<b>3 268 661</b>	<b>645 999</b>	<b>6 704 677</b>

Source: Census 2001 Magisterial District data adapted by Conningarth Economists.



**Figure 9.2 Total population distribution in the Upper Vaal WMA (2006 numbers)**



**Figure 9.3 Low income population distribution**

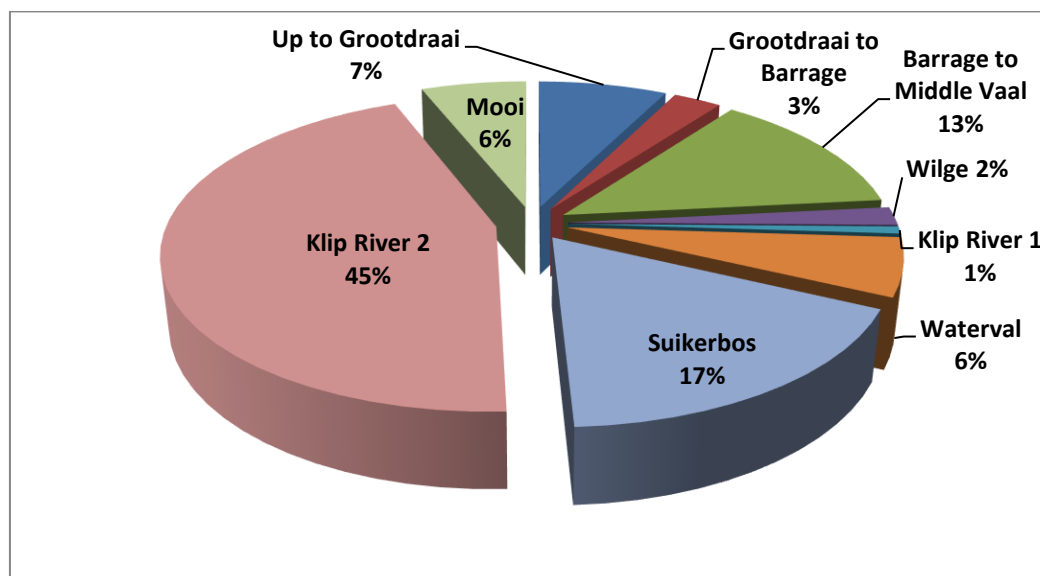
Table 9.1 and Figures 9.2 and 9.3 showed that 50% of the population in the WMA was in the Klip River 2 ( Gauteng) Economic Zone (EZ 8). This applied to the total as well as the low-income section of the population.

In the tables and figures below the GDP and Employment of the main water users are expressed per EZ.

### 9.4.1 Direct GDP

**Table 9.2 Total direct Gross Domestic Product (GDP) per EZ (Rand Million)**

Economic Zone	EZ 1	EZ 2	EZ 3	EZ 4	EZ 5	EZ 6	EZ 7	EZ 8	EZ 9	Total
Total	18 530	6 937	32 787	4 712	1 858	14 903	43 163	111 236	15 162	249 290



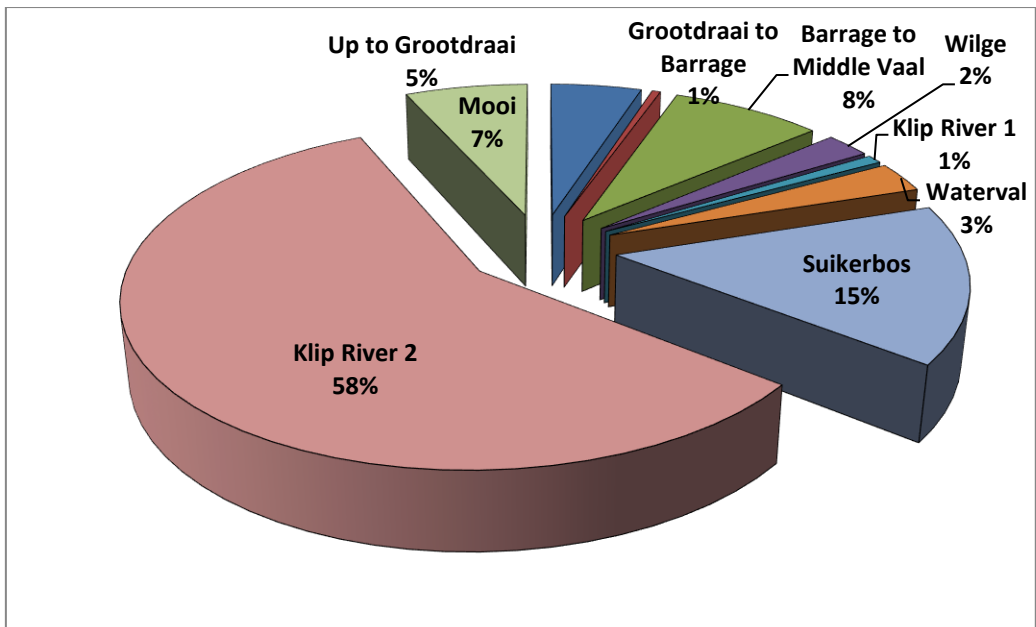
**Figure 9.4 Total direct Gross Domestic Product (GDP) per Economic Zone (Rand Million)**

Table 9.2 and Figure 9.4 show that, as far as GDP was concerned, Klip River 2 was the largest contributor with 45%, followed by Blesbok-Suikerbos with 17% and the Barrage to Middle Vaal with 13% Economic Zones.

### 9.4.2 Direct Employment

**Table 9.3 Total direct employment per EZ**

Economic Zone	EZ 1	EZ 2	EZ 3	EZ 4	EZ 5	EZ 6	EZ 7	EZ 8	EZ 9	Total
Total	139 318	12 982	231 888	68 698	23 363	83 261	430 687	1 610 966	187 641	2 788 805



**Figure 9.5 Total direct employment per EZ**

Table 9.3 and Figure 9.5 indicate that 58% of the employment was in the Klip River 2 (Gauteng) Economic Zone, followed by 15% in Hartebeest-Suikerbos EZ, with 8% in the Barrage to Middle Vaal economic zone.

The above showed the very important position of the three economic zones representing 70% of the GDP and 71% of the employment in the Upper Vaal Water Management area.

## 9.5 OPERATIONAL SCENARIOS

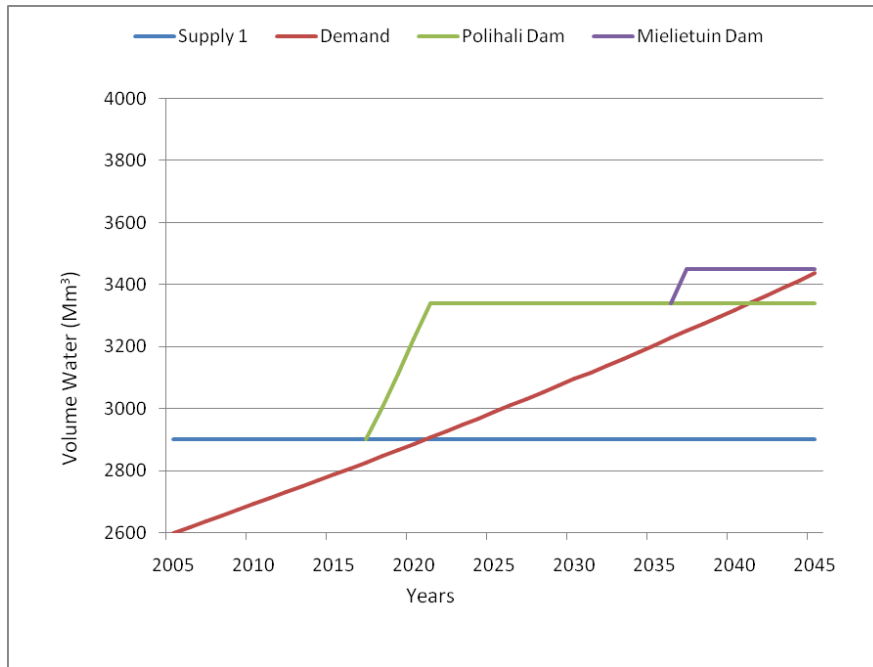
### 9.5.1 Approach

#### *Main Stem*

The approach to the economic impact of the application of the operational scenarios in the main stem was guided by the following directives:-

- The expected demand will be provided, and
- Water Conservation and Demand Management policies will be in place and applied.

Figure 9.6 gives an indication of how the Department of Waters Affairs is approaching the supply of additional water to the Vaal system. When interpreting the graph please take note that the values and years mentioned are fictitious and is only an illustration to convey the concept.

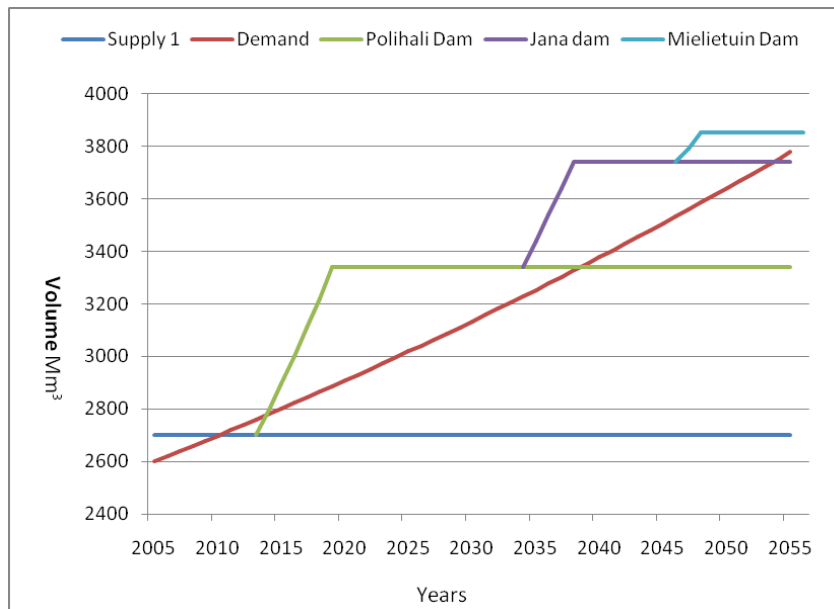


**Figure 9.6 Illustration of the planned dam construction to supply the Vaal River system**

The blue line represents the current supply available, before the introduction of the EWR, with the red line representing the estimated growth in demand. According to the present projected planning scenario the Polihali Dam in Lesotho will be build first (represented by the green line), followed by the Mielietuin Dam in the Tugela (purple line) and later to be followed by the Jana Dam also in the Tugela. The Polihali and Jana Dams are very large dams with the Mielietuin a much smaller dam.

