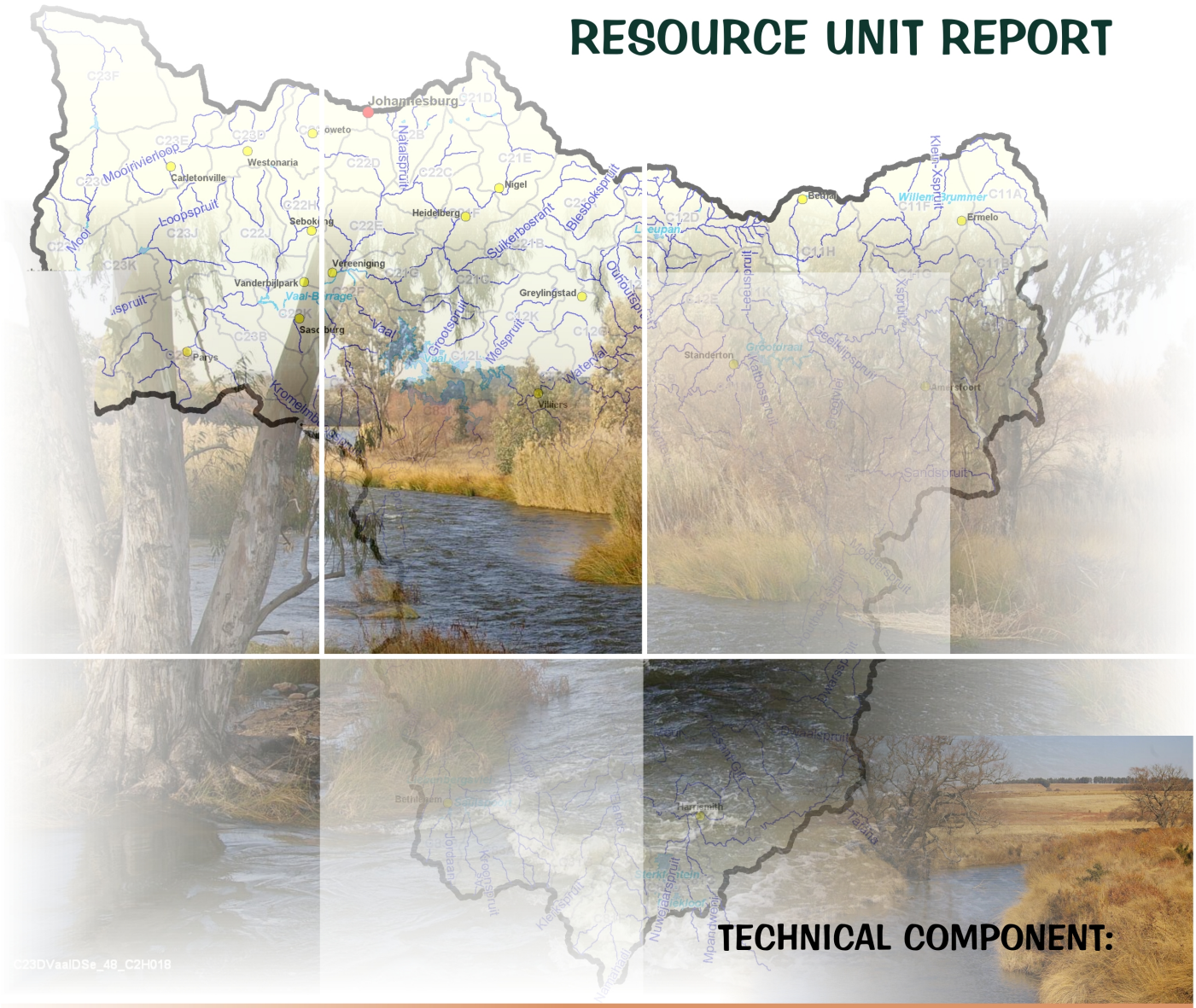
COMPREHENSIVE RESERVE DETERMINATION
INTEGRATED VAAL RIVER SYSTEM
SURFACE WATER
RESOURCE UNIT REPORT



TECHNICAL COMPONENT:

DECEMBER 2008

REPORT NO.: RDM/WMA8C000/01/CON/0208
PROJECT NO.: 8829/1

water & forestry
Department:
Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

RfA48_2010

COMPREHENSIVE RESERVE DETERMINATION STUDY OF THE INTEGRATED VAAL RIVER SYSTEM

UPPER VAAL WATER MANAGEMENT AREA TECHNICAL COMPONENT: RESOURCE UNIT REPORT

Report number:RDM/WMA8C000/01/CON/0208

DECEMBER 2008

This report should be cited as:
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.

Technical document authorised by:

Koekemoer Aquatic Services

PO Box 1100
Parys, 9585
084 240 5855

Water for Africa
Unit: IWR Source to Sea: Aquatic Ecology
PO Box 122
PersequorPark, Pretoria, 0020
082 461 1289

DOCUMENT INDEX

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. Results and generic method 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 Volume 1 and 2	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoClassification Report
1.6	RDM/WMA8C000/01/CON/0209 Volume 1 and 2	Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EWR Scenario Report
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
1.12	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: Main Report
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

TITLE:	Comprehensive Reserve determination study of the Integrated Vaal River System, Upper Vaal River Management Area. Resource Unit Report
DATE:	February 2009
AUTHORS:	MD Louw
REVIEW:	R Stassen
LEAD CONSULTANT:	Koekemoer Aquatic Services and Water for Africa, Joint Venture
EDITOR:	S Koekemoer
FILE NO.:	26/8/3/10/10
FORMAT:	MSWord and PDF
WEB ADDRESS:	www.dwaf.gov.za

Approved for Koekemoer Aquatic Services/Water for Africa Joint Venture:

Ms Shael Koekemoer
Administrative Project Leader

Ms Delana Louw
Technical Project Leader

Approved for the Department of Water Affairs and Forestry by:

Ms Retha Stassen
Consultant Project Management Team Leader & Manager

Ms Barbara Weston
Deputy Director: Surface Water Reserve Requirements

MANAGEMENT AND STEERING COMMITTEES

Project Management Committee

Barbara Weston	Department of Water Affairs	Project Manager
Jacqueline Jay	Department of Water Affairs	Study Manager
Retha Stassen	Blue Science Consulting	Consultant Project Leader and Manager
Shael Koekemoer	Koekemoer Aquatic Services	Consultant Upper Vaal Technical Team
Delana Louw	Rivers for Africa	Consultant Upper Vaal Technical Team

Project Team

Shael Koekemoer	Koekemoer Aquatic Services	Administrative Project Leader
Delana Louw	Rivers for Africa	Technical Project Manager
Shileen Louw	Rivers for Africa	Project Administrator
Greg Huggins	Rivers for Africa	Team Leader: Basic Human Needs
Mark Rountree	Fluvius Environmental Consultants	Team Leader: Wetlands. Geomorphology
TorisoTlou	Tlou Consulting	Team Leader: Resource Economics
Dr Patsy Scherman	SchermanColloty and Associates	Team Leader: Capacity Building
Dr Neels Kleynhans	DWA: RQS	EcoClassification Process
Ms Christa Thirion	DWA: RQS	EcoClassification Process
Dr Drew Birkhead	Streamflow Solutions	EcoHydraulics
Prof Denis Hughes	Institute for Water Research	EcoHydrology
Mr Johan Koekemoer	Koekemoer Aquatic Services	Fish
Dr Pieter Kotze	Clean Stream Biological Services	Fish
Mr James Mackenzie	BioRiver Solutions	Riparian Vegetation
Dr Dawie Mullins	Conningarth Economists	Resource Economics
Mr William Mullins	Conningarth Economists	Resource Economics
Mr Rob Palmer	Nepid Consulting	Macroinvertebrates
Ms Riekie Cloete	Conningarth Economists	Trainee
Ms C Engelbrecht	Rivers for Africa	GIS
Mr Ahmed Desai	Rivers for Africa	Trainee
Mr Bennie Haasbroek	Innovative Solutions	Trainee
Mr Lindokuhle Hlongwane	Wetland Consulting Services (Pty.) Ltd.	Trainee
Ms Nonkanyiso Maphumulo	Wetland Consulting Services (Pty.) Ltd.	Trainee
Mr David Mosaka	Conningarth Economists	Trainee
Mr Brenton Niehaus	Clean Stream Biological Services	Trainee
Mr Ntaki Senoge	Clean Stream Biological Services	Trainee
Ms Lindi Schwartz	Conningarth Economists	Trainee
Mr Lungile Gaulana	DWA: RQS	Trainee
Ms Pumza Maseti	DWA: RQS	Trainee
Ms Nceba Ncaphayi	DWA: RQS	Trainee
Mr Ramogale Sekwele	DWA: RQS	Trainee

Members of Project Steering Committee

Barbara Weston	Resource Directed Measures, Surface Water Reserve Requirements
Jackie Jay	Resource Directed Measures, Surface Water Reserve Requirements
Yakeen Atwaru	Resource Directed Measures, Surface Water Reserve Requirements
Nancy Motebe	Resource Directed Measures, Groundwater Reserve Requirements
Shane Naidoo	Resource Directed Measures, Classification System
Ndeleka Mohapi	Resource Directed Measures, Compliance
Bonani Madikizela	WRC
Valerie Killian	Water Abstraction and Instream Use (Environment & Recreation)
Seef Rademeyer	National Water Resource Planning
Niel van Wyk	National Water Resources Planning
Dragana Ristic	National Water Resources Planning
Jurgo van Wyk	Water Resource Planning Systems
Peter Pike	Option Analysis
Churchill Mkwalo	Stream flow Reduction
Marius Keet	Gauteng Regional Office
Nndanganeni (Lucky) Musekene	Resource Protection and Waste
Abe Abrahamse	Northern Cape Regional Office
Hanke Du Toit	Northern Cape Regional Office
Sam Dywili	Northern Cape Regional Office
Willem Grobler	Free State Regional Office
Dr Neels Kleynhans	Resource Quality Services
Reghardt Strauss	Spatial & Land information management
Frans Matfield	SAPPI
Maryna Mohr	Chamber of Mines of SA
Retha Stassen	Arcus GIBB/ Blue Science Consulting Project Management team
Beyers Havenga	Arcus GIBB/ Blue Science Consulting Project Management team

ACKNOWLEDGEMENTS

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

The following specialist contributed 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)

EXECUTIVE SUMMARY

INTRODUCTION

The CD: RDM identified the Integrated Vaal River System, with the focus of this study, the Upper Vaal Water Management Area (WMA) as requiring a comprehensive Reserve assessment as to provide input to the Reconciliation studies and the integrated water quality management plan for the Vaal River undertaken by the National Water Resources Planning Directorate (D: NWRP) of the DWAF. These studies require higher levels of confidence in the Reserve determination results as is currently available. This will assist the DWAF to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments.

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 the 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 preferable to select a EWR site within each MRU, and 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
- Local knowledge

DELINEATION RESULTS

The results are tabled below.

MRU	Delineation	Quaternary catchment
VAAL RIVER		
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 rapidsand 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
KLEIN VAAL RIVER		
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
KLIP RIVER		
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	Delineation	Quaternary catchment
MRU Klip D	Lowland geomorphological zone to the confluence with the Vaal.	C13D, C13F, C13H
WILGE RIVER		
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
LIEBENBERGSVLEI RIVER		
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
WATERVAL RIVER		
MRU Waterval A	Origin of the river to the Boesmanspruit confluence.	C12D, C12F
MRU Waterval B	Boesmanspruit to the Vaal River confluence.	C12F, C12G
SUIKERBOSRAND RIVER and BLESBOKSPRUIT		
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
MOOI RIVER		
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

EWR SITES

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.

The selected sites are tabled below and illustrated in the map along with the MRUs.

EWR site number	EWR site name	River	National RHP site	Co-ordinates		EcoRegion (Level II)	Geomorphic Zone	Altitude (m)	RU	Quaternary	Hydrological gauge
				Latitude	Longitude						
EWR1	Uitkoms	Vaal	C1Geel_Unspe	-26.8728	29.61384	11.05	Lowland	1570	MRU Vaal B	C11J	C1H007
EWR2	Grootdraai	Vaal	C1Vaal Braks	-26.9211	29.27929	11.03	Lowland	1537	MRU Vaal C	C11L	C1H019
EWR3	Gladdedrift	Vaal	C1Vaal-Villie	-26.99087	28.72971	11.03	Lowland	1487	MRU Vaal C	C12H	C1H012
EWR4	De Neys	Vaal	C2Vaal-Deny	-26.84262	28.1123	11.03	Lower Foothills	1445	MRU Vaal D	C22F	C2H122
EWR5	Skandinavia	Vaal		-26.93243	27.01367	11.08	Lowland	1309	MRU Vaal E	C23L	C2H018
EWR6	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
EWR8	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	
EWR10	Suikerbos DS	Suikerbosrand	Close to C2Suik-Badfo	-26.68137	28.16798	11.01	Lowland	1453	RU Suiker B	C21G	
EWR11	Blesbokspruit	Blesbokspruit	C2Bles-Marai (locality incorrect)	-26.47892	28.42488	11.03	Lower Foothills	1528	RU Bles A	C21F	
Rapid Level sites											
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	

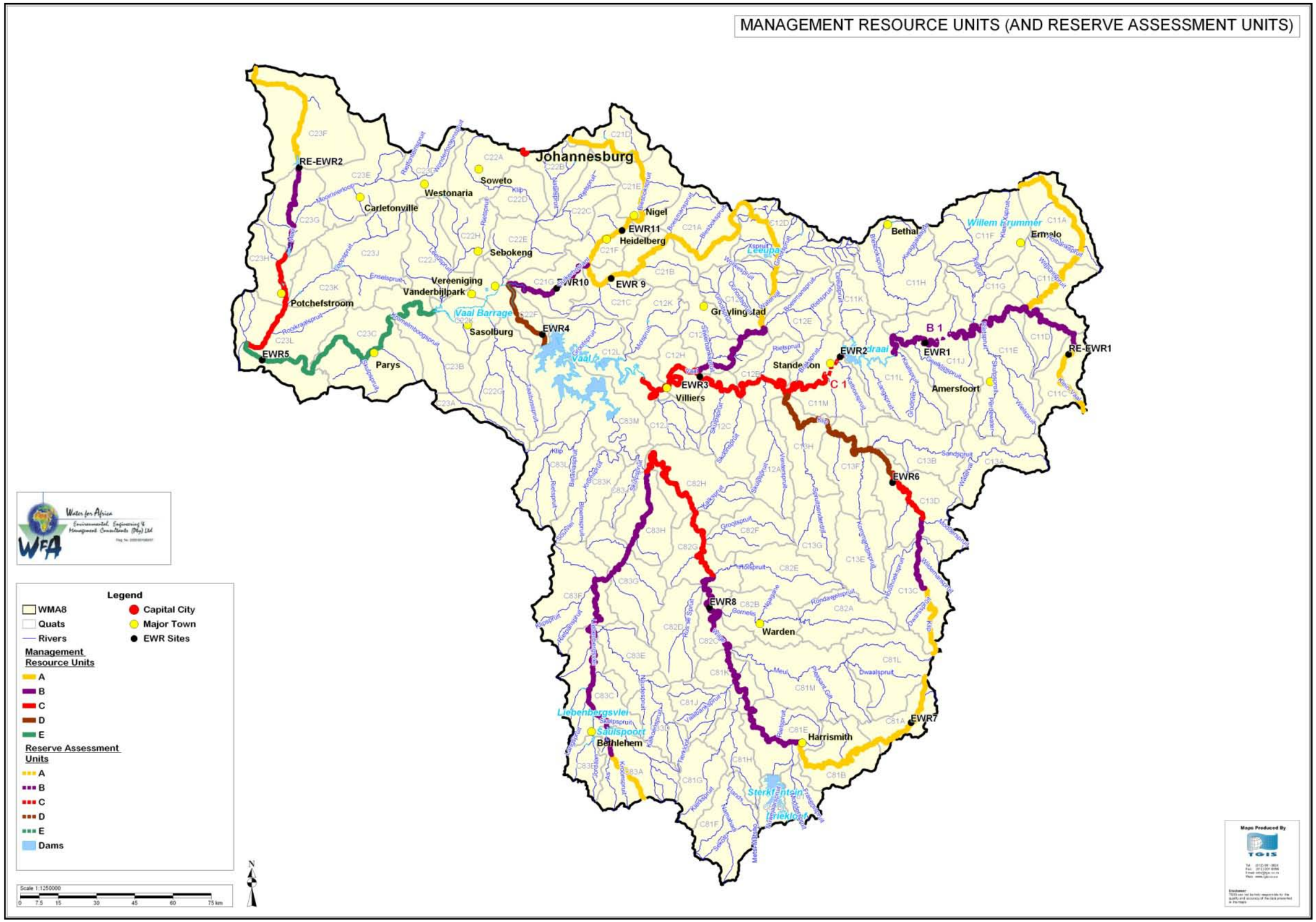

MANAGEMENT RESOURCE UNITS (AND RESERVE ASSESSMENT UNITS)
Johannesburg
RE-EWR2
Soweto
Westonaria
Carletonville
Nigel
EWR11
Heidelberg
Sebokeng
Vereeniging
Vanderbijlpark
EWR10
EWR 9
Potchefstroom
Vaal Barrage
Sasolburg
EWR4
EWR5
Parys
Bethal
Willem Brummer
Ermelo
Leeuhof
Grayling Stad
B 1
EWR1
RE-EWR1
EWR2
Standerton
C 1
EWR3
Villiers
Amersfoort
EWR6
EWR8
Warden
Liebenbergsvlei
Saulspoort
Bethlehem
Harrismith
EWR7
Sterkfontein
Driekloof
Water for Africa
Environmental, Engineering & Management Consultants (Pty) Ltd
Legend
WMA8
Quats
Rivers
Management Resource Units
A
B
C
D
E
Reserve Assessment Units
A
B
C
D
E
Dams
Capital City
Major Town
EWR Sites
Scale 1:1250000
0 7.5 15 30 45 60 75 km
N
Maps Produced By
TGIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

ACRONYMS

CD: RDM	Chief Directorate: Resource Directed Measures
D:NWRP	Directorate: National Water Resource Planning
D:RQS	Directorate: Resource Quality Services
DTM	Digital Terrain Model
DWAF	Department of Water Affairs and Forestry
EWR	Ecological Water Requirements
LB	Left Bank
LHWP	Lesotho Highlands Water Project
LM	Local Municipality
MRU	Management Resource Unit
NRU	Natural Resource Unit
NWA	National Water Act
RAU	Resource Assessment Unit
RB	Right Bank
RU	Resource Unit
TDS	Total Dissolved Salts
TLC	Transitional Local Council
TP	Total Phosphorous
VRSAU	Vaal River System Analysis Update
WMA	Water Management Area
WQSU	Water Quality Sub Unit

1 INTRODUCTION

1.1 BACKGROUND

The National Water Act (NWA, Act No. 36 of 1998, Section 3) requires that the Reserve be determined for all water resources, i.e. the quantity, quality and reliability of water needed to sustain both human use and aquatic ecosystems, so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems. It is therefore imperative that the Reserve be determined and requirements met before other economic activities can be satisfied. As the Department of Water Affairs and Forestry (DWAF) is the custodian of the nation's water resources, it is their responsibility to ensure the adequate protection and effective management of these resources. The Chief Directorate: Resources Directed Measures (CD:RDM) of DWAF is tasked with the responsibility of ensuring that Reserve assessments take place before licensing can proceed.

The CD:RDM identified the Integrated Vaal River System, with the focus of this study, the Upper Vaal Water Management Area (WMA) as requiring a comprehensive Reserve assessment as to provide input to the Reconciliation studies and the integrated water quality management plan for the Vaal River studies undertaken by the National Water Resources Planning Directorate (D:NWRP) of the DWAF. These studies require higher levels of confidence in the Reserve determination results as is currently available. This will assist the DWAF to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments.

1.2 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 and MooiRivers and extends to the confluence of the Mooi and VaalRivers. It covers a catchment area of 55 565 km^2.

1.3 PURPOSE OF THIS REPORT

The purpose of this report is:

- To provide the information used to define the Resource Units (RUs).
- To provide the delineation of the RUs in the study areas.
- To describe the Ecological Water Requirement (EWR) sites selected within the RUs.

1.4 REPORT STRUCTURE

This report combines various aspects of the study area (see Chapter 2) that relates to delineation of the resource units and selection of the EWR sites. An introduction is followed by the delineation approach, the delineation results, and the EWR sites (locality, characteristics and suitability).

2 RIVER REACH DEMARCATION AND DELINEATION

2.1 APPROACH

If an Ecological Reserve determination is required, for a large catchment, it is necessary to delineate the catchment into Resource Units (RUs). These are each significantly different to warrant their own specification of the Reserve, and the geographic boundaries of each must be clearly delineated (DWAF, 1999, volume 3).

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. These sections of a river frequently have different natural flow patterns, react differently to stress according to their sensitivity, and require individual specifications of the Reserve appropriate for that reach.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 (NRU). The more detailed approach is described in Appendix A.

Management requirements (DWAF, 1999, volume 3; DWAF, 2007) also play a role in the delineation. An example could be where large dams and/or transfer schemes occur. Furthermore, the type of disturbance/impact on a river plays a role to select homogenous river reaches from a biophysical basis under present circumstances. These are called Management Resource Units (MRU) and the more detailed approach is described in Appendix A.

The delineation process considers all of the above issues. Overlaying all the data does not necessarily result in a logical and clear delineation and expert judgement, a consultative process and local knowledge are required for the final delineation. The practicalities of dealing with numerous reaches within one study must also be considered to determine a logical and practical suite of MRUs.

MRUs can be further delineated in even smaller assessment units and the approach for this is described in Appendix A and DWAF (2007).

The Ecological Water Requirements (EWRs) are determined for each MRU by means of either the following (Louw & Hughes, 2002):

- An EWR site is selected within the MRU and represents a critical site within the relevant river section. Results generated at the EWR site will then be relevant for the MRU as a whole.
- If no EWR site is selected within the MRUthen extrapolated results from an adjacent MRU with aEWR site is used if appropriate. The reasons for an EWR site not being selected within the MRU can be the following:
    - The characteristics of the river within the MRU do not meet the criteria for EWR sites.
    - Due to the number of MRUs within the study area, it is not practical and/or cost-effective to address EWR sites within each MRU.

2.2 RESOURCE UNIT CONSIDERATIONS

2.2.1 EcoRegions (Level II)

The EcoRegion typing approach developed in the USA (Omernik, 1987) was applied and tested at a preliminary level in South Africa. EcoRegional classification or typing will allow the grouping of rivers according to similarities based on a top-down approach. The purpose of this approach is to simplify and contextualise assessments and statements on Ecological Water Requirements. One of the advantages of such a system is the extrapolation of information from data rich rivers to data poor rivers within the same hierarchical typing context.

The current effort, used available information to delineate EcoRegion boundaries at a very broad scale (i.e. Level I) for South Africa. Attributes such as physiography, climate, rainfall, geology and potential natural vegetation were evaluated in this process and 18 Level I EcoRegions were identified (Kleynhans *et al*., 2005). The next Level II (Kleynhans *et al*., 2007), used the same attributes but in more detail. Physiography can for example, be explored in more detail by considering terrain morphological classes, slopes, relief, altitude, etc.

The EcoRegions are illustrated in Figure 2.1.

2.2.2 Geomorphological zonation

Rowntree and Wadeson (1999) have developed a zonal classification system for Southern African Rivers modified from Noble and Hemens (1978). In their classification an attempt was made to give each zone a geomorphological definition in terms of distinctive channel morphological units and reach types. After working in a number of different rivers around the country it has become clear that channel gradient is a good indicator of channel characteristics and that probable or expected difference can be identified from an analysis of gradients (Table 2.1).

Table 2.1 Geomorphological Zonation of River Channels(adaptedfrom Rowntree and Wadeson, 1999)

Longitudinal zone	Characteristic channel features	
	Zone class	Description
Mountain stream	B	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach types include cascades, bedrock fall, and step-pool. Approximate equal distribution of 'vertical' and 'horizontal' flow components.
Transitional	C	Moderately steep stream dominated by bedrock or boulder. Reach types include plain-bed, pool-rapid or pool riffle. Confined or semi-confined valley floor with limited flood plain development.
Upper Foothills	D	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plain-bed, pool-riffle or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow flood plain of sand, gravel or cobble often present.
Lower Foothills	E	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool- riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Flood plain often present.
Lowland river	F	Low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct flood plain develops in unconfined reaches where there is an increased silt content in bed or banks.

The above classification was used and is illustrated in Figure 2.1.

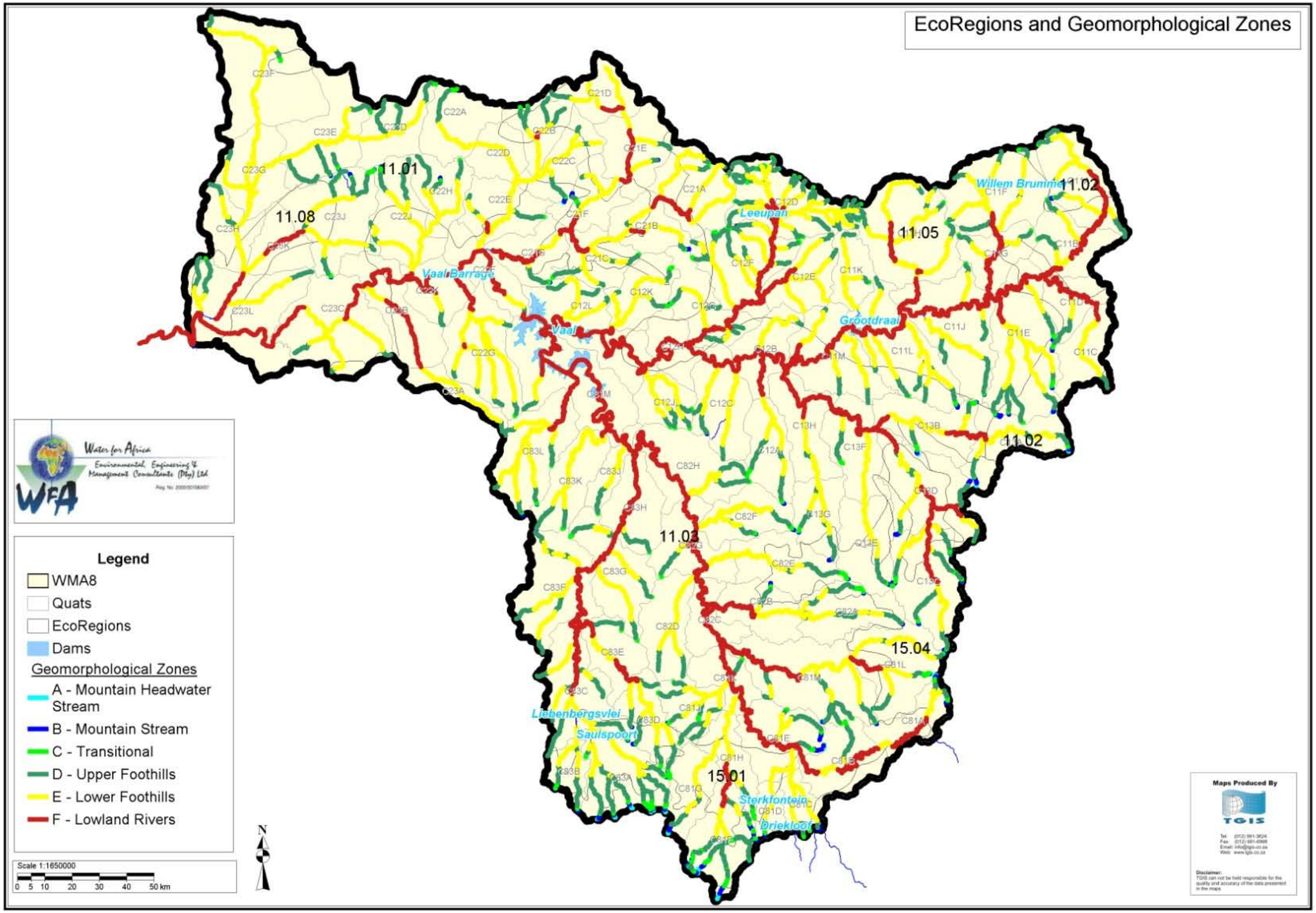


Figure 2.1 EcoRegions and geomorphological zonation of the Upper Vaal

2.2.3 Land cover[1]

The land cover per 500 m strip on both sides of the river is provided as a map with the associated Excel spreadsheets(Appendix B). This information is used to determine homogeneity of impacts and used in the decision-making regarding the MRUs.

The land cover (500 m strips) is dominated by natural grassland in the east and south. Urbanisation increases in the north-east, north and west to be dominated by severe degradation in the riparian and adjacent zones.

