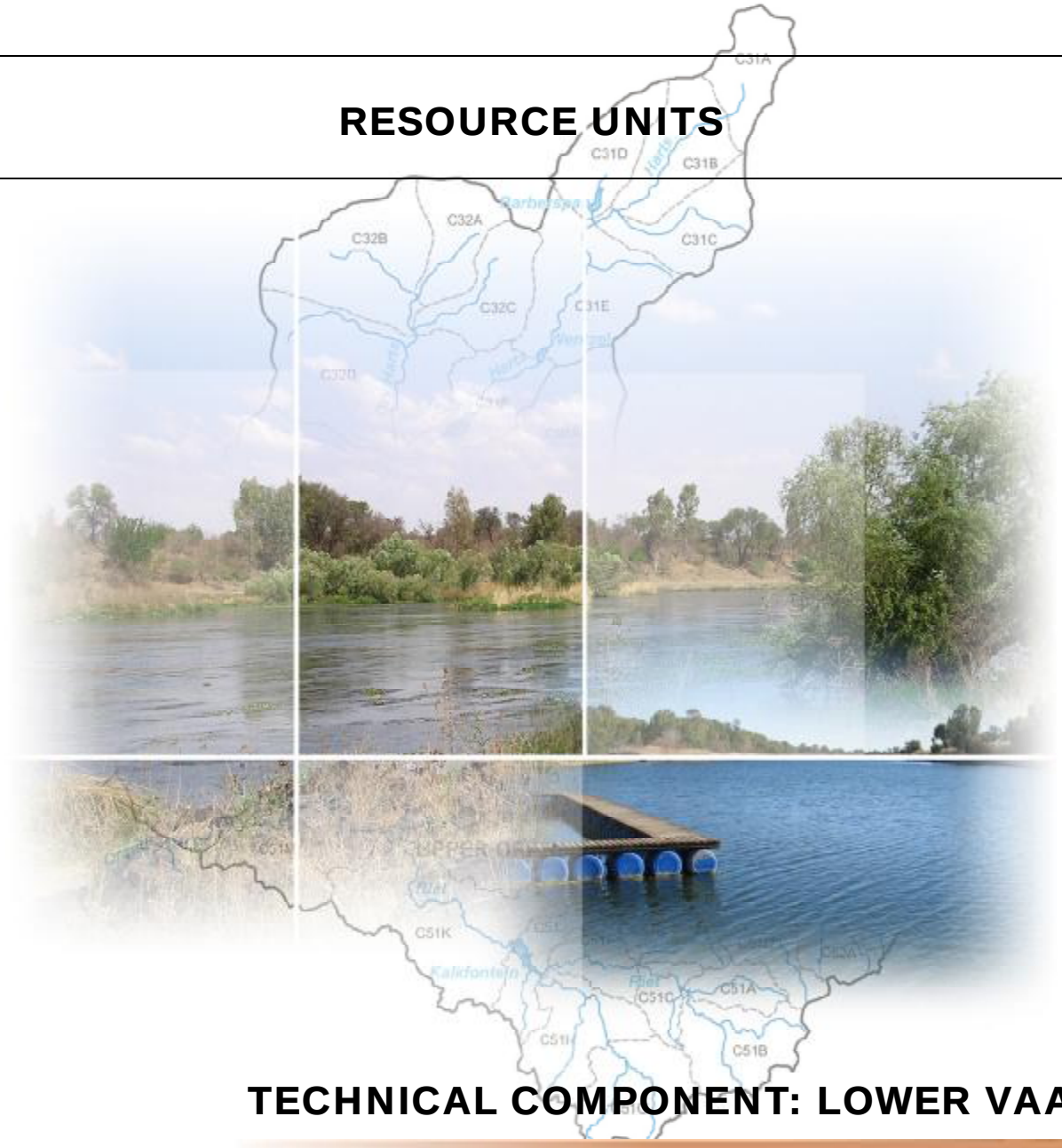
COMPREHENSIVE RESERVE DETERMINATION

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: Lower Vaal Water Management Area (WMA) – Vaal River catchment surface water quantity. The purpose of the Comprehensive Reserve Determination Study for the water resources of the Vaal River catchment of the Lower Vaal and Upper Orange WMAs 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 Vaal River catchment of the Lower Vaal and Upper Orange WMAs.

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 K	Outflow Bloemhof Dam to Vaalharts weir	C91A, C91B
MRU Vaal L	Vaalharts Barrage	C91B
MRU Vaal M	Vaalharts weir to Harts River confluence	C91D, C91E
MRU Vaal N	From Harts River confluence to Schmidtsdrift weir	C92A, C92B
MRU Vaal O	From Schmidtsdrift weir to Douglas Barrage	C92B, C92C
MRU Vaal P	Douglas Barrage	C92C
TRIBUTARIES		
HARTS RIVER		
MRU Harts A	From Origin of Dry Harts to confluence with Harts River	C32A, C32B, C32C, C32D
MRU Harts B	From origin of Harts River to Wentzel Dam	C31A, C31B, C31C,C31D, C31E
MRU Harts C	Wentzel Dam	C31E
MRU Harts D	From Wentzel Dam to Taung Dam	C31F
MRU Harts E	Taung Dam	C31F
MRU Harts F	From Taung Dam to irrigation canal	C31F, C33A
MRU Harts G	From irrigation canal to Spitskop Dam	C33A, C33B
MRU Harts H	Spitskop Dam	C33B, C33C
MRU Harts I	From Spitskop Dam to Vaal River confluence	C33C,C91E
*__Note__: Barberspan is assessed in Wetland report		C31D
RIET RIVER		
MRU Riet A	From origin to Kalkfontein Dam	C51A, C51B, C51C, C51D, C51E, C51F, C51G, C51H
MRU Riet B	Kalkfontein Dam	C51J
MRU Riet C	From Kalkfontein Dam to confluence with Modder River	C51K
MRU Riet C.1	Origin of Modder River to Krugerdrif Dam	C52A, C52B, C52C, C52D, C52E, C52F, C52G
MRU Riet C.2	Krugerdrif Dam	C52G
MRU Riet C.3	From Krugerdrif Dam to confluence with Riet River	C52H, C52J, C52K, C52L
MRU Riet D	From confluence with Modder River to confluence with Vaal River	C51L, C51M

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	Quaternary catchment
EWR 5	Vaal River: Just downstream Bloemhof Dam	Vaal River		S27.65541 E25.59564	11.08, 29.02	E: Lower Foothills	1211	MRU Vaal K	C91A
EWR 6	Harts River: Lloyds weir	Harts River	C3HART-DELPO	S28.37694 E24.30305	29.02; 30.01	E: Lower Foothills	1114	MRU Harts C	C33C
EWR 7	Vaal River: Schmidtsdrift	Vaal River	C9VAAL-SCHMI	S28.70758 E24.07578	29.02; 30.01	E: Lower Foothills	1239	MRU Vaal O	C92B
EWR 8	Riet River: At Lilydale Lodge	Riet River		S29 02 18.3 E24 30 10.2	29.02	E: Lower Foothills	1107	MRU Riet D	C51L

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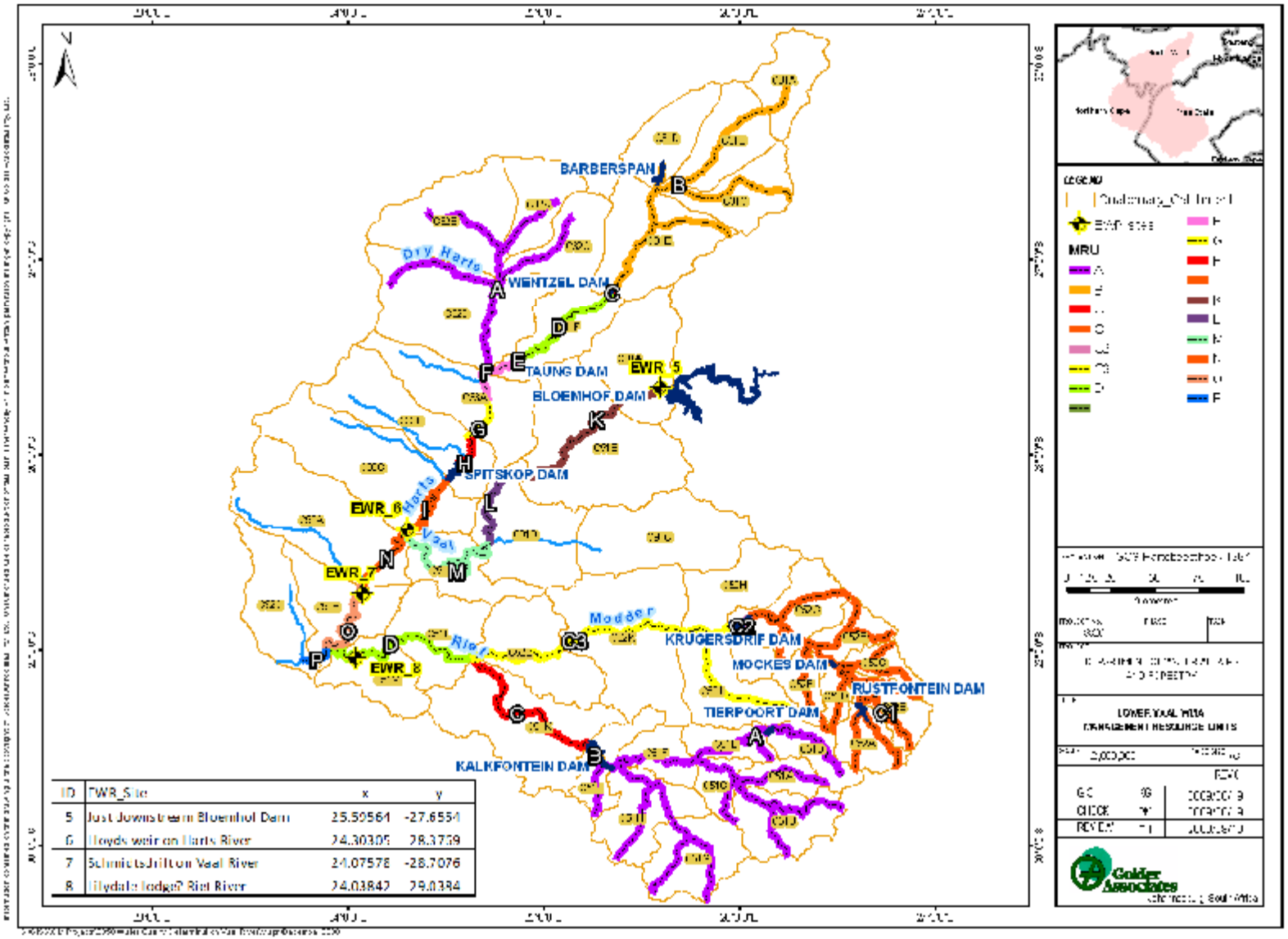

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1 INTRODUCTION

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 Vaal River catchment area within the Lower Vaal and Upper Orange Water Management Areas (WMAs) as requiring a comprehensive Reserve assessment. The purpose of the assessment is to determine the ecological and basic human needs water quantity Reserve for the rivers in the Vaal catchment areas within the WMAs. 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 lower Vaal River is the Vaal catchment within the Lower Vaal and Upper Orange WMAs (part of WMA 10 and 13) (**Error! Reference source not found.**). These catchment areas form part of the integrated Vaal River System, as they fall within the C drainage region of South Africa. The Lower Vaal WMA is one of the last 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 Lower Vaal WMA is situated in the north-western part of the country and forms part of the Orange River watercourse. It covers a catchment area of 133 354 km^2, and includes parts of the Northern Cape and North-West Provinces, and a small part of the Free State Province. The Vaal

River is the only major river in the WMA, as it flows in a westerly direction from Bloemhof Dam to the confluence with the Orange River. The largest part of the WMA falls within the catchment of the Molopo River, a tributary of the Orange River. The Molopo, Nossob and Kuruman rivers drain the remainder of the WMA but due to the very low rainfall in the WMA, these rivers are insignificant. The WMA consists of the D41 (excluding D41A), parts of D42C and D42D, parts of D73A and D73C, C31, C32, C33, C91, and C92 tertiary catchments. For the purpose of this study only the C drainage region is of relevance as it forms part of the Vaal River System, which includes the Harts River catchment and the Vaal River catchment. These two catchments as part of the Vaal River System cover a catchment area of 53 500km^2 within the Lower Vaal WMA. The C drainage region of the Lower WMA comprises four sub-catchments as listed in **Table 1**.

Table 1: Sub-catchments and related quaternary drainage regions within the C Drainage tertiary Catchment within the Lower Vaal WMA (DWAF, 2006)

PRIMARY CATCHMENT	SUB-CATCHMENT	QUARTENARY CATCHMENTS	AVERAGE GROSS AREA (km^2)
C	Dry Harts	C32A-D	10 205
	Harts	C31A-F	11 023
	Vaalharts	C33A-C	9843
	Vaal downstream Bloemhof	C91A-E, C92A-C	22 427

Virtually all the surface flow of the Vaal River, the main source of water in the Lower Vaal WMA, originates from the Upper and Middle Vaal WMAs. Very little surface run-off originates within the WMA itself due to the low rainfall, flat topography and sandy soils. The groundwater resource is more substantial, supplying an estimated 128 million m^3/annum. The Vaal River is fed by the only tributary, the Harts River which drains a catchment area of 31 000km^2, with the Dry Harts being the major tributary of the Harts River joining it just downstream of Taung. The only lake and wetlands of note are at Barberspan in the Upper Harts River catchment which has been given Ramsar status as a wildlife conservation area.

The development of the surface water resources occurring in the WMA has reached its potential, however all water is not being fully utilised. The water in Taung Dam and Spitskop Dam are currently not utilised and further studies are required to determine best how to utilise the water contained in these dams. There are several large dams that have been developed in the WMA.

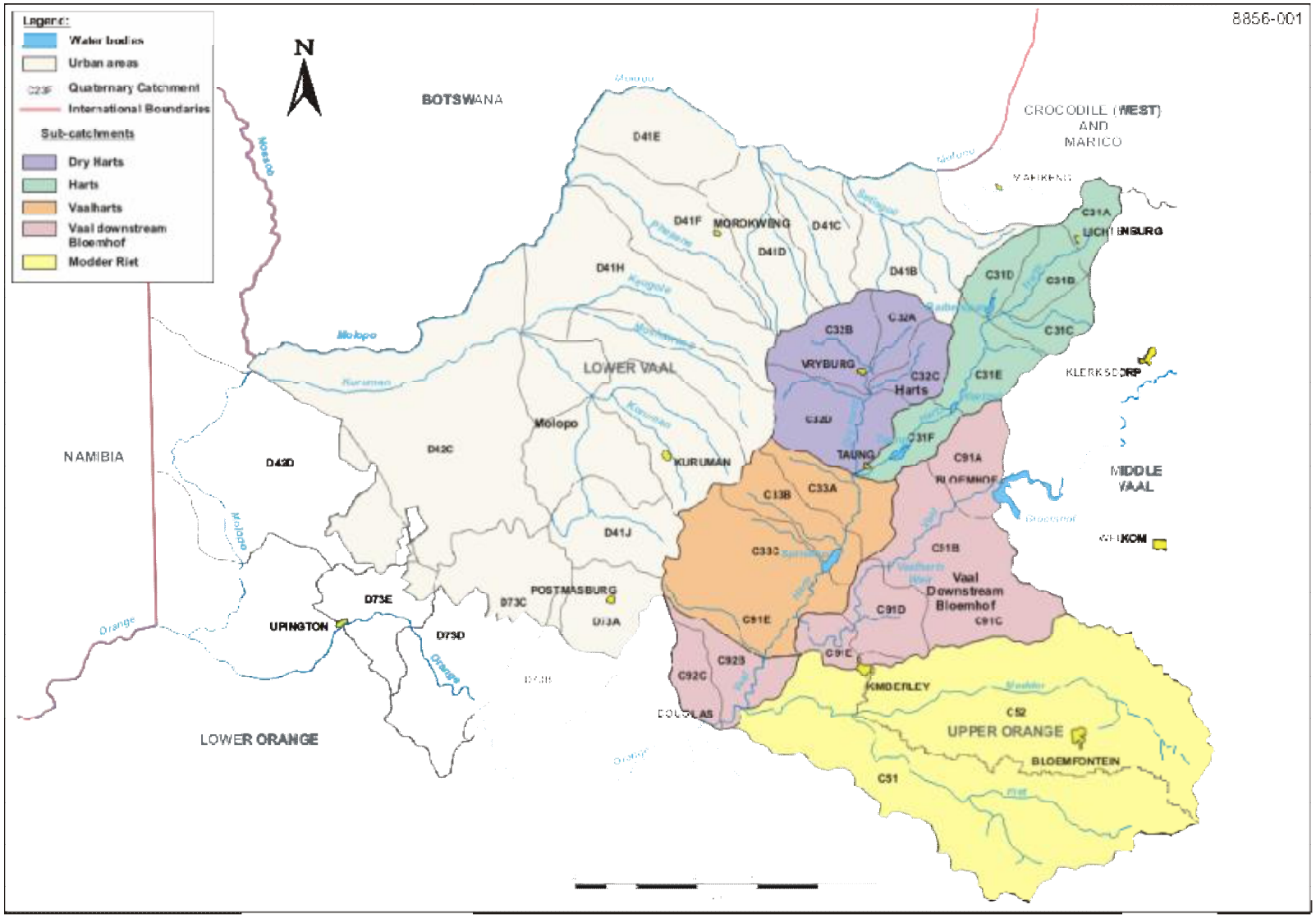

Figure 1: Lower Vaal River catchment areas (part of Lower Vaal and Upper Orange WMAs)

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 lower Vaal River catchment.