In terms of the economic evaluation this is then established as the current situation, any deviation from this position will affect the economic position. Moving the delivery date for the Polihali Dam will be a deviation, and changing the order of construction will be a deviation which will have economic implications.

The original projection was that the introduction of the EWR will reduce the available present supply, which will probably require that the Jana Dam be constructed before the Mielietuin Dam and even force the construction of the Polihali Dam to an earlier date. Figure 9.7 gives an indication of such a possible scenario.



**Figure 9.7 Theoretical illustration of the possible impact of the introduction of the EWR on the water provision situation on the Vaal System**

Figure 9.7 indicates that the supply available will be less than the pre-EWR supply and that the Jana Dam will have to be constructed before the Mielietuin Dam to accommodate the expected volume growth in demand.

The Unit Reference Values (URV) for the three dams was within acceptable limits if kept in the same order of construction; the Rand per m<sup>3</sup> cost to deliver the water do not differ much. However, with the Polihali and Jana Dams being very large dams and the Mielietuin Dam being a much smaller dam, the result is that the total construction cost for the Mielietuin Dam will be much less than for Jana. Expressed in 2007 prices the estimated cost for the Polihali Dam is R5 175.35 million, for the Jana Dam R6 425.24 million and for the Mielietuin Dam R2 100.00 million.

Constructing the Jana Dam first would involve much more capital than the construction of the Mielietuin Dam, resulting in a large capital investment being required earlier than anticipated and resulting in higher water tariffs than originally projected.

If the construction cost of the Jana Dam is presented by  $RX_j$  and that of the Mielietuin Dam by  $RX_m$ :

$RX_j > RX_m$ , then

- The difference  $RX_j - RX_m$  represents the extra capital cost involved,
- And taking into consideration that the water volume demand per annum will have to cover the extra capital cost, because although a larger volume is available it will not be used immediately. The impact on the tariffs is then capital and maintenance divided by incremental annual increase in the volume water. With  $RX_j$  more than  $RX_m$  it follows that the tariff paid for water from the Jana dam will be more than the tariff from the Mielietuin dam.
- Annual growth will take a number of extra years to reach the full capacity of the Jana Dam compared to the smaller Mielietuin Dam. Resulting in the consumers paying a higher tariff for water than the original planning projection.

This was the anticipated result on the main stem if the EWR is implemented; however, the water demand projections have now shown that it would not be necessary as the projected supply from Polihale and Mielietuin Dams will support the introduction of the EWR, with minor adjustments.

According to DWA (2010a):

- Implementation of the EWR resulted in more water to be transferred via the VRESSAP pipeline (an additional amount of 55.6 million m<sup>3</sup>/a is to be transferred for Scenario 8).
- Implementation of the EWR did not impact on the date on which the next augmentation scheme would be required; and
- Implementation of the EWR resulted in Sterkfontein Dam to be operated at lower storage levels (average storage for Scenario 7 was 2 367 million m<sup>3</sup> compared to the average storage of 2 294 million m<sup>3</sup> for Scenario 8).

From the above it appears that the only costs possibly foreseen are the additional pumping cost through the VRESSAP pipeline and possible monetary implications of the increased risk during times of drought because the Sterkfontein Dam storage is operating at a slightly lower level than without the EWR in place. However, further investigation into additional pumping and the related implied costs revealed that the lower operational storage levels of the Sterkfontein Dam did not affect the risk under which the system operates. After discussions with Pieter van Rooyen it was decided that it was not worthwhile to allocate a monetary value to the risk, if the proposed Polihali Dam was to be constructed within the projected period and therefore the extra pumping cost was discounted into the final calculations.

### ***Tributaries***

The calculation of the macro-economic impacts of a specific scenario in a tributary was guided by a number of assumptions and operational realities. The base assumptions were the following:

- The population, industry and mining would receive the expected water demand within Water Conservation and Demand Management targets. These targets were determined outside of the present study and it was assumed that they will be applied.
- Eskom power stations would receive the water needed for power generation.
- Curtailments would be instituted against irrigation if necessary to implement EWR targets.

The operational realities referred to included the following:

- Except for certain smaller urban areas, the urban population receive their water from the main stem of the Vaal River, via Water Boards and pumping schemes.
- Water is pumped from the main stem into catchment of certain tributaries to satisfy the demand. The VRESSAP line pumping water to the Secunda complex is an example.
- A few mines and smaller industries still receive water from a source in the tributary.
- It is too expensive to pump water into the tributaries for irrigation purposes.

With the above in place the impact per EWR site was restricted to irrigation activities, accepting that all other demands will be met.

According to DWA the volume of water allocated to irrigation in the Upper Vaal WMA has been ring fenced and no further volume increases will be allowed. However, nothing prevents farmers from improving their management practises and upgrading technology which will result in both vertical and horizontal expansion of their enterprises with the same volume of water.

Ecological consequences are determined at EWR sites which represent a Management Resource Unit. For comparison purposes, the EWR sites had to be allocated to the EZ zones. Table 9.4 below shows the overlaying of the economic zones and the EWR sites of which quantitative analyses were performed.

**Table 9.4 Detailed information regarding the distribution of Economic Zones to tributary catchments**

Economic Zone	River Type	Economic Zones	Catchment for Scenarios	EWR sites in EZs
EZ 1	Main Stem	Up to Grootdraai Dam	Klein Vaal; Vaal River at Uitkoms	RE-EWR 1; EWR 1
EZ 4	Tributary	Wilge	Wilge at Bavaria	EWR 8
EZ 5	Tributary	Klip River 1	Klip River	EWR 6
EZ 6	Tributary	Waterval	Waterval	EWR WA1 and EWR WA2
EZ 9	Tributary	Mooi	Mooi River (Klipdrift Dam)	EWR M2

### 9.5.2 Calculating the impacts of operational scenarios

The current economic activities were calculated using the economic models and together with the water demand per economic activity appropriate multipliers per activity was calculated.

Available water volumes for the specific EWR sites in the EZs were obtained from DWA (2010a).

The economic impacts of the scenarios were calculated by using the multipliers which were derived from the present state evaluation with the volume changes per EWR site. If the EWR site was situated in Economic Zone 1, a specific multiplier was developed for that zone. For example the employment multiplier is calculated as follows:

$$\text{Employment [Numbers] (EZ1) / Water Volume [Mm}^3\text{] (EZ1)}$$

This multiplier was used together with the change in water volume at a EWR site situated per scenario. The impact on employment was therefore represented in the following:

$$\text{Change in Water Volume [Mm}^3\text{] (EWR site in Zone 1) x Employment multiplier [Number/Mm}^3\text{] (EZ1)}$$

$$= \text{Employment Impact of EWR in EZ1 [Number]}$$

The same methodology was applied to calculate the impacts on GDP and households.

### 9.5.3 Evaluation of the operational EWR scenarios

In evaluating the impact of the scenarios it was necessary that the evaluation was done against the background of a number of factual realities and assumptions, namely:

- That the water demands at a specific EWR point was not representative of the total irrigation water use in the economic zone. However it gave a good indication of the situation in the rest of the zone.
- The multipliers used to calculate the impact at the specific point was calculated using the total irrigation activity in the zone, there was therefore a chance that the crop mix at the EWR point would differ from the mix in the total zone.
- The base irrigation water use was fixed in 2008 terms. It was assumed that the present crop mix would not change during the coming years.

- The impacts were based on the use of the total water per zone, without making a distinction between lawful and unlawful use.

The impact of the operational scenarios was extrapolated to compare the macroeconomic impacts on the total economic zones and the WMA and not only the area around the EWR point.

#### 9.5.4 Data source

Water volume data, required to determine the economic impacts of the operational scenarios, were provided from WRP (DWA, 2010a). The analysis of the water resource modelling in the Upper Vaal WMA was the result of evaluating a number of scenarios (Chapter 8; Table 8.1) by the rest of the project team, but the water volumes supplied to the economic team were Scenarios 7 and 8. With Scenario 7 representing the full water utilisation at a specific EWR site in 2020 without the introduction of the EWR. Scenario 8 represented the full utilisation in 2020 at a specific site with the introduction of the EWR. The impact of the introduction of the EWR was then the difference in water volume to the irrigators, which is then expressed in macroeconomic parameters.

#### 9.5.5 Assumptions

The following assumptions for the main stem as well as the rivers in the tributary catchments were applied:

- The basket of irrigation crops were not changed when the water was reduced in the scenarios.
- The water volumes identified for the lawful and unlawful use were combined to determine a total economic impact of what the economic value of water provides.

## 9.6 RESULTS

Table 9.5 represents the results of the introduction of the EWR, comparing the impact with base situation for irrigation per economic zone.