2.2.4 System operation

A qualitative systems operation description has been provided with specific emphasis of the locality and type of infrastructure (formal and informal) that could impact on the hydrological characteristics of the river. The system operation is summarised below:

- **Little Vaal River (C11C):**Water is transferred from Heyshope Dam into the Little Vaal River (i.e. into the lower part of quaternary C11C). The normal operating rule is to transfer water to the Vaal River system if Grootdraai Dam's storage decreases below 90%.
- **Skulpspruit River (C11E):** The transfer from Zaaihoek Dam discharges water into the Perdewaterspruit, which is a tributary of the Skulpspruit. The water is released in the river system upstream of Amersfoort Dam, which is a small storage dam providing water to the town. The transfer from Zaaihoek Dam is mainly for the purpose of supplying water to Majuba Power Station and the releases to Grootdraai Dam (into Perdewaterspruit) is only the excess yield that is available in Zaaihoek Dam after Majuba's water requirement has been supplied.The water transferred into Grootdraai Dam has decreased over time due to the increasing usage from Majuba Power Station, and as the different generation units were commissioned.
- **Rietspruit River (C11F):** Msukaligwa Local Municipality (former Ermelo Transitional Local Council (TLC)) is situated within this catchment.There are two dams, Willem Brummer and Douglas dams, in this river system supplying water to Msukaligwa(based on information received from Trevor Coleman).There are also coal mining activities in the catchment upstream of these dams. These dams are small storage structures and it is unlikely that they have any release capabilities. The town of Msukaligwa uses all the available water from these dams and in dry periods the dams are frequently depleted.Msukaligwa also receives water from the Rietspruit-Davelpipeline (i.e. the pipeline from Jericho Dam providing water to the Usutu-Vaal Eskom Power Stations).
- **Vaal River reach between C11M and Grootdraai Dam:** The Vaal River reach downstream of Grootdraai Dam receives compensation water from Grootdraai Dam. This is a variable flow (dependant on the inflow) and this water is used by LekwaLocal Municipality (LM) (former Standerton TLC)as well as downstream irrigators. The yield balance of Grootdraai Dam is such that all available water is used to supply Sasol (Secunda Complex) and Eskom Power Stations.
- **Klip River (including and upstream of C13H):** The Klip River is largely natural and there is no large regulating storage in the catchment. The yield balance of the river system is positive. This catchment is contributing a large portion of the incremental runoff to Vaal Dam and is an important tributary of the Vaal River, in terms of providing natural variable flow downstream of Grootdraai Dam.

[1] Data was generated and provided in GIS format by J Moolman from D: RQS, DWAF.

- **Wilge River System (upstream of quaternary catchment C82H):** This river system has Sterkfontein Dam (located in C81D) as the only regulating storage. Sterkfontein Dam receives water from the Thukela-Vaal Transfer Scheme and contains the "reserve" water for the Integrated Vaal River System.The operating rule of Sterkfontein Dam is such that water is only released from the dam when Vaal Dam is at low levels.In the upper portion of quaternary C81F water is abstracted from FikaPatso and MetsiMatso dams to supply the Phuthaditjaba area.The remainder of the Wilge River System is largely unregulated with only small dams for water supply to local users. Water users within this catchment comprise of both urban and irrigation user groups.
- **Liebenbergsvlei River (including and upstream of C83H):** The flow in the Liebenbergsvlei River is dominated by the transfer from the Lesotho Highlands Water Project (LHWP). The LHWP water is discharged into the river system upstream of Saulspoort Dam (located in quaternary catchment C83A).Saulspoort Dam supplieswater to the town of Bethlehem as well as to irrigation farmers. There are significant irrigation abstractions along the Liebenbergsvlei River, of which a significant portion is considered to be unlawful.
- **Waterval River (including C12G and upstream):** The Waterval River receives discharges from the Sasol Secunda Complex as well as treated urban wastewater.From the salinity balance done by Chris Herald as part of the Vaal River System Analysis Update (VRSAU) study, there is also evidence of mine water seepage and runoff from the paved urbanised areas contributing to the flow in the river. There are irrigators situated downstream of the above-mentioned discharges.
- **Vaal River, reach from Vaal Dam to Vaal Barrage:** The water body created by the Vaal Barrage dam wall dominates this river reach. Management of the flow into this reach is from Vaal Dam and is influenced by the water users in and downstream of the Vaal Barrage, the urban return flows and mine dewatering discharges as well as the releases form Vaal Dam to maintain the Total Dissolved Salts (TDS) concentration at 600 mg/ℓ. The three main tributaries (Suikerbosrand, Klip and Rietspruit rivers) discharging into the Vaal Barrage, each convey significant volumes of treated wastewater and mine discharge water.
- **Klip River (including and upstream of C22E):** This river reach receives about 200 million m^3/annum of treated urban wastewater which significantly changed the flow pattern from natural conditions. There is also significant runoff from the paved urbanised areas contributing to the flow in the Klip River and discharges from the mines are estimated at approximately 10 million m^3/annum.
- **Suikerbosrand River (C21C, C21B and C21A):** This portion of the Suikerbosrand River catchment is largely natural, there are no significant abstractions or discharges influencing the river flow.
- **Suikerbosrand and Blesbokspruit rivers (including C21G, C21F, C21E and C21D):** About 50 million m^3/annum of treated urban wastewater is discharged into this river system as well as mine water discharges from Grootvlei Mine (now referred to as Petrex) of approximately 27 million m^3/annum. Furthermore, runoff from the paved urbanised areas within the Suikerbosrand catchment also contributes to the flow in the river.
- **Rietspruit (including and upstream of C22J):** This river system receives in the order of 35 million m^3/annum treated urban wastewater with the result that high base flows are present in the river. Discharges from the Far West Basin Mines that are in the order of 18 million m^3/annum are made to the Rietspruit and runoff from the paved urbanised areas also contributes to the flow in the river.

- **Taaibosspruit River (C22K and C22G):** These catchments contain the Sasolburg industrial complex including coal-mining areas.
- **Kromdraai River – (C23A and part of C23B):** The Kromdraai River catchment down to its confluence with the Vaal River is largely natural. With the exception of relatively small irrigation water use, there are no significant abstractions or discharges influencing the river flow.
- **Mooi River– (C23H, Boskop and Klerkskraal dams):** Boskop Dam is located upstream of this river reach and has currently limited excess water available. This is due to significant mine water discharges into the river system. The catchment upstream of Boskop Dam is partly underlain by dolomite. The Wonderfonteinspruit is the most significant tributary of the Mooi River. Water from the Gerhard Minnebron eye is used for irrigation purposes. Urban return flows from the Flip Human Wastewater Treatment Works are also discharged into the Mooi River upstream of Boskop Dam. Potchefstroom Town is supplied from a small storage dam, Lakeside Dam, which is supported from Boskop Dam. Boskop Dam also supplies water to the Mooi River Irrigation Scheme. Klerkskraal Dam is located upstream of Boskop Dam in quaternary catchment C23F. There are irrigation water userssupplied directly from Klerkskraal Dam. Under certain conditions, water is released from Klerkskraal Dam to support Boskop Dam. In order to minimise river losses these releases are, however, made via the concrete lined Klerkskraal canal system. Portions of the natural spills from Klerkskraal Dam are also routed through the right bank canal that spills into Boskop Dam. It should be noted that there is a significant canal and pipe infrastructure conveying the urban return flows, mine discharges and irrigation water supply in this area.
- **Vaal River reach between the Vaal Barrage (C22K) and C25C:** The main flow regulating capability for this reach is from Vaal Barrage with support from Vaal Dam. There are obviously contributing flows from the Schoonspruit, Mooi, Vals and Rhenoster tributary rivers. The flow in this river reach is influenced by various factors as listed below:
  - Return flows from mine dewatering and treated urban wastewater into this reach and upstream of the Vaal Barrage contribute to the flow in this river reach.
  - In the past years a flow dilution operating rule has been applied where water is released from Vaal Dam to maintain the TDS concentration in the Vaal Barrage not to exceed 600 mg/ℓ. This results in “spills” from Vaal Barrage and in some years can be as much as 200 million m^3/annum.
  - There are significant evaporative losses in this river reach.

2.2.5 Physico chemical sub-units

The above is normally called Water Quality sub-units.Water quality sub-units (WQSUs) define areas of homogenous water quality. Changes in water quality may be natural e.g. input of water from tributaries, or man-made, e.g. abstractions and discharges, towns, tributaries, industries, Waste Water Treatment Works etc. All these factors therefore suggest changes in water quality and define WQSUs. The information below was provided by Golder and Associates, Dr Ralph Heath. The water quality study covers the whole of the WMA 8. Only the relevant WQSU is provided in Table 2.2 below.

Table 2.2 Relevant WQSU

WQSU	Quaternary Catchment(s)	Major River/Dam unit	Reason: Water Quality Issues
1	C11A - D, C11G,C11J	Upper reaches Vaal River (from origin) Grootdraai catchment.	Fairly good quality water. Some impacts detected - some increase in TDS from origin - could be diffuse impacts originating from coal mines.Witpuntspruit tributary is an issue - acid mine drainage (low pH, high sulphates).
4	C11H	Blesbokspruit.	High salinity concentrations and high nutrient concentrations.
6	C11L	Grootdraai dam.	Good quality water (however - impacting tributaries - Blesbokspruit, Leeuspruit and Witpuntspruit must be managed to ensure good quality is maintained). Quality of transferred water from Zaaihoek and Heyshope must also be monitored.
8	C12H, C12L (part of)	Vaal River (between Waterval confluence and Vaal Dam).	High TDS and high TP[1]. Impact of Waterval river observed in main stem.
13	C11M, C12A - C, C12J, C12K, C13A - H, C81A - C, C81E - H, C81J, C81K, C82A-H, C83J - L	Vaal River (downstream Grootdraai Dam - to just upstream Waterval confluence), Klip River, Wilge River.	• Klip River - Agricultural runoff (nutrients and sediments). • Wilge (main stem) - Seasonal variation is absent due to continuous releases from Katse Dam. Some agricultural runoff (nutrients) in Vaal Dam and turbidity. • Vaal River - Fairly good quality, Grootdraai dam water.
15	C21A - C	Suikerbosrant (upper reaches, before Blesbokspruit confluence).	Agricultural runoff (nutrients and sediments). Nature reserve.
16	C21E - F	Blesbokspruit.	High salinity - mine water discharges. High salinity - agricultural runoff (downstream from Heidelberg).
17	C21G	Suikerbosrant (after Blesbokspruit confluence).	High salinity concentrations and high nutrient concentrations. Highly impacted.
18	C22F (up to Lethabo weir)	Vaal River (outflow Vaal Dam to Lethabo weir).	Good water quality (Vaal Dam water). Salinity impacts from Waterval attenuated by Vaal Dam. Increasing trend in phosphate concentrations. Potential for algal blooms increasing.
25	C22K, C22F	Vaal River (includes Barrage portion).	Water quality is very poor. Severe nutrient over-enrichment. Very high salinity concentrations (almost 3 fold increase from concentration at outflow of Vaal Dam). Critically impacted.
26	C22H, C22J (upper reaches)	Leeuspruit and Rietspruit (upper reaches).	Highly polluted. High nutrient concentrations. Salinity also very high.
27	C22J	Rietspruit.	Highly polluted. High nutrient concentrations. Salinity also very high.
28	C23B - C	Vaal River (Parys) (includes Kromelmboogspruit).	• Kromelmboogspruit: water quality is fairly good. No major issues, however data sets are limited. • Vaal River (Parys) downstream barrage: Similar quality to Vaal Barrage. High salinity/high nutrient concentrations.
29	C23F - G	Mooi River (upper reaches - Klerkskraal Dam to upstream Wonderfonteinspruit confluence).	Fairly good quality water.
36	C23H	Mooi River (between Boskop Dam and Potchefstroom Dam).	Salinity and nutrients.
37	C23L	Mooi River (downstream of Loopspruit confluence to Vaal River confluence); and Vaal River downstream Parys to just upstream Mooi confluence.	High salinity, high nutrients. Potential for algal growth.

1 Total Dissolved Phosphorous

3 DELINEATION RESULTS

3.1 VAALRIVER

3.1.1 Vaal River from origin to Klein Vaal confluence: Natural Resource Units

The EcoRegions and geomorphic zones are described in the map below (Figure 3.1). Further subdivision in primary and secondary units is described and the rationale for all delineations is provided in Table 3.1. Derived from the EcoRegions and the geomorphic zones, the MRUs are delineated.

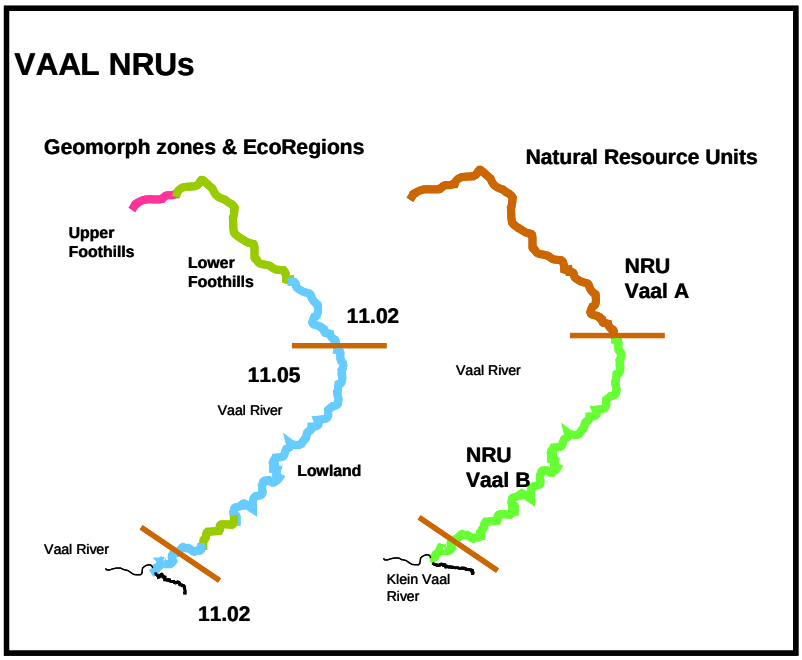


Figure 3.1 Natural Resource Units: Vaal River from origin to Klein Vaal confluence

Table 3.1 Description and rationale for the Vaal River NRUs (origin to Klein Vaal confluence)

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Vaal A	11.05 (97%) 11.02 (3%)	Lower Foothills (95%) Lowland (5%)	EcoRegions the major consideration and defines the NRU. The small section of 11.02 is ignored as this EcoRegion is represented in NRU Vaal B.	EcoRegion 11.02 30.1672 - -26.418 30.0079 - -26.7513
NRU Vaal B	11.02 (100%)	Upper foothills (20%) Lower Foothills (50%) Lowland (30%)	EcoRegions the major consideration and defines the NRU.	EcoRegion 11.02 29.9824 - -26.3257 30.1672 - -26.4118

3.1.2 Management Resource Units: Vaal River from origin to Klein Vaal confluence

The river is divided into MRUs and illustrated in Figure 3.2. The description of the MRUs and the rationale for selection is provided in Table 3.2.

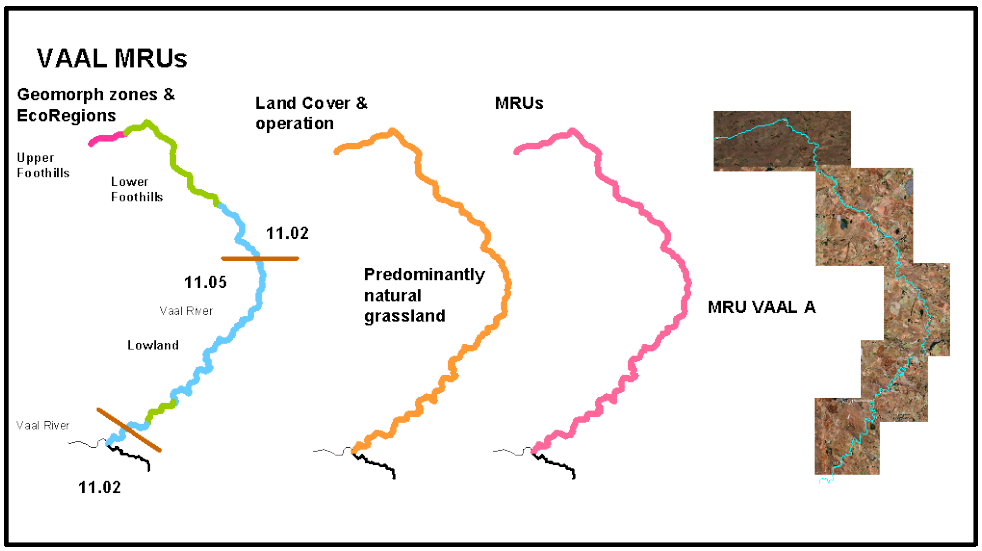


Figure 3.2 Management Resource Units: From origin to Klein Vaal confluence

Table 3.2 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[2] which does not warrant the selection of a comprehensive/intermediate EWR site.	29.9824 - - 26.3257 30.0079 - - 26.7513	C11B C11A

3.1.3 Natural Resource Units:Vaal River from Klein Vaal confluence to Vaal Dam

The EcoRegions and geomorphic zones are described in the map below (Figure 3.3). Further subdivision in primary and secondary units is described and the rationale for all delineations is provided in Table 3.3. Derived from the EcoRegions and the geomorphic zones, the MRUs are delineated.

[2] 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.

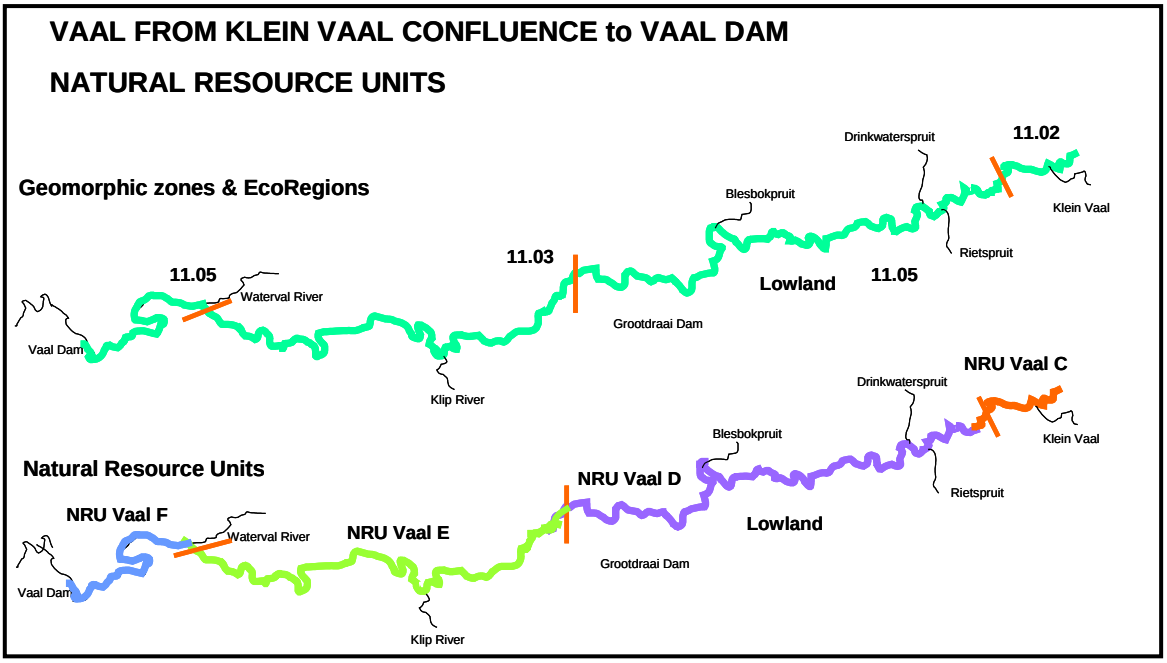


Figure 3.3 Natural Resource Units: Vaal River from Klein Vaal confluence to Vaal Dam

Table 3.3 Description and rationale for the Vaal River NRUs (Klein Vaal confluence to the Vaal Dam)

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Vaal C	11.02 (100%)	Lowland (100%)	EcoRegions the major consideration and defines the NRU.	Klein Vaal confluence to end of EcoRegion 11.02 30.0079 - 26.7513 29.9019,-26.7940
NRU Vaal D	11.05 (100%)	Lowland (100%)	EcoRegions the major consideration and defines the NRU.	29.9019,-26.7940 29.2254, -26.9778
NRU Vaal E	11.03 (100%)	Lowland (100%)	EcoRegions the major consideration and defines the NRU.	29.2254, -26.9778 28.7621, -27.00
NRU Vaal F	11.05 (100%)	Lowland (100%)	EcoRegions the major consideration and defines the NRU.	28.7621, -27.00 28.4739 - -26.9644

3.1.4 Management Resource Units: Vaal River from Klein Vaal confluence to Vaal Dam

The river is divided into MRUs and illustrated in Figure 3.4. The description of the MRUs and the rationale for selection is provided in Table 3.4.

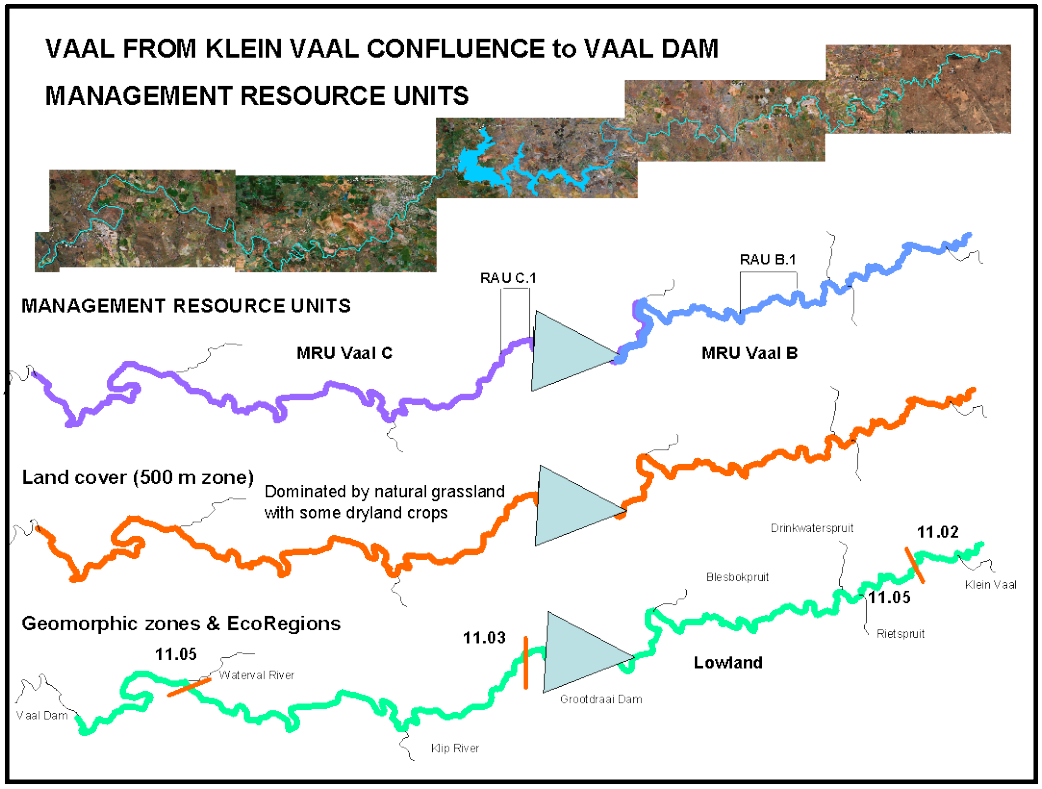


Figure 3.4 Management Resource Units: From Klein Vaal confluence to Vaal Dam

Table 3.4 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 Kaalbosspruit. 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 anRAU. 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 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	29.29476,- 26.91883 28.55902, -	C11L C11M C12B

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
				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.	27.05543	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

3.1.5 Natural Resource Units: Vaal River from Vaal Dam to the end of WMA8

The EcoRegions and geomorphic zones are described in the map below (Figure 3.5). Further subdivision in primary and secondary units is described and the rationale for all delineations is provided in Table 3.5. Derived from the EcoRegions and the geomorphic zones, the MRUs are delineated.

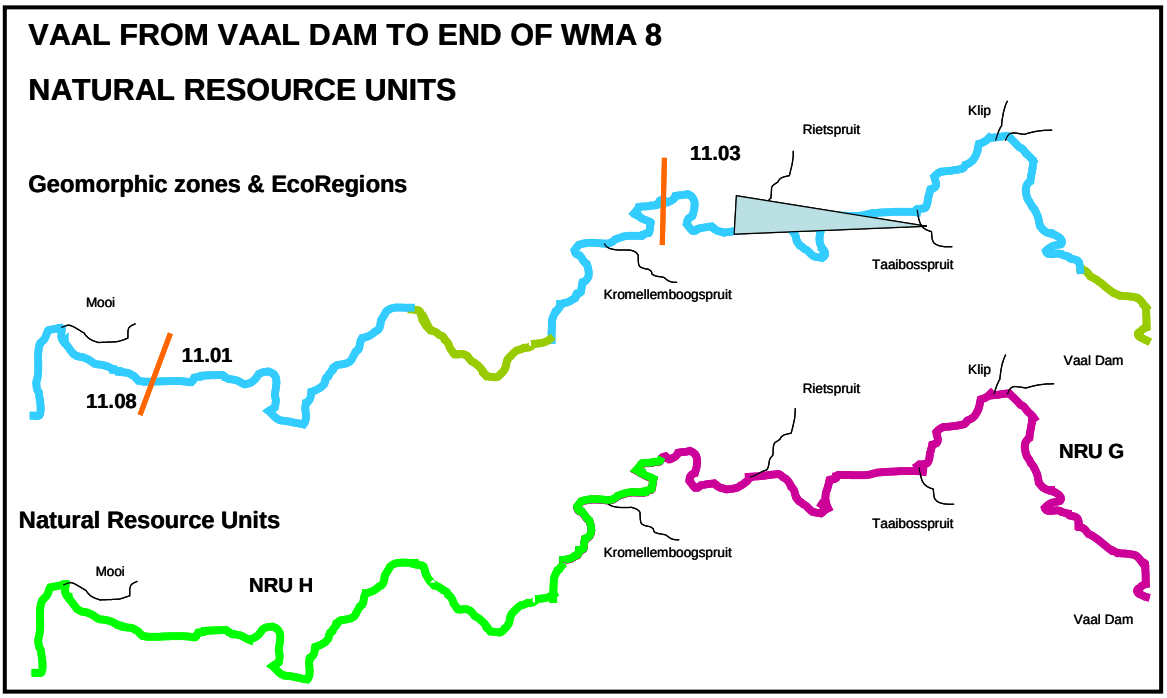


Figure 3.5 Natural Resource Units: Vaal River from Klein Vaal confluence to Vaal Dam

Table 3.5 Description and rationale for the Vaal River NRUs (Vaal Dam to end of WMA8)

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Vaal G	11.03 (100%)	Lowland (100%)	EcoRegions the major consideration and defines the NRU.	28.115368, -26.882574 27.6051, -26.7386
NRU Vaal H	11.03 (92%) 11.08 (8%)	Lowland (100%)	EcoRegions the major consideration and defines the NRU.	27.6051, -26.7386 26.95192, -26.87589

3.1.6 Management Resource Units: Vaal River from Vaal Dam to end of WMA 8

The river is divided into MRUs and illustrated in Figure 3.6. The description of the MRUs and the rationale for selection is provided in Table 3.6.

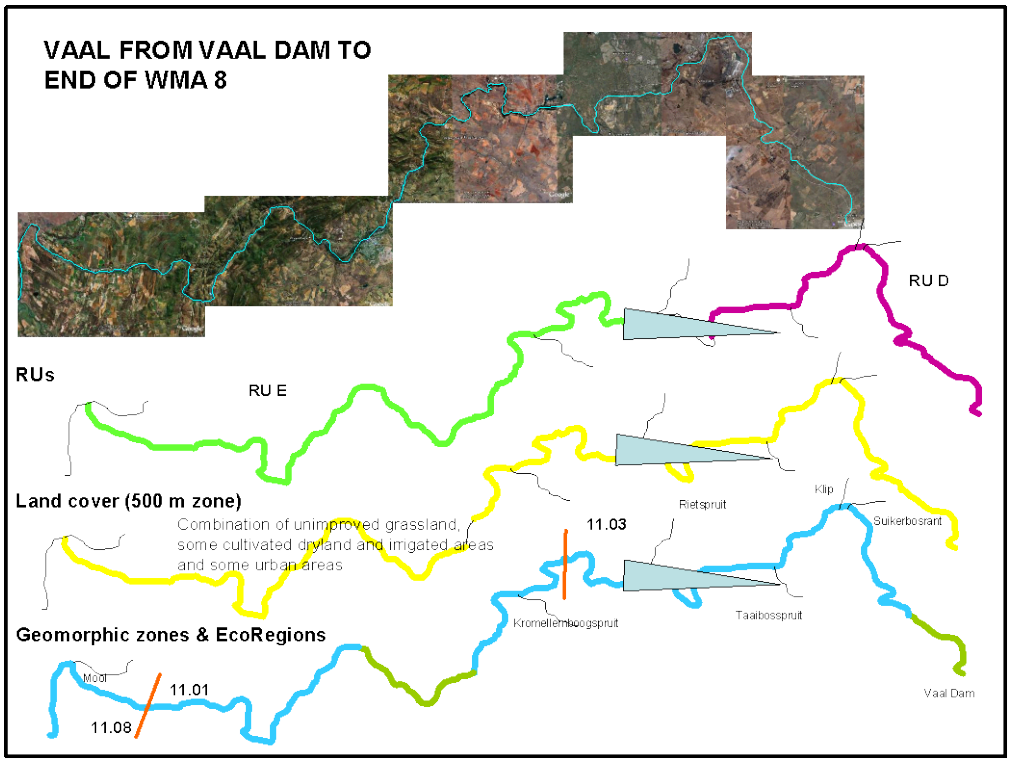


Figure 3.6 Management Resource Units: From Vaal Dam to end of WMA8

Table 3.6 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	28.115368, -26.882574 28.026476 -26.797013	C22F C22K

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
				also identified as a hot spot (3 priority rating) and therefore requires a detailed EWR site(DWAF, 2008).		
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 WMA8. 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

3.2 KLEIN VAAL

3.2.1 Natural Resource Units: Klein Vaal River

The EcoRegions and geomorphic zones are described in the map below (Figure 3.7). Further subdivision in primary and secondary units is described and the rationale for all delineations isprovided in Table 3.7. Derived from the EcoRegions and the geomorphic zones, the MRUs are delineated.