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 lower Vaal River on the basis of physiography, climate, geology and soils, natural vegetation and hydrological characteristics. The available Level II information was obtained from the DWAF, Directorate

Resource Quality Services (D:RQS). 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.

- ***Nama Karoo:*** This ecoregion is characterized by plains with a moderate to high relief and lowlands, hills and mountains with moderate to high relief are dominant. Vegetation consists almost exclusively of Nama Karoo types. The altitude ranges between 300 and 1700 m. Rainfall is concentrated in late to very late summer to winter, with a coefficient of annual variation of 30 to >40%. Mean annual air temperatures are between 12 and 20°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.

- ***Ghaap Plateau:*** This is an extensive dolomitic area characterized by plains with a low to moderate relief. Vegetation consists of a variety of Kalahari Bushveld types with Kalahari Plateau Bushveld being the most prominent. The altitude ranges between 900 and 1700 m. Rainfall is concentrated in mid to late summer, with a coefficient of annual variation of 30 to >40%. Mean annual air temperatures are between 16 and 20°C.

The Eco-Regions of the lower Vaal catchment are illustrated in

Figure 2.

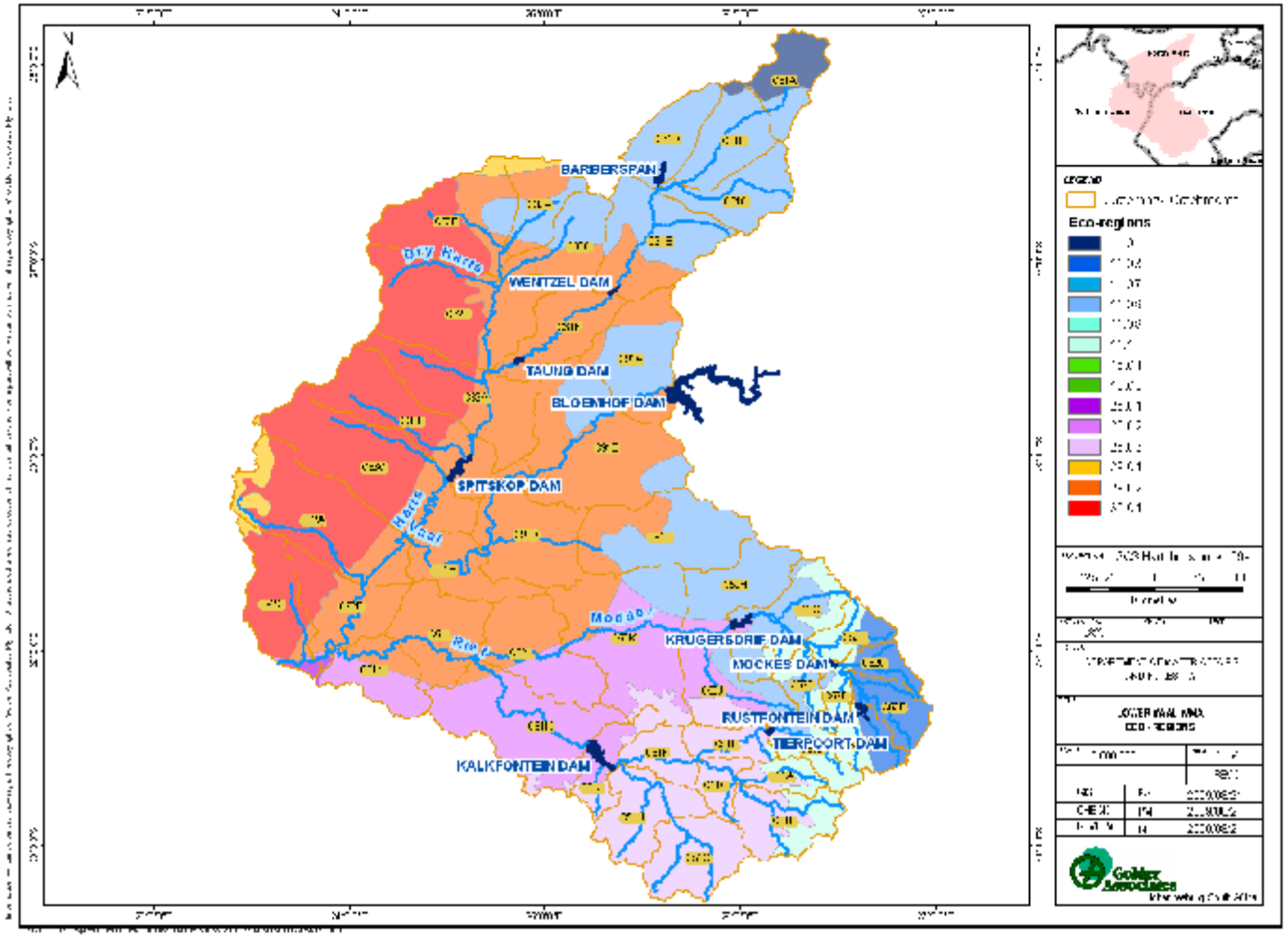

Figure 2: EcoRegion delineation of the lower Vaal catchment area

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 **Table 2**.

The hierarchical classification approach of Rowntree and Wadeson (1999) was followed. Based on the zone classification system the rivers in the lower Vaal catchment were delineated on the basis of their geomorphological features. The geomorphological delineation is illustrated in

Figure 3. All rivers in the lower Vaal River catchment area can be classified as a geomorhological Zone class E, Lower Foothills.

Table 2: 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.

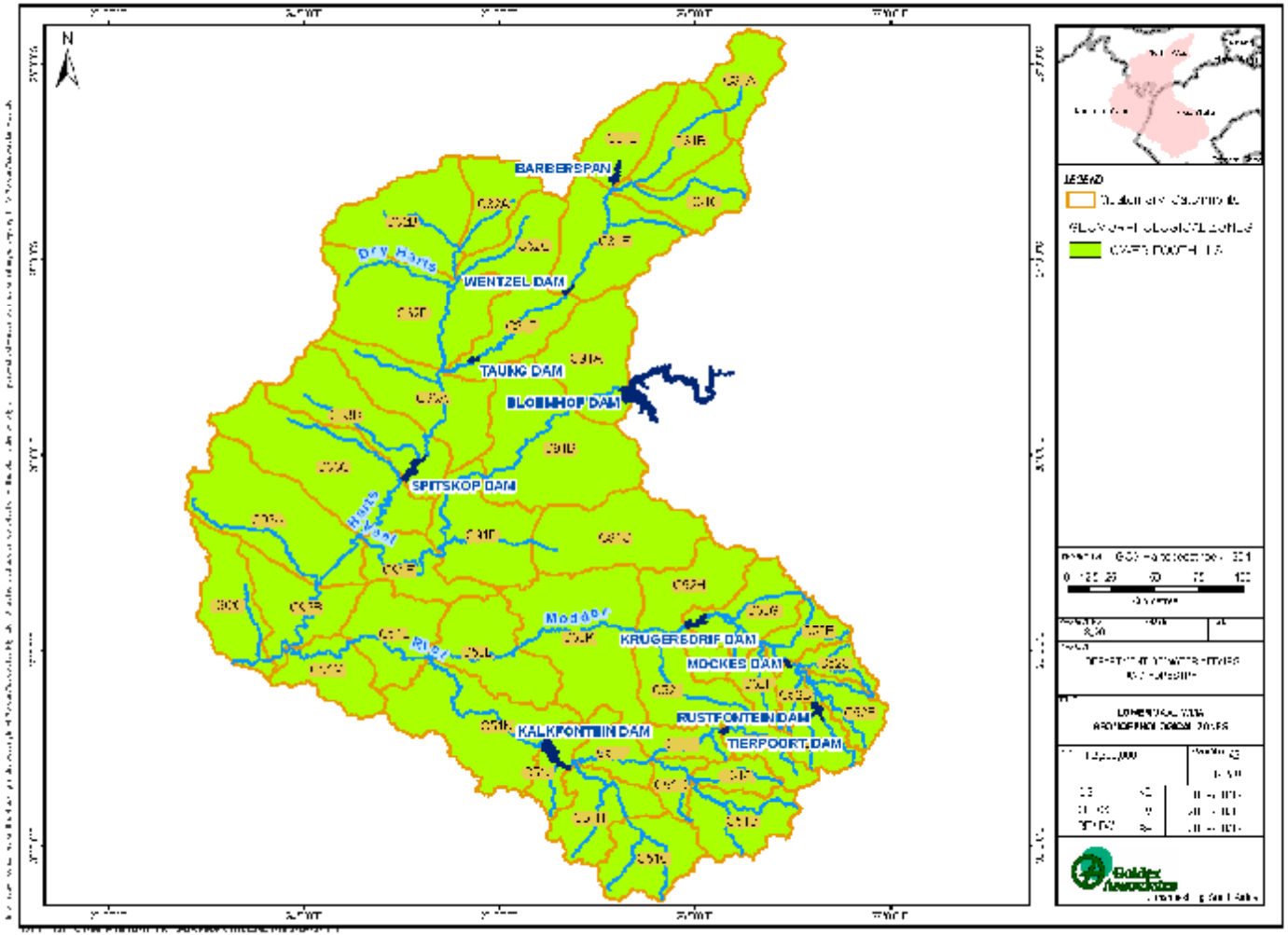

Figure 3: Geomorphological zonation of the rivers in the lower Vaal catchment area

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 lower Vaal River catchment 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 and some thorn trees, cultivated land and small scale alluvial diamond mines 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 Lower Vaal WMA is dependant on the Upper Vaal and Middle Vaal WMAs for supply of utilisable surface water resources, with over 90% of the water required being sourced through releases from the Upper Vaal WMA and from Bloemhof Dam. More than 50% of the yield from natural water resources in the tributary catchments within the WMA is supplied from groundwater. Water use in the water management area is dominated by irrigation, which represent 80% of the local requirements for water. About 12% of the requirements is for urban and industrial use, 7% for rural domestic supplies and stock watering, and the remainder for mining purposes. Over 85% of the requirements for irrigation are in the Harts sub-area, mainly at the Vaalharts irrigation scheme, with the balance being along the Vaal River. Water is also transferred into the WMA from the Upper Orange WMA into Douglas Weir. Large quantities of water are transferred from the Vaalharts weir on the Vaal River to supply the Vaalharts irrigation scheme in the Harts River catchment. The Vaalharts Irrigation scheme generates irrigation return flows which enter the Harts River upstream of Spitskop Dam. The return flows contribute salinity and nutrients to the Harts River.

There are several large dams that have been developed in the WMA. The main dams are listed in (**Table 3**).

Table 3: Major Dams in the Lower Vaal WMA (DWAF, 2006)

Dam name	Quaternary catchment	River	Purpose	Full Storage Capacity million m^3
Boegoeberg	D73B	Oranje	Irrigation	20.3
Douglas Weir	C92B	Vaal	Information/ irrigation	16.7
Spitskop	C33B	Harts	Irrigation	56.6
Taung Dam	C31F	Harts	Irrigation	6.6
Vaalharts Weir	C91B	Vaal	Domestic	48.7
Wentzel	C31E	Harts	Irrigation	6.6

The system operation is summarised below:

- **General description of overall system operation:** An important characteristic of the Integrated Vaal River System is the interdependencies that exist due to the numerous inter-basin transfers which form a complex network of interlinked reservoirs that are located in catchments with different hydrological characteristics. This necessitates that operation of the system is undertaken in an integrated manner to ensure the effects of operating rules are evaluated in a system context where the behaviour of all the components of the water resource system are evaluated and monitored. Therefore, as a general operation principle, the Integrated Vaal River System is operated as an integrated system irrespective of who owns or operate each component of the system.

  The 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 Lower Vaal WMA forms part of the Lower Vaal Subsystem of the Integrated Vaal River System, which extends from just downstream Bloemhof Dam to Douglas Barrage. The main dams in the subsystem, Wentzel, Taung and Spitskop with a combined storage capacity of 123 million m^3, are all located in the Harts River and their function is to supply local water requirements. Vaalharts Weir, with a capacity of 49 million m^3, is a regulation structure that diverts water into the canal system that feeds the Vaalharts Irrigation Scheme and releases water for the downstream users along the Vaal River.

- **Vaal River from Bloemhof Dam outflow to Vaalharts weir (C91A –B)**: The Lower Vaal Subsystem has limited local water resources and most of the water requirements in the subsystem are supplied through releases from Bloemhof Dam. The dam wall and outlet works are located within the Lower Vaal water management area immediately where the river enters the water management area from the Middle Vaal water management area. However most of the reservoir basin falls in the Middle Vaal water management area. The yield from the dam however, is available in the Lower Vaal water management area. Approximately 500 million m^3 of water per year is transferred from the Middle Vaal water management area to the Lower Vaal water management area.

  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. Only sufficient releases are made from Vaal Barrage and Vaal Dam for users along the Middle Vaal Reach (between Vaal Barrage and Bloemhof Dam) to satisfy their requirements and to

maintain the 600mg/l TDS concentration. These releases are mostly captured in Bloemhof Dam for subsequent supply to the downstream users.

The flow in this river reach is dominated by the releases made from Bloemhof Dam for the Vaalharts irrigation Scheme. Vaalharts Weir serves as the structure from where the irrigation water is diverted into the canal that feeds the Vaalharts Irrigation Scheme. Bloemhof Dam has substantial flow regulation capability.Due to the relative long river reach downstream of Bloemhof Dam and Vaalharts Weir, significant quantities of consumptive evaporative losses and non-consumptive operating losses are associated with releases in the river system.

To meet spiralling water demands within the basin, various importation schemes have been implemented.

- **Vaalharts Weir (C91B):** Vaalharts Weir is the main diversion weir on the Vaal River located downstream of Bloemhof Dam. It serves as a control structure to divert water into a canal system that feeds the Vaalharts Irrigation Scheme. Vaalharts Barrage has a capacity of 49 million m^3. Approximately 419 million m^3 of water is transferred per annum to Harts River catchment as part of the irrigation scheme.

  Water is released from Vaalharts Weir for irrigation and domestic users along this river reach. Vaalharts Weir has flow regulation capability of medium size freshets. Due to the negligible incremental runoff between Bloemhof Dam and Vaalharts Weir all water that has to be released from the Weir must be released from Bloemhof Dam. Any additional water released from the Weir will have an impact on the Integrated Vaal River System's water availability.

  Water quality in the Vaal River is seriously impacted upon by urban and industrial use as well as mining activities in the Upper and Middle Vaal WMAs, and is of relative high salinity. The Vaalharts irrigation scheme serves the purpose of beneficially utilising lower quality water discharged from the Upper Vaal WMA and thus prevents the build up of salinity in the lower reaches of the Lower Vaal WMA.

- **Vaal River from Vaalharts Barrage to Harts River confluence (C91D-E)**: The predominant water use in this region of the catchment is for irrigation agriculture with minor urban and industrial demands of which the water use to Kimberley is the most significant. The Vaal River also provides water to other riparian towns and to the Gamagara pipeline serving the Kalahari (Hotazel-Postmasburg) mineral complex.

- **Vaal River from Harts River confluence to Douglas Barrage (C92A-C):** In this part of the catchment the quality of surface water in the Harts and Vaal Rivers is highly impacted upon by irrigation return flows of the Vaalharts Irrigation Scheme as well as by water use in the Upper and Middle Vaal WMAs, which limits the usability of water in the lower reaches of these rivers. Water quality in the lower reaches of the Vaal River is also impacted upon by irrigation return flows from the Riet/Modder River necessitating further blending with low salinity water from the Orange River at the Douglas weir.

- **Douglas Barrage (C92C):** Douglas Barrage falls just outside the Lower Vaal WMA, immediately upstream of the Vaal River confluence with the Orange River. This is the most downstream section of the Vaal River before the confluence with the Orange River. Douglas Weir is the upstream storage structure, which has limited flow-regulating capability. Currently this river reach has no flow for most of the time and is operated to minimise flow in the reach. The river reach length is only 1 km.

