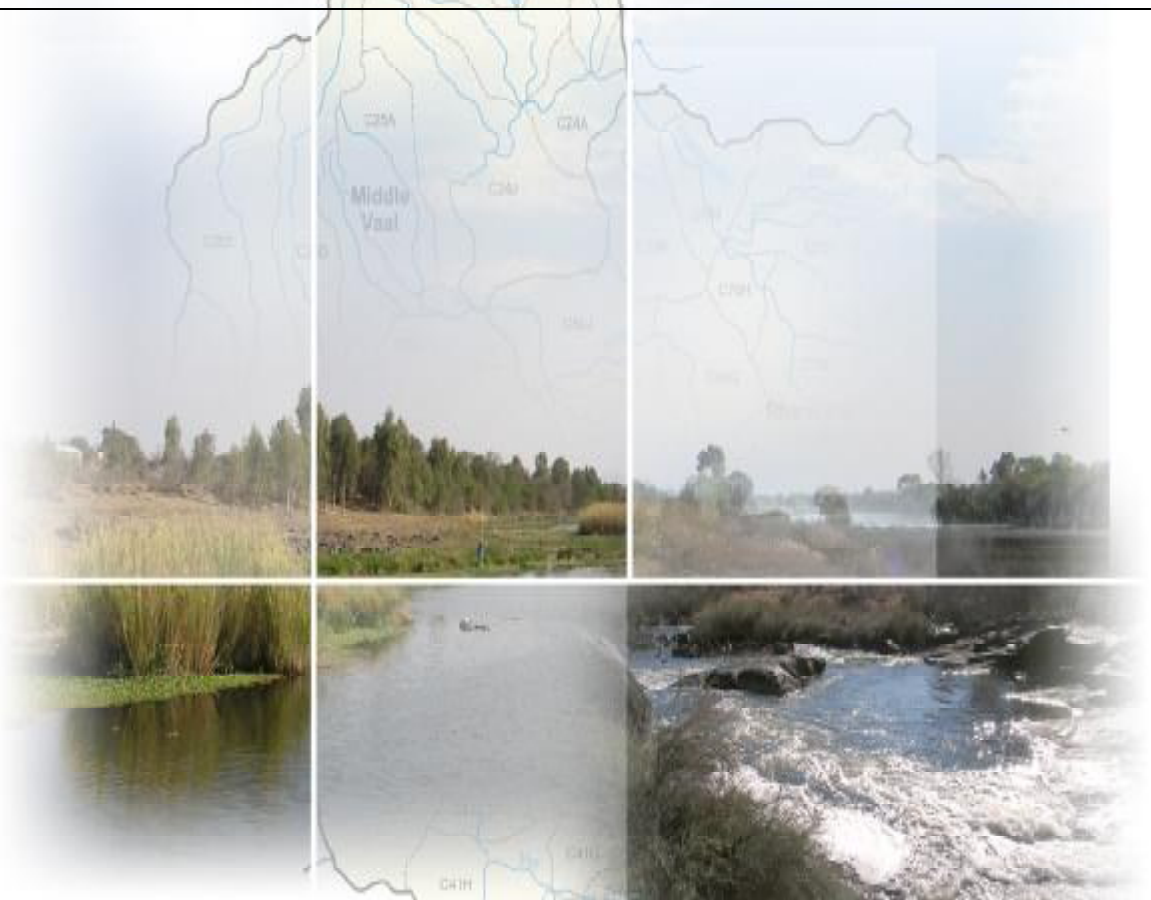
COMPREHENSIVE RESERVE DETERMINATION

INTEGRATED VAAL RIVER SYSTEM

SURFACE WATER

RESOURCE UNITS



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EXECUTIVE SUMMARY

Background

The Chief Directorate: Resource Directed Measures (RDM) has initiated the Comprehensive Reserve Determination Study for the Integrated Vaal River System: Middle Vaal Water Management Area (WMA) surface water quantity. The purpose of the Comprehensive Reserve Determination Study for the water resources of the Middle Vaal WMA is to determine the ecological and basic human needs water quantity Reserve for the rivers and pans in the WMA.

The Reserve studies require higher levels of confidence in the results as is currently available. This will assist the Department of Water Affairs and Forestry (DWAF) to make informed decisions regarding the management and operation of the system, authorisation of future water use and the magnitude of the impacts of the present and proposed developments.

As part of the Reserve Determination process it is necessary to define the study area for the comprehensive assessment and to delineate key rivers of the study area into Resource Units (RU). Each RU represents a homogenous area which requires its own specification of the Reserve. This report therefore details the process of delineating and determining the resource units for the water resources in Middle Vaal WMA.

Delineation Approach

The process followed was that described in the updated Reserve manuals (Louw and Hughes, 2002).

Resource Units 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:

- Geomorphological zones
- EcoRegions (Level II)
- Land cover
- System operation and presence of dams
- Water quality
- Local knowledge

Delineation Results

The results are tabled below.

MRU	Delineation	Quartenary Catchment
VAAL RIVER		
MRU Vaal F	From start of WMA at Vermaasdrift on Vaal River to upstream confluence with Schoonspruit	C24B
MRU Vaal G	From Schoonspruit confluence to Regina Bridge (weir)	C24J
MRU Vaal H	From downstream Regina Bridge to Klipplaatdrift	C24J
MRU Vaal I	From Klipplaatdrift to Bloemhof Dam	C24J, C25C
MRU Vaal J	Bloemhof Dam	C25E, C25F, C43D, C91A
TRIBUTARIES		
RHENOSTER RIVER		
MRU Rhenoster A	From origin to upstream Koppies Dam	C70A, C70B, C70C
MRU Rhenoster B	Koppies Dam	C70C
MRU Rhenoster C	From downstream Koppies Dam to confluence with Vaal River	C70E, C70D, C70F, C70G, C70H, C70J, C70K
KOEKEMOERSPRUIT		
MRU Koekemoerspruit A	From origin to confluence with Vaal River	C24A
	SCHOONSPRUIT	
MRU Schoonspruit A	From eye to Kalk Dam	C24C, C24E
MRU Schoonspruit B	From Kalk Dam to Klerkskraal Dam	C24D, C24E, C24F, C24G
MRU Schoonspruit C	Klerkskraal Dam	C24G
MRU Schoonspruit D	From Klerkskraal Dam to confluence with the Vaal River	C24H
VALS RIVER		
MRU Vals A	Origin of the Vals river to Kroonstad (Kroonvaal weir)	C60A, C60B, C60C, C60D, C60E, C60F
MRU Vals B	From confluence at Kroonstad to Vaal River confluence	C60G, C60H, C24J
VET RIVER		
MRU Vet A	Origin of Vet River to Erfenis Dam	C41A, C41B, C41C
MRU Vet B	Erfenis Dam	C41E
MRU Vet C	Erfernis Dam to confluence with Sand River	C41G, C41H, C41J
MRU Sand A	Origin of Sand River to Allemanskraal Dam	C42A, C42B, C42C, C42D
MRU Sand B	Allemanskraal Dam	C42E
MRU Sand C	Allemanskraal Dam to confluence with Vet River	C42F, C42G, C42H, C42J, C42K, C42L
MRU Vet D	From confluence with Sand River to Bloemhof Dam	C43A, C43C, C43D
MAKWASSIE RIVER		
MRU Makwassie A	From origin to confluence with Vaal River	C25D
SANDSPRUIT		
MRU Sandspruit A	From origin to confluence with Vaal River	C25B, C25C

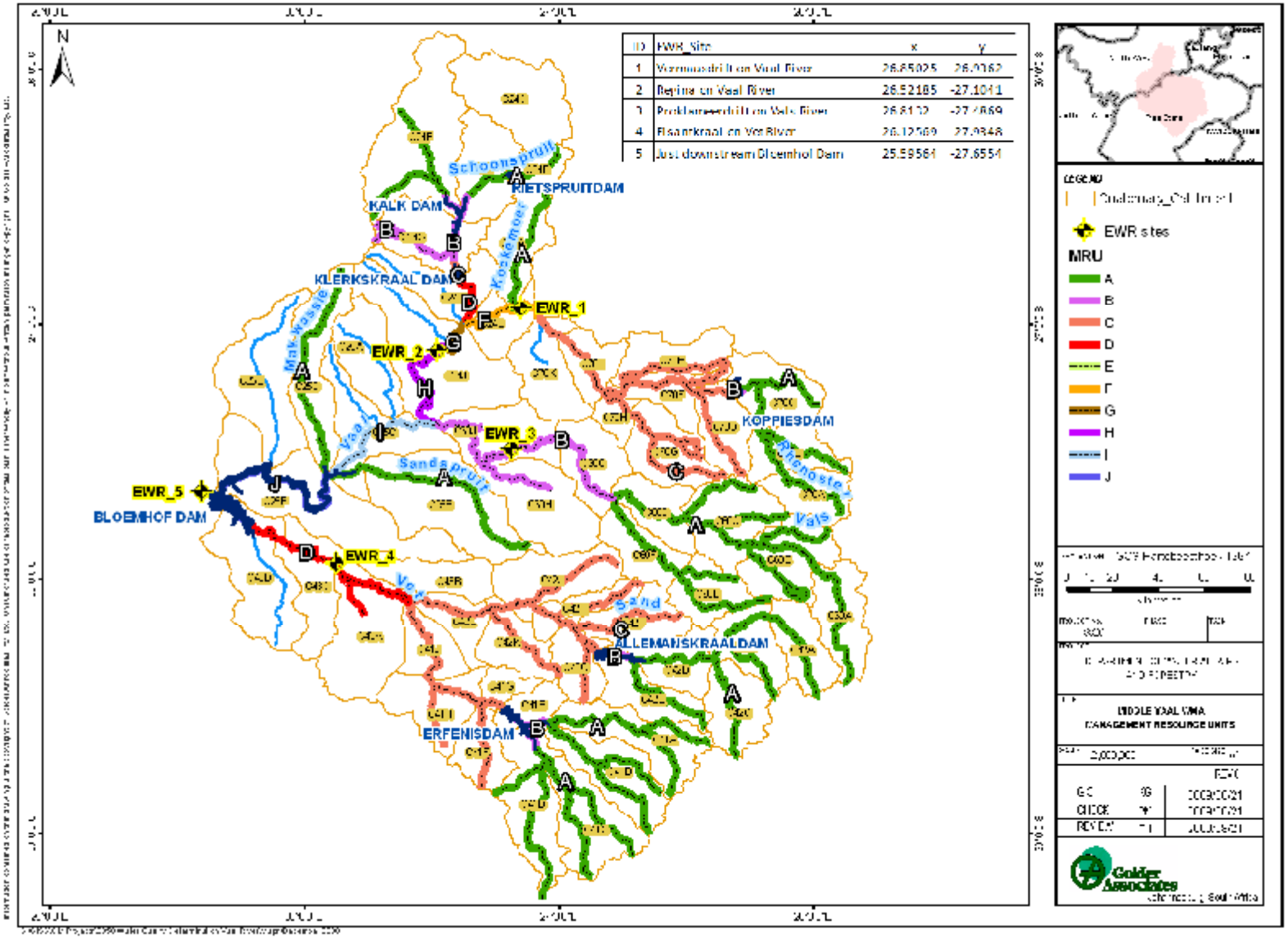
Ecological Water Requirement (EWR) Sites

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 sites selected are tabulated below and illustrated in the map with the MRUs.

EWR Site number	EWR site name	River	National RHP site	Coordinates	Ecoregion (Level II)	Geomorphic zone	Altitude (m)	RU	Quartenary catchment
EWR1	Vaal River: Vermaasdrift	Vaal	C2-Vaal Orkne	S26.93615 E26.85025	11.01	E: Lower Foothills	1348	MRU Vaal F	C24A
EWR2	Vaal River: Regina bridge	Vaal	C2-Vaal Orkne	S27.10413 E26.52185	11.08	E: Lower Foothills	1285	MRU Vaal G	C24J
EWR3	Vals River: Proklameersdrift	Vals	C6Vals-Prokl	S27.48685 E26.81320	11.07	E: Lower Foothills	1400	MRU Vals B	C60J/C60G
EWR4	Vet River: Fisantkraal	Vet	C4-Vet-Hoops C4-Vet-Erfen	S27.93482 E26.12569	11.08	E: Lower Foothills	1247	MRU Vet C	C43A
Rapid EWR	Klein-Vet, just downstream of Winburg	Klein Vet	C4GVet-V4	S28.564708 E26.943946	11.03	E: Lower Foothills	?	MRU Vet A	C41A


N
ID | EWR_Site | x | y
1 | Vaalmasdrift on Vaal River | 26.85025 | -26.9162
2 | Reptile on Vaal River | 26.52185 | -27.1041
3 | Prieskaroedrift on Vals River | 26.6172 | -27.4869
4 | Bloemkraal on Vet River | 26.12569 | -27.9948
5 | Just downstream Bloemhof Dam | 25.59561 | -27.6554
SCHOONSPRUIT DAM
KALK DAM
KLERKSKRAAL DAM
EWR_1
EWR_2
EWR_3
EWR_4
EWR_5
BLOEMHOF DAM
KOPPIESDAM
ALLEMANSKRAALDAM
ERFENISDAM
Schoonspruit
Koekemoer
Mak-kosie
Vaal
Sandspruit
Vet
Sand
Vals
Rhenoster
LEGEND
EWR sites
MRU
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MIDDLE VAAL WMA
MANAGEMENT RESOURCE UNITS
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1 INTRODUCTION

1.1 BACKGROUND

The National Water Act (Act No. 36 of 1998) (NWA) is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public without seriously affecting the functioning of the water resource systems. In order to achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the implementation of resource directed measures (RDM). As part of the RDM, a Reserve has to be determined for a significant water resource, as means to ensure a desired level of protection. The Reserve can be defined as, 'the quantity, quality and reliability of water needed to sustain both human basic use and aquatic ecosystems.

The Chief Directorate: Resource Directed Measures (CD:RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses in terms of the Act, are determined before any new water uses are authorised. The Reserve requirements must be met, before the requirements for economic development or water uses are satisfied so as to ensure that the long-term integrity of ecosystems are not comprised or severely impacted upon'. 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 CD: RDM identified the Integrated Vaal River System, with the focus of this study, the Middle Vaal Water Management Area (WMA) as requiring a comprehensive Reserve assessment, the purpose of which is to determine the ecological and basic human needs water quantity Reserve for the rivers in the WMA. The output of this study will provide input to the Reconciliation strategy and the integrated water quality management plan for the Vaal River developed 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. The comprehensive Reserves will assist the DWAF make more informed decisions regarding the authorisation of future water uses, operation and management of the system and the evaluation of the magnitude of the impacts of the present and proposed developments.

1.2 STUDY AREA

The study area for the Comprehensive Reserve determination of the middle Vaal River is the Middle Vaal WMA (WMA 9) (Figure 1). The Middle Vaal WMA forms part of the integrated Vaal River System, and falls within the C drainage region of South Africa. The Middle Vaal WMA is one of the three cascading WMAs in the Vaal River System catchment, which includes the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers.

The Middle Vaal WMA covers a catchment area of 52 563 km^2, and includes parts of the Free State and North-West Provinces. It is situated in the north-western part of the country and forms part of the Orange River watercourse. The Vaal River flows in a westerly direction to the Lower Vaal WMA. It is the middle WMA within the Vaal River System, with water being transferred *via* the Vaal River

through this WMA to Bloemhof Dam, from the Upper Vaal WMA to the Lower Vaal WMA. The WMA consists of the C24, C25, C41, C42, C43, C60 and C70 tertiary catchments.

The surface flow of the Vaal River, most of which originates in the Upper Vaal WMA, represents the bulk of the surface water in the Middle Vaal WMA. The Vaal River is fed by a number of tributaries of which the most significant are the Renoster, Schoonspruit, Vals and Vet Rivers. Vlei areas occur along the lower Vet River and in the upper Schoonspruit catchment. The surface water flows that originate within the WMA are highly seasonal and intermittent.

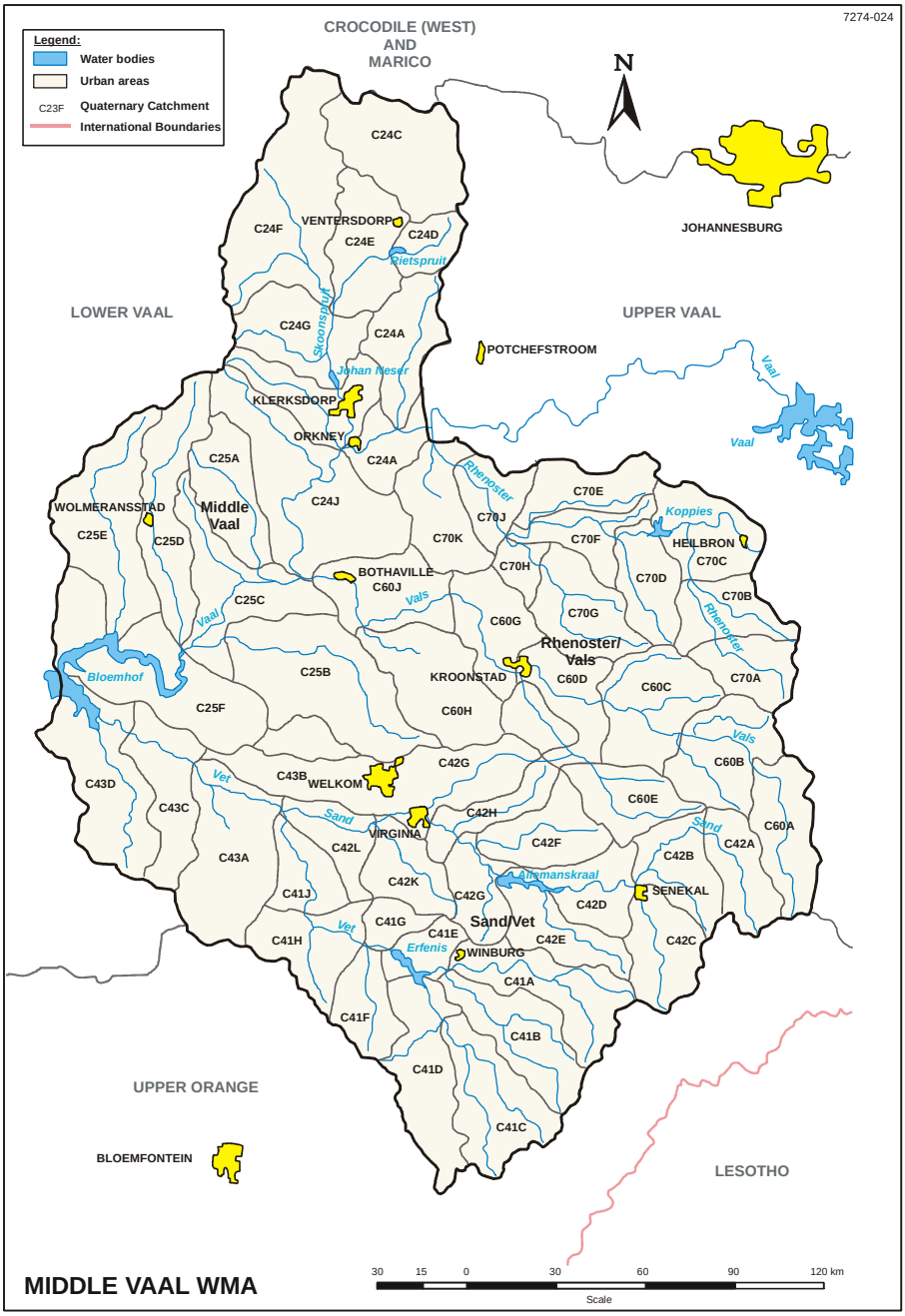

Figure 1: Middle Vaal WMA

1.3 PURPOSE OF THIS REPORT

As part of the Reserve Determination process it is necessary to define the study area for the comprehensive assessment and to delineate key rivers of the study area into Resource Units (RU). Each RU represents a homogenous area which requires its own specification of the Reserve. This report therefore details the process of delineating and determining the resource units for the water resources in Middle Vaal WMA.

The purpose of this report is therefore:

- To provide the information used to define the RUs;
- To provide the delineation of the RUs within the study area, and
- To describe the Ecological Water Requirement (EWR) sites selected within the RUs.

1.4 REPORT STRUCTURE

This report is structured into four parts:

- **Part One**: Introduction – *this section*
- **Part Two**: Delineation of the Resource Units
- **Part Three**: Delineation Results
- **Part Four**: The Ecological Water Requirement (EWR) sites

Part One provides background to the study and the context of the task. Part Two relates to delineation of the resource units and EWR sites. Part Three provides an assessment of the results and Part Four deals in essence with selection of the EWR sites (locality, characteristics and suitability).

2 RIVER REACH DEMARCATION AND DELINEATION

2.1 APPROACH

When an Ecological Reserve determination is required for an entire catchment, it is necessary to delineate the selected rivers into Resource Units (RUs). As it would not be appropriate to set the same numerical Reserve for the headwaters of a river as for the lowland reaches, RUs are required. The RUs are river reaches that are each significantly different to warrant their own specification of the Reserve, and as such the geographic boundaries of each must be clearly delineated. (DWAF, 1999, Volume 3).

A RU is a section of a river that frequently has different natural flow patterns, reacts differently to stress according to their sensitivity, and requires individual specifications of the Reserve appropriate for that reach, as compared to the rest of the river. The delineation of a catchment into RUs for the purpose of determining the Reserve for rivers is therefore done primarily on a biophysical basis, and where the hydrology, geomorphic characteristics (*i.e.* geomorphic zone), physico-chemical attributes and river size remains relatively similar, a Natural Resource Units (NRU) can be demarcated.

In addition to the biophysical (natural) characteristics of a catchment, management requirements also play a role in the delineation of a RU (DWAF, 1999, Volume 3). The purpose of distinguishing a RU of management requirements is to identify a management unit within which the EWR can be implemented and managed based on one set of identified flow requirements. These management units 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. 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 units of delineation are called Management Resource Units (MRU).

The RU delineation process considers all of the above considerations. 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 of the river reaches. 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.

The more detailed demarcation and delineation approach is described in Appendix A.

An Ecological Water Requirement (EWR) site is a locality within a river reach where measurements to determine the ecological water requirements of river are done. The determination of the EWR site locations in a river are done within the descending hierarchy of RU delineation *i.e.* from the NRU to MRU to Reserve Assessment Unit (RAU) to finally the EWR site.

The Ecological Water Requirement (EWRs) sites are determined for each delineated RU 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 MRU then extrapolated results from an adjacent MRU with EWR sites are used. 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

The following is considered for selection of MRUs:

- Geomorphological zones
- EcoRegions (Level II)
- Land cover
- System operation and presence of dams
- Water quality
- Local knowledge

2.2.1 Eco-Regions (Level II)

EcoRegional classification allows for the grouping of rivers according to similarities. The EcoRegion typing approach developed in the USA was applied and tested at a preliminary level in South Africa. The method is based on a top-down approach as developed by DWAF (Kleynhans *et al*., 2004). 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 available information was used 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, Level II, which used the same attributes but included more detail was defined in 2007 (Kleynhans *et al*., 2007).

The Eco-Region Level II information was used to delineate the catchment of the Middle Vaal WMA. The available Level II information was obtained from the DWAF, Directorate Resource Quality Services (D:RQS). Ecoregions integrate important physical variables, such as topography, landscape, geology, soils and vegetation cover, and as such, provided a basic template for identifying Resource

Unit Boundaries. The study area includes three revised Level II Ecoregions (Kleynhans, *et al*., 2007). The Level II Ecoregions in the study area are as follows:

- ***Highveld:*** This ecoregion (high lying region) is characterized by plains with low to moderate relief, and various grassland vegetation types. The altitude ranges between 1100 and 2100m. Rainfall is concentrated in early to late summer, with a coefficient of annual variation of <20 to 35%. Mean annual air temperatures are between 12 and 20°C.

- ***Northern Escarpment Mountains:*** This ecoregion is characterized by closed hills and mountains with moderate to high relief. Vegetation consists of a range of grassland types. The altitude ranges between 1100 and 3100 m. Rainfall is concentrated in early to late summer, with a coefficient of annual variation of <20 to 35%. Mean annual air temperatures are between <8 and 18°C.

- ***Southern Kalahari:*** This ecoregion is characterized by plains with low to moderate relief, and vegetation consists of a variety of Kalahari Bushveld types. The altitude ranges between 500 and 1700 m. Rainfall is concentrated in mid to very late summer, with a coefficient of annual variation of 30 to >40%. Mean annual air temperatures are between 14 and 22°C.

The Eco-Regions of the Middle Vaal WMA are illustrated in

Figure 2.

2.2.2 Geomorphological zonation

Geomorphology provides a basis of classification for the purpose of describing the physical habitat of riparian and aquatic ecosystems, as it encompasses the physical processes which have shaped the river channel. Rowntree and Wadeson (1999) have developed a zonal classification system for Southern African rivers modified from Noble and Hemens (1978). In their classification for each zone of a river a geomorphological definition in terms of distinctive channel morphological units and reach types are given. 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. On the basis of channel features a range of geomorphological zone classes have been defined and are described in

Figure 2: EcoRegion delineation of the Middle Vaal WMA

Table 1.

The hierarchical classification approach of Rowntree and Wadeson (1999) was followed. Based on the zone classification system the rivers in the Middle Vaal WMA were delineated on the basis of their geomorphological features. The geomorphological delineation is illustrated in Figure 3. All rivers in the Middle Vaal WMA can be classified as a geomorhological Zone class E, Lower Foothills.