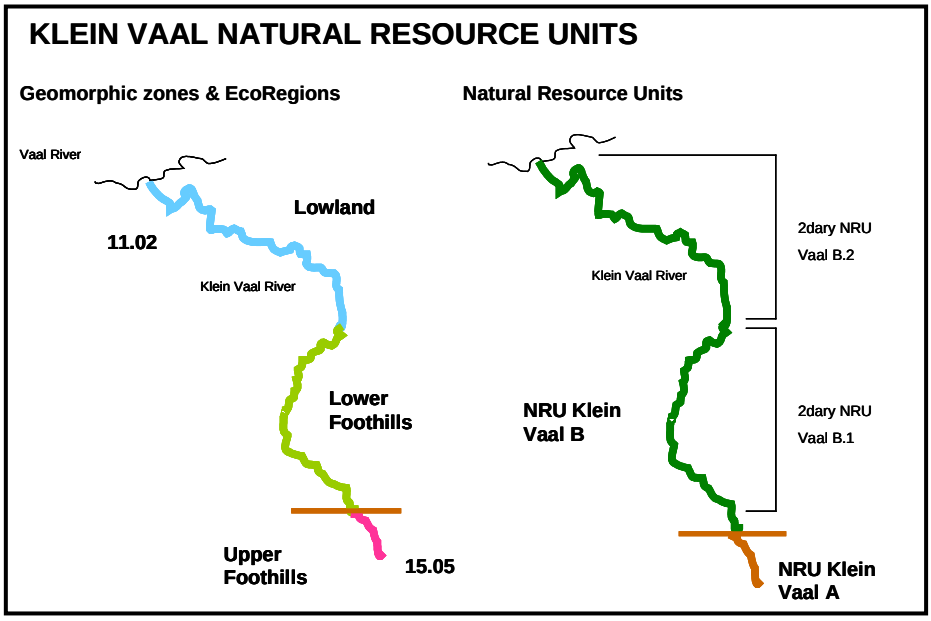


Figure 3.7 Natural Resource Units: Klein Vaal River

Table 3.7 Description and rationale for the Klein Vaal River NRUs

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Klein Vaal A	15.05 (100%)	Upper Foothills(100%)	EcoRegions the major consideration and defines the NRU.	30.2330 - -27.1142 30.21, -27.0727
NRU Klein Vaal B	11.02 (100%)	Lower Foothills(40%) Lowland (60%)	EcoRegions the major consideration and defines the NRU.	30.21, -27.0727 30.0063 - -26.7483

3.2.2 Management Resource Units: Klein Vaal

The river is divided into MRUs and illustrated in Figure 3.8. The description of the MRUs and the rationale for selection is provided in Table 3.8.

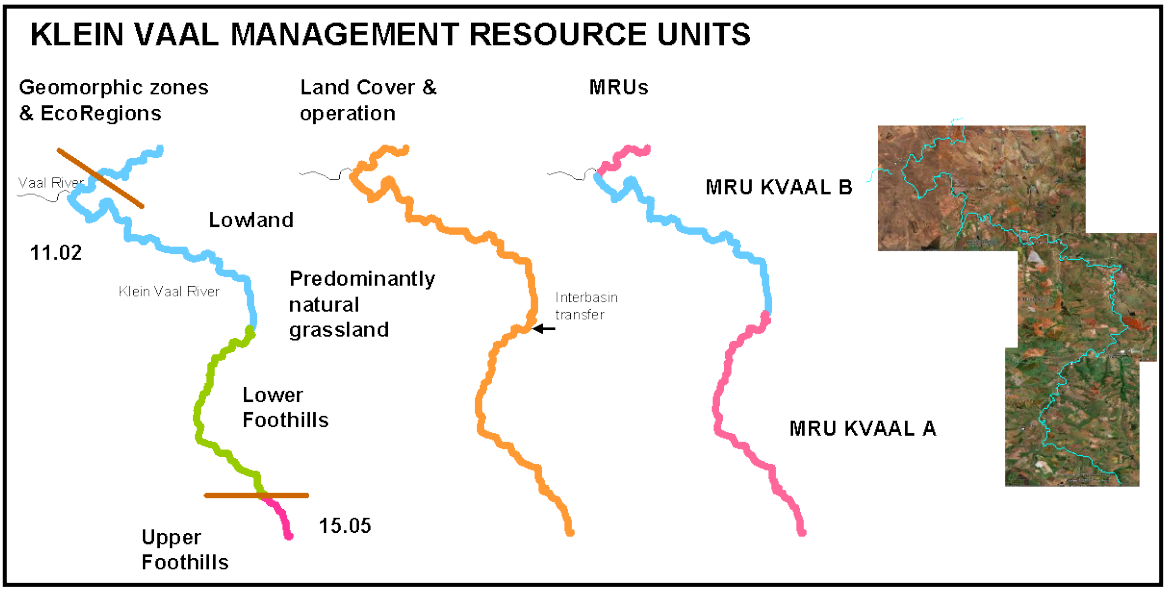


Figure 3.8 Management Resource Units:Klein Vaal River

Table 3.8 Description and rationale of the KleinVaal 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 change in geomorphic zone provides a logical break in the KleinVaalRiver. Ideally an EWR site should be selected within this reach as it has ecological importance.	Origin of river to end of Lower Foothills 30.2330 - -27.1142 30.1899 - -26.8912	C11C
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 VaalRiver. 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	30.1899 - -26.8912 30.0063 - -26.7483	C11C C11D

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
				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.		

3.3 KLIP RIVER

3.3.1 Natural Resource Units: Klip River

The EcoRegions and geomorphic zones are described in the map below (Figure 3.9). Further subdivision in primary and secondary units is described and the rationale for all delineations is provided in Table 3.9. Derived from the EcoRegions and the geomorphic zones, the MRUs are delineated.

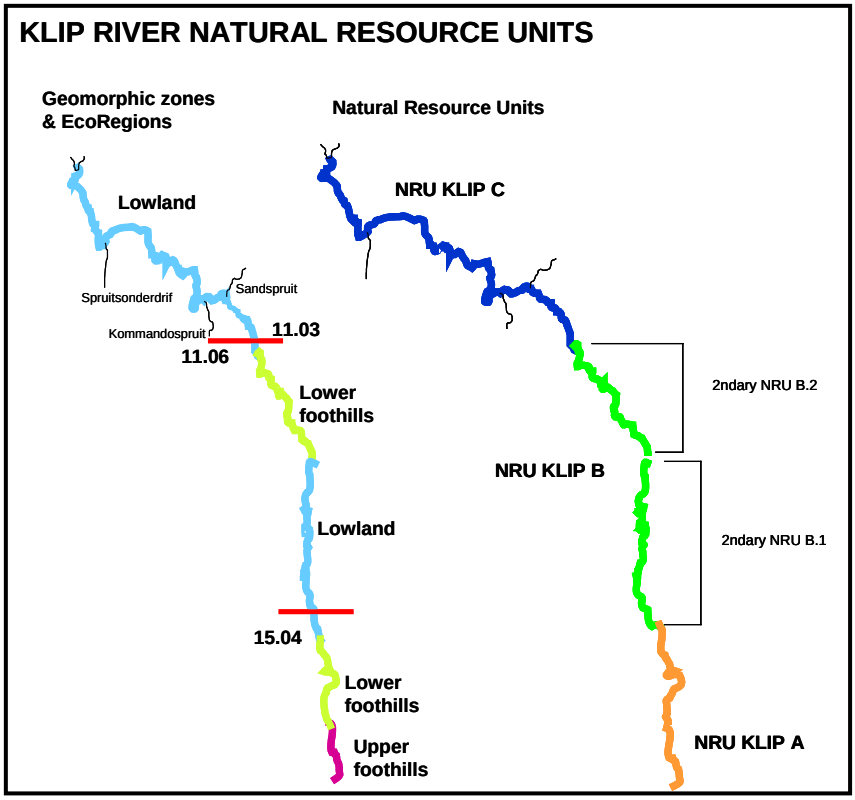


Figure 3.9 Natural Resource Units: Klip River

Table 3.9 Description and rationale for the Klip River NRUs

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Klip A	15.04 (100%)	Upper Foothills (30%) Lower Foothills (60%) Lowland (10%)	EcoRegions the major consideration and defines the NRU.	29.6409 - 27.9588 29.5804 - 27.6676
NRU Klip B	11.06 (100%)	Lowland (55%) Lower Foothills (35%)	EcoRegions the major consideration and defines the NRU	29.5804 - 27.6676 29.4642 to -27.2902
Secondary NRU Klip B.1	11.06 (100%)	Lowland (100%)	This section includes a major wetland associated with the lowland section within the NRU B. This therefore warrants an secondary NRU within the primary NRU	29.6409 - 27.9588 29.5804 - 27.6676
NRU Klip C	11.03	Lowland		29.4642 to -27.2902 29.0704 – 27.0556

3.3.2 Management Resource Units: Klip River

The river is divided into MRUs and illustrated in Figure 3.10. The description of the MRUs and the rationale for selection is provided in Table 3.10.

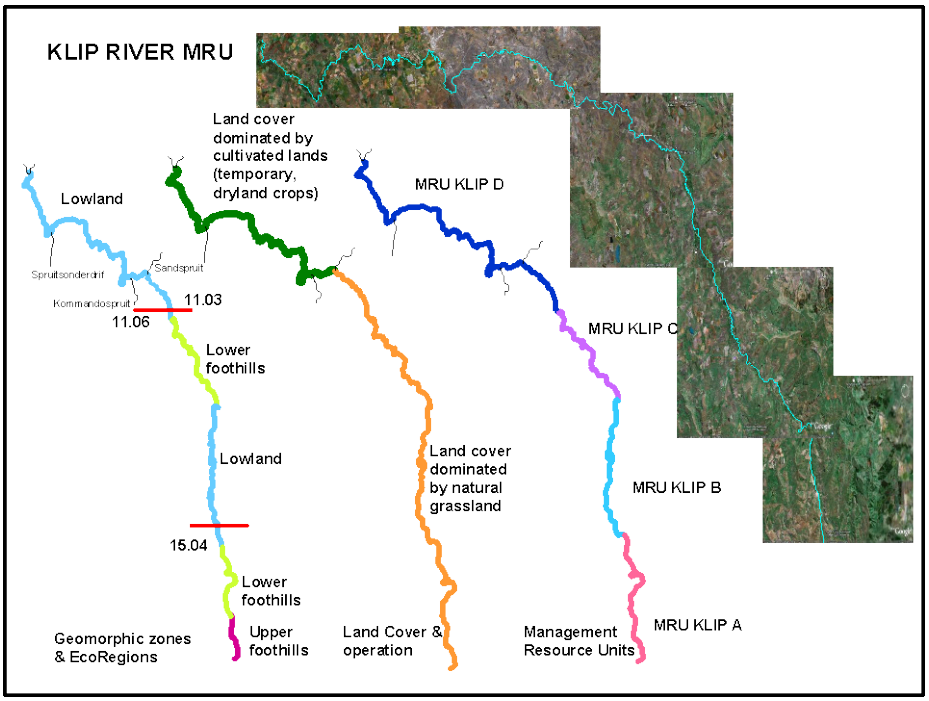


Figure 3.10 Management Resource Units:Klip River

Table 3.10 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 KlipRiver 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 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 VaalRiver 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

3.4 WILGE RIVER

3.4.1 Natural Resource Units: Wilge River

The EcoRegions and geomorphic zones are described in the map below (Figure 3.11). Further subdivision in primary and secondary units is described and the rationale for all delineations is provided in Table 3.11. Derived from the EcoRegions and the geomorphic zones, the MRUs are delineated.

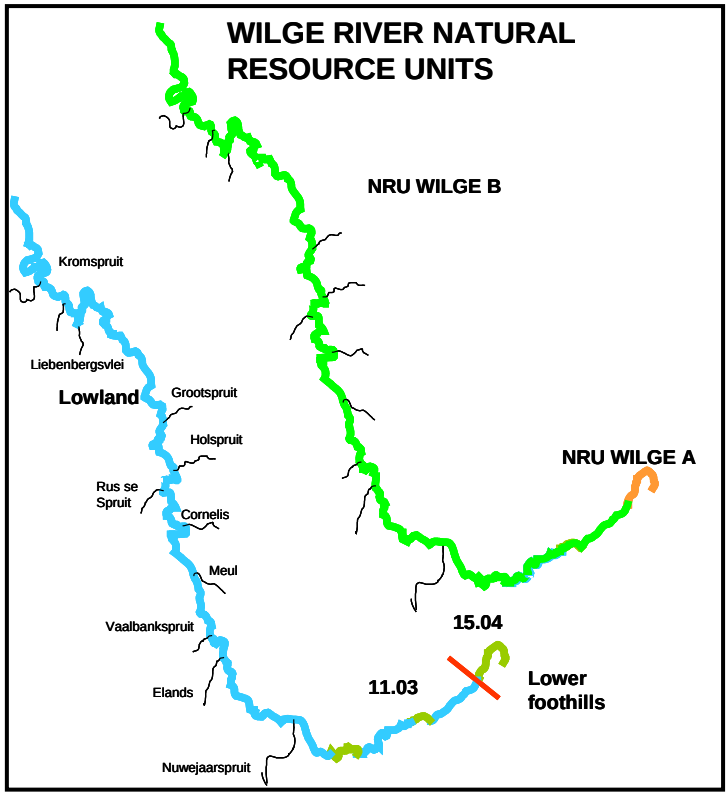


Figure 3.11 Natural Resource Units: WilgeRiver

Table 3.11 Description and rationale for the WilgeRiver NRUs

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Wilge A	15.04 (100%)	Lower Foothills (100%)	EcoRegions the major consideration and defines the NRU.	29.6409 - 27.9588 29.5885, -28.1571
NRU WilgeB	11.03 (100%)	Lowland (100%)	EcoRegions the major consideration and defines the NRU.	29.5885, -28.1571 28.415969, -27.168284

3.4.2 Management Resource Units: Wilge River

The river is divided into MRUs and illustrated in Figure 3.12. The description of the MRUs and the rationale for selection is provided in Table 3.12.

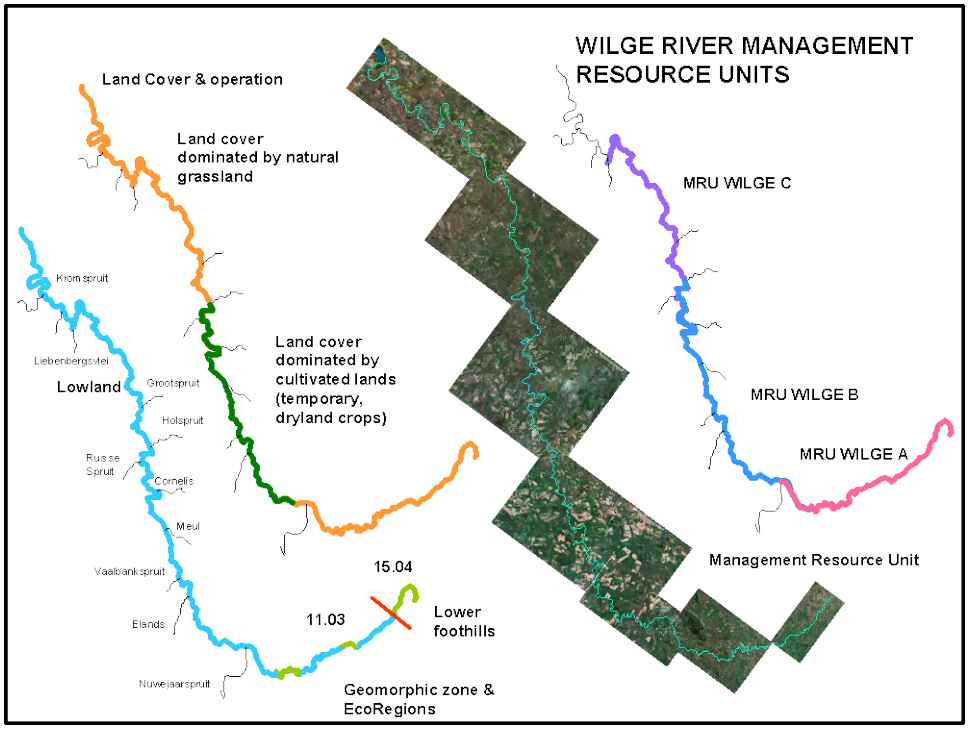


Figure 3.12 Management Resource Units:Wilge River

Table 3.12 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 WilgeRiver 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 WilgeRiver has been identified as a 3 priority rating that means that it requires a comprehensive or intermediate site(DWAF, 2008).	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 WilgeRiver has been identified as a 3 importance that means that it requires a comprehensive or intermediate site (RDM/ WMA8C000/01/CON/ 0307).	29.6211 - 27.7493 28.7799 - 27.6865	C81E C81K C82C C82G

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
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 landuse. Ends at Liebenbergsvlei confluence due to significant change in flow regime (increased flows from the LHWP). Downstream WilgeRiver 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 WilgeRiver 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

3.5 LIEBENBERGSVLEI RIVER

3.5.1 Natural Resource Units: Liebenbergsvlei River

The EcoRegions and geomorphic zones are described in the map below (Figure 3.13). Further subdivision in primary and secondary units is described and the rationale for all delineations is provided in Table 3.13. Derived from the EcoRegions and the geomorphic zones, the MRUs are delineated.

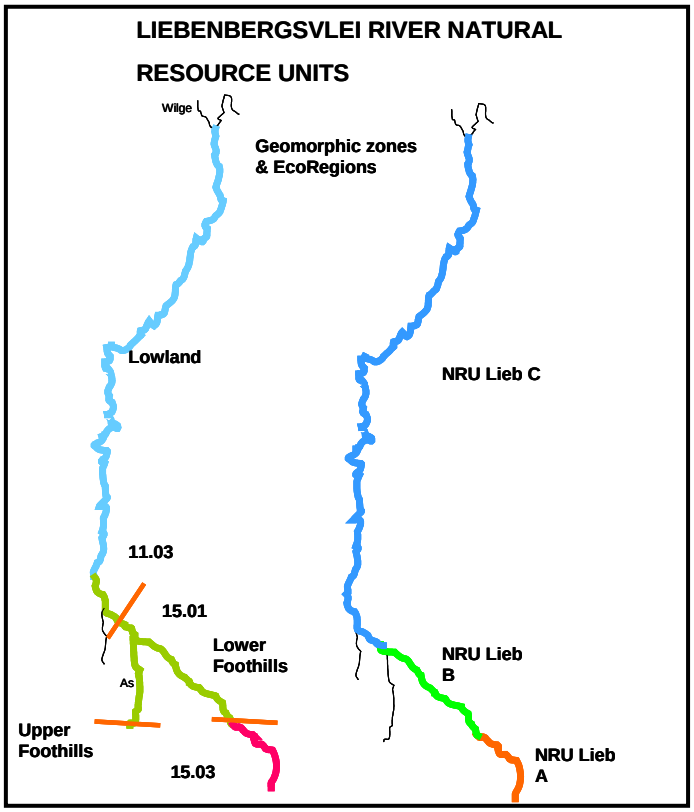


Figure 3.13 Natural Resource Units: Liebenbergsvlei River

Table 3.13 Description and rationale for the Liebenbergsvlei River NRUs

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Lieb A	15.03 (100%)	Upper Foothills (100%)	EcoRegions the major consideration and defines the NRU	28.3631 to -28.697 28.6037, -28.3971
NRU Lieb B	15.01 (100%)	Lower Foothills (100%)	EcoRegions the major consideration and defines the NRU	28.6037, -28.3971 28.3166, -28.1598
NRU Lieb C	11.03 (100%)	Lowland (100%)	EcoRegions the major consideration and defines the NRU	28.3166, -28.1598 28.3080 to -27.8667

3.5.2 Management Resource Units: Liebenbergsvlei River

The river is divided into MRUs and illustrated in Figure 3.14. The description of the MRUs and the rationale for selection is provided in Table 3.14.

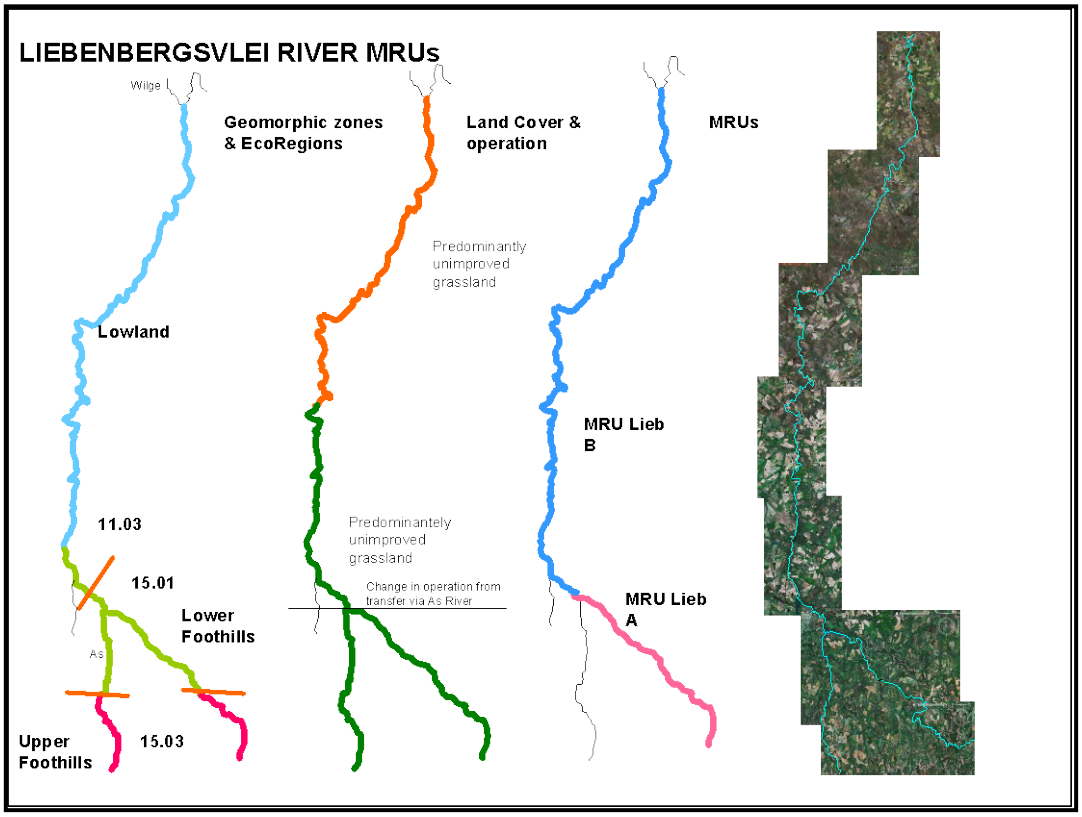


Figure 3.14 Management Resource Units:Liebenbergsvlei River

Table 3.14 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 LiebenbergsvleiRiver 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	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Lieb B	11.03	Lowland	Cultivated lands and 'unimproved grassland'	From the As River confluence to the WilgeRiver 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 to -28.2168 28.3080 to -27.8667	C83C

3.6 WATERVALRIVER

3.6.1 Natural Resource Units: Waterval River

The EcoRegions and geomorphic zones are described in the map below (Figure 3.15). Further subdivision in primary and secondary units is described and the rationale for all delineations is provided in Table 3.15. Derived from the EcoRegions and the geomorphic zones, the MRUs are delineated.

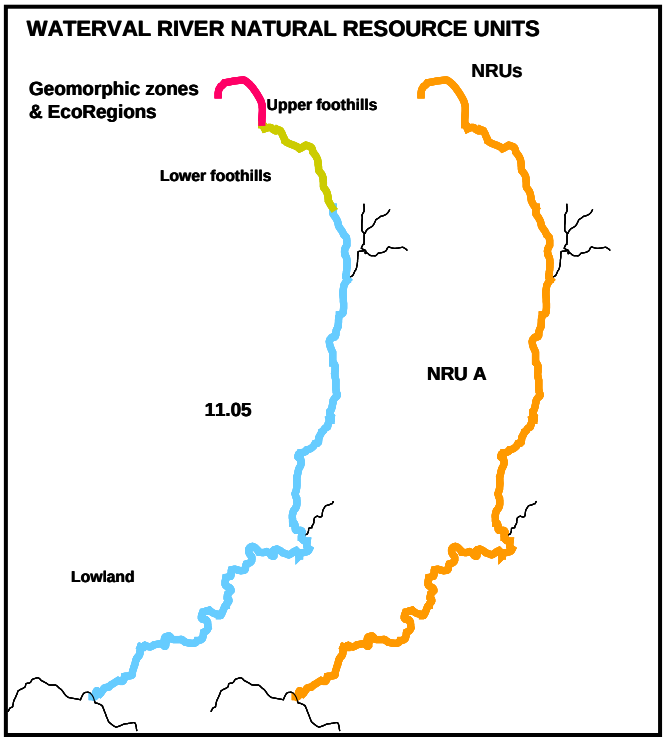


Figure 3.15 Natural Resource Units: Waterval River

Table 3.15 Description and rationale for the Waterval River NRUs

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Waterval A	11.05 (100%)	Upper Foothills (10%) Lower Foothills (20%) Lowland (70%)	EcoRegions the major consideration and defines the NRU	28.8708, -26.3982 28.7143, -26.9694

3.6.2 Management Resource Units: Waterval River

The river is divided into MRUs and illustrated in Figure 3.16. The description of the MRUs and the rationale for selection is provided in Table 3.16.

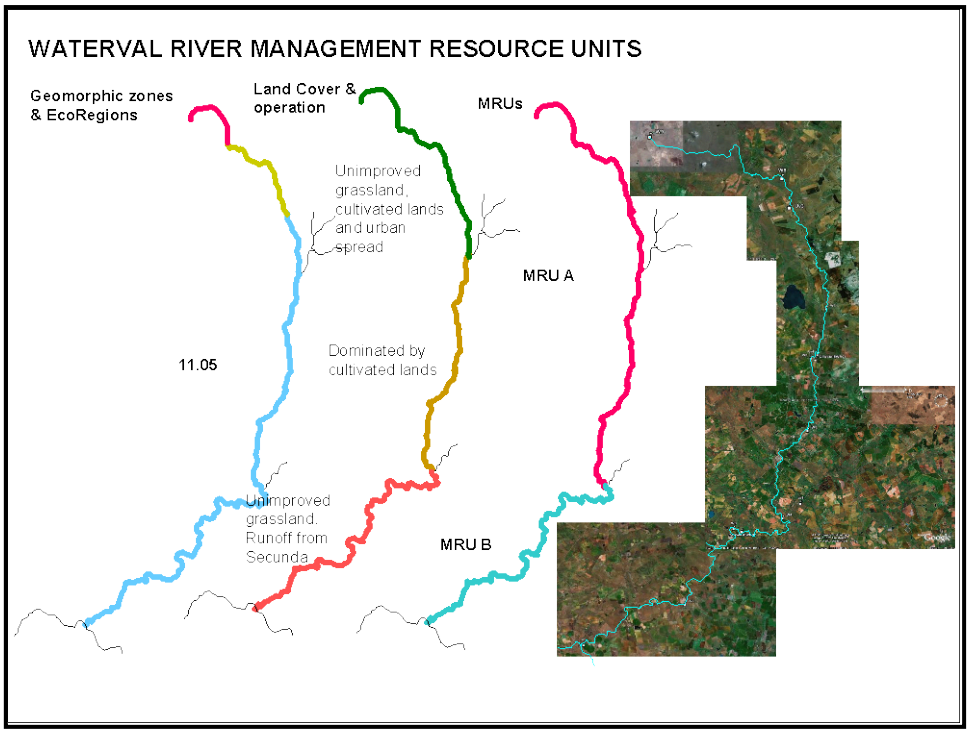


Figure 3.16 Management Resource Units:Waterval River

Table 3.16 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 2nd 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

3.7 SUIKERBOSRAND RIVER

3.7.1 Natural Resource Units: Suikerbosrand River

The EcoRegions and geomorphic zones are described in the map below (Figure 3.17). Further subdivision in primary and secondary units is described and the rationale for all delineations

isprovided in Table 3.17. Derived from the EcoRegions and the geomorphic zones, the MRUs are delineated.