  Water (18 million m^3/a) is also transferred into the water management area at Douglas Weir, from the upper Orange WMA (at Marksdrift) for water quality management purposes. The Douglas Irrigation Scheme is supplied from the Douglas Weir and, in addition to the runoff entering Douglas Weir from the upstream incremental catchments, water is transferred (pumped) from the Orange River into Douglas Weir. No releases are made from storage structures in the Vaal, Harts or Riet/Modder river systems to support the water requirements in Douglas Weir.

  Since the inception of the Douglas irrigation scheme water quality in the Lower Vaal River has deteriorated dramatically. The layout of the scheme as well as the position where the water transferred from the Orange River is discharged upstream of the weir, are poorly suited for water quality management purposes and the continued feasibility of the scheme is unclear. Without excess releases from Bloemhof Dam the scheme would not be sustainable. Douglas weir is operated such that no water apart from spills flows into the Orange River.

- **Harts River (C31, C32, C33):** The Harts River system is in the C3 drainage region of South Africa. Its source is near the town of Lichtenburg in the North West Province, although the larger part of the catchment is situated in the Northern Cape Province. The Harts River flows in a south-westerly direction via Barberspan, the Taung and Spitskop dams, after which it flows into the Vaal River near Delportshoop . The major water uses in the Harts River catchment are domestic and agriculture. Agriculture consists of irrigation and stock watering. Irrigation is the biggest water user with the majority of the irrigation located in the Vaalharts Irrigation Scheme. There is also irrigation located along the reach of the Harts River below Spitskop Dam**.** The only lake and wetlands of note are at Barberspan in the upper Harts River catchment, which has been given Ramsar status as a wildlife conservation area.

  The Harts River reach upstream of Wentzel Dam has no upstream regulating storage and there are substantial irrigation abstractions that are already experiencing low assurance of supply. Water is also transferred from the Harts River (approximately from the outlet of C31B) into Barberspan (located in quaternary C31D). This transfer will result in some of the base flow being removed from the river reach. The exact operation of this transfer is unknown (capacity of the transfer infrastructure etc.) at this point in time and is currently been investigated.

  Wentzel Dam is located at the outlet of quaternary C31E, and has limited release capability. The dam supplies water to Wentzel Town for domestic purposes. The available yield of Wentzel Dam is fully utilised and any further releases will result in a deficit in supply.

Taung Dam is not utilised and investigations are currently underway to determine the feasibility of using the dam to supply domestic and/or irrigation water requirements from the dam. Taung Dam will have limited release capability (remedial civil works are being carried out on the release structures).

Significant flows occur in the Harts River reach upstream of Spitskop Dam from the return flows of the Vaalharts Irrigation Scheme. The return flows have substantially changed the flow regime compared to natural conditions. This river reach receives flows from the Dry Harts River (upstream of and including quaternary C32D), which has no regulating storage structure as well as from Taung Dam located in quaternary C31F.

The water available in Spitskop Dam is more than the water requirements supplied from the dam. This is due to the large volume of return flows generated by the Vaalharts Irrigation Scheme located upstream of the dam. Water is released from Spitskop Dam from where it is abstracted for irrigation along the river reach. Spitskop Dam has the capability to regulate flow releases in this river reach. Investigations are in progress to identify potential further user of the excess water available in the dam.

An appropriate balance exists for the Harts River catchment as only enough water is transferred from the Vaal River into the area to meet the water requirements, while return flows from the catchment are available for use along the lower Vaal River.

According to the River Health Programme (2003), the overall water quality status of the lower Harts River is in a fair to poor condition while the upper region remains in a good to fair condition. The water quality and flows of the lower section of the Harts River between Taung Dam and Spitskop Dam is impacted by return flows from the Vaalharts Irrigation Scheme. The water is of exceptional high salinity as a result of saline leachate from the irrigation fields (± 1 100 mg/l salinity). The salinity and nutrient loads associated with the return flows has resulted in increased concentrations in the lower reaches of the Harts River and in Spitskop Dam. The quality of the water discharging from the Harts River into the Vaal River has been cited as a contributing factor to the blue-green algal blooms that sporadically occur in the lower reaches of the Orange River below the confluence with the Vaal River. Management of water quality (salinity) at the Vaalharts irrigation scheme and downstream of Spitskop Dam thus remains of primary importance.

- **Riet River (C51, C52):** The Modder Riet catchment is situated in the Free State and Northern Cape Provinces. It is part of the Upper Orange WMA, but forms part of the C drainage region (Vaal River System). It covers a catchment area of 35 000 km^2. The Modder and Riet Rivers are the only major rivers in the catchment, which drain into the Vaal River which subsequently flows into the Orange River. The catchment includes Kalkfontein, Rustfontein, Tierpoort, Groothoek and Krugersdrift Dams.

  The Riet River generally flows in a north-westerly, to the confluence with the Vaal River. The Tierpoort dam which is used for irrigation purposes is situated on the tributary of the Riet River,

and the Kalkfontein Dam which supplies water to the Riet River Government Water Scheme, is located just downstream of the confluence of the Kromellenboogspruit and Riet Rivers. The Modder River is the main tributary of the Riet River and joins the Riet River just upstream of Ritchie. The Modder River has its source in the high hills at the watershed near Dewetsdorp (1600m above mean sea level). The Krugersdrift Dam is located on the Modder River. Most of the natural runoff into the Modder River is from above the confluence of the Modder and Klein Modder Rivers. The rest of the Modder River catchment is very flat and very little runoff occurs.

Current land use in the catchment is related agricultural activities, urbanisation and mining and industrial activities. In the Modder and Riet River catchments agricultural use comprises primarily the irrigation of crops. Agricultural activities are concentrated around the dams in the catchment. Livestock watering also occurs, but to a lesser extent. The major urban centres in the catchment are Bloemfontein, Botshabelo and Thabu Nchu. The Modder River is a major source of water to these urban areas. Most industries in the Modder and Riet catchments are centred around Bloemfontein and use treated water from the municipal supply system. Only one industry that uses water directly out of the river is known.

2.2.5 Water Quality sub-units

Water quality sub-units (WQSUs) define areas of homogenous water quality. Changes in water quality may be natural e.g. input of water from tributaries, or man-made, e.g. abstractions and discharges, towns, tributaries, industries, sewage treatment works etc. All these factors therefore can cause changes in water quality and define WQSUs. The water quality delineation of the study area, Middle Vaal WMA (WMA 9) was undertaken to identify these changes. The relevant WQSUs are provided in Table 4 below.

Table 4: Water Quality sub-units of the Lower Vaal WMA

Water Quality Subunit Number	Quartenary Catchment(s)	Major River/Dam unit	Reason: Water Quality Issues
62	C91A, C91B	Vaal River (downstream Bloemhof Dam to Vaalharts Weir)	Fairly good water quality
63	C91C, C91D, C91E	Vaal River (Vaalharts weir to upstream Harts River confluence)	TDS moderately high but shows significant increase. Nutrients relatively low and stable.
64	C31A, C31B, C31C, C31D, C31E, C31F, C32A, C32B, C32C, C32D	Harts and Droë Harts River (Taung Dam)	Good quality water
65	C33A	Harts (below confluence upstream Spitskop Dam)	Good quality water
66	C33B	Spitskop Dam	Algal blooms/ Salinity

Water Quality Subunit Number	Quartenary Catchment(s)	Major River/Dam unit	Reason: Water Quality Issues
67	C33C	Harts River (downstream Spitskop Dam)	Extremely high salinity. Relatively low phosphates.
68	C92A, C92B	Vaal River (downstream Harts River confluence to just upstream Douglas weir)	Extremely high salinity
69	C52A	Rustfontein	WQ impacts from Cattle farming
70	C52A	Rustfontein Dam	Impact from Dewetsdorp sewage works. Algal blooms
71	C52B, C52D	Modder River (upper reaches, below Rustfontein Dam)	Increasing nutrients; impact from Botshabelo sewage works.
72	C52C	Korannaspruit	Agricultural activities impact on tributary is relatively low.
73	C52E, C52F, C52G	Middle Modder River	High phosphate concentrations - algal blooms (impact from Bloemfontein sewage works)
74	C52G	Krugerdrif Dam	Algal blooms - cyanobacteria; fish kills
75	C52H, C52J, C52K, C52L	Modder River (downstream Krugerddrif Dam to just upstream confluence with Riet)	Increasing salinity (irrigation)
76	C51D	Kafferspruit	No real issues at present.
77	C51D	Tierpoort Dam	
78	C51A, C51B, C51C, C51E, C51F, C51G, C51H	Riet River (upper reaches) / Kromellenboogspruit	High phosphate concentrations. Diamond diggers. Impact of sewage works in area.
79	C51J	Kalkfontein Dam	
80	C51K	Middle Riet River	Increasing salinity, high phosphate concentrations (however lower than upper reaches)
81	C51L, C51M	Lower Riet River (after confluence with Modder River)	High salinity
82	C92C	Vaal River at Douglas Barrage	Fairly good water quality, however, diluted by Orange River water. Increasing trend for phosphate concentrations. High salinity
83	C92C	Vaal River after Riet River confluence	High salinity

3 DELINEATION RESULTS

3.1 VAAL RIVER

3.1.1 Natural Resource Unit and Management Resource Unit: Vaal River outflow from Bloemhof Dam to Vaalharts weir:

Based on the biophysical characteristics of the Vaal River two natural resource units (NRU), NRU 1 NRU 2 are delineated from the outflow Bloemhof Dam to Vaalharts weir (

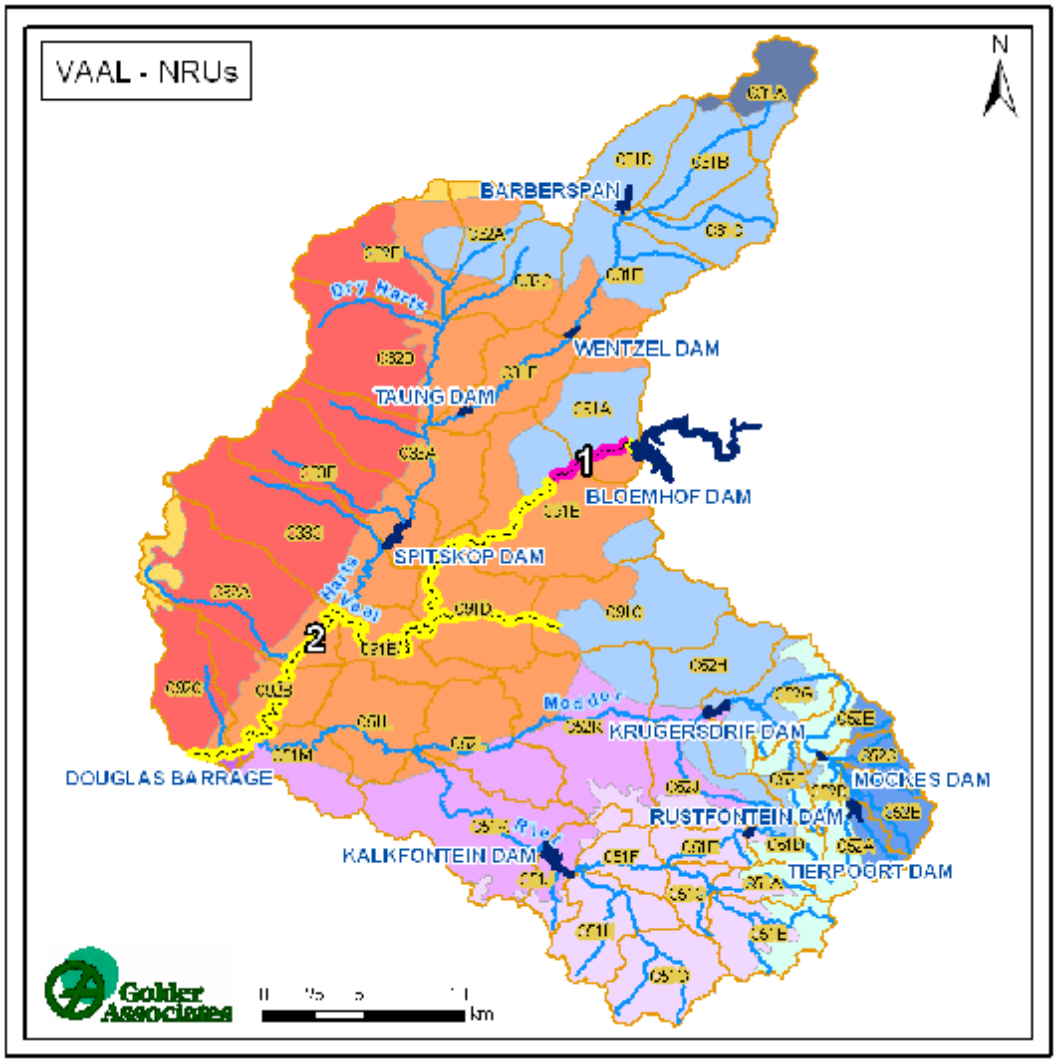

Figure 4). The EcoRegions and geomorphic zones of the NRUs are described in Table 5.

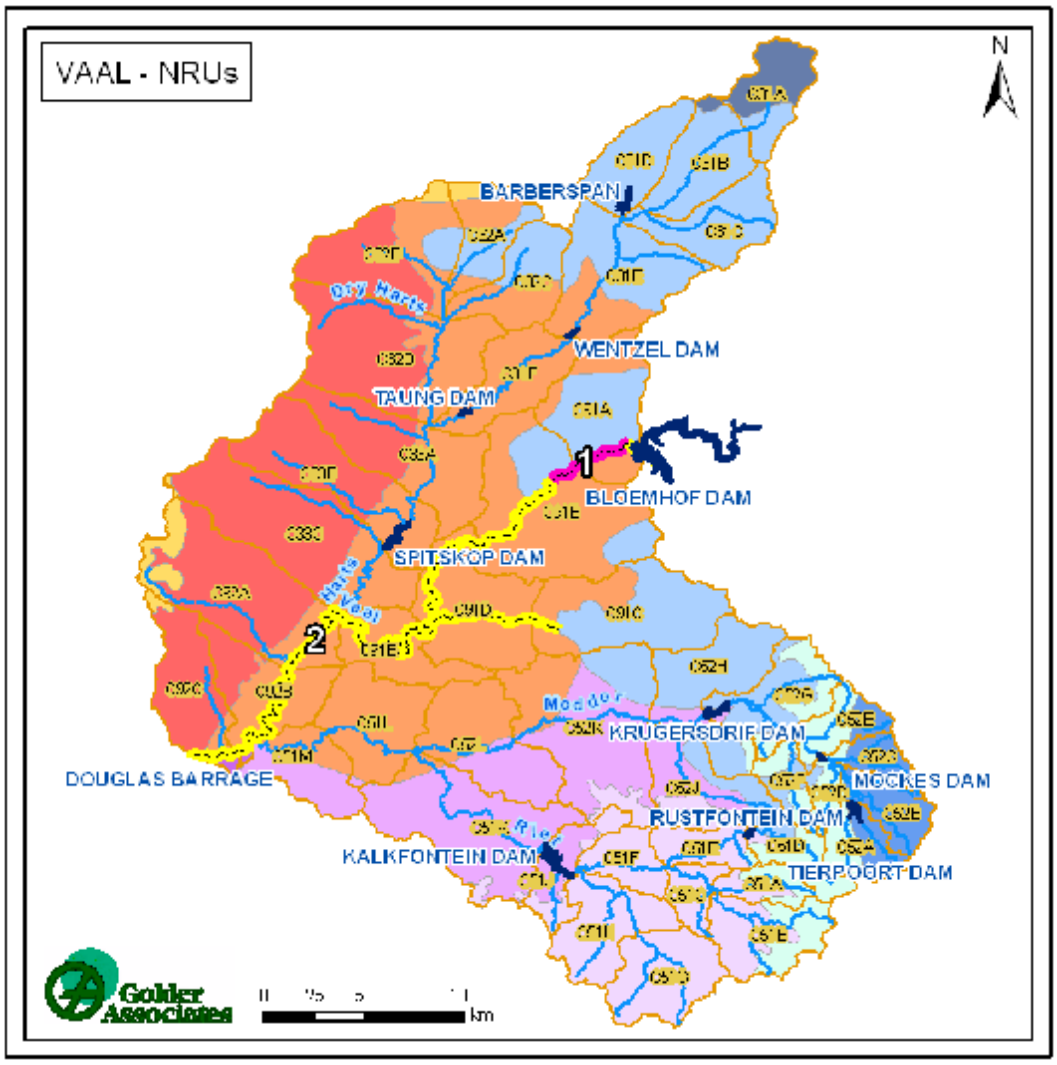

Figure 4: Vaal River from outflow Bloemhof Dam to Vaalharts weir: Natural Resource Units

Table 5: Description and rationale for the Vaal River Natural Resource Units, NRU 1 and NRU 2 (from outflow Bloemhof Dam to Vaalharts weir)

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU 1	11.08 29.02	Lower Foothills (100%)	The Eco-region is major considerations in defining the NRU.	25.73611; - 27.74138
NRU 2	29.02	Lower Foothills (100%)	The Eco-region is the major considerations in defining the NRU.	25.24829 ; - 29.07551

The NRUs, based on the system characteristics, management and operation is also delineated into a

management resource unit (MRU), MRU Vaal K. The MRU is shown in (Figure 5) and the rationale for its selection is defined in

Table 6.