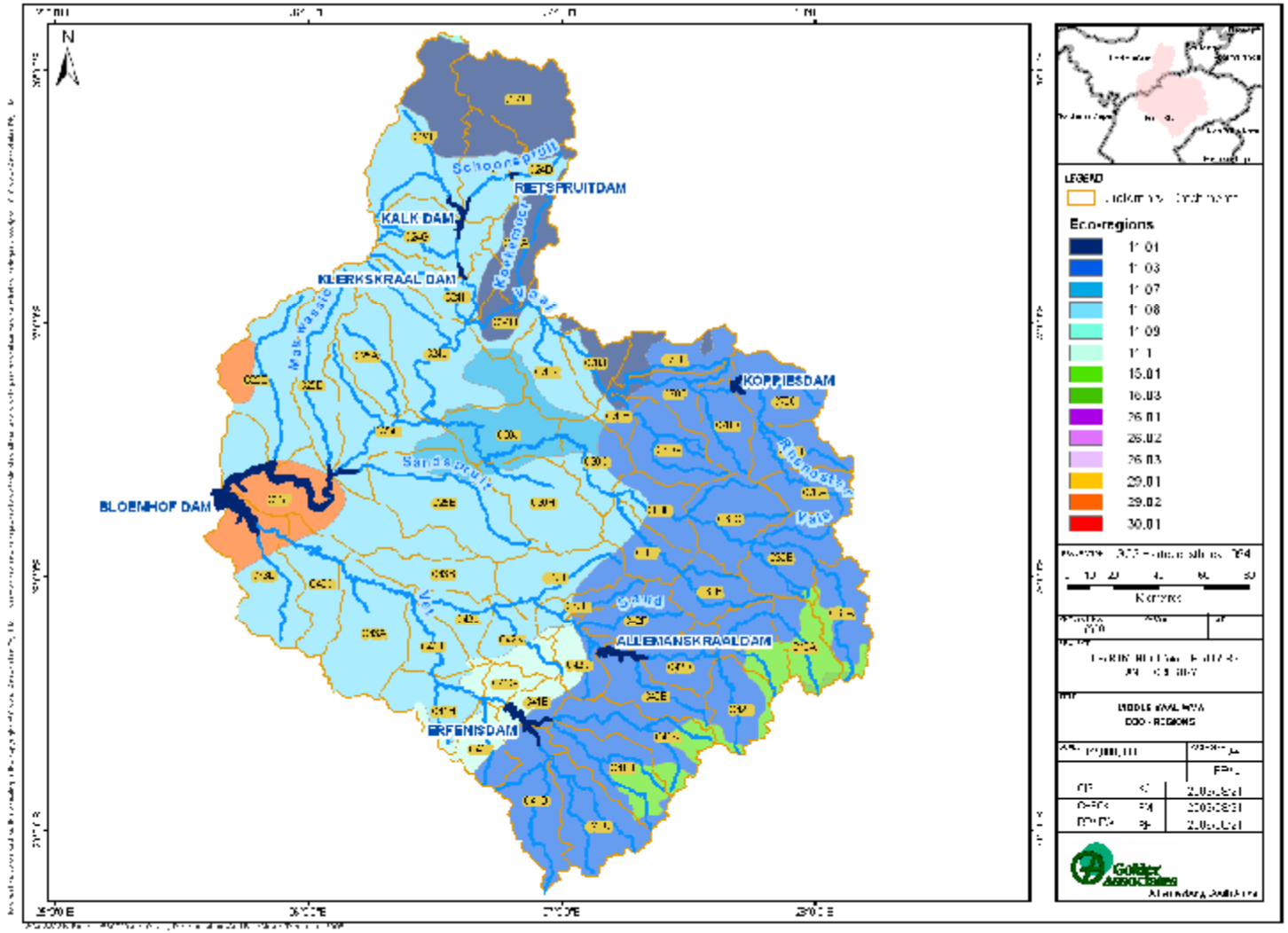

Figure 2: EcoRegion delineation of the Middle Vaal WMA

Table 1: Geomorphological Zonation of River Channels (adapted 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, 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.

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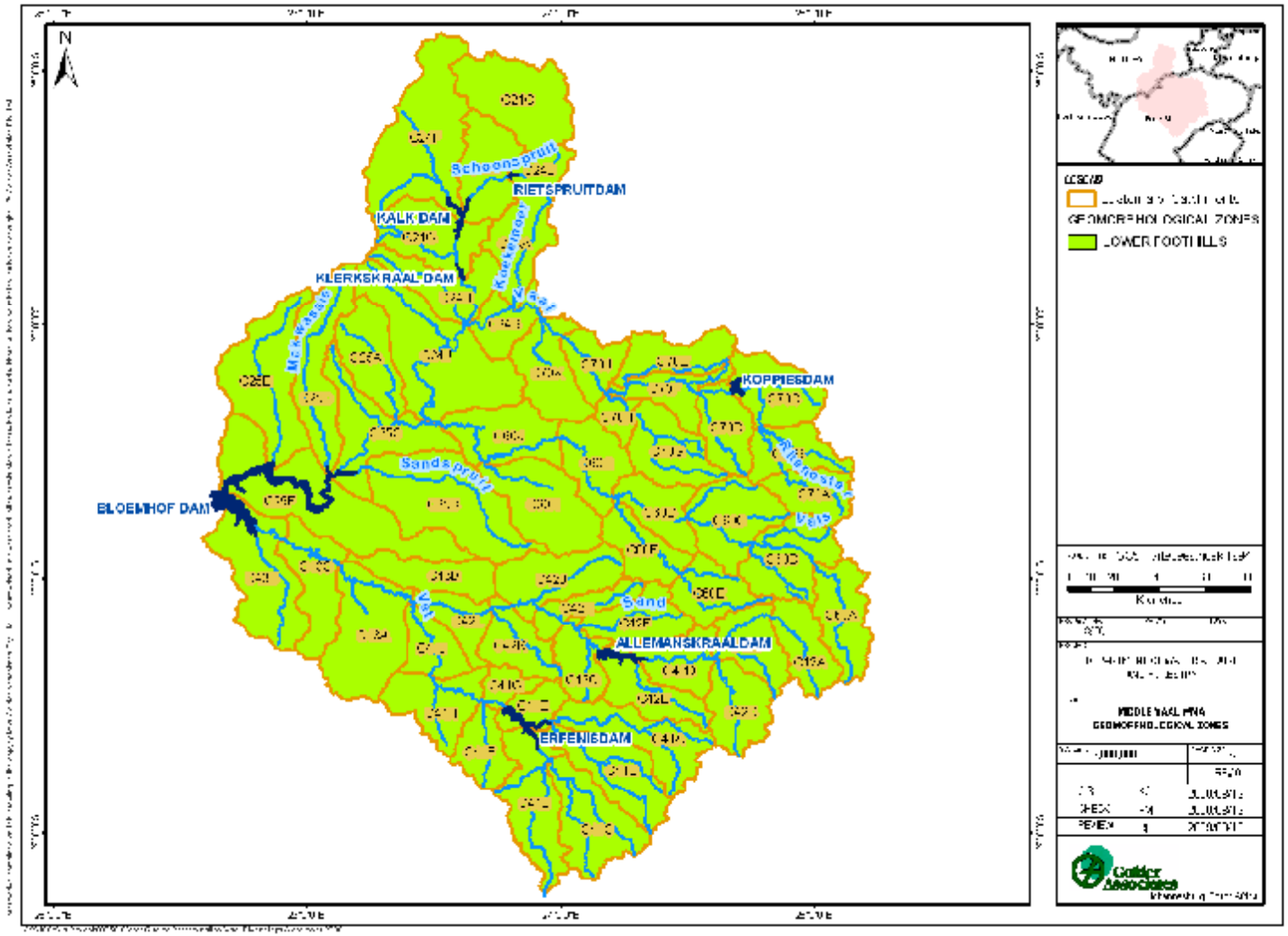


Figure 3: Geomorphological zonation of the rivers in the Middle Vaal WMA

2.2.3 Land cover

Land cover information of the catchment is used to determine homogeneity of impacts and used in the decision-making regarding the MRUs. The land cover information for the Middle Vaal WMA was obtained from the DWAF, D:RQS. The land cover per 500 m strip on both sides of the river is provided as a map with the associated Excel spreadsheets in Appendix B.

The land cover (500 m strips) is dominated by natural grassland, cultivated land, urban/built up areas and goldmines in the riparian and adjacent zones.

2.2.4 System operation

An overview of system management is required to ensure an understanding of the system operation and to interpret biological responses. System operation infrastructure is also often the logical endpoint of a RU. A description on the present operation which includes present uses, abstractions, curtailments *etc.*, and operational structures (formal and informal) if any, that could impact on the hydrological characteristics of the river within the system must be understood.

The surface flow of the Vaal River, most of which originates in the Upper Vaal WMA, represents the bulk of the surface water in the Middle Vaal WMA. The surface water flows that originate within the WMA are highly seasonal and intermittent. The Vaal River is fed by a number of tributaries of which the most significant are the Renoster, Schoonspruit, Vals and Vet Rivers. Vlei areas occur along the lower Vet River and in the upper Schoonspruit catchment. The surface water occurring in the WMA has been developed to its potential and all water is being fully utilised. There are several large dams that have been developed in the WMA (Table 2).

Most of the major tributaries of the Middle Vaal WMA support irrigation schemes. The Sand-Vet Irrigation Scheme within the Sand-Vet Government Water Scheme (GWS) is the most important in the Middle Vaal WMA. Other significant irrigation schemes in this WMA are the Schoonspruit and Rhenoster GWS.

Table 2: Major Dams in the Middle Vaal WMA (DWAF, 2006)

Dam name	Quaternary catchment	River	Purpose	Full Storage Capacity million m^3
Bloemhof	C91A	Vaal	Irrigation	1 218.0
Allemanskraal	C42E	Sand	Irrigation	179.3
Bloemhoek	C60D	Jordaan Spruit	Domestic	19.6
Erfenis	C41E	Vet	Irrigation	212.3
Johan Neser	C24G	Schoonspruit	Irrigation	5.7
Klipplaatdrift	C25A	Vaal		5.7
Koppies	C70C	Renoster	Irrigation	41.1
Marquard	C41A	Laai Spruit	Domestic	2.3
Rietspruit	C24D	Schoonspruit	Irrigation	7.3
Three Sisters	C42F	Sand		1.2
Uniefees	C70C	Eland Spruit	Domestic	1.4

The system operation is summarised below:

- **General description of overall system operation:** The Integrated Vaal River System is designed to maximise the long term water yield from the system. This is achieved by using water first from the most downstream impoundment in the system and only when depleted, water is released from upstream reservoirs to support the water requirements. The Integrated Vaal River System includes ten subsystems, seven transfer schemes and various internal supply schemes in the system, including the Vaal River Eastern Subsystem. The subsystems that form part of the Comprehensive Reserve Determination study area include the Lower Vaal Subsystem, Bloemhof Subsystem, Senqu Subsystem, Grootdraai Subsystem, Zaaihoek Subsystem, Heyshope Subsystem and Usutu subsystem. The Middle Vaal WMA forms part of the Bloemhof Subsystem of the Integrated Vaal River System, which extends from just downstream Grootdraai dam to Bloemhof Dam. The catchment area of this subsystem includes four large dams - Bloemhof, Vaal and Sterkfontein in the Vaal River catchment and Woodstock Dam in the upper part of the Thukela River catchment with a combined capacity of 6 840million m^3.

  Water stored in Bloemhof Dam is used to supply the downstream irrigation and urban users and only if Bloemhof Dam is empty will water be released from Vaal Dam to support those demands. Users along the Middle Vaal Reach (between Vaal Barrage and Bloemhof Dam) are supplied with incremental run-off supplemented from Vaal Barrage and if required from Vaal Dam. The objective is to only release sufficient water to satisfy the requirements of the users in the reach. In addition, releases are occasionally made from Vaal Dam for blending purposed. These releases are mostly captured in Bloemhof Dam for subsequent supply to the downstream users.

- **Vaal River inflow from Upper Vaal WMA (C24A) – at Vermaasdrift**: The Middle Vaal WMA is dependant on the Upper Vaal WMA for meeting the bulk water requirements of its mining, industrial and urban sectors in the Klerksdorp-Orkney and Welkom-Virginia areas. Large quantities of water are transferred into the WMA to augment local water resources. The North West Goldfields, therefore urban and bulk water requirements account for 40% of total requirements. The main urban centres are Klerksdorp, Orkney and Stilfontein in the NW Goldfields and Odendaalsrus in the Free State. The requirements of Stilfontein, Buffelsfontein, Vaal Reefs and Hartebeesfontein Gold Mines make up the bulk requirements in the area. Effluent returns from these towns and mines increase the water resources of the area significantly. This area also exports water from the Vaal River to a number of adjacent key areas, the most significant being Sedibeng Water export of water at Balkfontein to the Free State Goldfields in the Vet key area.

  The local water resources within the WMA are used by smaller towns (Bothaville and Wolmaranstad) and for irrigation. Some small transfers also occur from Vaal Dam to Heilbron in the Middle Vaal WMA and out of Erfenis Dam to the Upper Orange WMA. Water is also transferred via the Vaal River through this WMA to Bloemhof Dam, from the Upper Vaal WMA to the Lower Vaal WMA. Management of water quality and quantity in the Middle Vaal WMA is therefore integrally linked to both the Upper and Lower Vaal WMAs. Notable abstractions in the river reach between Vaal Barrage and Bloemhof Dam include Midvaal Water, Sedibeng Water

and abstractions for irrigation. These abstractions are supported with releases from Vaal Barrage (backed by Vaal Dam). The releases from Vaal Barrage are driven by either these downstream water requirements or through excess water in the Vaal Barrage (spills).

The water entering Middle Vaal WMA from the Upper Vaal WMA brings with it a large contribution of urban, industrial and mining return flows from the highly industrialised and urbanised areas within the Upper Vaal WMA. These carry with it high salinity levels and high nutrient concentrations which are "transferred" into the Middle WMA. As a consequence these high salinity levels need to be managed through dilution with fresh water from Vaal Dam to ensure water of an acceptable quality reaches the Middle Vaal WMA.

- **Vaal River from Vaal Barrage to downstream of the confluence with the Schoonspruit:**

  Three conditions or events influence the flow in this reach. Firstly, releases are made from Vaal Barrage (source Vaal Dam) to supply urban and industrial demands as well as riparian irrigation. The releases to these users are dependant on the run-off from the incremental catchments and are adjusted on a short term basis. Due to the limiting storage capacity at the intakes of these users, no flexibility exists in terms of the short term release rate.

  Secondly, during prolonged droughts additional releases are made from Vaal Dam for users downstream of Bloemhof Dam. These releases can be reasonably flexible with respect to the discharge rate and pattern within a monthly period due to the buffering capacity of Bloemhof Dam. The governing rule for these releases (in terms of seasonal and annual timescales) is to only release sufficient water to satisfy the demand.

  A third condition, to achieve specific water quality blending objective (the additional release of Vaal Dam water to maintain the TDS concentration in Vaal Barrage at 600 mg/l) may cause additional "spills" over Vaal Barrage. This is necessary due to the high salinity (TDS) content of the underground mine water that is pumped out of the gold mines into the river system and surface runoff from the highly urbanised areas in the incremental catchment of the Vaal Barrage. The flow rate into this reach is also flexible over the short term.

  Goldfields Water and MidVaal Water Company withdraw significant amounts of water from the Vaal River within this reach.

  The Pilgrims Estate weir (C2H007) which also influences flow in the Middle Vaal River is located just outside Orkney. The weir captures the inflows from the Koekemoerspruit and Vierfontein Spruit, and supports irrigation upstream of the Schoonspruit and Koekemoerspruit catchments. The MidVaal Water Company abstraction is at the Pilgrims Estate weir.

- **Vaal River from Schoonspruit confluence to Bloemhof Dam wall**: The system operation of 'Vaal Barrage to Schoonspruit reach' applies to this reach as well with the addition of run-off from the incremental catchment. It is important to note that developments in the form of small dams and irrigation schemes along the tributaries contributing to this reach do reduce the run-off to the Vaal River.

The Klipplaatdrift weir (C2H061) is situated approximately 60 km downstream of the Pilgrims Estate weir (at Balkfontein). Sedibeng Water abstracts it water at the Klipplaatdrift weir. There is an operational problem at the Balkfontein abstraction point as storage at the Balkfontein weir is too low. Consequently releases from the Vaal Dam need to coincide with actual water requirements in this catchment to ensure that the weir does not overflow or that water shortages do not occur. Sedibeng Water also enjoys a conditional water use from Allemanskraal when the dam is overflowing, provided that the Reserve requirements are catered for. This water is cheaper and of a better quality than water from the Vaal River (DWAF, 2004).

Renoster (C70): The Renoster River has its origin south of Petrus Steyn in the South Eastern Free State. It includes the C70 tertiary catchment (C70A to C70K). The major town influencing the Renoster River is Petrus Steyn. The Rhenoster catchment is rural in nature and has significant controlled irrigation and rural requirements (87 % of total requirements). Heilbron and Viljoenskroon are the most significant urban centers in the area. Water is imported from the Upper Vaal WMA (Vaal Dam) to supply the needs of Heilbron. This catchment area does not contribute to the yield of the Vaal River. The potential for water resources development within the key area is mostly limited to the exploitation of groundwater.

Only one dam exists, namely Koppies Dam, which was constructed mainly for irrigation purposes and completed in 1912. The height of the dam wall was increased to 5.94m in the late 1970's. Water is released through a channel system back into the original river channel. The presence of a large number of weirs (61), road bridges and roads has resulted in a large to serious impact on the Renoster River. Koppies Dam also adds to this impact. Koppies Dam provides flow regulating capability. The yield balance situation is such that the water available from the dam is fully utilised. There is also significant water use from the river downstream of the dam to the extent that there is not excess water available. The Voorspoed Mine has recently purchased water rights from irrigators that were supplied from Koppies Dam as part of the Koppies Government Water Scheme.

Large areas of the river are inundated and this has a serious impact on the flow, bed and channel of the river. The riparian zone is also impacted on by these obstructions in the river as the wetted and dry riparian zones of the river are altered. The many abstraction pumps present also indicate that there is a large volume of water abstracted from the river although not many irrigated lands were visible.

- **Koekemoerspruit (C24B):** The Koekemoerspruit catchment is highly altered by catchment development. The river falls within the C24B quartenary catchment. The Koekemoerspruit flows through the Hartebeesfontein and Stilfontein mines and is upstream of Klerksdorp and the Midvaal Water Company. Catchment development has led to severe deterioration in water quality. Major impacts on water quality include mining pollution, urban run-off, sewage effluent and irrigation return flows. The water quality issues in the catchment have an impact on the water abstracted by MidVaal Water. Flow in the Koekemoerspruit is measured at the Buffelsfontein weir (C2H139), however the gauging station is totally unreliable for gauging due to serious submergence problems (DWAF, 2007). There have been concerns that water is disappearing from

the Koekemoerspruit however this has been difficult to prove due to rapidly changing flows in the river.

The Buffelsfontein weir is also used to monitor the water quality of the discharges from the goldmines in the area, and whether the Margaret shaft water is entering the Vaal River. However this has not yet been proven.

- **Schoonspruit (C24):** As with the Koekemoerspruit, the Schoonspruit catchment is also characterised by intensive development. The Schoonspruit catchment comprises of six quaternary catchments C24C, C24D, C24E, C24F, C24G and C24H. Quaternary C24C and parts of C24E and C24F are considered as endoreic areas, as the surface runoff generated in these areas flow to localised pans in the area and therefore do not contribute to the stream flow in the Shoonspruit and its tributaries. The Schoonspruit Eye forms the origin of the Schoonspruit in the southern part of quaternary catchment C24C. Just downstream of the Schoonspruit Eye a diversion weir was constructed to divert water into the Schoonspruit Canal. The diversion weir (C2H064) is also used as a gauging weir to measure excess water that is not diverted into the canal but spills over the weir back into the mainstream of the Schoonspruit. The Schoonspruit canal supplies water to Ventersdorp as well as to the whole Schoonspruit Irrigation Scheme. The Right Bank Canal conveys the water to the Ventersdorp Municipality off take and further along the canal at Kalk Dam, the Municipality also abstracts water for agriculture use in the town.

  At the Kalk Dam, there is a structure that can reject excess water into the Schoonspruit as well as allowing water to flow underneath the Schoonspruit by means of a siphon to a canal. This canal supplies water for irrigation up to the Rietspruit Dam as well as supplies water by means of the Elandskuil siphon to the Elandskuil Dam and canal on the Right Bank of the Schoonspruit. All the excess water flows into the Rietspruit Dam. The Elandskuil Dam supplies water for irrigation and is considered more as a balancing dam. The Rietspruit Dam captures runoff from the Rietspruit catchment and is used to supply water for irrigation by means of a canal system (DWAF, 2006).

  Significant irrigation developments started on the dolomitic aquifer recharge areas in the late nineteen eighties. Irrigation water for these new developments was obtained from the dolomitic aquifers through boreholes. To be able to protect the resource the minister proclaimed the Ventersdorp Eye subterranean Government Water Control Area (G.W.C.A) in June 1995.

  The Klerksdorp Irrigation Scheme is located downstream of the Schoonspruit Irrigation Scheme and originates on the farm Witpoort and stretches to the Vaal River. Abstraction of water takes place at five points in and around Johan Neser Dam. The irrigation scheme includes weirs, directing pumping from the dam and river, a canal system and a 400 mm pipeline from the Johan Neser Dam to supply irrigation developments.

  Informal or diffuse irrigation also takes place within the tributary sub-catchments of the Schoonspruit. Water is abstracted directly from the streams or from farm dams located in the tributary sub-catchment. Urban/Industrial return flows from Klerksdorp, Hartbeesfontein and

Orkney enter the lower Schoonspruit catchment downstream of Johan Neser Dam. Return flows from Ventersdorp is relatively small and enters the Schoonspruit downstream of Kalk Dam.

- **Vals River (C60):** The Vals River which includes the C60 tertiary drainage region of the Vaal River catchment has its origin in the vicinity of Bethlehem from where it flows past Lindley in the north-westerly direction to Kroonstad and on to Bothaville from where it flows into the Vaal River. Various tributaries enter the Vals River of which the Elandspruit is the largest. While the Vals River catchment is rural in nature, it has significant urban requirements (73 % of total water requirements). The urban requirements are dominated by the requirement of Kroonstad Municipality. Water is imported from the Vaal River by Sedibeng Water to supply the needs of the Bothaville local municipality. Treated sewage and storm water returns from Kroonstad in particular contribute significantly (33 % of total resource) to the water resources of the Vals key area. All irrigation in the Vals catchment is regarded as diffuse and is not significant. The catchment does not contribute to the yield of the Vaal River. This river system does not have storage regulation capability with release capabilities, with the result that high flow control and management is not possible.

  Serfontein Dam is the only large Dam in the cachment on the Vals River and it is located near Kroonstad. It has a small storage relative to the runoff. The Serfontein Dam has a capacity of 4.200million m^3 and a surface area of 1.58 km^2. Seasonal water releases are made from the dam. The yield balance situation is such that there are deficits in supply as was recently experienced in restrictions to the town of Kroonstad.

  Water quality deterioration as a result of Kroonstad, Lindley and Bothaville Sewage Works runoff as well as runoff from irrigated and drylands has a serious to critical impact on the Vals River. Prolific growth of algae in the lower reach of the river has been observed.

  The overall modification to bed, channel and flow in the Vals River is moderate to large due to the presence of several weirs, roads through the river and roadbridges over the river, as well as Serfontein Dam. Some sand mining occurs in the river and these lead to bank erosion and siltation of the river.

- **Sandspruit (C25B):** The Sandspruit is located in quartenary catchment C25B of the Vaal River System. It is an ephimeral river that flows only during certain times during the year. There are no structures, weirs or dams.

- **Makwassie (C25D):** As with the Sandspruit the Makwassie is also an ephimeral river, with no flow regulation in the catchment.

- **Vet River (C40):** The Vet River catchment includes the secondary drainage (C4) of the Vaal River catchment. The Sand River is a major tributary of the Vet River. The river system includes two major dams, Erfenis on the Vet River and Allemanskraal Dam on the Sand River. The available water resources in this river system are fully utilised. Allemanskraal Dam (located in

quaternary C42E) on the Sand River and Erfenis Dam (located in quaternary C41E) on the Vet River have flow release regulating capabilities.

The water resources of this catchment area are augmented by transfers from Vaal River by Sedibeng Water for urban and bulk use in the Free State Goldfields and by the upstream yields of Erfenis and Allemanskraal catchment areas. The mining and urban water requirements of the Free State Goldfields dominate the water requirements of this catchment. The main urban centres are Welkom and Virginia and the main mines are Harmony, President Steyn, African Rainbow Minerals and Bambanani Gold Mines. Returns flows from these users contribute about 10 % to the water resources of the catchment.

Irrigation water requirements for controlled irrigation are significant in the Vet River catchment and are the most important in the Middle WMA as a whole. Approximately 122 km^2 is scheduled for irrigation in three areas, namely Sand-Vet GWS (Sand), Sand-Vet GWS (Vet) and Vet River GWS. Actual irrigation requirements are significant therefore Vet River catchment does not contribute to the yield of the Lower Vaal WMA.