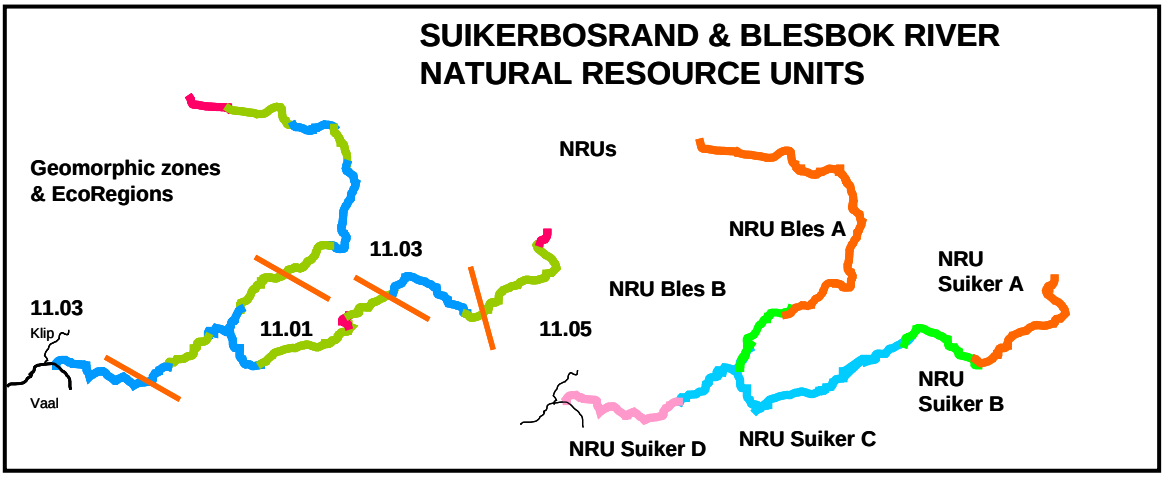


Figure 3.17 Natural Resource Units: Suikerbosrand and Blesbokspruit Rivers

Table 3.17 Description and rationale for the Suikerbosrand and Blesbokspruit RiversNRUs

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Bles A	11.03	Upper Foothills (10%) Lower Foothills (45%) Lowland (45%)	EcoRegions the major consideration and defines the NRU.	28.2172, -26.1557 28.3909, -26.4865
NRU Bles B	11.01	Lower Foothills (70%) Lowland (30%)	EcoRegions the major consideration and defines the NRU.	28.3909, -26.4865 28.2900, -26.5977
NRU Suiker A	11.05	Upper Foothills (2%) Lower Foothills (80%)	EcoRegions the major consideration and defines the NRU.	28.866, -26.4137 28.7383, -26.5747
NRU Suiker B	11.03	Lowland (100%)	EcoRegions the major consideration and defines the NRU.	28.7383, -26.574 28.5761,-26.5351
NRU Suiker C	11.01	Upper Foothills (2%) Lower Foothills (80%) Lowland (18%)	EcoRegions the major consideration and defines the NRU.	28.5761,-26.5351 28.1380, -26.7011
NRU Suiker D	11.03	Lowland (100%)	EcoRegions the major consideration and defines the NRU.	28.1380, -26.7011 27.9719, -26.6666

3.7.2 Management Resource Units: Suikerbosrand River

The river is divided into MRUs and illustrated in Figure 3.18. The description of the MRUs and the rationale for selection is provided in Table 3.18.

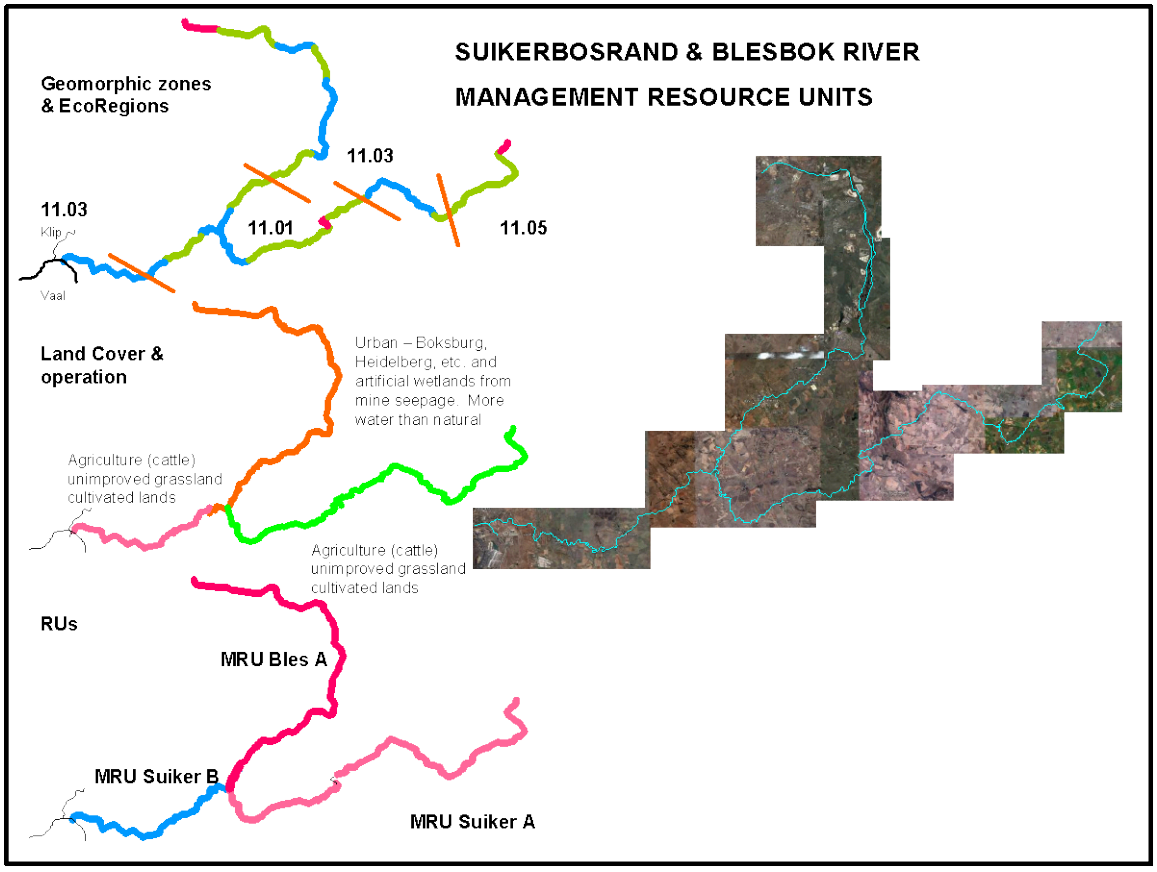


Figure 3.18 Management Resource Units:Suikerbosrand River

Table 3.18 Description and rationale of the Suikerbosrand 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 SuikerbosrandRiver 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	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quat
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 SuikerbosrandRiver. 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

3.8 MOOI RIVER

3.8.1 Natural Resource Units: Mooi River

The EcoRegions and geomorphic zones are described in the map below (Figure 3.19). Further subdivision in primary and secondary units is described and the rationale for all delineations is provided in Table 3.19. Derived from the EcoRegions and the geomorphic zones, the MRUs are delineated.

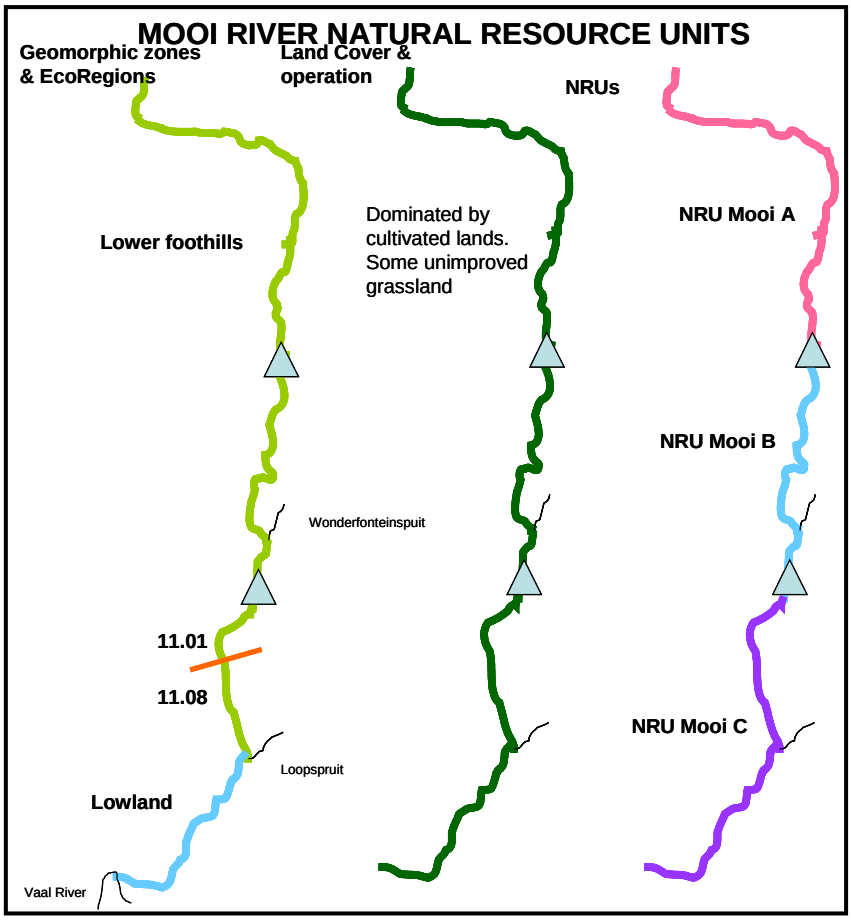


Figure 3.19 Natural Resource Units: Mooi River

Table 3.19 Description and rationale for the Mooi River NRUs

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
Mooi NRU A	11.01 (100%)	Lower Foothills (100%)	EcoRegions the major consideration and defines the NRU.	26.9846, -25.9105 27.0817, -26.6385
Mooi NRU B	11.08 (100%)	Lower Foothills (30%) Lowland (70%)	EcoRegions the major consideration and defines the NRU.	27.0817, -26.6385 26.953 - 26.8764

3.8.2 Management Resource Units: Mooi River

The river is divided into MRUs and illustrated in Figure 3.20. The description of the MRUs and the rationale for selection is provided in Table 3.20.

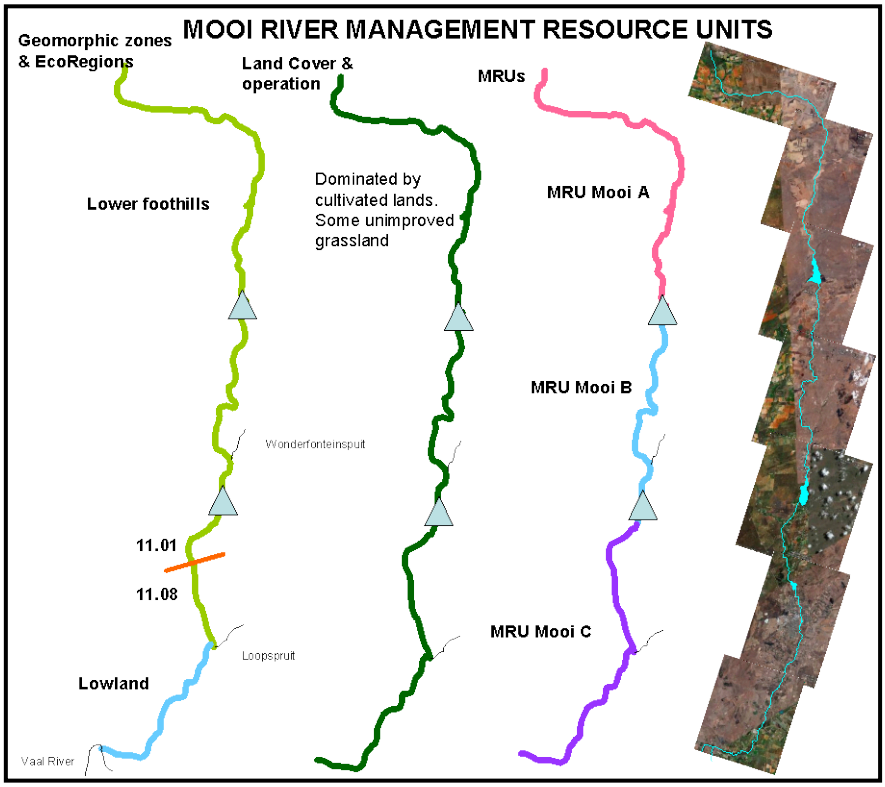


Figure 3.19 Management Resource Units:MooiRiver

Table 3.20 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 MooiRiver 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 prioritywhich 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 to -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 which has and is being extensively modified. This makes the selection of an EWR site very difficult.	27.158998 - 26.255203 27.124953 - 26.533479	C23G
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 VaalRiver. 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 VaalRiver.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

4 EWR SITE SELECTION

4.1 CRITERIA FOR SITE SELECTION

EWR sites (previously called IFR sites) are selected through a multi-disciplinary process consisting of evaluating an aerial video (if available) or Google Earth images of the river to identify a range of possible sites, and groundtruthing to make a final selection from the various options. An EWR site consists of a length of river which may consist of various cross-sections for both hydraulic and ecological purposes (modified from Louw *et al*., 1999).

EWR are determined at each of the EWR sites, and it is therefore vital that:

- The sites are selected to provide as much information as possible regarding the variety of conditions in a river reach.
- The specialists that need to use these sites to set flow requirements for their discipline can relate to the habitat the sites represent.
- The persons involved in selecting the sites understand and are experienced in the use of sites in EWR studies.

The selection of EWR sites is guided by a number of considerations, including:

- The locality of gauging weirs with good quality hydrological data.
- The locality of the proposed and existing developments.
- The locality and characteristics of tributaries.
- The habitat integrity or PES of the different river reaches.
- The boundaries of Level II EcoRegions within the study area.
- The reaches where people depend directly on a healthy river ecosystem.
- The suitability of the sites for follow-up monitoring.
- The locality of geomorphologically representative sites.
- The habitat diversity for aquatic organisms, marginal and riparian vegetation.
- **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.**

The criteria in bold are the most important and therefore the overriding criteria.

4.2 EWR SITES

4.2.1 Locality and description of sites

The locality of the EWR sites within the MRUs as identified during this study is provided in Table 4.1.

Table 4.1 MRUs and EWR sites

MRUs	Recommendation (see Chapter 3)	EWR site
VAAL RIVER		
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 aRapid 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 2nd 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.
KLEIN VAAL RIVER		
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.
KLIP RIVER		
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	EWR 6 was selected in this reach.

MRUs	Recommendation (see Chapter 3)	EWR site
	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).	
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.
WILGE RIVER		
MRU Wilge A	It is recommended that an EWR siteis selected in this MRU due to its different operation and wetland character. The whole Wilge River has been identified as a 3 priority ratingwhich 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.
LIEBENBERGSVLEI RIVER		
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.
WATERVAL RIVER		
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.	
SUIKERBOSRAND AND BLESBOKSPRUIT RIVERS		
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.
MOOI RIVER		
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 which has and is being extensively modified. This makes the selection of an EWR site very difficult.	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 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	No EWR site was selected.

MRUs	Recommendation (see Chapter 3)	EWR site
	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.	

The locality and characteristics of the EWR sites are provided in Table 4.2.

Table 4.2 Locality and characteristics of the VaalRiver EWR sites

Site information	EWR sites	Illustration
EWR nr and name	**EWR 1 Uitkoms**	
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	**EWR 2 Grootdraai**	
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	**EWR 3 Gladdedrift**	
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	**EWR 4 DeNeys**	
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	**EWR 5 Skandinavia**	
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	**RE-EWR 1 Klein Vaal**	
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	**EWR 6 Klip**	
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	**EWR 7 Upper Wilge**	
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	**EWR 8 Bavaria**	
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	-	

Site information	EWR sites	Illustration
EWR nr and name	**EWR 9 Suikerbos US**	
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	**EWR10 Suikerbos DS**	
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	**EWR11 Blesbokspruit**	
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	**RE-EWR 2 Mooi**	
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 4.1 and summarised in Table 4.3.

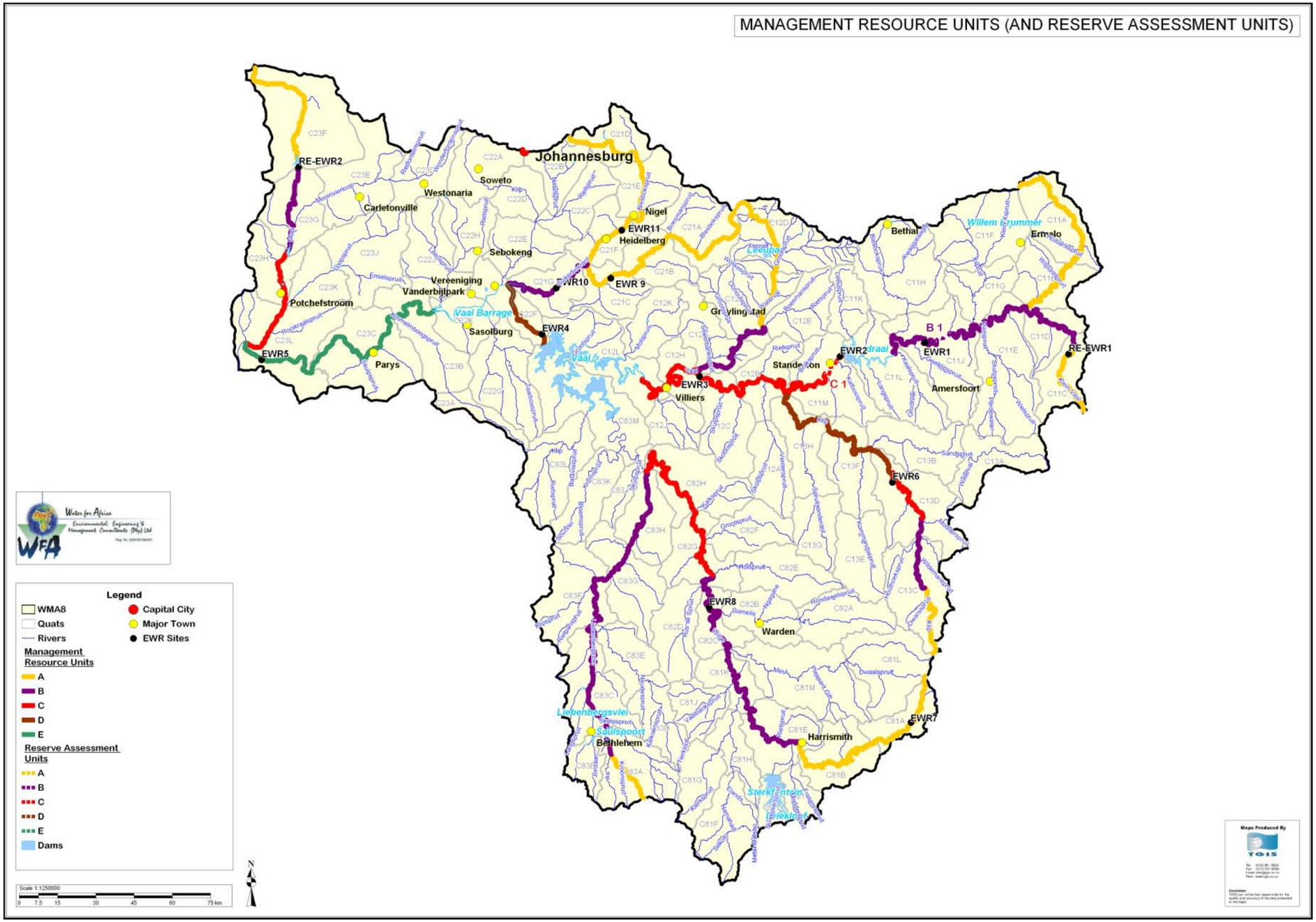


Figure 4.1 Locality of EWR sites and MRUs

Table 4.3 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	
Rapid Level sites											
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	

4.2.2 Site suitability

The site suitability of each EWR site was assessed and is provided in Table 4.4 and 4.5. The detail assessment per component is provided in Appendix C-G. All scores are out of 5 with 5 referring to very high suitability.

Table 4.4 Biophysical site suitability for the Upper Vaalsystem

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.

From a biophysical point of view, these sites are all moderately suitable apart from EWR 10 (high) and RE-EWR 2 (Low to moderate).

Table 4.5 Integrated site suitability for the Upper Vaalsystem

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 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 SITES	BIOPHYSICAL		HYDRAULICS		INTEGRATED SITE SUITABILITY		Comment
	Low flows	High flows	Low flows	High flows	Low flows	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.

Typically, site characteristics result in site suitability being low to moderate for low flows and moderate to high for high flows. Hydraulic evaluations are based on visual observation at the time of site selection. The confidence in the results of hydraulic analyses is based, amongst other considerations, on the range of measured flows. Therefore, if an adequate flow range is measured, reasonable confidence may be associated with the hydraulic results, even if the site is not ideally suitable for hydraulic analysis.

5 REFERENCES

AfriDev. 2006.Main Report. Komati Catchment Ecological Water Requirements Study.Department of Water Affairs and Forestry, Pretoria. Report No. RDM X100-00-CONCOMPR2-1205.

Department of Water Affairs and Forestry, South Africa (DWAF).1999. Resource Directed Measures for Protection of Water Resources: Volume 3: River Ecosystems Version 1.0. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry, South Africa (DWAF). 2004.Upper Vaal Water Management Area: Internal Strategic Perspective.Prepared by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 on behalf of the Directorate: National Water Resource Planning. DWAF Report No P WMA 08/000/00/0304.

Department of Water Affairs and Forestry, South Africa (DWAF). 2007. Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. Sabie and Crocodile Systems: Resource Unit Delineation: Prepared by Water for Africa, authored by Louw, MD. Report no. 26/8/3/10/12/006.

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/ WMA8 C000/01/CON/0207.

Kleynhans, C.J., Thirion, C. and Moolman, J. 2005.A Level I River EcoRegion classificationSystem for South Africa, Lesotho and Swaziland.Report No. N/0000/00/REQ0104.Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

Kleynhans, C.J., Thirion, C., Moolman, J. and Gaulana, L. 2007.A Level II River EcoRegion classification System for South Africa, Lesotho and Swaziland. Report No. N/000/00/REQ0XXX.Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

Louw, M.D., Kemper, N. and Birkhead, A.L. 1999.Procedure for selecting sites in intermediate and comprehensive determination of the ecological reserve (water quantity component). Appendix 18 in Resource Directed Measures for Protection of Water Resources: River Ecosystems. Published by Department of Water Affairs, South Africa.

Louw, M.D. and Hughes, D.A. 2002.Prepared for the Department of Water Affairs and Forestry, South Africa. Resource Directed Measures for Protection of Water Resources: River Ecosystems - Revision of a quantity component.

Noble, R.G., and Hemens, J. 1978. Inland water ecosystems in South Africa - a review of research needs. South African National Scientific Programmes Report No. 34: 150 pp.

Omernik, J.M. 1987. Ecoregions of the conterminous United Sites.Annals of the Association of American Geographers 77:118 – 125.

Rowntree, K.M. and Wadeson, R.A. 1999.A hierarchical framework for categorising the geomorphology of river systems, Water Research Commission Report. Report No. 497/1/99. WRC, Pretoria.

SPECIALIST APPENDICES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX A:
RIVER REACH DEMARCATION AND DELINEATION
Dr CJ Kleynhans and Ms MD Louw

A1 **RATIONALE**

This document defines and describes the different units according to which a river should be investigated and studied for the purpose of ecological Reserve determination. The objective is to demarcate and delineate river reaches[3] following a hierarchical approach according to the following considerations:

- Broad natural physical reaches that constitute the river from its source downstream. These reaches are the result of the various drivers of the system under reference conditions, *viz*. Hydrology, Geomorphology and Physico-chemical attributes. It follows that the biota responded and adapted to these reference conditions (i.e., the broad natural habitat template) in a dynamic way depending on natural climatic variation. The boundaries between different broad natural reaches are not necessarily crisp and clear. However, where marked and rapid changes occur due to geology (e.g. geomorphology and physico-chemical changes) and hydrology (e.g. large tributaries or a change in climate) these boundaries may be easy to identify.
- Smaller natural reaches may be distinguished within these large reaches. Depending on the characteristics of the biological group and taxa considered, the distribution of biota will broadly coincide with the demarcation of the natural reaches. However, depending on the attributes (e.g. preferences and intolerances) of the biota they may be limited to smaller natural reaches within the broad natural physical reaches. These will result in so-called biological habitat segments (e.g. fish habitat segments, Kleynhans 1999). Depending on the life-history requirements of the biota and the dynamic nature of the ecosystems, the boundaries of the habitat segments can vary temporally and spatially. Some biota may be limited to particular smaller reaches within the broad natural reach; others may be present throughout the broad natural reach while others may be present across two or more broad natural reaches.This must be considered when defining the reference biological assemblage for a particular river reach.
- Superimposed on these natural reaches are the changes brought about by anthropogenic activities. These activities may result in a homogenous impact throughout the length of a broad natural reach or their impact may be heterogeneous and result in smaller distinguishable sub-reaches. Physical driver changes as well as biological change agents (e.g. alien biota) may be involved.

Reference conditions (in terms of natural reaches, drivers and biota) need to be considered when the Reserve is determined as these provide the natural evolutionary setting that indicate the resilience of the system to various forms of modification and stress. However, pragmatic considerations that come into the picture include anthropogenic changes to the system that are within the medium and long term not likely to change. These may include modifications to the system such as impoundments, agricultural, urbanization and forestry. Such modifications brings about changes in the natural reach characteristics in terms of the system drivers and biota and indicates changed reaches that needs particular consideration in order to manage them according to ecological Reserve considerations (eco-classification) that encompass, *inter alia,* ecological importance and sensitivity, present ecological state, the recommended category and sustainability. This rationale also enables the setting of resource quality objectives, ecological specifications and monitoring objectives and specifications.

[3] For the purpose of this document, “reach” is broadly defined as “a specified segment of a stream’s path” (www.wwnorton.com/college/geo/earth2/glossary/r.htm).

Following this approach, the following classification of reaches is distinguished in terms of the setting of the ecological Reserve for particular river reaches:

- Natural Resource Units (NRU)
- Management Resource Units (MRU)
- Reserve Assessment Units (RAU)
- The Ecological Reserve is determined at a specific point in the river, *viz*. the Ecological Water Requirement Site (EWR Site)

The EWR sites are identified within a system context where reference conditions are formulated in context of a NRU according to physical drivers and biota. A hierarchical demarcation process is followed to select and define EWR within this system context. This is described in the following sections and the process is diagrammatically illustrated in Figure A1 and A2.

A2 NATURAL RESOURCE UNIT (NRU)

The guiding principle is that if the hydrology, geomorphic characteristics (i.e. geomorphic zone), physico-chemical attributes and river size remains relatively similar, a NRU can be demarcated.

Two levels can be distinguished:

- primary NRUs that are demarcated according to EcoRegionsincluding relevant components of an EcoRegion that may contribute to the demarcation of NRUs, This will determine the broad ecological context (climate, geomorphology, hydrology and the broad physico-chemical profile) within which the river is situated
- Secondary NRUs can be indicated and if present, are nested within the Primary NRU and are defined according to a significant change in:
  - Geomorphic zones (slopes and geological attributes), which will determine the potential presence of certain habitats.
  - Hydrology which may be due to the flow contribution (in volume or seasonality) of tributaries or a change in ground water contribution.
  - Physico-chemical conditions which may be the result of a change in hydrology or geology. This will result in a specific meso-habitat that can influence the presence and abundance of species (e.g. biological habitat segments).

Figure A1 provides a hypothetical example to illustrate the described delineation.An explanation of the hypothetical delineation in table form (Table A1) is also provided.

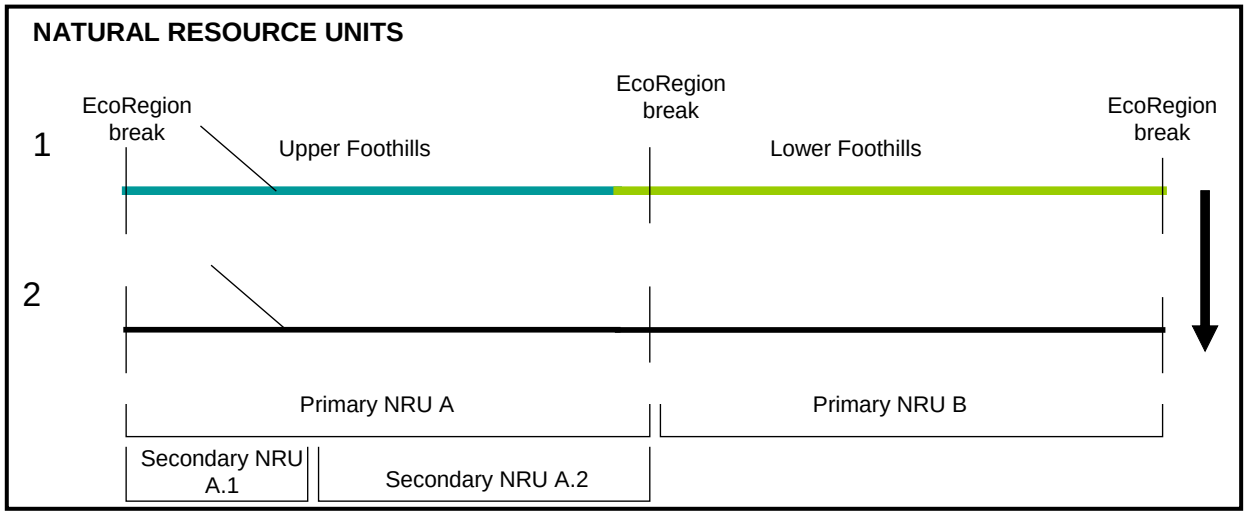


Figure A1 Delineation of Natural Resource Units

Table A1 Description of the rationale for the delineation of the Natural Resource Unit for the Figure A1

UNIT	RATIONALE	DELINEATION
Primary NRU A	EcoRegions main determinant. As most of the EcoRegion also consists of one geomorphic zone, this provides additional motivation for the delineation.	Start to end of EcoRegion
Secondary NRU A.1	The tributary provides sediment (alluvial) and different hydrology. This provides further delineation. The temperature is also different.	Start of EcoRegion to confluence of the tributary.
Secondary NRU A.2	Different hydrology and physico-chemical characteristics from the upstream section.	Confluence of tributary to end of EcoRegion

A3 MANAGEMENT RESOURCE UNIT (MRU)

The purpose of distinguishing MRUs is to identify a management unit within which the EWR can be implemented and managed based on one set of identified flow requirements.