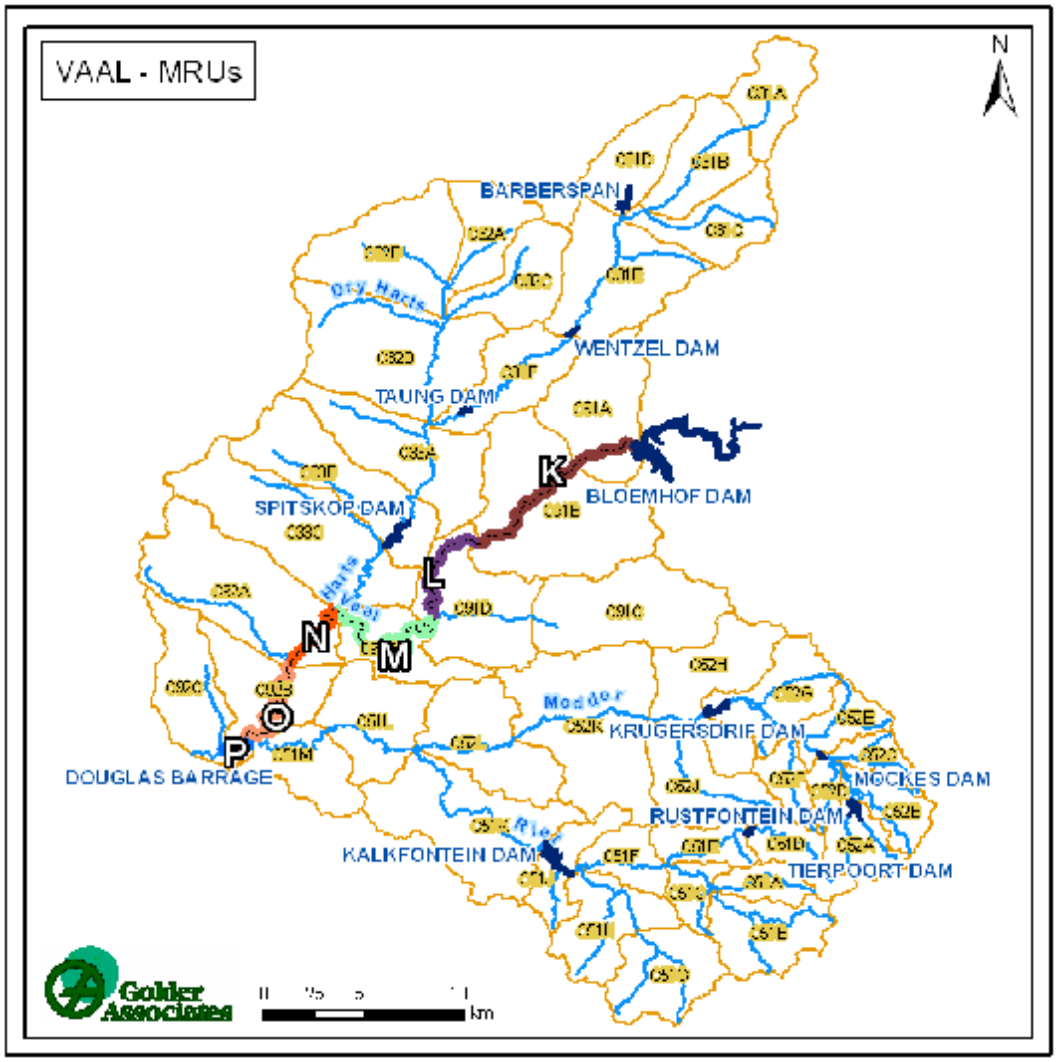

Figure 5: Vaal River MRU Vaal K (from outflow Bloemhof Dam to Vaalharts weir)

Table 6: Description and rationale of the Vaal River MRU Vaal K (from outflow Bloemhof Dam to Vaalharts weir)

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

MRU Vaal K	11.08; 29.02	Lower Foothills (100%)	Mostly thicket /bushveld. Some natural grassland.	The MRU is a logical break in the system and coincides with the boundaries of Bloemhof Dam (upper) and Vaalharts weir (lower). The area includes similar land use along the length of the river. It also delineated by the operation of the system in this reach. The unit does warrant a selection of a comprehensive EWR site as it just downstream the Middle Vaal WMA (it is important to understand the influence of the Upper and Middle Vaal WMAs); and importance was rated as 3.	24.92298; - 28.11121	C91A; C91B

3.1.2 Natural Resource Unit and Management Resource Units: Vaal River from Vaalharts weir to Douglas Barrage

Based on the biophysical characteristics of the Vaal River a natural resource unit (NRU), NRU 2 is delineated from Vaalharts weir to Douglas Barrage (

Figure 6). The EcoReg

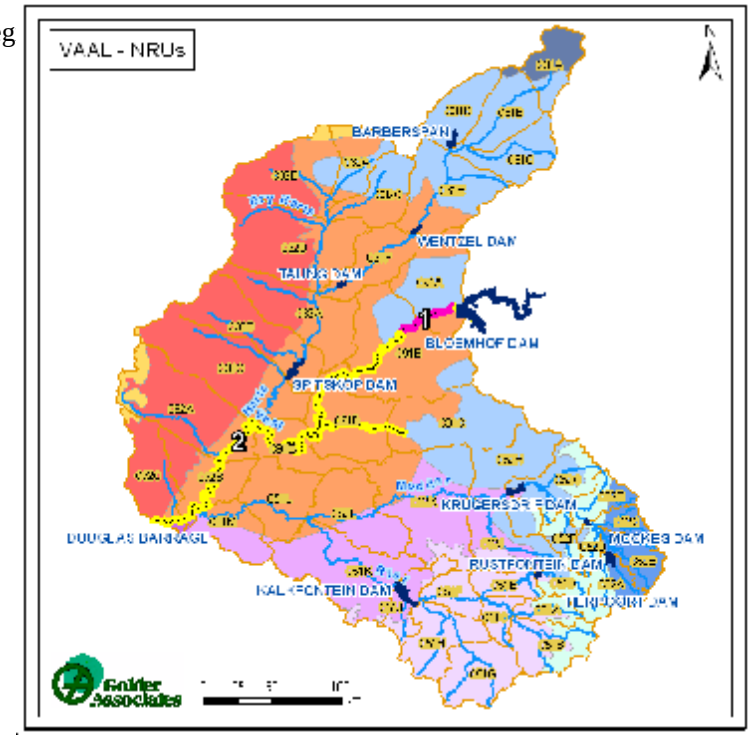

Figure 6: Vaal River from the Vaalharts weir to Douglas Barrage: Natural Resource Unit

Table 7: Description and rationale of the Vaal River Natural Resource Unit, NRU 2 (Vaalharts weir to Douglas Barrage)

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU 2	29.02	Lower Foothills (100%)	The Eco-Region and geomorphology are the major considerations in defining the NRU.	25.24829; - 29.07551

The NRU, based on the system characteristics, management and operation is also delineated into the management resource units (MRUs), MRU Vaal L, MRU Vaal M, MRU N and MRU Vaal O. The MRUs are shown in (Figure 7) and the rationale for their selection is defined in Table 8.

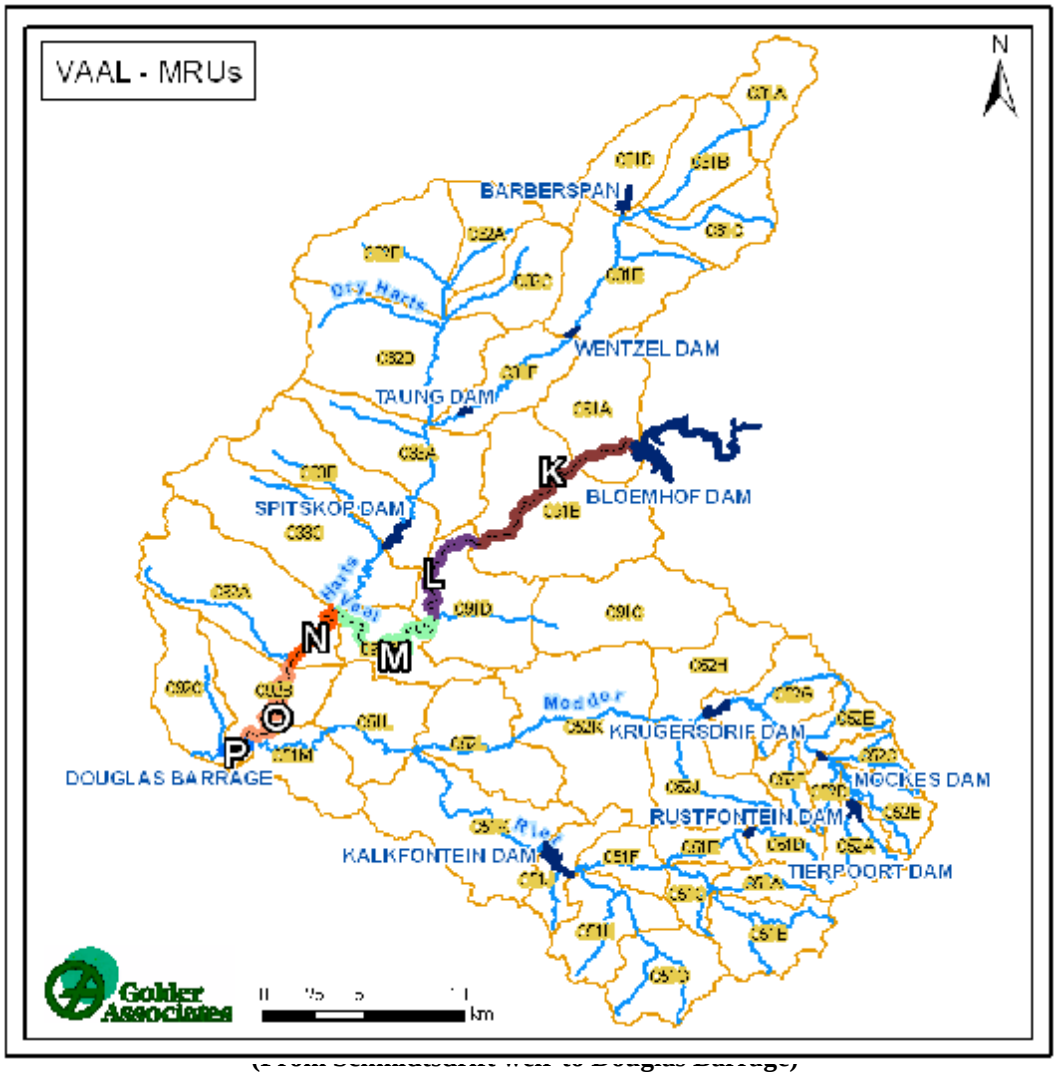

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Table 8: Description and rationale of the Vaal River MRU Vaal L (Vaalharts Barrage), MRU Vaal M (Vaalharts weir to Harts River confluence), MRU Vaal N (From Harts River confluence to Schmidtsdrift weir) and MRU Vaal O (From Schmidtsdrift weir to Douglas Barrage)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Vaal L	29.02	Lower Foothills	Mostly thicket/ bushveld/fynbos. Some natural grassland. Limited cultivated land (commercial crops).	The Vaal river is logically delineated at Vaalharts weir. This reach includes one Ecoregion and geomorphic zone. The MRU comprises the barrage, and is inundated with water. The barrage serves as a critical point in the system from an operation point of view in the Vaal River System. Water is released to supply the Vaalharts Irrigation Scheme. This MRU comprises the barrage only, but the Vaal River in this reach of the catchment has a priority rating of 3, (high EIS – integrity to be maintained).	24.72917; -28.45218	C91B
MRU Vaal M	29.02	Lower Foothills	Mostly thicket/ bushveld/fynbos. Some natural grassland. Limited cultivated land (commercial crops).	The MRU is delineated from Vaalharts weir to the Harts River confluence. The river consists of one geomorphic zone with similar land cover. The major water use in this reach is irrigation and some urban and industrial water demands. No major influences occur in this reach - the major abstractions occur at Vaalharts weir. The reach was rated as a priority of 3 – necessary to maintain integrity of Vaal River and environmental flows required for yellow fish movement.	24.27798; -28.40254	C91D, C91E
MRU Vaal N	29.02	Lower Foothills	Mostly thicket/ bushveld/fynbos. Limited cultivated land (commercial crops).	The MRU is delineated from the Harts River confluence to Schmidtsdrift weir on the Vaal River. The weir forms a management delineation break in the system. Abstractions occur at this weir. The river consists of one geomorphic zone with similar land cover within this reach. This reach is highly impacted by the Harts River in terms of water quality (high TDS). This reach was rated as a priority of 1.	24.06701; -28.66271	C92A, C92B

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Vaal O	29.02; 26.02	Lower Foothills	Mostly thicket/ bushveld/fynbos. Some cultivated land (commercial – irrigated).	The MRU is delineated from Schmidtsdtift weir to Douglas Barrage. The river consists of one geomorphic zone with similar land cover. Douglas Barrage forms the lower delineation area of the reach. The lower level of the reach is inundated with Douglas Barrage water. Priority of this reach was rated as a 3, to maintain integrity of the Vaal River.	24.06701; -28.66271	C92B, C92C

3.1.3 Natural Resource Unit and Management Resource Unit: Vaal River at Douglas Barrage (end of Vaal River System)

Based on the biophysical characteristics of the Vaal River a natural resource unit (NRU), NRU 2 is delineated on the Vaal River at Douglas Barrage (Figure 8). The EcoRegions and geomorphic zone of the NRU are described in **Table 9**.