The Allemanskraal Dam and Erfenis Dam catchments are rural in nature. In the Allemanskraal catchment area consumptive requirements by urban and rural users make up the rest of the requirements, with irrigation water requirements not being significant. Senekal is the most important urban centre in the area. The upper reaches of this catchment do contribute to the downstream yield of the Sand River.

There is an export of water from Erfenis Dam to Brandfort local municipality in the Upper Orange WMA. Irrigation water requirements are also not significant in the Erfenis Dam catchment. Winburg and Marquard are the most important urban centres in the catchment area.

- **Bloemhof Dam (C25, C43):** Bloemhof Dam was built in 1970 and helped to relieve Vaal Dam of part of the downstream water demands. Bloemhof Dam is the most downstream regulating storage in the subsystem with the function of supplying the water requirements in the Low Vaal Subsystem as their primary resource. The releases from the dam are made in accordance with a daily schedule of water requirements that are updated on a weekly basis. Since the water requirements supplied from Bloemhof Dam is more than the supply capability (incremental yield) of the dam, releases are made from Vaal Dam (via Vaal Barrage) once the water level in Bloemhof Dam reaches it's minimum operating level.

  Various sub-catchments contribute to the flow into Bloemhof Dam with each having various dams and water abstractions all impacting on the supply capability of the dam. There are no release obligations from these sub-catchments with the result that only spills from these dams and unused runoff flows into Bloemhof Dam.

  The requirements of this catchment area are dominated by non-consumptive requirements. Consumptive requirements by urban and rural users are small in comparison, approximately, 3% . Wolmaransstad and Wesselsbron are the most important urban centres in the catchment area.

There is no significant irrigation in this area. The potential for water resources development in this area is controlled by requirements in the Upper Vaal WMA and the upstream Middle Vaal River catchment area and by the scheduled irrigation requirements of the downstream Lower Vaal WMA.

2.2.5 Water Quality sub-units

Water quality sub-units (WQSUs) define areas of homogenous water quality. The land use defines the anthropogenic influences on water quality and provides a good indicator of which water quality variables would change over time. A water quality sub-unit is a length of river for which a single description of water quality can be given. This may be determined by ecoregions, dams, tributaries, towns, point sources of pollution etc. 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, sewage treatment works etc. All these factors therefore can cause changes in water quality and define WQSUs.

Water quality sub-units may not coincide with the Resource Units for flow, but where possible they should be integrated. This will be the start of the integration process between quantity and quality, and may be important later when integrated Resource Quality Objectives need to be set. The water quality delineation of the study area, Middle Vaal WMA (WMA 9) was undertaken to identify these changes. Table 3 indicates a preliminary water quality delineation using the current water quality information and data available.

Table 3: Water Quality sub-units of the Middle Vaal WMA

Water Quality Subunit Number	Quartenary Catchment(s)	Major River/Dam unit	Reason: Water Quality Issues
38	C70A, C70B, C70D, C70E, C70F, C70G, C70H, C70J, C70K	Rhenoster/Renoster spruit	Salinity and nutrients are relatively low - however, visual appearance of river is not good. Water appears milky turbid and there is algal growth on rocks. Agricultural impact is high (Koppies irrigation scheme).
39	C70C	Koppies Dam	Salinity and nutrients are relatively low. Water appears milky turbid and there is algal growth on rocks. Agricultural impact is high (Koppies irrigation scheme).
40	C24A	Koekemoerspruit/ Kromdaaispruit (before confluence); and Koekemoerspruit (downstream confluence)	Extremely high salinity (high sulphate) and very high nutrient concentrations. Spruit shows severe signs of eutrophication.
41	C24B	Vaal River (downstream Mooi River to upstream Schoonspruit)/ Vierfontein; and Vaal River (downstream Koekemoerspruit to upstream Schoonspruit)	High TDS and high DOC, increasing. High phosphates and inorganic nitrogen. High potential for algal growth. Microbiological contamination is a problem due to sewage pollution. Vierfonteinspruit - strong algal growth/high salt levels (limited data)
42	C24C, C24D, C24E	Upper reaches Schoonspruit/ Rietspruit (Rietspruit dam)	Agricultural runoff (nutrients and sediments). Dam - channel supplies water to farmers

Water Quality Subunit Number	Quartenary Catchment(s)	Major River/Dam unit	Reason: Water Quality Issues
43	C24F	Taaibosspruit (and Monamaladi)	Agricultural impact. Ventersdorp eye - extraction. Area includes piggeries which have an impact.
44	C24G	Johan Neser Dam	
45	C24G	Buisfonteinspruit	Agriculture
46	C24H	Schoonspruit (below dam upstream Jagspruit confluence)	Poor water quality. Extremely high salinity and very high nitrogen and phosphate concentrations.
47	C24H	Jagspruit	Impacts from Gold and uranium mining. Increasing impact - slimes dams. Downstream agricultural uses impact on river.
48	C24J	Vaal River where - Regina to Klipplaatdrift?	High Salinity, high nutrients and increasing. High potential for algal growth
49	C60A, C60B, C60C,C60D	Vals River (Upper reaches)	Downstream Kroonstad impacts from sewage works (Kroonstad, Lindley and Bothaville). Agricultural activities in lower reaches of catchment also have negative impacts.
50	C60E, C60F	Elandspruit Tributary	
51	C60D	Serfontein Dam	
52	C60G, C60H, C60J	Vals River	Nutrient concentrations are high and increasing. High levels of salinity also recorded.
53	C25A, C25B,C25C,C25D , C25E, C25F	Vaal River to Bloemhof Dam	High salinity and nutrients - upstream impacts (from Barrage downstream). Area also has a large amount of diamond digging (150 licences from DME). Agricultural activities also impact on river.
54	C42A, C42B, C42C, C242D	Sand River (upper reaches)	No real issues at present. Agriculture and cattle farming a key activities in catchment.
55	C41A, C41B, C41C, C41D	Vet River (upper reaches)	Agricultural impact on river. (two biomonitoring sites in catchment - on Vet and Klein Vet).
56	C41E	Erfenis Dam	Extraction from dam for irrigation
57	C42E	Allemanskraal Dam	Extraction from dam - canal - Sand Vet irrigation scheme.
58	C42F, C42G,C42H, C42J, C42K, C42L	Sand River (below Allemanskraal dam before confluence)	Large gold mines present in catchment. Also has a fair amount of agricultural activities in area. Impact negatively on Sand River. (WQOs at Bloudrif on Sand). High nutrients with filamentous algal and macrophyte growth.
59	C41F, C41G, C41H, C41J	Vet River (below Erfenis dam before confluence)	Impact from irrigation. High return flows to Vet river.
60	C43A, C43B, C43C, C43D	Vet River (downstream confluence with Sand)	Fairly high salinity. Impact from Hoopstad sewage treatment plant and agricultural activities. Fairly high phosphates.
61	C25F, C43D	Bloemhof Dam	TDS inversely correlated with dam levels. Algal blooms/water hyacinth. Relatively low phosphates ascribed to biogenic uptake.

3 DELINEATION OF RESOURCE UNITS: RESULTS

3.1 VAAL RIVER

3.1.1 Natural Resource Unit and Management Resource Unit: Vaal River inflow from Upper Vaal WMA to upstream Schoonspruit confluence:

Based on the biophysical characteristics of the Vaal River a natural resource unit (NRU), NRU 1 is delineated from the inflow of the Vaal River at Vermaasdrift to just upstream the Schoonspruit river confluence (

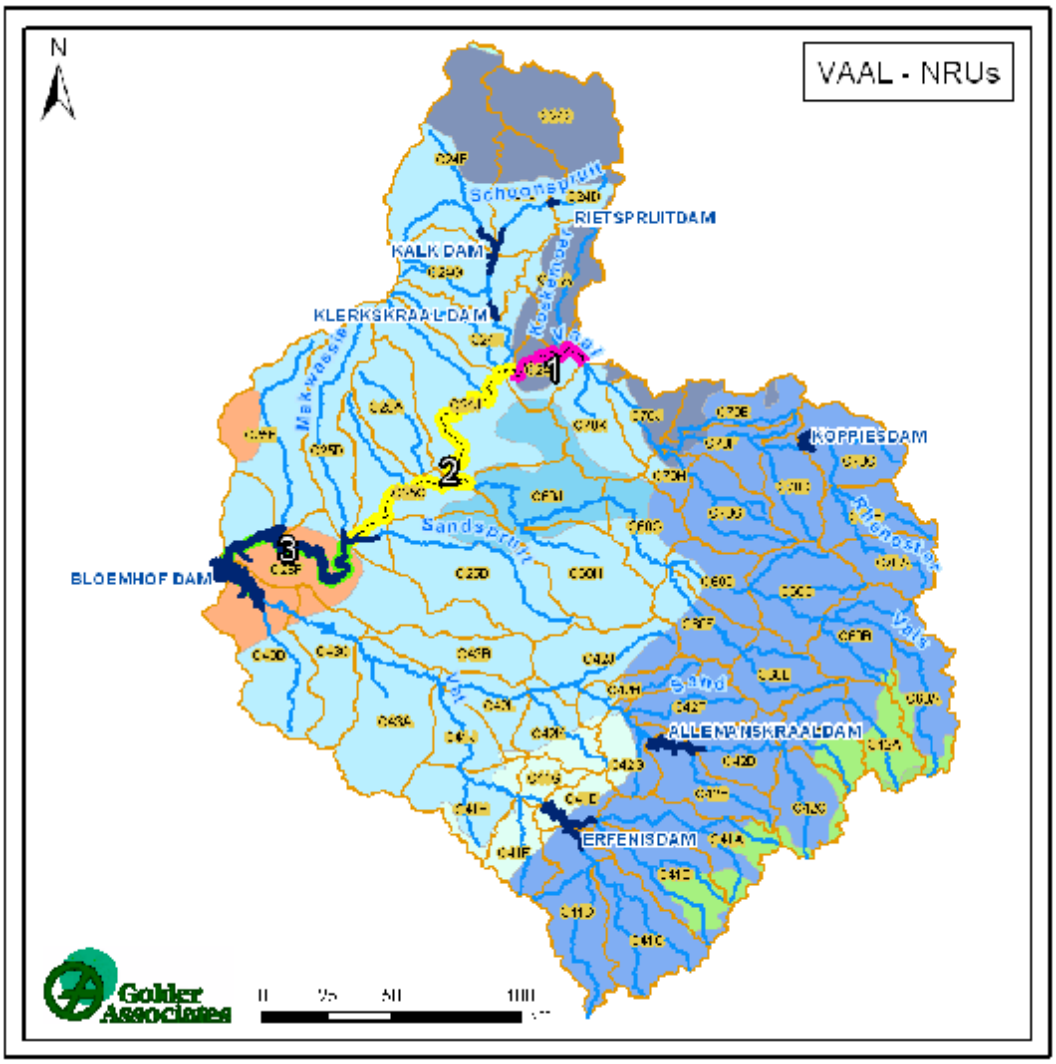


Figure 4). The EcoRegions are depicted in the figure below and described in Table 4.

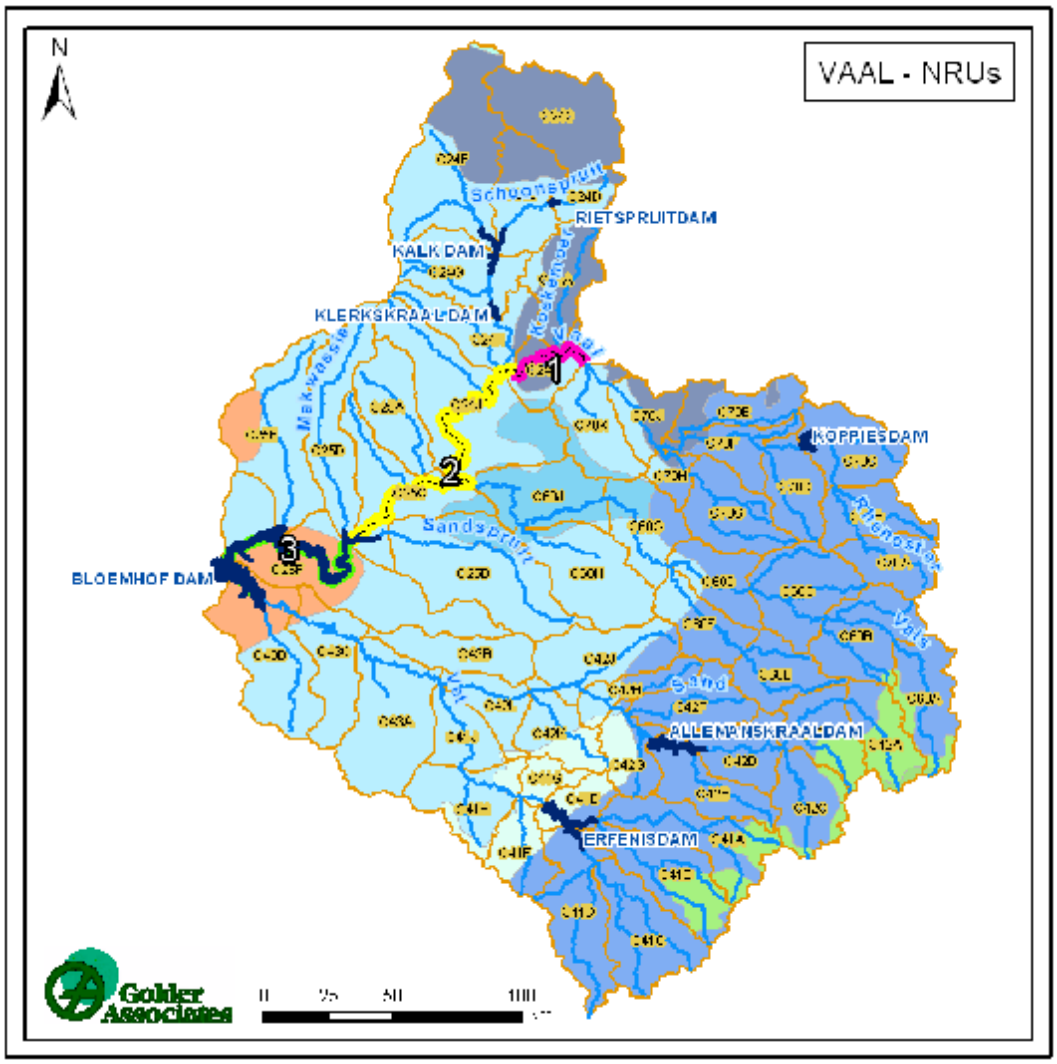


Figure 4: Vaal River from inflow at Vermaasdrift to upstream the confluence with the Schoonspruit: Natural Resource Unit 1

Table 4: Description and rationale for the Vaal River Natural Resource Unit 1 (inflow of the Vaal River at Vermaasdrift to just upstream the Schoonspruit river confluence)

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU 1	11.01	Lower Foothills (100%)	The Eco-region and geomorphology are the major considerations in defining the NRU.	EcoRegion 11.01 26.92190; -26.96830

The NRU, based on the system characteristics, management and operation is also delineated into the management resource units (MRUs), MRU F. The MRU F is shown in (Figure 5) and the rationale for

its selection is defined in

Table 5.

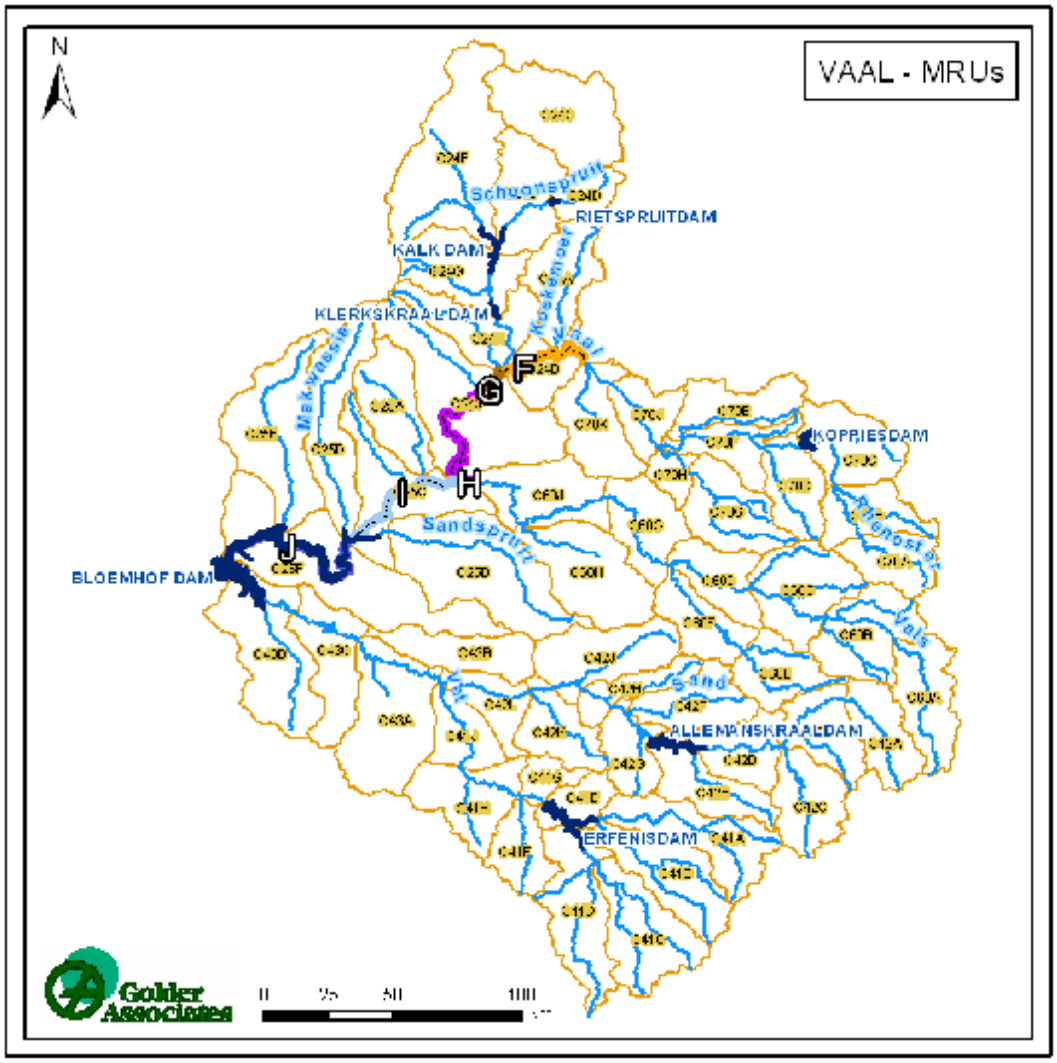


Figure 5: Vaal River MRU Vaal F (from inflow of the Vaal River at Vermaasdrift to just upstream the Schoonspruit river confluence)

Table 5: Description and rationale of the Vaal River MRU Vaal F (from inflow of the Vaal River at Vermaasdrift to just upstream the Schoonspruit river confluence)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment

MRU Vaal F	11.01	Lower Foothills (100%)	Mostly natural grass land (dominant) and thicket /bushveld. Some cultivated land and urban area.	The MRU coincides with the NRU and is a logical break in the system. The area includes similar land use along the length of the river. It also delineated by a weir at Pilgrims Estate. The unit does warrant a selection of a comprehensive EWR site as it just downstream Upper Vaal WMA downstream of the Mooi River confluence) so it is important to understand the influence of the Upper Vaal WMA; and importance was rated as 3.	26.92190; -26.96830	C24B

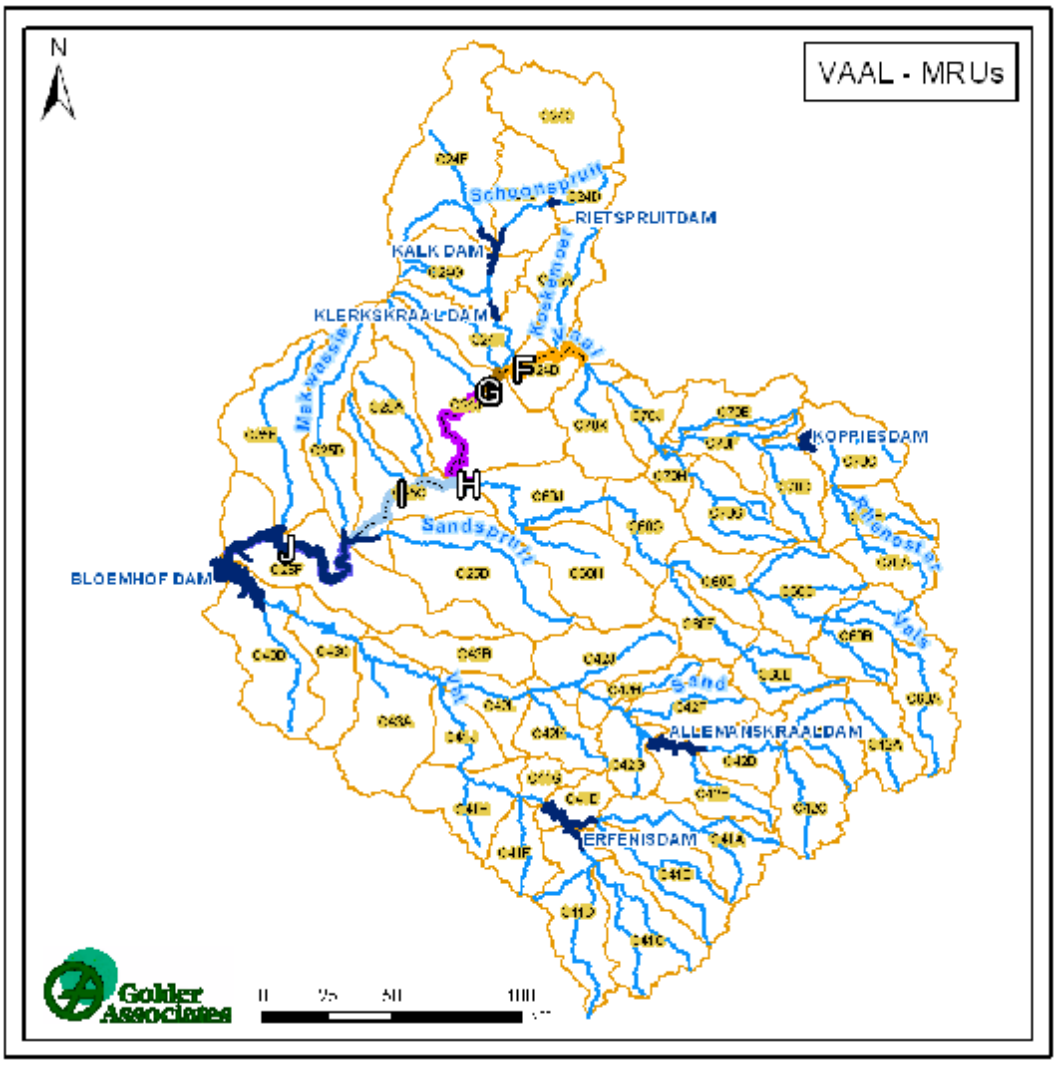
3.1.2 Natural Resource Unit and Management Resource Units: Vaal River from Schoonspruit confluence to Bloemhof Dam

Based on the biophysical characteristics of the Vaal River a natural resource unit (NRU), NRU 2 is delineated from the confluence of the Schoonspruit to Bloemhof Dam (**Figure 6**). The EcoRegions of the NRU are depicted in the figure below and described in Table 6.

Table 6: Description and rationale of the Vaal River Natural Resource Unit 2 (from the Schoonspruit confluence to Bloemhof Dam)

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU 2	11.08	Lower Foothills (100%)	The Eco-Region and geomorphology are the major considerations in defining the NRU.	EcoRegion 11.08 26.67392; -26.99561

The NRU 2, based on the system characteristics, management and operation is also delineated into the management resource units (MRUs), MRU Vaal G, MRU Vaal H and MRU Vaal I. The MRUs are



(

Figure 7) and the rationale for their selection is defined in

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Table 7.