The following provides the concept of Management Resource Units (MRUs):

- MRUs are based on the principle of homogeneity of impacts in the demarcated NRU.
- This may include the modification of flows in the system due to abstraction, regulation by impoundments and development along the NRU and upstream from the NRU which may influence the geomorphology and physico-chemical conditions.
- This can cause specific changes in the system drivers which will subdivide the NRU into MRUs.
- Modifications to a river reach may homogenize adjacent NRUs to the extent that they may constitute a single MRU.

MRUs are homogenous units which are sufficiently different from adjacent areas to warrant a separate EWR assessment being undertaken (Louw & Hughes, 2002). This means that an EWR set in the MRU, according to the EWR site selection criteria in context of the MRU, will provide for the whole MRU. Hydrological changes due to incremental runoff must obviously be taken into account.

The following information is used to demarcate a MRU in relation to the NRU:

- Land cover or land use data.
- Index of Habitat Integrity data if available.
- System driver information as obtained from EcoStatus assessments. This may include information on hydrological changes in system operation.

If there are no anthropogenic changes or modifications present along or upstream from a particular NRU, such a NRU will logically constitute a Management Resource Unit (MRU).

A3.1 RESERVE ASSESSMENT UNIT (RAU)

The Reserve Assessment Unit (RAU) is situated within a MRU and it is used to demarcate and describe a reach of river within the MRU with the most critical habitat in the MRU. It has bearing upon the following:

- “Critical” refers to habitat being particularly responsive to changes in flow (and the associated physico-chemical and geomorphic conditions) and which can be related to critical phases in the life-cycle of biota.
- Additionally, if critical habitats are present in a particular reach, the EWR set to protect such habitat and its associated biota will also protect less critical habitat (and the associated biota).
- If habitat with the same level of “critical” are present over the whole of the MRU (i.e. in all reaches within the MRU), the reach selected as the RAU should preferably be the one that are in the best present ecological state.
- To provide for an eventual management monitoring context, the RAU can be defined in terms of biological habitat segments that represent the presence of a homogenous biological assemblage. This is important when reference conditions are formulated.

- The demarcation of the RAU is particularly important as it plays a decisive role of where EWR sites should be located.

Figure A2 provides a hypothetical example to illustrate the described delineation.An explanation of the hypothetical delineation in table form (Table A2) is also provided. The figure and table shows the delineation into MRU, RAUs and also indicate where the EWR site should be situated (process described below.

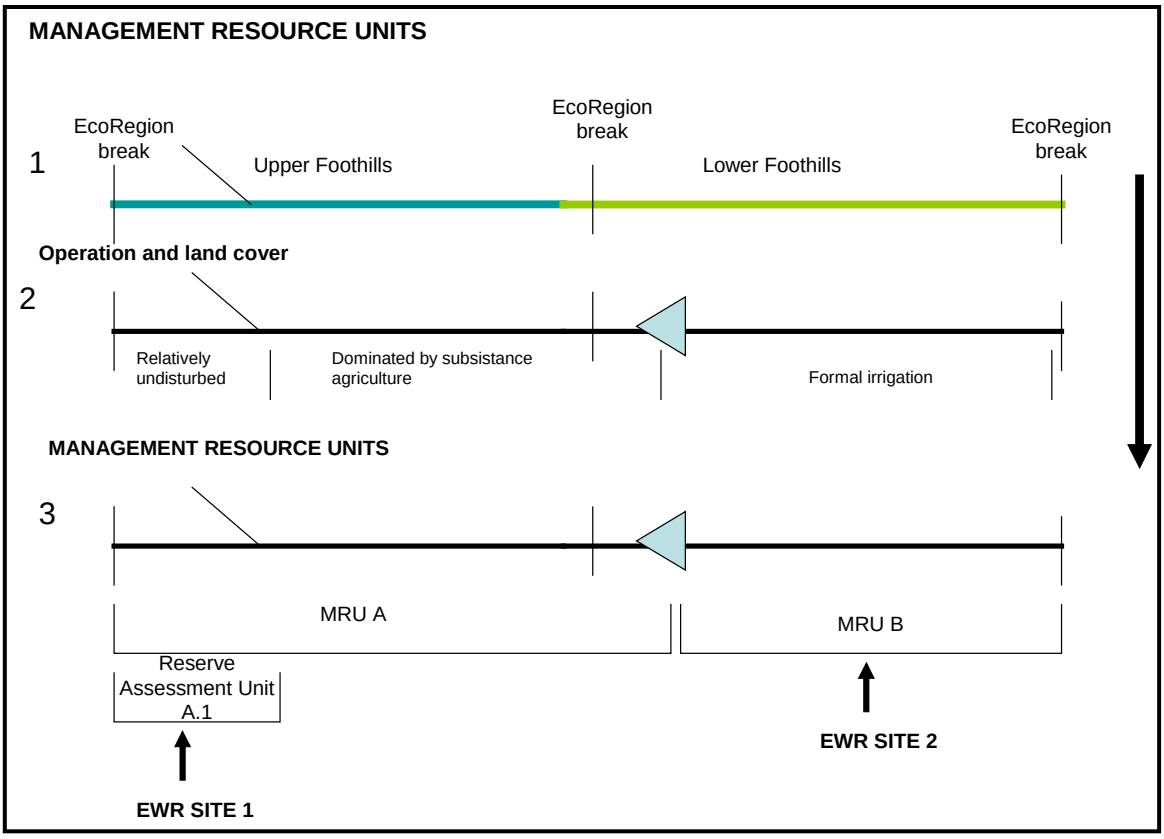


Figure A2 Delineation of Management Resource Units

Table A2 Description of the rationale for the delineation of the Management Resource Unit for the Figure A2

UNIT	RATIONALE	DECISION	DELINEATION
MRU A	Consists of mostly one EcoRegion. Consists mostly one Geomorphic zone. Land use dominated by subsistence agriculture. Dam provides an operational break.	MRU larger than NRU to include short section to the dam.	Start of EcoRegion to Dam
RAU A.1	RAU provides critical habitat for species that prefer colder temperatures as the tributary brings in warmer water. As area is isolated, critical vegetation habitat such as marginal and overhanging vegetation present to provide cover. In area downstream from the tributary, this habitat has been removed by grazing and bush clearing.	Assessment of RAU for EcoClassification and EWR assessment important as forms the critical section in the MRU	Start of EcoRegion to confluence of tributary (coincides with NRU A.1)
Recommendation: RAU A.1: EcoClassification + EWR assessment therefore EWR site if possible to be situated within RAU A.1 MRU A (excluding RAU A.1): EcoClassification. Refer to recommendation below.			

UNIT	RATIONALE	DECISION	DELINEATION
MRU B	Consists of one EcoRegion Consists one Geomorphic zone Land use dominated by formal irrigation End of EcoRegion provides logical break	MRU similar to NRU apart from the short section of NRU B which is above the dam.	Dam wall to end of EcoRegion
Recommendation: EcoClassification + EWR assessment As no RAU identified within the MRU, the EWR site to be selected anywhere in the MRU. If there are any areas that are potentially in a better state than the rest of the MRU, it is recommended that the EWR be placed within that.			

A4 ECOLOGICAL WATER REQUIREMENT SITE (EWR SITE)

"Site" refers to "features of a place related to the immediate environment on which the place is located (e.g. terrain, soil, subsurface, geology, groundwater)(www.geographic.org/glossary.html). Linked to this is the concept of "locality" which refers to the geographic area in which a collecting event occurs (porites.geology.uiowa.edu/entity.htm).

Ecological Water Requirement (EWR) sites are localities in a stream within the descending hierarchy of Primary NRU→Secondary NRU→MRU→RAU→EWR site. An EWR site is therefore a locality where measurements to determine the ecological water requirements of the river will be done.

The selection of EWR sites should consider the following physical attributes:

- Hydraulic cross section(s) will be established here. The purpose of hydraulic measurements and the consequent modelling is to provide an interpretive link between flows at different stages and the resulting aquatic habitats at the site. In some cases a digital terrain model ("habitat model") will be developed to provide a more accurate and detail perspective of the response of various habitat features to changes in flow.
- Preferably the EWR site should be representative of the RAU within which it is situated. "Representative" specifically refers to the hydraulics units at the site which should occur in similar proportions and with similar characteristics to that which occur at the majority of sites in the RAU. Generally, however, the more complicated the site is in terms of hydraulic units (e.g. diversity of bed material and multiple channels), the more difficult hydraulic modelling of the site becomes. This detrimentally influences the accuracy of the hydraulic model and thus the prediction of habitat at various discharges. As a result, a compromise needs to be found between the representivity of the EWR site and the accuracy of the hydraulics model.
- In addition to an ideal EWR site being representative of the RAU, it should also be sensitive in terms of its response to changes in water level (discharges). This will make the EWR site useful for future monitoring and the confidence in the interpretation of monitoring results.
- The ultimately ideal site would therefore be representative, practical and safe to measure and to model reasonably accurately, be accessible and be sensitive to changes in discharge to make it useful for habitat prediction.

Despite the above physical considerations, the following attributes are essential determinants of the suitability of a EWR site for specifying the ecological water requirements of biota, interpretation and eventually monitoring in terms of fish:

- The presence and abundance of rheophilics. If this group is present and abundant enough to make them useful in terms of monitoring, they would be the ideal subject to use for determining flow requirements as they are sensitive to a cessation of flow (usually fast flow) during all life-stages. If large[4] (about >20 cm in length) rheophilics are present and abundant enough, they would usually be preferable to small rheophilics due to the larger amount of flowing habitat required which would indicate higher discharges. In cases

[4] Size of any of the groups does not necessarily refer to a particular species: Different life-stages of the same species may, for example, be classified as large or small. In some case the adult semi-rheophilics may vary in size with the smaller adults also occurring in smaller streams.

where small rheophilics and large semi-rheophilics occur there may be a requirement for rheophilics during the dry season, but another requirement for large semi-rheophilics during the periods in the wet season when they breed.

- The presence of semi-rheophilics. If rheophilics are absent, semi-rheophilics should be used as the subject to determine flow requirements. Semi-rheophilics require flowing water (usually fast) during the breeding season. However, flowing water do not necessarily have to be present during the whole duration of the wet season. Duration of flow for rheophilics during the wet season will be determined by the length of time required for successful spawning, hatching and growth of larvae to juveniles. The size of the semi-rheophilics considered is also important as this will have an influence on the dimensions of the habitat requirements.
- The presence of limnophilics. If rheophilics and semi-rheophilics are absent, the requirements of limnophilics can be considered. This group do not require flowing water during any stage of their life-cycle.However, they do respond positively to improved habitat conditions (e.g. cover and feeding areas) caused by increased flows. In particular circumstances, the requirements of some limnophilics need to be considered where a drop in the water level in pools may result in a loss for example, of overhanging vegetation which may form an essential cover feature for some species to survive.

The following tables (Table A3 – A6) provide a simple framework to interpret the suitability of a site in terms of the habitats available, velocity-depth fish guilds present and their size at the site compared to the RAU[5]:

Table A3 Comparison of velocity-depth ratings for RAU and the EWR site

	FISH VELOCITY-DEPTH CLASSES (Abundance: 0=absent; 1=rare; 2=sparse; 3=moderate; 4=abundant; 5=very abundant) (SD=slow deep; SS=slow shallow; FD=fast deep; FS=fast shallow)			
	SD	**SS**	**FD**	**FS**
RAU				
SITE				
BRAY -CURTIS SIMILARITY				

Table A4 Comparison of cover ratings for RAU and the EWR site (UB=undercut banks and root wads; OV=overhanging vegetation; SUB=substrate; AM=aquatic macrophytes; WC=water column)

	COVER (Abundance: 0=absent; 1=rare; 2=sparse; 3=moderate; 4=abundant; 5=very abundant)									
	SD			**SS**			**FD**			**FS**	
	SITE	**RAU**		**SITE**	**RAU**		**SITE**	**RAU**		**SITE**	**RAU**
UB			**UB**			**UB**			**UB**		
OV			**OV**			**OV**			**OV**		
SUB			**SUB**			**SUB**			**SUB**		
AM			**AM**			**AM**			**AM**		
WC			**WC**			**WC**			**WC**		
BRAY - CURTIS SIMILARITY			**BRAY - CURTIS SIMILARITY**			**BRAY - CURTIS SIMILARITY**			**BRAY - CURTIS SIMILARITY**		

[5] Where appropriate the similarity between a RAU and the potential site is determined by the Bray-Curtis index, where similarity of 1 indicates complete similarity and 0 no similarity. The categorization of similarities is according to the following: 0=None;0.1-0.20=Very low; 0.20-0.40=Low;0.40-0.60=Moderate;0.60-0.80=High; 0.80-1.0=Very high

Table A5 Comparison between sizes of various velocity-depth guilds at a EWR site. Large>20 cm; Small <20 cm

	VELOCITY-DEPTH GUILDS (Indicate number for flow guild per size							
	SD		SS		FD		FS	
	LARGE	SMALL	LARGE	SMALL	LARGE	SMALL	LARGE	SMALL
RHEOPHILICS								
SEMI-RHEOPHILICS								
LIMNOPHILICS								

Table A6 Relative abundances of different flow guilds in RAU and at EWR sites

	RELATIVE ABUNDANCE (Abundance: 0=absent; 1=rare; 2=sparse; 3=moderate; 4=abundant; 5=very abundant)	
	RAU	SITE
RHEOPHILICS		
SEMI-RHEO		
LIMNOPHILICS		
BRAY -CURTIS SIMILARITY		

At this stage: the information summarized above should be used to provide a considered and informed decision as to the suitability of the EWR site for the interpretation of ecological water requirements of fish compared to the RAU. This should be ranked according to:

0: Not suitable
1.0-2.0: very low suitability
2.0-3.0: Moderate suitability
3.0-4.0: High suitability
4.0-5.0: Very high suitability

This suitability rating should be considered in conjunction with suitability ratings for other biota as well as the hydraulic suitability to provide an overall suitability rating.

APPENDIX B:
LAND COVER DETAIL FOR WMA 8
Ms J Moolman (D: RQS)

B1 LANDCOVER

Table B1 Landcover detail for WMA 8

MAIN VAAL RIVER					
QUAT	LEVEL	FREQ	LAND_CODE	DESCRIPTION	HA
C11A	11.02	2	05-01-000	Unimproved Grassland	4204.6
C11A	11.05	1	05-01-000	Unimproved Grassland	1280.1
C11A	11.05	13	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	443.9
C11A	11.02	13	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	289.7
C11A	11.02	3	06-00-000	Forest Plantations (exotic)	29.8
C11A	11.02	1	11-01-000	Urban / Built-up Land (residential)	24.8
C11A	11.02	1	07-00-000	Waterbodies	17.6
C11A	11.05	1	06-00-000	Forest Plantations (exotic)	8.7
C11A	11.05	1	07-00-000	Waterbodies	3.0
C11A	11.05	1	08-00-000	Wetlands	2.9
C11B	11.05	1	05-01-000	Unimproved Grassland	2962.8
C11B	11.02	1	05-01-000	Unimproved Grassland	616.5
C11B	11.05	20	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	383.1
C11B	11.05	1	06-00-000	Forest Plantations (exotic)	7.5
C11B	11.05	1	07-00-000	Waterbodies	7.1
C11E	11.05	2	05-01-000	Unimproved Grassland	1913.4
C11E	11.02	1	05-01-000	Unimproved Grassland	1559.6
C11E	11.05	7	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	274.8
C11E	11.02	5	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	84.4
C11E	11.02	2	06-00-000	Forest Plantations (exotic)	44.4
C11E	11.02	4	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	32.4
C11E	11.05	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	17.9
C11E	11.05	1	06-00-000	Forest Plantations (exotic)	10.8
C11G	11.05	2	05-01-000	Unimproved Grassland	41.0
C11G	11.05	1	08-00-000	Wetlands	7.8
C11J	11.05	5	05-01-000	Unimproved Grassland	4800.7
C11J	11.05	21	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	1186.5
C11J	11.05	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	52.7
C11J	11.05	3	08-00-000	Wetlands	33.5
C11J	11.05	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	20.2
C11J	11.05	2	06-00-000	Forest Plantations (exotic)	6.7
C11L	11.05	1	07-00-000	Waterbodies	2075.3
C11L	11.05	22	05-01-000	Unimproved Grassland	1928.8
C11L	11.05	14	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	243.0
C11M	11.03	6	05-01-000	Unimproved Grassland	2098.9
C11M	11.03	13	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	1048.2
C11M	11.05	2	05-01-000	Unimproved Grassland	974.5
C11M	11.05	1	11-01-000	Urban / Built-up Land (residential)	253.5
C11M	11.05	5	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	33.8
C11M	11.03	1	08-00-000	Wetlands	13.6
C11M	11.03	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	11.6
C11M	11.05	2	11-02-000	Urban / Built-up Land (commercial)	9.4
C11M	11.05	1	05-02-000	Improved Grassland	9.1
C11M	11.03	2	06-00-000	Forest Plantations (exotic)	7.8
C11M	11.05	1	07-00-000	Waterbodies	6.6
C11M	11.05	1	11-03-000	Urban / Built-up Land (industrial; transportation)	6.4
C12B	11.03	2	05-01-000	Unimproved Grassland	3005.3
C12B	11.03	11	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	379.4
C12B	11.03	5	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	198.6
C12B	11.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	23.3
C12B	11.03	1	09-02-001	Bare Rock & Soil (erosion surfaces)	4.8
C12C	11.03	5	05-01-000	Unimproved Grassland	1441.2
C12C	11.03	3	07-00-000	Waterbodies	381.5
C12C	11.03	7	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	226.6
C12C	11.03	4	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	57.5
C12C	11.03	1	08-00-000	Wetlands	11.8
C12G	11.05	1	05-01-000	Unimproved Grassland	32.6
C12G	11.05	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	3.9
C12H	11.05	1	05-01-000	Unimproved Grassland	3264.9
C12H	11.05	16	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	642.8
C12H	11.05	2	11-01-000	Urban / Built-up Land (residential)	97.1
C12H	11.03	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	33.0

BLESBOKSPRUIT					
QUAT	LEVEL	FREQ	LAND_CODE	DESCRIPTION	HA
C21D	11.03	2	08-00-000	Wetlands	770.39
C21D	11.03	7	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	649.51
C21D	11.03	7	05-01-000	Unimproved Grassland	427.59
C21D	11.03	3	11-01-000	Urban / Built-up Land (residential)	162.84
C21D	11.03	7	12-00-000	Mines & Quarries	110.13
C21D	11.03	1	11-01-011	Urban / Built-up Land (residential - smallholdings - grassland)	77.26
C21C	11.01	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	18.44
C21E	11.03	12	05-01-000	Unimproved Grassland	1479.01
C21E	11.03	3	08-00-000	Wetlands	911.31
C21E	11.03	2	11-01-011	Urban / Built-up Land (residential - smallholdings - grassland)	159.45
C21E	11.03	6	12-00-000	Mines & Quarries	157.89
C21E	11.01	1	05-01-000	Unimproved Grassland	89.19
C21E	11.03	5	07-00-000	Waterbodies	56.04
C21E	11.03	5	11-01-000	Urban / Built-up Land (residential)	51.15
C21E	11.03	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	42.39
C21E	11.03	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	32.52
C21E	11.03	1	11-03-000	Urban / Built-up Land (industrial; transportation)	24.54
C21E	11.01	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	16.84
C21E	11.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	16.13
C21E	11.03	3	06-00-000	Forest Plantations (exotic)	10.24
C21E	11.01	1	06-00-000	Forest Plantations (exotic)	2.28
C21E	11.01	1	11-01-000	Urban / Built-up Land (residential)	0.99
C21F	11.01	4	05-01-000	Unimproved Grassland	959.59
C21F	11.03	1	05-01-000	Unimproved Grassland	946.68
C21F	11.01	6	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	652.10
C21F	11.01	3	11-01-000	Urban / Built-up Land (residential)	254.04
C21F	11.03	7	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	52.24
C21F	11.01	1	08-00-000	Wetlands	51.27
C21F	11.01	1	05-02-000	Improved Grassland	27.48
C21F	11.01	1	12-00-000	Mines & Quarries	26.72
C21F	11.03	2	12-00-000	Mines & Quarries	15.58
C21F	11.01	1	11-03-000	Urban / Built-up Land (industrial; transportation)	13.21
C21F	11.01	1	07-00-000	Waterbodies	7.19
C21F	11.03	1	07-00-000	Waterbodies	3.85
C21G	11.01	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	0.08
SUIKERBOS RIVER					
C21A	11.05	11	05-01-000	Unimproved Grassland	1792.49
C21A	11.03	1	05-01-000	Unimproved Grassland	1567.47
C21A	11.05	1	08-00-000	Wetlands	1014.78
C21A	11.05	26	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	536.76
C21A	11.03	8	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	203.77
C21A	11.03	2	06-00-000	Forest Plantations (exotic)	27.41
C21A	11.05	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	11.69
C21B	11.01	5	05-01-000	Unimproved Grassland	1551.28
C21B	11.03	2	05-01-000	Unimproved Grassland	564.56
C21B	11.01	14	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	477.59
C21B	11.03	8	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	147.95
C21B	11.01	6	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	58.16
C21B	11.01	2	07-00-000	Waterbodies	28.08
C21B	11.01	1	12-00-000	Mines & Quarries	18.36
C21B	11.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1.23
C21B	11.01	1	06-00-000	Forest Plantations (exotic)	0.92
C21C	11.01	5	05-01-000	Unimproved Grassland	1947.77
C21C	11.01	9	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	602.52
C21C	11.01	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	99.20
C21C	11.03	1	05-01-000	Unimproved Grassland	83.24
C21C	11.01	2	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	59.29
C21C	11.01	1	06-00-000	Forest Plantations (exotic)	6.25
C21C	11.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1.36
C21C	11.03	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	0.43

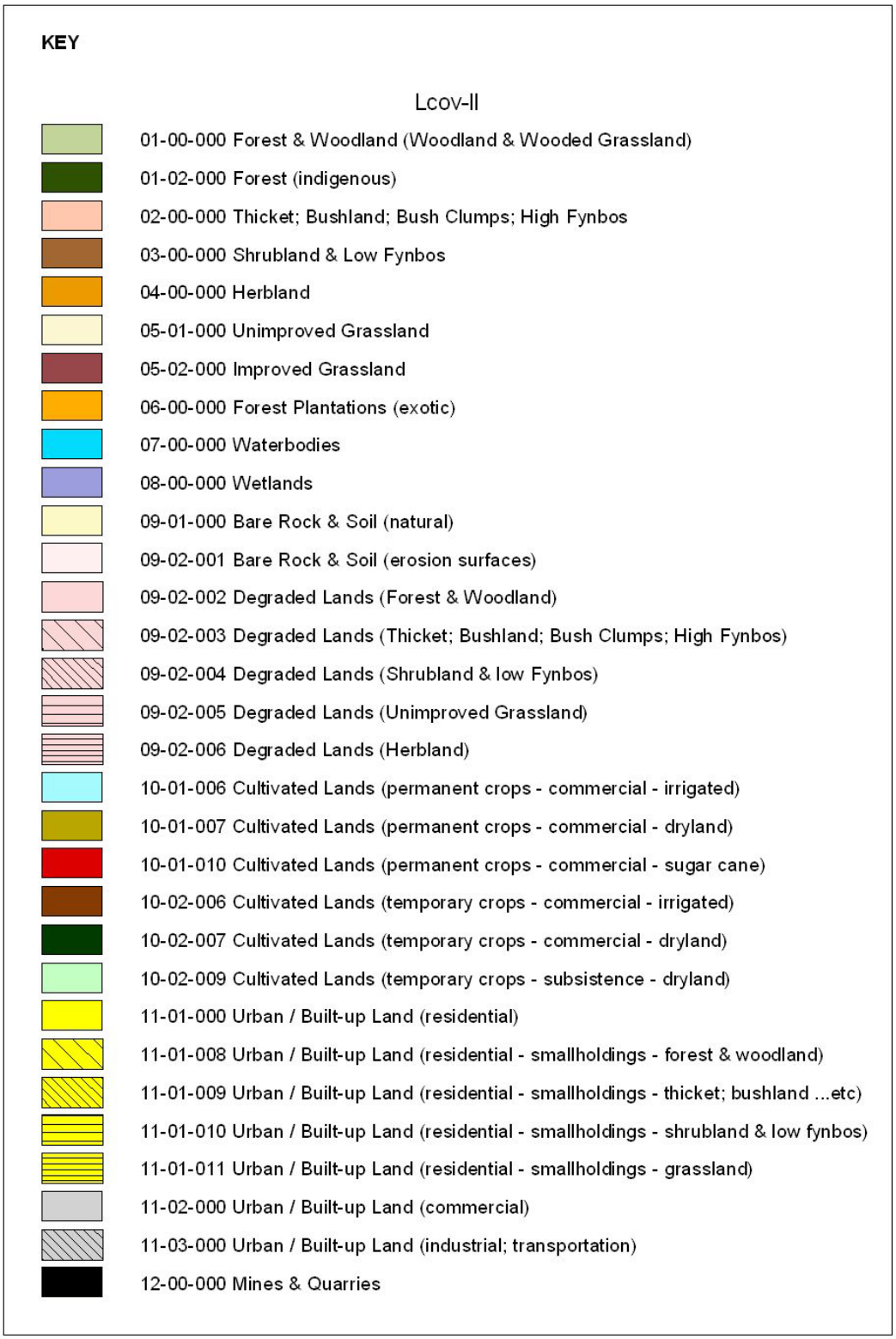
KLEIN VAAL RIVER					
QUAT	**LEVEL**	**FREQ**	**LAND_CODE**	**DESCRIPTION**	**HA**
C11C	11.02	2	05-01-000	Unimproved Grassland	3583.71
C11C	15.05	2	05-01-000	Unimproved Grassland	382.77
C11C	11.02	13	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	194.82
C11C	15.05	3	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	165.76
C11C	11.02	1	07-00-000	Waterbodies	18.45
C11C	11.02	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	11.23
C11C	11.02	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	9.05
C11C	15.05	1	06-00-000	Forest Plantations (exotic)	5.68
C11C	15.05	1	07-00-000	Waterbodies	0.29
C11D	11.02	2	05-01-000	Unimproved Grassland	2790.76
C11D	11.05	1	05-01-000	Unimproved Grassland	329.71
C11D	11.02	7	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	235.54
C11D	11.02	4	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	31.62
C11D	11.05	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	16.67
C11D	11.02	1	06-00-000	Forest Plantations (exotic)	3.08

WATERVAL RIVER							
QUAT	**LEVEL**	**FREQ**	**QUAT**	**LEVEL**	**LAND_COD**	**DESCRIPTION**	**HA**
C12D	11.05	1	C12D	11.05	05-01-000	Unimproved Grassland	3925.84
C12D	11.05	19	C12D	11.05	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	350.19
C12D	11.05	1	C12D	11.05	11-01-000	Urban / Built-up Land (residential)	58.21
C12D	11.05	1	C12D	11.05	11-03-000	Urban / Built-up Land (industrial; transportation)	41.33
C12D	11.05	1	C12D	11.05	11-01-011	Urban / Built-up Land (residential - smallholdings - grassland)	36.71
C12D	11.05	2	C12D	11.05	07-00-000	Waterbodies	10.82
C12D	11.05	2	C12D	11.05	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	1.41
C12F	11.05	9	C12F	11.05	05-01-000	Unimproved Grassland	2598.73
C12E	11.05	1	C12E	11.05	05-01-000	Unimproved Grassland	68.41
C12F	11.05	28	C12F	11.05	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	1757.27
C12F	11.05	8	C12F	11.05	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	195.68
C12F	11.05	1	C12F	11.05	08-00-000	Wetlands	169.58
C12F	11.05	1	C12F	11.05	06-00-000	Forest Plantations (exotic)	4.37
C12F	11.05	1	C12F	11.05	07-00-000	Waterbodies	0.97
C12G	11.05	5	C12G	11.05	05-01-000	Unimproved Grassland	2261.59
C12G	11.05	12	C12G	11.05	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	512.61
C12G	11.05	6	C12G	11.05	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	86.90
C12G	11.05	1	C12G	11.05	07-00-000	Waterbodies	1.26

KLIP RIVER (FROM SOUTH EAST)					
QUAT	**LEVEL**	**FREQ**	**LAND_CODE**	**DESCRIPTION**	**HA**
C13C	15.04	2	05-01-000	Unimproved Grassland	4051.26
C13C	11.06	2	08-00-000	Wetlands	751.77
C13C	11.06	9	05-01-000	Unimproved Grassland	453.19
C13C	15.04	12	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	301.20
C13C	11.06	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	128.31
C13C	11.06	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	87.82
C13C	15.04	1	11-01-000	Urban / Built-up Land (residential)	37.31
C13C	15.04	1	06-00-000	Forest Plantations (exotic)	13.21
C13C	15.04	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	11.55
C13C	15.04	1	08-00-000	Wetlands	3.81
C13D	11.06	3	05-01-000	Unimproved Grassland	4269.30
C13D	11.03	1	05-01-000	Unimproved Grassland	912.97
C13D	11.06	9	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	261.16
C13D	11.06	1	08-00-000	Wetlands	249.66
C13D	11.03	2	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	81.25
C13D	11.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	5.36
C13D	11.06	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	2.88
C13F	11.03	6	05-01-000	Unimproved Grassland	2958.45
C13F	11.03	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	532.83
C13F	11.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	64.66
C13F	11.03	1	09-02-004	Degraded Lands (Unimproved Grassland)	19.85
C13F	11.03	2	09-02-001	Bare Rock & Soil (erosion surfaces)	13.48
C13F	11.03	1	08-00-000	Wetlands	5.42
C13H	11.03	7	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	2210.59
C13H	11.03	11	05-01-000	Unimproved Grassland	1245.07
C13H	11.03	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	85.67
C13H	11.03	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	42.47
C13H	11.03	3	08-00-000	Wetlands	14.23
C13H	11.03	1	06-00-000	Forest Plantations (exotic)	3.69