**Table 9.5 Comparison of the Impact of Scenario 7 and Scenario 8 in all the EZs of the Upper Vaal WMA**

Economic Zone	GDP		Employment		Households	
	Base	EWR Impact	Base	EWR Impact	Base	EWR Impact
EZ 1. Main Stem Up to Grootdraai Dam	R 160.55	R -3.59	2271	-28	R 56.18	R -1.18
EZ 2. Main Stem - Grootdraai to Vaal Barrage	R 238.09	R 0.00	3050	0	R 83.12	R 0.00
EZ 3. Main Stem - Vaal Barrage to Middle Vaal WMA	R 143.69	R 0.00	1841	0	R 50.16	R 0.00
EZ 4. Wilge Tributary	R 232.61	R 0.00	3999	0	R 79.63	R 0.00
EZ 5. Klip 1 Tributary	R 47.19	R -0.63	590	-15	R 15.39	R -0.23
EZ 6. Waterval Tributary	R 66.50	R -0.57	942	-15	R 22.25	R -0.21
EZ 7. Suikerbosrand Tributary	R 98.45	R 0.00	1975	0	R 114.10	R 0.00
EZ 8. Klip 2 Tributary	R 195.08	R 0.00	4285	0	R 69.50	R 0.00
EZ 9. Mooi Tributary	R 143.13	R 0.00	1925	0	R 47.73	R 0.00
<b>Total</b>	<b>R 1 325.29</b>	<b>R -4.79</b>	<b>20877</b>	<b>-59</b>	<b>R 538.07</b>	<b>R -1.62</b>

From Table 9.5 it appears that the operational scenarios are only impacting on three of the nine economic zones and that the projected impact on the three economic zones would be very small. With a possible 59 jobs lost compared to a total employment of over 20 000 in the sector and a loss of R1.62 million in payments to low-income households.

However, it is important to keep in mind that although irrigation agriculture was not a very important sector in the WMA, it still contributed to food security with over 40 000 irrigated hectares in grain production and overall it supports 20 877 employment opportunities, mostly in the rural areas. The grain (cereal) production is a mix of maize, wheat and grain sorghum, with maize and grain sorghum production in the summer, followed by wheat during the winter.

For two tributaries, Suikerbosrand and Klip River 2 (Gauteng), no operational scenarios were presented for analysis.

## **9.7 RECOMMENDATIONS**

The weakness of the specific methodology used is that it only gives an overall picture of the impact with no indication of an impact on an individual irrigator.

It was recommended that at the time of the introduction of the EWR a detailed study be implemented to identify the possible economic impacts on individual producers in areas where major irrigation water curtailments are foreseen.

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## 10 IDENTIFICATION OF ECOSPECS

Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoSpecs Report. Report produced by Koekemoer Aquatic Services and Rivers for Africa. Report no: RDM/WMA8C000/01/CON/0310.

The purpose of this task was to set EcoSpecs and TPCs that could be used for future Ecological Water Resource Monitoring (EWRM). Further information on Ecological Water Resources Monitoring can be obtained from DWA (2009), and Kleynhans *et al.* (2009).

### 10.1 APPROACH

The NWA requires the establishment of a national monitoring system that must provide for the collection of appropriate data and information necessary to assess water resources. Such a system must collect relevant information that contributes to the management of the resource in a desirable ecological condition

Initially the aim was to develop monitoring guidelines and a Decision Support System (DSS) for Ecological Water Requirements (EWR) as required for the Ecological Reserve determination. River Health Programme (RHP) monitoring as such was not included. However, the implications of simultaneously operating two separate ecological monitoring programmes (Ecological Resource monitoring (ERM) and RHP) have serious resource implications. To mitigate this and still maintain an operational ecological monitoring programme that provides useful management information, integration of the ERM and RHP within an adaptive management approach is proposed (Kleynhans *et al.*, 2009). **This forms the basis of the integrated Ecological Water Resource Monitoring (EWRM) approach.**

During EWR studies, EcoSpecs are developed and specified in terms of the Resource Quality Objectives (RQOs) as per the Resource Directed Measures and the EcoClassification process (Kleynhans and Louw, 2007). This encompasses biological specifications or biocriteria that are numerical values or narrative statements that define a desired biological condition for a waterbody (Burton and Gerritsen, 2003). EcoSpecs then indicates the ecological detail that characterizes the EC.

TPCs indicate the values around the EcoSpecs that, if being approached would initiate more detailed investigation or even management action. TPCs are based on the acceptance that there is uncertainty as to accuracy or validity of EcoSpecs i.e. is deviation from EcoSpecs due to natural variation, sampling error, etc. In the context of EWRM, TPCs are regarded as early warning indicators of potential change from a particular Ecological Category (EC) to another (lower) EC.

EWRM operates within the following concepts (based on Elzinga *et al.*, 1998):

- The reference condition is the natural or unimpaired condition of the system.
- The monitoring baseline is a series of measurements taken before the initiation of the impact or management activity and is used for comparison with the series of measurements taken after the management activity. If the PES of the resource is unimpaired (natural), the reference will also be the baseline.
- It is important to assess whether there is a trend in the baseline, i.e. is it stationary or changing in a particular direction at the time when it is determined.
- This is the standard (“benchmark”) against which future deviations can be compared.

Therefore the Present Ecological State (PES) of the system must be determined prior to management interventions i.e.:

**PES = BASELINE = BASELINE ECOLOGICAL CATEGORY (BEC)**

Management actions are designed to maintain, or attain (if different from the PES) the REC. These management actions relate to the management objectives which are described in terms of the flow and quality (physico-chemical) EcoSpecs. Additional land use objectives may also be described if these non-flow related aspects are contributing to the PES of the system.

**Therefore one must clearly distinguish between setting management objectives in terms of the drivers to achieve/maintain certain Ecological Categories, and defining EcoSpecs for the biophysical response, that describes, in different level of detail, the Ecological Categories.**

In essence, during an EWR study, flow requirements (main driver) are defined that could result in a certain ecological state defined through an ecological category. These flow requirements inform the management objectives supported by the other drivers. Note that the word 'could' is used as the biological responses to driver conditions are all predicted and must be tested through monitoring. Determining the Ecological Response through monitoring, examines the predictions made during an EWR study, and/or whether adjustments to the EcoSpecs and TPCs are required. and of course, whether the overall management objective in terms of the REC (or class) is being achieved. It is therefore crucial that monitoring be driven by objectives as it forms the foundation of a monitoring project (cf. Elzinga *et al.*, 1998):

The condition and response of the resource is therefore monitored to determine if the REC has been attained or maintained.

**What is required at this stage is to provide detailed EcoSpecs and TPCs for the baseline, i.e. the BEC for the biological responses, physico-chemical variables and geomorphology.**

**The focus on this study is to provide the detailed EcoSpecs and to define the TPC for the BEC, i.e. the current or initial PES. Note that TPCs are set within the PES to indicate the probability or relative risk of the BEC changing to a lower EC. The purpose of this is to implement management actions to prevent this degradation, unless the Classification system has resulted in a state worse than the PES (BASELINE EC) being selected as the CLASS.**

The same level (qualitative/narrative to quantitative) of EcoSpecs is not set for the REC or any other EC as the focus is on the BEC. The level of EcoSpecs defined during the EcoClassification process will be sufficient during the initiation of monitoring. The EcoSpecs for ECs other than the PES are predictions and dependant on many driver variables and in essence, represents only one combination of driver conditions out of many that could result in this EC

## **10.2 RESULTS**

EcoSpecs and TPCs are listed in detail for each EWR site for:

- Physico-chemical variables
- Geomorphology
- Riparian vegetation

- Fish
- Macroinvertebrates

These are highly detailed and quantified data that must be refined during an Adaptive Management process within EWRM. A summary of the EcoSpecs and TPCs are provided as Appendix A.

### 10.3 CONCLUSIONS AND RECOMMENDATIONS

To date formal implementation of the monitoring step of the Reserve has not taken place (CJ Kleynhans, C Thirion, *pers. comm*). Furthermore, there has been minimal (only informally on the Palmiet River and on a private dam in the Western Cape) implementation (with reference to the supply of the flows and management of other drivers to achieve the required EC) of the Ecological Reserve. This is of major concern as all EWRs, EcoSpecs; TPCs etc. are hypotheses until tested. With increased development and pressure on the water resources in this country there are no structures in place to monitor the further deterioration of our rivers. All methods related to monitoring and the identification of EcoSpecs and TPCs therefore require testing and refinement.

The Upper Vaal River system has very high demands imposed on it by the irrigation sector, as well as industrial and domestic sectors and forms the backbone of the economic hub of South Africa.

The RHAM was developed during 2007 - 2009 and it was recommended that a RHAM survey is undertaken at sites where applicable. It is foreseen that due to the size and nature of the Vaal River, the RHAM for wadeable rivers might not be possible at all sites. The semi - wadeable (still to be tested) RHAM could be applicable. RHAM data may provide additional information on habitat suitability and the biota associated with this habitat.

No specific Ecological Reserve Monitoring has been initiated in this river system apart from the RHP monitoring conducted at EWR 9, 10, 11 and RE-EWR 2<sup>10</sup>. Immediate monitoring is necessary as the surveys undertaken during the Reserve study represent the baseline against which change is measured. These surveys were undertaken during 2007 and 2008 and it can already (pending changes in the catchments), not be applicable. The longer monitoring is delayed, the bigger the chance is that the baseline surveys will have to be repeated because of outdated data.

The main recommendation is that effective monitoring is started as soon as possible due to the economic importance of the Upper Vaal River and the presence of the Vredefort Dome Heritage site that falls within this study area below the Vaal River Barrage. The Upper Vaal River is exposed to regular water quality related impacts due to industrial activities that are not monitored as well as a failing municipal infrastructure that leads to pollution levels that lead to fish kills and the recreational activities being banned by the Department of Health, especially in the reaches below the Vaal Dam.

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<sup>10</sup> According to Ms Hermien Roux and Mr Piet Muller, River Health Champions for the North West and Gauteng Provinces respectively (*Pers. comm.*, 2010).

## 11 WETLAND TYPING AND ECOCLASSIFICATION

Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Wetland Report. Report authored Rountree, WM (Fluvius Environmental Consultants). Edited by Louw, D and Koekemoer, S. Report no: RDM/WMA8 C000/01/CON/0410.

This wetland assessment study focussed on wetlands in the Upper Vaal Water Management Area, one of three WMAs in the Vaal River catchment.