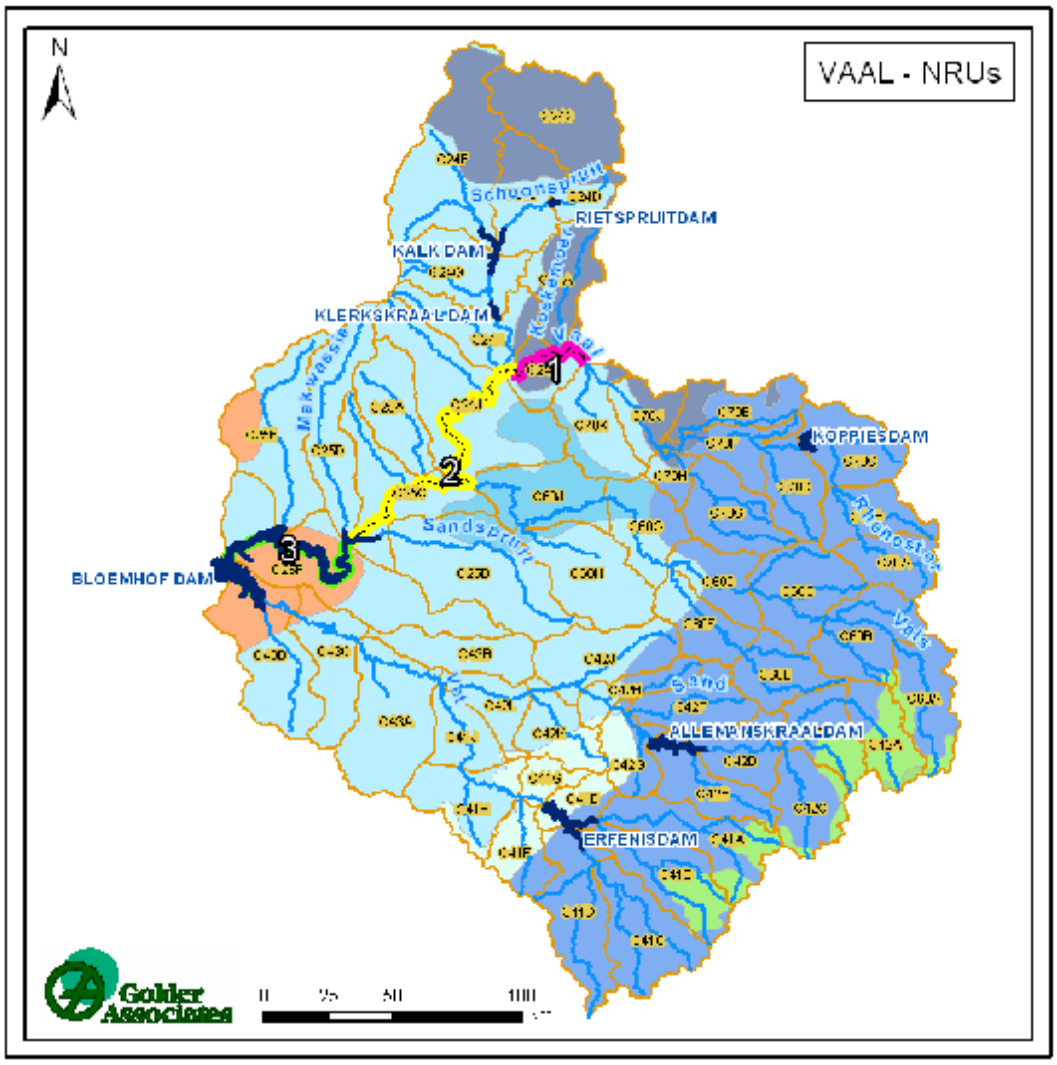


Figure 6: Vaal River from the Schoonspruit confluence to Bloemhof Dam: Natural Resource Unit 2

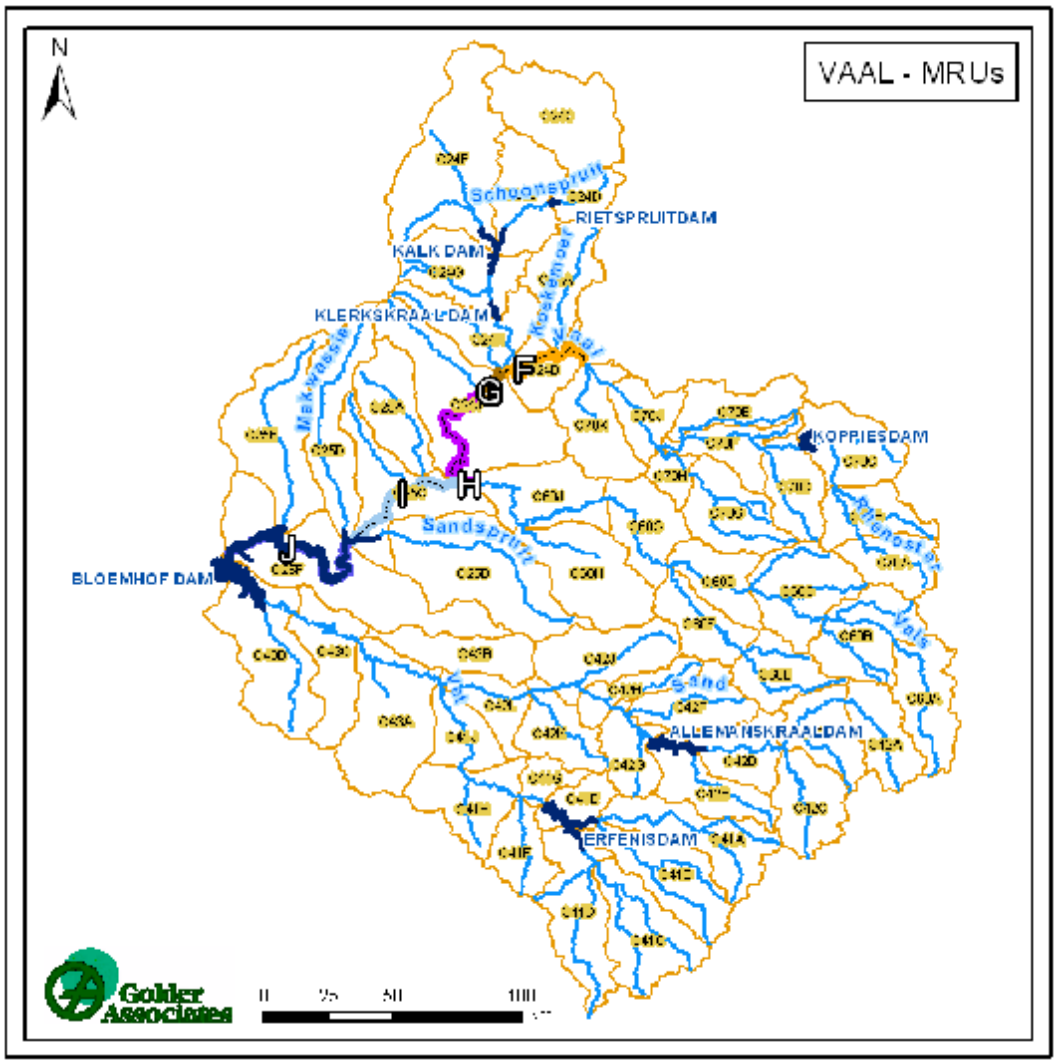


Figure 7: Vaal River MRU Vaal G (from Schoonspruit confluence to Regina Bridge), MRU Vaal H (from Regina Bridge to Klipplaatfrift) and MRU Vaal I (from Kliplaatdrift to Bloemhof Dam)

Table 7: Description and rationale of the Vaal River MRU Vaal G (from Schoonspruit confluence to Regina Bridge), MRU Vaal H (from Regina Bridge to Klipplaatfrift) and MRU Vaal I (from Kliplaatdrift to Bloemhof Dam)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Vaal G	11.08	Lower Foothills	Mostly natural grassland (dominant) with some thicket/ bushveld. Limited cultivated land (commercial/ dryland crops).	The MRU is delineated from downstream the Schoonspruit confluence to Regina Bridge (a weir). The river consists of one geomorphic zone with similar land cover. Importance of this reach was rated as a 3, and it is downstream of the Schoonspruit catchment a major influence in the system. The weir captures major water quality impacts from the upper and middle Vaal catchments - an EWR site should be selected. The weir also forms a management delineation break in the system.	26.62428; -26.99857	C24J
MRU Vaal H	11.08	Lower Foothills	Mostly natural grassland (dominant) and some thicket/ bushveld. Limited cultivated land (commercial/ dryland crops).	The MRU is delineated from downstream Regina Bridge (a weir) to Klipplaatdrift weir (Balkfontein). The river consists of one geomorphic zone with similar land cover. The weir also forms a management delineation break in the system. Abstractions occur at this weir. No major influences occur in this reach to warrant a selection of an EWR site.	26.54528; -27.08968	C24J
MRU Vaal I	11.08	Lower Foothills	Mostly natural grassland (dominant) and some thicket/ bushveld. Limited cultivated land (commercial/ dryland crops).	The MRU is delineated from downstream from the Klipplaatdrift weir at Balkfontein to Bloemhof Dam. The river consists of one geomorphic zone with similar land cover. Bloemhof Dam forms the lower delineation area of the reach. While the importance of this reach was rated as a 3, the lower level of the reach is inundated with Bloemhof Dam water which is not conducive for a suitable EWR site.	26.51577; -27.38779	C24J, C25C

3.1.3 Natural Resource Unit and Management Resource Unit: Vaal River at Bloemhof Dam (end of Middle Vaal WMA)

Based on the biophysical characteristics of the Vaal River a natural resource unit (NRU), NRU 3 is delineated on the Vaal River at Bloemhof Dam (Figure 8). The EcoRegion of the NRU is depicted in the figure below and described in Table 8.

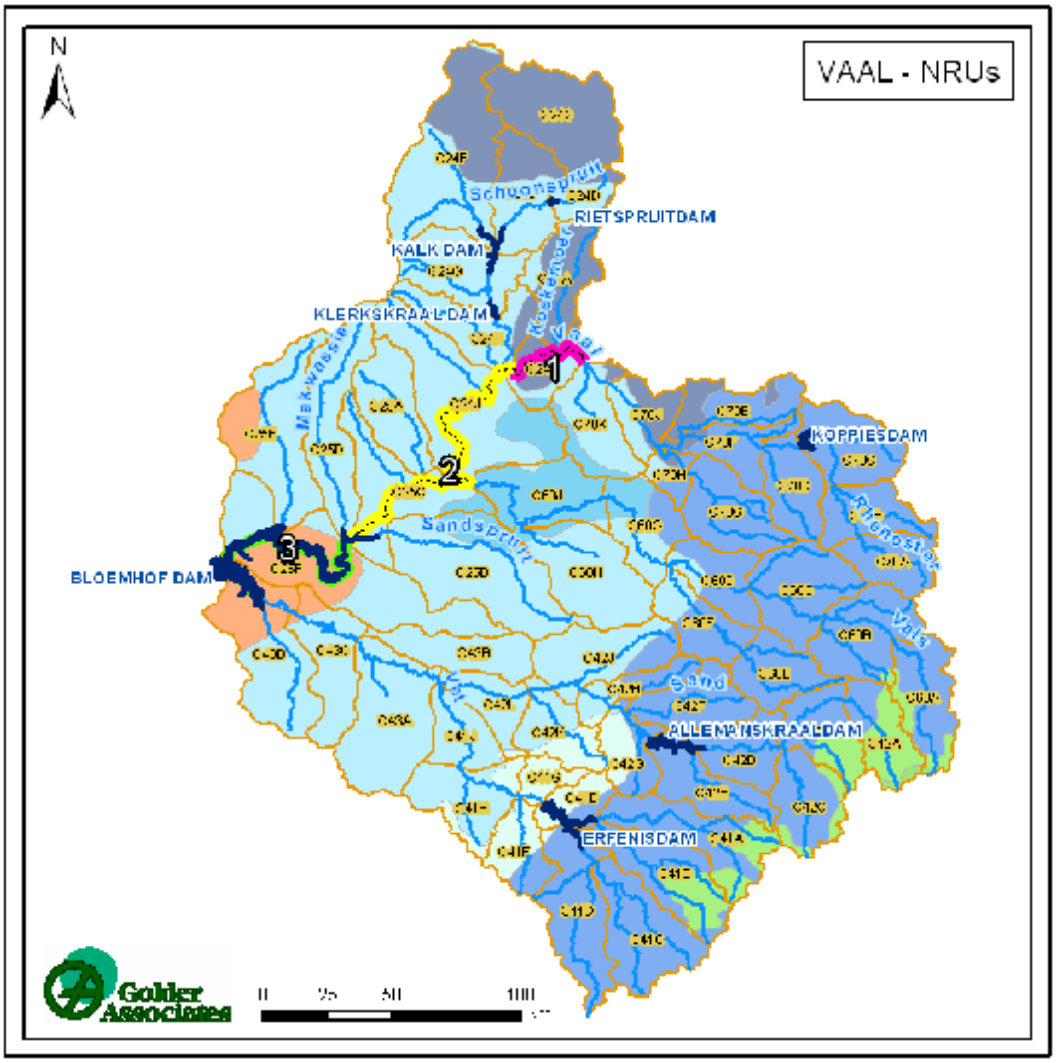


Figure 8: Vaal River at Bloemhof Dam: Natural Resource Unit 3

Table 8: Description and rationale for the Vaal River Natural Resource Unit 3 (Vaal River at Bloemhof Dam)

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU 3	29.02	Lower Foothills (100%)	The EcoRegion was the major consideration that defines the NRU.	26.09795; -27.59426

The NRU, based on the system characteristics, management and operation is also delineated as the MRU Vaal J, Bloemhof Dam. The MRU is shown in (Figure 9) and the rationale for its selection is defined in

Table 9.

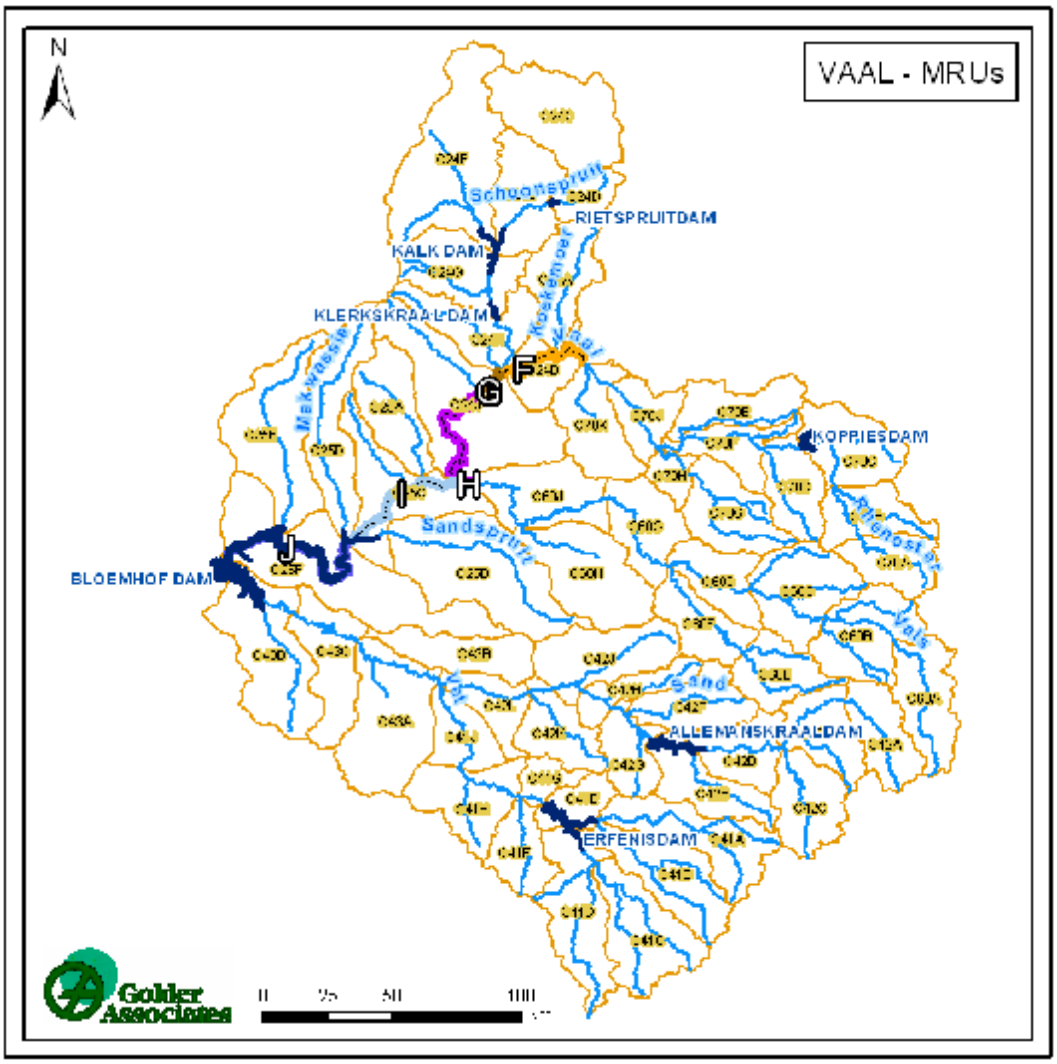


Figure 9: Vaal River MRU Vaal J (Bloemhof Dam)

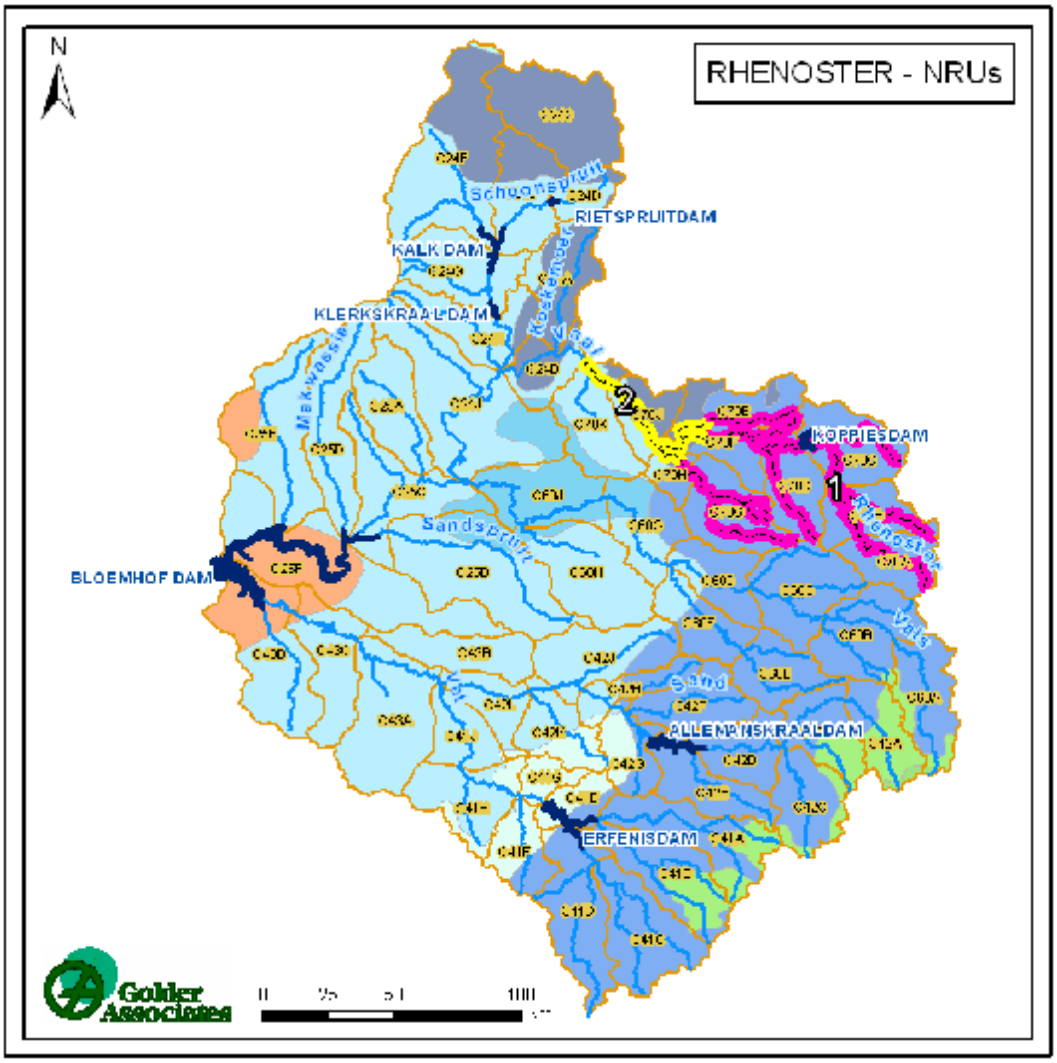
Table 9: Description and rationale of the Vaal River MRU Vaal J (Bloemhof Dam)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Vaal J	29.02	Lower Foothills (100%)	Dominated by waterbodies. Some cultivated crops occur in area.	The Vaal river is logically delineated at the end of the WMA by Bloemhof Dam. This reach includes one Ecoregion and geomorphic zone. The MRU comprises the Dam, and is inundated with water. The Dam serves as a critical point in the system from an operation point of view in the Vaal River System. Water is released to supply downstream irrigation and urban users. As this MRU comprises the Dam only, and has an importance rating of 2, the selection a EWR site is not recommended, as the site characteristics required will not be found.	26.09795; -27.59426	C25E, C25F, C43D, C91A

3.2 TRIBUTARIES OF THE VAAL RIVER

3.2.1 Rhenoster River: Natural Resource Units and Management Resource Units

Based on the biophysical characteristics of the Rhenoster River catchment two natural resource units NRU 1 and NRU 2 can be delineated (



Figure

Figure 10: Rhenoster River: Natural Resource Units

Table 10: Description and rationale for the Rhenoster River Natural Resource Units

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Rhenoster 1	11.03	Lower Foothills (100%)	The EcoRegion was the major consideration that defines the NRU.	28.10240; -27.75137
NRU Rhenoster 2	11.01; 11.08	Lower Foothills (100%)	The EcoRegion was the major consideration that defines the NRU.	27.34479; -26.96830

The NRUs, based on the system characteristics, management and operation is also delineated into the management resource units (MRUs), MRU Rhenoster A (From river origin to Koppies Dam), MRU Rhenoster B (Koppies Dam) and MRU Rhenoster C (From downstream Koppies Dam to confluence with Vaal River). The MRUs are shown in (

Figure 11) and the rationale for their selection is defined in Table 11.

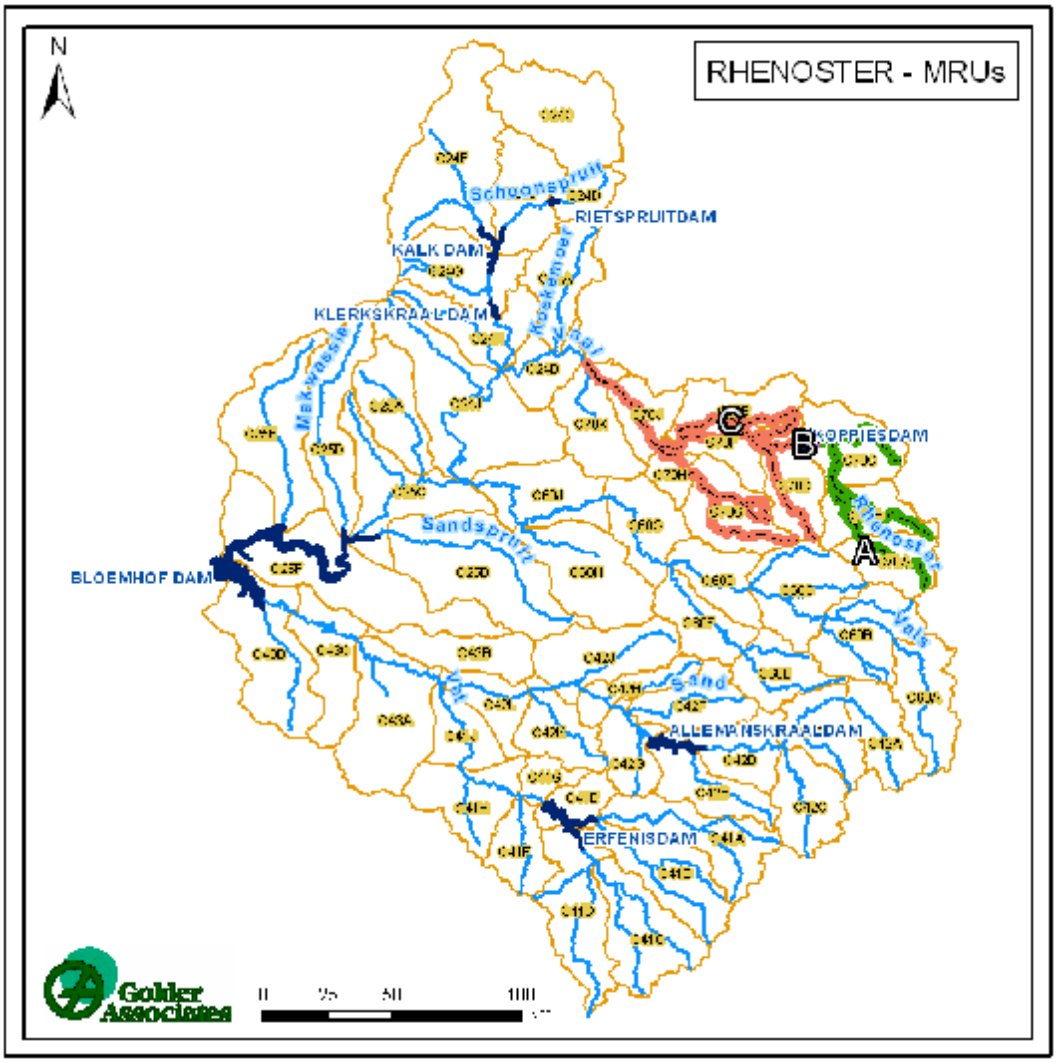


Figure 11: Rhenoster River Management Resource Units: MRU Rhenoster A (From river origin to Koppies Dam), MRU Rhenoster B (Koppies Dam) and MRU Rhenoster C (From downstream Koppies Dam to confluence with Vaal River).