WILGE RIVER					
QUAT	LEVEL	FREQ	LAND_COD	DESCRIPTION	HA
C81A	11.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	0.11
C81A	11.03	2	05-01-000	Unimproved Grassland	2473.95
C81A	11.03	5	06-00-000	Forest Plantations (exotic)	15.64
C81A	11.03	2	08-00-000	Wetlands	177.16
C81A	15.03	1	05-01-000	Unimproved Grassland	642.56
C81A	15.04	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	178.03
C81A	15.04	4	05-01-000	Unimproved Grassland	1541.38
C81A	15.04	3	06-00-000	Forest Plantations (exotic)	16.07
C81B	11.03	4	05-01-000	Unimproved Grassland	4859.74
C81B	11.03	1	06-00-000	Forest Plantations (exotic)	18.42
C81B	11.03	1	07-00-000	Waterbodies	2.72
C81B	11.03	1	08-00-000	Wetlands	26.33
C81B	11.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	60.55
C81B	11.03	12	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	506.62
C81B	11.03	1	11-01-000	Urban / Built-up Land (residential)	46.54
C81B	15.03	1	05-01-000	Unimproved Grassland	4.47
C81E	11.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	64.91
C81E	11.03	10	05-01-000	Unimproved Grassland	2396.80
C81E	11.03	2	07-00-000	Waterbodies	3.71
C81E	11.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	1.61
C81E	11.03	12	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	1748.97
C81E	11.03	4	11-01-000	Urban / Built-up Land (residential)	119.57
C81E	11.03	1	11-02-000	Urban / Built-up Land (commercial)	52.66
C81E	15.01	1	05-01-000	Unimproved Grassland	46.24
C81E	15.01	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	3.33
C81E	15.01	1	11-01-000	Urban / Built-up Land (residential)	6.60
C81K	11.03	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	23.01
C81K	11.03	7	05-01-000	Unimproved Grassland	1584.04
C81K	11.03	1	07-00-000	Waterbodies	4.91
C81K	11.03	6	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	2538.80
C81L	15.04	2	05-01-000	Unimproved Grassland	2.48
C81M	11.03	1	05-01-000	Unimproved Grassland	10.25
C82B	11.03	2	05-01-000	Unimproved Grassland	14.35
C82B	11.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	24.16
C82C	11.03	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	79.90
C82C	11.03	6	05-01-000	Unimproved Grassland	2282.70
C82C	11.03	2	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	0.90
C82C	11.03	7	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	2265.23
C82D	11.03	1	05-01-000	Unimproved Grassland	27.64
C82D	11.03	2	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	15.46
C82F	11.03	1	05-01-000	Unimproved Grassland	21.16
C82G	11.03	3	05-01-000	Unimproved Grassland	4294.36
C82G	11.03	1	06-00-000	Forest Plantations (exotic)	0.63
C82G	11.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	15.48
C82G	11.03	9	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	486.22
C82H	11.03	1	05-01-000	Unimproved Grassland	5059.40
C82H	11.03	1	08-00-000	Wetlands	46.00
C82H	11.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	210.67
C82H	11.03	9	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	168.75
C83H	11.03	1	05-01-000	Unimproved Grassland	61.91
C83J	11.03	1	05-01-000	Unimproved Grassland	667.17
C83J	11.03	2	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	80.69
C83J	11.03	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	3.40
C83J	11.03	2	11-01-000	Urban / Built-up Land (residential)	117.43
C83J	11.03	1	11-02-000	Urban / Built-up Land (commercial)	9.78
C83M	11.03	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	17.53
C83M	11.03	25	05-01-000	Unimproved Grassland	5557.10
C83M	11.03	4	07-00-000	Waterbodies	4212.97
C83M	11.03	2	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	45.73
C83M	11.03	5	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	581.80
C83M	11.03	1	11-01-000	Urban / Built-up Land (residential)	5.41
V31E	15.04	1	05-01-000	Unimproved Grassland	0.32

MOOI RIVER					
QUAT	**LEVEL**	**FREQ**	**LAND_CODE**	**DESCRIPTION**	**HA**
C23F	11.01	9	05-01-000	Unimproved Grassland	2264.09
C23F	11.01	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	960.91
C23F	11.01	1	07-00-000	Waterbodies	286.04
C23F	7.06	1	05-01-000	Unimproved Grassland	251.53
C23F	11.01	1	08-00-000	Wetlands	86.54
C23F	11.01	1	11-01-000	Urban / Built-up Land (residential)	52.06
C23F	11.01	1	10-02-009	Cultivated Lands (temporary crops - subsistence - dryland)	46.55
C23F	11.01	3	06-00-000	Forest Plantations (exotic)	24.00
C23G	11.01	10	05-01-000	Unimproved Grassland	2611.06
C23G	11.01	11	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	597.21
C23G	11.01	2	07-00-000	Waterbodies	289.83
C23G	11.01	1	08-00-000	Wetlands	271.20
C23G	11.01	2	01-00-000	Forest & Woodland (Woodland & Wooded Grassland)	263.38
C23G	11.01	5	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	107.24
C23G	11.01	9	06-00-000	Forest Plantations (exotic)	89.80
C23G	11.01	2	12-00-000	Mines & Quarries	46.72
C23H	11.01	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	641.02
C23H	11.08	5	05-01-000	Unimproved Grassland	573.61
C23H	11.01	8	05-01-000	Unimproved Grassland	356.52
C23H	11.08	7	11-01-000	Urban / Built-up Land (residential)	272.21
C23H	11.08	2	11-01-011	Urban / Built-up Land (residential - smallholdings - grassland)	205.61
C23H	11.08	2	05-02-000	Improved Grassland	91.07
C23H	11.01	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	90.83
C23H	11.08	1	07-00-000	Waterbodies	70.93
C23H	11.08	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	47.31
C23H	11.08	2	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	31.56
C23H	11.01	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	17.45
C23H	11.01	1	07-00-000	Waterbodies	14.74
C23H	11.08	1	06-00-000	Forest Plantations (exotic)	12.85
C23H	11.01	2	06-00-000	Forest Plantations (exotic)	9.62
C23H	11.08	2	11-02-000	Urban / Built-up Land (commercial)	3.92
C23K	11.08	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	24.53
C23K	11.08	2	05-01-000	Unimproved Grassland	3.35
C23K	11.08	1	11-01-000	Urban / Built-up Land (residential)	0.09
C23L	11.08	3	05-01-000	Unimproved Grassland	2174.99
C23L	11.08	17	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	457.15
C23L	11.08	7	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	127.60
C23L	11.08	4	11-01-011	Urban / Built-up Land (residential - smallholdings - grassland)	97.15
C23L	11.08	2	06-00-000	Forest Plantations (exotic)	6.68
C23L	11.08	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	5.57
C23L	11.08	1	11-01-000	Urban / Built-up Land (residential)	0.10


KEY
LCOV-II
01-00-000 Forest & Woodland (Woodland & Wooded Grassland)
01-02-000 Forest (indigenous)
02-00-000 Thicket; Bushland; Bush Clumps; High Fynbos
03-00-000 Shrubland & Low Fynbos
04-00-000 Herbland
05-01-000 Unimproved Grassland
05-02-000 Improved Grassland
06-00-000 Forest Plantations (exotic)
07-00-000 Waterbodies
08-00-000 Wetlands
09-01-000 Bare Rock & Soil (natural)
09-02-001 Bare Rock & Soil (erosion surfaces)
09-02-002 Degraded Lands (Forest & Woodland)
09-02-003 Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)
09-02-004 Degraded Lands (Shrubland & low Fynbos)
09-02-005 Degraded Lands (Unimproved Grassland)
09-02-006 Degraded Lands (Herbland)
10-01-006 Cultivated Lands (permanent crops - commercial - irrigated)
10-01-007 Cultivated Lands (permanent crops - commercial - dryland)
10-01-010 Cultivated Lands (permanent crops - commercial - sugar cane)
10-02-006 Cultivated Lands (temporary crops - commercial - irrigated)
10-02-007 Cultivated Lands (temporary crops - commercial - dryland)
10-02-009 Cultivated Lands (temporary crops - subsistence - dryland)
11-01-000 Urban / Built-up Land (residential)
11-01-008 Urban / Built-up Land (residential - smallholdings - forest & woodland)
11-01-009 Urban / Built-up Land (residential - smallholdings - thicket; bushland ...etc)
11-01-010 Urban / Built-up Land (residential - smallholdings - shrubland & low fynbos)
11-01-011 Urban / Built-up Land (residential - smallholdings - grassland)
11-02-000 Urban / Built-up Land (commercial)
11-03-000 Urban / Built-up Land (industrial; transportation)
12-00-000 Mines & Quarries

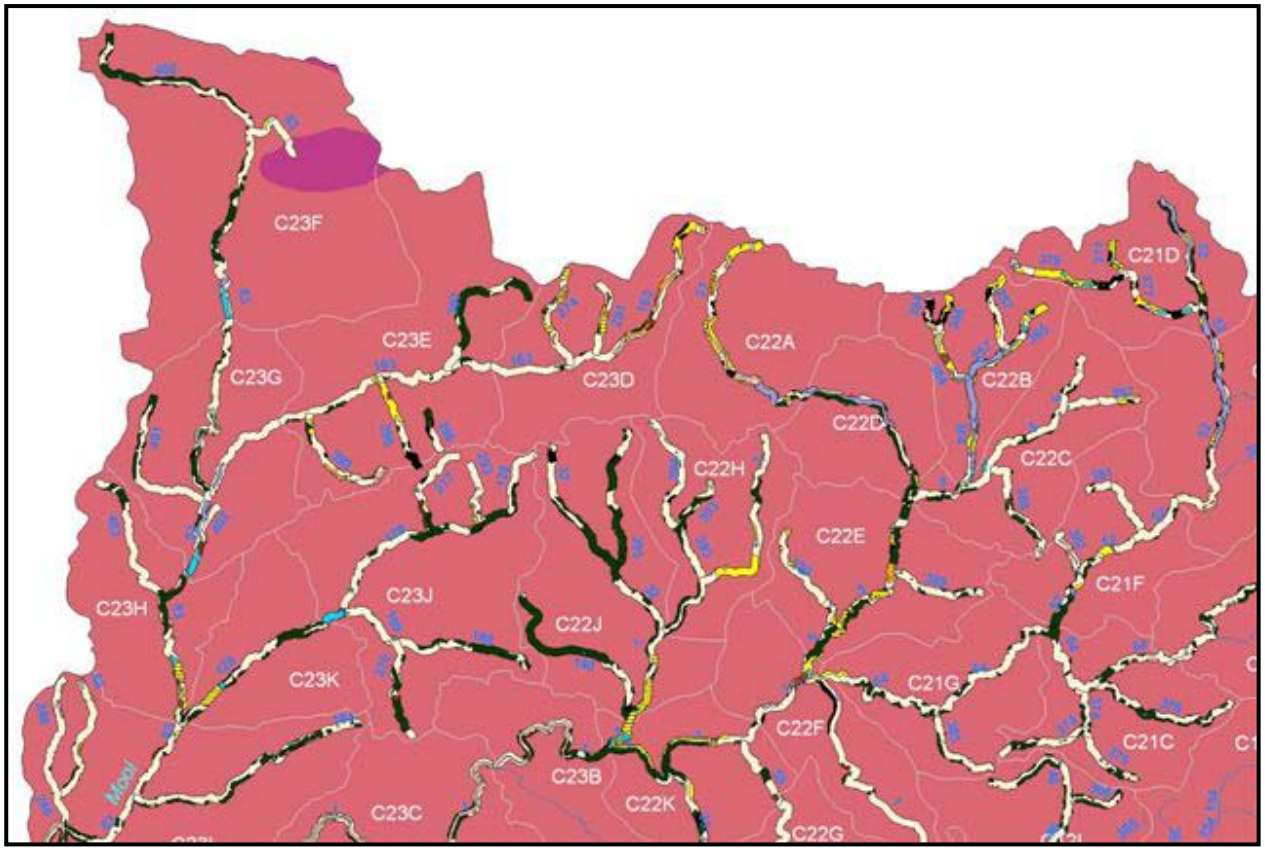


Figure B1 Landcover map for the Blesbokspruit, Suikerbosrand and upper Mooi rivers

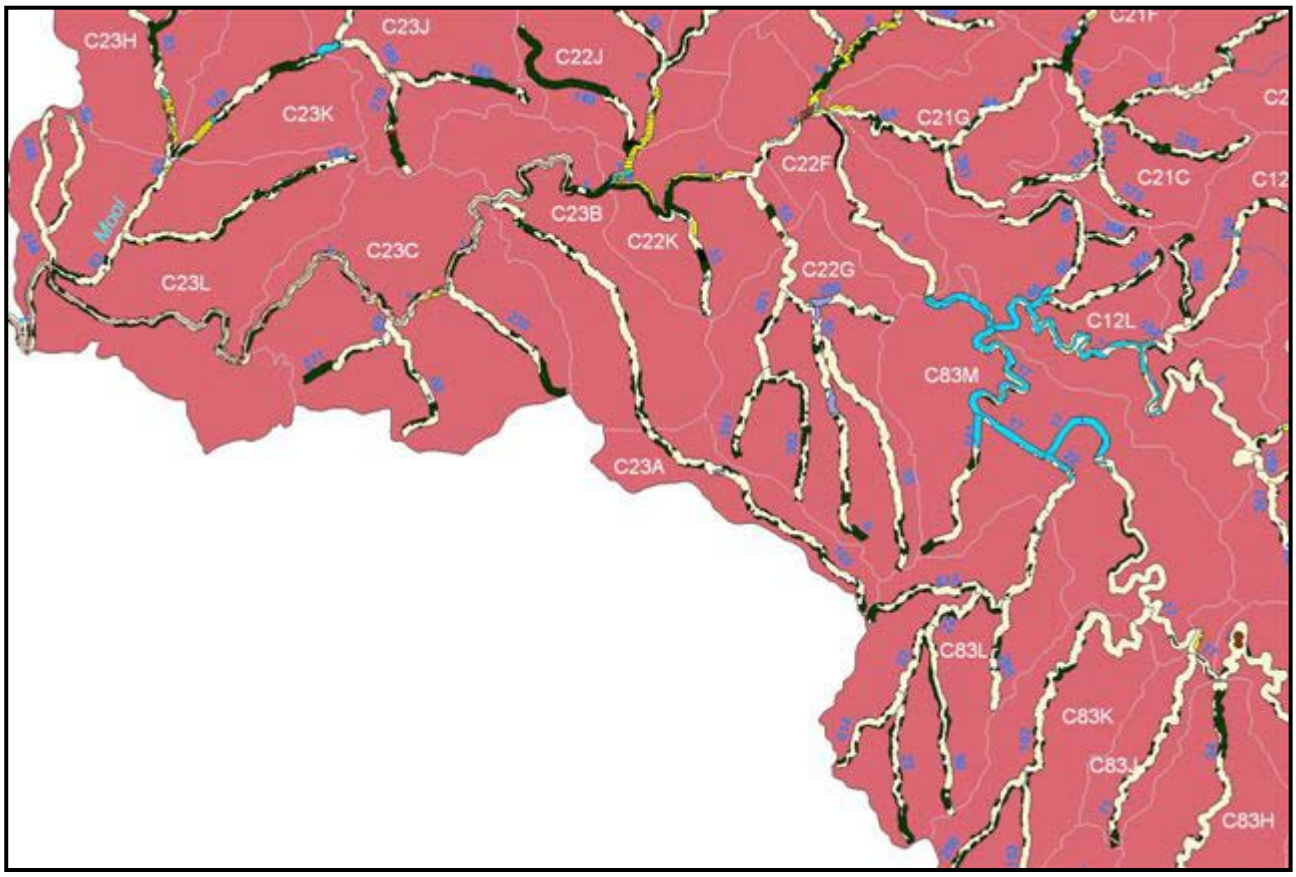


Figure B2 Landcover for the lower MooiRiver and VaalRiver below the Vaal Dam

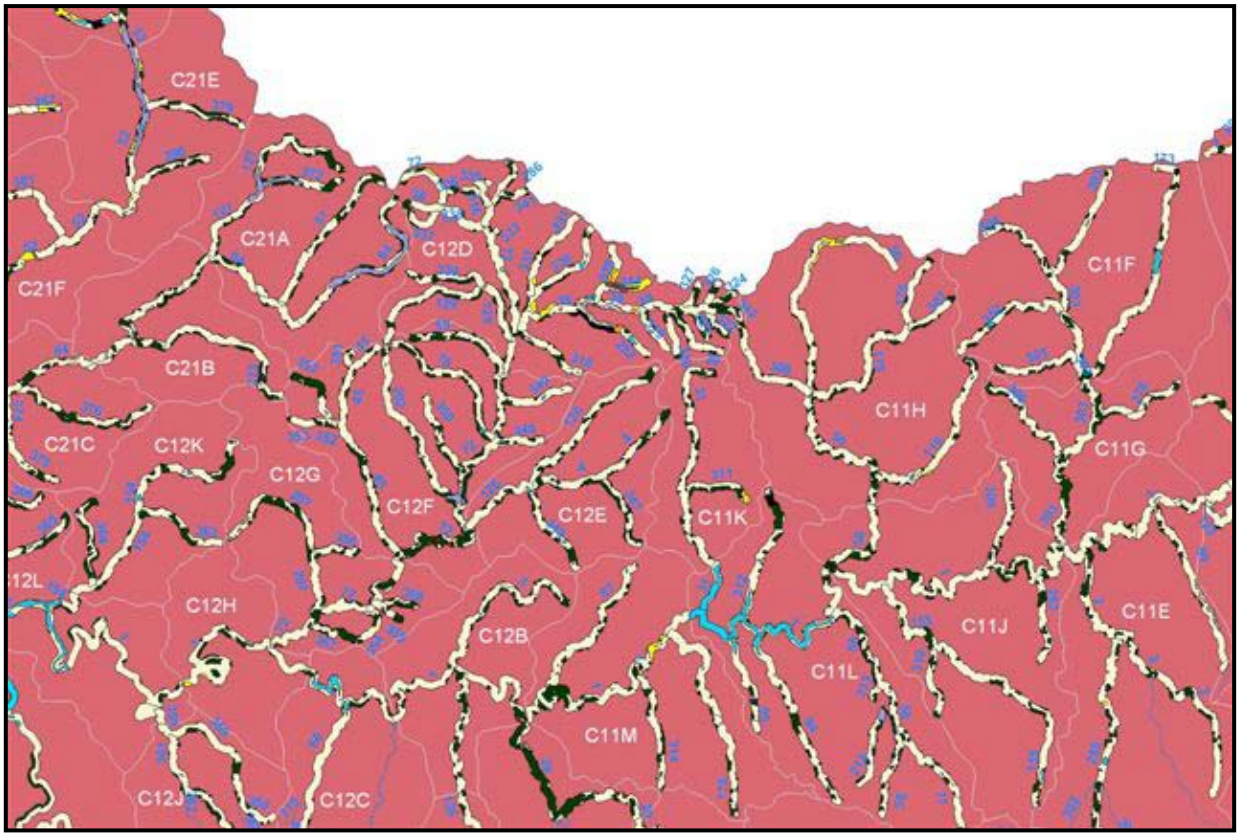


Figure B3 Landcover for the VaalRiver between Vaal and Grootdraai Dam

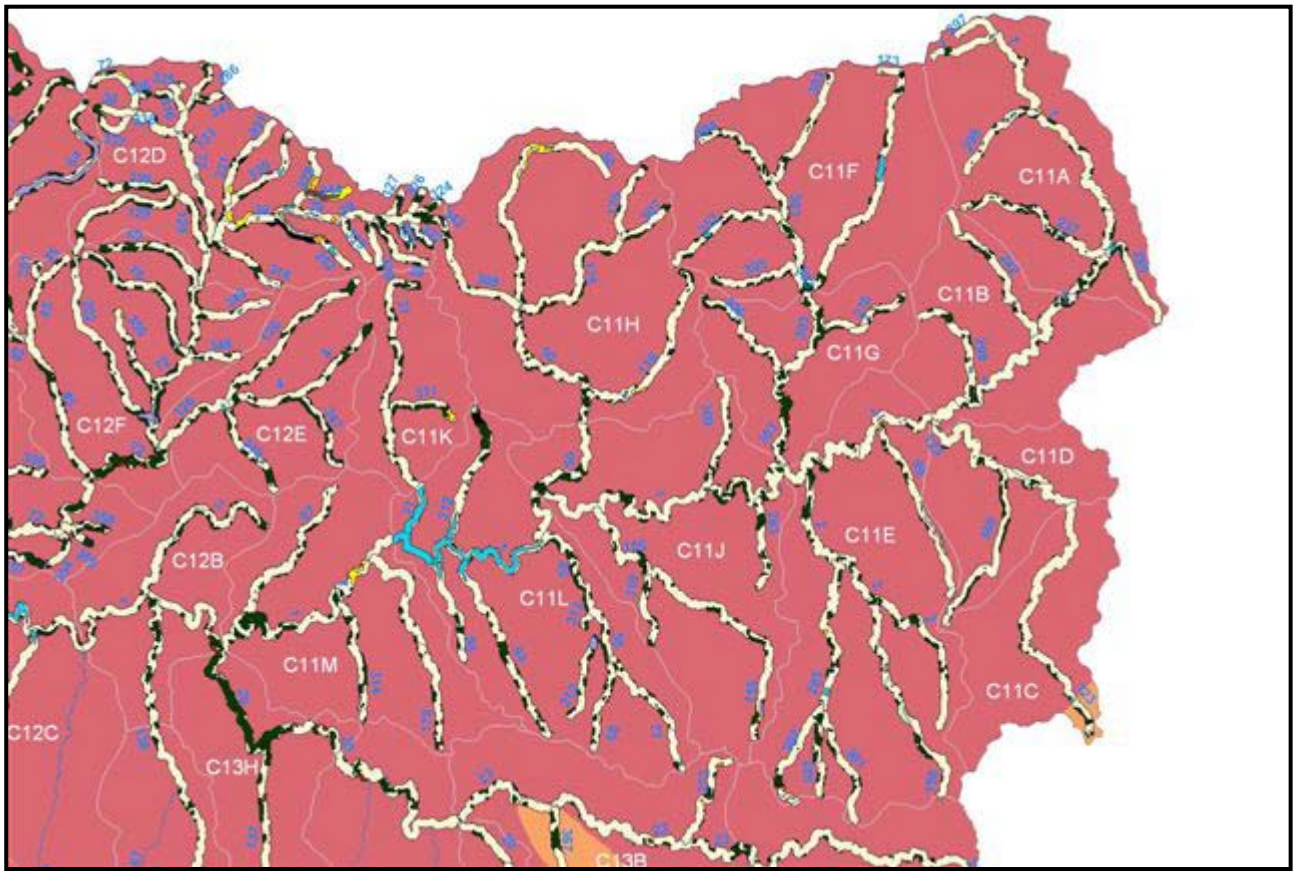


Figure B4 Landcover for the VaalRiver upstream of Grootdraai Dam and the KleinVaalRiver