### 11.1 PURPOSE OF THE STUDY

The purpose of this study was to identify the distribution and diversity of wetlands within the Upper Vaal catchment and conduct a primarily desktop assessment of the average current ecological state and ecological importance and sensitivity of these wetlands at a quaternary catchment scale. This study also included the delineation of Wetland Resource Units (WRUs). These WRUs represent a group of wetlands of similar type and functioning based on areas of geological, ecological and hydrological commonality and provides a catchment context and scoping level indication of the sensitivities of these wetlands to various activities for use in the future management of wetlands in the Upper Vaal Catchment. If any high priority wetlands (in terms of broad conservation importance, social importance and/or threats from proposed developments) were identified during the study, these were to be highlighted for further more in depth studies. This study also aimed to undertake Rapid EcoClassification assessments of at least two of these high priority wetlands, namely the Seekoeivlei and Suikerbos Wetlands.

### 11.2 METHODS

The most up-to-date version of the South African National Biodiversity Institute's (SANBI's) Wetland Probability Map was used as a first-level assessment of wetland occurrence within the study area. These data are not field verified, and should thus be treated with caution. Limited independent preliminary verification of the Probability Map suggests that these spatial data provide a significant underestimate of the actual occurrence and extent of wetlands. Farm dams are included in the dataset but, since most of these are located in seepage or valley bottom wetlands, they indicate locations (but not true extents) of modified wetlands. It does, however, provide an indication of relative wetland occurrence, size and density across the study area.

Since there are too many wetlands to evaluate on an individual basis, a desktop level quaternary-scale catchment assessment of the wetlands across the entire study area was undertaken. This information was used to determine (at a low confidence) the average PES and EIS categories of wetlands within each quaternary catchment. A desktop scoring system for quaternary catchment scale wetland PES and EIS determination was developed for this purpose.

A modification of a hierarchical system for the classification of South African wetlands was then used in to classify the wetlands in this study. The modified system uses the underlying hydrological processes and formative geomorphological setting as the basis of classification.

At the broadest spatial level (Level I), all inland wetlands are classified in a single unit. Nested within Level I are two classification systems that operate at smaller spatial scales, *viz*:

Level II: Broad geological groupings of wetlands based on, inter alia, underlying dominant geology and/or EcoRegions, which are referred to as Wetland Resource Units (WRUs) in this study.

Level III: Groups of wetlands based on geomorphological and hydrological criteria, referred to as hydrogeomorphic (HGM) wetland types in this study.

The common HGM wetland types within each WRU were then identified and described. The HGM wetland typology is based on the underlying hydrological processes that create and maintain the wetlands. The likely sensitivities to particular types of activities, and thus recommendations for future management, can then be determined, albeit at low confidence, from this information.

### 11.3 WETLAND RESOURCE UNITS

Wetland density declines from the south-east to the northwest across the WMA; following the general rainfall trends. Vegetation Types and Level I and II EcoRegion boundaries were poorly correlated with wetland type, average size or density, but underlying geology distinguished the major break in wetland resource units; with a secondary split due to land use, PES and EIS attributes.

Three Wetland Resource Units were identified for the Upper Vaal Water Management Area, namely the:

- **WRU 1: Dolomitic Peatlands WRU** (low density and diversity of wetland types but very large individual wetlands generally associated with peats and usually associated with high EIS scores).
- **WRU 2: Central Sedimentary WRU** (high density of wetlands with a moderate to high diversity, many of which may provide habitat for vulnerable to endangered vegetation. These wetlands are generally associated with moderate PES and EIS scores).
- **WRU 3: Eastern Sedimentary WRU** (high density of wetlands with a high diversity many of which may provide habitat for vulnerable to endangered vegetation. These wetlands are generally associated with moderate to high PES and EIS scores).

### 11.4 PES AND EIS RESULTS

Results from the desktop Wetland PES and EIS assessments (at the quaternary catchment scale), and comparison with the available quaternary river PES and EIS data are provided in Table 11.1. Quaternaries with high-scoring wetland PES (A, B and B/C) and/or EIS (High and Very High) scores are shaded. The PES and EIS scores reflect the expected *average* scores of all wetlands within the quaternary catchment.

Given the high intensity of economic activity and land use activities across most of the WMA, it is not surprising that much of the WMA is characterised by wetlands in a moderate condition, with poorer condition wetland areas concentrated around the highly urbanised and industrialised north and north-western margins of the WMA (Figure 11.1). Whilst PES is generally moderate, the EIS scores range from Moderate to High. The wetlands in the headwaters of the northwest and southernmost sections of the WMA have the highest EIS scores (Figure 11.2).

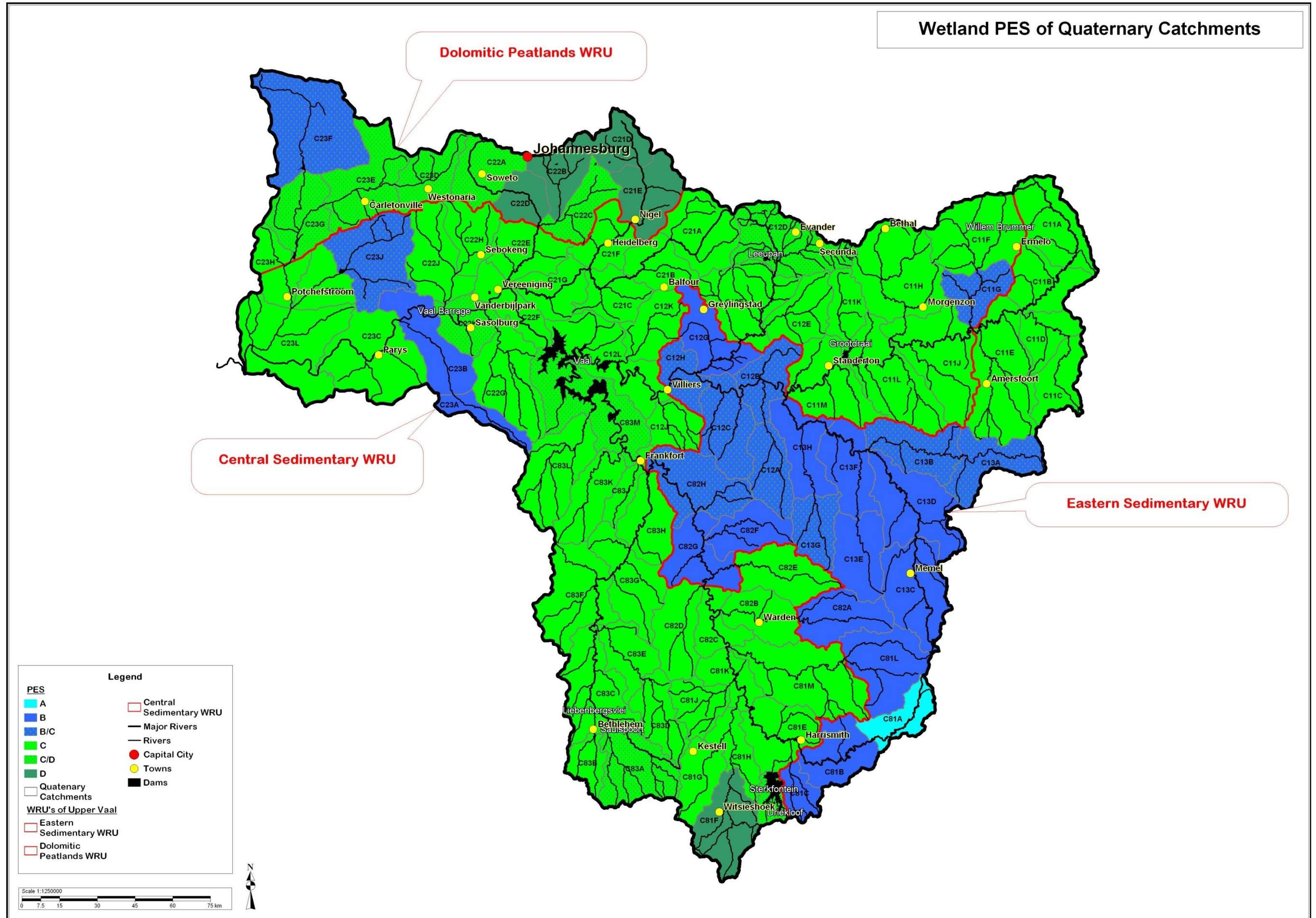
**Table 11.1 Average EIS and PES for the wetlands in quaternary catchments of the Upper Vaal WMA**

Quat. Catchment	Main river/s	Average Wetland EIS of the Quaternary	River EIS	Average Wetland PES of the Quaternary	River PES
C11A	Vaal	HIGH	Moderate	C	B/C
C11B	Vaal	HIGH	Moderate	C	C