Table 11: Description and rationale of the Rhenoster River Management Resource Units: MRU Rhenoster A (From river origin to Koppies Dam) and MRU Rhenoster B (From downstream Koppies Dam to confluence with Vaal River)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Rhenoster A	11.03	Lower Foothills (100%)	Mostly natural grass land (dominant). Some cultivated land.	The MRU coincides with a logical break in the system – Koppies Dam. Land use is also similar (irrigated agriculture). The reach has a low priority rating thus does not warrant the selection of an EWR site.	28.10240; -27.75137	C70A, C70B, C70C
MRU Rhenoster B	11.03	Lower Foothills (100%)	Mostly natural grass land (dominant). Some cultivated land.	The MRU includes Koppies Dam. The dam is delineated as a unit. The dam supports the irrigation scheme and includes weirs and canals. The dam provides flow regulating capability. The yield balance situation is such that the water available from the dam is fully utilised. There is also significant water use from the river downstream of the dam to the extent that there is not excess water available. The Land use is irrigated agriculture. The reach has a moderate priority rating.	27.71901; -27.25773	C70C
MRU Rhenoster C	11.01; 11.03; 11.08	Lower Foothills (100%)	Mostly natural grass land (dominant). Some cultivated land.	This reach of the Rhenoster is delineated as one MRU. No significant changes occur along these lower reaches below the Dam. The river has one geomorphic zone (Lower foothills), however the lower reaches (C70J and C70K) do display some difference in Eco-region level.	27.65737; -27.26714	C70D, C70E, C70F, C70G, C70H, C70J, C70K

3.2.2 Koekemoerspruit: Natural Resource Units and Management Resource Units

Based on the biophysical characteristics of the Koekemoerspruit catchment one natural resource unit (NRU), NRU 1 can be delineated (

Figure 12). The EcoRegion and geomorphic zone of the NRU are described in Table 12.

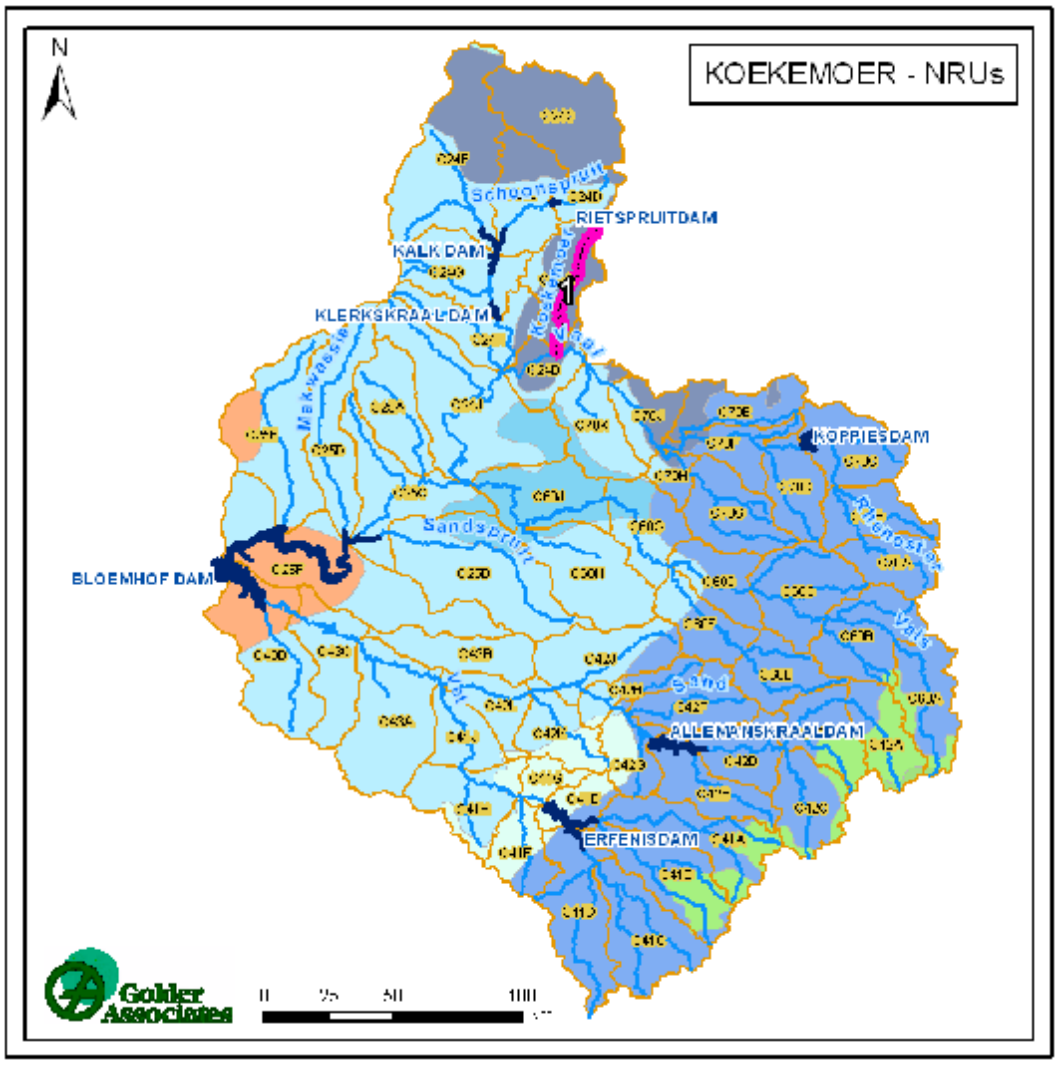


Figure 12: Koekemoerspruit: Natural Resource Unit

Table 12: Description and rationale for the Koekemoerspruit Natural Resource Unit

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation

NRU 1	11.01	Lower Foothills (100%)	The EcoRegion was the major consideration that defines the NRU.	26.94852; -26.47986

The NRU, based on the system characteristics, management and operation is delineated as a single management resource unit (MRU), MRU Koekemoerspruit A (From river origin to Vaal River confluence). The MRU is shown in (

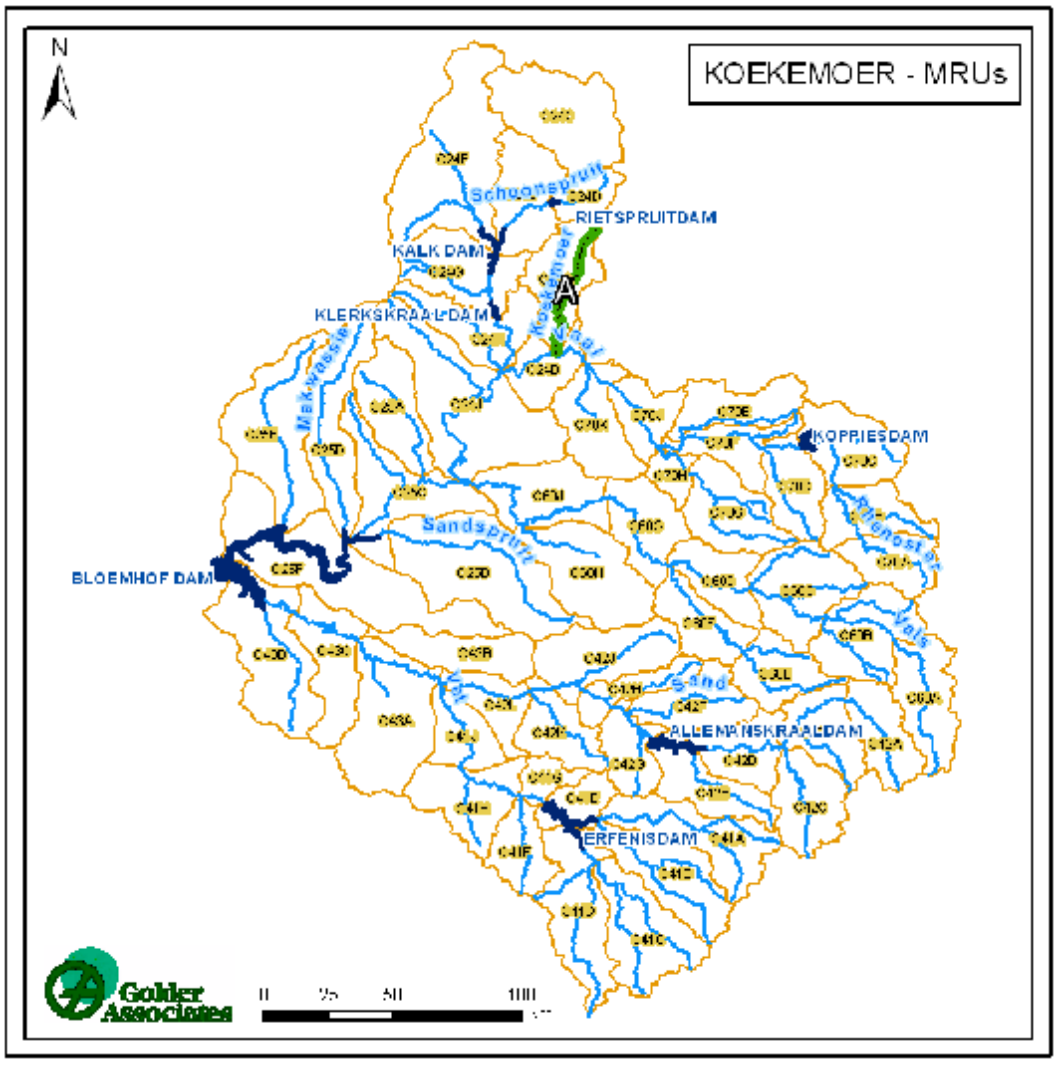


Figure 13) and the rationale for its delineation is defined in Table 13.

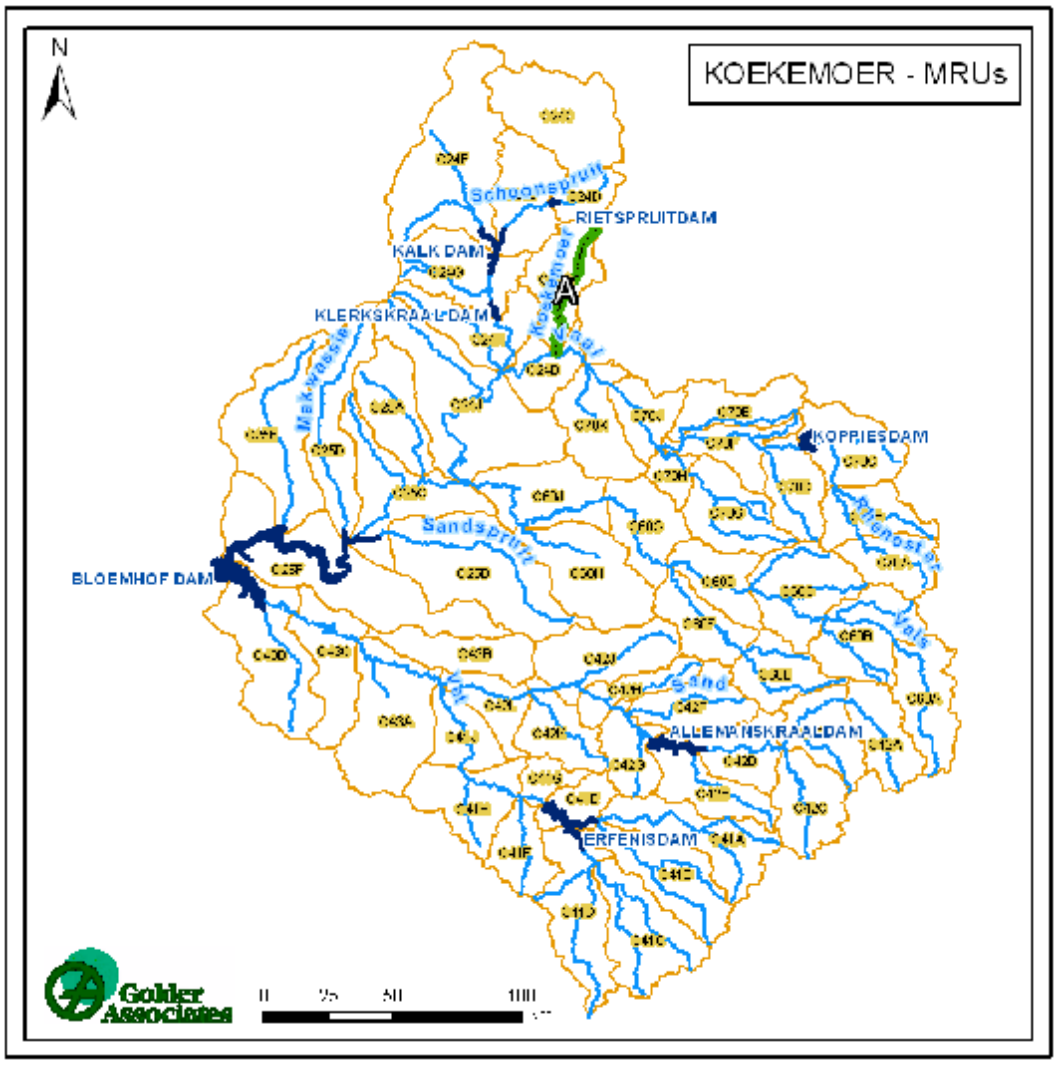


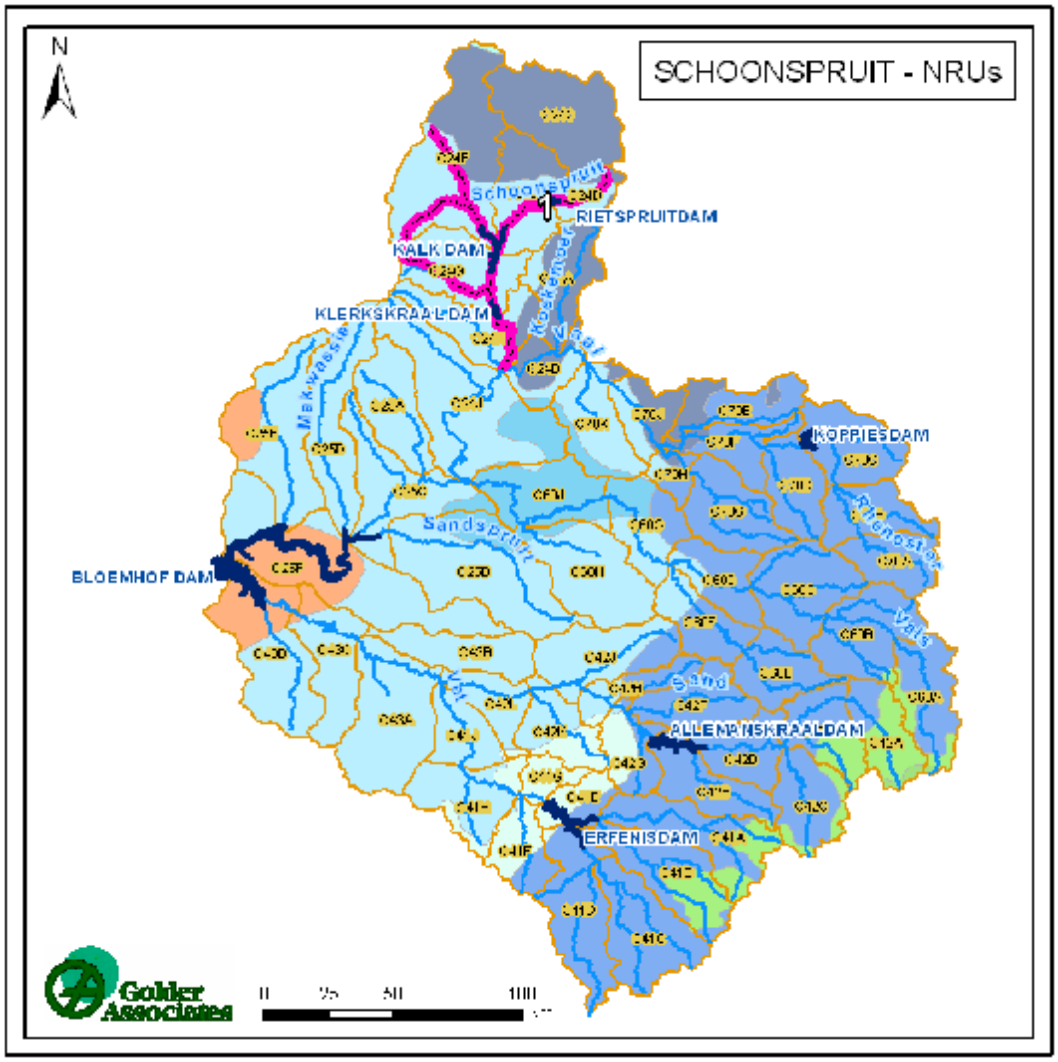
Figure 13: Koekemoerspruit: Management Resource Unit A (From river origin to confluence with the Vaal River)

Table 13: Description and rationale of the MRU Koekemoerspruit A (From river origin to confluence with the Vaal River)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Koekemoer-spruit A	11.01	Lower Foothills (100%)	Mostly natural grass land.	The Koekemoerspruit catchment – origin of river to confluence of the Vaal River is delineated as a MRU. There are no characteristic features, significant changes or physical structures in the system to define more than one MRU. Land use is also similar (mining). The reach has a low priority rating thus does not warrant the selection of an EWR site.	26.94852; -26.93682	C24A

3.2.3 Schoonspruit: Natural Resource Units and Management Resource Units

Based on the biophysical characteristics of the Koekemoerspruit catchment one natural resource unit (NRU), NRU 1 can be delineated (



Figur

Figure 14: Schoonspruit: Natural Resource Unit

Table 14: Description and rationale for the Schoonspruit Natural Resource Unit

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU 1	11.08 (100%)	Lower Foothills (100%)	The EcoRegion was the major consideration that defines the NRU.	26.97664; -26.99230

The NRU, based on the system characteristics, management and operation is delineated into the management resource units (MRUs), MRU Schoonspruit A (From eye of river to Kalk Dam), MRU Schoonspruit B (From Kalk Dam to Klerkskraal Dam), MRU Schoonspruit C (Klerkskraal Dam) and MRU Schoonspruit D (from Klerkskraal Dam to confluence with the Vaal River). The MRUs are shown in (

Figure 15) and the rationale for their delineation is defined in Table 15.

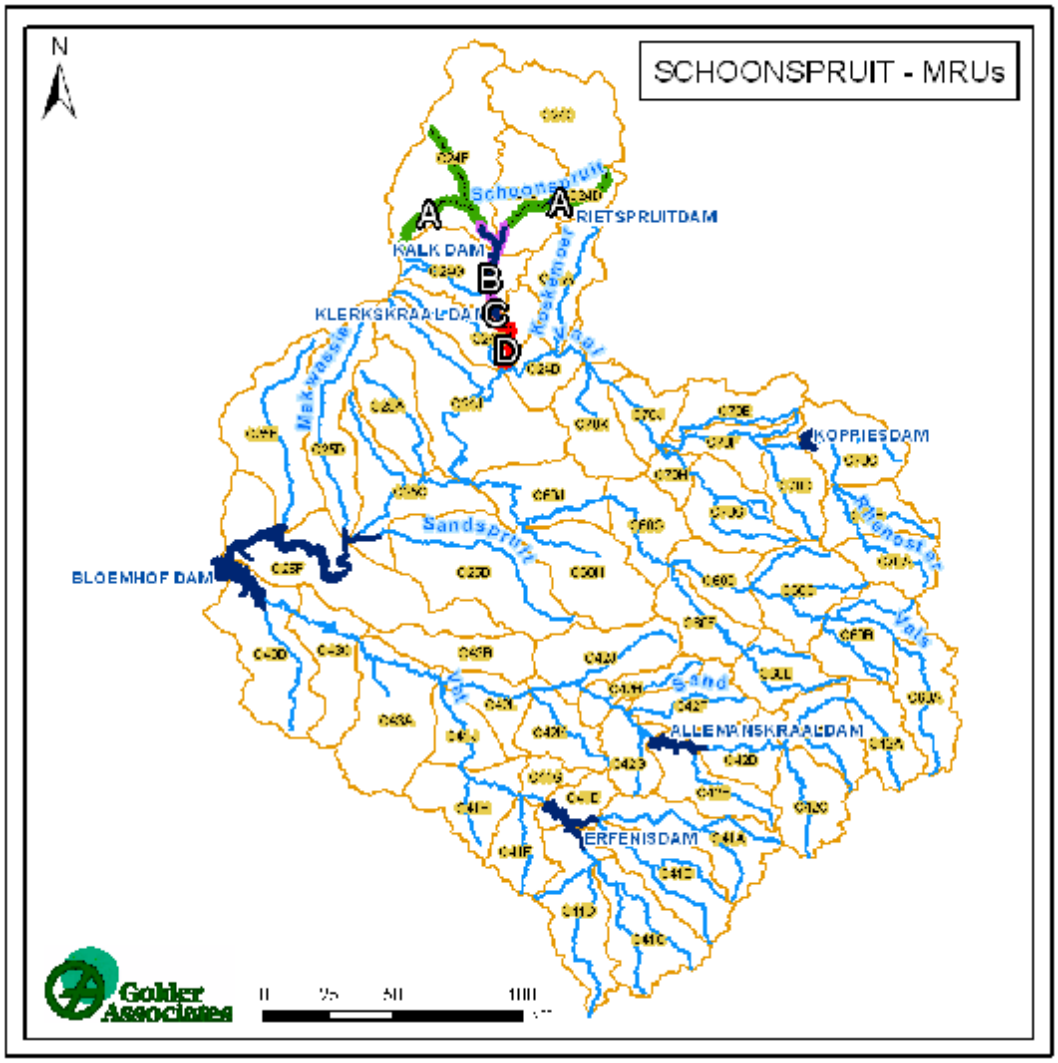


Figure 15: Schoonspruit Management Resource Units: MRU Schoonspruit A (From eye of river to Kalk Dam), MRU Schoonspruit B (From Kalk Dam to Klerkskraal Dam), MRU Schoonspruit C (Klerkskraal Dam) and MRU Schoonspruit D (from Klerkskraal Dam to confluence with the Vaal River)

Table 15: Description and rationale of the Schoonspruit Management Resource Units: MRU Schoonspruit A (From eye of river to Kalk Dam), MRU Schoonspruit B (From Kalk Dam to Klerkskraal Dam), MRU Schoonspruit C (Klerkskraal Dam) and MRU Schoonspruit D (from Klerkskraal Dam to confluence with the Vaal River

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Schoonspruit A	11.08	Lower Foothills (100%)	Mostly natural grass land (dominant).	The upper reaches of the Schoonspruit is highly modified with the Dam and canal systems. The MRU coincides with a logical break in the system – Kalk Dam. Land use is also similar (irrigated agriculture). Ventersdorp abstracts water for the town's supply and for irrigation. The Schoonspruit eye has a high importance rating and high EIS, and does warrant the selection of an EWR site. However due to the lack of any opportunity for changes in operation, no EWR site is to be selected.	26.97664; -26.49190	C24C, C24E
MRU Schoonspruit B	11.08	Lower Foothills (100%)	Mostly natural grass land (dominant). Some cultivated land.	This MRU is delineated by two Dams, Kalk Dam (upstream) and Klerksdorp Dam (downstream). The land use is predominantly irrigated agriculture. The reach has a low importance rating.	26.58940; -26.75375	C24D, C24E, C24F, C24G
MRU Schoonspruit C	11.08	Lower Foothills (100%)	Mostly natural grass land (dominant). Some cultivated land.	The MRU includes Klerkskraal Dam. The dam is delineated as a unit. The dam supports the Klerksdorp irrigation scheme and includes weirs, canals, direct pumping and a pipeline. Land use is irrigated agriculture. The reach has a moderate priority rating.	26.61115; -26.83934	C24G

MRU Schoonspruit D	11.08	Lower Foothills (100%)	Mostly natural grass land (dominant). Includes urban/built area.	This lower reach of the Schoonspruit, below the dam is delineated as one MRU. The only significant change that occurs along these lower reaches below the Dam is an increase in urban/built up areas. There is an increase in return flows from these areas into the Schoonspruit. This reach did score a high priority rating in terms of management of the system.	26.62428; -26.99857	C24H

3.2.4 Vals River: Resource Units and Management Resource Units

Based on the biophysical characteristics of the Vals River three natural resource units (NRUs), NRU 1, NRU 2 and NRU 3 can be delineated (**Figure 16**). The EcoRegion and geomorphic zones of the NRUs are described in Table 16.

Figure 16: Vals River: Natural Resource Units

Table 16: Description and rationale for the Vals River Natural Resource Units

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Vals 1	11.03; 11.08	Lower Foothills (100%)	The Eco-Regions is the major consideration and defines the NRU	28.11389; -28.40755
NRU Vals 2	11.08	Lower Foothills (100%)	The Eco-Region is the major consideration and defines the NRU	27.34461; -27.74517
NRU Vals 3	11.07	Lower Foothills (100%)	The Eco-Region is the major consideration and defines the NRU	27.09220; -27.50729

The NRUs, based on the system characteristics, management and operation is delineated into the management resource units (MRUs), MRU Vals A (From origin of river to Kroonvaal weir) and MRU Vals B (From Kroonvaal weir to confluence with the Vaal River). The MRUs are shown in (

Figure 17) and the rationale for their delineation is defined in

Table 17.