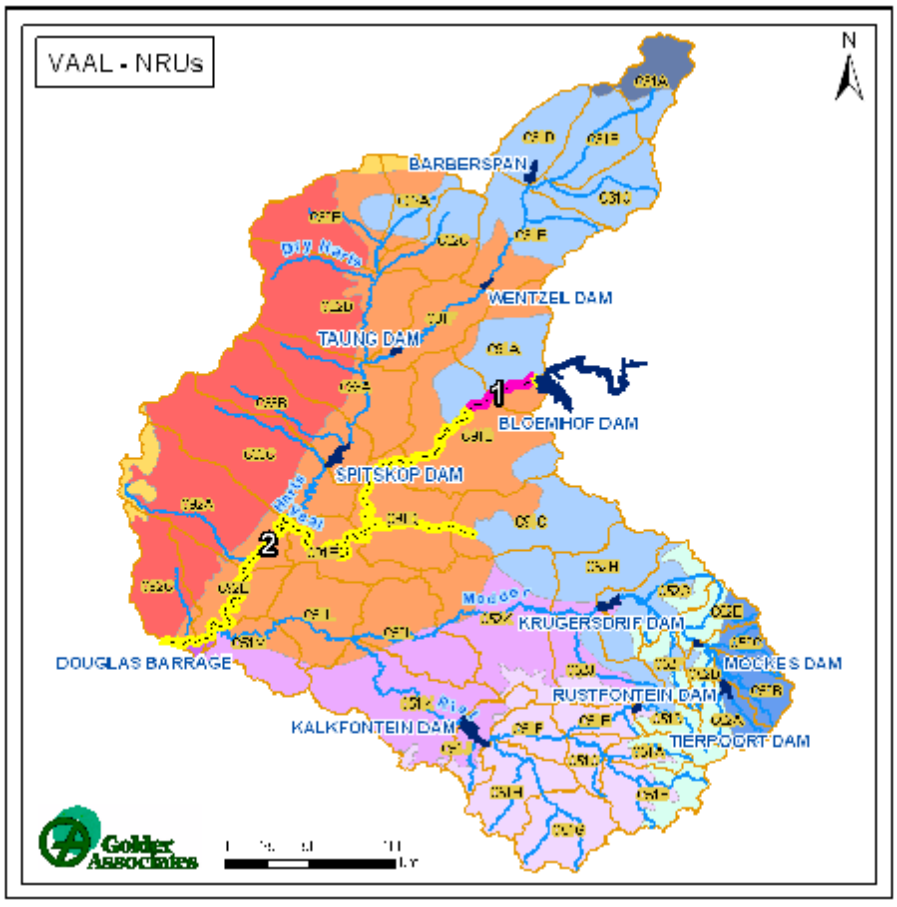


Figure 8: Vaal River at Douglas Barrage: Natural Resource Unit

Table 9: Description and rationale for the Vaal River Natural Resource Unit (Vaal River at Douglas

Barrage)

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU 2	29.02; 26.01; 26.02	Lower Foothills (100%)	The EcoRegions were the major consideration that defines the NRU.	25.24829; -29.07551

The NRU, based on the system characteristics, management and operation is also delineated as the MRU Vaal P, Douglas Barrage. The MRU is shown in (

Figure

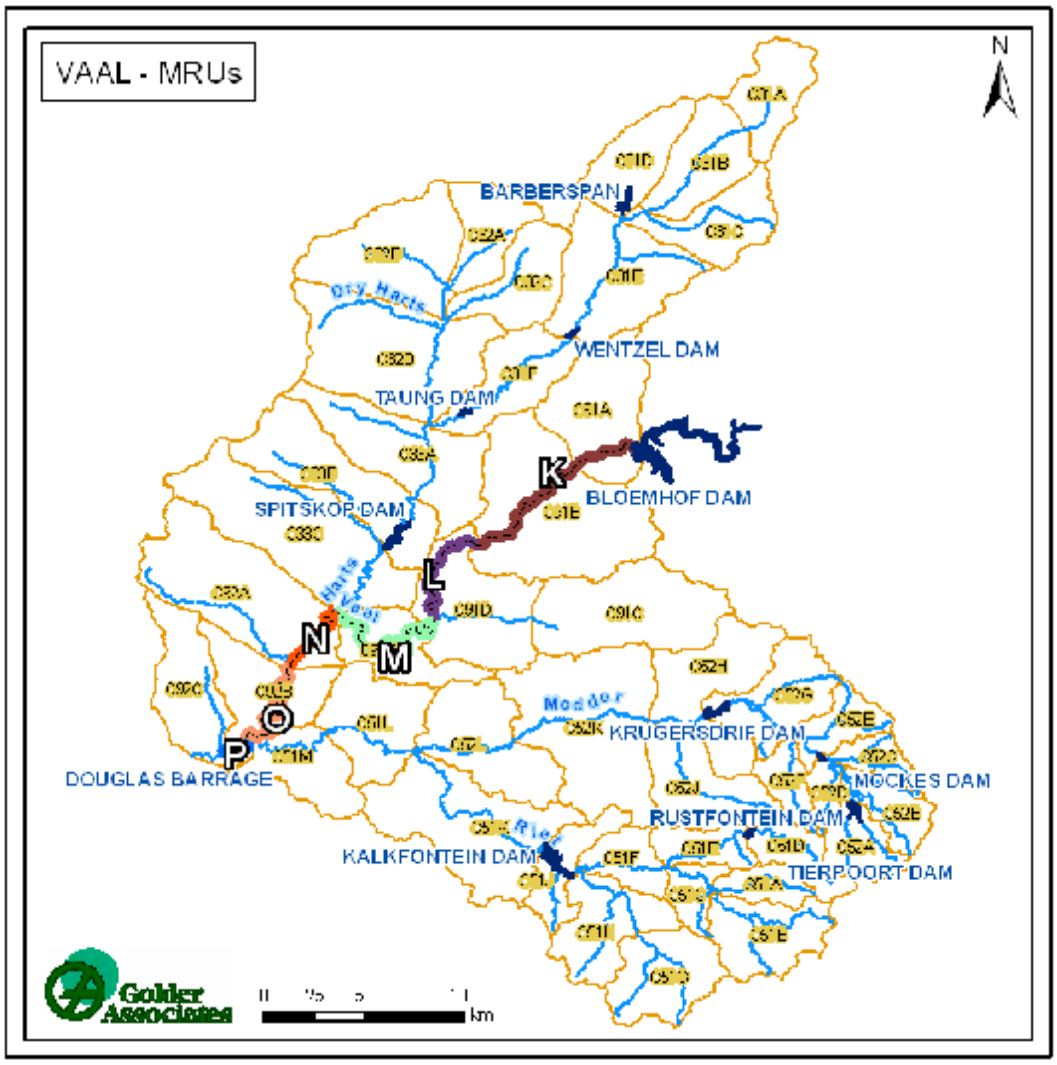


Figure 9: Vaal River MRU Vaal P (Douglas Barrage)

Table 10: Description and rationale of the Vaal River MRU Vaal P (Douglas Barrage)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Vaal P	29.02; 26.01; 26.02	Lower Foothills (100%)	Dominated by cultivated commercial crops (irrigated). Includes some thicket/ bushveld/fynbos.	The Vaal river is logically delineated at the end of the WMA/system by Douglas Barrage. The MRU comprises the Barrage, and is inundated with water. This reach includes more than one Ecoregion and one geomorphic zone. This is the most downstream section of the Vaal River before the confluence with the Orange River. The Riet River flows into the Barrage from the Upper Orange WMA. Water is also transferred into the water management area at Douglas from the Upper Orange WMA for water quality management purposes. The Barrage supports the Douglas Irrigation System. This MRU has a priority rating of 1.	24.06701; -28.66271	C92C

3.2 TRIBUTARIES OF THE VAAL RIVER

3.2.1 Harts River: Natural Resource Units and Management Resource Units

Based on the biophysical characteristics of the Harts River catchment three natural resource units (NRUs), NRU 1, NRU 2 and NRU 3 can be delineated (Figure 10). The EcoRegion and geomorphic zone of the NRUs are described in Table 11.

Table 11: Description and rationale for the Harts River Natural Resource Units

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Harts 1	11.01	Lower Foothills (100%)	The EcoRegion was the major consideration that defines the NRU.	26.25874; -26.08378
NRU Harts 2	11.08	Lower Foothills (100%)	The EcoRegion was the major consideration that defines the NRU.	25.47628; -26.92132
NRU Harts 3	29.02	Lower Foothills (100%)	The EcoRegion was the major consideration that defines the NRU.	24.27798; -28.40254

The NRUs, based on the system characteristics, management and operation is also delineated into the management resource units (MRUs), MRU Harts A (from origin of Dry Harts to confluence with Harts River), MRU Harts B (from origin of Harts River to Wentzel Dam), MRU Harts C (Wentzel Dam), MRU Harts D (From Wentzel Dam to Taung Dam), MRU Harts E (Taung Dam), MRU Harts F (from Taung Dam to irrigation canal), MRU Harts G (from irrigation canal to Spitskop Dam), MRU Harts H (Spitskop Dam) and MRU Harts I (from Spitskop Dam to Vaal River confluence). The MRUs are shown in (Figure 11) and

the rationale for their selection is defined in Table 12.

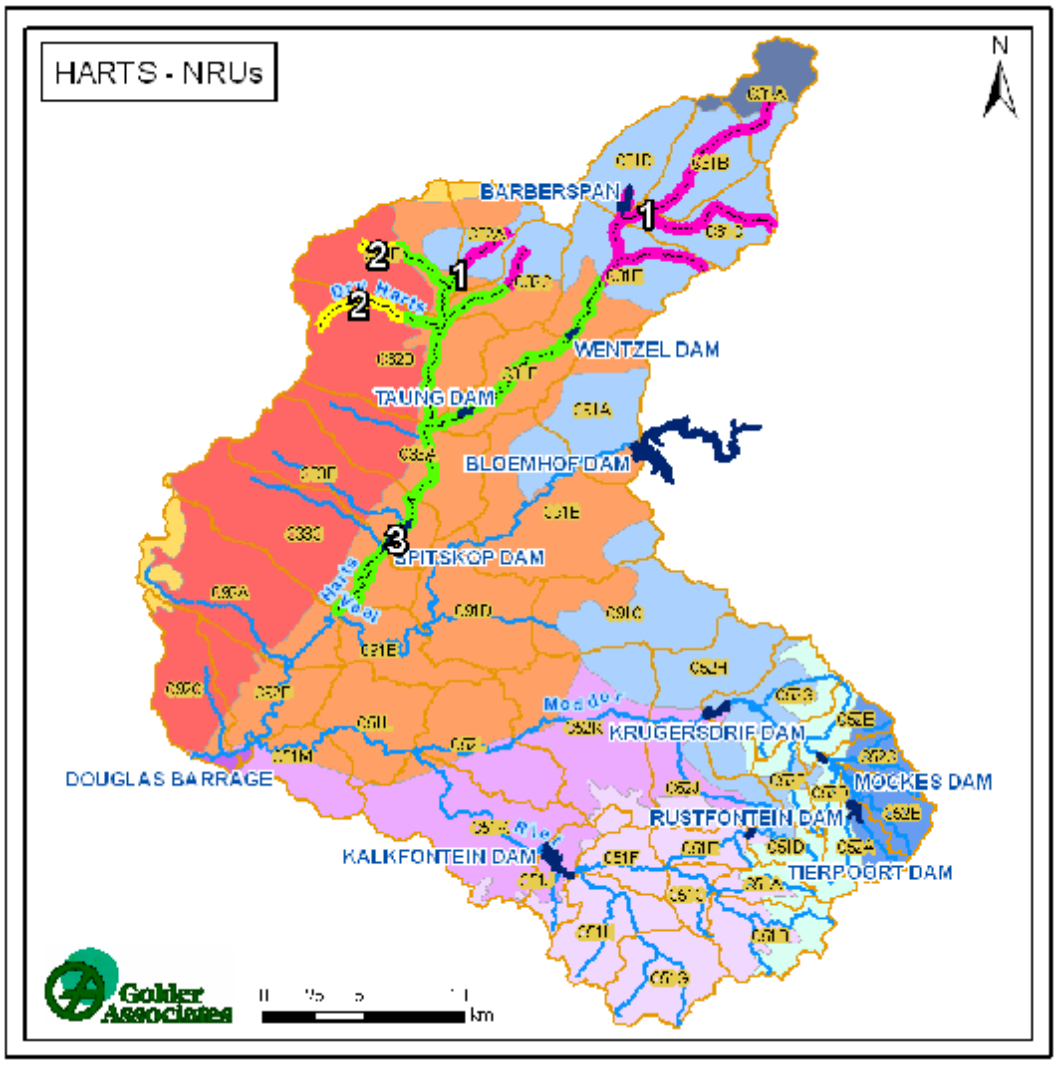


Figure 10: Harts River: Natural Resource Units

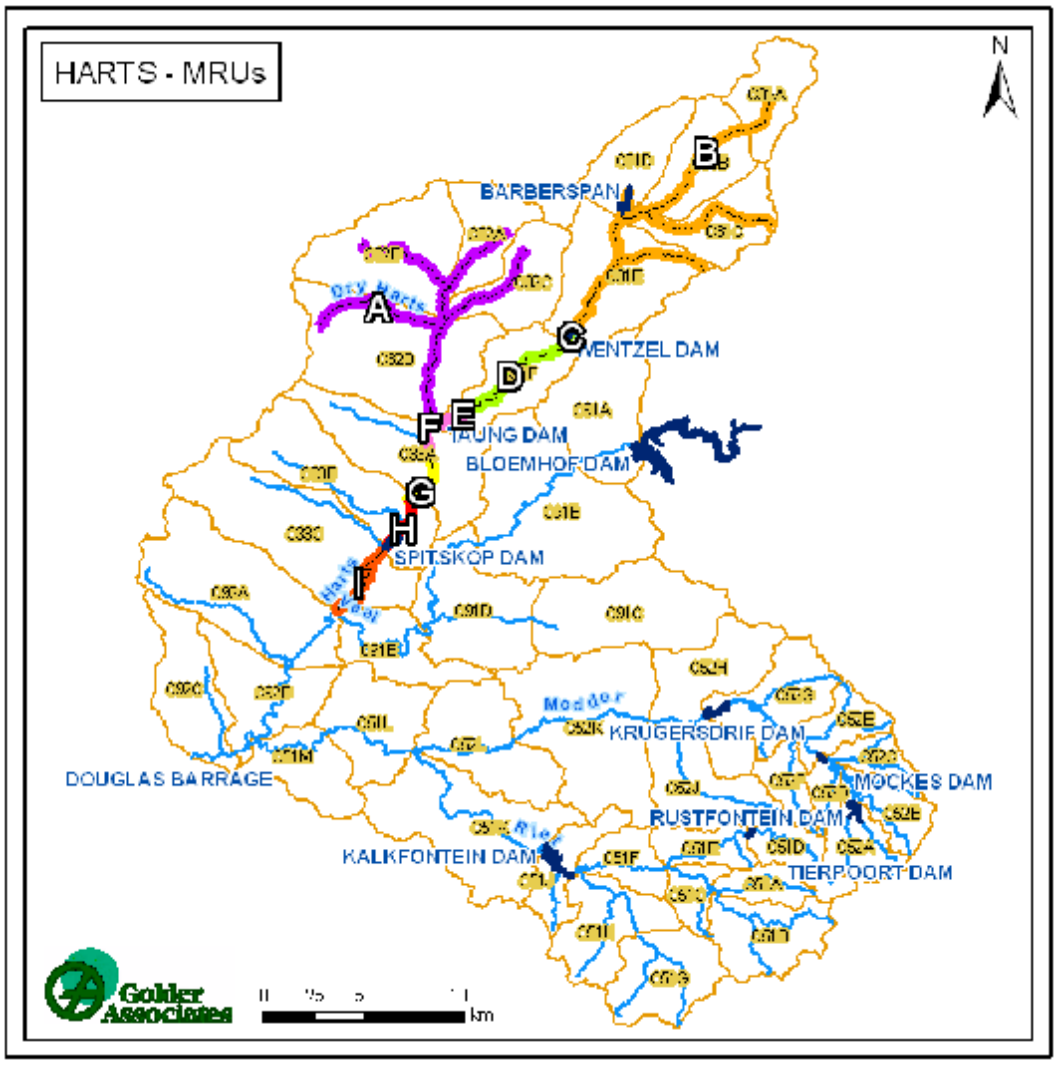


Figure 11: Harts River Management Resource Units: MRU Harts A (from origin of Dry Harts to confluence with Harts River), MRU Harts B (from origin of Harts River to Wentzel Dam), MRU Harts C (Wentzel Dam), MRU Harts D (From Wentzel Dam to Taung Dam), MRU Harts E (Taung Dam), MRU Harts F (from Taung Dam to irrigation canal), MRU Harts G (from irrigation canal to Spitskop Dam), MRU Harts H (Spitskop Dam) and MRU Harts I (from Spitskop Dam to Vaal River confluence).

Table 12: Description and rationale of the Harts River Management Resource Units: MRU Harts A (from origin of Dry Harts to confluence with Harts River), MRU Harts B (from origin of Harts River to Wentzel Dam), MRU Harts C (Wentzel Dam), MRU Harts D (From Wentzel Dam to Taung Dam), MRU Harts E (Taung Dam), MRU Harts F (from Taung Dam to irrigation canal), MRU Harts G (from irrigation canal to Spitskop Dam), MRU Harts H (Spitskop Dam) and MRU Harts I (from Spitskop Dam to Vaal River confluence).