Quat. Catchment	Main river/s	Average Wetland EIS of the Quaternary	River EIS	Average Wetland PES of the Quaternary	River PES
C11C	Klein Vaal	MODERATE	Moderate	C	B
C11D	Klein Vaal (Rietspruit)	MODERATE	Low	C	C
C11E	Rietspruit	<b>HIGH</b>	Moderate	C	C
C11F	Kaffirspruit	MODERATE	Moderate	C	C
C11G	Kaffirspruit	MODERATE	Moderate	<b>B/C</b>	C
C11H	Blesbokspruit	MODERATE	Moderate	C	C/D
C11J	Vaal	MODERATE	Moderate	C	C
C11K		<b>HIGH</b>	Moderate	C	D
C11L	Grootdraai dam	MODERATE		C	
C11M	Vaal (downstream from Grootdraai)	MODERATE	Moderate	C	D
C12A	Ventersspruit	MODERATE	Moderate	<b>B/C</b>	B/C
C12B	Vaal (main)	MODERATE	Moderate	<b>B/C</b>	C
C12C	Vaal (main)	MODERATE	Moderate	<b>B/C</b>	C
C12D	Waterval (Kleinspruit)	MODERATE	Low	C/D	D
C12E	Rietspruit	MODERATE	Low	C	D
C12F	Waterval (Kleinspruit)	<b>HIGH</b>	Moderate	C	D
C12G	Waterval (Kleinspruit)	<b>HIGH</b>	Moderate	<b>B</b>	D
C12H	Vaal (main)	MODERATE	Moderate	<b>B/C</b>	C
C12J	Unnamed trib.	MODERATE	Low	C	C/D
C12K	Molspruit	MODERATE	Low	C	C/D
C12L	Vaal (Vaal dam backwater portion)	MODERATE		C	
C13A	Sandspruit	<b>HIGH</b>	Moderate	<b>B/C</b>	B/C
C13B	Sandspruit	<b>HIGH</b>	Moderate	<b>B/C</b>	C
C13C	Seekoevlei	<b>VERY HIGH</b>	High	<b>B</b>	B/C
C13D	Klip	<b>VERY HIGH</b>	Moderate	<b>B</b>	B/C
C13E	Komandospruit	MODERATE	Moderate	<b>B</b>	B
C13F	Klip	<b>HIGH</b>	Moderate	<b>B</b>	C
C13G	Spruitsonderdrif	MODERATE	Moderate	<b>B/C</b>	C
C13H	Klip	MODERATE	Moderate	<b>B</b>	C
C21A	Suikerbosrand	<b>HIGH</b>	Moderate	C	B/C
C21B	Suikerbosrand	<b>HIGH</b>	Moderate	C	C
C21C	Suikerbosrand	<b>HIGH</b>	High	C	C
C21D	Blesbokspruit	<b>HIGH</b>	Low	D	E/F
C21E	Blesbokspruit	<b>HIGH</b>	Moderate	D	D/E
C21F	Blesbokspruit (l	MODERATE	Low	C	D/E
C21G	Suikerbosrand	MODERATE	Moderate	C	C/D
C22A	Klipriver	<b>HIGH</b>	Moderate	C/D	E
C22B	Natalspruit	<b>HIGH</b>	Low	D	E
C22C	Rietspruit	<b>HIGH</b>	Low	C/D	E
C22D	Klip	<b>HIGH</b>	Moderate	D	D
C22E	Klip	MODERATE	Moderate	C	D/E
C22F	Vaal (downstream from Vaal dam)	MODERATE	Moderate	C	D
C22G	Taaibospruit	MODERATE	Moderate	C	C
C22H	Rietspruit	MODERATE	Low	C	D/E
C22J	Leeuspruit	MODERATE	Moderate	C	D/E
C22K	Vaal (Barrage portion)	MODERATE		C/D	
C23A	Vaal	MODERATE	Moderate	<b>B</b>	B/C
C23B	Vaal	MODERATE	Moderate	<b>B</b>	D

Quat. Catchment	Main river/s	Average Wetland EIS of the Quaternary	River EIS	Average Wetland PES of the Quaternary	River PES
C23C	Vaal (Parys)	MODERATE	High	<b>C</b>	D
C23D	Mooirivierloop	<b>HIGH</b>	Low	C/D	E
C23E	Mooirivierloop	<b>HIGH</b>	Moderate	C/D	E
C23F	Upper Mooi	<b>HIGH</b>	High	<b>B/C</b>	C/D
C23G	Mooi (upstream from Boskop)	<b>HIGH</b>	Moderate	C/D	D/E
C23H	Mooi (before confluence with Loopspruit)	<b>HIGH</b>	Moderate	C	D/E
C23J	Loopspruit (above Klipdrif dam)	MODERATE	Low	<b>B/C</b>	D
C23K	Loopspruit	MODERATE	Low	C	D
C23L	Vaal (downstream from Parys)	MODERATE	High	C	D
C81A	Wilge (main stem)	<b>HIGH</b>	Low	<b>A</b>	B
C81B	Wilge (main stem)	<b>HIGH</b>	Moderate	<b>B</b>	B/C
C81C	Nuwejaarsspruit (Wilge trib.)	MODERATE	Moderate	<b>B</b>	B/C
C81D	Sterkfontein Dam	MODERATE		C/D	
C81E	Wilge (main stem)	MODERATE	Moderate	C	D
C81F	Elands (Wilge trib.)	MODERATE	Moderate	D	D
C81G	Elands (Wilge trib.)	MODERATE	Moderate	C	C
C81H	Elands (Wilge trib.)	MODERATE	Moderate	C	C
C81J	Vaalbanks (Wilge trib.)	MODERATE	Moderate	C	C
C81K	Wilge (main stem)	MODERATE	Moderate	C	C
C81L	Meul (Wilge trib.)	MODERATE	Moderate	<b>B</b>	B
C81M	Meul (Wilge trib.)	MODERATE	Moderate	C	B
C82A	Cornelis (Wilge trib.)	MODERATE	Moderate	<b>B</b>	B
C82B	Cornelis (Wilge trib.)	MODERATE	Moderate	C	C
C82C	Wilge (main stem) - EWR 8	MODERATE	Moderate	C	C
C82D	Rus se Spruit (Wilge trib.)	MODERATE	Moderate	C	C
C82E	Holspruit (Wilge trib.)	MODERATE	Moderate	C	C
C82F	Grootspruit (Wilge trib.)	MODERATE	Moderate	<b>B</b>	C
C82G	Wilge (main stem)	MODERATE	Moderate	<b>B</b>	C
C82H	Wilge (main stem)	MODERATE	Moderate	<b>B/C</b>	C
C83A	Ash	MODERATE	Low	C/D	D/E/F
C83B	Jordaans	MODERATE	Moderate	C	C
C83C	Liebenbergsvlei	MODERATE	Moderate	C	D/E
C83D	Tierkloof	MODERATE	Moderate	C	C/D
C83E	Tierkloof	MODERATE	High	C	C/D
C83F	Liebenbergsvlei	MODERATE	Moderate	C	D
C83G	Liebenbergsvlei	MODERATE	Moderate	C	D
C83H	Libenbergsvlei	MODERATE	Moderate	C	D
C83J	Wilge (main stem)	MODERATE	Moderate	C	D
C83K	Kromspruit	MODERATE	Moderate	C	B
C83L	Klipriver	MODERATE	Moderate	C	B
C83M	Wilge (main stem) - Vaal Dam	MODERATE		C/D	

Within the Wetland Resource Units, PES and EIS attributes are generally more consistent than across the entire Water Management Area. Wetlands within the Dolomitic Peatlands WRU are characterised by low to moderate PES (Figure 11.1) but High EIS (Figure 11.2). The Central Sedimentary WRU is characterised by generally moderate PES (Figure 11.1) and EIS (Figure 11.2) scores, whereas the wetlands of the Eastern Sedimentary WRU generally have higher PES (Figure 11.1) with the same to higher EIS characteristics (Figure 11.2).



**Figure 11.1** Average wetland PES scores of the quaternary catchments of the Upper Vaal WMA

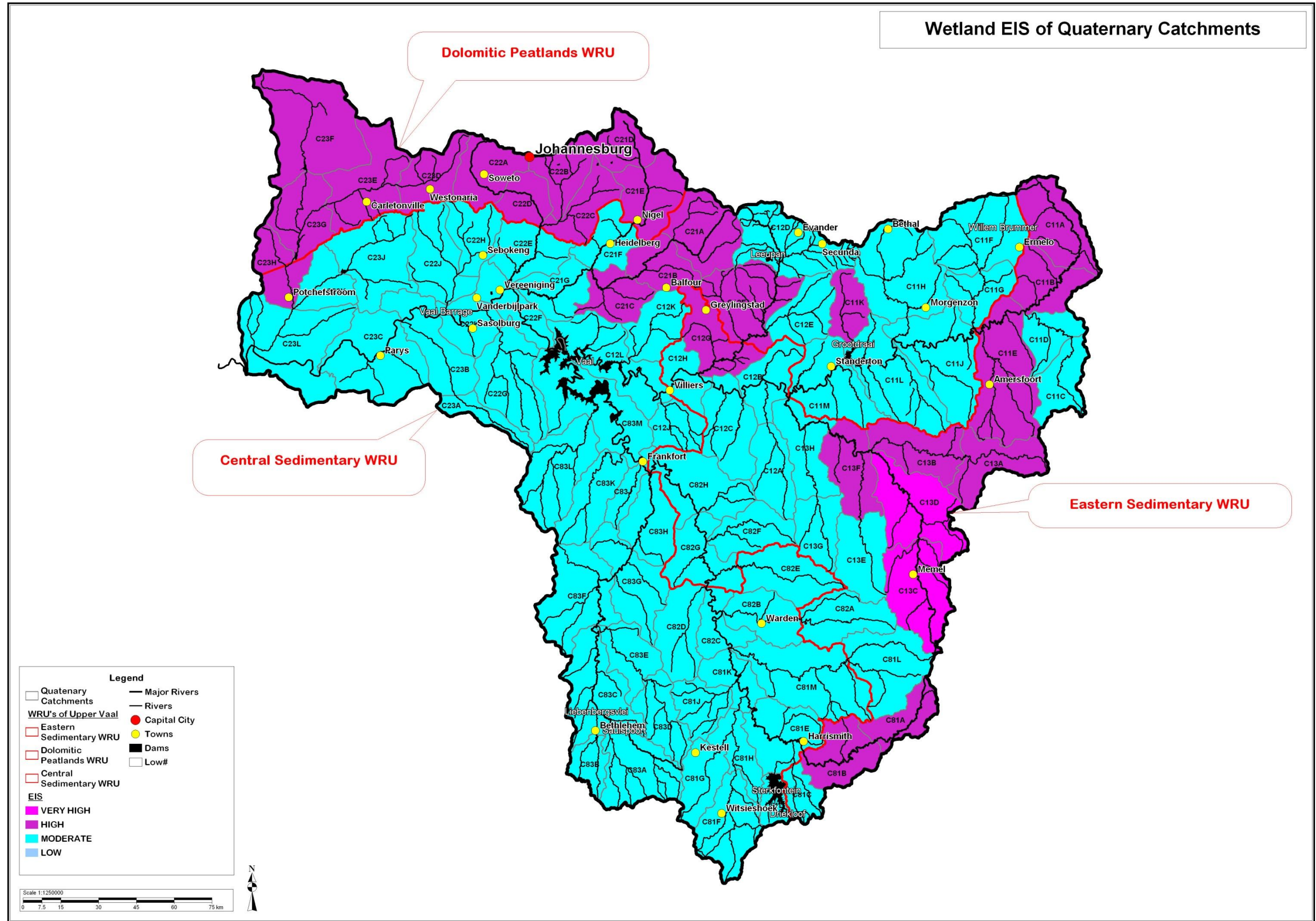


Figure 11.2 Average wetland EIS scores of the quaternary catchments of the Upper Vaal WMA

## 11.5 PRIORITY WETLANDS

Wetlands that were deemed important by DWA and various other stakeholders were identified through a workshop process. Prioritisation criteria were identified during the same workshop, and the wetlands were assessed and ranked according to the prioritisation scores ascribed to each.