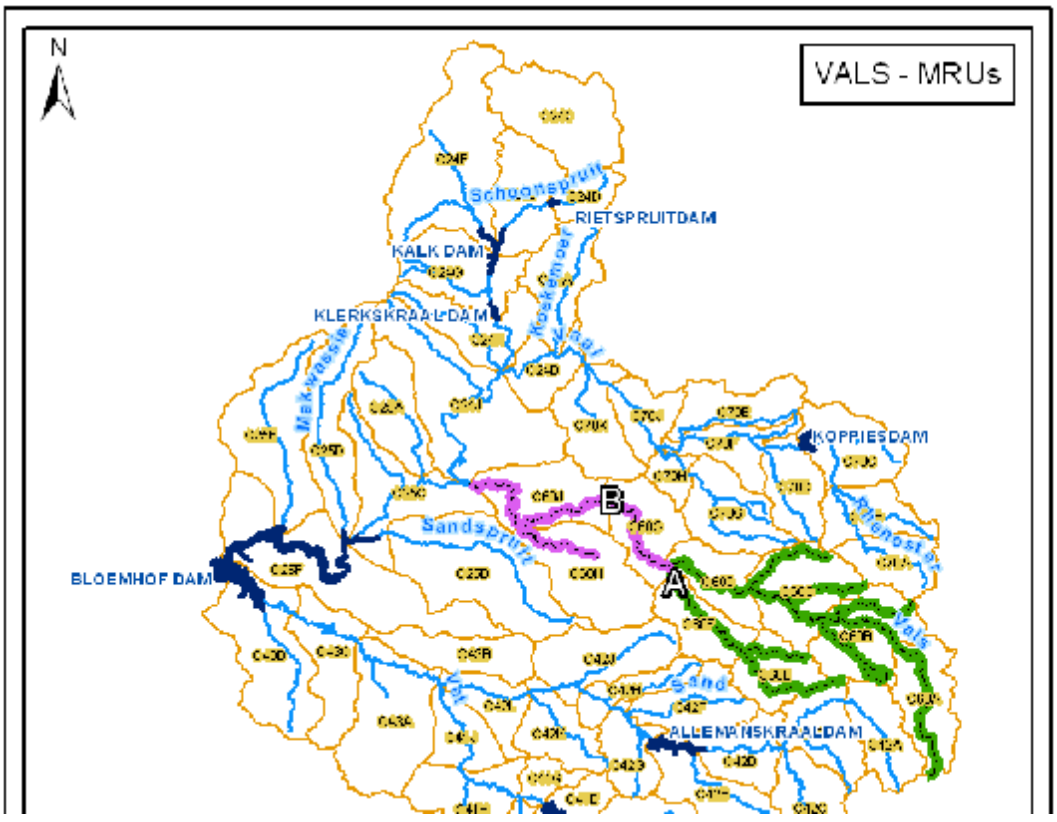


Figure 17: Vals River Management Resource Units: MRU Vals A (From the origin of the river to the Kroonvaal weir) and MRU Vals B (From the Kroonvaal weir to the confluence with the Vaal River)

Table 17: Description and rationale of the Vals River Management Resource Units MRU Vals A (From the origin of the river to the Kroonvaal weir) and MRU Vals B (From the Kroonvaal weir to the confluence with the Vaal River)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Vals A	11.03; 11.08	Lower Foothills (100%)	Mostly natural grass land (dominant) with some cultivated land in the upper reaches.	The MRU includes the origin of the river to the Kroonval weir. The weir forms a break in the system and creates a delineation between the upper and lower reaches of the Vals river system. This MRU is largely rural in nature. The area is dominated by one Eco-Region, however this changes at in the vicinity of Kroonstad. The area does not warrant the selection of an EWR site. The importance rating was low.	28.11389; -28.40755	C60A, C60B, C60C, C60D, C60E, C60F

MRU Vals B	11.08; 11.07	Lower Foothills (100%)	Dominated by natural grass land.	This MRU includes the Vals river downstream of the weir to the confluence with the Vaal River. Water quality is impacted by Kroonstad and Bothaville, and from agricultural run-off. Ecoregion level does change from the upper reaches. Catchment did receive a priority rating of 3 requiring the integrity of the river to be maintained upstream of the confluence with the Vaal River. MRU should be considered for the selection of an EWR site.	27.21207; -27.67403	C60G, C60H, C60J

3.2.5 Vet River: Natural Resource Units and Management Units

Based on the biophysical characteristics of the Vet River four natural resource units (NRU), NRU 1, NRU2, NRU 3 and NRU 4 can be delineated (

Figure 18). The EcoRegion and geomorphic zones of the NRUs are described in Table 18.

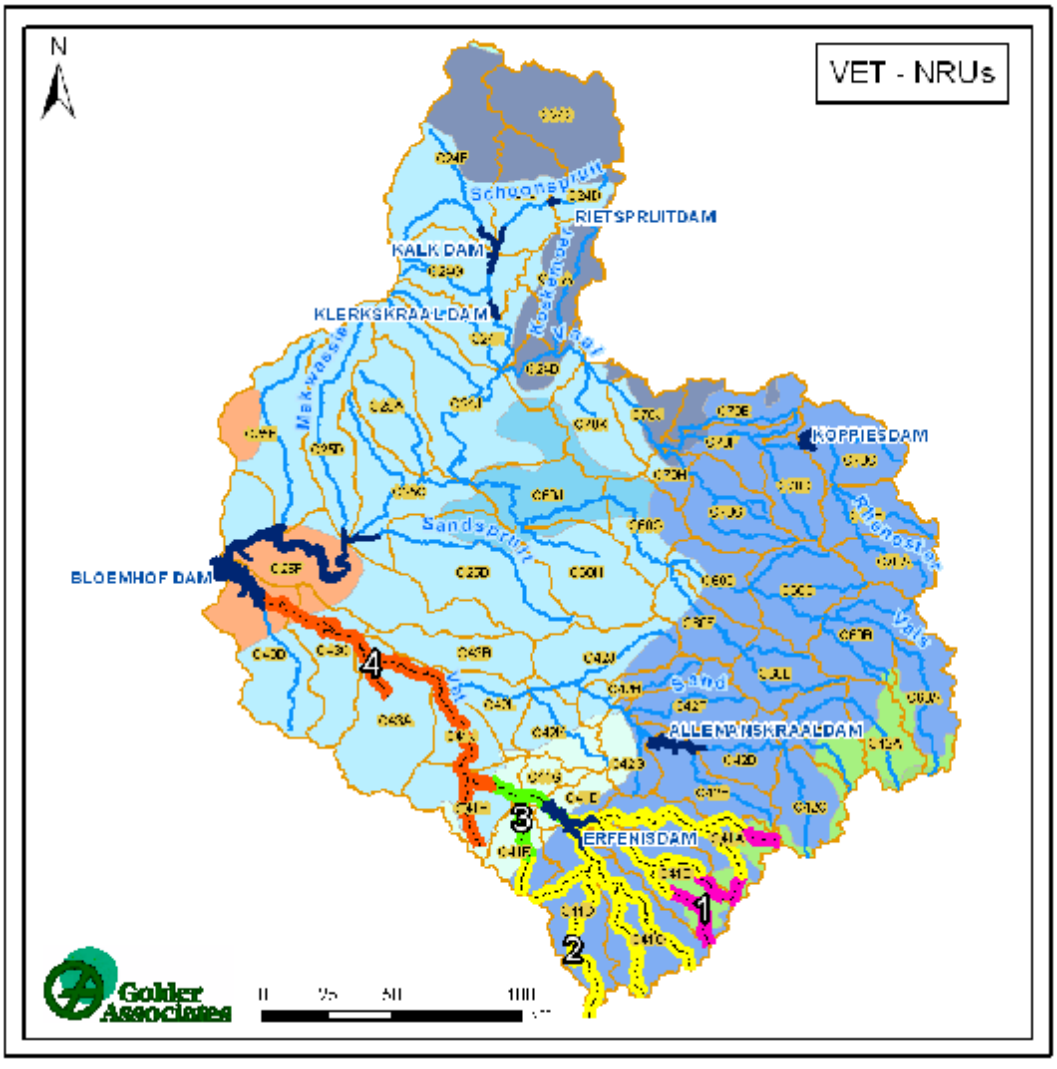


Figure 18: Vet River: Natural Resource Units

Table 18: Description and rationale for the Vet River Natural Resource Units

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Vet 1	15.01	Lower Foothills (100%)	The Eco-Regions is the major consideration and defines the NRU	27.28665; -29.08817
NRU Vet 2	11.03	Lower Foothills (100%)	The Eco-Region is the major consideration and defines the NRU	26.85819; -28.57652
NRU Vet 3	11.1	Lower Foothills (100%)	The Eco-Region is the major consideration and defines the NRU	26.59919; -28.43705
NRU Vet 4	11.08	Lower Foothills (100%)	The Eco-Region is the major consideration and defines the NRU	25.77087; -27.79060

The NRUs, based on the system characteristics, management and operation is delineated into the management resource units (MRUs), MRU Vet A (From origin of river to Erfenis Dam), MRU Vet B (Erfenis Dam), MRU Vet C (Erfenis Dam to confluence with the Sand River), MRU Sand A (Origin of Sand River to Allemanskraal Dam), MRU Sand B (Allemanskraal Dam), MRU Sand C (Allemanskraal Dam to confluence with the Vet River) and MRU Vet D (From confluence with the Sand River to Bloemhof Dam). The MRUs are shown in (Figure 19) and the rationale for their delineation is defined in Table 19.

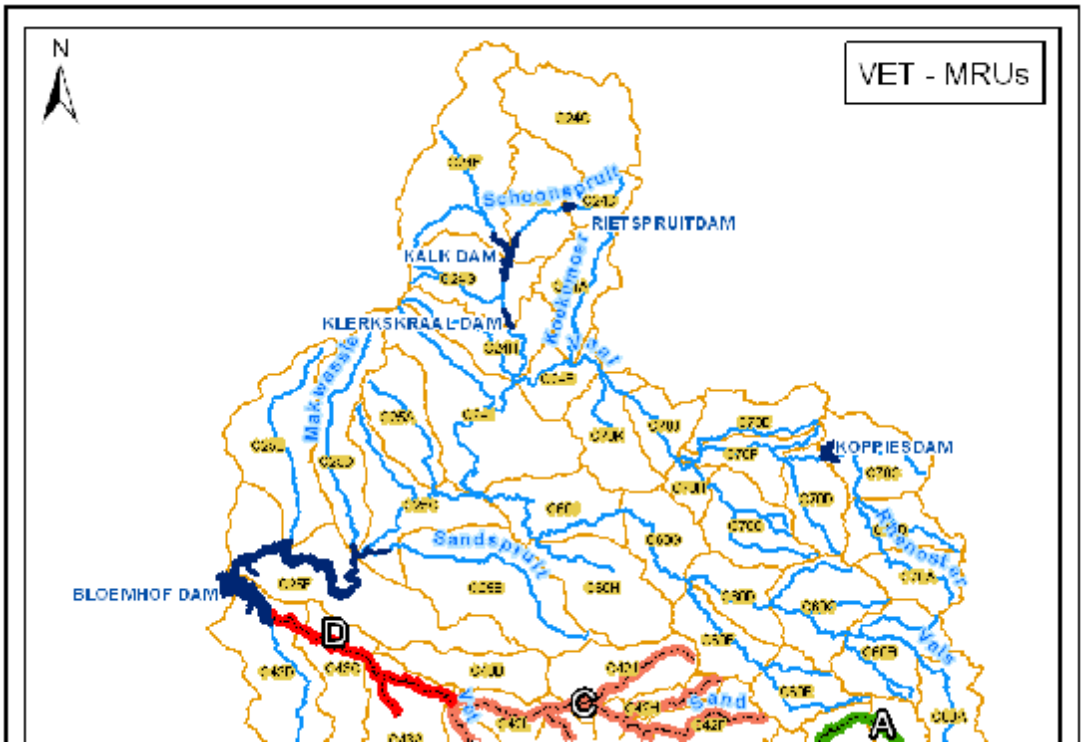


Figure 19: Vet River Management Resource Units: MRU Vet A (From origin of river to Erfenis Dam), MRU Vet B (Erfenis Dam), MRU Vet C (Erfenis Dam to confluence with the Sand River), MRU Sand A (Origin of Sand River to Allemanskraal Dam), MRU Sand B (Allemanskraal Dam), MRU Sand C (Allemanskraal Dam to confluence with the Vet River) and MRU Vet D (From confluence with the Sand River to Bloemhof Dam).

Table 19: Description and rationale of the Vet River Management Resource Units: MRU Vet A (From origin of river to Erfenis Dam), MRU Vet B (Erfenis Dam), MRU Vet C (Erfenis Dam to confluence with the Sand River), MRU Sand A (Origin of Sand River to Allemanskraal Dam), MRU Sand B (Allemanskraal Dam), MRU Sand C (Allemanskraal Dam to confluence with the Vet River) and MRU Vet D (From confluence with the Sand River to Bloemhof Dam).

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Vet A	15.01; 11.03	Lower Foothills (100%)	Dominated by natural grasslands with some cultivated land.	MRU extends from origin of the river to the Erfenis Dam. The Dam forms the lower delineation boundary of the unit. Region is rural in nature and includes irrigated agriculture as major land use. Region has a low priority rating.	27.28665; -29.08817	C41A, C41B, C41C
MRU Vet B	11.03; 11.1	Lower Foothills (100%)	Waterbodies – dominated by natural grassland as riparian vegetation	Erfenis Dam is delineated as a resource unit. Dam supports irrigation and some urban and bulk water users. Forms part of the Sand Vet GWS.	26.91030; -28.67032	C41E

MRU Vet C	11.1; 11.08	Lower Foothills (100%)	Catchment is dominated by thicket (bushland) and natural grassland.	From Erfenis dam to confluence with the Sand River (downstream of Erfenis Dam). No significant changes in land use however does include two Eco-regions. Reach was rated as a moderate priority rating.	26.77686; -28.50622	C41G, C41H, C41J
MRU Sand A	15.01; 11.03	Lower Foothills (100%)	Mostly natural grassland with some cultivated lands. Does include some urban area.	Origin of Sand River to Allemanskraal Dam. Includes three Eco-regions in upper reaches. Does include some irrigation. Region has a low priority rating	28.00949; -28.46850	C42A, C42B, C42C, C42D
MRU Sand B	11.03	Lower Foothills (100%)	Waterbodies – dominated by natural grassland as riparian vegetation	Allemanskraal Dam is delineated as a resource unit. Dam supports irrigation and some urban and bulk water users further downstream. Forms part of the Sand Vet GWS.	27.28061; -28.31007	C42E
MRU Sand C	11.03 ; 11.1; 11.08	Lower Foothills (100%)	Mostly thicket (bushveld) and natural grassland, with some cultivated land and urban areas in the lower reaches.	Resource unit is delineated from downstream Allemanskraal Dam to Vet River confluence. Area is impacted by return flows from the urban centres, bulk water users and irrigation. Catchment area has a low to moderate priority rating.	27.14751; -28.28667	C42F, C42G, C42H, C42J, C42K, C42L
MRU Vet D	11.08; 29.02	Lower Foothills (100%)	Mostly thicket (bushveld) and natural grassland. Includes some cultivated lands.	RU includes Vet River from confluence with Sand River to inflow into Bloemhof Dam. Catchment area is dominated by irrigated agriculture. Area has a moderate priority rating (2) assessment requires the integrity of the river to be maintained upstream of the confluence with the Vaal River. MRU should be considered for the selection of an EWR site.	26.41953; -28.09121	C43A, C43C, C43D

3.2.6 Makwassie River: Natural Resource Units and Management Resource Units

Based on the biophysical characteristics of the Makwassie catchment one natural resource unit (NRU), NRU 1 can be delineated (

Figure 20). The EcoRegion and geomorphic zone of the NRU are described in Table 20.

Table 20: Description and rationale for the Maklwassie River Natural Resource Unit

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU	11.08	Lower Foothills (100%)	The EcoRegion was the major consideration that defines the NRU.	26.14247; -27.59426

The NRU, based on the system characteristics, management and operation is delineated as a single management resource unit (MRU), MRU Makwassie A (From river origin to Vaal River confluence). The MRU is shown in (

Figure 22) and the rationale for its delineation is defined in Table 21.

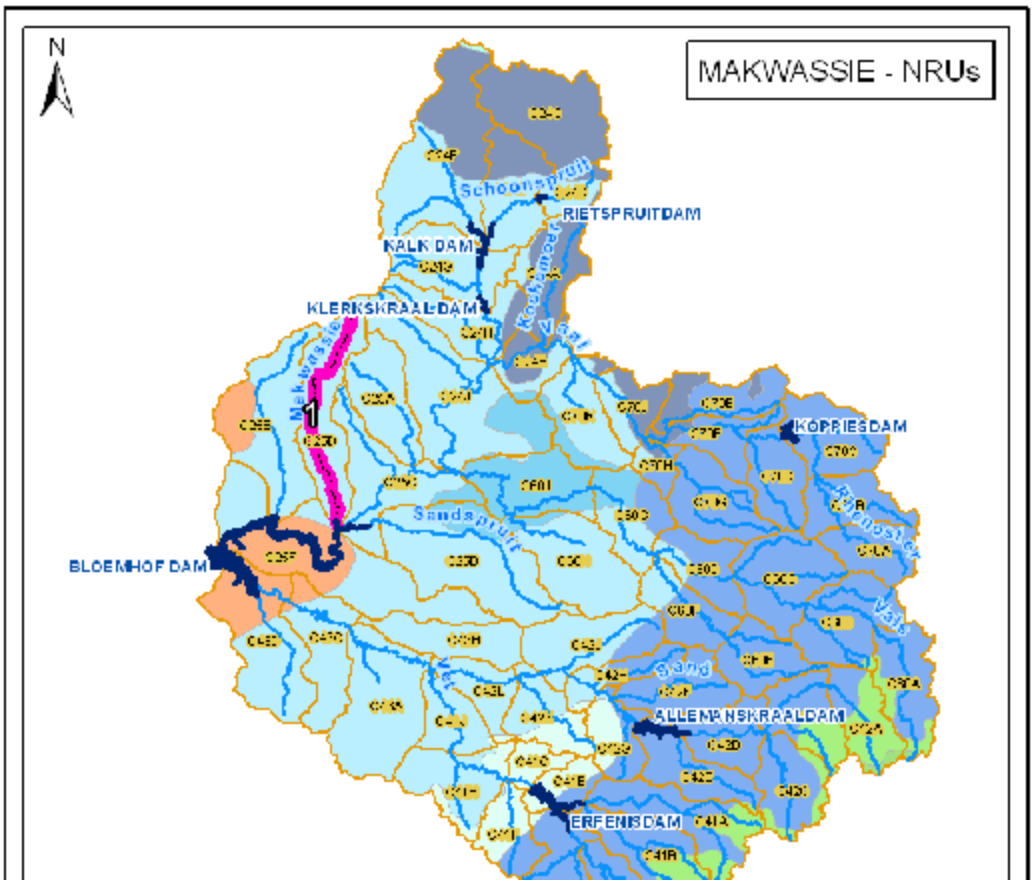


Figure 20: Makwassie River: Natural Resource Unit

Figure 21: Makwassie River: Natural Resource Unit

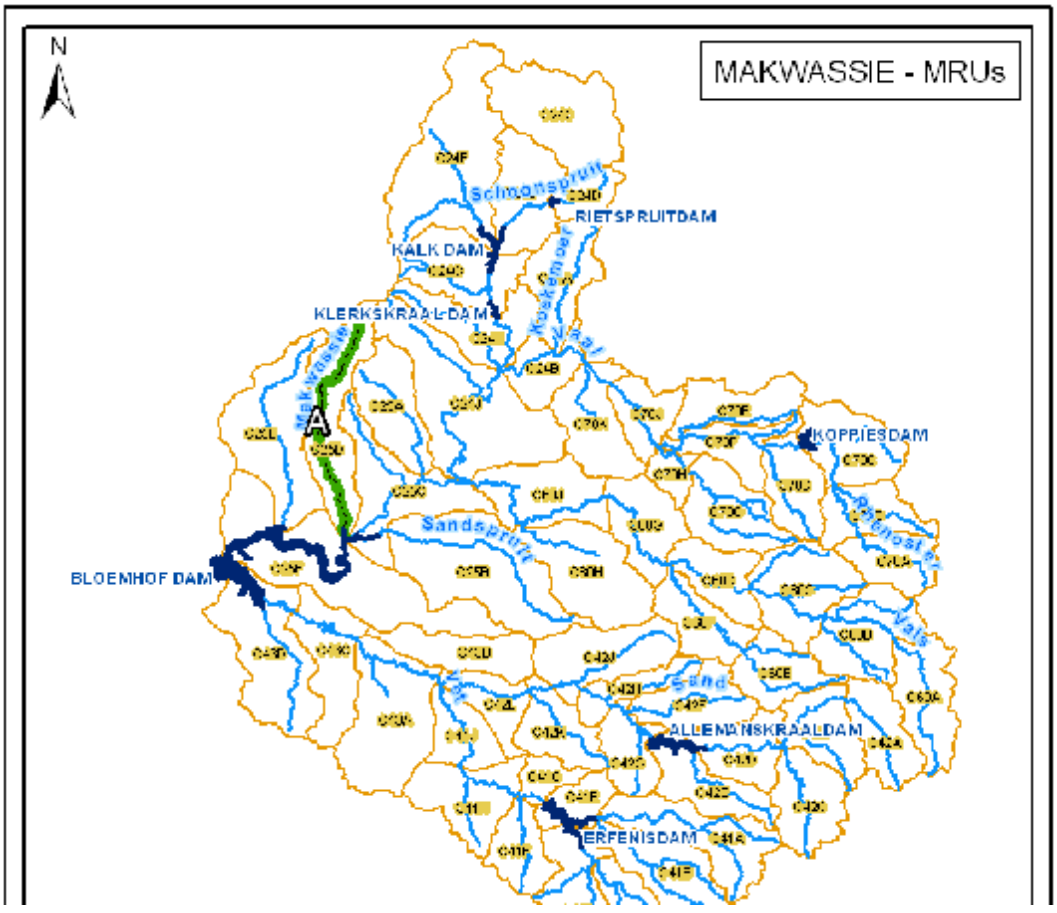


Figure 22: Makwassie River Management Resource Unit: MRU Makwassie A (From origin of River to confluence with the Vaal River)

Table 21: Description and rationale of the Makwassie River Management Resource Unit: MRU Makwassie A (From origin of River to confluence with the Vaal River)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Makwassie A	11.08	Lower Foothills (100%)	Thicket/ Bushveld	The Makwassie catchment – origin of river to confluence of the Vaal River is delineated as a MRU. There are no characteristic features or significant changes to define more than one MRU. Land use is also similar with limited activity. MRU includes Makwassie Dam and the town of Wolmeransstad. While the river is under stress it has a low priority rating thus does not warrant the selection of an EWR site.	26.14247; -27.59426	C25D

3.2.7 Sandspruit: Natural Resource Units and Management Resource Units

Based on the biophysical characteristics of the Sandspruit catchment one natural resource unit (NRU), NRU 1 can be delineated (Figure 23). The EcoRegion and geomorphic zone of the NRU are described in Table 22.

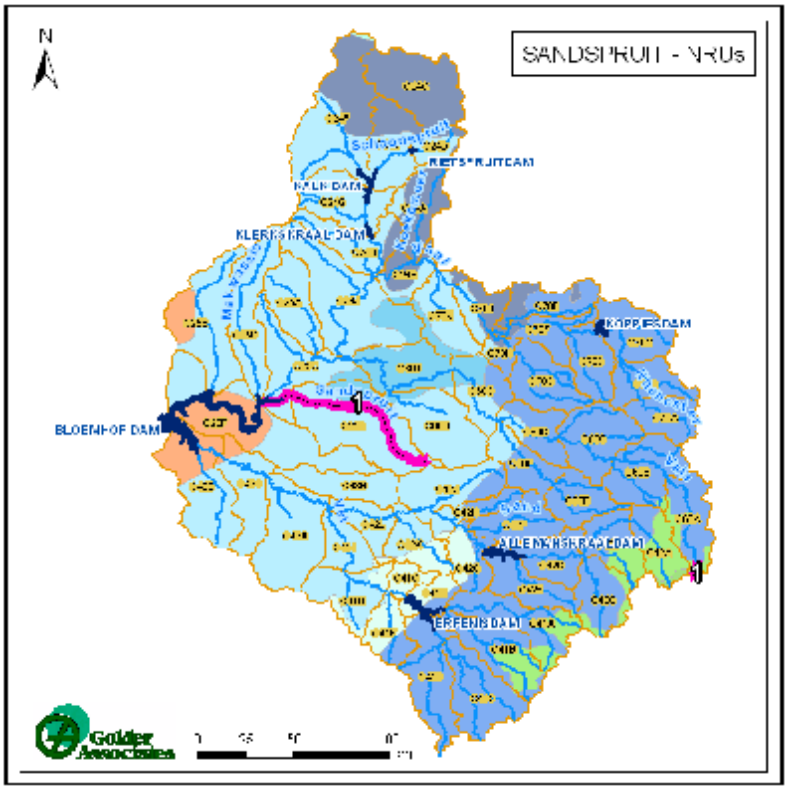


Figure 23: Sandspruit: Natural Resource Unit

Table 22: Description and rationale for the Sandspruit Natural Resource Unit

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU	11.08	Lower Foothills (100%)	The EcoRegion was the major consideration that defines the NRU.	26.88262; -27.59426

The NRU, based on the system characteristics, management and operation is delineated as a single management resource unit (MRU), MRU Sandspruit A (From river origin to Vaal River confluence). The MRU is shown in (Figure 24) and the rationale for its delineation is defined in Table 23.