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Harts A	11.08, 29.01, 29.02, 30.01	Lower Foothills (100%)	Mostly thicket/ bushveld/fynbos. Some natural grassland.	The Dry Harts river a tributary of the Harts is delineated as a MRU. The river has one geomorphic zone, however four Eco-region levels are present. The tributary has a low priority rating (1).	26.25874; -26.08378	C32A, C32B, C32C, C32D
MRU Harts B	11.01, 11.08, 29.02	Lower Foothills (100%)	Mostly natural grass land (dominant).	The origin of the Harts River to Wentzel Dam is delineated as a MRU. No significant changes occur along this reach before the Dam. The river has one geomorphic zone however the reach displays difference in Eco-region level. This upstream reach has substantial irrigation abstractions. Water is also transferred from the Harts River into Barberspan. This transfer will result in some of the base flow being removed from the river reach. The exact operation of this transfer is unknown and is currently been investigated. Priority was rated between 1 and 2.	25.36522; - 27.14574	C31A, C31B, C31C, C31D, C31E
MRU Harts C	29.02	Lower Foothills (100%)	Mostly natural grass land (dominant). Includes some thicket/ bushveld/fynbos.	The MRU includes Wentzel Dam. The dam is delineated as a unit. The dam supports the domestic water use in Wentzel. The yield of the dam is fully utilised. The reach has a low priority rating.	25.33629; -27.17634	C31E
MRU Harts D	29.02	Lower Foothills (100%)	Mostly thicket/ bushveld/fynbos. Includes some natural grassland. Limited cultivated land (commercial – irrigated).	The reach between Wentzel Dam to Taung Dam is delineated as a MRU. The reach has one geomorphic zone and Ecoregion level. No significant changes occur along this reach between the dams. The reach has a moderate priority rating.	24.89396; -27.49360	C31F

MRU Harts E	29.02	Lower Foothills (100%)	Mostly thicket/ bushveld/fynbos. Includes some natural grassland. Limited cultivated land (commercial – irrigated).	Taung Dam is delineated as a MRU. The dam is not utilised currently and studies are underway to assess its feasibility to supply domestic and agricultural users. The reach has a moderate priority rating.	24.85772; -27.52909	C31F
MRU Harts F	29.02	Lower Foothills (100%)	Mostly thicket/ bushveld/fynbos. Includes some natural grassland.	The middle reaches of the Harts River catchment highly modified with canal systems. The MRU coincides with a logical break in the system – from Taung Dam to the irrigation canal. Land use is also similar (irrigated agriculture). Reach includes one Ecoregion level and one geomorphic zone. The reach has a priority rating of 2.	24.71434; -27.71893	C31F, C33A
MRU Harts G	29.02	Lower Foothills (100%)	Dominated natural grassland. Includes some thicket/ bushveld/fynbos.	The reach from the irrigation canal to Spitskop Dam is delineated as a MRU. The canal and dam form the logical break in the river from an operational point of view. This reach also includes major canal systems. Significant flows occur in this Harts River reach upstream of Spitskop Dam from the return flows of the Vaalharts Irrigation Scheme. The return flows have substantially changed the flow regime compared to natural conditions and have highly impacted the system in terms of water quality. Priority rating is low to moderate.	24.61945; -27.91405	C33A, C33B
MRU Harts H	29.02	Lower Foothills (100%)	Includes natural grassland and thicket/ bushveld/fynbos.	Spitskop Dam is delineated as a MRU. The dam supports some downstream irrigated agriculture but does have available capacity that is not currently utilised. The return flows from the Vaalharts Irrigation Scheme flow into Spitskop Dam, thus the dam and the downstream reach experiences the associated water quality problems. The reach has a low importance rating.	24.50059; -28.12588	C33B, C33C

MRU Harts I	29.02	Lower Foothills (100%)	Mostly thicket/ bushveld/fynbos. Includes some natural grassland.	This lower reach of the Harts River, below Spitskop dam is delineated as one MRU (to confluence with the Harts River). No significant change occurs along these lower reaches below the Dam. This reach is highly impacted from the irrigation return flows (water quality impacts). Reach includes one Ecoregion level and one geomorphic zone. This reach did score a high priority rating in terms of maintaining the integrity of the Harts River.	24.27798; -28.40254	C33C, C91E

3.2.2 Riet River: Natural Resource Units and Management Units

Based on the biophysical characteristics of the Riet River four natural resource units (NRUs), NRU 1, NRU 2, NRU 3 and NRU 4 can be delineated (

Figure 12

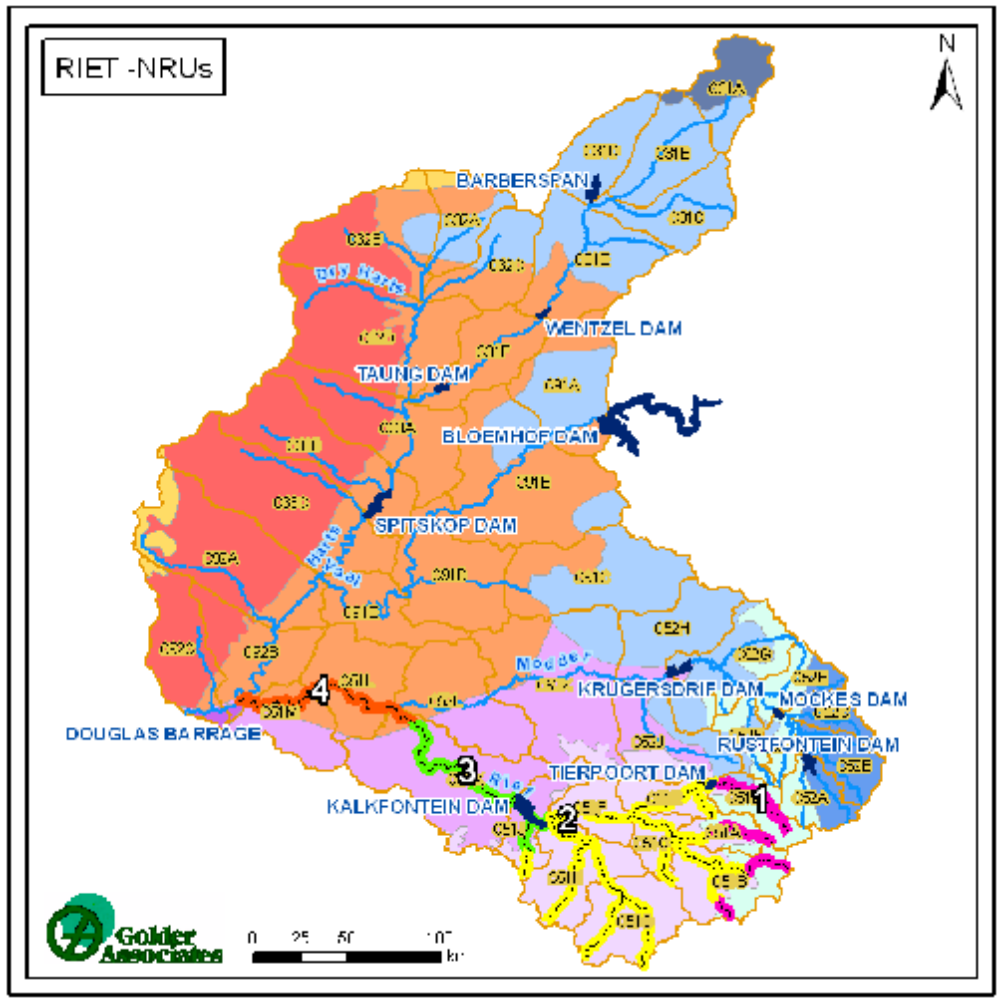


Figure 12: Riet River: Natural Resource Units

Table 13: Description and rationale for the Riet River Natural Resource Units

NRU	EcoRegion Level 2	Geomorphic zone	Rationale	Delineation
NRU Riet 1	11.1	Lower Foothills (100%)	The Eco-Regions is the major consideration and defines the NRU	26.5285; -29.81144
NRU Riet 2	26.03	Lower Foothills (100%)	The Eco-Region is the major consideration and defines the NRU	26.32672; -29.83176
NRU Riet 3	26.02	Lower Foothills (100%)	The Eco-Region is the major consideration and defines the NRU	25.38483; -29.56200
NRU Riet 4	29.02	Lower Foothills (100%)	The Eco-Region is the major consideration and defines the NRU	24.73389; -29.11378

The NRUs, based on the system characteristics, management and operation is delineated into the management resource units (MRUs), MRU Riet A (From origin of river to Kalkfontein Dam), MRU Riet B (Kalkfontein Dam), MRU Riet C (from Kalkfontein Dam to confluence with the Modder River), MRU Riet C.1 (Origin of Modder River to Krugerdrif Dam), MRU Riet C.2 (Krugerdrif Dam), MRU Riet C.3 (from Krugerdrif Dam to confluence with the Riet River) and MRU Riet D (From confluence with the Modder River to Vaal River confluence). The MRUs are shown in (Figure 13) and the rationale for their delineation is defined in Table 14.

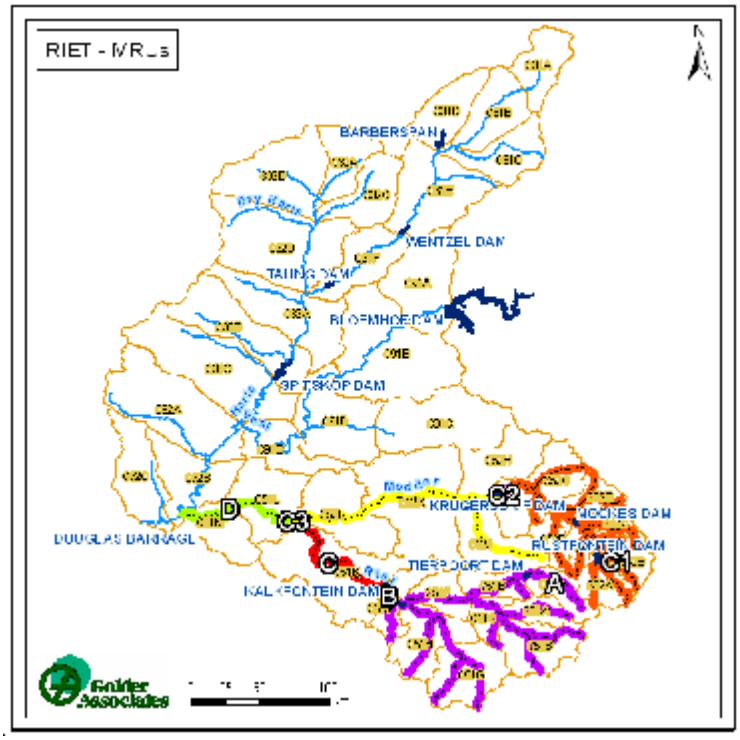


Figure 13: Riet River Management Resource Units: MRU Riet A (From origin of river to Kalkfontein Dam), MRU Riet B (Kalkfontein Dam), MRU Riet C (from Kalkfontein Dam to confluence with the Modder River), MRU Riet C.1 (Origin of Modder River to Krugerdrif Dam), MRU Riet C.2 (Krugerdrif Dam), MRU Riet C.3 (from Krugerdrif Dam to confluence with the Riet River) and MRU Riet D (From confluence with the Modder River to Vaal River confluence)

Table 14: Description and rationale of the Riet River Management Resource Units: MRU Riet A (From origin of river to Kalkfontein Dam), MRU Riet B (Kalkfontein Dam), MRU Riet C (from Kalkfontein Dam to confluence with the Modder River), MRU Riet C.1 (Origin of Modder River to Krugerdrif Dam), MRU Riet C.2 (Krugerdrif Dam), MRU Riet C.3 (from Krugerdrif Dam to confluence with the Riet River) and MRU Riet D (From confluence with the Modder River to Vaal River confluence)

MRU	EcoRegion Level 2	Geomorphic zone	Land cover 500 m both banks	Rationale	Delineation	Quartenary catchment
MRU Riet A	11.1; 26.03	Lower Foothills (100%)	Dominated by natural grasslands with some cultivated land. Lower end of reach includes some shrubland and low fynbos.	MRU extends from origin of the river to the Kalkfontein 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 to moderate priority rating.	26.52851; -29.81144	C51A, C51B, C51C, C51D, C51E, C51F, C51G, C51H
MRU Riet B	26.02	Lower Foothills (100%)	Has shrubland and low fynbos as riparian vegetation	Kalkfontein Dam is delineated as a resource unit. Dam supports mainly irrigation water use. Forms part of the Riet River GWS.	25.30143; -29.57508	C51J
MRU Riet C	26.02; 29.02	Lower Foothills (100%)	Catchment is dominated by thicket (bushland) and shrubland and low fynbos. Also includes cultivated crops.	MRU extends from Kalkfontein Dam to confluence with the Modder River. No significant changes in land use or operatiom. Reach was rated as a high priority rating (integrity of Riet River must be maintained).	25.21476; -29.49215	C51K
MRU Riet C.1	11.03; 11.1; 11.08	Lower Foothills (100%)	Mostly natural grassland with some cultivated lands. Limited thicket/bushland. Does include some urban area.	MRU is delineated from origin of Modder River to Krugerdrif Dam. Includes three Eco-regions within the reach. Does include irrigation as the primary water use. Water is also supplied to urban centres and industrial activities. Reach has a low priority rating.	23.88955; -28.99402	C52A, C52B, C52C, C52D, C52E, C52F, C52G
MRU Riet C.2	11.08	Lower Foothills (100%)	Dominated by thicket (bushveld) and some natural grassland.	Krugerdrif Dam is delineated as a resource unit. Dam supports irrigation and some urban and bulk water users.		C52G
MRU Riet C.3	11.08; 26.02; 29.02	Lower Foothills (100%)	Mostly thicket (bushveld) and natural grassland, with some cultivated land.	Resource unit is delineated from downstream Krugerdrif Dam to Riet River confluence. Area is impacted by return flows from the urban centres, bulk water users and irrigation. Catchment area has a moderate priority rating. (reach is a migratory corridor from Modder to Riet River confluence).		C52H, C52J, C52K, C52L

MRU Riet D	29.02	Lower Foothills (100%)	Mostly thicket (bushveld) and natural grassland. Includes cultivated lands.	RU is delineated from Riet River confluence with Modder River to the inflow into Douglas Barrage. Catchment area is dominated by irrigated agriculture. Area has a high priority rating (3). Assessment requires the integrity of the river to be maintained upstream of the confluence with the Vaal River (Douglas Barrage). MRU should be considered for the selection of an EWR site.	24.73389; -29.11378	C51L, C51M

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 15.

Table 15: Assessment of MRU and recommendations on EWR sites

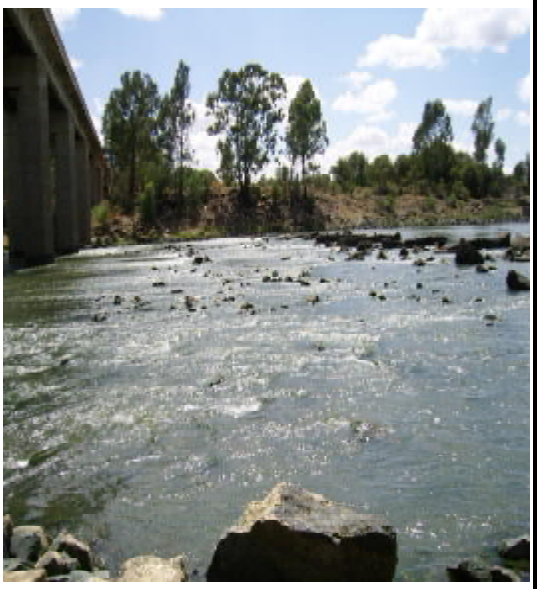
MRUs	Assessment of Resource Unit	Recommendations on EWR site
VAAL RIVER		
MRU Vaal K	The unit is it just downstream Bloemhof Dam - it is important to understand the influences of the Upper and Middle Vaal WMAs. The river reach is considered a high priority as it forms the upper most reach of the Lower 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 5 just downstream Bloemhof Dam was selected. Site will account for influences from the Upper and Middle Vaal WMAs.
MRU Vaal L	Importance of this reach was rated as a 3, as the Bloemhof Dam releases asre required to maintain the integrity of the system. The Vaalharts weir captures major water quality impacts from the upper and middle Vaal catchments however much of the water is transferred to the Vaalharts irrigation scheme. An EWR site should be selected. Site is Easy to access. It is a single channel and has a gauging weir for flow records.	No EWR site was selected as there is little opportunity to change the operation of system (Vaalharts weir and irrigation scheme).
MRU Vaal M	Reach was rated as an importance of 3 as it was noted that the integrity of Vaal River downstream of Bloemhof Dam should be maintained (dependent of Bloemhof releases). There is also a need to keep environmental flows for yellow fish movement.	No EWR site selected due to operation rules of Bloemhof Dam and Vaalharts weir.
MRU Vaal N	Reach was rated as an importance of 1. Heavily impacted by Harts River (water quality – high TDS).	No EWR site was selected.
MRU Vaal O	Schmidtsdrift weir forms the upper delineation area of the reach. The lower level of the reach is inundated with Douglas Barrage water. Importance of this reach was rated as a 3 to ensure integrity of Vaal River is maintained. Site is Easy to access. It is a single channel and has a gauging weir for flow records.	EWR site 7 was selected (at Schmidtsdrift).
MRU Vaal P	RU comprises Douglas Barrage. Lowest end of Lower Vaal WMA and Vaal River System. Includes inflow from Riet River and transfer of water from Upper Orange River WMA (through pipeline). Water quality is impacted mainly from irrigation activities. Importance was rated as a 1.	No EWR site was selected.
HARTS RIVER		
MRU Harts A	No major characteristic features, habitat and biota diversity or major operational influences occur in this MRU. The reach has a low priority rating (1).	No EWR site was selected.