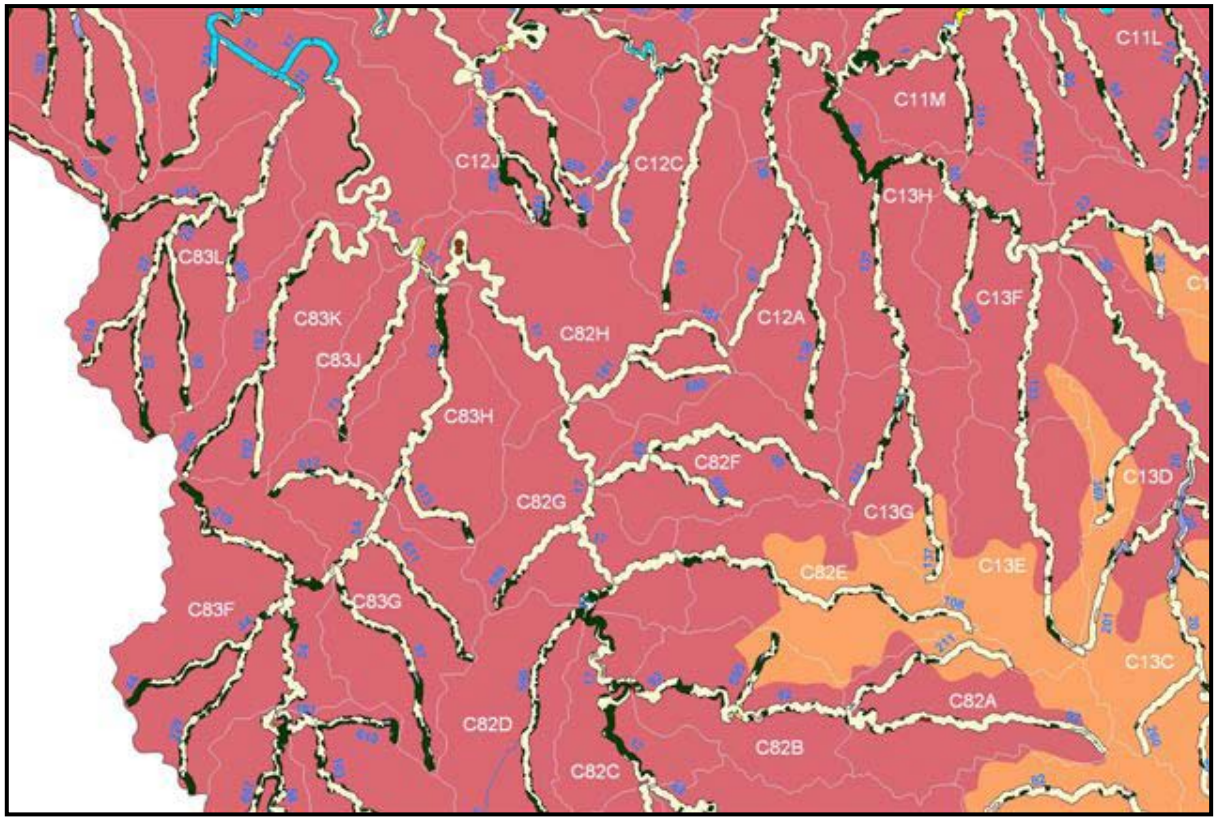


Figure B5 Landcover for the LowerWilgeRiver and LiebenbergsvleiRiver

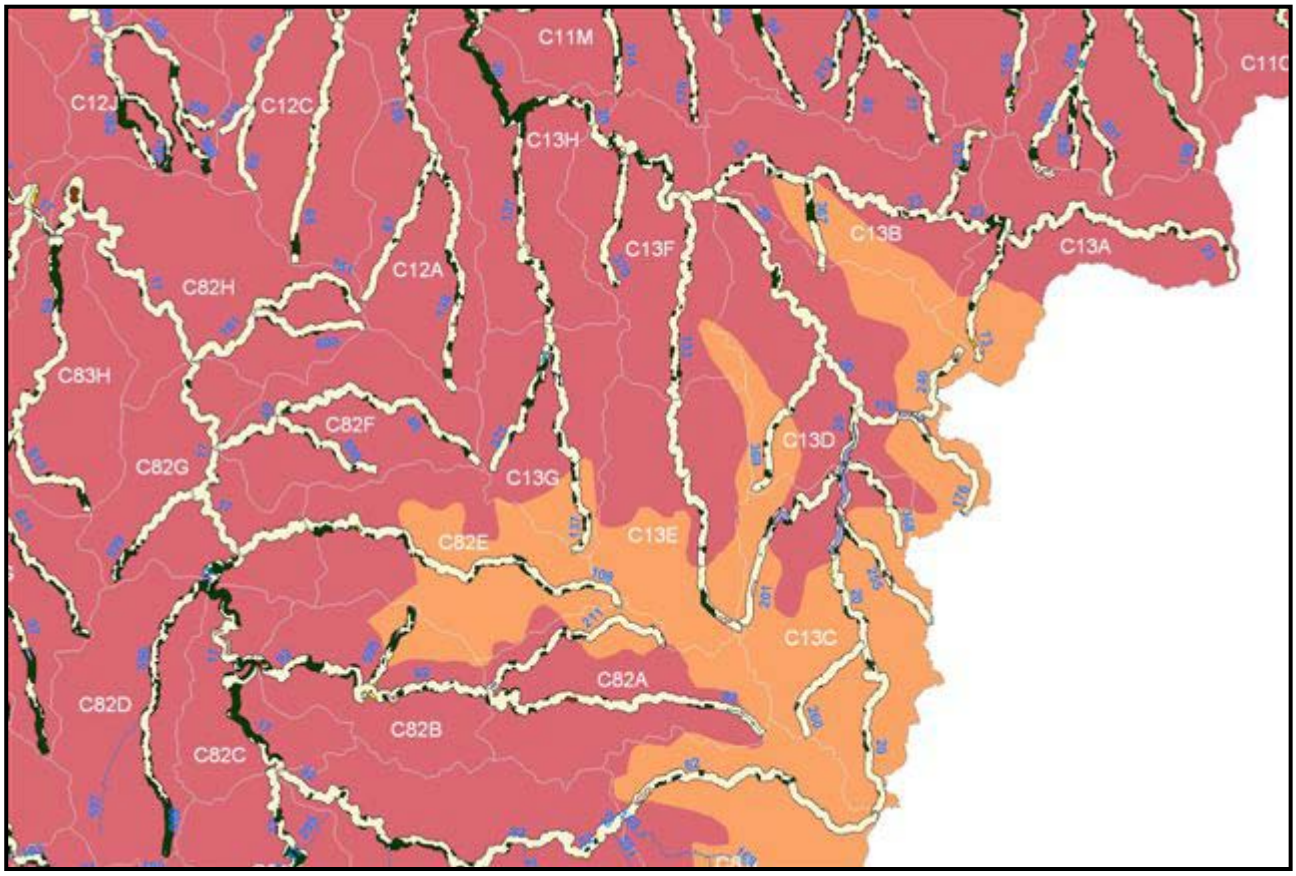


Figure B6 Landcover for the KlipRiver

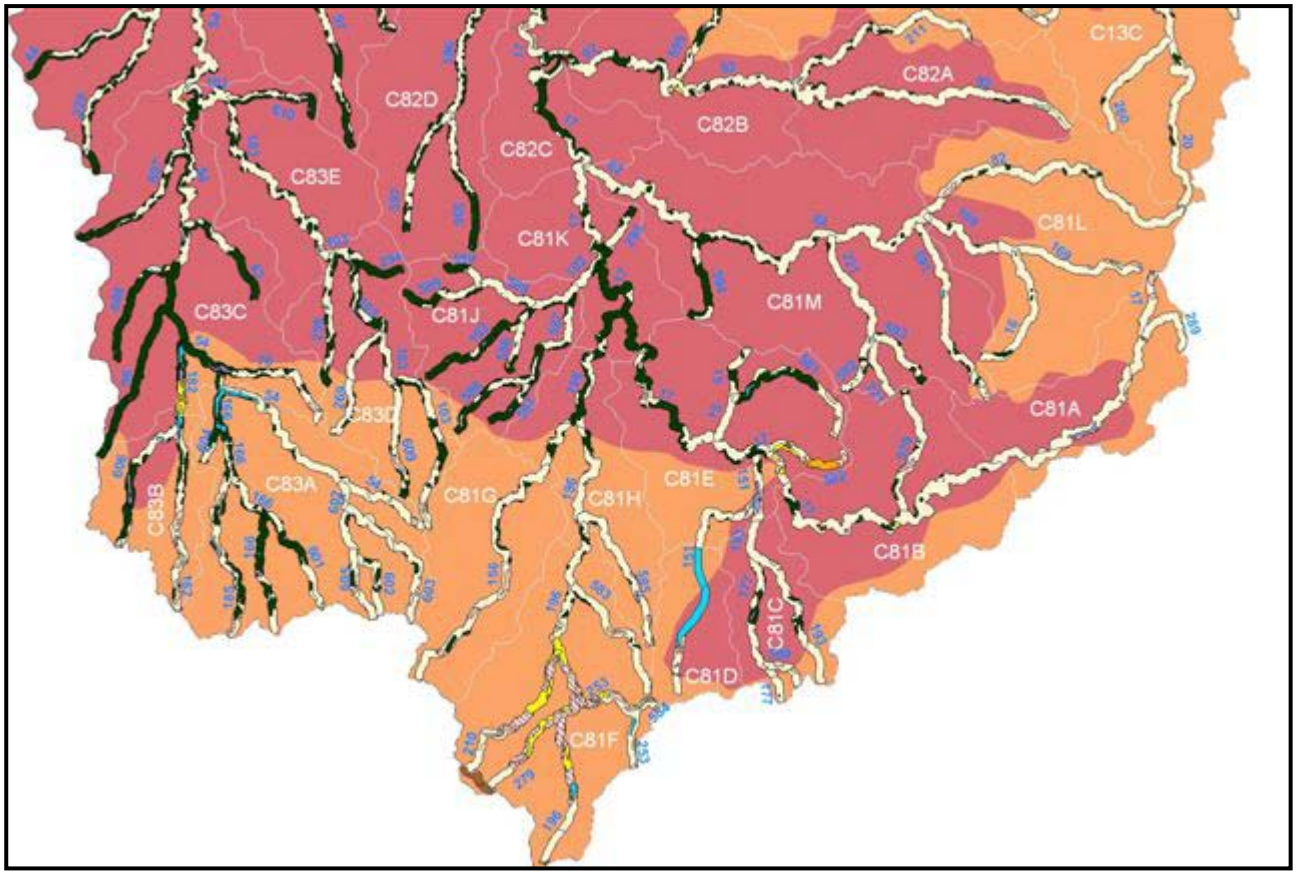


Figure B7 Landcover for the upper reaches of the Liebenbergsvlei and Wilge rivers

APPENDIX C:
FLUVIAL GEOMORPHOLOGY: SITE SUITABILITY
Mr M Rountree

C1 GEOMORPHOLOGY SITE SUITABILITY

C1.1 EWR 1: UITKOMS

This provides an assessment of the suitability of the site for EWR determination studies					Notes
	SCORES: 5	2	1	SCORE	
Representivity of the site for the reach				**3.0**	Site is a boulder riffle section - highly atypical of the reach. Alluvial sections upstream show indications of increased flows (cut banks, likely ue to interbasin transfers) - bu our site is not very flow sensitive.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	3.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.0	
Morphological Cues				**2.5**	Floodplain wetlands are present
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	3.5	
If these are present, are the terraces paired?	Yes	Don't know	No	2.0	
Sediment Transport Modelling				**4.3**	PBMT will be undertaken, but the site is not representative of the reach, and likely that the sediment is atypical (probably coarser) than the reach - PBMT results may be misloeading and should be used as low confidence
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	3.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:				**3.1**	

C1.2 EWR 2: GROOTDRAAI

This provides an assessment of the suitability of the site for EWR determination studies					Notes
	SCORES: 5	2	1	SCORE	
Representivity of the site for the reach				**1.5**	Site is immediately below the large Grootdraai Dam - all upstream sediment sources (with possiblility of fines, maybe maintained through bottom releases) being cut off
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	1.5	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	1.5	
Morphological Cues				**2.7**	bedrock banks, incised channel; paired low benches but no terraces
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	3.0	
If these are present, are the terraces paired?	Yes	Don't know	No	3.0	
Sediment Transport Modelling				**1.7**	Site was a bedload system, but now upstream sediment supply is cut off, so PBMT not really appropriate
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	1.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	2.0	
OVERALL SCORE:				**2.1**	

C1.3 EWR 3: GLADDEDRIFT

This provides an assessment of the suitability of the site for EWR determination studies					Notes
	SCORES: 5	2	1	SCORE	
Representivity of the site for the reach				**2.5**	Site is immediately below a bridge - riffle over a dyke across the river. Not representative morhology for the reach; but condition fairly representative
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	1.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				**1.0**	bedrock riffle - no terraces. Banks are cut
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	1.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	1.0	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**5.0**	Site is a bedload system, and sediment sample taken from the upstream pool which is more representative of the reach sediment (than is the immediate x-section)
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:				**2.4**	

C1.4 EWR 4: DE NEYS

This provides an assessment of the suitability of the site for EWR determination studies					Notes
	SCORES: 5	2	1	SCORE	
Representivity of the site for the reach				**2.5**	Site is immediately below a bridge - riffle over a dyke across the river. Not representative morhology for the reach; but condition fairly representative
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	1.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				**1.0**	bedrock riffle - no terraces. Banks are cut
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	1.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	1.0	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**5.0**	Site is a bedload system, and sediment sample taken from the upstream pool which is more representative of the reach sediment (than is the immediate x-section)
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:				**2.4**	

C1.5 EWR 5: SKANDINAVIA

This provides an assessment of the suitability of the site for EWR determination studies					Notes
	SCORES: 5	2	1	SCORE	
Representivity of the site for the reach				**2.8**	The x-section runs across a bedrock/boulder riffle area, but the reach characterised by generally long pools.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	1.5	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				**4.0**	Well developed alluvial terraces
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	5.0	
If these are present, are the terraces paired?	Yes	Don't know	No	5.0	
Sediment Transport Modelling				**4.7**	Site is a bedload system, and although there are large dams far upstream, the fines component at the site suggets that the impact of the dam is lessened due to subsequent tributary inputs of sediment.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:				**3.9**	

C1.6 EWR 6: KLIP

This provides an assessment of the suitability of the site for EWR determination studies					Notes
	SCORES: 5	2	1	SCORE	
Representivity of the site for the reach				**5.0**	The x-section runs across a bedrock/boulder riffle area, and there are numerous such areas in the reach
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	5.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	5.0	
Morphological Cues				**2.5**	Alluvial (cobble- dominated) bed. One bank at the site is bedrock, so no paired terraces
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	4.5	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**5.0**	Site is a bedload system, and although there are large dams far upstream, the fines component at the site suggets that the impact of the dam is lessened due to subsequent tributary inputs of sediment.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:				**3.8**	

C1.7 EWR 7: UPPER WILGE

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**5.0**	This is a meandering floodplain area - extensive reach, generally little impacts (at present, but Braamhoek pumped storage scheme is under construction in the upper reaches - approx 17km upstream from the site)
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	5.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	5.0	
Morphological Cues				**4.7**	meandering alluvial floodplain system with good morphological cues (ox-bows etc)
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	5.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	5.0	
If these are present, are the terraces paired?	Yes	Don't know	No	4.0	
Sediment Transport Modelling				**1.0**	System is a suspended load (fine silts and clays) dominated system - PBMT not appropriate
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	1.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	1.0	
OVERALL SCORE:				**3.8**	

C1.8 EWR 8: BAVARIA

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**2.3**	The site is at the beginning of a bedrock gorge - not representative of most of the reach. Bedrock nature makes the banks insensitive to flow changes, so not a good area for obtaining information on condition of the river
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	1.5	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.0	
Morphological Cues				**1.3**	No morphological cues in this predominantly fixed boulder dominated area
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	1.0	
If these are present, are the terraces paired?	Yes	Don't know	No	1.0	
Sediment Transport Modelling				**3.3**	System has a mobile bed component, but much of the bed composed of fixed boulders which are locally derived (from the cliffs), as well as a large suspended load component. We tried to measure only the mobile component of the bed sediment.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	3.0	
OVERALL SCORE:				**2.1**	

C1.9 EWR 9: SUIKERBOS US

This provides an assessment of the suitability of the site for EWR determination studies	SCORES: 5	2	1	SCORE	Notes
Representivity of the site for the reach				**3.8**	Site is in a bedrock rapid, and although the reach is generally characterised by long pools, there are a number of such rapids in the reach.
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	3.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.5	
Morphological Cues				**3.3**	Some morphological cues in the upstream pool area - upper terrace is paired on opposite bank; lower bench is annually flooded
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	4.0	
If these are present, are the terraces paired?	Yes	Don't know	No	4.0	
Sediment Transport Modelling				**5.0**	System has a mobile bed component, and PBMT is appropriate and suitable for this site.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:				**3.9**	

C1.10 EWR 10:SUIKERBOS DS

This provides an assessment of the suitability of the site for EWR determination studies					Notes
	SCORES: 5	2	1	SCORE	
Representivity of the site for the reach				**3.5**	Morphology is generally representative, but impacts concentrated around the road/bridge access make the banks in a poorer condition than generally seen along the reach
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.0	
Morphological Cues				**4.3**	Upper and lower terraces are paired on opposite bank
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	5.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	4.0	
If these are present, are the terraces paired?	Yes	Don't know	No	4.0	
Sediment Transport Modelling				**5.0**	System has a mobile bed component and is suitable for PBMT approach.
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:				**4.3**	

C1.11 EWR 11: BLESBOKSPRUIT

This provides an assessment of the suitability of the site for EWR determination studies					Notes
	SCORES: 5	2	1	SCORE	
Representivity of the site for the reach				**3.5**	Morphology is generally representative, but impacts concentrated around the road/bridge access make the banks in a poorer condition than generally seen along the reach
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.0	
Morphological Cues				**3.3**	Approximately paired terraces on either bank. Instream features are scoured out (probably due to increased flows and recent floods)
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	4.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	3.0	
If these are present, are the terraces paired?	Yes	Don't know	No	3.0	
Sediment Transport Modelling				**3.5**	PBMT would be appropriate, but the increased flows, coarsened bed material and cut banks (decreased roughness) at the site may make the PBMT results of very low confidence in setting flows
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	3.5	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	3.5	
OVERALL SCORE:				**3.4**	

APPENDIX D
MACROINVERTEBRATE: SITE SUITABILITY
Dr R Palmer

D1 MACROINVERTEBRATE SITE SUITABILITY

D1.1 EWR 1:UITKOMS

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	4
Stones Out Of Current (SOOC)	6	2
Bedrock	1	2
Aquatic Veg	1	0
MargVeg In Current	6	4
MargVeg Out Of Current	5	4
Gravel	3	3
Sand	2	1
Mud	1	3
Terraces and bars	10	4
Overall Suitability (%)	45	68%
Category		Moderate

D1.2 EWR 2: GROOTDRAAI

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	4
Stones Out Of Current (SOOC)	6	2
Bedrock	1	1
Aquatic Veg	1	1
MargVeg In Current	6	4
MargVeg Out Of Current	5	3
Gravel	3	3
Sand	2	2
Mud	1	1
Terraces and bars	10	5
Overall Suitability (%)	45	70%
Category		Good

D1.3 EWR 3: GLADDEDRIFT

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	4
Stones Out Of Current (SOOC)	6	2
Bedrock	1	4
Aquatic Veg	1	0
MargVeg In Current	6	3
MargVeg Out Of Current	5	3
Gravel	3	3
Sand	2	2
Mud	1	4
Terraces and bars	10	2
Overall Suitability (%)	45	56%
Category		Poor

D1.4 EWR 4: DE NEYS

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	5
Stones Out Of Current (SOOC)	6	3
Bedrock	1	1
Aquatic Veg	1	4
MargVeg In Current	6	4
MargVeg Out Of Current	5	4
Gravel	3	3
Sand	2	2
Mud	1	1
Terraces and bars	10	2
Overall Suitability (%)	45	67%
Category		Moderate

D1.5 EWR 5: SKANDINAVIA

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	4
Stones Out Of Current (SOOC)	6	3
Bedrock	1	0
Aquatic Veg	1	4
MargVeg In Current	6	4
MargVeg Out Of Current	5	5
Gravel	3	4
Sand	2	4
Mud	1	0
Terraces and bars	10	1
Overall Suitability (%)	45	63%
Category		Moderate

D1.6 EWR 6: KLIP

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	4
Stones Out Of Current (SOOC)	6	3
Bedrock	1	2
Aquatic Veg	1	0
MargVeg In Current	6	3
MargVeg Out Of Current	5	4
Gravel	3	3
Sand	2	0
Mud	1	3
Terraces and bars	10	4
Overall Suitability (%)	45	67%
Category		Moderate

D1.7 EWR 7: UPPER WILGE

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	0	0
Stones Out Of Current (SOOC)	0	0
Bedrock	0	0
Aquatic Veg	1	4
MargVeg In Current	6	4
MargVeg Out Of Current	5	4
Gravel	0	0
Sand	0	0
Mud	1	2
Terraces and bars	10	1
Overall Suitability (%)	23	52%
Category		Very Poor

D1.8 EWR 8: BAVARIA

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	4
Stones Out Of Current (SOOC)	6	3
Bedrock	1	3
Aquatic Veg	1	0
MargVeg In Current	6	4
MargVeg Out Of Current	5	4
Gravel	3	2
Sand	2	0
Mud	1	4
Terraces and bars	10	2
Overall Suitability (%)	45	60%
Category		Moderate

D1.9 EWR 9: SUIKERBOS US

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	5
Stones Out Of Current (SOOC)	6	4
Bedrock	1	0
Aquatic Veg	1	0
MargVeg In Current	6	3
MargVeg Out Of Current	5	5
Gravel	3	2
Sand	2	3
Mud	1	0
Terraces and bars	10	2
Overall Suitability (%)	45	66%
Category		Moderate

D1.10 EWR 10: SUIKERBOS DS

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	5
Stones Out Of Current (SOOC)	6	5
Bedrock	1	2
Aquatic Veg	1	0
MargVeg In Current	6	5
MargVeg Out Of Current	5	5
Gravel	3	5
Sand	2	0
Mud	1	3
Terraces and bars	10	5
Overall Suitability (%)	45	91%
Category		Excellent

D1.11 EWR 11: BLESBOKSPRUIT

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	4
Stones Out Of Current (SOOC)	6	4
Bedrock	1	0
Aquatic Veg	1	4
MargVeg In Current	6	4
MargVeg Out Of Current	5	4
Gravel	3	0
Sand	2	4
Mud	1	4
Terraces and bars	10	1
Overall Suitability (%)	45	60%
Category		Poor

APPENDIX E
RIPARIAN VEGETATION: SITE SUITABILITY:
Mr J Mackenzie

E1 RIPARIAN VEGETATION SITE SUITABILITY

E1.1 EWR 1:UITKOMS

Site Suitability for the Assessment of Environmental Flows; EWR1		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	0	marginal completely present
Proportion of marginal zone that is able to be sampled	0	entire marginal zone was sampled
	0	
Channel morphology		
Channel bank stabilization	0	less than 20% undercutting, and stabilized by vegetation
Channel manipulation	0	no channel manipulation observed at site
Profile distance too long to effectively conduct VEGRAI	2	only RHB and mid-channel features sampled
	2	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone: Cyperus emarginata common
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, Cyperus spo mainly, & Miscanthus
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s at site	0	no recent fires at site
Exotic species at the site	1	less than 10% exotic species at the site
Left and right-hand banks have riparian vegetation in similar condition	0	banks similar
Able to obtain sufficient survey points of indicator species for flow requirements	1	sufficient, but not on LHB
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	0	not observed in immediate vacinity
	0	
Overall Site Suitability Rating	**1.0**	**Site suitable**

E1.2 EWR 2: GROOTDRAAI

Site Suitability for the Assessment of Environmental Flows: EWR2		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	0	marginal zone intact
Proportion of marginal zone that is able to be sampled	1	up to 40% of marginal zone inundated
	1	
Channel morphology		
Channel bank stabilization	0	not more than 20% eroded, but RHB upper zone did have erosion
Channel manipulation	1	some paths on lower and upper zone have resulted in bank erosion
Profile distance too long to effectively conduct VEGRAI	0	entire profile sampled
	1	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone: Cyperus emarginata common, Cliffortia
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, Cyperus spp mainly, Persecaria
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s at site	0	no recent fires at site
Exotic species at the site	1	up to 20% cover by exotics, mainly Salix
Left and right-hand banks have riparian vegetation in similar condition	0	similar banks
Able to obtain sufficient survey points of indicator species for flow requirements	0	sufficient
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	3	upstream gauging wier
	3	
Overall Site Suitability Rating	**1.8**	**Site moderately suitable**

E1.3 EWR 3: GLADDEDRIFT

Site Suitability for the Assessment of Environmental Flows: EWR3		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	1	up to or less than 20% marginal zone trampled and eroded
Proportion of marginal zone that is able to be sampled	0	entire marginal zone was sampled
	1	
Channel morphology		
Channel bank stabilization	1	60-80% not eroded (small scale erosion from trampling, large scale erosion from bridge)
Channel manipulation	1	presence of bridge i.e. minor manipulation
Profile distance too long to effectively conduct VEGRAI	0	entire profile sampled
	1	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone: Cyperus emarginata common, Cliffortia
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, Cyperus spp mainly, Persecaria
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s at site	0	no recent fires at site
Exotic species at the site	1	up to 20% cover by exotics, mainly Salix
Left and right-hand banks have riparian vegetation in similar condition	0	similar banks
Able to obtain sufficient survey points of indicator species for flow requirements	0	sufficient
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	3	upstream bridge & debris caused erosion
	3	
Overall Site Suitability Rating	**1.8**	**Site moderately suitable**

E1.4 EWR 4: DE NEYS

Site Suitability for the Assessment of Environmental Flows: EWR4		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	2	marginal zone present, but not easly distinguished from lower zone
Proportion of marginal zone that is able to be sampled	2	about 50% of marginal zone was sampled
	2	
Channel morphology		
Channel bank stabilization	0	80-100% bank not undercut or eroding
Channel manipulation	1	minor landscaping ans buolder piling
Profile distance too long to effectively conduct VEGRAI	3	about 40% of profile sampled
	3	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, excluding the floodplain
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s or mowing at site	2	no recent fires at site, but mowing also obscured sampling
Exotic species at the site	2	up to 40% exotics in places
Left and right-hand banks have riparian vegetation in similar condition	1	banks similar
Able to obtain sufficient survey points of indicator species for flow requirements	2	sufficient points for channel to set flows, but only 5
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	4	upstream and downstream dams, and cobble/buolder piling instream
	4	
Overall Site Suitability Rating	**2.8**	**Site almost unsuitable**

E1.5 EWR 5: SKANDINAVIA

Site Suitability for the Assessment of Environmental Flows: EWR5		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	2	marginal zone present, but not easly distinguished from lower zone
Proportion of marginal zone that is able to be sampled	2	about 50% of marginal zone was sampled
	2	
Channel morphology		
Channel bank stabilization	0	80-100% bank not undercut or eroding
Channel manipulation	1	some landscaping on RHB
Profile distance too long to effectively conduct VEGRAI	3	about 40% of profile sampled
	3	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, excluding the floodplain
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s or mowing at site	0	no recent fires at site
Exotic species at the site	4	up to 60% exotics in places
Left and right-hand banks have riparian vegetation in similar condition	3	banks dissimilar due to recreation on RHB
Able to obtain sufficient survey points of indicator species for flow requirements	1	sufficient points for channel to set flows
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	4	
Hydraulic control		
unnatural up/downstream control affecting site	1	damming effect on riffle by exotic aquatic species (Eichornia)
	1	
Overall Site Suitability Rating	**2.5**	**Site moderately suitable to unsuitable**

E1.6 EWR 6: KLIP

Site Suitability for the Assessment of Environmental Flows: EWR6		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	0	marginal completely present
Proportion of marginal zone that is able to be sampled	0	entire marginal zone was sampled
	0	
Channel morphology		
Channel bank stabilization	0	less than 20% undercutting, and stabilized by vegetation
Channel manipulation	1	unnatural cannal on upper zone
Profile distance too long to effectively conduct VEGRAI	0	entire profile sampled
	1	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone: Cyperus emarginata common
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, Cyperus spo mainly, & Miscanthus
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s at site	0	no recent fires at site
Exotic species at the site	2	up to 40% cover by exotics, mainly Salix and Bidens
Left and right-hand banks have riparian vegetation in similar condition	2	banks slightly different, LHB rocky (Shrubs) & grassy; RHB alluvial with Ouhout
Able to obtain sufficient survey points of indicator species for flow requirements	0	sufficient
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	1	small wier upstream
	1	
Overall Site Suitability Rating	**1.0**	**Site suitable**

E1.7 EWR 7: UPPER WILGE

Site Suitability for the Assessment of Environmental Flows: EWR7		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	0	marginal completely present
Proportion of marginal zone that is able to be sampled	0	more than 80% of marginal zone was sampled
	0	
Channel morphology		
Channel bank stabilization	0	only natural undercutting and slumping observed (on cutting bends of main channel)
Channel manipulation	0	no channel manipulation observed at site
Profile distance too long to effectively conduct VEGRAI	3	site occurs in vast floodplain, while channel profile was sufficient, floodplain was too extensive
	3	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, excluding the floodplain
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s at site	0	no recent fires at site
Exotic species at the site	1	less than 10% exotic species at the site
Left and right-hand banks have riparian vegetation in similar condition	0	banks similar
Able to obtain sufficient survey points of indicator species for flow requirements	0	sufficient points for channel and aspects of floodplain with oxbows
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	1	upstream low-level bridge, but does not have a large effect
	1	
Overall Site Suitability Rating	**1.5**	**Site suitable**

E1.8 EWR 8: BAVARIA

Site Suitability for the Assessment of Environmental Flows EWR 8		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	2	marginal zone severely masked by extensive exotic species woody debris
Proportion of marginal zone that is able to be sampled	1	large proportion not sampled due to woody debris
	2	
Channel morphology		
Channel bank stabilization	0	80-100% bank not undercut or eroding
Channel manipulation	0	no channel manipulation observed at site
Profile distance too long to effectively conduct VEGRAI	0	entire profile was sampled
	0	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, excluding the floodplain
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s at site	0	no recent fires at site
Exotic species at the site	1	less than 10% exotic species at the site, poplars are aggressive invaders locally
Left and right-hand banks have riparian vegetation in similar condition	0	banks similar
Able to obtain sufficient survey points of indicator species for flow requirements	0	sufficient points for channel to set flows
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	4	site affected by upstream gauging wier and extensive localised damming by exotic woody debris
	4	
Overall Site Suitability Rating	**2.0**	**Site moderately suitable**

E1.9 EWR 9: SUIKERBOS US

Site Suitability for the Assessment of Environmental Flows: EWR9		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	1	marginal zone present, but close to downstream bridge
Proportion of marginal zone that is able to be sampled	0	80-100% marginal zone was ampled
	1	
Channel morphology		
Channel bank stabilization	0	80-100% bank not undercut or eroding
Channel manipulation	2	some channel manipulation from the construction of bridge downstream
Profile distance too long to effectively conduct VEGRAI	0	entire profile was sampled
	2	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, excluding the floodplain
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s at site	0	no recent fires at site
Exotic species at the site	2.5	about 40% exotic species coverage
Left and right-hand banks have riparian vegetation in similar condition	0	banks similar
Able to obtain sufficient survey points of indicator species for flow requirements	1	sufficient points for channel to set flows
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2.5	
Hydraulic control		
unnatural up/downstream control affecting site	3	site affected by downstream bridge
	3	
Overall Site Suitability Rating	**2.1**	**Site moderately suitable**

E1.10 EWR 10: SUIKERBOS DS

Site Suitability for the Assessment of Environmental Flows		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	2	marginal zone present, but not easly distinguished from lower zone
Proportion of marginal zone that is able to be sampled	0	80-100% marginal zone was ampled
	2	
Channel morphology		
Channel bank stabilization	0	80-100% bank not undercut or eroding
Channel manipulation	1	some channel manipulation from roads, but minor influence
Profile distance too long to effectively conduct VEGRAI	1	entire profile was sampled
	1	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, excluding the floodplain
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s at site	0	no recent fires at site
Exotic species at the site	3	up to 60% exotics in places
Left and right-hand banks have riparian vegetation in similar condition	0	banks similar
Able to obtain sufficient survey points of indicator species for flow requirements	1	sufficient points for channel to set flows
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	3	
Hydraulic control		
unnatural up/downstream control affecting site	1	site slightly affected by downstream bridge
	1	
Overall Site Suitability Rating	**1.8**	**Site moderately suitable**

E1.11 EWR 11: BLESBOKSPRUIT

Site Suitability for the Assessment of Environmental Flows:11		
Habitat availability	**Rate**	**Motivation where applicable**
Presence / absence of the marginal zone	1	marginal zone present, but largely inundated
Proportion of marginal zone that is able to be sampled	0	80-100% marginal zone was ampled
	1	
Channel morphology		
Channel bank stabilization	1	60-80% bank not undercut or eroding
Channel manipulation	1	some channel manipulation from low and high-level bridges upstream
Profile distance too long to effectively conduct VEGRAI	1	entire profile was sampled
	1	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	more than sufficient obligate riparian species in marginal zone
Occurrence of obligate, non-marginal zone riparian species	2	sufficient obligate riparian species in non-marginal zone, excluding the floodplain
Occurrence of species that are (regional) indicators of the riparian zone, or wetness		obligates present, so unrated
Recent fire/s at site	0	no recent fires at site
Exotic species at the site	2	up to 20% exotics in places
Left and right-hand banks have riparian vegetation in similar condition	0	banks similar
Able to obtain sufficient survey points of indicator species for flow requirements	1	sufficient points for channel to set flows
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	3.5	site affected by upstream bridges with increased erosion
	3.5	
Overall Site Suitability Rating	**1.9**	**Site moderately suitable**

APPENDIX F:
FISH: SITE SUITABILITY
Dr CJ Kleynhans
Dr Piet Kotze

F1 BACKGROUND

According to Kleynhans and Louw (2007), “site” refers to “features of a place related to the immediate environment on which the place is located (e.g. terrain, soil, subsurface, geology, groundwater)(www.geographic.org/glossary.html). Linked to this is the concept of “locality” which refers to the geographic area in which a collecting event occurs (porites.geology.uiowa.edu/entity.htm).Ecological Water Requirement (EWR) sites are localities in a stream within the descending hierarchy of Primary NRU→Secondary NRU→MRU→RAU→EWR site.An EWR site is therefore a locality where measurements to determine the ecological water requirements of river will be done. The information gathered at the EWR site furthermore provides the primary information for the EcoClassification process. It is therefore essential that the EWR site must be suitable to meet the above mentioned objectives.

The selection of EWR sites should consider the following physical attributes (Kleynhans & Louw, 2007):

- Hydraulic cross section(s) will be established here. The purpose of hydraulic measurements and the consequent modelling is to provide an interpretive link between flows at different stages and the resulting aquatic habitats at the site. In some cases a digital terrain model (“habitat model”) will be developed to provide a more accurate and detailed perspective of the response of various habitat features to changes in flow.
- In addition to an ideal EWR site being representative of the RAU, it should also be sensitive in terms of its response to changes in water level (discharges). This will make the EWR site useful for future monitoring and the confidence in the interpretation of monitoring results.
- The ultimately ideal site would therefore be representative, practical and safe to measure and to model reasonably accurately, it would be accessible and sensitive to changes in discharge to make it useful for habitat prediction.