Figure 24: Sandspruit Management Resource Unit: MRU Sandspruit A (From origin to confluence with the Vaal River)

Table 23: Description and rationale of the Sandspruit Management Resource Unit: MRU Sandspruit A (From origin to confluence with the Vaal River)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Sandspruit A	11.08	Lower Foothills (100%)	Dominated by natural grassland with some cultivated land.	The Sandspruit catchment is delineated as one MRU. There are no characteristic features, significant changes or physical structures in the catchment to define more than one MRU. Land use is limited to agriculture. Catchment has a low priority rating thus does not warrant the selection of an EWR site.	26.88262; -27.59426	C25B, C25C

4 ECOLOGICAL WATER REQUIREMENTS (EWR) SITE SELECTION

4.1 CRITERIA FOR SITE SELECTION

Ecological Water Requirements (EWR - quantity) sites are set at specific points on the river. These points are critical sites within a reach of river. The EWR sites must provide sufficient indicators for the specialists to assess environmental flows and as much information as possible about the variety of conditions in a river reach. EWR 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)

Sites were selected to represent the widest possible range of river conditions within the catchment. Consideration was also given to sites that had been used in previous EWR assessment because of the added value that could be achieved through more hydraulic calibrations. The final selection of sites depended on various considerations and constraints as follows:

- ***Hydraulics***: sites that were suitable for measuring and modeling hydraulics over a wide range of flows, especially low flows, were chosen. This was generally taken as the over-riding factor in site selection, as reliable hydraulics provides the basis of an EWR assessment;

- ***Flow gauges***: Sites that were located close to flow gauging stations were generally preferred to those that were not, partly because of the link with the available hydrological data, and partly because of the ability to measure flows during freshets and floods, when the river may be inaccessible for flow measurement;

- ***Biota and habitats***: sites that provided diverse habitats for in-stream and riparian biota, particularly critical habitats that are sensitive to changes in flow, such as riffles and rapids were chosen in preference to sites where these habitats were absent;

- ***Geomorphology***: sites that were suitable for providing reliable indicators to monitor geomorphological change were chosen. Stable areas with bedrock were therefore avoided;

- ***Land use***: sites that were least disturbed by non-flow related factors were given preference. Sites receiving agricultural return flows were generally avoided because the riparian vegetation would be partly maintained by the return flows, rather than the river flows;

- ***Accessibility***: sites that were easily accessible and therefore suitable for follow-up work and monitoring were chosen in preference to sites that were inaccessible;

- ***Location of tributaries***: cognisance was taken of those sites that were influenced by tributary characteristics and operation;

- ***Regulation***: sites were chosen in relation to the position of existing and potential regulatory structures, including points of abstraction or return flows. Sites that were downstream of regulatory structures were

generally preferred over unregulated sites, simply because the flows in regulated rivers are easier to manage;

- ***Position in the catchment***: Sites that were lower in a catchment or subcatchment were given preference to sites in the upper catchment because it is far better to extrapolate results upstream rather than downstream. The reason for this is that the conditions at any particular point in a river generally reflect the conditions and activities upstream of that point, and not downstream, and

- ***Water demands***: Sites in areas were current and projected demands for water were high were given priority over sites were demands for water are low.

4.2 EWR SITES

4.2.1 Selection of sites

The rationale and assessment of the recommended EWR sites within the MRUs as identified in the study are detailed Table 24.

Table 24: Assessment of MRU and recommendations on EWR sites

MRUs	Assessment of Resource Unit	Recommendations on EWR site
VAAL RIVER		
MRU Vaal F	The unit is it just downstream Upper Vaal WMA (downstream of the Mooi River confluence) so it is important to understand the influence of the Upper Vaal WMA. The river reach does include similar land use and has is considered a high priority as it forms the upper most reach of the Middle Vaal River. Importance of the MRU was rated as 3 thus it does warrant a selection of a comprehensive EWR site. Site is Easy to access. It is a single channel and has a gauging weir for flow records.	EWR site 1 at Vermaasdrift was selected. Site will account for influences from the Upper Vaal WMA.
MRU Vaal G	Importance of this reach was rated as a 3, and it is downstream of the Schoonspruit catchment a major influence in the system. The weir captures major water quality impacts from the upper and middle Vaal catchments - an EWR site should be selected. Site is Easy to access. It is a single channel and has a gauging weir for flow records.	EWR site 2 at Regina Bridge was selected. It is the 'middle site' in the Vaal River. As it is close to the downstream section of this MRU, it is situated ideally to address all impacts upstream Regina Bridge.
MRU Vaal H	No major characteristic features, habitat and biota diversity or major operational influences occur in this reach to warrant a selection of an EWR site. However reach was rated as an importance of 3 as it was noted that the sustainability of Vaal River upstream of Bloemhof Dam should be maintained.	No EWR site selected. Management at EWR site 2 will address requirements in this MRU and maintain sustainability.
MRU Vaal I	Bloemhof Dam forms the lower delineation area of the reach. While the importance of this reach was rated as a 3, the lower level of the reach is inundated with Bloemhof Dam water which is not conducive for a suitable EWR site.	No EWR site was selected.
MRU Vaal J	RU comprises Bloemhof Dam. It forms an operational break in the system. Importance was rated as a 1.	No EWR site was selected.
RHENOSTER RIVER		
MRU Rhenoster A	Includes one geomorphic zone and land cover type. No major characteristic features, habitat and biota diversity or major operational influences occur in this reach. Koppies Dam forms lower boundary of MRU. The reach has a low priority rating thus does not warrant the selection of an EWR site.	No EWR site was selected.
MRU Rhenoster B	The dam is delineated as a unit. It forms an operational break in the system. The reach has a moderate priority rating.	No EWR site was selected.

MRUs	Assessment of Resource Unit	Recommendations on EWR site
MRU Rhenoster C	No significant changes occur along these lower reaches below the Dam. No significant habitat and biota diversity. Importance rating is 2 in the lower reaches of the river (upstream confluence with the Vaal River).	No EWR site was selected.
KOEKEMOERSPRUIT		
MRU Koekemoerspruit A	There are no characteristic features, significant changes or physical structures in the system. Flow is dominated by mine water discharge. Habitat is significantly impacted by land use impacts. Land use is also similar (mining). The reach has a low priority rating thus does not warrant the selection of an EWR site.	No EWR site was selected.
SCHOONSPRUIT		
MRU Schoonspruit A	The Schoonspruit eye has a high importance rating and high EIS, and does warrant the selection of an EWR site. However due to the lack of any opportunity for changes in operation, the selection of EWR site is not proposed.	An intermediate Reserve determination study was undertaken on the Schoonspruit through a previous DWAF study. Thus no EWR sites were selected.
MRU Schoonspruit B	The reach has a low importance rating. MRU is delineated by two dams. System is highly regulated. A EWR site is not proposed.	
MRU Schoonspruit C	The dam is delineated as a unit. It forms an operational break in the system. The reach has a moderate priority rating. The Dam is not representative of site requirements.	
MRU Schoonspruit D	There is an increase in return flows from these areas into the Schoonspruit. This reach did score a high priority rating (3) in terms of management of the system.	
VALS RIVER		
MRU Vals A	The weir forms a break in the system and creates a delineation between the upper and lower reaches of the Vals river system. This MRU is largely rural in nature. No significant changes occur along these upper reaches below. No significant habitat and biota diversity. The importance rating was low.	No EWR site was selected.
MRU Vals B	Ecoregion level does change from the upper reaches. Catchment did receive a priority rating of 3 requiring the integrity of the river to be maintained upstream of the confluence with the Vaal River. MRU should be considered for the selection of an EWR site. Site is easy to access and has a gauging weir for flow records. However hydraulics is complex (two channels, standing pools).	EWR site 3 selected at Proklameersdrift.
VET RIVER		
MRU Vet A	The Dam forms the lower delineation boundary of the unit. Upper most reach of river. Region has a low priority rating. MRU includes the Klein Vet as a tributary.	No EWR site was selected on Vet River. However Rapid EWR site was selected on Klein- Vet just downstream of Winburg.
MRU Vet B	Erfenis Dam is delineated as a resource unit. It forms an operational break in the system. The Dam is not representative of site requirements.	No EWR site was selected.
MRU Vet C	No significant changes in land use, however MRU does include two Eco-regions. System is regulated by dam. Reach was rated as a moderate priority rating.	No EWR site was selected.
MRU Sand A	Includes three Eco-regions in upper reaches. Region has a low priority rating.	No EWR site was selected.
MRU Sand B	Allemanskraal Dam is delineated as a resource unit. It forms an operational break in the system. The Dam is not representative of site requirements.	No EWR site was selected.
MRU Sand C	Area is impacted by return flows from the urban centres, bulk water users and irrigation. System is regulated by dam. Catchment area has a low to moderate priority rating.	No EWR site was selected.

MRUs	Assessment of Resource Unit	Recommendations on EWR site
MRU Vet D	Area has a moderate priority rating (2). Assessment requires the integrity of the Vet river to be maintained upstream of the confluence with the Vaal River. MRU should be considered for the selection of an EWR site. Single low flow channel and gauging weir for flow records is present.	EWR site 4 selected at Fisantkraal.
MAKWASSIE		
MRU Makwassie A	The river is under stress but it has a low priority rating. Assessment was undertaken to identify a possible site. However no suitable site could be found.	No EWR site was selected.
SANDSPRUIT		
MRU Sandspruit A	There are no characteristic features, significant habitat or biota diversity, significant changes or physical structures in the catchment. MRU has a low priority rating thus does not warrant the selection of an EWR site.	No EWR site was selected.

The site information and photographs of the selected EWR sites are shown in Table 25.

Table 25: Locality and characteristics of the Middle Vaal WMA EWR sites

Site information	EWR sites	Site
EWR number and name	**EWR 1 Vermaasdrift**	
River	Vaal	
National RHP site	C2-Vaal Orkne	
Decimal degrees:	S26.93615; E26.85025	
EcoRegion (Level II)	11.01	
Geomorphic Zone	Lower Foothills	
Altitude (m)	1348	
RU	Vaal F	
Quaternary	C24A	
Hydrological gauge	C1H007	

Site information	EWR sites	Site
EWR nr and name *River* *National RHP site* *Decimal Degrees* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Hydrological gauge*	**EWR 2 Regina Bridge** Vaal C2-Vaal Orkne S27.10413; E26.52185 11.08 Lower Foothills 1285 Vaal G C24J C2H007	
EWR nr and name *River* *National RHP site* *Decimal Degrees* *EcoRegion (Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Hydrological gauge*	**EWR 3 Proklameersdrift** Vals C6 Vals-Prokl S27.48685; E26.81320 11.07 Lower Foothills 1400 Vals B C60J C6H001	

Site information	EWR sites	Site
EWR nr and name *River* *National RHP site* *Decimal Degrees* *EcoRegion(Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Hydrological gauge*	**EWR 4 Fisantkraal** Vet C4-Vet-Hoops S27.93482; E26.12569 11.08 Lower Foothills 1247 Vet C C43A C4H004	
EWR nr and name *River* *National RHP site* *Decimal Degrees* *EcoRegion(Level II)* *Geomorphic Zone* *Altitude (m)* *RU* *Quaternary* *Hydrological gauge*	**Rapid EWR** Klein-Vet C4G Vet-V4 S28.564708; E26.943946 11.03 Lower Foothills Vet A C41A	

The location of EWR sites and the MRUs are illustrated in

Figure 25 .

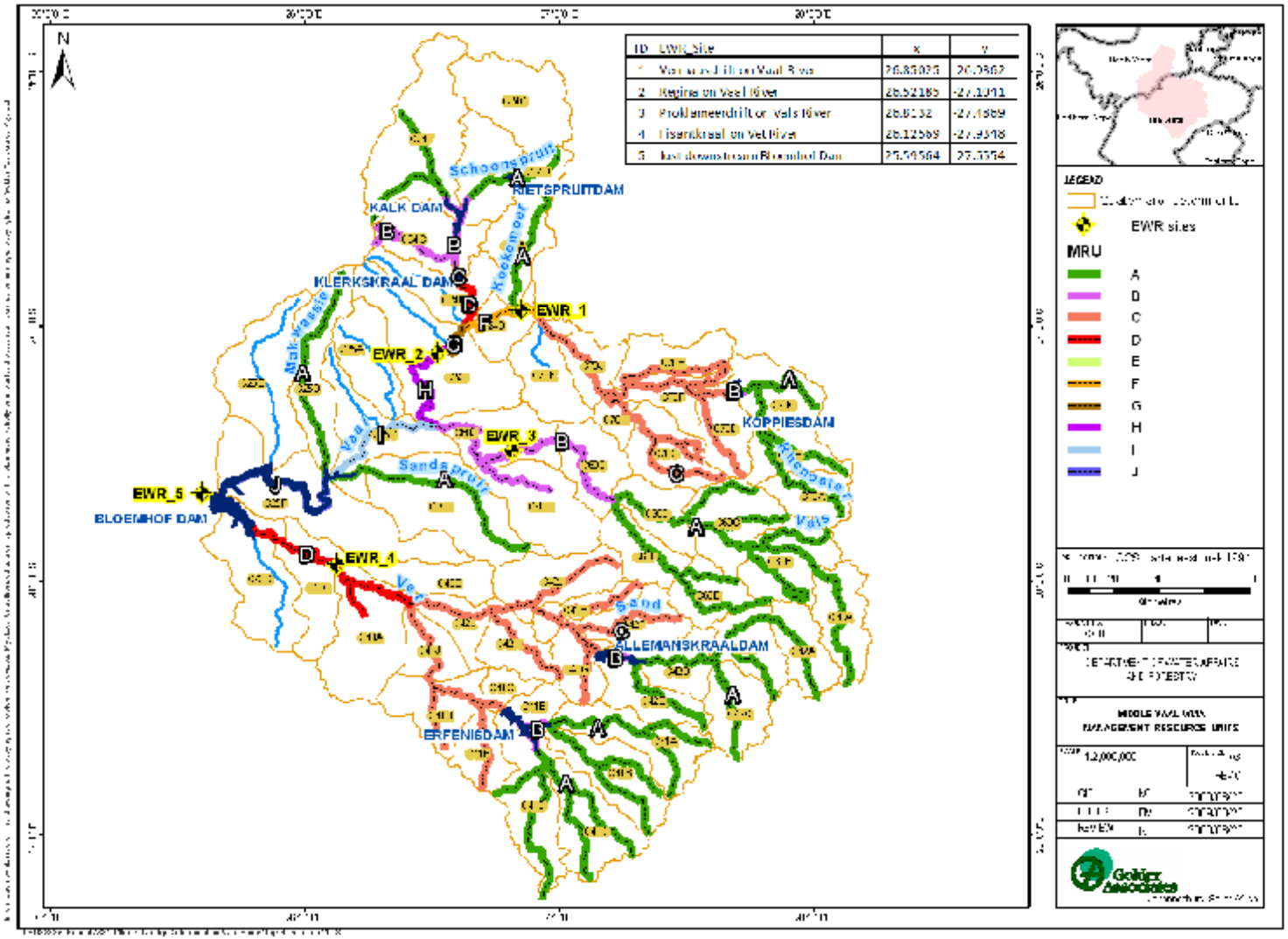


Figure 25: Location of EWR sites and MRUs in the Middle Vaal WMA

4.2.2 Site suitability

The site suitability of each site was assessed and is provided in Table 26 and Table 27. 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 26: Biophysical Site suitability for the Middle Vaal WMA

EWR sites	Geomorphology	Riparian vegetation	Fish	Invertebrates	Average	Maximum	Minimum	Comments
EWR 1	3.1	1	3.5	3.4	2.75	3.5	1	Riparian vegetation denuded at site due to mining and agricultural activities
EWR 2	2.1	1.8	3.0	3.5	2.6	3.5	1.8	Riparian vegetation denuded by agriculture.
EWR 3	2.4	2.8	3.5	2.8	2.87	3.5	2.4	Riparian vegetation dominated by exotics and encroachment due to agriculture.
EWR 4	2.4	2.5	3.5	3.4	2.95	3.5	2.4	Riparian vegetation dominated by exotics and encroachment due to agriculture.
Rapid EWR	3.9	3.0	3.0	3.1	3.25	3.9	3	Potential for site to be back flooded when dam full

From a biophysical point of view, these sites are all moderately suitable with the exception of the Riparian vegetation at EWR 1.

Table 27: Integrated site suitability for the Middle Vaal WMA

EWR SITES	BIOPHYSICAL		HYDRAULICS		CONFIDENCE		COMMENT
	Low flows	High flows	Low flows	High flows	Low flows	High flows	
EWR 1	2.9	2.7	2	3	3	2.5	Good flow records in the Vaal River
EWR 2	3.0	2.5	4	4	3	2.5	Good flow records in the Vaal River
EWR 3	3.0	2.6	2	4	3	2.5	Flow records close to site
EWR 4	3.1	2.6	3	3	3	3	Flow records close to site
Rapid EWR	3.4	3.1	2	4	3	3	Flow records close to site

In general the site suitability is low-moderate for low flows. This must be seen in the context of the hydraulic calibrations obtained at the stage the report has been written. The confidence will be adjusted once it is known which hydraulic calibrations have been obtained. The high flow calibrations range from moderate to high.

5 REFERENCES

Department of Water Affairs and Forestry. (2004). Middle Vaal ISP. July 2004.

Department of Water Affairs and Forestry. (2006), Vaal River Continuous Studies. Schoonspruit Sub-system Analysis study. Draft Report. February 2006.

Department of Water Affairs and Forestry. (2007). Development of a CMS forSchoonspruit...

Kleynhans, CJ, Thirion, C and Moolman, J. (2005). A Level I River EcoRegion classification System 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, CJ, 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.

CJ Kleynhans, C.J and DM Louw, D.M (2007) River reach demarcation and delineation.

Louw MD, Kemper N and Birkhead AL. (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, MD and Hughes, DA. (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.

Rowntree, KM and Wadeson, RA. (1999). A hierarchical framework for categorising the geomorphology of river systems, Water Research Commission Report. Report No. 497/1/99. WRC, Pretoria.

Van Bosch, J. and F. le Roux (2003). Report on the Koekemoer Spruit Flow Investigation. DWAF Report, First revision.

APPENDIX A
RIVER REACH DEMARCATION AND DELINEATION

RIVER REACH DEMARCATION AND DELINEATION

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September 2007

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[1] 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,

[1] 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).

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.

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 A.1 and A.2.

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 ecoregions including 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 A.1 provides a hypothetical example to illustrate the described delineation. An explanation of the hypothetical delineation in tabulated form (Table A.1) is also provided.

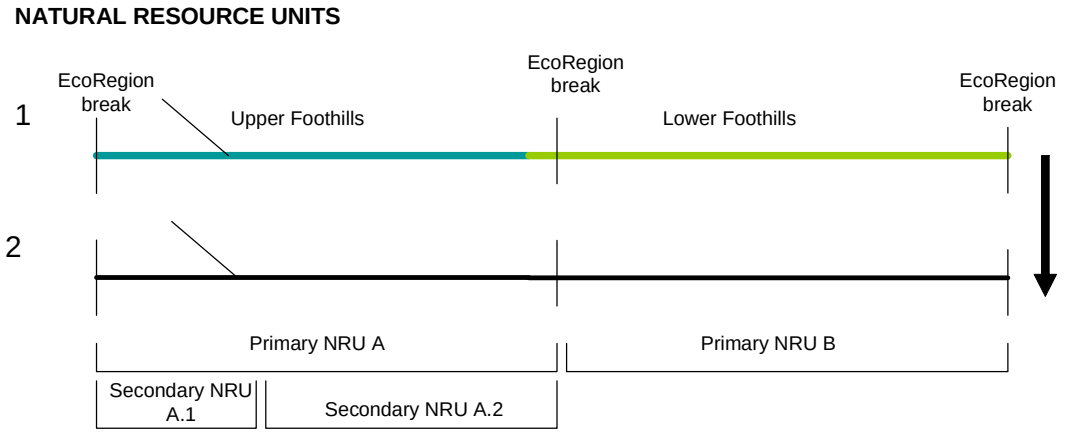


Figure A.1: Delineation of National Resource Units

Table A.1: Description of the rationale for the delineation of the National Resource Unit (Fig A.1)

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

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.

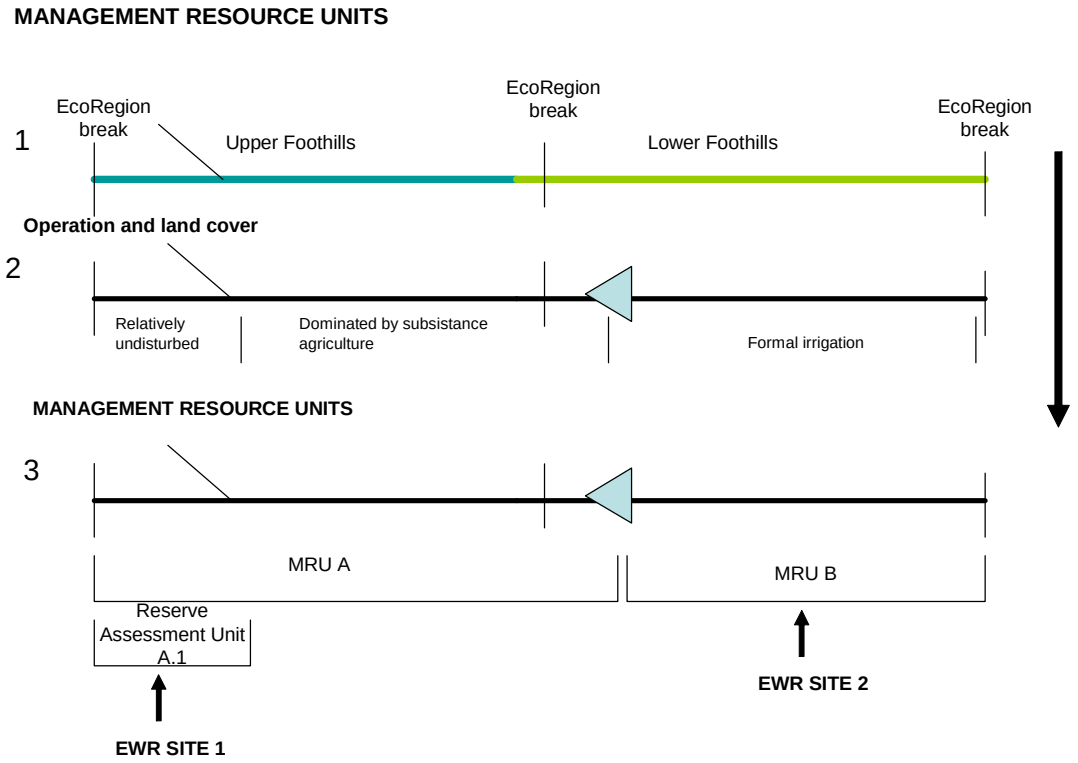
If there are no anthropogenic changes or modifications present along or upstream from a particular NRU, such a NRU will logically constitute a Management Resource Unit (MRU).

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 A.2 provides a hypothetical example to illustrate the described delineation. An explanation of the hypothetical delineation in tabulated form (Table A.2) is also provided. The figure and table show the delineation into MRU, RAUs and also indicate where the EWR site should be situated (process



described below.

Figure A.2: Delineation of Management Resource Units

Table A.2: Description of the rationale for the delineation of the Management Resource Unit (Fig A.2).

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	Assessment of RAU for EcoClassification and EWR	Start of EcoRegion to confluence of tributary

	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 important as forms the critical section in the MRU	(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			
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.			

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 **à** Secondary NRU **à** MRU **à** RAU **à** EWR site. An EWR site is therefore a locality where measurements to determine the ecological water requirements of 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 representativeness 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 flow 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[2] (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.
- 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.