MRUs	Assessment of Resource Unit	Recommendations on EWR site
MRU Harts B	No significant habitat and biota diversity. Priority rating was between 1 and 2 for these upper reaches of the Harts River.	No EWR site was selected.
MRU Harts C	Wentzel Dam forms the MRU. It forms an operational break in the system. The reach has a low priority rating. The Dam is not representative of site requirements.	No EWR site was selected.
MRU Harts D	The reach has a moderate priority rating. MRU is delineated by two dams. System is highly regulated. A EWR site is not proposed.	No EWR site was selected.
MRU Harts E	Taung dam is delineated as a unit. It forms an operational break in the system. The MRU has a moderate priority rating. The Dam is not representative of site requirements.	No EWR site was selected.
MRU Harts F	MRU has an increase in return flows from irrigation practices in the catchment areas. This reach did score a moderate priority rating (2). Includes many canal systems. Not suitable for an EWR site due to constant releases of irrigation return flows.	No EWR site was selected.
MRU Harts G	In this MRU the return flows have substantially changed the flow regime compared to natural conditions and has highly impacted the system in terms of water quality. Reach also includes many canal systems.	No EWR site was selected.
MRU Harts H	Spitskop dam is delineated as a unit. It forms an operational break in the system. The MRU has a low priority rating. The Dam is not representative of site requirements.	No EWR site was selected.
MRU Harts I	Reach scored a high priority rating in terms of maintaining the integrity of the Harts River. Most downstream reach on Harts River before confluence with the Vaal. Site is Easy to access. It is a single channel and has a gauging weir for flow records.	EWR site 6 selected at Lloyds weir.
RIET RIVER		
MRU Riet A	Upper most reach of the river. The Dam forms the lower delineation boundary of the unit. Region has a low priority rating.	No EWR site was selected.
MRU Riet B	Kalkfontein Dam is delineated as a resource unit. It forms an operational break in the system.	No EWR site was selected.
MRU Riet C	No significant changes in land use or operation. Reach was rated as a high priority rating (integrity of Riet River must be maintained).	No EWR site was selected as this MRU as it does include the influence of the Modder River.
MRU Riet C.1	Includes three Eco-regions in upper reaches of Modder River. No significant habitat or biota diversity. Region has a low priority rating.	No EWR site was selected.
MRU Riet C.2	Krugerdrif Dam is delineated as a resource unit. It forms an operational break in the system.	No EWR site was selected.
MRU Riet C.3	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.
MRU Riet D	Reach has a high priority rating (3). Assessment requires the integrity of the Riet 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 8 selected at Lilydale Lodge.

The site information and photographs of the selected EWR sites are shown in Table 16.

Table 16: Locality and characteristics of the Vaal River EWR sites

Site information	EWR sites	Illustration

Site information	EWR sites	Illustration
EWR nr and name	**EWR 5 Downstream Bloemhof Dam**	
River	Vaal	
National RHP site		
Decimal degrees:	S27.65541; E25.59564	
EcoRegion (Level II)	11.08; 29.02	
Geomorphic Zone	E: Lower Foothills	
Altitude (m)	1211	
RU	Vaal K	
Quaternary	C91A	
Hydrological gauge	C9H021	
EWR nr and name	**EWR 6 Lloyds weir on Harts River**	
River	Harts	
National RHP site	C3HART-DELPO	
Decimal Degrees	S28.37694; E24.30305	
EcoRegion (Level II)	29.02; 30.01	
Geomorphic Zone	E: Lower Foothills	
Altitude (m)	1114	
RU	Harts C	
Quaternary	C33C	
Hydrological gauge	C3H016	

Site information	EWR sites	Illustration
EWR nr and name	**EWR 7 Schmidtsdrift**	
River	Vaal	
National RHP site	C9VAAL-SCHMI	
Decimal Degrees	S28.70758; E24.07578	
EcoRegion (Level II)	29.02; 30.01	
Geomorphic Zone	E: Lower Foothills	
Altitude (m)	1239	
RU	Vaal O	
Quaternary	C92B	
Hydrological gauge	C9H024	
EWR nr and name	**EWR 8 Lilydale lodge**	
River	Riet	
National RHP site		
Decimal Degrees	S29.0218.3; E24.3010.2	
EcoRegion(Level II)	29.02	
Geomorphic Zone	E: Lower Foothills	
Altitude (m)	1107	
RU	Riet D	
Quaternary	C51L	
Hydrological gauge	C5H048	

The location of EWR sites are illustrated in Figure 14.

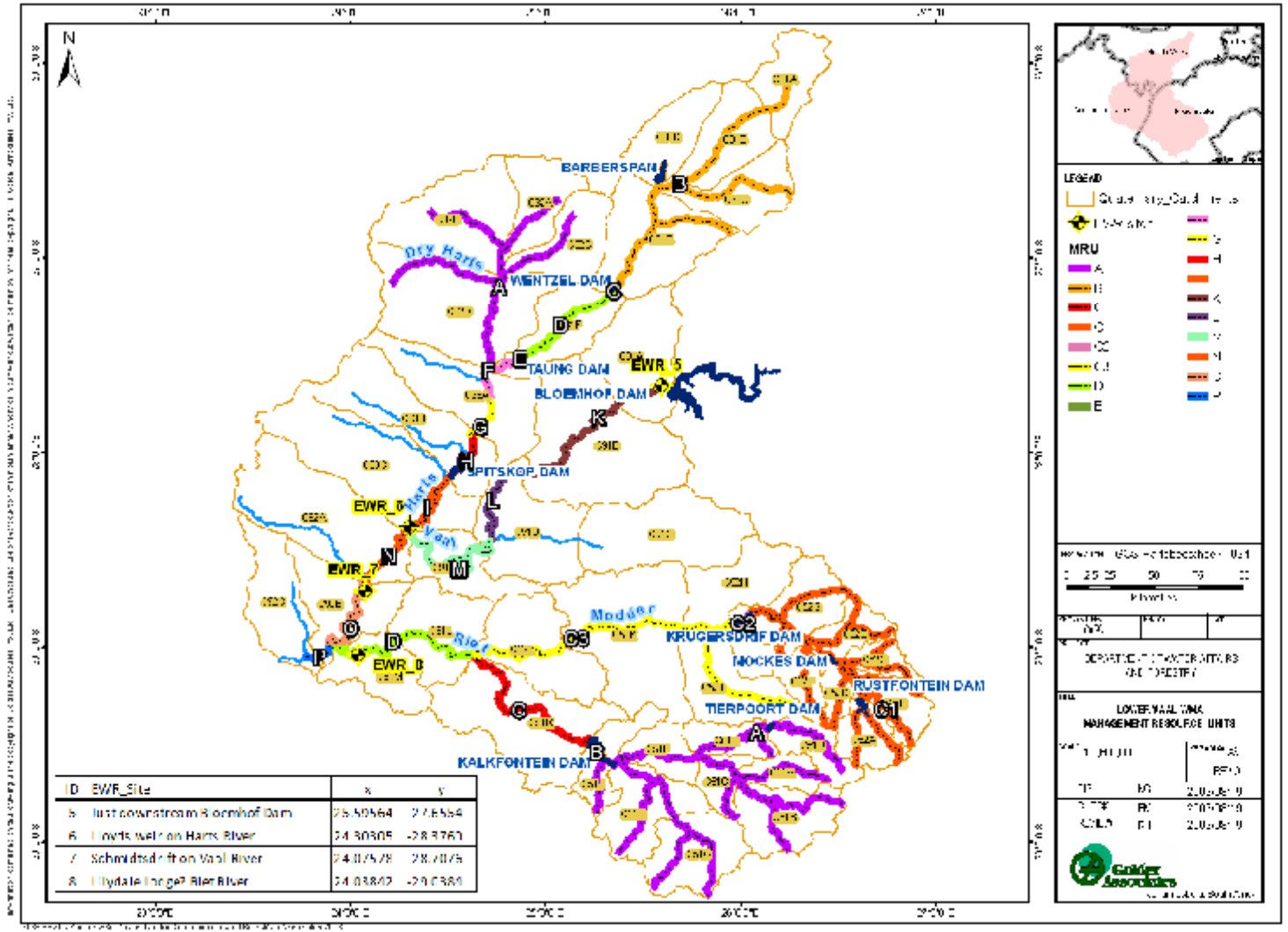


Figure 14: Locality of EWR sites and MRUs in the Lower Vaal WMA

4.2.2 Site suitability

The site suitability of each site was assessed and is provided in Table 17. 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 17: Biophysical Site suitability for the Lower Vaal WMA – Vaal catchment

EWR sites	Geomorph	Riparian vegetation	Fish	Inverts	Average	Max	Min	Comments
EWR 5	3.1	1	3.5	3.4	2.8	3.5	1	Suitability moderate to high for all components except riparian vegetation used for wood. Bleomhof Town
EWR 6	2.1	1.8	3	3.5	2.6	3.5	1.8	Geomorhic cues collected in upstream dam. Riparian vegetation impacted by farming.
EWR 7	3.4	1.8	3.5	2.8	2.6	3.5	1.8	Geomorhic cues collected in upstream dam. Riparian vegetation dominated by exotics.
EWR 8	2.4	2.8	3.5	3.8	3.1	2.8	2.4	Good site in nature reserve and habitat protected

From a biophysical point of view, these sites are all moderately suitable.

Table 18: Integrated Site suitability for the Lower Vaal WMA – Vaal catchment

EWR SITES	BIOPHYSICAL		HYDRAULICS		CONFIDENCE		COMMENT
	Low flows	High flows	Low flows	High flows	Low flows	High flows	
EWR 5	2.8	2.8	2	2	2	3.5	Lack of low flow data to calibrate low flow requirements resulted in overall low suitability of the site as it is complex to model
EWR 6	2.4	2.8	4	4	2	4	Lack of low flow data to calibrate low flow requirements resulted in overall low suitability of the site as it is complex to model
EWR 7	2.5	2.7	2	4	2	4	Lack of low flow data to calibrate low flow requirements resulted in overall low suitability of the site as it is complex to model
EWR 8	3	3.2	3	3	2	4	Large nature of bed-substrate will cause problems with low flow determination.

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 high to very high (Kleynhans and Louw, 2007) River reach demarcation and delineation. As all high flow calibrations have been obtained at the time of this report being documented this will not change.

5 REFERENCES

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APPENDIX A

RIVER REACH DEMARCATION AND DELINEATION

RIVER REACH DEMARCATION AND DELINEATION

CJ Kleynhans & DM Louw

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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, agricultural, urbanization and forestry. Such modifications brings about changes in the natural reach

[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).

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.

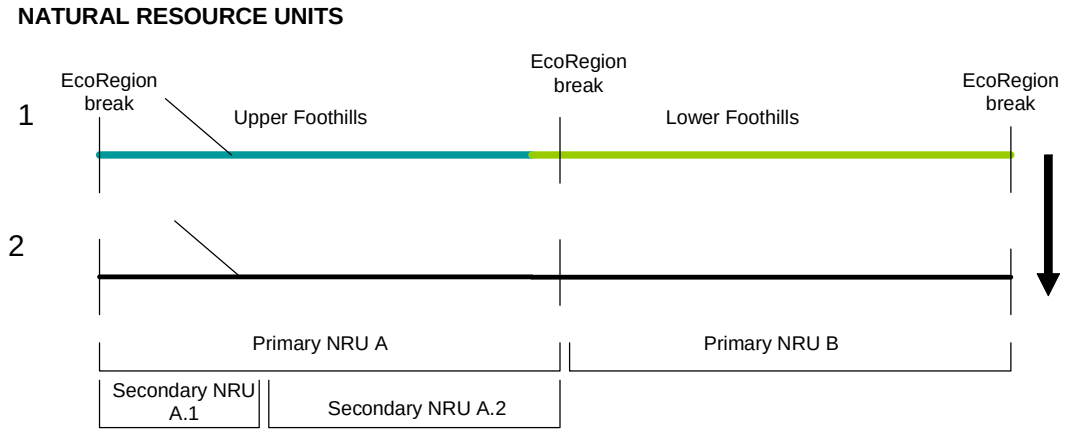


Figure A.1: Delineation of National Resource Units

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.

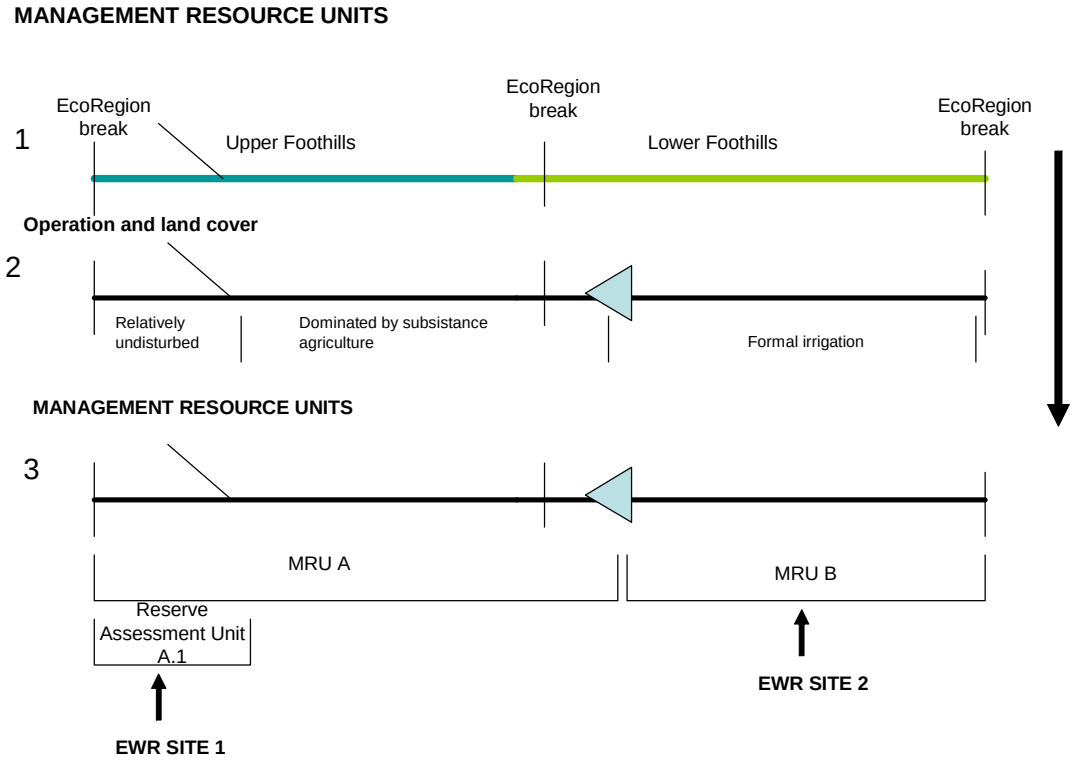
If there are no anthropogenic changes or modifications present along or upstream from a particular NRU, such a NRU will logically constitute a Management Resource Unit (MRU).