Several high priority areas requiring urgent assessment or more detailed Reserve studies were identified and are provided below. Of these, the PES and EIS of Seekoeivlei and lower Suikerbosrand (Heidelberg) Floodplain wetlands were assessed in more detail as part of this study. Rapid EcoClassification determinations were also undertaken for the Boovenste Oog Wetland (in Quaternary catchment C23F), Klip River Wetland (in Quaternary Catchment C22A, this study included a Reserve determination component) and the Bedford Wetland (in Quaternary Catchment C81A) as part of the WRC/RDM Rapid Wetland Reserve Method Development Project (the results of these studies and associated Reports can be obtained from the RDM).

Seekoeivlei is a RAMSAR site with a high (A/B) PES and Very High EIS. The wetland system is stable and there are few major current threats to this internationally recognised and protected water resource. The lower Suikerbosrand Floodplain has a low to moderate EIS and moderate (B/C) PES. The lower reach close to the Blesbokspruit confluence is currently under threat by proposed mining activities, the impacts from the surrounding cattle feedlots and upstream urbanisation of the catchment. The threats to the condition of this wetland are ubiquitous across the WMA – agricultural impacts; expansion of mining and urbanisation.

## 11.6 APPLICATION OF THE DATA

The approaches developed and information yielded through this assessment will be able to assist the CD:RDM in obtaining regional PES and EIS information for wetlands. This information can be used to guide more detailed Reserve studies, if required, as well as to assess the regional context of wetlands linked to WULA and EIA applications.

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## 12 ESTIMATION AND EXTRAPOLATION OF EWRs AT SELECTED HYDRONODES

Department of Water Affairs (DWAF), 2010. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Estimation Report. Report produced by Koekemoer Aquatic Services and Rivers for Africa. Authored by Louw, D and Birkhead, AL. Report no: RDM/WMA8C000/01/CON/0510.

### 12.1 INTRODUCTION

A comprehensive EWR study has been undertaken for the whole Vaal River. The Vaal catchment was divided into three study areas namely the upper, middle and lower Vaal. This study comprises the Upper Vaal Water Management Area (WMA 8) in support of strategic, national and catchment management, development and planning.

A comprehensive Reserve study assesses EWRs at EWR sites that are usually situated on the main rivers and large tributaries. For the purpose of, amongst others, Compulsory Licensing and general licensing, Reserves have to be determined at many points (hydronodes) in the catchment. EWR sites at each of these nodes where EWRs are determined at a comprehensive level will become time consuming and therefore costly.

The objective of this task is to provide an estimate which will be of higher confidence than the Desktop Reserve Model at every hydronode in the Sabie, Crocodile Mokolo and Upper Vaal systems (the Komati information has already been supplied through a WRC/DWAF research project). The report therefore deals with the extrapolation/estimation approach, methods and results.

### 12.2 APPROACH

Extrapolation consists of determining which sites are sufficiently similar to the comprehensive EWR sites in terms of biophysical similarity as well indicator guilds used for setting EWRs. The relevant EWR results are then hydrologically extrapolated to those points.

Estimation consisted of the following:

- The collection of Rapid III level hydraulic information at selected sites in the catchments of the Sabie-Sand, Crocodile, Mokolo and Upper Vaal Rivers.
- The analysis of the field data and provision of hydraulic characterisations for the sites in accordance with the procedures described by Birkhead (2010).
- Examining the EWR results for these (Rapid III) sites in conjunction with (Intermediate and Comprehensive level) flow requirements for the purpose of developing a simple method for estimating EWR at hydronodes in these catchments.
- Predicting the indicator fish guilds at each hydronode.
- Estimating the EWRs at each hydronode for the Recommended Ecological Category (REC) (using the information generated as part of the Desktop EcoClassification (Kleynhans & Louw, 2007).

The decision-making process to determine whether to estimate or extrapolate is summarised in the flow diagram below (Figure 12.1).

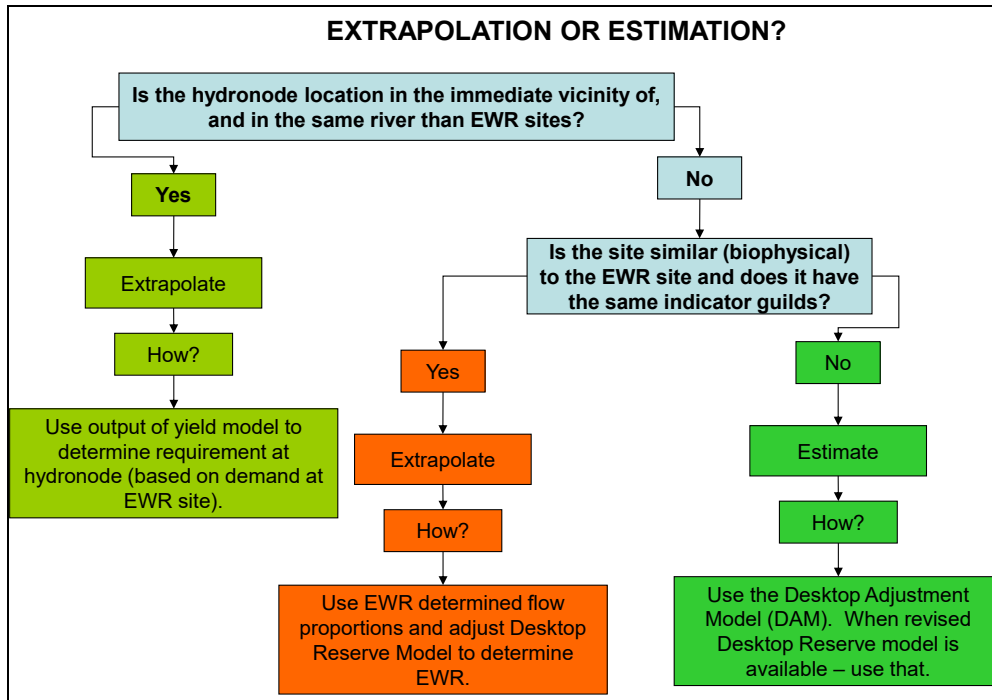


Figure 12.1 Flow diagram showing when it is appropriate to extrapolate or when estimation is required

### 12.3 HYDRONODES AND DATABASE

Hydronodes are points on a map which represents a catchment, usually at the quinary scale. These points were selected by Rivers for Africa situated mostly at the outlet of quaternary catchments and other sites where surveys had been undertaken and were included in an Excel database. Additional points were also provided in the database, the so-called known fish sites. This inclusion was required as the database was used to compare the known fish sites with hydronodes to derive the indicator fish guild for which the EWR had to be set. For each point in the database, a range of biophysical information was provided to characterise the nodes and fish sites.

Figure 12.2 provides the locality of the hydronodes, fish and calibrations sites within the Upper Vaal WMA.