[2] Size of any of the groups do 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 following Tables 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[3]:

Table A.3: 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 A. 4: 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**			

[3] 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 A.5: 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 A.6: 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 environmental flow 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
LANDCOVER

LANDCOVER

VAAL RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C24B	11.01	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1213.341
C24B	11.01	16	05-01-000	Unimproved Grassland	1313.220
C24B	11.01	2	05-02-000	Improved Grassland	107.850
C24B	11.01	1	06-00-000	Forest Plantations (exotic)	1.422
C24B	11.01	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	5.028
C24B	11.01	5	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	173.373
C24B	11.01	1	11-01-000	Urban / Built-up Land (residential)	44.676
C24B	11.01	2	12-00-000	Mines & Quarries	21.307
C24B	11.08	5	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	503.944
C24B	11.08	9	05-01-000	Unimproved Grassland	757.676
C24B	11.08	1	05-02-000	Improved Grassland	12.162
C24B	11.08	2	06-00-000	Forest Plantations (exotic)	8.112
C24B	11.08	4	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	15.296
C24B	11.08	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	59.235
C24B	11.08	1	11-01-000	Urban / Built-up Land (residential)	4.030
C24J	11.08	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	3572.780
C24J	11.08	25	05-01-000	Unimproved Grassland	2240.527
C24J	11.08	2	06-00-000	Forest Plantations (exotic)	168.628
C24J	11.08	1	07-00-000	Waterbodies	6.628
C24J	11.08	1	08-00-000	Wetlands	61.698
C24J	11.08	13	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	139.969
C24J	11.08	20	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	1448.339
C25C	11.08	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	2864.279
C25C	11.08	25	05-01-000	Unimproved Grassland	3249.793
C25C	11.08	2	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	19.042
C25C	11.08	16	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	438.763
C25C	11.08	1	11-01-000	Urban / Built-up Land (residential)	32.726
C25C	11.08	1	12-00-000	Mines & Quarries	1.667
C25F	11.08	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	10.797
C25F	11.08	2	05-01-000	Unimproved Grassland	25.522
C25F	29.02	6	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1528.216
C25F	29.02	28	05-01-000	Unimproved Grassland	2709.191
C25F	29.02	2	06-00-000	Forest Plantations (exotic)	11.004
C25F	29.02	8	07-00-000	Waterbodies	2818.652
C25F	29.02	5	08-00-000	Wetlands	607.902
C25F	29.02	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	15.689
C25F	29.02	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	96.261

KOEKEMOERSPRUIT					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C24A	11.01	2	05-01-000	Unimproved Grassland	32.795
C24A	11.01	2	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	7.389
C24A	11.01	1	12-00-000	Mines & Quarries	7.061

SCHOONSPRUIT					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C24D	11.01	1	05-01-000	Unimproved Grassland	319.472
C24D	11.01	1	06-00-000	Forest Plantations (exotic)	29.437
C24D	11.01	5	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	139.691
C24D	11.08	1	01-00-000	Forest & Woodland (Woodland & Wooded Grassland)	0.293
C24D	11.08	4	05-01-000	Unimproved Grassland	1553.431
C24D	11.08	4	06-00-000	Forest Plantations (exotic)	12.165
C24D	11.08	2	07-00-000	Waterbodies	210.065
C24D	11.08	15	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	360.232
C24E	11.08	5	01-00-000	Forest & Woodland (Woodland & Wooded Grassland)	130.424
C24E	11.08	2	05-01-000	Unimproved Grassland	1698.557
C24E	11.08	4	06-00-000	Forest Plantations (exotic)	6.081
C24E	11.08	2	07-00-000	Waterbodies	18.006
C24E	11.08	1	08-00-000	Wetlands	666.743
C24E	11.08	8	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	64.597
C24E	11.08	25	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	844.941
C24F	11.08	1	08-00-000	Wetlands	33.878
C24F	11.08	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	0.032
C24G	11.08	1	01-00-000	Forest & Woodland (Woodland & Wooded Grassland)	0.275
C24G	11.08	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	127.868
C24G	11.08	7	05-01-000	Unimproved Grassland	1434.330
C24G	11.08	5	06-00-000	Forest Plantations (exotic)	14.830
C24G	11.08	1	07-00-000	Waterbodies	236.378
C24G	11.08	1	08-00-000	Wetlands	524.989
C24G	11.08	10	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	114.346
C24G	11.08	21	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	378.579
C24H	11.01	1	05-01-000	Unimproved Grassland	91.138
C24H	11.08	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	6.567
C24H	11.08	5	05-01-000	Unimproved Grassland	1879.045
C24H	11.08	1	07-00-000	Waterbodies	12.098
C24H	11.08	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	12.505
C24H	11.08	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	96.576
C24H	11.08	8	11-01-000	Urban / Built-up Land (residential)	586.357
C24H	11.08	1	11-01-011	Urban / Built-up Land (residential - smallholdings - grassland)	213.431
C24H	11.08	2	11-02-000	Urban / Built-up Land (commercial)	48.893

RENOSTER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)

VALS RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C60A	11.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1.556
C60A	11.03	16	05-01-000	Unimproved Grassland	3148.566
C60A	11.03	2	07-00-000	Waterbodies	1.852
C60A	11.03	2	08-00-000	Wetlands	33.093
C60A	11.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	7.358
C60A	11.03	26	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	3280.217
C60A	15.01	3	05-01-000	Unimproved Grassland	127.311
C60A	15.01	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	583.461
C60A	15.03	1	05-01-000	Unimproved Grassland	274.396
C60A	15.03	2	09-01-000	Bare Rock & Soil (natural)	15.359
C60A	15.03	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	101.493
C60B	11.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	95.065
C60B	11.03	3	05-01-000	Unimproved Grassland	3197.777
C60B	11.03	1	06-00-000	Forest Plantations (exotic)	16.197
C60B	11.03	1	07-00-000	Waterbodies	5.768
C60B	11.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	21.272
C60B	11.03	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	78.513
C60B	11.03	1	11-01-000	Urban / Built-up Land (residential)	12.318
C60C	11.03	4	05-01-000	Unimproved Grassland	3207.837
C60C	11.03	1	08-00-000	Wetlands	0.131
C60C	11.03	4	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	62.892
C60C	11.03	5	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	593.090
C60D	11.03	1	05-01-000	Unimproved Grassland	1991.348
C60D	11.03	1	08-00-000	Wetlands	11.898
C60D	11.03	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	8.611
C60D	11.08	9	05-01-000	Unimproved Grassland	812.354
C60D	11.08	3	07-00-000	Waterbodies	302.338
C60D	11.08	8	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	409.028
C60D	11.08	2	11-01-000	Urban / Built-up Land (residential)	571.084
C60D	11.08	1	11-01-011	Urban / Built-up Land (residential - smallholdings - grassland)	57.909
C60D	11.08	3	11-02-000	Urban / Built-up Land (commercial)	104.015
C60F	11.08	1	05-01-000	Unimproved Grassland	22.799
C60G	11.07	1	05-01-000	Unimproved Grassland	1849.278
C60G	11.07	1	07-00-000	Waterbodies	2.699
C60G	11.07	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	0.780
C60G	11.08	1	05-01-000	Unimproved Grassland	3188.314
C60G	11.08	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	17.515
C60G	11.08	2	11-01-000	Urban / Built-up Land (residential)	0.734

C60G	11.08	1	11-02-000	Urban / Built-up Land (commercial)	0.850
VALS RIVER *(continued)*					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C60H	11.07	1	05-01-000	Unimproved Grassland	9.984
C60J	11.07	1	05-01-000	Unimproved Grassland	7620.497
C60J	11.07	1	06-00-000	Forest Plantations (exotic)	0.430
C60J	11.07	2	07-00-000	Waterbodies	6.831
C60J	11.07	1	08-00-000	Wetlands	8.763
C60J	11.07	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	1.219
C60J	11.07	16	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	346.450
C60J	11.07	4	11-01-000	Urban / Built-up Land (residential)	96.903
C60J	11.08	1	05-01-000	Unimproved Grassland	236.241
C60J	11.08	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	31.496
C60J	11.08	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	70.590

VET RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C41C	11.03	4	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	391.305
C41C	11.03	4	05-01-000	Unimproved Grassland	5979.055
C41C	11.03	2	06-00-000	Forest Plantations (exotic)	17.077
C41C	11.03	1	09-02-004	Degraded Lands (Unimproved Grassland)	273.682
C41C	11.03	38	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	684.380
C41C	11.03	2	11-01-000	Urban / Built-up Land (residential)	98.419
C41D	11.03	4	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	570.675
C41D	11.03	8	05-01-000	Unimproved Grassland	1276.929
C41D	11.03	1	07-00-000	Waterbodies	143.802
C41D	11.03	2	08-00-000	Wetlands	74.704
C41D	11.03	3	09-02-004	Degraded Lands (Unimproved Grassland)	21.342
C41D	11.03	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	105.042
C41E	11.03	3	05-01-000	Unimproved Grassland	57.257
C41E	11.03	1	07-00-000	Waterbodies	100.927
C41E	11.10	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	5.393
C41E	11.10	9	05-01-000	Unimproved Grassland	126.992
C41E	11.10	1	07-00-000	Waterbodies	788.652
C41E	11.10	1	08-00-000	Wetlands	9.239
C41F	11.10	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	16.821
C41F	11.10	2	05-01-000	Unimproved Grassland	4.297
C41G	11.10	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	617.731
C41G	11.10	10	05-01-000	Unimproved Grassland	534.639
C41G	11.10	2	06-00-000	Forest Plantations (exotic)	18.888
C41G	11.10	1	08-00-000	Wetlands	1.494
C41G	11.10	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	83.647
C41H	11.08	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1110.437
C41H	11.08	14	05-01-000	Unimproved Grassland	786.656

C41H	11.08	3	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	17.154
C41H	11.10	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	669.546

VET RIVER *(continued)*

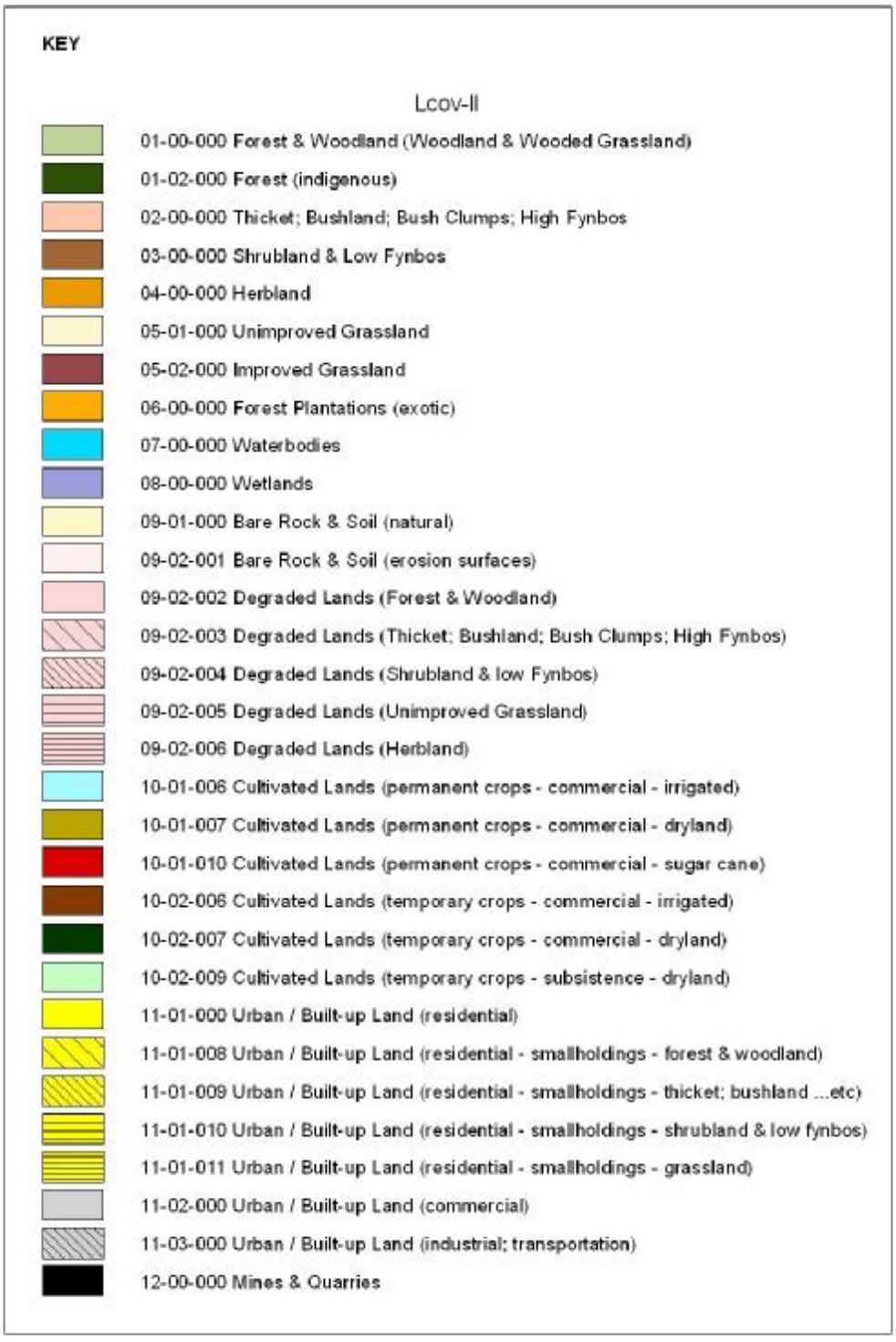
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C41H	11.10	8	05-01-000	Unimproved Grassland	491.071
C41H	11.10	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	62.051
C41J	11.08	7	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	2556.076
C41J	11.08	26	05-01-000	Unimproved Grassland	1869.296
C41J	11.08	4	08-00-000	Wetlands	142.760
C41J	11.08	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	57.469
C41J	11.08	8	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	254.340
C42A	11.03	7	05-01-000	Unimproved Grassland	1008.077
C42A	11.03	1	08-00-000	Wetlands	5.894
C42A	11.03	8	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	833.951
C42A	15.01	2	05-01-000	Unimproved Grassland	2112.952
C42A	15.01	2	08-00-000	Wetlands	46.777
C42A	15.01	1	09-02-001	Bare Rock & Soil (erosion surfaces)	6.270
C42A	15.01	15	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	468.501
C42A	15.03	1	05-01-000	Unimproved Grassland	399.836
C42A	15.03	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	16.985
C42B	11.03	2	05-01-000	Unimproved Grassland	3532.953
C42B	11.03	4	07-00-000	Waterbodies	28.498
C42B	11.03	7	08-00-000	Wetlands	105.616
C42B	11.03	20	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	425.666
C42B	11.03	2	11-01-000	Urban / Built-up Land (residential)	0.071
C42C	11.03	3	05-01-000	Unimproved Grassland	2.574
C42C	11.03	1	11-01-000	Urban / Built-up Land (residential)	8.421
C42D	11.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	170.373
C42D	11.03	6	05-01-000	Unimproved Grassland	3127.883
C42D	11.03	2	07-00-000	Waterbodies	8.834
C42D	11.03	4	08-00-000	Wetlands	63.602
C42D	11.03	2	09-02-001	Bare Rock & Soil (erosion surfaces)	6.390
C42D	11.03	5	09-02-004	Degraded Lands (Unimproved Grassland)	427.014
C42D	11.03	12	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	644.157
C42D	11.03	1	11-01-000	Urban / Built-up Land (residential)	1.907
C42E	11.03	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	118.747
C42E	11.03	13	05-01-000	Unimproved Grassland	215.612
C42E	11.03	1	07-00-000	Waterbodies	1005.748
C42E	11.03	4	09-02-004	Degraded Lands (Unimproved Grassland)	66.088
C42F	11.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	45.214
C42F	11.03	1	05-01-000	Unimproved Grassland	15.120
C42G	11.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1592.329
C42G	11.03	10	05-01-000	Unimproved Grassland	541.207
C42G	11.03	1	06-00-000	Forest Plantations (exotic)	6.904
C42G	11.03	1	07-00-000	Waterbodies	6.214

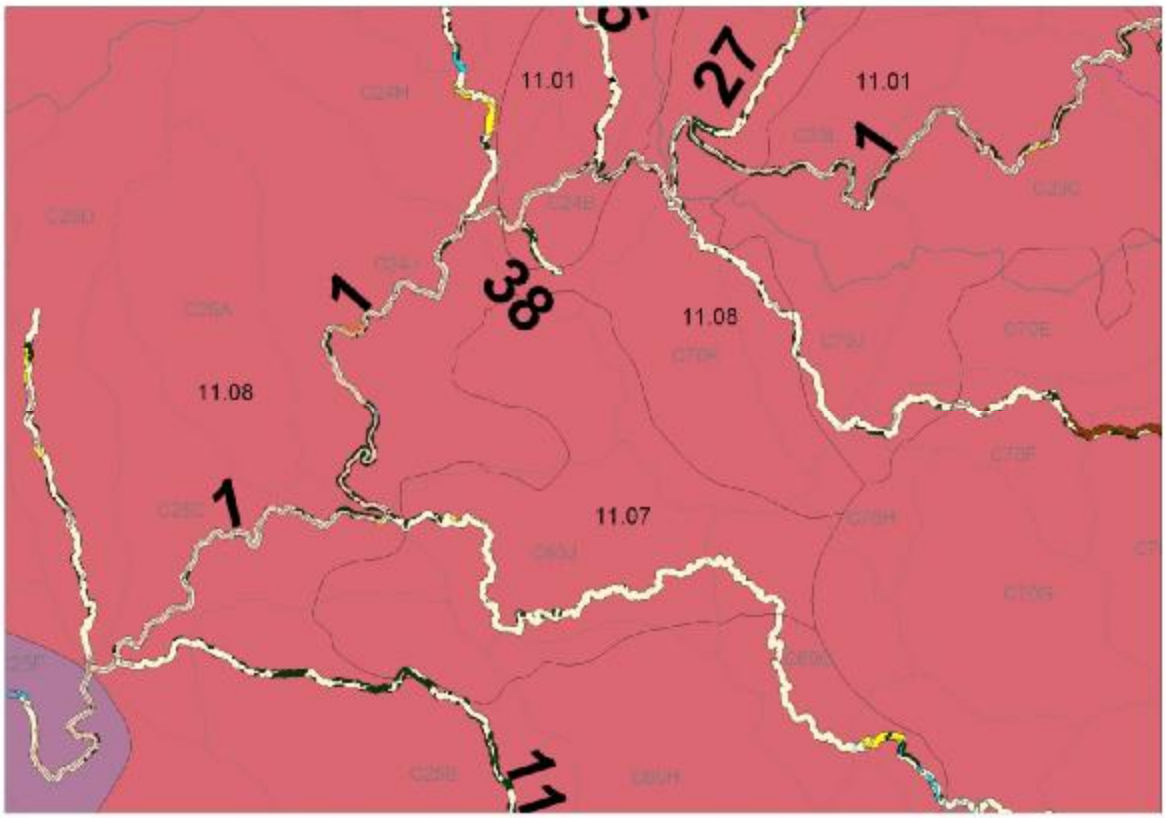
C42G	11.03	1	08-00-000	Wetlands	6.514
C42G	11.03	12	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	95.810
C42G	11.08	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	210.169
C42G	11.08	6	05-01-000	Unimproved Grassland	128.709
VET RIVER *(continued)*					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C42G	11.08	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	39.312
C42G	11.10	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	2.761
C42H	11.08	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	791.271
C42H	11.08	11	05-01-000	Unimproved Grassland	537.347
C42H	11.08	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	49.175
C42J	11.08	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	843.039
C42J	11.08	3	05-01-000	Unimproved Grassland	138.022
C42J	11.08	3	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	199.453
C42J	11.08	3	11-01-000	Urban / Built-up Land (residential)	317.046
C42J	11.08	3	11-03-000	Urban / Built-up Land (industrial; transportation)	147.387
C42J	11.08	3	12-00-000	Mines & Quarries	97.049
C42K	11.08	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	532.282
C42K	11.08	7	05-01-000	Unimproved Grassland	391.552
C42K	11.08	3	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	162.802
C42L	11.08	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1964.766
C42L	11.08	33	05-01-000	Unimproved Grassland	917.373
C42L	11.08	2	08-00-000	Wetlands	29.615
C42L	11.08	5	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	18.421
C42L	11.08	8	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	1313.894
C42L	11.08	1	11-01-011	Urban / Built-up Land (residential - smallholdings - grassland)	19.656
C43A	11.08	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	3425.335
C43A	11.08	26	05-01-000	Unimproved Grassland	1103.167
C43A	11.08	4	08-00-000	Wetlands	160.632
C43A	11.08	2	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	42.419
C43A	11.08	11	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	691.900
C43C	11.08	4	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1779.308
C43C	11.08	11	05-01-000	Unimproved Grassland	1695.329
C43C	11.08	2	08-00-000	Wetlands	9.440
C43C	11.08	4	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	34.904
C43C	11.08	9	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	328.058
C43C	29.02	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	253.942
C43C	29.02	6	05-01-000	Unimproved Grassland	162.762
C43C	29.02	1	08-00-000	Wetlands	22.063
C43C	29.02	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	0.364
C43C	29.02	1	11-01-000	Urban / Built-up Land (residential)	0.885
C43D	29.02	5	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1613.934
C43D	29.02	21	05-01-000	Unimproved Grassland	681.603
C43D	29.02	5	07-00-000	Waterbodies	984.706
C43D	29.02	7	08-00-000	Wetlands	498.324

C43D	29.02	3	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	83.342
C43D	29.02	1	11-01-000	Urban / Built-up Land (residential)	23.468
C43D	29.02	1	11-02-000	Urban / Built-up Land (commercial)	7.071

MAKWASSIE					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C25D	11.08	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	14.038
C25D	11.08	1	05-01-000	Unimproved Grassland	5.605

SANDSPRUIT					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C25B	11.07	3	05-01-000	Unimproved Grassland	220.459
C25B	11.07	1	07-00-000	Waterbodies	2.460
C25B	11.07	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	303.051
C25B	11.08	6	05-01-000	Unimproved Grassland	5978.057
C25B	11.08	2	06-00-000	Forest Plantations (exotic)	22.328
C25B	11.08	1	07-00-000	Waterbodies	1.294
C25B	11.08	48	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	2814.368
C25C	11.08	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	117.944
C25C	11.08	1	05-01-000	Unimproved Grassland	1201.260
C25C	11.08	6	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	58.790


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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APPENDIX C
FLUVIAL GEOMORPHOLOGY SITE SUITABILITY

EWR 1:

Site suitability

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**	

EWR 2:

Site suitability

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**	

EWR 3:

Site suitability

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**	

EWR 4:

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**	

EWR 5:

Site suitability

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**	

APPENDIX D
AQUATIC INVERTEBRATE SITE SUITABILITY

EWR 1:

Site suitability

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

EWR 2:

Site suitability

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

EWR 3:

Site suitability

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

EWR 4:

Site suitability

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

EWR 5:

Site suitability

Site Suitability: Aquatic Invertebrates BIOTOPE	Weight (0-10)	Rating of Site (0-5)
Stones In Current (SIC)	10	4

APPENDIX E
RIPARIAN VEGETATION SITE SUITABILITY

EWR 1

Site suitability

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**

EWR 2

Site suitability

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**

EWR 3

Site suitability

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**

EWR 4

Site suitability

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**

EWR 5

Site suitability

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**

APPENDIX F
FISH SITE SUITABILITY

1. 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 à Secondary NRU à MRU à RAU à 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 eco-classification 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.

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

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

- The response of the various velocity-depth classes and associated cover at different discharges.

- 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).

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 Middle Vaal River catchments, used for the purpose of the Vaal River System Comprehensive Reserve determination.

2. METHODOLOGY

According to Kleynhans & Louw (2007) the following attributes are essential determinants of the suitability of an EWR site for specifying the ecological flow 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 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 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

[4] Size of any of the groups do 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.

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 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 representativeness of the EWR site and the accuracy of the hydraulics model.

The following Tables 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 1: 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 2: Comparison of cover ratings for 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 3: 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
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 EWR (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 3).
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 to 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 1)

2. Estimate the expected habitat composition of the entire RAU (velocity-depth class composition, cover etc.) (Table 1)

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 environmental flow 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

3. RESULTS & DISCUSSION

Study Area

Five EWR sites were selected in the Middle Vaal Catchment for the purpose of a Comprehensive Reserve Determination.

Site Suitability

EWR 1: Vermaasdrift on Vaal River

Table 5: 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)**
	Pphi
	Tspa

Table 6: 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.		

EWR 2: Regina Bridge on Vaal River

Table7: 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)**
	Pphi
	Tspa

Table 8: 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.		

EWR 3: Proklameersdrift on Vals River

Table 9: 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)**

	Pphi
	Tspa

Table 10: Suitability scores of site in terms of EWR 3and 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.		

EWR 4: Fisantkraal on Vet River

Table 11: 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)**
	Pphi
	Tspa

Table 12: Suitability scores of site in terms of EWR 4 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, 1 - 1.9: very low suitability, 2 - 2.9: Moderate suitability, 3 - 3.9: High suitability, 4 - 5: Very high suitability.		

EWR 5: Rapid site – Klein Vet (Winburg)

Table 13: 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	Btri
Lumb	
Cgar	
Limnophilics	
Large	**Small (<20cm)**
	Pphi
	Tspa

Table 14: 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, 1 - 1.9: very low suitability, 2 - 2.9: Moderate suitability, 3 - 3.9: High suitability, 4 - 5: Very high suitability.		

REFERENCES

Kleynhans, C.J. & 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 F
HYDRAULIC SITE SUITABILITY

Site 1: Vermaasdrift

Site suitability = 2 low-flows; 3 high-flows (scale 0-5)

River	Site	Advantages	Disadvantages
Vaal	EWR 1	Easy access to the site. Single channel. Gauging weir for flow records.	Vegetation on both banks and islands in the river bed influence overall flow resistance at high flows.

Site 2: Regina Bridge

Site suitability = 4 low-flows; 4 high-flows (scale 0-5)

River	Site	Advantages	Disadvantages
Vaal	EWR 2	Easy access to the site. Single channel. Gauging weir for flow records.	Vegetation on the right bank influences overall flow resistance at high flows.

Site 3: Proklameersdrift

Site suitability = 2 low-flows; 4 high-flows (scale 0-5)

River	Site	Advantages	Disadvantages
Vals	EWR 3	Easy access to the site. Gauging weir for flow records.	Hydraulics is complex: 2 channels, islands, standing water pools.

Site 4: Fisantkraal

Site suitability = 3 low-flows; 3 high-flows (scale 0-5)

River	Site	Advantages	Disadvantages
Vet	EWR 4	Single low flow channel. Gauging weir for flow records.	Large scale river bad substrates result to non-uniform flow with potential for non-horizontal water profile at low flow conditions.

Rapid Site 5: Klein Vet

Site suitability = 2 low-flows; 4 high-flows (scale 0-5)

River	Site	Advantages	Disadvantages
Klein Vet	Rapid EWR 5		