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	Start of EcoRegion to

	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.	and EWR assessment important as forms the critical section in the MRU	confluence of tributary (coincides with NRU A.1)
Recommendation: RAU A.1: EcoClassification + EWR assessment therefore EWR site if possible to be situated within RAU A.1 MRU A (excluding RAU A.1): EcoClassification			
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								
OV								
SUB								
AM								
WC								
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

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LANDCOVER

VAAL RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C91A	11.08	6	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1522.797
C91A	11.08	17	05-01-000	Unimproved Grassland	357.979
C91A	11.08	3	08-00-000	Wetlands	71.236
C91A	11.08	1	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	41.172
C91A	11.08	7	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	91.177
C91A	11.08	10	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	89.248
C91A	11.08	1	11-01-009	Urban / Built-up Land (residential - smallholdings - thicket; bushland ...etc)	4.334
C91A	11.08	1	11-02-000	Urban / Built-up Land (commercial)	10.959
C91A	29.02	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	549.143
C91A	29.02	8	05-01-000	Unimproved Grassland	210.303
C91A	29.02	1	07-00-000	Waterbodies	516.085
C91A	29.02	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	21.223
C91A	29.02	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	8.098
C91B	11.08	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1291.146
C91B	11.08	10	05-01-000	Unimproved Grassland	258.871
C91B	11.08	2	06-00-000	Forest Plantations (exotic)	2.376
C91B	11.08	3	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	29.715
C91B	11.08	8	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	116.794
C91B	11.08	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	14.545
C91B	29.02	4	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	4405.730
C91B	29.02	25	05-01-000	Unimproved Grassland	449.990
C91B	29.02	17	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	302.070
C91B	29.02	13	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	373.735
C91B	29.02	2	11-01-000	Urban / Built-up Land (residential)	147.719
C91D	29.02	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	6331.610
C91D	29.02	12	05-01-000	Unimproved Grassland	291.624
C91D	29.02	2	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	51.743
C91D	29.02	12	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	637.005
C91D	29.02	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	26.292
C91D	29.02	3	11-01-000	Urban / Built-up Land (residential)	154.311
C91D	29.02	1	11-02-000	Urban / Built-up Land (commercial)	9.185
C91D	29.02	3	12-00-000	Mines & Quarries	26.404
C91E	29.02	5	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	6600.206
C91E	29.02	6	05-01-000	Unimproved Grassland	214.775
C91E	29.02	10	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	327.537
C91E	29.02	22	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	1215.890
C91E	29.02	3	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	99.629
C91E	29.02	2	11-01-000	Urban / Built-up Land (residential)	167.193
C92A	29.02	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	3472.456
C92A	29.02	22	05-01-000	Unimproved Grassland	508.106
C92A	29.02	3	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	52.492
C92A	29.02	8	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	187.998
C92A	29.02	2	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	18.542

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VAAL RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C92A	29.02	1	11-01-000	Urban / Built-up Land (residential)	18.391
C92B	26.01	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	243.740
C92B	26.01	1	07-00-000	Waterbodies	100.576
C92B	26.01	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	194.440
C92B	26.02	4	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	29.061
C92B	26.02	1	07-00-000	Waterbodies	56.581
C92B	26.02	2	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	210.158
C92B	29.02	5	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	4472.592
C92B	29.02	15	05-01-000	Unimproved Grassland	417.064
C92B	29.02	1	07-00-000	Waterbodies	158.793
C92B	29.02	1	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	166.544
C92B	29.02	22	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	1475.417
C92C	26.01	5	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	546.631
C92C	26.01	4	07-00-000	Waterbodies	275.342
C92C	26.01	6	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	672.533
C92C	26.01	4	11-01-000	Urban / Built-up Land (residential)	59.659
C92C	26.02	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	187.135
C92C	26.02	2	07-00-000	Waterbodies	173.926
C92C	26.02	1	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	12.644
C92C	26.02	6	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	373.585
C92C	26.02	2	11-01-000	Urban / Built-up Land (residential)	44.308
C92C	29.02	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	2.527

HARTS RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
Dry Harts					
C31F	29.02		02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	29.208
C31F	29.02		05-01-000	Unimproved Grassland	7.661
C32A	11.08		02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1305.590
C32A	11.08		05-01-000	Unimproved Grassland	2675.398
C32A	11.08		06-00-000	Forest Plantations (exotic)	3.486
C32A	11.08		10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	50.486
C32A	29.02		02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	799.734
C32A	29.02		05-01-000	Unimproved Grassland	214.676
C32A	29.02		06-00-000	Forest Plantations (exotic)	9.479
C32B	29.02		02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1866.443
C32B	29.02		05-01-000	Unimproved Grassland	175.339
C32B	29.02		06-00-000	Forest Plantations (exotic)	0.565
C32B	29.02		10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	15.102
C32C	11.08		05-01-000	Unimproved Grassland	11.668
C32C	29.02		02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	66.639
C32D	29.02		02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1908.796
C32D	29.02		05-01-000	Unimproved Grassland	1882.551

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HARTS RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C32D	29.02		08-00-000	Wetlands	1147.232
C32D	29.02		09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	787.191
C32D	29.02		10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	198.454
C32D	29.02		10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	34.217
C32D	30.01		02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	32.032
C32D	30.01		05-01-000	Unimproved Grassland	76.863
C32D	30.01		08-00-000	Wetlands	151.495
C32D	30.01		09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	182.480
C32D	30.01		11-01-000	Urban / Built-up Land (residential)	4.243
C33A	29.02		05-01-000	Unimproved Grassland	0.082
Harts					
C31A	11.08	4	01-00-000	Forest & Woodland (Woodland & Wooded Grassland)	53.257
C31A	11.08	2	05-01-000	Unimproved Grassland	1747.669
C31A	11.08	11	06-00-000	Forest Plantations (exotic)	58.757
C31A	11.08	1	07-00-000	Waterbodies	12.139
C31A	11.08	5	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	72.423
C31A	11.08	14	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	352.417
C31B	11.08	5	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	417.654
C31B	11.08	1	05-01-000	Unimproved Grassland	6504.099
C31B	11.08	15	06-00-000	Forest Plantations (exotic)	51.577
C31B	11.08	3	08-00-000	Wetlands	33.802
C31B	11.08	2	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	24.680
C31B	11.08	32	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	392.742
C31C	11.08	1	05-01-000	Unimproved Grassland	1408.545
C31C	11.08	4	06-00-000	Forest Plantations (exotic)	14.581
C31C	11.08	4	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	25.049
C31D	11.08	1	05-01-000	Unimproved Grassland	30.504
C31E	11.08	6	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1162.473
C31E	11.08	10	05-01-000	Unimproved Grassland	3163.438
C31E	11.08	14	06-00-000	Forest Plantations (exotic)	45.483
C31E	11.08	1	08-00-000	Wetlands	2.620
C31E	11.08	2	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	0.703
C31E	11.08	15	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	109.391
C31E	29.02	9	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	623.900
C31E	29.02	3	05-01-000	Unimproved Grassland	2667.267
C31E	29.02	10	06-00-000	Forest Plantations (exotic)	41.967
C31E	29.02	1	07-00-000	Waterbodies	242.424
C31E	29.02	1	08-00-000	Wetlands	6.388
C31E	29.02	6	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	133.308
C31F	29.02	20	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	6476.161
C31F	29.02	29	05-01-000	Unimproved Grassland	2157.495
C31F	29.02	1	07-00-000	Waterbodies	3.023
C31F	29.02	1	08-00-000	Wetlands	3.359
C31F	29.02	8	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	850.729
C31F	29.02	10	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	149.951

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HARTS RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C31F	29.02	32	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	1018.786
C31F	29.02	6	11-01-000	Urban / Built-up Land (residential)	209.978
C31F	29.02	1	11-02-000	Urban / Built-up Land (commercial)	1.743
C31F	29.02	1	11-03-000	Urban / Built-up Land (industrial; transportation)	17.862
C32D	29.02	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	4.371
C32D	29.02	1	05-01-000	Unimproved Grassland	9.219
C32D	29.02	1	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	17.867
C33A	29.02	13	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1342.971
C33A	29.02	7	05-01-000	Unimproved Grassland	1950.130
C33A	29.02	1	08-00-000	Wetlands	28.883
C33A	29.02	9	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	1586.300
C33A	29.02	13	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	605.477
C33B	29.02	13	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	581.737
C33B	29.02	14	05-01-000	Unimproved Grassland	1420.150
C33B	29.02	2	07-00-000	Waterbodies	1222.224
C33B	29.02	2	08-00-000	Wetlands	280.273
C33B	29.02	4	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	16.274
C33B	29.02	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	71.472
C33C	29.02	15	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	4286.675
C33C	29.02	24	05-01-000	Unimproved Grassland	1137.527
C33C	29.02	1	07-00-000	Waterbodies	27.496
C33C	29.02	2	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	5.301
C33C	29.02	19	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	1102.680
C91E	29.02	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	18.388
C91E	29.02	1	05-01-000	Unimproved Grassland	2.650

RIET RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
Riet					
C51C	26.03	1	05-01-000	Unimproved Grassland	48.390
C51C	26.03	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	0.275
C51D	11.08	1	05-01-000	Unimproved Grassland	2507.049
C51D	11.08	1	06-00-000	Forest Plantations (exotic)	2.949
C51D	11.08	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	39.540
C51D	11.08	3	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	27.292
C51D	11.10	2	05-01-000	Unimproved Grassland	2292.959
C51D	11.10	5	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	77.384
C51D	26.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	0.818
C51D	26.03	6	05-01-000	Unimproved Grassland	475.668
C51D	26.03	1	07-00-000	Waterbodies	266.229
C51E	26.03	10	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	323.498
C51E	26.03	4	05-01-000	Unimproved Grassland	4545.113
C51E	26.03	2	06-00-000	Forest Plantations (exotic)	5.284
C51E	26.03	3	08-00-000	Wetlands	54.617

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RIET RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C51E	26.03	14	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	184.831
C51E	26.03	13	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	273.243
C51F	26.03	10	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	749.782
C51F	26.03	10	03-00-000	Shrubland & Low Fynbos	2632.024
C51F	26.03	1	05-01-000	Unimproved Grassland	1849.398
C51F	26.03	9	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	111.897
C51F	26.03	3	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	46.512
C51H	26.03	4	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	2.774
C51H	26.03	1	03-00-000	Shrubland & Low Fynbos	5.775
C51J	26.02	8	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	449.833
C51J	26.02	15	03-00-000	Shrubland & Low Fynbos	730.847
C51J	26.02	1	07-00-000	Waterbodies	1425.866
C51J	26.03	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	48.019
C51J	26.03	2	03-00-000	Shrubland & Low Fynbos	19.935
C51K	26.02	14	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	3967.309
C51K	26.02	56	03-00-000	Shrubland & Low Fynbos	4307.001
C51K	26.02	10	05-01-000	Unimproved Grassland	468.701
C51K	26.02	2	06-00-000	Forest Plantations (exotic)	7.045
C51K	26.02	1	07-00-000	Waterbodies	7.136
C51K	26.02	1	08-00-000	Wetlands	0.363
C51K	26.02	36	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	1193.518
C51K	26.02	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	4.069
C51K	26.02	3	11-01-000	Urban / Built-up Land (residential)	41.144
C51K	29.02	4	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	686.530
C51K	29.02	1	03-00-000	Shrubland & Low Fynbos	20.361
C51K	29.02	6	05-01-000	Unimproved Grassland	155.648
C51K	29.02	9	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	1029.946
C51L	29.02	7	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	3702.553
C51L	29.02	5	03-00-000	Shrubland & Low Fynbos	62.199
C51L	29.02	2	05-01-000	Unimproved Grassland	67.980
C51L	29.02	9	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	829.889
C51L	29.02	19	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	672.937
C51L	29.02	1	11-01-000	Urban / Built-up Land (residential)	44.981
C51L	29.02	1	11-01-009	Urban / Built-up Land (residential - smallholdings - thicket; bushland ...etc)	57.037
C51L	29.02	1	12-00-000	Mines & Quarries	2.029
C51M	26.02	7	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	491.479
C51M	26.02	1	05-01-000	Unimproved Grassland	6.416
C51M	26.02	1	07-00-000	Waterbodies	58.257
C51M	26.02	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	936.759
C51M	29.02	12	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	2861.184
C51M	29.02	6	05-01-000	Unimproved Grassland	207.221
C51M	29.02	1	07-00-000	Waterbodies	3.516
C51M	29.02	7	09-02-003	Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)	471.794
C51M	29.02	26	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	963.866
C52L	29.02	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	9.273

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RIET RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C52L	29.02	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	33.723
Modder					
C52A	11.03	7	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	405.668
C52A	11.03	9	05-01-000	Unimproved Grassland	3648.849
C52A	11.03	6	07-00-000	Waterbodies	782.200
C52A	11.03	3	08-00-000	Wetlands	50.678
C52A	11.03	13	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	291.092
C52B	11.03	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	337.577
C52B	11.03	8	05-01-000	Unimproved Grassland	1301.706
C52B	11.03	1	06-00-000	Forest Plantations (exotic)	4.266
C52B	11.03	2	09-02-004	Degraded Lands (Unimproved Grassland)	218.686
C52B	11.10	1	05-01-000	Unimproved Grassland	87.546
C52B	11.10	2	09-02-004	Degraded Lands (Unimproved Grassland)	31.578
C52C	11.10	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	22.959
C52C	11.10	2	05-01-000	Unimproved Grassland	110.437
C52D	11.03	1	05-01-000	Unimproved Grassland	4.139
C52D	11.03	1	09-02-004	Degraded Lands (Unimproved Grassland)	10.753
C52D	11.10	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	148.312
C52D	11.10	6	05-01-000	Unimproved Grassland	1342.021
C52D	11.10	1	07-00-000	Waterbodies	204.514
C52D	11.10	1	09-02-004	Degraded Lands (Unimproved Grassland)	220.990
C52D	11.10	1	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	3.835
C52E	11.10	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1386.266
C52E	11.10	9	05-01-000	Unimproved Grassland	638.723
C52E	11.10	3	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	40.198
C52E	11.10	2	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	5.183
C52F	11.10	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	13.909
C52G	11.08	3	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	2684.588
C52G	11.08	7	03-00-000	Shrubland & Low Fynbos	513.495
C52G	11.08	24	05-01-000	Unimproved Grassland	1249.374
C52G	11.08	1	08-00-000	Wetlands	4.480
C52G	11.08	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	1.536
C52G	11.08	15	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	500.554
C52G	11.10	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	117.984
C52G	11.10	1	05-01-000	Unimproved Grassland	20.107
C52G	11.10	1	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	32.343
C52G	26.02	7	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	69.067
C52G	26.02	13	03-00-000	Shrubland & Low Fynbos	296.760
C52G	26.02	1	05-01-000	Unimproved Grassland	10.231
C52G	26.02	2	07-00-000	Waterbodies	965.656
C52G	26.02	2	08-00-000	Wetlands	34.071
C52H	26.02	1	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1419.264
C52H	26.02	3	03-00-000	Shrubland & Low Fynbos	147.015
C52H	26.02	18	05-01-000	Unimproved Grassland	1750.145
C52H	26.02	1	07-00-000	Waterbodies	1.654

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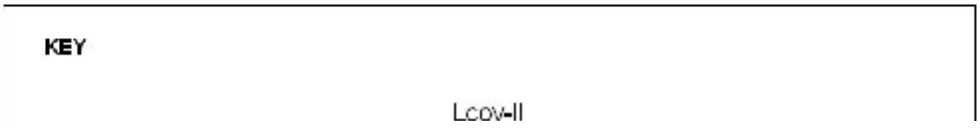
RIET RIVER					
QUATERNARY	LEVEL	FREQUENCY	LAND_CODE	LANDCOVER DESCRIPTION	AREA (Hectares)
C52H	26.02	5	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	121.898
C52H	26.02	2	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	16.652
C52J	26.02	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	10.112
C52J	26.02	2	05-01-000	Unimproved Grassland	12.784
C52K	26.02	5	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1946.193
C52K	26.02	1	03-00-000	Shrubland & Low Fynbos	261.046
C52K	26.02	43	05-01-000	Unimproved Grassland	3331.465
C52K	26.02	31	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	602.700
C52K	26.02	5	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	97.804
C52K	29.02	4	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	677.829
C52K	29.02	1	03-00-000	Shrubland & Low Fynbos	42.243
C52K	29.02	18	05-01-000	Unimproved Grassland	1013.578
C52K	29.02	14	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	353.226
C52K	29.02	3	10-02-007	Cultivated Lands (temporary crops - commercial - dryland)	68.797
C52L	26.02	2	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	618.100
C52L	26.02	1	03-00-000	Shrubland & Low Fynbos	161.463
C52L	26.02	16	05-01-000	Unimproved Grassland	1264.415
C52L	26.02	3	06-00-000	Forest Plantations (exotic)	7.225
C52L	26.02	9	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	173.987
C52L	29.02	7	02-00-000	Thicket; Bushland; Bush Clumps; High Fynbos	1331.635
C52L	29.02	1	03-00-000	Shrubland & Low Fynbos	2.333
C52L	29.02	15	05-01-000	Unimproved Grassland	1447.272
C52L	29.02	21	10-02-006	Cultivated Lands (temporary crops - commercial - irrigated)	1450.746



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APPENDIX C

FLUVIAL GEOMORPHOLOGY SITE SUITABILITY

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				**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 6:

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 7:

Site suitability

OVERALL SCORE:	**2.4**	

EWR 8:

Site suitability

OVERALL SCORE:	**2.4**	

APPENDIX D

AQUATIC INVERTEBRATE SITE SUITABILITY

EWR 5:

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 6:

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 7:

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 8:

Site suitability

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

APPENDIX E

RIPARIAN VEGETATION SITE SUITABILITY

EWR 5

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 6

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		
		more than sufficient obligate riparian species in marginal zone: Cyperus emarginata common,
Occurrence of obligate, marginal zone riparian species	1	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 7

Site suitability

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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 8

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**

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 Lower Vaal River catchment, 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 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.

[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.

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.

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).

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 5: Vaal River d/s Bloemhof Dam

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 6: Lloyds weir on Harts 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 7: Schmidtsdrift on Vaal 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 and FRAI application.

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

EWR 8: Lilydale Lodge on Riet 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 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.		

REFERENCES

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APPENDIX F

HYDRAULIC SITE SUITABILITY

Site 1: D/S Bloemhof Dam

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

Cross-section is located at.

River	Site	Advantages	Disadvantages
Vaal	EWR 5		

Site 2: Lloyds weir on Harts River

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

Site is located at a.

River	Site	Advantages	Disadvantages
Harts	EWR 6		

Site 3: Schmidtsdrift on Vaal River

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

Site is located at.

River	Site	Advantages	Disadvantages
Vaal	EWR 7		

Site 4: Lilydale Lodge on Riet River

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

Cross-section is located at

River	Site	Advantages	Disadvantages
Riet	EWR 8		