A two tiered approach to site suitability determinations was followed regarding fish assessments. The suitability of the selected sites both as an Ecological Water Requirements site, as well as its suitability for the application of the FRAI was assessed.

F2 SITE SUITABILITY FOR EWR DETERMINATION (Kleynhans & Louw, 2007)

Defined as the suitability of the site in terms of the ability to interpret:

1. The response of the various velocity-depth classes and associated cover at different discharges.
2. The presence of fish species that respond to different discharges and the associated velocity-depth and cover classes. This would be associated with rheophilic, semi-rheophilic and limnophilic species as well as the size of the species involved.

Confidence is correlated with suitability, e.g., the higher the suitability of a site in terms of EWR, the higher the confidence in the EWR specification.

Criticality: A site is critical when it has a high suitability in terms of EWR specifications (or the highest suitability compared to other sites in the RAU).

F2.1 SITE SUITABILITY FOR FRAI

A site is highly suitable for FRAI determination if the velocity-depth and cover classes at the site occur in similar proportions as in the RAU. If a site is not representative of the RAU, it means that the FRAI may need to be 'tweaked' in order to make the site data more representative of the RAU. It is also recommendable that under such conditions, other site/s may have to be sampled to cover all habitats present in RAU adequately to ensure representative results.

It therefore follows that a site may be suitable for EWR determination but not completely suitable for FRAI determination.

This report describes the methodology followed and the results of a site suitability assessment of the selected EWR sites in the Upper Vaal WMA catchments, used for the purpose of theIntegratedVaalRiver system Comprehensive Reserve determination.

F2.2 METHODOLOGY

According to Kleynhans & Louw (2007) the following attributes are essential determinants of the suitability of an EWR site for specifying the ecological water requirements of biota, interpretation and eventually monitoring in terms of fish:

- The presence and abundance of rheophilics. If this group is present and abundant enough to make them useful in terms of monitoring, they would be the ideal subject to use for determining flow requirements as they are sensitive to a cessation of flow (usually fast flow) during all life-stages. If large[6] (about >20 cm in length) rheophilics are present and abundant enough, they would usually be preferable to small rheophilics due to the larger amount of flowing habitat required which would indicate higher discharges. In cases where small rheophilics and large semi-rheophilics occur there may be a requirement for rheophilics during the dry season, but another requirement for large semi-rheophilics during the periods in the wet season when they breed.

[6] Size of any of the groups does not necessarily refer to a particular species: Different life-stages of the same species may, for example, be classified as large or small. In some case the adults semi-rheophilics may vary in size with the smaller adults also occurring in smaller streams.

- The presence of semi-rheophilics. If rheophilics are absent, semi-rheophilics should be used as the subject to determine flow requirements. Semi-rheophilics require flowing water (usually fast) during the breeding season. However, flowing water does not necessarily have to be present during the whole duration of the wet season. Duration of flow for rheophilics during the wet season will be determined by the length of time required for successful spawning, hatching and growth of larvae to juveniles. The size of the semi-rheophilics considered is also important as this will have an influence on the dimensions of the habitat requirements.
- The presence of limnophilics. If rheophilics and semi-rheophilics are absent, the requirements of limnophilics can be considered. This group does not require flowing water during any stage of their life-cycle. However, they do respond positively to improved habitat conditions (e.g. cover and feeding areas) caused by increased flows. In particular circumstances, the requirements of some limnophilics need to be considered where a drop in the water level in pools may result in, for example, a loss of overhanging vegetation which may form an essential cover feature for some species to survive.

The selection of EWR site in terms of Fish Response Assessment Index (FRAI) application should furthermore consider the following physical attributes (Kleynhans & Louw, 2007):

- Preferably the EWR site should be representative of the RAU within which it is situated. “Representative” specifically refers to the hydraulics units at the site which should occur in similar proportions and with similar characteristics to that which occur at the majority of sites in the RAU. Generally, however, the more complicated the site is in terms of hydraulic units (e.g. diversity of bed material and multiple channels), the more difficult hydraulic modelling of the site becomes. This detrimentally influences the accuracy of the hydraulic model and thus the prediction of habitat at various discharges.As a result, a compromise needs to be found between the representivity of the EWR site and the accuracy of the hydraulics model.

The following tables (Table F1 – 3) provide a simple framework to interpret the suitability of a site in terms of the habitats available, velocity-depth fish guilds present and their size at the site compared to the RAU:

Table F1 Comparison of velocity-depth ratings for RAU and the EWR site

	FISH VELOCITY-DEPTH CLASSES			
	Slow-Deep	**Slow-Shallow**	**Fast-Deep**	**Fast-Shallow**
RAU				
EWR SITE				
Abundance: 0=absent; 1=rare; 2=sparse; 3=moderate; 4=abundant; 5=very abundant				

Table F2 Comparison of cover ratings for RAU and the EWR site

	COVER					
	Slow-Deep				Slow-Shallow	
	RAU	SITE			RAU	SITE
Undercut banks/Rootwads				Undercut banks/Rootwads		
Overhanging vegetation				Overhanging vegetation		
Substrate				Substrate		
Aquatic macrophytes				Aquatic macrophytes		
Water column				Water column		
	Fast-Deep				Fast-Shallow	
	RAU	SITE			RAU	SITE
Undercut banks/Rootwads				Undercut banks/Rootwads		
Overhanging vegetation				Overhanging vegetation		
Substrate				Substrate		
Aquatic macrophytes				Aquatic macrophytes		
Water column				Water column		
Abundance: 0=absent; 1=rare; 2=sparse; 3=moderate; 4=abundant; 5=very abundant						

Table F3 Comparison of different fish species and size groups of various velocity-depth guilds at a EWR site (Large>20 cm; Small <20 cm)

EXPECTED SPECIES	Slow-Deep		Slow-Shallow		Fast-Deep		Fast-Shallow	
	LARGE	SMALL	LARGE	SMALL	LARGE	SMALL	LARGE	SMALL
RHEOPHILICS								
Species 1						Species 1		Species 1
Species 2								Species 2
SEMI-RHEOPHILICS								
Species 3	Species 3				Species 3		Species 3	
Species 4		Species 4		Species 4				
LIMNOPHILICS								
Species 5		Species 5		Species 5				

The following general steps were followed to determine the site suitability in terms of fish for EWR determinations:

1. Determine the preliminary expected fish species assemblage for the RAU (the expected species list should be optimised after sampling has been completed).
2. Categorise the species according to large (>20cm) and small (<20cm) rheophilics, semi-rheophilics and limnophilics (Table F3).
3. Decide on the category of fish that could best be used to set ecological water requirements / flows for the RAU. Generally rheophilics will provide the best measure, thereafter semi-rheophilics and then limnophilics. Large species will have preference over small species as they will require deeper habitats, and thus more water.
4. Determine the habitat preference of the key EWR group (i.e. all expected rheophilic species), and draw up an optimal habitat profile for this group.
5. The suitability of the EWR site can now be measured based on its compliance to these habitats, i.e. if this habitat profile is optimally available at the EWR site to support the selected component (i.e. rheophilic) at all life stages, the site will have very high suitability as an EWR site (EWR suitability score of 4 to 5). If none of the habitats available at the EWR site comply with the requirements of the selected component under any of their life stages, the site is not suitable for EWR determinations (this will obviously require selection of different sites).

The following general steps were followed to determine the suitability of an EWR site for the application of the FRAI:

1. Assess the habitat composition at the EWR site (velocity-depth class composition, cover, etc). (Table F1)
2. Estimate the expected habitat composition of the entire RAU (velocity-depth class composition, cover etc.) (Table F1)
3. If all the habitat components of the RAU are adequately represented at the EWR site, the site will have a high suitability for FRAI application (FRAI suitability score of 4-5). If the site is not comparable at all, or lacks representivity of selected (important) habitat components, the site will have low suitability and another site may have to be selected and sampled to supplement the EWR site data for optimal FRAI application for the RAU. The information on comparability of the EWR site in terms of the RAU can furthermore help to indicate which aspects need to be tweaked for improved confidence in the FRAI application (i.e. limited FS habitat available at a site, and limited fish with preference for FS were sampled, it should be considered in the application of the FRAI, both in terms of expected species, as well as observed species for this habitat type).

At this stage the information summarized above could be used to provide a considered and informed decision as to the suitability of the EWR site for the interpretation of ecological water requirements of fish compared to the RAU, as well as its suitability for FRAI application in terms of the entire RAU. This should be ranked according to:

0: Not suitable
1.0-1.9: Very low suitability
2.0-2.9: Moderate suitability
3.0-3.9: High suitability
4.0-5.0: Very high suitability

F3 RESULTS AND DISCUSSION

F3.1 STUDY AREA

Eleven EWR sites were selected in the Upper Vaal River Catchmentfor the purpose of a Comprehensive Reserve Determination.

F3.2 SITE SUITABILITY

F3.2.1 EWR 1: Vaal Uitkoms

Table F4 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
ASCL	BNEE
BKIM	BANO
BAEN	
LCAP	
LUMB	
CGAR	
Limnophilics	
Large	**Small (<20cm)**
None	PPHI
	TSPA

Table F5 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**3.5**	No rheophilic species expected. Six large and 2 small semi-rheophilic spp. expected. Their required habitat well represented at site. Two limnophilic species expected, and their habitat requirements are also met at site.
FRAI SITE SUITABILITY	**4.5**	Habitat requirements (flow-depth categories and cover) of all expected species well represented at site.
0: Not suitable	1 - 1.9: Very low suitability	2 - 2.9: Moderate suitability
3 - 3.9: High suitability	4 - 5: Very high suitability	

F3.2.2 EWR 2: Vaal Grootdraai

Table F6 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
ASCL	BNEE
BKIM	BANO
BAEN	
LCAP	
LUMB	
CGAR	
Limnophilics	
Large	**Small (<20cm)**
None	PPHI
	TSPA

Table F7 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	3	No rheophilic species expected. Six large and 3 small semi-rheophilic spp. expected. Their required habitat well represented at site. Two limnophilic species expected, and their habitat requirements are also met at site. Flow modification by Grootdraai Dam short distance upstream of site expected to result in unnatural habitat fluctuation. Weir directly upstream of site may result in unnatural high abundance of species during migrations.
FRAI SITE SUITABILITY	4.5	Habitat requirements (flow-depth categories and cover) of all expected species very well represented at site.
0: Not suitable	1 - 1.9: Very low suitability	2 - 2.9: Moderate suitability
3 - 3.9: High suitability	4 - 5: Very high suitability	

F3.2.3 EWR 3: Vaal Gladdedrift

Table F8 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
ASCL	BNEE
BKIM	BANO
BAEN	BPAU
LCAP	
LUMB	
CGAR	
Limnophilics	
Large	**Small (<20cm)**
None	PPHI
	TSPA

Table F9 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	3.5	No rheophilic species expected. Six large and 3 small semi-rheophilic spp. expected. Their required habitat well represented at site. Two limnophilic species expected, and their habitat requirements are also met at site.
FRAI SITE SUITABILITY	4.5	Habitat requirements (flow-depth categories and cover) of all expected species very well represented at site.
0: Not suitable	1 - 1.9: Very low suitability	2 - 2.9: Moderate suitability
3 - 3.9: High suitability	4 - 5: Very high suitability	

F3.2.4 EWR 4: De Neys

Table F10 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
ASCL	BNEE
BKIM	BANO
BAEN	BPAU
LCAP	
LUMB	
CGAR	

Limnophilics	
Large	**Small (<20cm)**
None	PPHI
	TSPA

Table F11 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**3.5**	No rheophilic species expected. Six large and 3 small semi-rheophilic spp. expected. Their required habitat fairly well represented at site. Two limnophilic species expected, and their habitat requirements are also met at site.
FRAI SITE SUITABILITY	**3**	Habitat requirements (flow-depth categories and cover) of species favoring fast habitats are well represented at site. Slow (especially slow-deep) habitats had to be supplemented by sampling of another site).
0: Not suitable 3 - 3.9: High suitability	1 - 1.9: Very low suitability 4 - 5: Very high suitability	2 - 2.9: Moderate suitability

F3.2.5 EWR 5: Skandinavia

Table F12 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
ASCL	BNEE
BKIM	BANO
BAEN	BPAU
LCAP	
LUMB	
CGAR	
Limnophilics	
Large	**Small (<20cm)**
None	PPHI
	TSPA

Table F13 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**3**	No rheophilic species expected. Six large and 3 small semi-rheophilic spp. expected. Their required habitat fairly well represented at site. Two limnophilic species expected, and their habitat requirements were very well represented.
FRAI SITE SUITABILITY	**3**	Habitat requirements (flow-depth categories and cover) of species were present at site. Fast habitats were limited and were supplemented by sampling of another site.
0: Not suitable 3 - 3.9: High suitability	1 - 1.9: Very low suitability 4 - 5: Very high suitability	2 - 2.9: Moderate suitability

F3.2.6 EWR 6: Klip

Table F14 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
BAEN	BNEE
LCAP	BANO
LUMB	
CGAR	
Limnophilics	
Large	**Small (<20cm)**
None	None

Table F15 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**3**	No rheophilic or limnophilic species expected. Four large and 2 small semi-rheophilic spp. expected. Their required habitat very well represented at site. Presence of small weir at site may alter natural habitat and species composition slightly.
FRAI SITE SUITABILITY	**4**	Habitat requirements (flow-depth categories and cover) of expected species were very well represented at site.
0: Not suitable	1 - 1.9: Very low suitability	2 - 2.9: Moderate suitability
3 - 3.9: High suitability	4 - 5: Very high suitability	

F3.2.7 EWR 7: Upper Wilge

Table F16 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
BAEN	BNEE
	BANO
	BPAU
Limnophilics	
Large	**Small (<20cm)**
None	None

Table F17 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**2**	No rheophilic species expected. One large and 3 small semi-rheophilic spp. expected. The required habitat for small rheophilic species well represented at site. Very limited stable flow-sensitive habitats available, although the site is representative of this reach. Non-flow related impacts may have negative impact on fish species (alien predatory bass) which may reduce ability of site to sustain these species, and therefore reflect adequate flow conditions.
FRAI SITE SUITABILITY	**3.5**	Habitat requirements (flow-depth categories and cover) of expected species were well represented at site, and habitats at site representative of this in RU.
0: Not suitable 3 - 3.9: High suitability	1 - 1.9: Very low suitability 4 - 5: Very high suitability	2 - 2.9: Moderate suitability

F3.2.8 EWR 8: Bavaria

Table F18 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
ASCL	BNEE
BAEN	BPAU
LCAP	BANO
LUMB	
CGAR	
Limnophilics	
Large	**Small (<20cm)**
None	PPHI
	TSPA

Table F19 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**3**	No rheophilic or limnophilic species expected. Five large and 3 small semi-rheophilic spp. expected. Their required habitat very well represented at site.
FRAI SITE SUITABILITY	**5**	Habitat requirements (flow-depth categories and cover) of all the expected species were very well represented at site.
0: Not suitable 3 - 3.9: High suitability	1 - 1.9: Very low suitability 4 - 5: Very high suitability	2 - 2.9: Moderate suitability

F3.2.9 EWR 9: SuikerbosUS

Table F20 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
ASCL	BNEE
BAEN	BPAU
LCAP	BANO
LUMB	
CGAR	
Limnophilics	
Large	**Small (<20cm)**
None	PPHI
	TSPA

Table F21 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**2.8**	No rheophilic species expected. Six large and 3 small semi-rheophilic spp. expected. Their required habitat fairly well represented at site. Two limnophilic species expected, and their habitat requirements were very well represented.
FRAI SITE SUITABILITY	**3**	Habitat requirements (flow-depth categories and cover) of species were met at site. Slow- deep and fast-deep habitats limited were limited.
0: Not suitable	1 - 1.9: Very low suitability	2 - 2.9: Moderate suitability
3 - 3.9: High suitability	4 - 5: Very high suitability	

F3.2.10 EWR 10: SuikerbosDS

Table F22 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
ASCL	BNEE
BKIM	BPAU
BAEN	BANO
LCAP	
LUMB	
CGAR	
Limnophilics	

Large	Small (<20cm)
	PPHI
	TSPA

Table F23 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**4**	No rheophilic species expected. Six large and 3 small semi-rheophilic spp. expected. Their required habitat fairly well represented at site. Two limnophilic species expected, and their habitat requirements were very well represented.
FRAI SITE SUITABILITY	**4.5**	Habitat requirements (flow-depth categories and cover) of expected species were abundant at site, and were a good representation of the expected habitats of the RU.
0: Not suitable 3 - 3.9: High suitability	1 - 1.9: Very low suitability 4 - 5: Very high suitability	2 - 2.9: Moderate suitability

F3.2.11 **EWR 11: Blesbok**

Table F24 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
ASCL	BNEE
BAEN	BPAU
LCAP	BANO
LUMB	
CGAR	
Limnophilics	
Large	**Small (<20cm)**
None	None
	PPHI
	TSPA

Table F 25 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**3**	No rheophilic species expected. Five large and 3 small semi-rheophilic spp. expected. Their required habitat well represented at site. Two limnophilic species expected, and their habitat requirements were very well represented. Non-flow related impacts may have negative impact on semi-rheophilic species (reduced water quality, extensive algal growth on substrate) which may reduce ability of site to sustain these species.
FRAI SITE SUITABILITY	**3.5**	Habitat requirements (flow-depth categories and cover) of expected species were well represented at site.
0: Not suitable 3 - 3.9: High suitability	1 - 1.9: Very low suitability 4 - 5: Very high suitability	2 - 2.9: Moderate suitability

F3.2.12 **RE - EWR 1: Klein Vaal**

Table F26 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
BAEN	BNEE
	BANO
Limnophilics	
Large	**Small (<20cm)**
None	None
	PPHI
	TSPA

Table F27 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**2.5**	No rheophilic species expected. At least one large and 2 small semi-rheophilic spp. expected. Their required habitat present at site.
FRAI SITE SUITABILITY	**3.5**	Habitat requirements (flow-depth categories and cover) of expected species were presented at site.
0: Not suitable 3 - 3.9: High suitability	1 - 1.9: Very low suitability 4 - 5: Very high suitability	2 - 2.9: Moderate suitability

F3.2.13 **RE - EWR 2: Mooi**

Table F28 Expected fish species of RAU classified according to flow-depth preference and requirements for flow (rheophilic, semi-rheophilic, limnophilic)

Rheophilics	
Large	**Small (<20cm)**
None	None
Semi-Rheophilics	
Large	**Small (<20cm)**
CGAR	BNEE
	BPAU
	BANO
	BTRI
Limnophilics	
Large	**Small (<20cm)**
None	None
	PPHI
	AJOH

	TSPA

Table F29 Suitability scores of site in terms of EWR and FRAI application

SUITABILITY SCORES		Comments
EWR SUITABILITY	**1.5**	No rheophilic species expected. One large and 4 small semi-rheophilic spp. expected. Their preferred habitats were limited at site (especially deep habitats). Fast shallow habitats unnaturally created.
FRAI SITE SUITABILITY	**2**	Habitat requirements (flow-depth categories and cover) of expected were not well represented at site. Slow habitats at site are representative of habitats of the RU.
0: Not suitable	1 - 1.9: Very low suitability	2 - 2.9: Moderate suitability
3 - 3.9: High suitability	4 - 5: Very high suitability	

F4 REFERENCES

Kleynhans, C.J.and Louw, M.D. 2007.River reach demarcation and delineation (Sabie River Catchment). Draft working document.

Kleynhans, C.J., Louw, M.D., Moolman, J. 2007. Reference frequency of occurrence of fish species in South Africa. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Water Research Commission.

APPENDIX G:
HYDRAULICS: SITE SUITABILITY
Dr AL Birkhead

G1 HYDRAULIC SITE SUITABILITY

G1.1 EWR 1: UITKOMS

Site suitability = 2 lowflows; 3 highflows (scale 0-5)
Cross-section is located at the upstream end of an extensive high gradient boulder rapid.

Positive attributes

- Upstream gauging weir (C1H007) for the measurement of discharge. The data for this gauge is available at near real-time on the DWAF hydrology web site, making it useful for the follow-up collection of hydraulic data over the duration of the Reserve study.

Negative attributes

- Non-horizontal water levels likely at low-flows, but seldom experienced under present day conditions in this section of the river (elevated lowflows due to inter-basin transfer).
- Large resistance elements (boulders and bedrock), which will reduce the confidence with which the stage-discharge relationship may be predicted at low- to mediumflows.
- Non-uniform flows - cross-section is located at the upstream end of an extensive rapid (approx. 300m).
- Low confidence in the predicted velocity distribution at low- to mediumflows (slack-water area on right bank). This will reduce the confidence in the modelled habitattypes incorporating velocity (e.g. velocity-depth habitat types for fish and velocity habitattypes for macroinvertebrates).

G1.2 EWR 2: GROOTDRAAI

Site suitability = 4 lowflows; 4 highflows (scale 0-5)
Site is located at a riffle approximately 4km downstream of the Grootdraai Dam wall, with the cross-section positioned (approx.) through the middle of the riffle.

Positive attributes

- Upstream gauging weir (C1H019) for the measurement of discharge. The data for this gauge is available at near real-time on the DWAF hydrology web site, making it useful for the follow-up collection of hydraulic data over the duration of the Reserve study.
- Extent of uniform riffle - approx. 40m in length.

Negative attributes

- Large nature of the bed substrate (including small boulders), making resistance predictions difficult at lowflows. This reduces the confidence in the prediction of the stage-discharge relationship difficult at lowflows.
- Non-horizontal water surfaces at lowflows.

G1.3 EWR 3: GLADDEDRIFT

Site suitability = 2 lowflows; 4 highflows (scale 0-5)
Site is located at a bedrock section of the river immediately downstream of a high-level bridge. A digital terrain model (DTM) and two-dimensional hydraulic modelling is anticipated for this site.

Positive attributes

- Upstream gauging weir (C1H012) for the measurement of discharge. The data for this gauge is available at near real-time on the DWAF hydrology web site, making it useful for the follow-up collection of hydraulic data over the duration of the Reserve study.

Negative attributes

- Large and irregular nature of the bed substrate (bedrock and boulders), making resistance predictions difficult at lowflows.
- Difficult to characterise hydraulics behaviour of site using cross-sectional surveys – hence two-dimensional hydraulic modelling anticipated for this site.
- Non-horizontal water surfaces at low-flows.
- Lowconfidence in the lowflow hydraulic characterisation in the absence of a range of measured low-flow discharges.

G1.4 EWR 4: DE NEYS

Site suitability = 3 lowflows; 3 highflows (scale 0-5)
Cross-section is located at the downstream end of an extensive rapid, with two active channels.

Positive attributes

- Upstream gauging weir (C2H122) for the measurement of discharge. The data for this gauge is available at near real-time on the DWAF hydrology web site, making it useful for the follow-up collection of hydraulic data over the duration of the Reserve study.
- Non-horizontal water surfaces across the channel width at low-flows, but should not present a problem since elevated low-flows are purportedly experienced and likely to continue being supplied to this section of the river.
- Relatively long rapid unit (approx. 150m), with near uniform flow conditions at medium-flows (approx. 10-15 m^3/s) and higher.

Negative attributes

- Bedrock rapid with relatively large angular roughness elements (on bedrock substrate). This reduces the confidence in the prediction of the stage-discharge relationship difficult at low-flows.

G1.5 EWR 5: SKANDINAVIA

Site suitability = 2 lowflows; 4 highflows (scale 0-5)
Cross-section is located through a short rapid, which will drown-out at medium-flows (approx. $20m^3/s$) and above.

Positive attributes

- Reasonably uniform flow conditions at medium- to high-flows (this section of the river purportedly experiences elevated low-flows under present day conditions).
- Upstream gauge (C2H018 @ Schoemansdrift) for measuring medium to high discharges, although unsteady effects will have to be considered, particularly at low-flows.
- The data for the gauge below the Barrage (C2H140 at GooseBay) is available at near real-time on the DWAF hydrology web site, making it useful for the follow-up collection of hydraulic data over the duration of the Reserve study.

Negative attributes

- Difficult to measure discharge at any flows.
- Non-horizontal water levels likely at low-flows, but purportedly not experienced frequently in this section of the river (elevated low-flows).
- Large resistance elements (boulders and bedrock), which will reduce the confidence with which the stage-discharge relationship may be predicted at low- to mediumflows.
- Low confidence in the predicted velocity distribution at low- to mediumflows.This will reduce the confidence in the modelled habitat-types incorporating velocity (e.g. velocity-depth habitat types for fish and velocity habitat-types for invertebrates).

G1.6 EWR 6: KLIP

Site suitability = 3 lowflows; 4 highflows (scale 0-5)
Cross-section is located through a rapid on a bed in the river planform which will become drowned-out at medium- to high-flows (approx. 10m^3/s).

Positive attributes

- None.

Negative attributes

- Large nature of the bed substrate (including small boulders), making resistance predictions difficult at lowflows.
- Influence of bend on flow resistance at medium to highflows when riffle bed-control becomes drowned-out.
- Changes in the flow direction as flow increases.

G1.7 EWR 7: UPPER WILGE

Site suitability = 4 lowflows; 3 highflows (scale 0-5). High flows in this instance refer for 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.

Positive attributes

- Prismatic channel with approximately uniform flow conditions, which also facilitates themeasurement of discharge.

Negative attributes

- Possibility of backup due to downstream morphologicalcontrols.
- Difficulty of estimating floodplain resistance for overbank flows.

G1.8 EWR8: BAVARIA

Site suitability = 2 lowflows; 3 highflows (scale 0-5)
Site is located at the upstream end of an extensive and complex bedrock and boulder rapid.

Positive attributes

- Upstream gauging weir (C8H028) for the measurement of discharge. The data for this gauge is available at near real-time on the DWAF hydrology web site, making it useful for the follow-up collection of hydraulic data over the duration of the Reserve study.

Negative attributes

- Large nature of the bed substrate (bedrock and boulders), making resistance predictions difficult, particularly for low and medium flows.
- Extensive woody debris in the active channel, influencing flow resistance and medium-flows and above.
- Non-horizontal water surfaces at low- and mediumflows.
- Low confidence in the hydraulic characterisation is anticipated in the absence of a range of measured discharges.

G1.9 EWR9: SUIKERBOSUS

Site suitability = 2 lowflows; 3 highflows (scale 0-5)
Site is located at a high level bridge and therefore has unnatural influences. The cross-section is located immediately upstream of the bridge structures (piers). Low-confidence site in the absence of an adequate range of measured rating data.

Positive attributes

- None.

Negative attributes

- Non-horizontal water surfaces across two-channels at lowflows.
- Large and irregular nature of the bed substrate, making resistance predictions difficult.
- Influence of bridge structures at medium- and highflows.

G1.10 EWR10: SUIKERBOS DS

Site suitability = 3 lowflows; 4 highflows (scale 0 - 5)
Cross-section is located at the upstream end of a long (approx. 80m) uniform riffle - The upstream position was influenced by habitat indicators for fish and the location of instream vegetation.

Positive attributes

- Uniform flow conditions at medium- to highflows.
- Downstream bridge for the measurement of high flows when access into the river is not possible.

Negative attributes

- Non-horizontal water surfaces across the channel at low-flows, with a slack-water area (reduced velocities) on the right side, and an additional channel on the left side with the likelihood of different water levels.
- Difficult to manually measure discharge using velocity-area method during low-flows due to the presence of algae.

G1.11 EWR 11: BLESBOKSPRUIT

Site suitability = 4 lowflows; 4 highflows (scale 0-5)
Site is located downstream of a low level bridge with culverts, and upstream of a bend in the river planform.

Positive attributes

- Extent of uniform riffle - approx. 40m in length.
- Culverts for the measurement of medium- to highflows, although these are partially clogged with flood debris.

Negative attributes

- Large nature of the bed substrate (including small boulders), making resistance predictions difficult at low-flows.
- Influence of downstream bend on flow resistance at medium- to highflows when riffle bed-control becomes drowned-out.
- Difficult to manually measure discharge using velocity-area method during low-flows due to the presence of algae.

G1.12 RE - EWR 1: KLEIN VAAL

Site suitability = 3 lowflows; 5 highflows (scale 0-5)
Cross-section is located through a small rapid with bedrock influence, but will become drowned-out at low- to mediumflows (approx. 0.5m^3/s).

Positive attributes

- Reasonably small nature of the bed substrate, including up to cobble-sized elements.

Negative attributes

- Short length of rapid - few metres in extent.

G1.13 RE-EWR 2: MOOI RIVER

Site suitability = 2 lowflows; 1 highflows (scale 0-5)
Site is located at a low-level bridge (culverts) with the cross-section positioned immediately (approx. 10m) upstream of the bridge immediately upstream. This site is likely to be low-confidence without a range of measured flows during the duration of data collection within this study.

Positive attributes

- Culverts for the measurement of medium- to high-flows.

Negative attributes

- Short (approx. 15m) riffle located immediately upstream of a bridge crossing (with 3 off 0.media. culverts) in densely vegetated reed vegetation. The bridge is likely to back-up the flow at medium- to highflows.
- Difficult to estimate the flow resistance of the vegetation, and hence predict the stage-discharge relationship. Structural controls have been surveyed to enable a backwater analysis to be undertaken.
- Difficult to measure lowflow discharges due to the large bed elements (approx. 20 – 30cm in size).