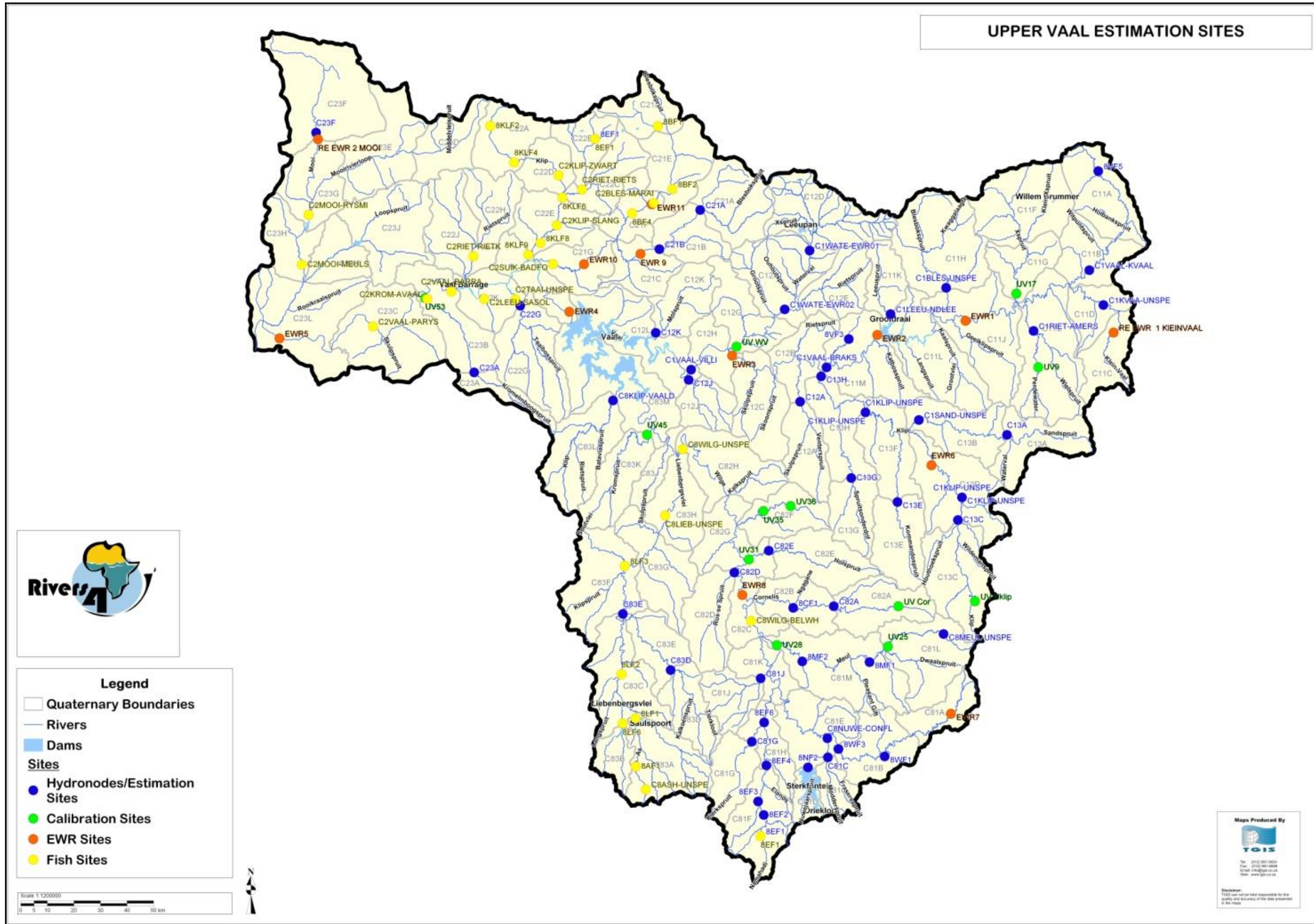


Figure 12.2 Localities of Upper Vaal hydronodes, fish and calibration sites

## 12.4 PREDICTION OF INDICATOR FISH GUILDS

Conceptually the prediction approach was based on the physical similarity between sites where fish information was available and hydronodes without fish information. If sites were physically similar to a high degree (many variables the same), then the assumption could be made that the same indicator fish guild would be present at both sites.

The results of the above analysis provided the indicator guilds for each hydronode (Table 12.1). The hydronodes are in the rows shaded in colour. The indicator fish guilds are provided in the rows below the hydronodes and refers to LSR (large semi-rheophilic) and SSR (small semi-rheophilic).

**Table 12.1 Indicator fish guilds at the hydronodes**

JV Ukliip	JV9	JV17	JV25	JV Coor	JV28	JV31	JV WV	JV35	JV36	JV45	JV53	C1VAAL-KVAAL	C1VAAL-BRAKS	C1VAAL-VILLI	8VF3	8VF5	C1BLES-UNSP	C1KVA-UNSP	C1KLIP-UNSP (8KF2)	C1KLIP-UNSP (8KF1)
SSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	SSR	SSR	SSR	LSR	LSR	LSR
C1LEEU-NDLEE	C1RIET-AMERS	C1SAND-UNSP	C1WATE-EWR01	C1WATE-EWR02	C8KLIP-VAALD	8WF1	8WF3	8EF1	8EF2	8EF3	8EF4	8EF6	C8NUWE-CONFL	8NF2	C8MEUL-UNSP	8MF1	8MF2	8CF1	C23F	C22G
LSR	SSR	LSR	LSR	LSR	LSR	SSR	LSR	SSR	LSR	LSR	LSR	LSR	LSR	LSR	SSR	SSR	LSR	LSR	SSR	LSR
C23A	C21A	C21B	C12K	C82E	C82D	C83E	C83D	C81J	C81G	C81C	C13C	C82A	C13E	C13G	C13H	C12A	C12J	C13A		
SSR	SSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	SSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR	LSR		

## 12.5 CALIBRATION SITES USED FOR EWR ESTIMATION

Various EWR sites (Rapid Level III, Intermediate and Comprehensive) were used to develop an EWR estimation method for hydronodes where no hydraulic data existed. These sites focussed on smaller rivers (to add to the database which is based on comprehensive determinations focussing on large rivers) in the Mokolo, Komati, Crocodile, Sabie and Upper Vaal catchments.

## 12.6 EWR ESTIMATION METHOD

EWR sites were determined as part of this study. EWRs available at the EWR sites are for specific Ecological Categories (ECs) (may include the Present Ecological State (PES), Recommended Ecological Category (REC) and/or the Alternative Ecological Category (AEC)), specified separately for fish and macroinvertebrates. For the Rapid Level III sites (Komati, Sabie, Crocodile, Mokolo and upper Vaal River catchments), the Fish Flow Habitat Assessment (FFHA) model (developed by Dr C.J. Kleynhans) was used for estimating the EWRs (the model was modified for application to macro-invertebrates). The FFHA model provides a consistent procedure for estimating EWRs (at the Rapid Level III and higher) and gives requirements for the A to D range of Ecological Categories (ECs).

The EWR data were entered into an Excel data base for processing, together with the tabulated (modelled) hydraulic information (or lookup tables) for the site cross-sections. Code was written in

Visual Basic Applications (VBA) to compile EWR and hydraulic data as a function of ecological and hydrological parameters. The ecological information included the indicator fish guild and macroinvertebrate taxa, and the hydrological information included the season and percentage (time) exceedance of maintenance and drought conditions on the flow duration table (FDT).

For each of the four fish guilds (Small Semi-Rheophilic (SSR), Large Semi-Rheophilic (LSR), Small Rheophilic (SR) and Large Rheophilic (LR), and a single macro-invertebrate taxa (flow dependant cobble dwelling (FDCD)), there were three variables to consider. These included hydrological season (wet or dry), percentage point on the FDT (the points denoting maintenance and drought conditions) and EC (B, C or D - the FFHA model considered an A to be natural). Thirty-six data sets for fish and 12 for macroinvertebrates were used.

For each of these 48 data sets, the EWR requirement (from the Comprehensive and Rapid Level III (FFHA model) studies), hydrological (natural flow) and relevant hydraulic information (wetted channel width, maximum depth, average depth and average velocity) were compiled. Following from the findings of a previous EWR estimation study (Birkhead, 2008), the data was analysed to assess whether the EWR could be expressed as a constant unit-width value (i.e. a constant discharge per unit (wetted) width of channel).

A regression procedure was coded (using VBA) to automate the curve-fitting for the 48 data sets, and allowed the regressions to be easily re-determined with changes to the data sets.

## 12.7 APPLICATION OF ESTIMATION TO HYDRONODES

A procedure for applying the EWR estimation method as a Desktop Adjustment Method (DAM - refer to Birkhead, 2008) was developed using MS-Excel and VBA. The procedure consists of the various steps which were used to provide EWR estimates for the 62 hydronodes.

The hydronodes and method used to determine the EWRs are provided in the tables and figures below.

**Table 12.2 Estimation methods followed at the Vaal hydronodes**

Hydronode	Quat	River	Method
UV Uklip	C13C	Klip	Estimate
UV9	C11E	Skulpspruit	Estimate
UV17	C11G	Drinkwaterspruit	Estimate
UV25	C81L	Meul	Estimate
UV Cor	C82A	Cornelius	Estimate
UV28	C81M	Meul	Estimate
UV31	C82G	Holspruit	Estimate
UV WV	C12G	Waterval	Estimate
UV35	C82F	Grootspruit	Estimate
UV36	C82F	Grootspruit	Estimate
UV45	C83K	Kromspruit	Estimate
UV53	C23B	Kromelumboogspruit	Estimate
C1VAAL-KVAAL	C11B	Vaal	Yield model
C1VAAL-BRAKS	C11M	Vaal	Yield model
C1VAAL-VILLI	C12L	Vaal	Extrapolate from EWR 3
8VF3	C11M	Brakspruit	Estimate
8VF5	C11A		Estimate
C1BLES-UNSPE	C11H	Blesbokspruit	Estimate
C1KLIP-UNSPE (8KF2)	C13F	Klip (Grootdraai)	Estimate
C1KLIP-UNSPE (8KF1)	C13D	Klip (Grootdraai)	Estimate

Hydronode	Quat	River	Method
C1LEEU-NDLEE	C11L	Leeuspruit	Estimate
C1RIET-AMERS	C11E	Rietspruit	Estimate
C1SAND-UNSP	C13B	Sandspruit	Estimate
C1WATE-EWR01	C12F	Waterval	Existing EWR results
C1WATE-EWR02	C12F	Waterval	Existing EWR results
C8KLIP-VAALD	C83L	Klip (flows into Vaal Dam from FS)	Estimate
8WF1	C81B	Wilge	Estimate
8WF3	C81B	Wilge	Estimate
8EF1	C81F	Elands	Estimate
8EF2	C81F	Elands	Estimate
8EF3	C81F	Elands	Estimate
8EF4	C81H	Elands	Estimate
8EF6	C81H	Elands	Estimate
C8NUWE-CONFL	C81E	Nuwejaarspruit	Estimate
8NF2	C81D	Nuwejaarspruit	Estimate
C8MEUL-UNSP	C81L	Meul	Estimate
8MF1	C81M	Meul	Estimate
8MF2	C81M	Meul	Estimate
8CF1	C82B	Cornelisspruit	Estimate
C23F	C23F	Mooi River	Estimate
C22G	C22G	Taalbospruit	Estimate
C23A	C23A	Kromelbospruit	Estimate
C21A	C21A	Suikerbosrand	Estimate
C21B	C21B	Suikerbosrand	Extrapolate from EWR 9
C12K	C12K	Molspruit	Estimate
C82E	C82E	Holspruit	Estimate
C82D	C82D	Rus-se-spruit	Estimate
C83E	C83E	Tierkloof	Estimate
C83D	C83D	Tierkloof	Estimate
C81J	C81J	Vaalbanksspruit	Estimate
C81G	C81G	Klerkspruit	Estimate
C81C	C81C	Fraser/Modder	Estimate
C13C	C13C	Klip	Estimate
C82A	C82A	Cornelis	Estimate
C13E	C13E	Komandospruit	Estimate
C13G	C13G	Spruitsonderdrif	Estimate
C13H	C13H	Klip	Estimate
C12A	C12A	Skulpspruit	Estimate
C12J	C12J	??	Estimate
C13A	C13A	Sandspruit	Estimate

The final results as the .rul and .tab tables are provided as electronic data (RDM Report no RDM/WMA8C000/01/CON/0710; DWA, 2010b).

## 13 CAPACITY BUILDING

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Author: PA Scherman

One of the tasks of the Comprehensive Reserve studies co-ordinated by the CD:RDM of the DWA from 2007 to 2010, was the development of an Integrated Technical Training Programme (ITTP) for the studies. An integrated Training Report will be produced as output of this task, i.e. Report number RDM/TR-S/CRITR/01/2010, entitled *Comprehensive Reserve Integrated Training Report - Training for Reserve specialists as part of the Vaal, Outeniqua, Mokolo and Crocodile east Comprehensive Reserves (2007 – 2010)*. The information provided in this chapter of the Main Report is therefore an outline of activities, with all analyses and detailed feedback for all specialist trainees appearing in the Integrated Training Report.

### 13.1 OBJECTIVE

The objective of the training task undertaken during the Comprehensive Reserve studies was to build capacity and conduct effective training on Reserve principles and methods. Training was focussed at the level of specialist trainees, i.e. persons who would act in the role of specialists in future Reserve studies. *Note that the training programme presumed that trainees have an understanding of the Reserve concept and process.* Training was primarily conducted in the form of specialist workshops, fieldwork and one-on-one training.

### 13.2 AIMS

The main aims of the training were to ensure that specialist trainees have developed or enhanced a range of Reserve-related skills:

- Developed an understanding of Ecological Water Requirements (EWR) and the process to be followed during the steps of a Reserve study.
- Developed an understanding of the role of each specialist within the broader Reserve process.
- Worked within a team to achieve EcoClassification, define EcoStatus and set flow requirements (where relevant).
- Understand the links between physical driver processes and biotic responses.
- Understand data formats (e.g. hydrological data), and the link between data collection in the field and how the data are presented.
- The ability to use the tools or software required by a specific discipline, and to understand the use of these tools.
- The ability to interpret information related to a specific discipline within the Reserve process.
- Developed an understanding of how flow requirements are set per indicator (where relevant).
- Developed an understanding of how to operate as a specialist within a particular field or component.
- Developed some knowledge regarding various components of a Reserve study, including setting Reserve requirements for different water resources (e.g. rivers, estuaries, groundwater, and wetlands).

### 13.3 OUTPUTS

The outputs of the training process were as follows:

- Training for specialists with limited Reserve experience, e.g. learning to set flow requirements for biological indicators and using EcoClassification models. These trainees were referred to as *specialist trainees*, and their training was considered an extension of their specialist skills. Note that specialist trainees were paired with mentors (i.e. study specialists) in their relevant field.
- Introducing trainees to the use of their specialist tools within a Reserve context. This category refers to less experienced trainees.
- Broadening the pool of specialists in fields where expertise is severely limited, i.e. hydrology, hydraulics and water quality specialists for Reserve assessment studies (Weston, CD: RDM, *pers. comm.*). Another specialist field that can be added to this list is geomorphology.
- Exposing staff from DWA's scientific services, e.g. Directorate: Resource Quality Services (D: RQS) and CD: RDM, to Reserve process and methods.

The Training Report being produced for this task, which will be finalized upon completion of the Vaal Reserve study, outlines activities, shortcomings and list recommendations for future training. The Training Report will contain the following information:

- An audit and evaluation of the training process.
- An assessment of each trainee's ability to operate within a Reserve team.
- A critical assessment of the training programme, within the confines of its scope and objectives.
- Additional training needs and recommendations.
- An evaluation of the success of training amongst previously disadvantaged groups, and specialist fields earmarked for capacity building (e.g. hydraulics).
- A database of specialists available for Reserve studies, and a comment on each person's level of expertise and experience within the Reserve field.

#### 13.4 MENTOR-TRAINEE TEAMS

MENTOR	TRAINEE	COMPONENT
Delana Louw	Shileen Louw	Financial administration and coordination
	Shael Koekemoer	Operational scenarios
Denis Hughes	Bennie Haasbroek	SPATSIM and hydrology
Drew Birkhead	Ahmed Desai	Hydraulics
Neels Kleynhans	Pieter Kotzé	Fish
	Johan Koekemoer	
Mark Rountree	Lindo Hlongwane	Geomorphology and wetlands (until mid-2009)
	Adrian Pietersen	Geomorphology (from mid-2009)
	Nonkanyiso Maphumlo	Wetlands (until mid-2009)
Mandy Uys	Ntaki Senoge	Macroinvertebrates
Rob Palmer	Brenton Niehaus	Macroinvertebrates
James Mackenzie	Jackie Jay	Riparian vegetation
Greg Huggins	Katie Maasdorp	BHNR
William Mullins	Riekie Cloete	Economics
	David Mosaka	
Koos Vivier	Joubert Balasigobo	Groundwater
Susan Swart	Colin Talanda	Yield modelling
	Bennie Haasbroek	
	Albert Jeleni	
	Tim Phaladi	
	B Sejamoholo	
	Owen Wilson	

### 13.5 TRAINING ACTIVITIES/APPROACH

Training activities need to be divided into project-specific activities vs. those related to the Integrated Technical Training Programme. Project-specific activities included trainee attendance at project workshops or training workshops, while activities of the ITTP included the following workshops:

- **Workshop 1, 22-23 January 2008:** Multi-disciplinary roles in defining EcoStatus and setting flow requirements during an Ecological Reserve study.

**Aim:** The training workshop focused on the links between flows and biotic responses. The principles of Ecological Water Requirements (EWR) were discussed per discipline, as well as the principle of integrating the various metrics to achieve EcoClassification and define EcoStatus. The workshop also covered the general process followed to set flow requirements per metric, i.e. for both driver and response indicators.

- **Workshop 2, 26-27 March 2008:** Habitat Flow Stressor-Response workshop. The agenda is shown in Appendix 2. A course evaluation questionnaire was not distributed as this workshop formed the basis of the one-to-one specialist training, which was covered in a questionnaire of November 2009.

**Aim:** This training workshop focussed on the application of the Habitat Flow-Stressor Response (HFSR) process during a specialist river workshop. The workshop was aimed at specialist trainees who worked within the following specialist teams:

- Invertebrate team led by Christa Thirion.
  - Fish team led by Neels Kleynhans.
  - Riparian vegetation team led by James Mackenzie.
  - Geomorphology team led by Mark Rountree.
  - Hydrological support provided by Delana Louw (with prior assistance by Denis Hughes).
  - Hydraulic input provided by Drew Birkhead.
  - Yield modelling information provided by Stephen Mallory on day 2 of the workshop.
- **Workshop 3, 16-17 February 2010:** Closure workshop. The agenda and workshop evaluation questionnaire distributed to participants is shown in Appendix 3. Although the closure workshop was not a required task of the Integrated Technical Training Programme conducted for the Vaal, Inkomati and Mokolo trainees during 2008 - 2010, and therefore not compulsory, it was considered a necessary final step to technical training.

**Aim:** To provide an overview of the technical steps followed during a Comprehensive Ecological Water Requirements (EWR) study.

### 13.6 TRAINING FEEDBACK

The success of training was evaluated with the use of the following:

- Questionnaire to gather training evaluation information from trainees. Questionnaires were completed following workshops, as well as for the training programme.
- Short reports from mentors.

### **13.7 TRAINEE DATABASE**

One of the outcomes of this task is an evaluation of the training process and assessment of each trainee's ability and knowledge regarding EWRs. This information should be captured on a trainee database housed at CD:RDM, so that the following type of information can be available per trainee:

- Specialist field and mentor details per Reserve study
- Project exposure and dates, e.g. worked as a specialist trainee on the Thukela and Croc East Reserve studies.
- Level of expertise, e.g. specialist trainee level 1 (no previous exposure to Reserve studies). This information will enable CD: RDM to identify appropriately trained specialist for future studies, as well as build further capacity in fields where skills are lacking.
- Outcomes of performance evaluations on Reserves studies.

It must be noted that the training provided by this study may be one step in the training process and that additional exposure to Reserve studies may be required for certain trainees before they are sufficiently capacitated to operate as specialists.

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## 14 WHERE TO FROM HERE

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### 14.1 ECOLOGICAL WATER RESOURCES MONITORING PROGRAMME

A detailed monitoring programme as part of the Ecological Water Resources Monitoring (EWRM) programme must be designed by the PSP appointed to undertake the monitoring according to the guidelines set out by DWA. It was not part of the TOR of this Reserve study to undertake this. However, the design of the technical Ecological Specifications (EcoSpecs) to be used when interpreting the EWRM results was part of this study and is provided in Appendix B. It must be noted that the specifications are technical specifications which is used to interpret monitoring results by specialists and not for use for providing specifications for licensing.

During the comprehensive Reserve study, the PES was set based on biophysical surveys. This PES acts as the Baseline Ecological Category (BEC) and all EcoSpecs and TPCs were identified for the BEC. Unless monitoring is implemented within a short time frame, the baseline could/will have changed and the information generated during this study will not be valid anymore. This is not a cost-effective approach and it is recommended that monitoring should be implemented as soon as possible.

The section below provides ONLY broad details and certain key aspects of the Ecological Water Resources Monitoring (EWRM) programme. Technical detail of the EWRM is still in development by CD:RQS, DWA and the latest methods and models must be incorporated into the EWRM.

- The EWRM must be followed according to the specifications provided broadly in: Department of Water Affairs, South Africa. 2009. Operationalise the Reserve: Main Report. Prepared by Water for Africa. Compiled by D Louw and S Louw. Report no. RDM/NAT/05/CON/0907.
- The further refinements of EWRM and exact specifications as currently being developed by D:RQS, DWA should be used as baseline.
- EcoSpecs and Threshold of Concern provided in Appendix B should be applied during the EWRM.
- EWRM should be implemented at all the EWR sites as the minimum.
- The EWRM should be implemented immediately as the information gained during the EWR study can form part of the baseline.
- The EWRM monitoring must be undertaken within a structured DSS.

## 15 ELECTRONIC DATA

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Electronic data supplied as part of this study are summarised in a Read Me file in Excel according to the structure of the electronic data. The Read Me file is provided below to indicate the information available electronically.

**WILL BE INCLUDED WHEN COMPLETED**

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